# SPARC 2004

## 3rd GENERAL ASSEMBLY OF THE WCRP PROJECT SPARC

### Stratospheric Processes And their Role in Climate

# Programme
# and
# Abstracts

Victoria (BC), Canada
August 1-6, 2004

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Dear Colleagues,

We are delighted that you have come to Victoria to participate in the 3rd General Assembly of the WCRP Project "Stratospheric Processes And Their Role in Climate".

Here, during this week, you will enjoy doing science in an unforgettable area. And if you have time after the meeting, perhaps you will be able to explore more of Canada's beautiful province of British Columbia and enjoy the scenery, the culture and traditions, which have many agreeable surprises.

We welcome you and wish you all a rewarding and pleasant stay.

A. Ravishankara
Co-Chair of the SPARC SSG
Co-Chair of the SOC

A. O'Neill
Co-Chair of the SPARC SSG

T. Shepherd
Co-Chair of the SOC

N. McFarlane
Chair of the LOC

M.-L. Chanin
Director of the SPARC Office

# ACKNOWLEDGEMENTS

The Assembly Secretariat wishes to acknowledge and thank, on behalf of all the participants, the following organisations for their assistance, sponsorship and support.

## INTERNATIONAL SPONSORS

| | |
|---|---|
| CFCAS | Canadian Foundation for Climate and Atmospheric Sciences - Canada |
| CSA | Canadian Space Agency - Canada |
| CNRS | Centre National de la Recherche Scientifique - France |
| COSPAR | Committee on Space Research |
| EC | European Commission |
| ESA | European Space Agency |
| GAW | Global Atmosphere Watch |
| IAGA | International Association of Geomagnetism and Aeronomy |
| ICSU | International Council of Scientific Union |
| IGBP | International Geosphere-Biosphere Programme |
| IOC | International Ozone Commission |
| IUGG | International Union of Geodesy and Geosphysics |
| MSC | Meteorological Service of Canada - Canada |
| METEO FRANCE | Météo France - France |
| NASA | National Aeronautics and Space Administration – USA |
| NOAA | National Oceanic and Atmospheric Administration – USA |
| NSF | National Science Foundation - USA |
| WCRP | World Climate Research Programme |
| WMO | World Meteorological Organization |


## SPARC 2004 GENERAL ASSEMBLY ORGANIZING COMMITTEES

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T. Shepherd (Co-Chair)
J. Burrows
C. Granier
P. Haynes
T. Peter
W. Randel

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V. Arora (Webmaster)

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P. Canziani, CONICET, Argentina
M. Chipperfield, University of Leeds, UK
T. Dunkerton, Northwest Research Associates, USA
C. Granier, Service d'Aeronomie du CNRS, Paris, France
P. Haynes, University of Cambridge, UK
P. Kushner, University of Toronto, Canada
E. Manzini, National Institute for Geophysics and Volcanology, Italy
P. Newman, NASA Goddard Space Flight Center, USA
T. Peter, ETH Zurich, Switzerland
W. Randel, NCAR, USA
U. Schmidt, Johann Wolfgang Goethe-University, Germany
T. Shepherd, University of Toronto, Canada
V. Yushkov, Central Aerological Observatory, Russia

## SPARC Office

M.-L. Chanin (Director)
C. Michaut
E. Oikonomou

# PROGRAMME

# PROGRAMME

## Sunday August 1, 2004

| | | |
|---|---|---|
| 13.30-14.00 | **A. O'Neill** | Welcome and overview of SPARC |
| | **N. McFarlane** | Logistics |
| | **A. Ravishankara** | Structure of the General Assembly |
| 14.00-14.40 | **F. S. Rowland** | *****Special Lecture***** |
| | | "Environmental science in the global arena: stratospheric ozone to megacities to climate" *(O-1-01)* |
| | | Session Chair: T. Shepherd |
| 14.40-15.10 | **J. Abbatt** | *****Invited Talk***** |
| | | "Laboratory studies of atmospheric chemistry in the upper troposphere" *(O-1-02)* |

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15.10-15.40 *Coffee Break*

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|---|---|---|
| 15.40-16.10 | **B. Kärcher** | *****Invited Talk***** |
| | | "Formation of the ice phase in the UT/LS region: A review of microphysics based on measurements and modelling" *(O-1-03)* |
| 16.10-16.40 | **M. J. Alexander** | *****Invited Talk***** |
| | | "The role of gravity waves in the general circulation" *(O-1-04)* |
| 16.40-17.10 | **R. Rood** | *****Invited Talk***** |
| | | "Assimilation of stratospheric meteorological and constituent observations: a review" *(O-1-05)* |

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18.00 *Opening Reception*

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## Monday August 2, 2004

### *"Focus on Chemistry Climate Coupling"*

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|---|---|---|
| 08.30-10.20 | | *****Poster Session, detailed p 17***** (with buffet breakfast)<br>Monday's posters will also be available for viewing on Tuesday |
| | | Session Chair: C. Granier |
| 10.20-10.40 | **C. Granier** | Session Overview |
| 10.40-11.10 | **J. Pyle** | *****Invited Talk***** |
| | | "Chemistry-climate coupling studies with the Met Office UM" *(O-2-01)* |
| 11.10-11.40 | **R. Garcia** | *****Invited Talk***** |
| | | "Simulation of secular trends in the middle atmosphere since 1979" *(O-2-02)* |

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|---|---|---|
| 11.40-12.25 | | *****Contributed Talks***** |
| | **J. Zawodny** | “Variability in SAGE II $NO_2$ over the past 19 years” *(O-2-03)* |
| | **J. Austin** | “Coupled chemistry climate simulations: some key diagnostics” *(O-2-04)* |
| | **V. Eyring** | “Process-oriented validation of coupled chemistry-climate models” *(O-2-05)* |
| ---------------- | | |
| 12.25-14.00 | *Lunch* | |
| ---------------- | | |
| | | Session Chair: U. Schmidt |
| 14.00-15.00 | **G. Brasseur** | *****SPARC Lecture***** |
| | | “The role of the middle atmosphere in the Earth system” *(O-2-06)* |
| ---------------- | | |
| *15.00-15.30* | *Coffee Break* | |
| ---------------- | | |
| | | Session Chair: M. Chipperfield |
| 15.30-16.00 | **W.J. Collins** | *****Invited Talk***** |
| | | “The importance of coupling chemistry to climate models” *(O-2-07)* |
| 16.00-17.00 | | *****Contributed Talks***** |
| | **D. Fonteyn** | “Operational chemical data assimilation using Envisat: an overview” *(O-2-08)* |
| | **M. Weber** | “Dynamical control of ozone transport and chemistry from satellite observations and coupled chemistry-climate models” *(O-2-09)* |
| | **M. Rex** | “Arctic ozone loss and climate change” *(O-2-10)* |
| | **S. Polavarapu** | “Coupled chemical-dynamical data assimilation in the stratosphere: prospects for separating model and measurement bias” *(O-2-11)* |
| 17.00-19.00 | | *****Poster Session, detailed p 17***** (cash bar) |
| | | Monday's posters will also be available for viewing on Tuesday. |

# Tuesday August 3, 2004

## *“Focus on Extratropical Upper Troposphere/Lower Stratosphere”*

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|---|---|---|
| 08.30-10.20 | | *****Poster Session, detailed p 19***** (with buffet breakfast) |
| | | Tuesday's posters will also be available for viewing on Monday. |
| | | Session Chair: J. Burrows |
| 10.20-10.40 | **J. Burrows** | Session Overview |
| 10.40-11.10 | **D. Fahey** | *****Invited Talk***** |
| | | “*In situ* measurements in the extratropical UT/LS: a perspective on progress and needs” *(O-3-01)* |
| 11.10-11.40 | **H. Wernli** | *****Invited Talk***** |
| | | “Key issues of STE in the extra-tropics ” *(O-3-02)* |
| 11.40-12.25 | | *****Contributed Talks***** |
| | **L. Pan** | “Lagrangian model simulations of mixing near the tropopause” *(O-3-03)* |

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|---|---|---|
| | **J.-P. Cammas** | "Isentropic mixing layer across the mid-latitude tropopause as seen by MOZAIC measurements: regional and inter-annual aspects" *(O-3-04)* |
| | **C. Schiller** | "Transport of water vapour into the lowermost stratosphere" *(O-3-05)* |

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12.25-14.00 *Lunch*

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|---|---|---|
| | | Session Chair: V. Yushkov |
| 14.00-15.00 | **M. Schoeberl** | *****SPARC Lecture***** |
| | | "The satellite view of extra-tropical stratosphere-troposphere exchange and the UT/LS" *(O-3-06)* |

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15.00-15.30 *Coffee Break*

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|---|---|---|
| | | Session Chair: P. Newman |
| 15.30-16.00 | **H. Kanzawa** | *****Invited Talk***** |
| | | "Observation of the polar ozone layer by satellite sensors of ILAS and ILAS-II" *(O-3-07)* |
| 16.00-17.00 | | *****Contributed Talks***** |
| | **D. Knopf** | "Experimental and theoretical investigation of the nucleation of NAD and NAT particles" *(O-3-08)* |
| | **L. Poole** | "Polar stratospheric cloud analyses using SAGE III data "*(O-3-09)* |
| | **J. Logan** | "Interannual variability and trends in the vertical distribution of ozone in the lower stratosphere and troposphere" *(O-3-10)* |
| | **G. Mullendore** | "Cross-tropopause tracer transport in midlatitude convection" *(O-3-11)* |
| 17.00-19.00 | | *****Poster Session, detailed p 19***** (cash bar) |
| | | Tuesday's posters will also be available for viewing on Monday |

## Wednesday August 4, 2004

### *"Focus on Stratosphere-Troposphere Dynamical Coupling"*

| | | |
|---|---|---|
| | | Session Chair: P. Haynes |
| 08.30-08.50 | **P. Haynes** | Session Overview |
| 08.50-09.20 | **S. Yoden** | *****Invited Talk***** |
| | | "Large ensemble experiments on the interannual variability and trends with a stratosphere-troposphere coupled model" *(O-4-01)* |
| 09.20-09.50 | **M. Baldwin** | *****Invited Talk***** |
| | | "How are weather and climate affected by stratospheric variability?" *(O-4-02)* |
| 09.50-10.20 | | *****Contributed Talks***** |
| | **B. Christiansen** | "Downward propagation and statistical forecast of near surface weather" *(O-4-03)* |
| | **T. Hirooka** | "A plausible mechanism of the major stratospheric warming in the Southern Hemisphere of 2002 as inferred from numerical prediction model simulation" *(O-4-04)* |

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10.20-10.50 *Coffee Break*

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Session Chair: P. Kushner

10.50-11.20 **W. Robinson** *****Invited Talk*****

"Dynamical mechanisms for stratospheric influences on the troposphere" *(O-4-05)*

11.20-12.35 *****Contributed Talks*****

**L.M. Polvani** "Upward wave activity flux as precursor to extreme stratospheric events and subsequent anomalous surface weather regimes" *(O-4-06)*

**J. Perlwitz** "Downward coupling between the stratosphere and troposphere: the relative roles of wave and zonal mean processes" *(O-4-07)*

**K. Hamilton** "Effect of the tropical Quasi-Biennial Oscillation on tropospheric circulation" *(O-4-08)*

**L. Gray** "A possible mechanism for the 11-year solar signal to impact the lower atmosphere" *(O-4-09)*

**G. Stenchikov** "Study of stratosphere-troposphere dynamic interaction forced by a radiative effect of volcanic aerosols" *(O-4-10)*

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Free Afternoon *Optional tours starting at around 14.00*

18.00- *Dinner and Dance at the Hatley Castle (Royal Roads University)*

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## Thursday August 5, 2004

### *"Focus on Tropical Tropopause Layer"*

08.30-10.20 *****Poster Session, detailed p 22***** (with buffet breakfast)

Thursday's posters will also be available for viewing on Friday

Session Chair: T. Peter

10.20-10.40 **T. Peter** Session Overview

10.40-11.10 **P. Wennberg** *****Invited Talk*****

"Impact of short-lived compounds on stratospheric ozone" *(O-5-01)*

11.10-11.40 **I. Folkins** *****Invited Talk*****

"Transport and chemistry in the TTL" *(O-5-02)*

11.40-12.25 *****Contributed Talks*****

**A. O'Neill** "The role of the S.E. Asian monsoon and other seasonal features in creating the 'tape-recorder' signal in the Unified Model" *(O-5-03)*

**J. Kaiser** "Isotopic composition of nitrous oxide as tracer of stratospheric transport and chemistry" *(O-5-04)*

**D. Weisenstein** "Microphysical model calculations for the SPARC Assessment of 'Stratospheric Aerosol Properties Report' " *(O-5-05)*

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12.25-14.00 *Lunch*

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|---|---|---|
| | | Session Chair: P. Canziani |
| 14.00-15.00 | **D. Hartmann** | *****SPARC Lecture***** |
| | | "The stratosphere and climate" *(O-5-06)* |

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15.00-15.30 *Coffee Break*

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|---|---|---|
| | | Session Chair: T. Dunkerton |
| 15.30-16.00 | **A. Gettelman** | *****Invited Talk***** |
| | | "What goes up and what comes down: dynamics and radiation in the Tropical Tropopause Layer" *(O-5-07)* |
| 16.00-17.00 | | *****Contributed Talks***** |
| | **A. Dessler** | "Does convection hydrate or dehydrate the UT/LS?" *(O-5-08)* |
| | **J. Smith** | "Observations and implications of supersaturation in clear air and in the presence of cirrus in the tropical and subtropical upper troposphere" *(O-5-09)* |
| | **E. Jensen** | "Implications of enhanced relative humidity in cold tropical cirrus" *(O-5-10)* |
| | **T. Birner** | "Dehydration in the Tropical Tropopause Layer of a cloud-resolving model" *(O-5-11)* |
| 17.00-19.00 | | *****Poster Session, detailed p 22***** (cash bar) |
| | | Thursday's posters will also be available for viewing on Friday |

## Friday August 6, 2004

### *"Focus on Detection, Attribution and Prediction"*

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|---|---|---|
| 08.30-10.20 | | *****Poster Session, detailed p 25***** (with buffet breakfast) |
| | | Friday's posters will also be available for viewing on Thursday |
| | | Session Chair: W. Randel |
| 10.20-10.40 | **W. Randel** | Session Overview |
| 10.40-11.10 | **K. Rosenlof** | *****Invited Talk***** |
| | | "Changes in stratospheric water vapour" *(O-6-01)* |
| 11.10-11.40 | **B. Santer** | *****Invited Talk***** |
| | | "Identification of human-induced climate change in a second-generation reanalysis" *(O-6-02)* |
| 11.40-12.25 | | *****Contributed Talks***** |
| | **L. Thomason** | "Long-term measurements of stratospheric aerosol extinction" *(O-6-03)* |
| | **M. Marchand** | "Validation of the self-consistency of GOMOS $NO_3$, $NO_2$ and $O_3$ data using chemical data assimilation" *(O-6-04)* |
| | **M.-L. Chanin** | "The role of dynamics in the response of the middle atmosphere to solar forcing: data analysis and modelling" *(O-6-05)* |

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12.25-14.00 *Lunch*

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|---|---|---|
| | | Session Chair: E. Manzini |
| 14.00-14.30 | **U. Langematz** | *****Invited Talk***** |
| | | "Dynamical changes in the stratosphere" *(O-6-06)* |
| 14.30-15.00 | | *****Contributed Talks***** |
| | **P. Forster** | "Comparison of radiation schemes used in climate models" *(O-6-07)* |
| | **J. Scinocca** | "Do current non-orographic gravity-wave drag parameterisations differ in their application?" *(O-6-08)* |

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15.00-15.30 *Coffee Break*

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|---|---|---|
| 15.30-16.00 | | *****Contributed Talks***** |
| | **N. Butchart** | "Model inter-comparison of the effect of climate change on stratosphere-troposphere exchange and the role of planetary wave activity entering the stratosphere?" *(O-6-09)* |
| | **N. Gillett** | "Simulation of the tropospheric response to Antarctic ozone depletion" *(O-6-10)* |
| 16.00-18.00 | | *****Poster Session, detailed p 25***** (cash bar) |
| | | Friday's posters will also be available for viewing on Thursday |

# Poster Session
# Monday August 2, 2004

| | |
|---|---|
| T. Cox | "Laboratory studies on the interaction of nitric acid with ice surfaces at temperatures of the upper troposphere" *(P-2-01)* |
| C. Hoyle | "The effect of changes in stratospheric transport on the lifetimes of chlorine containing gases" *(P-2-02)* |
| G. Folberth | "Biosphere-troposphere chemical interaction in the LMDz-INCA Climate-Chemistry Model: impact on upper tropospheric $HO_x$ and implications for future climate" *(P-2-03)* |
| N. P. Wedi | "Laboratory for internal gravity-wave dynamics: the numerical equivalent to the Quasi-Biennial Oscillation (QBO) analogue" *(P-2-04)* |
| B. Bregman | "Age of air from ECWMF meteorology and its dependence on the assimilation procedure" *(P-2-05)* |
| Y. Orsolini | "Transport of ozone, water vapour and other trace constituents in the stratosphere, diagnosed in ENVISAT/MIPAS data" *(P-2-06)* |
| W. Tian | "Interaction between stratospheric and tropospheric chemistry in a coupled chemistry climate model" *(P-2-07)* |
| A. Jrrar | "Model study of ozone signatures of climate patterns over the Northern Hemisphere" *(P-2-08)* |
| M. Dameris | "Simulation of recent developments of atmospheric dynamics and chemistry with an interactively coupled global chemistry-climate model" *(P-2-09)* |
| C. Lemmen | "Recalculation of Arctic ozone hole recovery predictions with a detailed chemistry Lagrangian transport model" *(P-2-10)* |
| S. Veerabuthiran | "Temperature dependences of stratospheric aerosol extinction observed at a low latitude station, Trivandrum (8.33°N, 77°E), India using lidar" *(P-2-11)* |
| D. Rault | "Ozone, $NO_2$ and aerosol retrieval from SAGE III limb scattering measurements" *(P-2-12)* |
| D. Knopf | "Thermodynamical study of $H_2SO_4/H_2O$ particles at UT/LS conditions: implication for heterogeneous chemistry" *(P-2-13)* |
| T. Egorova | "Atmospheric response to the decadal variability of the solar ultraviolet and visible irradiance simulated with CCM SOCOL" *(P-2-14)* |
| P. Braesicke | "Sensitivity of dynamics and ozone to different representations of SSTs in the Unified Model" *(P-2-15)* |
| P. Braesicke | "Relationship between ozone variability in high and low latitudes in the Unified Model: how important is the QBO?" *(P-2-16)* |
| A. Geer | "Assimilation of stratospheric ozone and water vapour into the Unified Model" *(P-2-17)* |
| M. Fernandez | "Reactive uptake of chlorine nitrate on ice at temperatures of the upper troposphere" *(P-2-18)* |
| C. Bruehl | "Transient simulations of the near past with interactive middle atmosphere chemistry climate models" *(P-2-19)* |
| N. Kilifarska | "Decadal variability of the UT/LS water vapour, ozone and temperature from HALOE data" *(P-2-20)* |
| S. Zhou | "Assessment of ozone assimilation and prediction in the NCEP global forecast system" *(P-2-21)* |
| J. Kuttippurath | "Measurements and model calculations of nitrous oxide: implications for stratospheric transport" *(P-2-22)* |
| J. Buchholz | "Polar stratospheric cloud simulations with the chemistry-climate model ECHAM5/MESSy" *(P-2-23)* |

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| A. Dethof | "Assimilation of ozone data in the ECMWF integrated forecast system" *(P-2-24)* |
| E. Rozanov | "Evolution of the atmospheric state during 1975-2000 simulated with a chemistry-climate model: an attempt to evaluate the role of different forcing mechanisms" *(P-2-25)* |
| G. Millard | "Interannual variability of polar contributions to the lower stratosphere middle latitude ozone and ozone trend" *(P-2-26)* |
| J. de Grandpré | "Middle atmosphere modelling of ozone and climate" *(P-2-27)* |
| M. Pulido | "A case study of gravity wave momentum deposition estimation using an adjoint model" *(P-2-28)* |
| S. Beagley | "The interaction between chemistry and dynamics in a climate model during Antarctic ozone depletion events" *(P-2-29)* |
| Y. J. Rochon | "Background error statistics for middle atmosphere data assimilation" *(P-2-30)* |
| A.I. Jonsson | "Greenhouse gases induced cooling and ozone radiative feedback" *(P-2-31)* |
| L. Zhou | "Lower stratospheric $N_2O$ distributions in the early and late Arctic vortex breakup years" *(P-2-32)* |
| H. Akiyoshi | "A CTM study of lower stratospheric ozone destruction due to bromine species inside/outside the Arctic polar vortex" *(P-2-33)* |
| N. Kawamoto | "Wave-like ozone variability in the Northern Hemisphere summer stratosphere" *(P-2-34)* |
| W. Ward | "Ozone/temperature correlations during the CRISTA 2 Flight" *(P-2-35)* |
| H. Oelhaf | "Cloud properties of synoptic PSCs and uptake of $HNO_3$: MIPAS-B observations and microphysical model calculations" *(P-2-36)* |
| E. Manzini | "Chemistry climate modelling of the middle atmosphere: dynamical feedbacks in a transient simulation" *(P-2-37)* |
| S. Ren | "Some diagnoses in the stratosphere using CMAM-DA analyses" *(P-2-38)* |
| Y. Yang | "First results of assimilating ozone data into CMAM with CMC's 3D VAR" *(P-2-39)* |
| C. Curry | "Prognostic greenhouse tracers in the CCCma atmospheric GCM" *(P-2-40)* |
| M. Ilyas | "Impact of climate change on ozone depletion and UV radiation effects" *(P-2-41)* |
| C. von Savigny | "Impact of the October 2003 solar proton event on the composition of the middle atmosphere: measurements and model studies" *(P-2-42)* |
| M. Reszka | "A diagnostic balance in equatorial flow" *(P-2-43)* |
| M. Pritchard | "The 5-day wave in atmospheric analyses and in CMAM, and its effects on late-summer chemical variability" *(P-2-44)* |
| J. Shilling | "Uptake of C1 - C5 monocarboxylic acids on ammonium nitrate as a function of temperature and relative humidity" *(P-2-45)* |
| E. Arnone | "Solar terrestrial influences on ozone transport processes" *(P-2-46)* |
| C. Cagnazzo | "Temperature variability in the stratosphere and links with ozone change" *(P-2-47)* |
| L. Jourdain | "Evaluation of the stratosphere in the chemistry-climate model LMDzT-INCA" *(P-2-48)* |
| S. Massart | "Assimilation of ozone profiles in a global tropospheric and stratospheric CTM" *(P-2-49)* |
| C. Marquart | "Assimilation of radio occultation measurements in the UT/LS" *(P-2-50)* |
| D. Sankey | "On the use of data assimilation to help identify model errors in the Canadian Middle Atmosphere Model" *(P-2-51)* |
| W. Evans | "Investigations of stratosphere mesosphere coupling with WINDII and OSIRIS data" *(P-2-52)* |
| F. Sassi | "The effects of interactive chemistry in simulations of the middle atmosphere" *(P-2-53)* |
| J. M.P. Silvestre | "Radiative-dynamical processes modulating the vertical structure of thestratospheric polar vortex" *(P-2-54)* |
| M. Gupta | "Preliminary investigation of chemistry-climate feedback on stratospheric chemical composition" *(P-2-55)* |
| M. Gauss | "Future time slice experiments with a new coupled climate-chemistry model" *(P-2-56)* |

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| R. Stolarski | "Sensitivity of the FVGCM to changes in ozone" *(P-2-57)* |
| D. Shindell | "Stratosphere-troposphere interactions in the new GISS model E GCM" *(P-2-58)* |
| I. Stajner | "Can assimilation of satellite ozone data contribute to the understanding of the lower stratospheric ozone?" *(P-2-59)* |
| L. Coy | "Stratospheric forecasting with the NOGAPS (Navy Operational Global Atmospheric Prediction System) GCM" *(P-2-60)* |
| R. Kawa | "Polar processes in a 50-year simulation of stratospheric chemistry and transport" *(P-2-61)* |
| R. Hudson | "The total ozone record as a climate diagnostic" *(P-2-62)* |
| M. Giorgetta | "The role of the QBO in the climate and chemistry of the stratosphere in a transient chemistry-climate simulation for the period 1960 to 2000" *(P-2-63)* |
| K. Strong | "The mid-latitude summertime stratosphere: a comparison between MANTRA balloon campaign measurements and the Canadian Middle Atmosphere Model" *(P-2-64)* |
| D. Kirk-Davidoff | "Maintenance of polar stratospheric clouds in a moister stratosphere: what are the limits?" *(P-2-65)* |
| G. Hansen | "A multiple linear regression analysis of the 65-year Tromsö total ozone series" *(P-2-66)* |
| P. Forster | "Resolving uncertainties in the radiative forcing of HFC-134a" *(P-2-67)* |
| R.-S. Gao | "Evidence that nitric acid increases relative humidity in low-temperature cirrus clouds" *(P-2-68)* |
| P. Popp | "Observations of gas- and condensed-phase $HNO_3$ in the tropical UT/LS" *(P-2-69)* |
| T. Nagashima | "Toward the more realistic simulation of the Antarctic ozone hole by using a chemistry-climate model" *(P-2-70)* |
| L. Makarova | "Heating of the middle Atmosphere by the solar wind induced electric currents" *(P-2-71)* |
| A. Shirochkov | "Possible mechanisms of the solar wind energy influenceon the ozone layer dynamics" *(P-2-72)* |
| A. Pandy | "Effect of haze on the surface level solar UV-B radiation and temperature" *(P-2-73)* |

## Poster Session

## Tuesday August 3, 2004

| | |
|---|---|
| J. Brioude | "Case study of troposphere-stratosphere transport associated with a summer extratropical low: MOZAIC aircraft measurements analysis and modelling" *(P-3-01)* |
| J.C. Antuna | "Characterising UT/LS aerosols over the wider Caribbean under volcanic background conditions" *(P-3-02)* |
| P. Siegmund | "Antarctic ozone transport and depletion in Austral spring 2002" *(P-3-03)* |
| A. Gahein | "Diagnostic study on the relation between ozone and potential vorticity" *(P-3-04)* |
| B. Bregman | "A new PSC algorithm for global chemistry climate models: $NO_y$ redistribution in the Arctic winter" *(P-3-05)* |
| M. Olsen | "Model analysis of mass and ozone cross-tropopause transport" *(P-3-06)* |
| M. Bruns | "$NO_2$ profile retrieval using Airborne MultiAXis Differential Optical Absorption Spectrometer (AMAX-DOAS) data" *(P-3-07)* |
| M. Follette | "Classification of HALOE data by meteorological regime" *(P-3-08)* |
| G. Wang | "Variations of the tropopause and their influence on ozone in UT/LS over Beijing district" *(P-3-09)* |
| W. Feng | "Chemistry and transport in the lower stratosphere" *(P-3-10)* |

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|---|---|
| M. Riese | "High-resolution limb-observations of trace constituents and clouds in the UT/LS region" *(P-3-11)* |
| D. Cunnold | "Isentropic ozone transport across the tropopause" *(P-3-12)* |
| K. Miyazaki | "Diagnosis of meridional ozone transport based on mass weighted isentropic zonal means" *(P-3-13)* |
| Y. Hio | "Quasi-periodic variations of the polar vortex in the Southern Hemisphere stratosphere due to wave-wave interaction" *(P-3-14)* |
| M. Müller | "UT/LS water vapour measurements in Ny-Alesund, Spitsbergen" *(P-3-15)* |
| M. Hitchman | "Influence of the Tibetan high on the distribution of column ozone in the Southern Hemisphere" *(P-3-16)* |
| Y. Tomikawa | "Short-period disturbance observed in the Antarctic stratosphere" *(P-3-17)* |
| T. Birner | "The extratropical tropopause inversion" *(P-3-18)* |
| T. Reichler | "Determining the tropopause height from gridded data" *(P-3-19)* |
| D. J. Kim | "Decadal and year-to-year variations of the Arctic lower stratospheric temperature in March and their relationship with eddy heat flux" *(P-3-20)* |
| W. Reburn | "Limb-sounding tomography of the UT/LS" *(P-3-21)* |
| C. David | "Classification and scales of Antarctic polar stratospheric clouds using wavelet decomposition" *(P-3-22)* |
| T. Narayana Rao | "Climatology of UT/LS ozone and the ratio of ozone and potential vorticity over Northern Europe" *(P-3-23)* |
| T. Woollings | "Entropy and the simulated temperature of the extratropical UT/LS region" *(P-3-24)* |
| C. David | "Color indices from SAOZ observations as polar stratospheric clouds detection flags" *(P-3-25)* |
| T. Narayana Rao | "Characteristics of tropopause folds over an Arctic station" *(P-3-26)* |
| M. Marchand | "Model simulations of the impact of the 2002 Antarctic ozone hole on midlatitudes" *(P-3-27)* |
| V. Sivakumar | "Climatological characteristics of troposphere-stratosphere ozone from Reunion Island (21°S 55°E): using *in situ* (ozonesonde and lidar) and satellite (HALOE and TOMS) measurements" *(P-3-28)* |
| M. Chipperfield | "Age of air simulations with a stratosphere/troposphere CTM" *(P-3-29)* |
| Z. Litynska | "Changes of temperature, ozone, and humidity in the UT/LS layer over Central Europe" *(P-3-30)* |
| R. Plougonven | "Potential uncertainties in using the hodograph method to retrieve gravity wave characteristics from individual soundings" *(P-3-31)* |
| E. Jadin | "Antarctic ozone hole in 2002 and SST anomalies in the South oceans" *(P-3-32)* |
| A.E. Dessler | "Generation of deep convection by forest fire" *(P-3-33)* |
| A. Lukyanov | "Stratospheric water vapour laminae over Sodankyla in winter 2004 during LAUTLOS campaign" *(P-3-34)* |
| D. Peters | "Inertia-gravity waves generated during poleward Rossby wave breaking events over Northern Germany in winter" *(P-3-35)* |
| D. Peters | "Atmospheric angular momentum balance for the Southern Hemisphere during the polar vortex break-up of September 2002" *(P-3-36)* |
| K. Nishii | "The tropospheric origin of the major waming event over Antarctica in September 2002" *(P-3-37)* |
| P. Hoor | "A seasonal perspective on the tropospheric influence in the lowermost stratosphere" *(P-3-38)* |
| S. Khaykin | "Water vapour vertical distribution inside, outside and at the edge of the polar vortex over Sodankyla, Finland in winter 2004 during LAUTLOS-WAVVAP campaign" *(P-3-39)* |
| P. Konopka | "How can we quantify the effect of mixing on the transport and chemistry in the stratosphere? CLaMS - Chemical Lagrangian model of the stratosphere" *(P-3-40)* |

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| W. Kouker | “Diagnostics of stratosphere-troposphere exchange by means of the mechanistic model KASIMA and the chemistry climate model DLR/E39C” *(P-3-41)* |
| P. Canziani | “The use of an adaptive mesh refinement transport code to study the 2002 Antarctic polar vortex evolution” *(P-3-42)* |
| P. Canziani | “Tropospheric synoptic scale disturbances and the deformation of the Antarctic polar vortex” *(P-3-43)* |
| V. A. Yushkov | “Intrusions of the tropospheric air into the mixing layer above polar tropopause: aircraft observations of water vapour and ozone” *(P-3-44)* |
| P. Canziani | “An alternative mechanistic model of the Antartic polar vortex” *(P-3-45)* |
| T. P. Lane | “Observations and numerical simulations of inertia-gravity waves and shearing instabilities in the vicinity of a jet stream” *(P-3-46)* |
| P. Kushner | “A very large, spontaneous stratospheric sudden warming in a simple AGCM: a prototype for the Southern Hemisphere warming of 2002?” *(P-3-47)* |
| L. Jourdain | “Evaluation of the distributions of ozone, nitrogen oxides and water vapour in the UT/LS in the chemistry climate model LMDzT-INCA” *(P-3-48)* |
| V. Yushkov | “LAPBIAT UT/LS water vapour validation project (LAUTLOS WAVVAP): first results” *(P-3-49)* |
| C. Trepte | “SAGE III tropospheric ozone measurements” *(P-3-50)* |
| L. Pan | “The NCAR initiative on integrated study of dynamics, chemistry, clouds and radiation of the UT/LS” *(P-3-51)* |
| W. Evans | “Investigations of the polar vortex structure with the OSIRIS ozone product” *(P-3-52)* |
| R. J. Sica | “Lidar measurements of the seasonal variation of water vapour in the troposphere and lower stratosphere from a midlatitude station” *(P-3-53)* |
| V. Yushkov | “Fast vertical transport of humid air into the upper troposphere in extratropics: M-55 Geophysica water vapour observations” *(P-3-54)* |
| W.L. Grose | “Analysis of the February 2002 stratospheric warming using SABER data” *(P-3-55)* |
| F. Fierli | “Analysis of water vapour LIDAR measurements during the MAP campaign: evidence of sub-structures of stratospheric intrusions” *(P-3-56)* |
| T. Portafaix | “A state of the southern subtropical barrier during the 2003 Austral winter, deduced from Ertel potential vorticity and chemical tracer measurements” *(P-3-57)* |
| A. Klekociuk | “Influences of inertia gravity waves on Antarctic polar stratospheric clouds and chemical ozone depletion” *(P-3-58)* |
| B. Kärcher | “The impact of aerosols and mesoscale gravity waves on cirrus clouds at midlatitudes” *(P-3-59)* |
| M. Lavorato | “Operation of backscatter lidar at Buenos Aires (34.6°S/58.5°W) for the retrieval and analysis the atmospheric parameters in cirrus clouds, tropospheric height and aerosols layer.” *(P-3-60)* |
| F. Fierli | “Analysis of UT/LS transport based on data assimilation of MIPAS measurements” *(P-3-61)* |
| M. Sprenger | “A 15-year climatology of streamers and cutoffs and their relation to cross-tropopause mass exchange” *(P-3-62)* |
| B. Legras | “Lagrangian turbulent diffusion in the lower stratosphere” *(P-3-63)* |
| J. Pittman | “Identifying transport mechanisms of air into the subtropical middleworld during the summertime” *(P-3-64)* |
| P.-H. Wang | “SAGE II lower stratospheric/upper tropospheric ozone climatology” *(P-3-65)* |
| G. Hansen | “A climatological study of the Arctic UT/LS region, with special emphasis on Northern Scandinavia” *(P-3-66)* |
| D. Lu | “Stratosphere-troposphere exchange in East Asia: seasonal variation and major processes by using NCEP data” *(P-3-67)* |
| A. Dell’Aquila | “Effects of the baroclinic activity on the tropopause structure” *(P-3-68)* |
| S. Chabrillat | “Stratospheric chemistry of the Antarctic winter 2002: GOME observations explained by a 3D-CTM” *(P-3-69)* |

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| R. Kivi | "Stratospheric and upper tropospheric water vapour observations at Sodankyla, Finland" *(P-3-70)* |
| F. Zhang | "Observations and explicit simulations of extratropical sources of middle-atmospheric mesoscale gravity waves associated with tropospheric baroclinic jet-front systems" *(P-3-71)* |
| L. Pfister | "Dehydration in winter Arctic tropopause region" *(P-3-72)* |
| M. Andrade | "Total ozone trends within meteorological regimes: the Southern Hemisphere" *(P-3-73)* |
| E. Ray | "Evidence of the effect of summertime midlatitude convection on the subtropical lower stratosphere from CRYSTAL-FACE tracer measurements" *(P-3-74)* |
| W. J. Rodriguez | "Seasonal cycle and vertical structure of cross-tropopause transport determined from SAGE II Data" *(P-3-75)* |
| J. Burrows | "Measurements of trace constituent profiles using SCIAMACHY" *(P-3-76)* |
| M. Hegglin | "Troposphere-to-stratosphere transport and its impact on lowermost stratospheric $NO_y$ and $O_3$ *(P-3-77)* |
| CM. Volk | "Airborne *in situ* observations in the 2002/2003 Arctic vortex: analysis of descent, mixing, and ozone loss" *(P-3-78)* |
| T. Gierczak | "Evaluation of UT/LS loss processes of peroxynitric acid ($HO_2NO_2$)" *(P-3-79)* |
| E. Oikonomou | "Ozone intrusion events and their effect on climate over the Eastern Mediterranean" *(P-3-80)* |
| B. Morel | "Modelling of tropospheric dynamical forcing leading to isentropic mixing in the stratosphere: a new approach" *(P-3-81)* |
| T. Marcy | "Quantifying stratospheric ozone in the upper troposphere using *in situ* measurements of HCl" *(P-3-82)* |
| T. S. Rhee | "Rapid mixing across the extra-tropical tropopause as observed during a CARIBIC Boeing 767 Flight" *(P-3-83)* |

## Poster Session

## Thursday August 5, 2004

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|---|---|
| A.R. Jain | "Observations of extremely low cold point tropopause (CPT) temperature over Indian tropical region during summer monsoon months: possible implications for stratospheric water vapour" *(P-5-01)* |
| S. Shankar Das | "VHF radar observations of tropical tropopause and its temporal variability associated with gravity wave activities" *(P-5-02)* |
| N. Badu | "Long term VHF radar observations of vertical velocities and cross tropopause mass flux over Gadanki (13.5°N, 79.2°E)" *(P-5-03)* |
| S. Kleppek | "Influence of tropospheric teleconnection patterns on the stratosphere in winter" *(P-5-04)* |
| N. Patmore | "A tropopause moist pool over arid Asia Minor: upper tropospheric and lower stratospheric moistening in the Asian summer monsoon region" *(P-5-05)* |
| T. Reichler | "Response of the stratosphere-troposphere system to impulsive topographic forcing" *(P-5-06)* |
| H.-F. Graf | "The stratospheric polar vortex and tropospheric teleconnections in Northern Hemisphere winter" *(P-5-07)* |
| E. Jadin | "Ozone as the predictor of extreme weather events" *(P-5-08)* |
| P. Siegmund | "Stratospheric predictors for extended-range surface predictions" *(P-5-09)* |
| F. Robinson | "Modelling convective impacts on the tropopause temperature" *(P-5-10)* |

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| P. Haynes | "A trajectory-based study of the tropical tropopause region" *(P-5-11)* |
| J. Leclair de Bellevue | "Stratosphere-troposphere exchange near tropical convection: observations, mesoscale and global analyses *(P-5-12)* |
| L. Skelton | "Quantification of the rate of transport from the UT to the LS *via* the Tropical Tropopause Layer (TTL) using a 3D CTM" *(P-5-13)* |
| W. Randel | "An idealised model of the seasonal cycle in dehydration and cirrus formation near the tropical tropopause" *(P-5-14)* |
| R. Spackman | "Examining the thermal modes of the Tropical Tropopause Layer (TTL) with GPS radio occultation measurements" *(P-5-15)* |
| H. Clark | "Water vapour and cirrus in the Tropical Tropopause Layer (TTL) observed by UARS" *(P-5-16)* |
| H. Koernich | "The influence of the tropospheric annular mode on the polar vortex vacillations in a simple global circulation model" *(P-5-17)* |
| B. McDaniel | "Mechanisms for intraseasonal variability in the Northern Annular Mode" *(P-5-18)* |
| Q. Li | "Planetary wave propagation in Northern Hemisphere winter – climatological analysis of the refractive index" *(P-5-19)* |
| M. Keil | "The impact of high resolution stratospheric modelling on the troposphere" *(P-5-20)* |
| M. Taguchi | "Nonlinear climate response to ENSO and stratospheric warmings" *(P-5-21)* |
| S. Hardiman | "Downward propagation of dynamical signals in the middle atmosphere" *(P-5-22)* |
| A. Charlton | "The dynamical impact of the stratosphere on the tropopshere in a numerical weather prediction model" *(P-5-23)* |
| M. Milz | "Measurements of water vapour in the tropical and subtropical tropopause region with MIPAS/Envisat" *(P-5-24)* |
| C. Schiller | "Dehydration at the tropical tropopause over the Indian Ocean" *(P-5-25)* |
| A. Charlton | "The dynamical impact of the stratospheric state on the tropospheric flow during the Southern Hemisphere major warming 2002" *(P-5-26)* |
| J. Haigh | "How solar heating of the lower stratosphere influences tropospheric climate" *(P-5-27)* |
| L. Oman | "Climatic response to high latitude volcanic eruptions" *(P-5-28)* |
| A.E. Dessler | "The effect of convection on the thermal structure of the TTL" *(P-5-29)* |
| P. Canziani | "A climatology of planetary waves and synoptic systems over the Southern Hemisphere troposphere and lower stratosphere" *(P-5-30)* |
| X. Zhou | "Tropical temperature structures by radiosonde, ECMWF, and NCEP Reanalyses" *(P-5-31)* |
| C. Buontempo | "The effect of a tropical cyclone on the tropical tropopause layer: measurements and simulations for the Davina cyclone" *(P-5-32)* |
| P. Kushner | "Tropospheric response to stratospheric cooling in a simple AGCM: impact of the seasonal cycle" *(P-5-33)* |
| S. Eichelberger | "Tropospheric jet structure and the downward propagation of stratospheric zonal wind anomalies" *(P-5-34)* |
| C. Buontempo | "Mesoscale numerical experiments of the tropical cyclone Davina" *(P-5-35)* |
| P.A. Newman | "Stratospheric impact of varying sea surface temperatures" *(P-5-36)* |
| A. Gettelman | "Insights into stratospheric dehydration using isotopes of water" *(P-5-37)* |
| J.B. Nee | "Cirrus cloud occurrence studies by using lidar and HALOE observations" *(P-5-38)* |
| K. Kodera | "Solar influence on the spatial structure of the interannual variation of the stratospheric jet and its impact on the troposphere" *(P-5-39)* |
| N. Eguchi | "Intraseasonal variations of water vapour and cirrus clouds in the Tropical Tropopause Layer (TTL)" *(P-5-40)* |
| J. Gille | "The High Resolution Dynamics Limb Sounder (HIRDLS) on Aura: capabilities for UT/LS studies, status and first results" *(P-5-41)* |
| M. Shiotani | "SOWER/Pacific - results and a future plan" *(P-5-42)* |

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| M. Geller | "The roles of the Hadley circulation and downward control in tropical upwelling" *(P-5-43)* |
| A. Huesman | "Stratosphere-Troposphere Exchange and the QBO" *(P-5-44)* |
| M. Wittman | "Stratospheric influence on baroclinic instability: connection to the Arctic Oscillation" *(P-5-45)* |
| H. Shiogama | "Modulation of the stratosphere-troposphere coupling process of the Northern Hemisphere annular mode associated with the ENSO cycle" *(P-5-46)* |
| S. Fueglistaler | "Zonal variability of the heat budget in the tropical UT/LS" *(P-5-47)* |
| H. Mukougawa | "Predictability of stratosphere-troposphere dynamical interaction during stratospheric sudden warming events in the Northern Hemisphere" *(P-5-48)* |
| M. Niwano | "5-day variation of equatorial convective activity over 100-110°E and its influence on the upper troposphere and stratosphere" *(P-5-49)* |
| Y. Jaya Rao | "MST radar observations of vertical velocity and diabatic heating rates in the vicinity of tropical tropopause: possible influence on stratosphere troposphere exchange" *(P-5-50)* |
| B. Kärcher | "Cirrus clouds in the Tropical Tropopause Layer (TTL): role of heterogeneous ice nuclei" *(P-5-51)* |
| B. Lu | "Structure and variability of the Quasi-Biennial Oscillation (QBO)" *(P-5-52)* |
| S. Nishizawa | "Temperature trends estimated with finite-length datasets and evaluation of their significance with some idealised models" *(P-5-53)* |
| M. Niwano | "The occurrence of tenuous cloud in the tropical tropopause layer as related with the equatorial Kelvin waves coupled with the MJO" *(P-5-54)* |
| Y. Jaya Rao | "Lidar and MST radar observations of stratosphere troposphere exchange over a tropical Indian station" *(P-5-55)* |
| I. K.T. Kindem | "Seasonal forecast of the North Atlantic Oscillation with a stratosphere-troposphere model" *(P-5-56)* |
| J. M. Castanheira | "A signal in the energy due to planetary wave reflection in the upper stratosphere" *(P-5-57)* |
| R. Scott | "Downward wave propagation on the stratospheric polar vortex" *(P-5-58)* |
| R. Scott | "On the propagation of transient Rossby waves on the edge of stratospheric polar vortices" *(P-5-59)* |
| J. Anstey | "Downward phase propagation in a simple model of extratropical zonal variability" *(P-5-60)* |
| D. Weisenstein | "Influence of tropospheric $SO_2$ on particle formation and stratospheric humidity" *(P-5-61)* |
| K. Mohankumar | "Stratosphere troposphere exchange during Southwest and Northeast monsoon in India" *(P-5-62)* |
| R. Scott | "Is stratospheric variability completely determined by tropospheric forcing?" *(P-5-63)* |
| T. Garrett | "Are pileus clouds a source for tropopause cirrus?" *(P-5-64)* |
| T. Corti | "Mean radiative energy balance and vertical mass fluxes in the equatorial UT/LS" *(P-5-65)* |
| C.M. Volk | "Upwelling and mixing within the TTL: airborne *in situ* measurements over the Indian Ocean" *(P-5-66)* |
| D. Ortland | "Can stratospheric warmings affect the evolution of synoptic scale eddies?" *(P-5-67)* |
| K. Minschwaner | "Investigation of the mean tropical tropopause using GPS and the NCAR-NCEP Reanalysis" *(P-5-68)* |
| T. Halenka | "Solar activity impact on stratosphere-troposphere global circulation patterns" *(P-5-69)* |
| Y. Naito | "Statistical analysis on significant effects of the QBO on the extratropical stratosphere and the troposphere" *(P-5-70)* |
| A. Bertram | "Cubic ice in the atmosphere" *(P-5-71)* |
| Y. Kuroda | "On the origin of the meridional circulation and the surface pressure change associated with the Arctic Oscillation and comparison with the Polar-night Jet Oscillation" *(P-5-72)* |
| T. Dunkerton | "The role of monsoon circulations in the chemistry and composition of the tropical and subtropical UT/LS" *(P-5-73)* |

# Poster Session
# Friday August 6, 2004

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|---|---|
| D. Narayana Rao | "Indian MST radar and lidar observations of QBO and QBO-like oscillations in lower and upper atmospheres over Gadanki during 1995-2003" *(P-6-01)* |
| M. E. Castaneda | "Interhemispheric temporal variability of lower stratosphere temperature anomalies" *(P-6-02)* |
| N. Calvo | "Differences in the variability associated with ENSO in the middle atmosphere between a General Circulation Model (WACCM) and Reanalysis Data (ERA-40)" *(P-6-03)* |
| E. Lysenko | "Long-term changes of the horizontal wind parameters in the middle atmosphere over the rocket station Volgogra" *(P-6-04)* |
| D. Seidel | "Alternatives to linear trends for characterising stratospheric temperature changes" *(P-6-05)* |
| S. Burton | "An improved water vapour product for the SAGE II Version 6.2 data set" *(P-6-06)* |
| S. Tegtmeier | "Variations of the residual circulation in Northern hemispheric winter and the impact on Arctic ozone" *(P-6-07)* |
| Y. Chen | "Distribution of HCl and $NO_x$ over Tibet plateau in stratosphere" *(P-6-08)* |
| N. J. Muthama | "Cross-equatorial wave propagation over Africa as inferred from total ozone" *(P-6-09)* |
| Q. Fu | "Contribution of stratospheric cooling to satellite-inferred tropospheric temperature trends" *(P-6-10)* |
| D. Offermann | "Middle atmosphere parameter fluctuations as related to eddy transports and long term circulation changes" *(P-6-11)* |
| W. Tian | "Stratospheric water vapour: a CCM study of its potential impacts on ozone depletion and climate change" *(P-6-12)* |
| S.P. Burton | "Temperature climatology for 40-60 km from SAGE II" *(P-6-13)* |
| S. Pillai Abhilash | "VHF radar observations on prominent features of gravity waves and weakening of tropopause associated with tropical covection" *(P-6-14)* |
| J. Shanklin | "Stratospheric changes over Antarctica" *(P-6-15)* |
| M. Ponater | "Water vapour in the tropopause region as a forcing and feedback component in climate model simulations" *(P-6-16)* |
| R. Batchelor | "Measuring by moonlight: stratospheric trace gases during the 2003 Antarctic winter" *(P-6-17)* |
| T. Wehr | "Preparatory activities for future atmospheric climate and chemistry missions of the European Space Agency" *(P-6-18)* |
| Y. Koshelkov | "Space and time variations of temperature trends in the Arctic stratosphere" *(P-6-19)* |
| V.Subba Reddy | "Studies on convectively generated gravity waves over the tropics using Indian MST Radar at Gadanki" *(P-6-20)* |
| T. Shaw | "Assessing the importance of momentum conservation in the parameterisation of gravity wave drag in atmospheric models" *(P-6-21)* |
| V. Sivakumar | "Rayleigh lidar observations of double stratopause structure over Northern and Southern Hemisphere stations" *(P-6-22)* |
| W. Norton | "Changes in stratosphere/troposphere exchange in a doubled $CO_2$ climate" *(P-6-23)* |
| G. Taha | "Comparison of SAGE II Version 6.2 water vapour with balloon-borne and multiple space-based instruments" *(P-6-24)* |
| V. Sivakumar | "Studies on gravity wave characteristics including saturation process at a low latitude using Lidar and MST Radar" *(P-6-25)* |
| M. Chipperfield | "Multi-decadel 3D CTM simulations of past ozone variability and trends" *(P-6-26)* |

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| M. Ern | "Global measurement and modelling of gravity wave momentum flux" *(P-6-27)* |
| L. Hood | "The contribution of long-term circulation changes to column ozone trends at Northern midlatitudes" *(P-6-28)* |
| S. Rohs | "Long-term changes of methane in the stratosphere in the period 1978-2003" *(P-6-29)* |
| P. Canziani | "The evolution of total column ozone at southern midlatitudes 1980-2000" *(P-6-30)* |
| D. Sayres | "Methods for validation and intercomparison of remote sensing and *in situ* ice water measurements: case studies from CRYSTAL-FACE and model results" *(P-6-31)* |
| N. Lautié | "Odin/SMR global measurements of water vapour and its isotopes in the middle atmosphere" *(P-6-32)* |
| H. Roscoe | "The Brewer-Dobson circulation in the stratosphere and mesosphere: is there a trend?" *(P-6-33)* |
| Y. Kawatani | "Gravity wave activities around baroclinic waves in an AGCM simulation" *(P-6-34)* |
| H. Roscoe | "Lower stratospheric temperatures in Antarctic winter: the 40-year record conflicts with mid-latitude trends in stratospheric water vapour" *(P-6-35)* |
| H. Roscoe | "The broad edge region of the Antarctic ozone hole could allow increased greenhouse gases to delay ozone-hole recovery" *(P-6-36)* |
| F. Rohrer | "On the decay of stratospheric pollutants: observation of the longest-lived eigenmode of the stratospheric distribution of a conserved tracer" *(P-6-37)* |
| D. Schwarzkopf | "GCM simulations of the stratospheric global temperature response to realistic $20^{th}$ century forcings" *(P-6-38)* |
| E. Weinstock | "Benchmark water vapour measurements: requirements, measurement techniques, and validation" *(P-6-39)* |
| R. Plougonven | "On gravity waves near the tropopause associated to jet-streams" *(P-6-40)* |
| M. Stowasser | "The temporal and spatial variability of minor constituents as obtained by MIPAS-B measurements" *(P-6-41)* |
| M. Venkat Ratnam | "Peculiar behaviour of tropopause observed in tropical and extra tropical latitudes with CHAMP/GPS radio occultation measurements" *(P-6-42)* |
| V.S. Prasad | "Monitoring East Asian summer monsoon using upper troposphere humidity data from geo-stationery meteorological satellites" *(P-6-43)* |
| C. Pea Ortiz | "Detection of the secondary meridional circulation" *(P-6-44)* |
| M. Venkat Ratnam | "Enhancement of gravity wave activity observed during major Southern Hemisphere stratospheric warming by CHAMP/GPS measurements" *(P-6-45)* |
| A. Engel | "The temporal trend of $CO_2$ and the mean age of stratospheric air derived from balloon borne whole air samples" *(P-6-46)* |
| F. Chane-Ming | "Gravity wave activity over the South West Indian Ocean basin" *(P-6-47)* |
| K. Hiroshi | "Forcing mechanisms of the semiannual oscillation" *(P-6-48)* |
| M. Takahashi | "Equatorial gravity waves in a general circulation model" *(P-6-49)* |
| E. V. Holm | "Stratospheric water vapour analysis at ECMWF" *(P-6-50)* |
| S. Watanabe | "A quantitative comparison of gravity waves simulated by a high-resolution GCM to those calculated within the Doppler spread parameterisation" *(P-6-51)* |
| M. Petitdidier | "Momentum flux in the troposphere and lower stratosphere during the MAP experiment" *(P-6-52)* |
| P. Kafando | "Seasonal and interannual variations of gravity waves in equatorial Africa" *(P-6-53)* |
| D. Faduilhe | "Activity of gravity waves above La Réunion Island (21°S, 55°E)" *(P-6-54)* |
| E. Llewellyn | "The response of mesospheric ozone to the solar storm of October 28, 2004 as seen by OSIRIS on Odin" *(P-6-55)* |
| M. dela Torre Juárez | "Remote sensing of the UT/LS *via* GPS radio occultation" *(P-6-56)* |
| Z. Chen | "Seasonal gravity waves drags on the upper stratosphere due to Northwestern Pacific typhoons" *(P-6-57)* |

O. Dessens "Impact studies on atmospheric chemistry of future supersonic aircraft fleet." *(P-6-58)*

C. Marquardt "Gravity wave characteristics obtained from radio occultation soundings: observational filter and climatology" *(P-6-59)*

M.J. Alexander "Gravity wave generation by small-scale transient convection: a model study and comparisons to observations and a parameterisation" *(P-6-60)*

M. dela Torre Juárez "Trend comparisons between GPS occultation, ECMWF, NCEP reanalysis, and the Microwave Sounding Unit" *(P-6-61)*

Z. Chen "Stratospheric gravity waves generated by typhoon-A numerical simulation study" *(P-6-62)*

T. Song "Stratospheric ozone evolution at OHP (43.9°N, 5.7°E) during 1985-2003 based on multiple regression analysis" *(P-6-63)*

C. Hoyle "A comparison of CTM generated total ozone with the NIWA homogenised TOMS/GOME data set" *(P-6-64)*

J. Syktus "The impact of stratospheric ozone depletion and $CO_2$ on AAO trend and regional climate changes at surface of Southern Hemisphere: Implications for water resources in Australia" *(P-6-65)*

J. Anderson "Geophysical variability in v6.2 stratospheric aerosol and Gas Experiment II water vapour measurements" *(P-6-66)*

T. Scherrer "Gravity waves in the low stratosphere of the tropical region of the South America - Impacts of vertical resolution" *(P-6-67)*

D. Ortland "The interaction of gravity waves with stationary wave/mean flow vacillation cycles in the stratosphere" *(P-6-68)*

R.J. Sica "Midlatitude temperature climatology of the middle atmosphere measured by Rayleigh lidar" *(P-6-69)*

H. Voemel "Progress towards routine soundings of upper tropospheric and stratospheric water vapour" *(P-6-70)*

M. Govindankutty "Tropical cyclone and associated stratosphere troposphere exchange" *(P-6-71)*

S. Griffiths "Parameterising mean flow changes associated with equatorial inertial instability" *(P-6-72)*

L. Deaver "Assessment of Version 19 HALOE Ozone Data" *(P-6-73)*

S. K. Dhaka "Observations of shallow and deep convection and their role in generation of gravity waves using Indian MST radar" *(P-6-74)*

S. Crooks "The 11-year solar cycle influence on the atmosphere" *(P-6-75)*

D. Pendlebury "Gravity wave generation by equatorial inertial instability" *(P-6-76)*

K. Krueger "The unusual occurrence of recent major midwinter warmings in both hemispheres - an indicator of possible climate change?" *(P-6-77)*

R. Vincent "Constant pressure balloon studies of gravity waves in the tropical and extratropical lower stratosphere" *(P-6-78)*

I. Pomares "Total ozone behaviour in the Caribbean" *(P-6-79)*

M. Zondlo "Development of a lightweight, fast, and accurate hygrometer for use on balloons and aircraft" *(P-6-80)*

J. Burkert "Process study of the day-night-variation and twilight chemistry of nitrogen- and halogen oxides in the lower and middle stratosphere" *(P-6-81)*

J. M Russell III "Recent advances in the HALOE $4^{th}$ Public Release (v20) Algorithm" *(P-6-82)*

L. Gulstad "Modelling water vapour in the UT/LS" *(P-6-83)*

V. Fomichev "Model response to the doubling of $CO_2$ as simulated by the Canadian Middle Atmosphere Model" *(P-6-84)*

# ABSTRACTS

# ORAL PRESENTATIONS

## SUNDAY AUGUST 1, 2004

**O-1-01**

ENVIRONMENTAL SCIENCE IN THE GLOBAL ARENA:
STRATOSPHERIC OZONE TO MEGACITIES TO CLIMATE

**F. S. Rowland**

Department of Chemistry, University of California, Irvine, USA

**Abstract**: Atmospheric chemistry has played a major role in identifying, understanding, and helping confront many of the environmental issues of today. In this talk, I will discuss several atmospheric problems using examples from the work of our laboratory over the past three decades. First, I will discuss the issue of stratospheric ozone depletion, followed by the emerging issue of chemistry in large cities. Finally, I will make some observations on the atmospheric greenhouse gases and their role in global warming and climate change, and what the future is likely to hold.

**O-1-02**

LABORATORY STUDIES OF ATMOSPHERIC CHEMISTRY
IN THE UPPER TROPOSPHERE

**J. Abbatt**

University of Toronto, Toronto, Canada

**Abstract**: This talk will illustrate the central role that laboratory experiments play in deciphering the details of chemical and cloud processes in the upper troposphere. Particular emphasis will be given to measurements of the degree to which nitric acid vapour partitions to ice surfaces. For the first time partitioning experiments have been performed in the laboratory across the range of nitric acid partial pressures and temperatures prevalent in this part of the atmosphere. These results will be compared to partitioning measurements performed in a number of recent field campaigns. To illustrate the breadth of ongoing laboratory studies, selected studies of gas-phase chemistry and ice nucleation will also be briefly presented.

**O-1-03**

FORMATION OF THE ICE PHASE IN THE UT/LS REGION: A REVIEW
OF MICROPHYSICS BASED ON MEASUREMENTS AND MODELLING

**B. Kärcher**

Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen, Oberpfaffenhofen, Germany

**Abstract:** Aerosol particles are the precursors for ice crystals in cirrus and polar stratospheric clouds. The distribution of ice in the upper troposphere and lower stratosphere is determined by homogeneous and heterogeneous freezing processes, and vertical air motions leading to temperature fluctuations. Recent laboratory measurements, field studies, and modelling exercises have advanced the understanding of these fundamental processes. These studies and possible atmospheric implications are briefly reviewed.

**O-1-04**

## THE ROLE OF GRAVITY WAVES IN THE GENERAL CIRCULATION

**M. J. Alexander**

Colorado Research Associates Division of North West Research Associates, Boulder, USA

**Abstract**: Gravity wave forcing of the general circulation has been inferred from missing forcing in data assimilation models that is assumed to be due to unresolved waves in the assimilation. Gravity wave forcing is also widely parameterised in global circulation models, and studies with these models give estimates of their effects. However, different parameterisation methods make very different assumptions about the wave dissipation mechanisms, and sometimes use wildly different inputs for fundamental properties like net momentum flux crossing the tropopause. Ideally, one would like to use gravity wave observations to constrain the inputs to these model studies. Analyses of gravity wave properties from global observations have been reported for this purpose: however, the results and interpretation of these studies are sensitive to many factors: the observation technique, the resolution and averaging scales used in the analysis, the method of separating the background variations from the perturbations, and the climatology of the background winds. This talk will summarize recent studies on the role of gravity waves on the general circulation from each of these approaches.

**O-1-05**

## ASSIMILATION OF STRATOSPHERIC METEOROLOGICAL AND CONSTITUENT OBSERVATIONS: A REVIEW

**R. Rood**[1] and S. Pawson[2]

[1]Earth and Space Data Computing Division, NASA GSFC, Greenbelt, USA

[2]Global Modeling and Assimilation Office, NASA GSFC, Greenbelt, USA

**Abstract**: This talk reviews the assimilation of meteorological and constituent observations of the stratosphere. The first efforts to assimilate observations into stratospheric models were during the early 1980s, and a number of research studies followed during the next decade. Since the launch of the Upper Atmospheric Research Satellite (UARS) in 1991, model-assimilated data sets of the stratospheric meteorological state have been routinely available. These assimilated data sets were critical in bringing together observations from the different instruments on UARS, as well as linking UARS observations to measurements from other platforms. Using trajectory-mapping techniques, meteorological assimilation analyses are, now, widely used in the analysis of constituent observations and have increased the level of quantitative study of stratospheric chemistry and transport. During the 1990s the use of winds and temperatures from assimilated data sets became standard for offline chemistry and transport modelling.

Assimilated data sets provide accurate analyses of synoptic and planetary scale variability in middle latitudes. The transport experiments, however, reveal a set of shortcomings that become obvious as systematic errors are integrated over time. Generally, the tropics are not well represented, mixing between the tropics and middle latitudes is overestimated, and the residual circulation is not accurate. These shortcomings reveal underlying fundamental challenges related to bias and noise. Current studies using model simulation and data assimilation in controlled experimentation are highlighting the issues that must be addressed if assimilated data sets are to be convincingly used to study interannual variability and decadal change.

At the same time, stratospheric assimilation is evolving to include constituent observations. The primary focus has been on stratospheric ozone, but there are efforts that investigate a suite of reactive chemical constituents. Recent progress in ozone assimilation shows the potential of assimilation to contribute to the validation of ozone observations and, ultimately, the retrieval of ozone profiles from space-based radiance measurements.

# ORAL PRESENTATIONS

## MONDAY AUGUST 2, 2004

### *"FOCUS ON CHEMISTRY CLIMATE COUPLING"*

**O-2-01**

CHEMISTRY-CLIMATE COUPLING STUDIES WITH THE MET OFFICE UM

**John A Pyle**

Centre for Atmospheric Science, Department of Chemistry, University of Cambridge, UK

**Abstract:** The Met Office UM has been used to perform a number of chemistry/climate studies. Both stratospheric and tropospheric problems have been considered and one major theme emerging is the importance of changes in stratosphere/troposphere exchange in a changing climate. The pre-industrial, present and future (2100) atmospheres will all be discussed. Studies of the short-term, interannual variability of composition and its correlation with climate parameters such as the SOI will also be presented.

**O-2-02**

SIMULATION OF SECULAR TRENDS IN THE MIDDLE ATMOSPHERE SINCE 1979

**R. Garcia**, D. Marsh, D. Kinnison, and F. Sassi

National Center for Atmospheric Research, Boulder, USA

**Abstract:** Satellite and ground-based observations over the last few decades have documented secular trends in middle atmospheric composition and temperature that have been attributed to increases in the concentration of greenhouse gases (GHG) and chlorofluorocarbons (CFCs). In this study, we present results of a simulation of the middle atmosphere for the period 1979-2001 carried out with the Whole Atmosphere Community Climate Model (WACCM). WACCM is a comprehensive climate model that extends from the ground to the lower thermosphere and includes interactive chemistry, radiation and transport. The model is run with inputs for GHG, CFC, aerosol surface area density, and sea-surface temperatures taken from observations. Trends for the period 1979-2001 are calculated and compared with observations and also with the results of a control run that uses fixed inputs representative of 1975.

**O-2-03**

VARIABILITY IN SAGE II $NO_2$ OVER THE PAST 19 YEARS

**J. Zawodny**[1], J. Anderson[2], and P. Johnston[3]

[1]NASA Langley, Hampton, USA

[2]Hampton Univ., Hampton, USA

[3]NIWA Lauder, Omakau, New Zealand

**Abstract:** Observations of the stratospheric $NO_2$ profile by SAGE II began in late 1984 and continue through to the present. This nearly 20-year record is not, by itself, of trend quality, however, in combination with other satellite and ground-based records the suite is capable of revealing changes over most of the globe. SAGE II $NO_2$ vertical columns are compared to the Lauder twilight column measurements over the entire record and are shown to be consistent. The shape of the $NO_2$ profile from SAGE II is compared to HALOE. Relative trends in both the column and profile are evaluated. Given this underpinning, the SAGE II record has been deseasonalized with a simple linear regression model to reveal the interannual changes over most of the globe. Early in the record, $NO_2$ increased dramatically and has continued to increase although at a slower rate. SAGE II ozone measurements are used to see what portion of the observed $NO_2$ change is due to a change in $NO_2$/NO partitioning that results from changes in ozone and temperature.

**O-2-04**

## COUPLED CHEMISTRY CLIMATE SIMULATIONS: SOME KEY DIAGNOSTICS

**J. Austin**, J. Wilson, and V. Ramaswamy

Geophysical Fluid Dynamics Lab., Princeton, USA

**Abstract:** Results from an ad hoc intercomparison of chemistry-climate models, recently published in WMO (2002 Ozone Assessment, 2003) and in expanded form in Austin *et al*. (Atmos. Chem. Phys, 3, 1-27, 2003) will be presented and discussed. Key diagnostics will be briefly presented showing how the heat flux into the stratosphere is related to the temperature of the high latitude lower stratosphere. In turn, the high latitude lower stratospheric temperature directly influences the amount of heterogeneous ozone destruction as demonstrated in observations of the Arctic (Rex *et al*., GRL, in press, 2004). The results of the model intercomparison will be supplemented by recent results from the dynamics version of the GFDL model. This will be used to guide the choice of model parameters such as gravity wave forcing and tracer transport scheme. An important additional diagnostic is the "age-of-air". For the GFDL model the age-of-air, in common with other models, is too short, peaking at about 5 years, compared with the value of observed 7 years. The implications of this for ozone chemistry will be discussed. In particular it implies the need to enhance the photolysis rates of the halogen source molecules to obtain realistic distributions of the radical species. With appropriate modifications to the model parameterisations, the GFDL model has been coupled to a chemistry scheme, based on UMETRAC (Austin and Butchart, 129, QJRMS, 3225-3249, 2003), which contains comprehensive stratospheric chemistry and simplified (methane-based) tropospheric chemistry. Preliminary results show that the model reproduces a reasonable ozone climatology, but the ozone hole is too small in area and is slightly too shallow.

**O-2-05**

## PROCESS-ORIENTED VALIDATION OF COUPLED CHEMISTRY-CLIMATE MODELS

**V. Eyring**[1], N.R.P. Harris[2], M. Rex[3], T. G. Shepherd[4], D. W. Fahey[5], J. Austin[6], M. Dameris[1], B. D. Santer[7], and others[8]

[1]DLR Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany;

[2]European Ozone Research Coordinating Unit, Cambridge, UK; [3]Alfred Wegener Institute for Polar and Marine Research, Potsdam, Germany; [4]Atmospheric Physics Group, Department of Physics, University of Toronto, Canada; [5]NOAA Aeronomy Laboratory, Boulder, USA; [6]NOAA GFDL, Princeton, USA; [7]Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, Limermore, USA; [8]from Europe, the USA, Canada, Japan, and New Zealand

**Abstract:** Providing accurate and reliable predictions of future changes in stratospheric ozone is of central importance in climate studies. Simulating the interaction between chemistry and climate is of particular importance, because continued increases in greenhouse gases and a slow decrease in halogen loading are expected, which both influence the abundance of stratosphere ozone. In recent years a number of coupled chemistry-climate models (CCMs) with different levels of complexity have been developed. They produce a wide range of results concerning the timing and extent of ozone layer recovery. Interest in reducing this range has created a need to identify the main dynamical, chemical, and physical processes that determine the long term behaviour of ozone in the models and to validate these processes by comparison with observations and other models.

We present the outcome of a workshop on Process-oriented validation of coupled chemistry-climate models held on November 17-19, 2003 in Garmisch-Partenkirchen/Grainau, Germany. The workshop was motivated by the need to evaluate the skill of coupled chemistry-climate models to predict the future state of the ozone layer. The workshop brought together members of the CCM and CTM communities, as well as various measurement groups. A master table of key validation processes structured around four major topics (Dynamics, Transport Characteristics, Stratospheric Chemistry & Microphysics, and Radiation) has been developed. Each process is associated with one or more model diagnostics and relevant datasets, which could be used to validate this process. The master table is based on the contributions and discussions at the workshop. The table provides a framework for validating CCMs in a coordinated way and could be used as a basis for future assessments. The lasting impact and the full benefit from the workshop will come from concerted validation activities that will be based on this framework. These activities will unfold over the next couple of years and will require broad support from the atmospheric sciences community.

More about the workshop can be found at **http://www.pa.op.dlr.de/workshops/ccm2003/**.

**O-2-06**

## THE ROLE OF THE MIDDLE ATMOSPHERE IN THE EARTH SYSTEM

**G. Brasseur**

Max Planck Institute for Meteorology, Hamburg, Germany

**Abstract:** As we consider the evolution of the Earth system and its response to human influences, do we need to take into account the complex processes that occur in the stratosphere, the mesosphere, and even the thermosphere?

The middle atmosphere plays a key role in protecting life from harmful solar radiation and in affecting the Earth's climate. At the same time, the chemical composition of the middle atmosphere is not only affected by solar-induced photochemical processes, but also by biogenic emissions at the Earth's surface and wave generation in the troposphere. Finally, stratospheric variability could affect tropospheric dynamics and tropospheric composition.

This introductory paper will review progress made in our understanding of the dynamics, energetics and chemistry of the middle atmosphere, and will highlight scientific questions that remain to be addressed in the coming years.

**O-2-07**

## THE IMPORTANCE OF COUPLING CHEMISTRY TO CLIMATE MODELS.

**W. Collins**

Met Office, Exeter, UK

**Abstract:** Climate change is one of the most important problems facing us today, and atmospheric chemistry controls the abundances and distributions of many of the radiatively important gases. Ozone and other chemically active long-lived greenhouse gases have contributed about half of the radiative forcing of climate since the pre-industrial. Climate change itself affects atmospheric chemistry, for instance through changes in temperature and water vapour which directly affect the rates of ozone production and destruction processes. This interelation has prompted the development of the current generation of coupled climate-chemistry models. These focus primarily on tropospheric chemistry and impose climatologies in the stratosphere. However, radiative forcing from ozone is most sensitive to changes in the upper troposphere and lower stratosphere (UT/LS). So the next generation of models will treat dynamics, radiation and chemistry (tropospheric and stratospheric) simultaneously. Such coupling is essential for reproducing the observed trend in ozone in the troposphere and in particular in the UT/LS region. Climate-induced changes in the Brewer-Dobson circulation are expected to affect the exchange of ozone between the stratosphere and troposphere, and hence alter the distribution in the most radiatively sensitive region.

While the direct radiative effects of atmospheric chemistry are beginning to be quantified with more certainty, it is possible that the indirect effects could be of similar importance, but their magnitudes and even sign are often unknown. One of the most important indirect effects could be through the carbon cycle by the impact of atmospheric chemistry on the biosphere. The biosphere will be sensitive to changes in ground level ozone, UV, and deposition of nutrients. Again, there is a feedback loop with the biosphere emitting and removing reactive species from the atmosphere. The long-term goal of the climate community must be to treat, and model, the climate as a tightly coupled system, from the biosphere up to the stratosphere.

**O-2-08**

## OPERATIONAL CHEMICAL DATA ASSIMILATION USING ENVISAT: AN OVERVIEW.

**D. Fonteyn**, S. Bonjean, S. Chabrillat, F. Daerden, and Q. Errera

BIRA - IASB, Brussel, Belgium

**Abstract**: Since the operational phase of Envisat, the chemical level 2 near real time products have been assimilated operationally delivering near real time stratopsheric chemical analyses. Here an overview of relevant results is presented.

A brief description and set-up of the system will be given. Attention will be given to the validation of the results and to the *a posteriori* validation of the assimilation system.

The added value of chemical data assimilation with respect to free model simulations will be illustrated by three distinct examples. The support to CAL/VAL will be discussed. The remaining examples address more scientific issues: the chemistry of the polar vortex and the transport properties derived from long-lived species.

**O-2-09**

## DYNAMICAL CONTROL OF OZONE TRANSPORT AND CHEMISTRY FROM SATELLITE OBSERVATIONS AND COUPLED CHEMISTRY-CLIMATE MODELS

**M. Weber**[1], I. Wohltmann[2], V. Eyring[3], S. Dhomse[1], M. Rex[2], and M. Dameris[3]

[1]Institute of Environmental Physics, University of Bremen, Bremen, Germany

[2]Alfred Wegener Institute Potsdam, Potsdam, Germany

[3]Institute of Atmospheric Physics, DLR Oberpfaffenhofen, Oberpfaffenhofen, Germany

**Abstract:** Planetary scale wave driving regulates the winter transport of ozone into mid to high latitude as part of the residual circulation. In addition, the strength of the residual circulation regulates stratospheric temperatures at high latitudes and, thus, controls chemical depletion and in particular its interannual variabilty during Arctic winters. Using total ozone and chlorine dioxide column measurements from GOME the close interaction between ozone transport and ozone chemistry and the relationship to eddy heat flux/Eliassen-Palmen flux variability has been investigated combining data from both hemispheres and using different meteorological analyses. The GOME data period (1995-2003) represents a time close to the maximum of stratospheric halogen loading. The relationship derived from the observations provides a good diagnostic for CCM validation. TOMS total ozone data differences in the compact relationship between winter ozone transport in the past (early 80s) and present have been investigated and are compared with analogous relationships derived from different ECHAM4.L39(DLR)/CHEM model runs. Apart from uncertainties in the diagnostic capabilities of CCMs, the differences in met analysis quality between the 80s ad 90s have a large impact on the diagnostic relationships and long term trend assessment.

**O-2-10**

ARCTIC OZONE LOSS AND CLIMATE CHANGE

**M. Rex**[1], R. J. Salawitch[2], P. von der Gathen[1], N. R. Harris[3], M. P. Chipperfield[4], and B. Naujokat[5]

[1]Alfred Wegener Institute for Polar and Marine Research, Potsdam, Germany

[2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA

[3]European Ozone Research Coordinating Unit, Cambridge, UK

[4]School of the Environment, University of Leeds, Leeds, UK

[5]Free Univ. of Berlin, Meteorological Institute, Berlin, Germany

**Abstract:** We report the first empirical quantification of the relation between winter-spring loss of Arctic ozone and changes in stratospheric climate. Our observations show that 15 DU additional loss of column ozone can be expected per Kelvin cooling of the Arctic lower stratosphere, an impact nearly three times larger than current model simulations suggest. We show that stratospheric climate conditions became significantly more favorable for large Arctic ozone losses over the past four decades *i.e.*, the maximum potential for formation of polar stratospheric clouds increased steadily by a factor of three. These results demonstrate that the severe Arctic ozone losses reported for some winters during the 1990s were not only the result of increased stratospheric halogen loading compared to earlier decades, but also resulted from a long term change in the climate of the Arctic stratosphere. We show that the interannual variability of chemical ozone loss is well correlated with the natural variability of dynamical supply of ozone to the Arctic driven by the residual circulation. We find that for current climate conditions and halogen levels, chemical loss of ozone amplifies the natural interannual variability of the Arctic ozone column in spring by about a factor of two.

**O-2-11**

COUPLED CHEMICAL-DYNAMICAL DATA ASSIMILATION IN THE STRATOSPHERE: PROSPECTS FOR SEPARATING MODEL AND MEASUREMENT BIAS

**S. Polavarapu**

Meteorological Service of Canada, Downsview, Canada

**Abstract:** Middle atmosphere GCM intercomparisons reveal discrepancies in mean temperature fields, which are due in large measure to uncertainties in gravity wave drag parameterisation. At the same time, the primary source of temperature observations in the upper stratosphere is satellite radiances from nadir sounders, which have biases that are typically larger than the signal itself. In the troposphere and lower stratosphere, the radiosonde network provides an unbiased source of observations, which can be used to remove the bias in the satellite measurements. However, this strategy is not possible in the upper stratosphere due to the paucity of *in situ* measurements. Thus, both models and measurements have significant but unknown biases, yet almost all implementations of data assimilation rely on the assumption of no bias in either.

Coupled chemical-dynamical data assimilation offers the prospect of separating model from measurement bias, by bringing in additional constraints. In the upper stratosphere, there is a well-known negative correlation between ozone and temperature through chemistry. In this work, coupled chemical-dynamical data assimilation is performed with the Canadian Middle Atmosphere Model (CMAM), whose domain extends sufficiently high that assimilation in the upper stratosphere is not contaminated by upper boundary effects. Without assimilating ozone, temperature biases are evident in the upper stratosphere and can grow without bound due to a positive model feedback through gravity wave drag. When ozone is assimilated, model biases of ozone can be improved if the bias is attributed entirely to the model. This assumption is valid if cross-validation of different ozone measurement sources is done. Finally, the impact of ozone assimilation on temperature bias will be examined.

# ORAL PRESENTATIONS

## TUESDAY AUGUST 3, 2004

## *"FOCUS ON EXTRATROPICAL UT/LS"*

**O-3-01**

## *IN SITU* MEASUREMENTS IN THE EXTRATROPICAL UT/LS: A PERSPECTIVE ON PROGRESS AND NEEDS

**D. W. Fahey**

NOAA Aeronomy Laboratory, Boulder, USA

**Abstract:** Interest in the upper troposphere and lower stratosphere in the extratropics (E-UT/LS) has increased in recent years as the need to understand global change grows and the sophistication of our global models has advanced. Our understanding of the E-UT/LS depends on accurate descriptions of trace gas and aerosol distributions and clouds and their roles in chemical, transport and radiative processes. Characterising the E-UT/LS remains challenging because of the significant differences in chemical and dynamical processes between the stratosphere and troposphere. Our understanding of the E-UT/LS remains incomplete, in part, because of limited measurements. A perspective will be given on recent progress in *in situ* measurements in the E-UT/LS and their interpretation along with some ideas about future measurement needs.

**O-3-02**

## KEY ISSUES OF STE IN THE EXTRA-TROPICS

**H. Wernli**

Institute for Atmospheric Physics, University of Mainz, Mainz, Germany

**Abstract**: Various methods have been developed in recent years to diagnose and quantify the flux of air and chemical constituents across the extratropical tropopause. Among them, the Lagrangian approach has been applied to case studies and climatological data sets, for instance the ERA15 reanalyses, and revealed novel aspects of STE in the extra-tropics. These aspects include the concept and significance of residence times and the distinction between shallow and deep exchange events.

The talk will have 3 parts and first will summarize some results from the recent EU project STACCATO related to residence times and the vertical extent of STE.

Secondly, preliminary results of global STE mass and ozone fluxes based upon the ERA40 data set will be shown and compared to estimates using ERA15 data.

In the final part, the Lagrangian technique will be used to investigate some features observed during the recent experimental project SPURT in the European UT/LS. The combination of *in situ* observations and diagnostic techniques allows to validate the diagnostics and to identify key issues for future research as, for instance, the possible chemical implications of the high variability in the STE events' residence time.

**O-3-03**

LAGRANGIAN MODEL SIMULATIONS OF MIXING NEAR THE TROPOPAUSE

**L. Pan**[1], P. Konopka[2], C. Schiller [2], P. Hoor[3], and E. Browell[4]

[1]National Center for Atmospheric Research, Boulder, USA

[2]Forschungszentrum Jülich, ICG-I, Jülich, Germany

[3]Max Planck - Institute for Chemistry, Mainz, Germany

[4]NASA Langley Research Center, Hampton, USA

**Abstract:** Mixing processes play an essential role in the stratosphere-troposphere exchange (STE) of chemical species. Although the effect of mixing between stratospheric and tropospheric air is frequently observed in tracer-tracer correlations, quantifying the contribution of mixing to STE has been a significant challenge. Eulerian models often produce more mixing than observed due to numerical diffusion. Lagrangian models, on the other hand, often use idealised air parcels that never mix, and the approach therefore has limited utility in quantifying STE of chemical species, such as ozone and water vapour. We present initial results of a model investigation of mixing in the tropopause region, using the 3D version of Chemical Lagrangian Model of the Stratosphere (ClaMS), which allows advection and parameterised mixing. Case studies simulating LIDAR and *in situ* observations during the SONEX campaign in October 1997 and the SPURT experiment during 2001-2003 will be presented to demonstrate the models strengths and weaknesses in characterising mixing near the tropopause. The ClaMS simulation allows a simple comparison of calculated STE with and without mixing. The mixing lines observed in the CO-$O_3$ tracer correlation indicate irreversible exchange across the tropopause and provide a physical mechanism of evaluating the mixing algorithm used in CLaMS. The results show that intensive mixing between stratospheric and tropospheric air occurs on the cyclonic side of the jet. To quantify the transport across the tropopause, an artificial tracer is initialised as 1 and 0 in the stratosphere and troposphere, respectively. This technique helps to identify asymmetric signatures of mixing layers above and below the subtropical jet. The seasonal dependence of the stratosphere-troposphere transition layer will be highlighted.

**O-3-04**

ISENTROPIC MIXING LAYER ACROSS THE MID-LATITUDE TROPOPAUSE AS SEEN BY MOZAIC MEASUREMENTS: REGIONAL AND INTER-ANNUAL ASPECTS.

**J.-P. Cammas**, J. Brioude, P. Nedelec, and V. Thouret

Laboratoire d'Aérologie, Observatoire Midi-Pyrénées, Toulouse, France

**Abstract:** MOZAIC aircraft *in situ* measurements of ozone, water vapour and carbon monoxide provide from January 2002 a detailed data base over most of the midlatitude Northern Hemisphere (from western America to eastern Asia, **http://www.aero.obs-mip.fr/mozaic/**) to analyse the chemical composition of the UT/LS and to investigate the impact of isentropic mixing processes across the tropopause. Slopes and correlations of mixing lines between the stratospheric and tropospheric reservoirs are computed from aircraft time series, grouped by regions and seasons, and analysed with respects to zonal differences in upper level dynamics and in CO surface emissions. Interpretations are further conducted with the analysis of 5-days backward trajectories of air parcels sampled along aircraft paths. It is shown that the composition of the mixing layer depends on regional CO surface emissions and on the effect of polar and subtropical jet streams lying at different levels.

**O-3-05**

## TRANSPORT OF WATER VAPOUR INTO THE LOWERMOST STRATOSPHERE

**C. Schiller**[1], G. Günther[1], P. Konopka[1], M. Krebsbach[1], N. Spelten[1], and H. Wernli[2]

[1]Forschungszentrum Jülich, Jülich, Germany

[2]University of Mainz, Mainz, Germany

**Abstract:** During the SPURT and other projects, airborne high-resolution *in situ* measurements of a large set of trace gases, such as water vapour and ozone in the UT/LS were performed in a wide latitude region (20-80°N) covering all seasons. Based upon this data set, we derived a seasonal climatology and characteristics of tracer distributions, their gradients and wind velocities in that region around the polar jet. Elevated amounts of total water in the UT/LS have been detected in all seasons with a pronounced maximum in late spring and early summer. The seasonal and latitudinal variability of extratropical tropopause temperatures determines the transport of water vapour into the LS. A mixing layer with $H_2O$ mixing ratios well above 5 ppmv, indicative for significant tropospheric contribution, ranges several ten degrees latitude polewards or, in potential temperature, several ten K above the tropopause.

To identify the effects of cross-tropopause transport by advection and mixing processes in the observations, the Chemical Lagrangian Model of the Stratosphere (CLaMS) is used for high-resolution hemispherical simulations based on trajectory calculations with mixing between the considered air parcels. For the simulation of water vapour, phase changes and sedimentation of ice particles are considered utilising a simplified water model. Comparisons between the CLaMS results and the observations show good agreement for both large and small scale features, *e.g.* the occurrence of clouds and filamentary structures. The global distribution of the simulated tracers show the strong spatial and temporal variability of the UT/LS emphasising the importance of small scale mixing processes for stratospheric-tropospheric exchange. Analyses of the budgets of the artificial tracers allow for an estimation of the net mass flux across the tropopause and its annual variation. The results obtained for water vapour imply that the lower stratosphere may be moister than usually expected, in agreement with the campaign observations.

**O-3-06**

## THE SATELLITE VIEW OF EXTRA-TROPICAL STRATOSPHERE-TROPOSPHERE EXCHANGE AND THE UT/LS

**M. Schoeberl**

NASA/GSFC, Greenbelt, USA

**Abstract:** This talk will review satellite studies, which have helped define the UT/LS and stratosphere-troposphere exchange (STE). Satellites have provided a global perspective but have had limited temporal and spatial measurements for STE studies. Nonetheless, long-lived tracer measurements from satellites can be used as proxies for age-of-air and can, thus, provide estimates of mixing and transport processes in the UT/LS. These measurements can be compared to model estimates of the mean age-of-air and trace gas fluxes providing an important model diagnostic. With the launch of EOS Aura, the potential for satellite trace gas measurements of the lower-most stratosphere and STE is significantly improved, and Aura's mission will be briefly described.

**O-3-07**

OBSERVATION OF THE POLAR OZONE LAYER BY SATELLITE SENSORS OF ILAS AND ILAS-II

**H. Kanzawa**[1], T. Sugita[2], T. Yokota[2], H. Nakajima[2], and Y. Sasano[2]

[1]Graduate School of Environmental Studies, Nagoya University, Nagoya, Japan

[2]National Institute for Environmental Studies, Tsukuba, Japan

**Abstract:** ILAS (Improved Limb Atmospheric Spectrometer) aboard ADEOS (renamed Midori after the launch) and ILAS-II aboard ADEOS-II (Midori-II ) measured trace species such as $O_3$, $HNO_3$, $NO_2$, $N_2O$, $CH_4$, $H_2O$, and aerosol in the polar stratosphere continuously from November 1996 to June 1997 and from April to October 2003, respectively (see **http://www-ilas.nies.go.jp/** and **http://www-ilas2.nies.go.jp/en/**). A main advantage of solar occultation sensors of ILAS and ILAS-II is to provide longitude – height cross-sections of the trace species at a latitude per day in both polar regions: it covers the stratosphere with altitude resolution of about 1-2 km (see the details in the ILAS Special Section papers of J. Geophys. Res. Atmospheres, Vol. 107, D24, 2002 and in the succeeding papers). The main results of ILAS include estimates of stratospheric ozone loss rates and detections of denitrification and dehydration in the characteristic Arctic winter of 1996/1997 when the polar vortex was maintained until the beginning of May 1997, that is, the polar vortex was stable and maintained abnormally long, mainly based on chemically active tracer data analyses. They also includes descriptions of mixing features of the polar vortex breakdown in the Antarctic spring around November 1996 and estimates of downward motion in the Antarctic early winter around May-June 1997, mainly based on long-lived tracer data analyses. This paper will review some of the main results of ILAS and ongoing research using ILAS-II data that cover the total winter period of the Antarctic and the total summer period of the Arctic in 2003.

**O-3-08**

EXPERIMENTAL AND THEORETICAL INVESTIGATION OF THE NUCLEATION OF NAD AND NAT PARTICLES

**D. Knopf**[1], T. Koop[2], B. Luo[2], U. Weers[2], and T. Peter[2]

[1]University of British Columbia, UBC Vancouver, Canada

[2]Swiss Federal Institute of Technology, ETH, Zurich, Switzerland

**Abstract:** Polar Stratospheric Clouds (PSCs) play a key role in the depletion of stratospheric Ozone by providing a surface for the heterogeneous activation of chlorine species. In the Arctic winter 1999/2000 large nitric acid containing particles consisting of NAD and NAT crystals, up to 20 micrometer in diameter, were observed in particle number densities of $10^{-4}$ 1/cm$^3$. The sedimentation of these particles causes denitrification and dehydration of the lower stratosphere. Denitrification of the stratosphere results in a slower Ozone recovery. The nucleation of NAD and NAT from $HNO_3/H_2O$ and $HNO_3/H_2SO_4/H_2O$ solution droplets was investigated both theoretically and experimentally with respect to the formation of PSCs. Our analysis showed that volume-based homogeneous NAD and NAT nucleation from liquid aerosols is insufficient to explain the number densities of large nitric acid containing particles recently observed in the Arctic stratosphere. Recently, it was suggested that the nucleation of NAD and NAT in aqueous $HNO_3$ solutions performed in laboratory experiments occurs at the droplet surface. The experimental nucleation data are reanalysed with respect to a potential surface-induced nucleation pathway, and compared to the theoretically derived homogeneous nucleation rate coefficients. The corresponding surface-based production rates are too low by up to 4 orders of magnitude, if they were to explain the occurrence of large nitric acid containing particles with number densities of about $10^{-4}$ 1/cm$^3$. Therefore, our measurements suggest that also surface-based nucleation of NAD and NAT is insufficient to explain the observed polar denitrification. We conclude that there are other formation mechanisms such as heterogeneous nucleation processes, which may be responsible for the occurrence of NAD and NAT-particles, respectively.

**O-3-09**

POLAR STRATOSPHERIC CLOUD ANALYSES USING SAGE III DATA

**L. Poole**
NASA Langley Research Center, Hampton, USA

**Abstract:** The Stratospheric Aerosol and Gas Experiment (SAGE) III was launched onboard the Russian Meteor-3M spacecraft in December 2001 and has been making routine solar occultation measurements since late February 2002. SAGE III sunset occultation data are collected at latitudes from 65°N-80°N during local winter, making the platform ideal for Arctic polar stratospheric cloud (PSC) observations. Southern Hemisphere PSC observations are less frequent, since data (sunrise occultations) are collected near the edge of the Antarctic polar vortex during local austral winter (from 50°S-60°S in latitude). A new PSC detection algorithm has been developed using SAGE III aerosol extinction data from three channels (449 nm, 1022 nm and 1545 nm). This approach enables discrimination of PSCs by thermodynamic type and appears to be quite sensitive to the presence of a few large particles (*i.e*., NAT rocks). This talk will present the new algorithm and discuss PSC observations by SAGE III since its launch.

**O-3-10**

INTERANNUAL VARIABILITY AND TRENDS IN THE VERTICAL DISTRIBUTION OF OZONE IN THE LOWER STRATOSPHERE AND TROPOSPHERE.

**J. Logan** and I. Megretskaia
Harvard University, Cambridge, USA

**Abstract:** Mid-latitude column ozone reached minimum values in 1993, and then increased for several years, with considerable interannual variability in 1995 that was the second lowest year for column ozone. We present an analysis of ozonesonde data that shows the altitude regimes that contributed to the column behaviour, and we examine the relationship of ozone to variables such as the QBO, solar cycle, Arctic Oscillation (AO), North Atlantic Oscillation (NAO), and tropopause height using linear regression modelling. There is a significant dependence of ozone from 200 hPa to 80 hPa on the AO (or NAO) over Europe in all seasons except summer, but not in the troposphere. Conversely, over Canada, ozone does not depend significantly on the AO (or NAO) from 200 to 80 hPa, but there is a significant fit to the AO in some seasons in the troposphere. Ozone depends significantly on the tropopause pressure in all seasons at most mid-latitude locations from 300 hPa to 80 hPa, and even in some seasons at 50 hPa. By comparing time series of monthly ozone anomalies to those of the linear regression fits with various explanatory variable included, we will demonstrate which features of the interannual variability are reproduced by the different explanatory variables; these comparisons are a valuable complement to the standard statistical measures of the model fit. We will also present trends in the ozone profiles with variable ending dates.

**O-3-11**

CROSS-TROPOPAUSE TRACER TRANSPORT IN MIDLATITUDE CONVECTION

**G. Mullendore**, J. Holton, and D. Durran
University of California, Los Angeles, USA

**Abstract:** Simulations performed by a 3D cloud-resolving model are used to study the transport of tropospheric tracers into the lowermost stratosphere via midlatitude convection. Direct transport by convection is believed to be the most likely mechanism by which short-lived chemical species can be transported from the boundary layer to the stratosphere. In previous studies of troposphere to stratosphere convective transport, the extent of irreversible transport is unclear. The tropopause location is poorly defined in the highly perturbed environment directly above an active storm. Thus, to determine the irreversibility of cross-tropopause transport, ten-hour simulations are carried out to cover the growth and decay cycles of the storm. After the decay of convection, isentropes relax to quasi-flat surfaces, allowing more confident tropopause location. At ten hours in the typical supercell simulation, at 1 km above the tropopause, the concentration of the tracer originating below 1 km has maximum of 26 % of its original concentration. The concentration of the tracer originating in the layer between 1 and 4 km has a maximum of 23 % of its original concentration. Increasing the altitude of the level of neutral buoyancy in model soundings and adding upper level wind shear are both found to produce more transport into the stratosphere. Supercell storms produce more transport when compared with multicell storms.

# ORAL PRESENTATIONS

## WEDNESDAY AUGUST 4, 2004

### *“FOCUS ON STRATOSPHERE-TROPOSPHERE DYNAMICAL COUPLING”*

**O-4-01**

# LARGE ENSEMBLE EXPERIMENTS ON THE INTERANNUAL VARIABILITY AND TRENDS WITH A STRATOSPHERE-TROPOSPHERE COUPLED MODEL

**S. Yoden**

Department of Geophysics, Kyoto University, Kyoto, Japan

**Abstract:** We have performed numerical experiments with an idealised stratosphere-troposphere global circulation model to investigate the internal variability of the stratosphere-troposphere coupled system (Taguchi, Yamaga and Yoden, 2001; Taguchi and Yoden, 2002a,b,c) and the effects of equatorial QBO on such variability (Naito, Taguchi and Yoden, 2003). Recent progress in computing facilities enabled us to perform large ensemble experiments in which many trials of computations were done by sweeping the value of a control parameter or an initial condition (Yoden, Taguchi and Naito, 2002).

A large number of ensembles make it possible to use a large sample method in statistical tests instead of a small sample method with Student t-test, so that it is not necessary to assume the equality of the variances of two populations. This kind of new statistical approach based on large ensemble experiments, which is new in a sense that it has become possible very recently for ordinary people, might be applied for the discussion of the rarity of the stratospheric sudden warming event in the Southern Hemisphere in September 2002 (Hio and Yoden, 2004).

Another example, which appeals the advantage of large ensemble experiments, is the statistical significance test of linear trends estimated with short-length data that have natural internal variability (Nishizawa and Yoden, 2004). Statistical characteristics of such spurious trends due to the shortness of data can be argued by investigating the probability distribution function of the spurious trends theoretically and numerically. Combining 10000-year model data and some observed trends in the past two decades, it is shown that a large cooling trend about - 4 K/decade in mid-stratosphere at the North Pole in September is highly significant.

**O-4-02**

# HOW ARE WEATHER AND CLIMATE AFFECTED BY STRATOSPHERIC VARIABILITY?

**Mark Baldwin**

Northwest Research Associates, Bellevue, USA

**Abstract:** This topic is really three questions: 1) what are the effects at Earth's surface? 2) What will the effects be in the future? 3) Do we understand how stratospheric effects are communicated to Earth's surface?

In this talk, I will present an overview of observational evidence that variations in the circulation of the lower stratosphere during winter affect weather patterns. In the Northern Hemisphere, stratospheric effects are mainly seen as changes to Northern Annular Mode (NAM) index, or more precisely, shifts in the PDFs of the NAM index. In the Southern Hemisphere, stratospheric variability peaks in the late spring, so that surface effects are seen during late spring and early summer. Both observations and models support the hypothesis that the springtime ozone hole not only strengthened the stratospheric polar vortex, but that these effects shifted surface weather over Antarctica.

On climate-change timescales, stratospheric effects on surface climate are potentially large, yet we are not yet able to predict how the stratosphere will change in the coming decades. Climate models do not agree as to whether the polar vortex will become colder and stronger as greenhouse gas concentrations increase, or if, due to increased wave activity from the troposphere, the vortex will become warmer and weaker.

Rapid progress is being made on understanding the dynamics of how stratospheric circulation anomalies affect the surface. I will review the various mechanisms that could contribute to downward communication of stratospheric signals. It appears that much of the communication (but not all) involves the effects of wind anomalies in the lowermost stratosphere on tropospheric baroclinic waves.

**O-4-03**

# DOWNWARD PROPAGATION AND STATISTICAL FORECAST OF NEAR SURFACE WEATHER

**B. Christiansen**

Danish Meteorological Institute, Copenhagen, Denmark

**Abstract**: We investigate the potential for using the downward propagation of anomalies from the stratosphere to the troposphere in extended range statistical forecasts. Considering the near surface zonal mean zonal wind at 60°N, the Arctic Oscillation index, or the North European near surface temperature as predictands, we find that the inclusion of stratospheric information increases the skill of the daily forecast on lead times larger than 5 days. Similar skill cannot be obtained if the forecast model only includes tropospheric information. The largest skills are obtained for predictors in the lower stratosphere.

The simple statistical forecast based on stratospheric winds compares favourably to a state-of-the-art dynamical ensemble prediction system. The skills of the statistical forecast model can be substantially improved by considering only strong stratospheric anomalies or by predicting averaged values.

**O-4-04**

# A PLAUSIBLE MECHANISM OF THE MAJOR STRATOSPHERIC WARMING IN THE SOUTHERN HEMISPHERE OF 2002 AS INFERRED FROM NUMERICAL PREDICTION MODEL SIMULATION

**T. Hirooka**[1], A. Mori[1], H. Mukougawa[2], and Y. Kuroda[3]

[1]Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, Japan

[2]Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan

[3]Meteorological Research Institute, Japan

**Abstract:** In late September 2002, an unprecedented major stratospheric sudden warming occurred in the Southern Hemisphere accompanied with the split of the polar vortex. In this study, by the use of the stratospheric assimilated data operationally produced by the Japan Meteorological Agency (JMA), as well as a series of one-month forecast data based on the JMA numerical weather prediction model initialised every 12 hours, we investigate a causation mechanism of the sudden warming event.

In the stratosphere, planetary waves of both zonal wavenumber 1 and 2 were very active throughout the winter season prior to the major warming, which brought about frequent occurrence of minor warmings. With regards to the subsequent major warming, however, planetary waves of zonal wavenumber 2 and 3 played an important role in splitting the polar vortex to cause the sudden warming. In case that the vertical propagation of the waves from the upper troposphere to the stratosphere is well simulated in the forecast data, a sudden warming event with the polar vortex split successfully occurs. Furthermore, both assimilated data and successful prediction indicate that the zonal mean zonal wind in the mid-latitude lower stratosphere was decelerated by synoptic-scale disturbances. Such activity of synoptic-scale disturbances made mean flows favorable for the unusual vertical propagation of planetary waves of zonal wavenumber 2 and 3. Eventually, the polar vortex split into two parts.

**O-4-05**

# DYNAMICAL MECHANISMS FOR STRATOSPHERIC INFLUENCES ON THE TROPOSPHERE

**W. Robinson**

University of Illinois at Urbana-Champaign, USA

**Abstract:** Observations and models offer increasingly strong evidence that the stratosphere exerts a dynamical influence on the troposphere, during those months of the year in which there is robust variability within the stratosphere. The means by which this influence is exerted, however, remains uncertain. In particular, it is not clear what the relative roles are of the zonal mean circulation, of planetary waves, and of synoptic eddies.

Dynamical budgets indicate that the proximate source of tropospheric zonal flow anomalies, induced by preceding stratospheric changes, are anomalous momentum fluxes due to tropospheric waves and eddies. How does the stratosphere alter the behaviour of tropospheric eddies? Several possibilities have been suggested:

- Tropospheric eddies respond to changes in the tropospheric zonal flow, induced, through the mean meridional circulation, by changes in stratospheric wave driving.
- Tropospheric eddies respond directly to changes in the lower stratospheric winds.
- Planetary waves are refracted by changes in the stratospheric winds, leading to altered planetary wave propagation, and thus momentum fluxes, in the troposphere. One version of this idea suggests that planetary waves are reflected back to the troposphere from the middle or upper stratosphere. Another suggests that lower stratospheric winds, especially their vertical shear across the tropopause, are key.
- Anomalous winds in the lower stratosphere alter the generation and propagation of baroclinically unstable planetary waves in high latitudes.

Here we compare and contrast the results of observational studies, general circulation model experiments, and investigations using idealised models, to assess the evidence supporting and refuting these different proposed mechanisms.

**O-4-06**

# UPWARD WAVE ACTIVITY FLUX AS PRECURSOR TO EXTREME STRATOSPHERIC EVENTS AND SUBSEQUENT ANOMALOUS SURFACE WEATHER REGIMES

**L.M. Polvani**[1] and D.W. Waugh[2]

[1]Columbia University, New York, USA

[2]Johns Hopkins University, Baltimore, USA

**Abstract:** It has recently been shown that Extreme Stratospheric Events (ESEs) are followed by surface weather anomalies (for up to 60 days), suggesting that stratospheric variability might be used to extend weather prediction beyond current time scales. In this paper we draw attention away from the stratosphere, and demonstrate that originating point of ESEs is located in the troposphere. First, we show that anomalously strong eddy heat fluxes at 100 hPa nearly always precede weak vortex events and, conversely, anomalously weak eddy heat fluxes precede strong vortex events, consistent with wave-mean flow interaction theory. This finding clarifies the dynamical nature of ESEs, and suggests that a major source of stratospheric variability (and thus predictability) is located in the troposphere below, and not in the stratosphere itself. Second, we find that the daily time series of eddy heat flux at 100 hPa, integrated over the prior 40 days, exhibits a remarkably high anti-correlation (-0.8) with the Arctic Oscillation index at 10 hPa. Following Baldwin & Dunkerton (2001), we then demonstrate that events with anomalously strong/weak integrated eddy heat fluxes at 100 hPa are followed by anomalously large/small surface values of the AO index up to 60 days following each event. This suggests that the stratosphere is unlikely to be the dominant source of the anomalous surface weather regimes discussed in Thompson *et al*. (2002).

**O-4-07**

DOWNWARD COUPLING BETWEEN THE STRATOSPHERE AND TROPOSPHERE: THE RELATIVE ROLES OF WAVE AND ZONAL MEAN PROCESSES

**J. Perlwitz**[1] and N. Harnik[2]

[1]Columbia University/NASA-GISS, New York, USA

[2]Lamont-Doherty Earth Observatory, Palisades, USA

**Abstract**: Wave and zonal mean features of the downward dynamic coupling between the stratosphere and troposphere are compared by applying a time-lagged singular value decomposition analysis to Northern Hemisphere height fields decomposed into zonal mean and its deviations. It is found that both zonal and wave components contribute to the downward interaction, with zonal wave 1 (due to reflection) dominating on the short time scale (up to 12 days) and the zonal mean (due to wave-mean flow interaction) dominating on the longer time scale. It is further shown that the two processes dominate during different years, depending on the state of the stratosphere. Winters characterised by a basic state that is reflective for wave 1 show strong correlations (and covariance) for wave 1 components when the stratosphere is leading and no relationship in the zonal mean. On the other hand, winters characterised by a stratospheric state that does not reflect waves show a strong correlation only in the zonal mean fields. This study suggests that downward reflection of waves (primarily of zonal wavenumber 1) is a significant component of troposphere/stratosphere dynamics.

**O-4-08**

EFFECT OF THE TROPICAL QUASI-BIENNIAL OSCILLATION ON TROPOSPHERIC CIRCULATION

**K. Hamilton**[1] and G. Stenchikov[2]

[1]University of Hawaii, Honolulu, USA

[2]Rutgers University, New Brunswick, USA

**Abstract:** The quasi-biennial oscillation (QBO) dominates the interannual variability of the tropical middle atmosphere, and is known to have quite significant effects on the extratropical middle atmosphere as well. The question of whether the QBO affects tropospheric circulation has been more controversial. This paper will revisit the question of how the QBO may affect seasonal-mean tropospheric circulation, using both empirical and model approaches. Data from long records in reanalysis products will be examined to look for correlations of tropospheric quantities with the phase of the stratospheric QBO. Then extensive global atmospheric model simulations obtained with a model with an imposed realistic QBO will be analysed.

**O-4-09**

A POSSIBLE MECHANISM FOR THE 11-YEAR SOLAR SIGNAL
TO IMPACT THE LOWER ATMOSPHERE

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[1]Reading University, Reading, UK

[2]Oxford University, Oxford, UK; [3]Rutherford Appleton Laboratory, Didcot, UK

**Abstract:** The interaction of the 11-yr Solar Cycle (SC) and the Quasi Biennial Oscillation (QBO) and their influence on the Northern Hemisphere polar vortex and the underlying tropospheric circulation are studied using ERA-40 analyses, idealised model and GCM experiments. The major result from the ERA-40 analysis is that both the 11-year solar cycle and QBO affect the timing of Sudden Stratospheric Warmings (SSWs): QBO/E years are more disturbed than QBO/W years primarily during early winter (November-January). SSWs in Smax years tend to occur later than in Smin years. Mid-winter SSWs are more likely during Smin/E and Smax/W years. The model experiments confirm this. A mechanism is proposed in which zonal wind anomalies in the upper equatorial / subtropical stratosphere associated with the QBO and 11-year SC either reinforce each other or cancel out. When they reinforce, as in Smin/E and Smax/W, the resulting anomaly is sufficiently large to influence the development of the Aleutian High and hence the timing of the onset of the sudden warmings. Although highly speculative, this mechanism may help to understand the puzzling observations that major warmings often occur in Smax/W years even though there is no strong wave guide provided by the QBO winds in the lower equatorial stratosphere. The influence of the solar cycle / QBO signals in stratospheric warmings on the underlying tropospheric circulation is also examined, in the light of recent results that show a stratospheric influence on the AO/NAO. Other possible mechanisms for solar/QBO impacts on the troposphere will also be explored.

**O-4-10**

STUDY OF STRATOSPHERE-TROPOSPHERE DYNAMIC INTERACTION FORCED BY
A RADIATIVE EFFECT OF VOLCANIC AEROSOLS

**G. Stenchikov**[1], A. Robock[1], K. Hamilton[2], V. Ramaswamy[3], and M. D. Schwarzkopf[3]

[1]Department of Environmental Sciences, Rutgers University, New Brunswick, USA

[2]International Pacific Research Center, University of Hawaii, Honolulu, USA; [3]NOAA Geophysical Fluid Dynamics Laboratory, Princeton University, Princeton, USA

**Abstract:** Observations show that strong equatorial volcanic eruptions are followed by a pronounced positive phase of the Arctic Oscillation (AO) for one or two Northern Hemisphere winters. We show that this response is forced by stratosphere-troposphere dynamic interaction, which is caused by aerosol-induced radiative heating in the lower tropical stratosphere, surface radiative cooling, and radiative effects of high-latitude ozone depletion as a result of ozone destruction through chlorine activation on aerosol surfaces. To understand the atmospheric processes that cause this stratosphere-troposphere dynamic interaction we studied the impact of the 1991 Mt. Pinatubo eruption, which produced the largest global volcanic aerosol cloud of the 20$^{th}$ Century. A series of control and perturbation experiments were conducted with the GFDL SKYHI general circulation model to examine the evolution of the circulation in the two years following the Pinatubo eruption.

Forced by aerosols, SKYHI produced a statistically significant positive phase of the AO in winter, as observed. Ozone depletion caused a positive phase of the AO in late winter and early spring by cooling the lower stratosphere in high latitudes, strengthening the polar night jet, and delaying the final warming. A positive phase of the AO was also produced in the experiment with only the tropospheric effect of aerosols showing that aerosol heating in the lower tropical stratosphere is not necessary to force positive AO response, as was previously assumed. We also used long-term stratospheric wind observations at Singapore station to implement a quasi-biennial oscillation (QBO) in our simulations. Using this setup we showed that the phase of the QBO modulates the climate system sensitivity to an external forcing. The QBO in its westerly phase strengthens the Arctic Oscillation response. Because of nonlinear interactions, aerosols and the QBO together produce a stronger response than a linear superposition of responses to each of these forcings. Improved quantification of the aerosol, ozone and QBO effects helps us to better understand the mechanisms of stratosphere-troposphere dynamic coupling and their contribution to natural and externally forced climate variability.

# ORAL PRESENTATIONS

## THURSDAY AUGUST 5, 2004

## *“FOCUS ON TROPICAL TROPOPAUSE LAYER”*

**O-5-01**

IMPACT OF SHORT-LIVED COMPOUNDS ON STRATOSPHERIC OZONE

**P. Wennberg**[1] and R. Salawitch[2]

[1]California Institute of Technology, Pasadena, USA

[2]NASA Jet Propulsion Laboratory, Pasadena, USA

**Abstract**: In the tropics, short-lived compounds prevalent in the terrestrial and marine boundary layer (such as $H_2S$, $SO_2$, $H_2CBr2$, and HCBr3) can be lofted into the upper troposphere and lower stratosphere. Once in the upper troposphere, these compounds or their degradation products can be transported into the lower stratosphere. We will discuss the possible role of these compounds in directly altering the sulfur and bromine budget of the stratosphere and indirectly how they may modify ozone.

**O-5-02**

TRANSPORT AND CHEMISTRY IN THE TTL

**I. Folkins**

Dalhousie University, Halifax, Canada

**Abstract:** The Tropical Transition Layer is a region of overlap between the Hadley circulation and the stratospheric Brewer-Dobson circulation. The circulations are forced to overlap because the Brewer Dobson circulation requires a source of mass from deep convection to feed its upward tropical branch. This mass must be injected into a region where the mean upward motion is positive, otherwise it will sink back to the surface. Since the Hadley circulation is about one hundred times stronger than the Brewer Dobson circulation, the injection of only about one percent of the outflow from deep convection above the level of zero radiative heating is sufficient to provide the required mass source. I will discuss the shape of the deep convective outflow mode in the tropics, its relationship to radiative heating and stability profiles, and to the thermodynamic structure of the boundary layer, and its impact on chemical tracers, such as ozone and water vapour in the TTL and upper tropical troposphere.

**O-5-03**

THE ROLE OF THE S.E. ASIAN MONSOON AND OTHER SEASONAL FEATURES IN CREATING THE 'TAPE-RECORDER' SIGNAL IN THE UNIFIED MODEL

R. Bannister[1], **A. O'Neill**[1], A. Gregory[2], and K. Nissen[3]

[1]D.A.R.C. and C.G.A.M., University of Reading, Reading, UK

[2]C.G.A.M., University of Reading, Reading, UK

[3]University of Edinburgh, Edinburgh, UK

**Abstract:** A simulation with the Unified Model (UM), is shown to simulate the main features of seasonal variations in the concentrations of water vapour in the stratosphere - the so-called tape-recorder signal. An off-line transport model, utilizing winds from the AGCM, is used to synthesize the signal from local contributions. During June-July-August, the most significant localised contribution to the moist phase of the signal comes from an air stream emanating from the S.E. Asian Monsoon. The moist air does not enter the stratosphere immediately above the monsoon in a localised fountain. Rather the air stream moves southward, via the monsoon's upper level anticyclone into the tropical stratosphere while moving steadily upwards across isentropic surfaces in a field of radiative heating in the tropical tropopause layer (TTL). As a result of this steady ascent during equatorward movement, not all the airstream is freeze dried in the cold cap of low temperatures, which exists in the TTL above the monsoon. The water vapour mixing ratios of air entering the stratospheric tape-recorder are, therefore, not entirely set by the minimum temperatures near the equator, but in part by physical conditions outside the inner tropical region used to define the tape-recorder signal. During December-January-February the flow near the tropopause is simpler. Dry air enters the stratosphere by slow upglide through the localised temperature minimum near the tropical tropopause over the Western Pacific. The mixing ratios during the dry phase are set largely by freeze drying in this region. The simple tape-recorder model, which envisages that mixing ratios are set by the minimum temperature near the tropical tropopause is, therefore, an oversimplification.

**O-5-04**

## ISOTOPIC COMPOSITION OF NITROUS OXIDE AS TRACER OF STRATOSPHERIC TRANSPORT AND CHEMISTRY

**J. Kaiser**[1], T. Roeckmann[2], A. Engel[3], and R. Borchers[4]

[1]Princeton University, Dept. of Geosciences, Princeton, USA

[2]Max Planck Institute for Nuclear Physics, Atmospheric Physics Division, Heidelberg, Germany; [3]Max Planck Institute for Aeronomy, Katlenburg-Lindau, Germany; [4]Johann Wolfgang Goethe-University, Institute for Meteorology and Geophysics, Frankfurt, Germany

**Abstract**: Nitrous oxide isotopologues are ideal tracers of stratospheric transport and chemistry because they are subject to the same chemical reactions, but have slightly different rate coefficients. Laboratory analyses of air samples reveal strong enrichments of isotopically heavy nitrous oxide species in the lower and middle stratosphere. These enrichments can be attributed to isotopic fractionation in the stratospheric sinks, photolysis and photo-oxidation by singlet oxygen atoms.

Kinetic measurements have led to a good understanding of the wavelength- and temperature-dependent isotopic fractionation due to photolysis and photo-oxidation. Moreover, the position-dependent nitrogen isotope fractionation reveals clear differences between these two sinks, with photo-oxidation showing a stronger enrichment at the terminal nitrogen atom than at the central nitrogen atom, in diametrical opposition to the enrichment due to photolysis. These differences can be used to infer the latitude- and altitude-dependent relative contributions of the two sinks, which can be used to verify models of stratospheric transport and chemistry.

To this end, we have recently analyzed a total of 118 balloon samples from tropical to polar latitudes spanning the years 1987 to 2002 and more than 70 aircraft samples that were obtained in Geophysica flights over Kiruna during the 2003 EUPLEX campaign. As in previous studies, we find clear differences of the apparent fractionation constants for different altitudes, but for the first time also resolve meridional and interannual variations. These variations can be attributed to the interplay of transport and chemistry. However, we also find differences in the ratio of the relative enrichments at the oxygen and nitrogen atoms in the nitrous oxide molecule, which cannot be caused by transport but must be due to chemistry.

**O-5-05**

## MICROPHYSICAL MODEL CALCULATIONS FOR THE SPARC ASSESSMENT OF STRATOSPHERIC AEROSOL PROPERTIES REPORT

**D. Weisenstein**[1], S. Bekki[2], G. Pitari[3], C. Timmreck[4], and M. Mills[5]

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[2]Service d'Aéronomie, CNRS, Paris, France; [3]University L'Aquila, Coppito, Italy; [4]Max-Planck Institute for Meteorology, Hamburg, Germany; [5]University of Colorado, Boulder, USA

**Abstract**: Chapter 5 of the SPARC Assessment of Stratospheric Aerosol Processes (ASAP) report involves modelling to assess whether transport of sulfur compounds (primarily $SO_2$ and OCS) from the troposphere and known physical processes can explain the distribution and variability of the stratospheric aerosol layer. Since aerosol models encompass our knowledge of coupled aerosol processes, together with observations, they are the main tools used here to test our current quantitative understanding of the processes controlling the formation and evolution of the stratospheric aerosol layer. Five different modelling groups with sectional microphysical models participated in the comparisons for this chapter. The two 3-dimensional models are from University L'Aquila (ULAQ) and the Max-Planck Institute for Meteorology (MPI). The three two-dimensional models are from Atmospheric and Environmental Research (AER), CNRS/University Pierre et Marie Curie (UPMC), and the University of Colorado Laboratory for Atmospheric and Space Physics (LASP). We present model results and comparisons with observations for a simulation under nonvolcanic conditions and for the atmospheric response to the Mt. Pinatubo injection. Model-calculated source gases are compared with OCS measurements from the ATMOS and MkIV instruments, and $SO_2$ is compared with an ATMOS measurement from 1985. Comparisons of aerosol extinction to satellite measurements, from the SAGE II and HALOE instruments, show that models do reproduce the overall structure and magnitude of the stratospheric aerosol layer, but with some deficiencies. The importance of aerosol size distribution to derived aerosol quantities, such as effective radius and surface area are explored. Sensitivity calculations are used to assess how uncertainties in input of sulfur at the tropical tropopause influence the stratospheric aerosol budget. The simulations of the Mt. Pinatubo period assess whether models remove sulfur from the stratosphere at the correct rate.

**O-5-06**

## THE STRATOSPHERE AND CLIMATE

**D. Hartmann**

University of Washington, Seattle, USA

**Abstract**: In the past few decades the perception of the role of the stratosphere in climate has changed from a passive one to a more active and important role.

This talk will review two main themes in this transformation. One theme is the apparent influence of chemical and dynamical changes in the stratosphere on tropospheric climate, and the apparent role of low-frequency modes of dynamical variability in this context. Stratospheric warmings seem to play a particularly important role in coupling the stratosphere and troposphere. Another theme is the dynamics and thermodynamics of the tropical tropopause and the transition between the troposphere and the stratosphere in the tropics. In this region the influences of radiation, convection and planetary-scale dynamics all play important roles, which in turn are important for the chemistry of the stratosphere and its influence on surface climate.

**O-5-07**

## WHAT GOES UP AND WHAT COMES DOWN: DYNAMICS AND RADIATION IN THE TROPICAL TROPOPAUSE LAYER

**A. Gettelman**

National Center for Atmospheric Research, Boulder, USA

**Abstract:** The current paradigm now proposes that the tropical tropopause is not a material surface, but a transition layer between the troposphere and the stratosphere, the Tropical Tropopause Layer (TTL). This layer is critical for modelling the middle atmosphere, as most air entering the stratosphere enters through this region, a paradigm unchanged for many years. Processes in the TTL set the boundary conditions for many chemical species and families, foremost of these being hydrogen, and water its major reservoir. The TTL may also have important effects on the climate of the lower atmosphere through interactions between humidity (clouds) and radiation. Various processes and their interactions are described with current uncertainties, focusing on understanding the transport of water in the TTL and its role in the dynamics of the region. Critical processes include the radiation balance, the formation of clouds, tropical waves, and dynamic and thermodynamic balances and responses to clouds and radiation. The interplay of these processes, and the ability to model them on many scales will be discussed, with results from some current work presented, and current uncertainties highlighted.

**O-5-08**

## DOES CONVECTION HYDRATE OR DEHYDRATE THE UPPER TROPOSPHERE/LOWER STRATOSPHERE?

**A. Dessler**[1] and S. Sherwood 2

[1]Univ. of Maryland, College Park, USA

[2]Yale University, New Haven, USA

**Abstract:** Water vapour and ozone observations near the 380-K potential temperature surface are examined in the tropics and northern mid-latitudes, with a focus on how their horizontal variations are influenced by deep convection, horizontal winds, and large-scale upwelling. It has previously been argued that convection dehydrates the so-called tropical tropopause layer. Here, we examine the effects of convection on the extratropical lower stratosphere during Northern Hemisphere summer. This dichotomy, where convection dehydrates in the deep tropics and moistens in the extratropics, is explained by the simple idea that the effect of convection depends on the background relative humidity (RH). To test this hypothesis, we implement RH-dependent convective moistening in a simplified model of water vapour and ozone on the 380-K potential temperature surface. The model produces realistic simulations of water vapour at 380 K, while model runs that do not include convective effects do far worse. Deep convective moistening is shown to be significant over both Asia and North America during summer well above the local tropopause, even reaching the base of the overworld. Unlike water vapour, ozone is little affected by convection at 380-K owing to a different balance of terms in its conservation equation.

**O-5-09**

# OBSERVATIONS AND IMPLICATIONS OF SUPERSATURATION IN CLEAR AIR AND IN THE PRESENCE OF CIRRUS IN THE TROPICAL AND SUBTROPICAL UPPER TROPOSPHERE

**J. Smith**[1], E. Weinstock[1], J. Pittman[1], D. Sayres[1], E. Jensen[2], and J. Anderson[1]

[1]Harvard University, Cambridge, USA

[2]NASA Ames Research Center, Moffett Field, USA

**Abstract:** We present *in situ* observations of water vapour and relative humidity with respect to ice, RHice, in the tropical and sub-tropical upper troposphere acquired aboard NASA's WB-57 high-altitude research aircraft. Our tropical dataset consists of measurements made during two field campaigns flown out of San Jose, Costa Rica: the Clouds and Water Vapour in the Climate System (CWVCS) mission, which took place during August 2001, and the Pre-Aura Validation Experiment (PREAVE), which took place in January 2004. The sub-tropical data was obtained during the CRYSTAL-FACE mission in July 2002 on flights out of Key West, Florida.

The Harvard water instrument uses the established Lyman-a photo-fragment fluorescence detection technique to make accurate and precise measurements of water vapour in the vicinity of the tropopause. We frequently observe ice-supersaturation both in clear air and in the presence of cirrus. The distribution of supersaturations in clear air and in-cloud may be used to infer the degree of supersaturation required to nucleate cloud particles. Our observations from both the tropics and sub-tropics, in conjunction with modelling studies, suggest that homogeneous freezing is dominant. Furthermore, flight-to-flight variability in the distributions provides some evidence that ambient aerosol composition can affect nucleation thresholds. Observations of in-cloud relative humidity appear to be sensitive to both temperature and cloud Ice Water Content (IWC), with the highest supersaturations, approximately 180 percent with respect to ice, present at the coldest temperatures and in very thin cirrus. The full complement of data sets allows us to explore these dependencies over 50 degrees in temperature, and three orders of magnitude in IWC. In-cloud relative humidities of this magnitude may have important implications for the dehydration potential of near tropopause cirrus. Furthermore, our Costa Rica data allow us to compare and contrast the properties of tropopause cirrus formed in and around summertime local deep convection, with those of cirrus formed *in situ* in the wintertime tropical UT. In summary, these data provide an outstanding opportunity to examine both the large and small-scale processes that control the formation of tropopause cirrus, and that regulate upper tropospheric humidity.

**O-5-10**

# IMPLICATIONS OF ENHANCED RELATIVE HUMIDITY IN COLD TROPICAL CIRRUS

**E. Jensen** and L. Pfister

NASA Ames Research Center, Moffett Field, USA

**Abstract:** *In situ* measurements of water vapour concentration and temperature in tropical cirrus during the CRYSTAL-FACE and Pre-AVE missions indicate that the steady-state relative humidity within cirrus at T less than 200 K is about 20-30 % higher than ice saturation. These measurements challenge the conventional belief that any water vapour in excess of ice saturation should be depleted by crystal growth given sufficient time. Detailed simulations of thin cirrus near the tropopause indicate that this enhanced steady-state relative humidity increases ice number densities, decreases crystal sizes and extends cloud lifetimes. The area coverage of thin cirrus in the tropics is increased rather than decreased as indicated by simpler conceptual models. Perhaps most significantly, the increased steady-state $H_2O$ saturation mixing ratio over ice in thin cirrus near the tropopause results in about a 0.5-1 ppmv increase in the amount of water that can enter the stratosphere across the tropical tropopause cold trap. Hence, the enhanced steady-state relative humidity in cold cirrus implies that lower tropopause temperatures are required to explain the observed stratospheric water vapour mixing ratios than previously assumed.

# DEHYDRATION IN THE TROPICAL TROPOPAUSE LAYER OF A CLOUD-RESOLVING MODEL

**T. Birner**[1], C. Kuepper[1], J. Thuburn[1], and G. Craig[2]

[1]Department of Meteorology, University of Reading, UK

[2]Institut fuer Physik der Atmosphaere, DLR - Oberpfaffenhofen, Germany

**Abstract:** Dehydration in the Tropical Tropopause Layer (TTL) is studied using a three-dimensional cloud-resolving model. A mean ascent representative of the upward branch of the Brewer-Dobson circulation is imposed and the model is run to radiative-convective equilibrium. The simulated mass and moisture fluxes across the cold point into the stratosphere are primarily non-convective. The final stage of dehydration, which sets the water content of air entering the stratosphere, takes place outside cumulus clouds and is enhanced by small-scale gravity waves. Additional dehydration occurs when wave-like perturbations typical of observed Kelvin waves are superposed to the mean ascent. The sensitivity of the model results to the initial conditions and to the saturation mixing ratio threshold for primary ice nucleation is investigated.

# ORAL PRESENTATIONS

## FRIDAY AUGUST 6, 2004

## *"FOCUS ON DETECTION, ATTRIBUTION AND PREDICTION"*

**O-6-01**

## CHANGES IN STRATOSPHERIC WATER VAPOUR

**K. Rosenlof**

NOAA Aeronomy Laboratory, Boulder, USA

**Abstract**: Increases have been noted in Northern Hemisphere middle latitude stratospheric water vapour over an extended period of time. However, over the past few years, a substantial decrease has been observed in tropical HALOE water vapour measurements in the 100-70 hPa layer. Similar decreases in the lower stratosphere are also seen in the frost balloon observations taken by the NOAA Climate Monitoring and Diagnostics Laboratory in Boulder, Colorado, USA (40°N) and the POAM and SAGE-II satellite records. In this presentation, data from these varied instrument records will be presented, and possible mechanisms for the observed temporal changes discussed.

**O-6-02**

## IDENTIFICATION OF HUMAN-INDUCED CLIMATE CHANGE IN A SECOND-GENERATION REANALYSIS

**B. Santer**[1], A. Simmons[2], T. Wigley[3], P. Kallberg[2], G. Kelly[2], S. Uppala[2], J. Meehl[3], R. Sausen[4], and M. Wehner[5]

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[2]European Centre for Medium-Range Weather Forecasts, Shinfield Park, Reading, UK

[3]National Center for Atmospheric Research, Boulder, USA

[4]Institut für Physik der Atmosphäre, Oberpfaffenhofen, Wessling, Germany

5Lawrence Berkeley National Laboratory, Berkeley, USA

**Abstract:** Changes in the height of the tropopause may provide a sensitive indicator of human effects on climate. A previous attempt to identify human effects on tropopause height (Santer *et al.*, 2003) relied on climate information from first-generation reanalyses, which have well-documented deficiencies. This raised justifiable concerns regarding the reliability of earlier detection work that employed this data.

We address these concerns using information from the new second-generation ERA-40 reanalysis (Simmons and Gibson, 2002). We also address another common question: whether the relatively poor vertical resolution of most current climate models precludes their use for studies of tropopause height change. Our analysis of ERA-40 data illustrates that estimated changes in pLRT (the pressure of the lapse-rate tropopause) are relatively insensitive to the vertical resolution of the temperature data used in pLRT calculations.

Over 1979 to 2001, global mean tropopause height increases by nearly 200 meters in ERA-40. This rise is partly due to tropospheric warming. The spatial pattern of height increase is consistent with climate model predictions of the expected response to anthropogenic forcing, significantly strengthening earlier detection results. Atmospheric temperature changes in two different satellite datasets (Mears *et al*., 2003; Christy *et al*., 2003) are more highly correlated with changes in ERA-40 than with those in the first- generation NCEP-50 reanalysis (Kalnay *et al.*, 1996). This highlights the improved quality of temperature information in ERA-40, and suggests that tropopause height detection results based on ERA-40 data are more reliable than those obtained with NCEP-50. Our findings provide independent support for claims that human activities have warmed the troposphere over the last several decades of the 20th century, and that this warming has contributed to the overall increase in tropopause height.

**References**

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**O-6-03**

LONG-TERM MEASUREMENTS OF STRATOSPHERIC AEROSOL EXTINCTION

**L. W. Thomason**[1], V. L. Harvey[2], and S. P. Burton[3]

[1]NASA Langley Research Center, Hampton, USA

[2]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, USA

[3]Science Applications International Corporation, Hampton, USA

**Abstract**: Measurements of stratospheric aerosol extinction by the Stratospheric Aerosol and Gas Experiment (SAGE) series of instruments continuously cover the period from October 1978 and the present. This record is dominated by a few volcanic events that perturbed existing aerosol levels by as much as a factor of one hundred and require many years to relax toward something approaching non-volcanic levels. In this presentation, we will focus primarily on three periods in which aerosol loading is at global temporal minima: 1979, 1989-1990, and 1999 and onwards. The late 1980's appear to have never reached a non-volcanic state, while in the other periods appear far more likely. In those two periods, aerosol levels within 3-5 km of the tropopause are within approximately 10 percent with the current period generally being slightly larger. On the other hand, above that altitude the current aerosol extinction levels are significantly less than 1979, particularly in the tropics where they are as much as 40 percent less. This suggests that 1979 was either still influenced by the 1975 eruption of Fuego or that there are other changes in non-volcanic aerosol sources possibly including human-derived ones. Since we rely on data from two instruments (SAGE I and II) to quantify differences between 1979 and the current period, we use data from the Stratospheric Aerosol Measurement (SAM II) and trajectory matching to show the relative bias between SAGE I and SAGE II. While aerosol extinction levels are at historically low values, we demonstrate the dynamic range of all instruments easily encompasses observed aerosol levels including instrument sensitivity and uncertainties in meteorological fields used in the data processing.

**O-6-04**

VALIDATION OF THE SELF-CONSISTENCY OF GOMOS $NO_3$, $NO_2$ AND $O_3$ DATA USING CHEMICAL DATA ASSIMILATION

**M. Marchand**, S. Bekki, A. Hauchecorne, and J.-L. Bertaux

Service d'Aéronomie, CNRS, Paris, France

**Abstract:** The $NO_3$ measurement by the GOMOS instrument on board the ENVISAT platform is the first satellite measurements of this species. The simultaneous measurements of $O_3$ and $NO_2$, which are strongly coupled chemically to $NO_3$, allow us to test the self-consistency of the GOMOS measurements of the different species. The self-consistency of the night-time measurements by GOMOS of $O_3$, $NO_2$ and $NO_3$ are tested using chemical data assimilation.

Measurements obtained between 25 and 55 km during two distinct periods are assimilated. Analysed $NO_3$ (*i.e.* $NO_3$ calculated by the model after assimilation of GOMOS $O_3$ and $NO_2$ data) are then compared to corresponding GOMOS $NO_3$ measurements in correlation plots (GOMOS $NO_3$ versus analysed $NO_3$). Overall, the differences between the $NO_3$ measurements and corresponding analysed $NO_3$ are found to be small. The linear regressions for both periods are also found to be close to the 1-to-1 line with small errors. This agreement indicates that $O_3$, $NO_2$ and $NO_3$ GOMOS measurements are self-consistent chemically and that there is no substantial bias in GOMOS $NO_3$ data. It also suggests that the night-time $NO_3$ chemistry is well understood.

**O-6-05**

# THE ROLE OF DYNAMICS IN THE RESPONSE OF THE MIDDLE ATMOSPHERE TO SOLAR FORCING: DATA ANALYSIS AND MODELLING

**M.-L. Chanin**, J. Hampson, P. Keckhut, and A. Hauchecorne

Service d'Aéronomie, CNRS, Verrières le Buisson, France

**Abstract:** This paper will present the results of data analysis and of a 3-D Coupled Chemistry-Dynamics model developed within the European Project SOLICE (SOLar Influences on Climate and the Environment) performed in our institute. It includes the analysis of most of the available data sets covering the stratosphere-mesosphere region in order to put in evidence the solar response. Three independent types of temperature data sets have been analysed (lidar, rockets and SSU). This analysis was possible because the overall quality and the knowledge of the continuity of the data series have been intensively studied during the last decade in order to look for anthropogenic fingerprints within the SPARC Project. The analysis of the different data set has been performed using the same multi-parameters regression model.

The 11-year solar signature obtained presents a behaviour varying as a function of season and location (latitude, longitude). However, a relatively good agreement, among the output of the data sets, has been obtained, and thus the global picture of the solar impact in the upper stratosphere and lower mesosphere has been improved. In the tropics, a 1-2 Kelvin positive response between solar minimum and maximum around the stratopause has been found, in agreement with most 2D and 3D models. At mid-latitudes, a negative response of several Kelvin has been observed in the upper stratosphere, mainly during winters, in the analysis of most of the data sets analysed. However, the behaviour differs depending on the longitude of the site. In the mesosphere, at sub-tropic and mid-latitude regions, a systematic positive response is observed increasing by a factor of two during winter period.

Result from a 3-D Coupled Chemistry-Dynamics Model developed for that purpose will also be presented. Model runs have been carried out for different amplitude of the planetary wave forcing using solar forcing corresponding to solar minimum and solar maximum conditions. The difference in temperature signal between the pairs of runs will show the sensitivity of the response to the strength of the planetary waves and a relatively good agreement with observations, including the variation of response with the longitude.

**O-6-06**

# DYNAMICAL CHANGES IN THE STRATOSPHERE

**U. Langematz**

Freie Universität Berlin, Berlin, Germany

**Abstract**: Dynamical changes in the stratosphere have been reported for the past two decades. Observations showed for example an increase in stratospheric circulation during winter and spring of both hemispheres. Simulations with General Circulation Models (GCMs) could partially relate the dynamical changes to the impact of the observed changes in stratospheric ozone and greenhouse gases. However, questions remain open, *e.g.* the relative contributions of other factors, such as natural decadal variability, on past stratospheric circulation changes.

In this presentation, an update of the observed dynamical changes from different data sets will be given. These will be compared with new results from a range of GCM studies performed within the framework of the GRIPS GCM intercomparison, as well as with Chemistry Climate Model results. Based on these model studies, causes for the observed dynamical changes and predictions of future dynamical changes will be discussed.

**O-6-07**

## COMPARISON OF RADIATION SCHEMES USED IN CLIMATE MODELS

**P. Forster**

University of Reading, Reading, UK

**Abstract:** The calculation of radiative heating rates is fundamental to both a model's climatology and its prediction of temperature changes. It is difficult to compare different model simulations without an understanding of how the radiation codes differ. I will present pertinent results from a direct comparison of GCM radiation schemes. This work has been performed as part of the GRIPS initiative and has employed input and the support of many colleagues. My focus will be on comparisons at the stratopause and below and the significance of our findings for temperature change prediction.

**O-6-08**

## DO CURRENT NON-OROGRAPHIC GRAVITY-WAVE DRAG PARAMETERISATIONS DIFFER IN THEIR APPLICATION?

**J. Scinocca**[1] and C. McLandress[2]

[1]CCCma, MSC, University of Victoria, Canada

[2]Department of Physics, University of Toronto, Toronto, Canada

**Abstract**: A number of non-orographic gravity-wave drag (GWD) parameterisation schemes have been developed for use in middle atmosphere general circulation models (GCMs). Central to each scheme are assumptions regarding how best to account for the nonlinear breakdown and turbulent dissipation of the wavefield. In principle, each scheme differs only in the method by which dissipation is applied. Debate within the community regarding the validity and appropriateness of each scheme has been vigorous and ongoing. Here we consider the more practical issue of identifying and understanding differences in the response that arise solely from the method of dissipation employed in each scheme. We accomplish this by building the dissipation mechanisms from a number of the most widely used schemes into one parameterisation so that no other factors enter into the comparison.

Differences in the response to the application of each dissipation mechanism are documented in both offline calculations and fully interactive climate simulations. Our main conclusions are that (1) differences arise not from fundamental differences in the dissipation mechanisms themselves but more simply from systematic differences in the typical elevation of wave breaking, and (2) when schemes behave most similarly their behaviour is dominated by critical level interactions, which are treated identically in each scheme. These conclusions are supported by supplementary experiments in which we demonstrate that the response to one scheme may be obtained by the application of another if one makes parameter adjustments designed to cause a shift in the typical elevation of wave breaking. Consequently, there does not appear to be significant differences in the application of one dissipation scheme relative to another. Further, this would suggest that the use of climate GCMs to validate the physical basis of a particular non-orographic parameterisation scheme may be problematic.

**O-6-09**

## MODEL INTER-COMPARISON OF THE EFFECT OF CLIMATE CHANGE ON STRATOSPHERE-TROPOSPHERE EXCHANGE AND THE ROLE OF PLANETARY WAVE ACTIVITY ENTERING THE STRATOSPHERE

**N. Butchart**[1], A. Scaife[1], M. Bourqui[2], J. de Grandpre[3], S. Hare[2], J. Kettleborough[4], U. Langematz[5], E. Manzini[6], and 4 others[7]

[1]Met Office, Exeter, UK

[2]University of Reading, Reading, UK

[3]York University, Toronto, Canada

[4]RAL, Didcot, UK

[5]FUB, Berlin, Germany

[6]INGV, Bologna, Italy

[7]Various

**Abstract:** The effect of climate change on the large-scale seasonal-mean transport between the stratosphere and troposphere is compared in a number of middle atmosphere general circulation and chemistry-climate models. All the models reproduce the observed upwelling across the tropical tropopause balanced by downwelling in the extra tropics, though the seasonal cycle in upwelling in some models is more semi-annual than annual. All the models also consistently predict an increase in the mass exchange rate in response to growing greenhouse gas concentrations, irrespective of whether or not the model includes interactive ozone chemistry. The mean trend is about 2 % per decade but varies between models by up to a factor of 2. The role of changes in wave activity entering the stratosphere is investigated using mass fluxes derived from the EP-flux divergence by the Cambridge Downward Control Principle. This shows considerable variability between models in the contribution that the resolved wave driving makes to both the mean mass flux and the trend. An ensemble of integrations of one of the models also suggests that a significant part of the variability in the annual mean mass flux in that model is attributable to a modulation of the wave driving by other external factors, such as the sea surface temperatures.

**O-6-10**

## SIMULATION OF THE TROPOSPHERIC RESPONSE TO ANTARCTIC OZONE DEPLETION

**N. Gillett**[1] and D. Thompson[2]

[1]University of Victoria, Victoria, Canada

[2]Colorado State University, Boulder, USA

**Abstract:** Recent observations indicate that climate change over the high latitudes of the Southern Hemisphere is dominated by a strengthening of the circumpolar westerly flow that extends from the surface to the stratosphere. We demonstrate that both the structure and magnitude of the observed climate trends are simulated by a high vertical resolution version of the UK Met Office Unified Model forced solely with prescribed stratospheric ozone depletion. As in observations, the modelled tropospheric response reflects a shift in the Southern Hemisphere annular mode towards stronger circumpolar westerly flow that peaks several months after the most pronounced ozone depletion. We examine model eddy forcing and radiation diagnostics to elucidate the mechanisms responsible for this realistic tropospheric response to stratospheric forcing.

# POSTER PRESENTATIONS

## MONDAY AUGUST 2, 2004

**P-2-01**

## LABORATORY STUDIES ON THE INTERACTION OF NITRIC ACID WITH ICE SURFACES AT TEMPERATURES OF THE UPPER TROPOSPHERE

M. Fernandez , A. Hemblade , and **T. Cox**

Department of Chemistry, University of Cambridge, Cambridge, UK

**Abstract:** $HNO_3$ is a major trace gas constituent in the Upper Troposphere with a high propensity for adsorption to ice surfaces. Our experiments have shown that the $HNO_3$-ice interaction has important consequences for the subsequent reactivity of the ice surface in the temperature range 215-235 K and at $HNO_3$ partial pressures of (1-10) x $10^{-7}$ Torr. Our experimental observations have shown that adsorbed $HNO_3$ can affect both non-reactive scavenging of other trace gases (*e.g.* HCl) and also the rates of reactive processes of importance in the upper troposphere (*e.g.* $ClONO_2$(g) HCl(ad) = $Cl_2$(g) $HNO_3$ (ad)). We are also conducting experiments to investigate the effect of adsorbed $HNO_3$ on exchange of water vapour at the ice surface and will report these results. The atmospheric implications and nature of the $HNO_3$ ice interaction will be discussed.

**P-2-02**

## THE EFFECT OF CHANGES IN STRATOSPHERIC TRANSPORT ON THE LIFETIMES OF CHLORINE CONTAINING GASES

**C. Hoyle**[1], E. Rozanov[1], T. Egorova[1], T. Peter[2], and J. Staehelin[2]

[1]Physikalisch-Meteorologisches Observatorium Davos and World Radiation Center, Davos, Switzerland

[2]Institute for Atmospheric and Climate Science, ETH, Zurich, Switzerland

**Abstract:** The source of the majority of stratospheric chlorine is the photolysis of anthropogenic gases. The time required for these gases to reach their stratospheric region of destruction is dependent upon the rate of transport from the troposphere into the stratosphere, and upon transport within the stratosphere. Future changes in climate may result in changes in these transport processes (WMO 2003), increasing or decreasing the lifetime of chlorine containing gases in the atmosphere. Butchart and Scaife (2001) suggested that the possible future increase in mass flux into the stratosphere, resulting from an increase in extra-tropical wave driving, will result in faster destruction of these gases. This could accelerate the recovery of the ozone layer. Using Mezon, a 3D CTM, we calculate the time series of global instantaneous lifetimes for a range of gases, over the time period 1993-2002. There is substantial interannual variation in the calculated lifetimes. The results show a general similarity in the temporal evolution of the lifetimes of these gases, however, there are a number of periods where the time trends of the lifetimes differ from one another, or are even of opposite sign. Therefore the effect of a change in stratospheric circulation on the removal rate of each chlorine containing gas must be assessed separately.

**References:**

Butchart, N., and A. A. Scaife, 2001 Removal of Chloroflurocarbons by increased mass exchange between the stratosphere and troposphere in a changing climate. Nature, 410.

WMO (World Meteorological Organization), Scientific Assessment of Ozone Depletion: 2002, Global Ozone Research and Monitoring Project Report No. 47, 498 pp., Geneva, 2003.

**P-2-03**

BIOSPHERE-TROPOSPHERE CHEMICAL INTERACTION IN THE LMDz-INCA CLIMATE-CHEMISTRY MODEL: IMPACT ON UPPER TROPOSPHERIC $HO_X$ AND IMPLICATIONS FOR FUTURE CLIMATE

**G. Folberth**[1], D. Hauglustaine[2], and J. Lathière[2]

[1]Canadian Centre for Climate Modelling and Analysis (CCCma), University of Victoria, Canada

[2]Laboratoire des Sciences du Climat et de l'Environnement (LSCE), Gif-sur-Yvette, France

**Abstract**: Recently, several aircraft campaigns revealed upper tropospheric $HO_x$ levels frequently exceeding the expected concentrations from the commonly assumed primary source (ozone photolysis and ensuing reaction of O(1D) radicals with water vapour) by a factor of 2 to 4. Such elevated $HO_x$ concentrations imply a photochemically more active upper troposphere than previously thought, with enhanced ozone formation rates and, thus, a potentially more important role in the ozone greenhouse forcing related to anthropogenic and natural emissions of nitrogen oxides. Another implication is a faster oxidation of sulfate precursors by OH, which would tentatively promote the formation of new aerosol particles in the upper troposphere.

It has been shown that the elevated concentration of upper tropospheric $HO_x$ can be partially explained by convective injection of $HO_x$ precursors, such as acetone, peroxides, and aldehydes. Most of these volatile organic compounds (VOC) have the terrestrial and, possibly, the oceanic biosphere as their primary source (*e.g.* approximately 90-95 percent in the case of acetone). Thence, there exists a strong interrelation between the biosphere and the atmospheric chemical composition in general.

On the other hand, it has been suggested that increasing atmospheric $CO_2$ levels will result in an increase of the net primary production (NPP) and, therefore, also in the amount of biogenic VOC emitted. Furthermore, anthropogenic $NO_x$ emissions are assumed to increase quite dramatically over the next 100 years. The coaction of these two largely independent trends could result in tremendous changes of the upper tropospheric $HO_x$ budget in particular and the chemical composition of the upper troposphere and lower stratosphere in general.

We use the recently developed chemistry-climate model LMDz-INCA to investigate the chemical structure of the upper tropospheric/lower stratospheric region for present day and future conditions. The findings will serve as a basis to work out implications for the future climate.

**P-2-04**

LABORATORY FOR INTERNAL GRAVITY-WAVE DYNAMICS: THE NUMERICAL EQUIVALENT TO THE QUASI-BIENNIAL OSCILLATION (QBO) ANALOGUE

**N. P. Wedi**[1] and P. K. Smolarkiewicz[2]

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[2]National Center for Atmospheric Research (NCAR), Boulder, USA

**Abstract:** We have extended the classical terrain-following coordinate transformation of Gal-Chen and Somerville to a broad class of time-dependent vertical domains. The proposed extension facilitates modelling of undulating vertical boundaries in various areas of computational fluid dynamics. The theoretical development and the efficient numerical implementation have been documented in the context of the generic Eulerian/semi-Lagrangian NFT nonhydrostatic model framework. In particular, it allows the simulation of stratified flows with intricate geometric, time-dependent boundary forcings, either at the top or at the bottom of the domain. We have applied our modelling framework in the direct numerical simulation of the celebrated laboratory experiment of Plumb and McEwan creating the numerical equivalent to their quasi-biennial oscillation (QBO) analogue. The QBO represents a conspicuous example of a fundamental dynamical mechanism with challenging detail, which is difficult to deduce from experimental evidence alone. A series of 2D and 3D simulations demonstrate the ability to reproduce the laboratory results. The numerical experiments identify the developing periodically reversing mean flow pattern as an entirely wave-interaction driven phenomena, in contrast to the original interpretation of a weakly-nonlinear damped wave problem. Furthermore, we find the oscillation mechanism different to the one originally described. The results not only enhance the confidence in the numerical approach but further elevate the importance of the laboratory setup in its fundamental similarity to the atmosphere, while allowing the study of the principal atmospheric mechanisms and their numerical realizability in a confined 'laboratory' environment.

**P-2-05**

## AGE OF AIR FROM ECWMF METEOROLOGY AND ITS DEPENDENCE ON THE ASSIMILATION PROCEDURE

**B. Bregman**[1], E. Meijer[2], R. Scheele[1], and P. van Velthoven[1]

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**Abstract:** The age of air has proven to be a useful integrated quantity for evaluation of stratospheric transport. Recent calculations have indicated that the age of air in data assimilation systems (DAS) is too young compared to multi-year mean observations. The reasons for this discrepancy are not fully understood, but are likely due to the 'non-physical' relaxation of the winds towards observations. This introduces artificial variability in the divergence, which is manifested as 'noise' in the vertical winds as an integrated product. These effects can be characterised as second-order and may enhance the residual circulation. As a consequence they are not visible in instantaneous comparisons with observed winds, but in quantities like age of air. To gain more insight in the underlying causes of these fundamental short-comings of DAS winds, we have performed sensitivity studies by using winds obtained from a variety of assimilation procedures, including 3DVAR, 4DVAR, different forecasts and update frequencies. We will present a summary of the results from these studies.

**P-2-06**

## TRANSPORT OF OZONE, WATER VAPOUR AND OTHER TRACE CONSTITUENTS IN THE STRATOSPHERE, DIAGNOSED IN ENVISAT/MIPAS DATA

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**Abstract:** MIPAS is an infrared limb-sounding instrument launched aboard the ENVISAT satellite in March 2002. We analyse ESA Near-Real-Time (NRT) MIPAS observations of ozone, water vapour and other trace constituents in the stratosphere. We consider several periods of interest: (i) the austral spring 2002 during the final breakdown of the Antarctic stratospheric vortex, (ii) the summer 2003, with a focus on northern mid and high latitudes, (iii) the Northern Hemisphere winter 2003/2004. Isentropic maps of ozone/water vapour have been analysed in October and November 2002, during the breakdown of the Southern Hemisphere stratospheric polar vortex. Consecutive to the unusual September stratospheric sudden warming and vortex splitting, the polar vortex was small, but nearly re-centered around the south pole. In late October and early November, the pool of low-ozone air is drifting eastwards and equatorwards at 10 mb, before disappearing by mid-November. Comparisons are drawn with other satellite observations, *e.g.* from POAM or HALOE, as well as with advected dynamical tracers. We further show evidence of summertime low-ozone episodes over Northern Europe during the summer 2003, when the Arctic pool of low-ozone air is displaced of the pole. Finally, we highlight some features of the stratospheric circulation in the winter 2003/2004 diagnosed from long-lived trace species.

**P-2-07**

INTERACTION BETWEEN STRATOSPHERIC AND TROPOSPHERIC CHEMISTRY IN A COUPLED CHEMISTRY CLIMATE MODEL

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**Abstract:** Future changes in climate are expected to cause important changes in the distribution of key chemical species in both the stratosphere and troposphere. Stratospheric cooling may enhance polar $O_3$ loss in the near future but ultimately lead to higher levels of $O_3$ than in the past. In the troposphere there are many competing processes (*e.g.* regional changes in anthropogenic emissions) and climate feedbacks (*e.g.* increases in water vapour, and hence OH), which may lead to increases or decreases in regional pollution. Through limitations in computer resources, and the general immaturity of coupled chemistry-climate models (CCMs), these stratospheric or tropospheric processes have so far only been studied in isolation and then often with simplified models. However, these stratospheric and tropospheric changes will interact and should be studied together in a fully coupled model. We have coupled two detailed stratospheric and tropospheric chemistry schemes within the U.K. Met Office Unified Model (UM). Both schemes have been successfully used independently in previous UM studies. The stratospheric scheme is the same as that used in the SLIMCAT/TOMCAT 3D off-line CTM. It contains a description of $O_x$, $NO_y$, $HO_x$, Cly, Bry, source gases and methane oxidation gas-phase chemistry, as well as a treatment of heterogeneous chemistry on sulphate aerosols and polar stratospheric clouds. The tropospheric scheme is that used in the well-establised STOCHEM model. This includes detailed non-methane hydrocarbon chemistry, and many of the natural sources (*e.g.* lightning $NO_x$, isoprene from vegetation) are derived interactively from the underlying climate model. The two schemes operate independently but the common fields in the two schemes (*e.g.* $O_3$) are merged in an overlap region in the UT/LS.

We will present first results from the combined stratospheric/tropospheric coupled CCM. We will compare the present day and future atmosphere and investigate both the direct (*e.g.* through transport of $O_3$) and indirect (*e.g.* through changing photolysis rates) impact of the stratosphere on the troposphere.

**P-2-08**

MODEL STUDY OF OZONE SIGNATURES OF CLIMATE PATTERNS OVER THE NORTHERN HEMISPHERE

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**Abstract:** A multiannual integration using the off-line chemical transport model SLIMCAT was forced by the ECMWF analyses from 1979 to 1998. The simple chemistry scheme did not include any variations in stratospheric chlorine or aerosols, to highlight the effect of changing dynamics on the modelled trend. The middle latitude winter model ozone is correlated with the North Atlantic Oscillation, the Arctic Oscillation and the polar night jet index. A Singular Value Decomposition analysis is applied to the modelled winter total ozone and the geopotential heights at 4 levels, over the Northern Hemisphere. The EOFs from both the ozone and the meteorological fields are analysed to attribute changes in ozone to climate modes of variability. For example, the first EOF from model ozone correlates highly with the first EOF at 30 hPa, both are also correlated with the polar night jet index and the Arctic Oscillation index.

**P-2-09**

## SIMULATION OF RECENT DEVELOPMENTS OF ATMOSPHERIC DYNAMICS AND CHEMISTRY WITH AN INTERACTIVELY COUPLED GLOBAL CHEMISTRY-CLIMATE MODEL

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**Abstract:** The fully coupled chemistry-climate model E39/C has been employed for a transient simulation covering the time period between 1960 and 2000. As boundary conditions observed changes with respect to sea surface temperature, concentrations of radiative active gases (*e.g.* $CO_2$, $CH_4$, $N_2O$), emissions of nitrogen oxides and chlorine compounds, etc. are used. Additionally, the effects of large volcanic eruptions (Agung: 1963, El Chichon: 1982, Pinatubo: 1991) are considered in the chemistry module and the radiation scheme of E39/C. The solar cycle is taken into account and the quasi-biennial oscillation (QBO) is nudged according to observations of the equatorial wind field. The model results are compared to observations, in particular to long-term measurements derived from satellite instruments and ground-based stations. The analyses, which will be presented, will focus on the model's capability to reproduce inter-annual and seasonal variability, as well as long-term trends of dynamical and chemical values and parameters.

**P-2-10**

## RECALCULATION OF ARCTIC OZONE HOLE RECOVERY PREDICTIONS WITH A DETAILED CHEMISTRY LAGRANGIAN TRANSPORT MODEL

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**Abstract:** While stratospheric halogen loading has reached its maximum and is expected to decline over the next decades, predicted Arctic ozone minimum values lag several years behind, probably due to enhanced greenhouse gas concentrations that have led to a cooling of the stratosphere. Minimum ozone column densities are predicted by Global Climate Models (GCM) between 2004 and 2019. Against the trend in transient simulations by other major GCMs, the ECHAM4.L39(DLR)/CHEM(E39/C) coupled model simulates the beginning of Arctic total ozone recovery already before 2020 in its 2015 time slice experiment. While increased wave activity has been identified as the major explanation for early recovery, the chemistry scheme itself underestimates ozone depletion at least due to missing bromine chemistry, an error which is generally assumed to be on the order of 20 to 30 %. To quantify better the effect of bromine chemistry and, thus, provide more reliable predictions for future Arctic ozone depletion, we employ the Chemical Lagrangian Model of the Stratosphere (CLaMS) based on meteorological and chemical boundary conditions from E39/C. We perform 90-day multi-level isentropic simulations to derive chemical ozone loss by (a) a tracer correlation and (b) passive ozone tracer method. For the coldest 2015 winter (also lowest minimum Arctic ozone column in E39/C, 296 DU) we find significantly lower column densities (Arctic minimum 253 DU, including bromine chemistry) with maximum chemical ozone depletion of 65 DU. During the considered winter, the lack of bromine chemistry leads to an underestimation of chemical ozone loss of 25 %. However, simulations which did not consider bromine reactions also display lower column densities than predicted in earlier GCM simulations: in a mixing parameter and resolution sensitivity study enhanced diffusion leading to overestimated deactivation of $ClO_x$ is identified to cause the observed underestimation of ozone loss.

**P-2-11**

## TEMPERATURE DEPENDENCES OF STRATOSPHERIC AEROSOL EXTINCTION OBSERVED AT A LOW LATITUDE STATION, TRIVANDRUM (8.33°N, 77°E), INDIA, USING LIDAR

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**Abstract:** In order to study the temperature dependence of stratospheric aerosol extinction coefficient, the monthly mean aerosol extinction profiles are obtained by averaging the daily profiles of the respective month. The tropopause temperature data obtained from the radiosonde measurements at Trivandrum corresponding to the days for which lidar data are available in a month are averaged to obtain the monthly mean temperature. The relevance of tropopause temperature lies in the fact that its variations are indicative of over all convective activity in the troposphere and it is the tropospheric convective activity that is mainly responsible for transporting (vertically) the trace constituents and aerosols into the stratosphere. The variations of monthly mean integrated aerosol extinction coefficient in the altitude region 18-27 km with monthly mean tropopause temperatures are studied. It is clearly observed that there is a negative correlation between the tropopause temperature and integrated aerosol extinction. The correlation is found to be negative with coefficient value of 0.6. A decrease in the tropopause temperature is the result of an increase in the tropopause altitude, which indicates the stronger convective activity in the troposphere. This increased convective activity leads to the injection of a significant tropospheric mass containing small size aerosol particles and precursor gases like OCS and $SO_2$ into the stratosphere. The precursor gases in the stratosphere become oxidized and finally converted into sulphuric acid vapour, which in combination with stratospheric water vapour condenses on the pre-existing nuclei and forms the condensation nuclei leading to the subsequent growth. A decrease in the stratospheric temperature causes more water vapour to condense onto $H_2SO_4$ droplets leading to the growth of these particles. An increase in the size of the particles causes an increase in the aerosol extinction.

**P-2-12**

## OZONE, $NO_2$ AND AEROSOL RETRIEVAL FROM SAGE III LIMB SCATTERING MEASUREMENTS

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**Abstract:** The Stratospheric Aerosol and Gas Experiment (SAGE III) instrument has been making a series of measurements of the Earth’s limb radiance over the past year. The limb is scanned at relatively low speed (1 scan / minute) and spectral data is recorded over 340 channels (spread across the UV, visible and near infrared) with a vertical resolution of 0.5 km. The methodologies developed to retrieve gas density and aerosol extinction vertical profiles from measured spectral radiance will be presented and discussed. SAGE III in limb scattering mode is characterised by large stray light contamination, which necessitated a special procedure to analyse the data. Results will be presented for a wide range of illumination conditions, and comparison will be made with measurements made by ground instruments (ozone sondes, Lidars) and other satellite instruments (SAGE II, SAGE III, HALOE and POAM).

**P-2-13**

THERMODYNAMICAL STUDY OF $H_2SO_4/H_2O$ PARTICLES AT UT/LS CONDITIONS: IMPLICATION FOR HETEROGENEOUS CHEMISTRY

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**Abstract:** In the lower stratosphere the aerosol particles consist of highly concentrated aqueous sulfuric acid solutions. Heterogeneous reactions occur on the surface of the particles and involve the dissolutions of trace gases, such as HCl, into the particles leading to the activation of chlorine. The solubility of trace gases into aqueous $H_2SO_4$ solutions depends on the amount of H in the solution, which is controlled by the dissociation of $H_2SO_4$. Under atmospheric conditions (temperatures and concentrations) it can be assumed that the first dissociation step is complete. But, the dissociation reaction of the bisulfate ion, $HSO_{4-}$, depends strongly on temperature and concentration. We have investigated the dissociation of $HSO_{4-}$ in aqueous $H_2SO_4$ solutions with concentrations of 0.54-15.23 mol/kg in the temperature range of 180-326 K using Raman spectroscopy. All investigated $H_2SO_4$ solutions show a continuous increase in the degree of dissociation of $HSO_{4-}$ with decreasing temperature, in contrast to predictions from thermodynamic models of aqueous $H_2SO_4$ solutions. A Pitzer ion interaction model is used to derive a thermodynamically consistent formulation of the thermodynamic dissociation constant of the bisulfate ion, K(T), that is in agreement with the experimental data. The new formulation of K(T) is valid from 180 K to 473 K. Calculations performed with our Pitzer model which includes the newly derived thermodynamic dissociation constant of $HSO_4$- reveal significant differences in ion activity coefficients, water activities, water vapour pressure, and HCl solubilities, when compared to existing thermodynamic models of $H_2SO_4/H_2O$ solutions, in particular at lower temperatures.

**P-2-14**

ATMOSPHERIC RESPONSE TO THE DECADAL VARIABILITY OF THE SOLAR ULTRAVIOLET AND VISIBLE IRRADIANCE SIMULATED WITH CCM SOCOL

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**Abstract:** To investigate the effects of solar variability during 11-year solar cycle we have applied the chemistry-climate model SOCOL and carried out four 20-year long steady state simulations with observed spectral solar fluxes: (1) Solar minimum (2) Solar maximum (3) Solar maximum for ultraviolet radiation only and (4) Solar maximum for visible radiation only. The obtained results have been compared with the solar minimum case. The simulated ozone response is positively correlated with solar irradiance in the tropical stratosphere and negatively correlated in the mesosphere, which is in an agreement with theoretical expectation. For the experiments 2 and 3 the model suggests a weak acceleration of the polar night jets resulting in a dipole structure in the temperature response over the high latitudes of both hemispheres. These dynamical changes lead to an alternation of the tropospheric circulation, which in turn, influences the surface air temperature. The pattern in surface temperature changes resembles the signal of positive AO phases, which implies downward propagation of the solar signal via intensification of the polar night jets. For the simulation where only the visible radiation was enhanced we have also obtained a stratospheric response, which appears only over the northern high latitudes and is probably caused by upward propagating dynamical perturbations. Our analysis of the surface air temperature response shows that the visible and ultraviolet radiation dominates in different geographical regions providing a noticeable combined effect.

**P-2-15**

## SENSITIVITY OF DYNAMICS AND OZONE TO DIFFERENT REPRESENTATIONS OF SSTs IN THE UNIFIED MODEL

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**Abstract:** We use a version of the Met Office Unified Model with a simple stratospheric chemistry to perform a set of multi-annual integrations of 20 years each. The runs have different representations of ozone in the radiation and prescribed SSTs. In one experiment the same long-term mean monthly mean SSTs are used each model year, whereas all other experiments use annually varying AMIP II monthly mean SSTs instead. All runs have the same simplified ozone chemistry included (regardless of which ozone is used in the radiation), so we can estimate the impact of dynamical changes on ozone. We show that the appearance of extreme events in the Northern Hemisphere winter stratosphere as modelled with the Unified Model is linked more to the representation of SSTs than it is to ozone. We will demonstrate that the transient nature of the SSTs is an important factor for the development of weak vortex regimes in the model and, therefore, for the ozone variability in high latitudes as well.

**P-2-16**

## RELATIONSHIP BETWEEN OZONE VARIABILITY IN HIGH AND LOW LATITUDES IN THE UNIFIED MODEL: HOW IMPORTANT IS THE QBO?

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**Abstract:** We will revisit the relationship between mid-latitude planetary wave forcing, polar vortex strength and phase of the QBO in determining the meridional abundance of ozone using the Met Office Unified Model in conjunction with stratospheric chemistry. We will focus on the role of the QBO in moderating inter-annual variability by analysing a set of runs with and without a nudged QBO. The relationships between tropical and extra-tropical ozone will be discussed using correlation analysis. In doing so, we will contrast different vertical and meridional regions in terms of their ozone variability: *e.g.* the TTL, the mid-latitude UT/LS and the polar vortex region and we will assess how these regions have been affected by the QBO in the model. To investigate the validity of our model results we will use ERA-40 data to compare the QBO signal in temperature in the tropics and extra-tropics.

**P-2-17**

## ASSIMILATION OF STRATOSPHERIC OZONE AND WATER VAPOUR INTO THE UNIFIED MODEL

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**Abstract:** The Data Assimilation Research Centre is creating assimilated datasets of ozone and water vapour in the stratosphere as part of the European Union ASSET project (Assimilation of Envisat Data). The assimilation system is a variant of that used to produce Met Office stratospheric analyses, which uses three-dimensional variational assimilation (3D-Var) to assimilate data into the Unified Model. We assimilate temperature, ozone and water vapour from the MIPAS instrument, alongside the operational dataset, which includes ATOVS and sonde observations. Bringing together observations and models reveals the strengths and weaknesses of both.

In order to assimilate ozone, the model transport and chemistry must adequately represent the ozone field in the absence of observations. However, vertical transport is much too fast in the tropical pipe. The model's tracer transport scheme already has deficiencies, but the assimilation of dynamical data degrades model transport still further. Additionally, it is seen that parameterisations of ozone chemistry exhibit large differences. These linear, zonal mean parameterisations may have difficulties representing the Southern Hemisphere polar vortex during particularly disturbed conditions, such as the major warming of September 2002. The assimilation of water vapour is particularly challenging in the upper troposphere and lower stratosphere. Operational radiosondes and ATOVS do not provide much humidity information above 250 hPa. Water vapour from the limb-scanning MIPAS instrument is much affected by cloud on the 12 km (approx 150 hPa) retrieval level and below. 3D-Var spreads the influence of one observation over a wider area, but near the strong humidity gradients at the tropopause there may be difficulties with this approach. With the new observations we expect to be able to test the model's dynamics, radiation, cloud and convection schemes in a region that is difficult to simulate accurately.

**P-2-18**

## REACTIVE UPTAKE OF CHLORINE NITRATE ON ICE AT TEMPERATURES OF THE UPPER TROPOSPHERE

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**Abstract:** This work addresses the issue of reactive chlorine in the Upper Troposphere, which can influence the ozone budget in this region. Chlorine activation results from surface reactions of HCl absorbed on cirrus clouds with other chlorine reservoirs, such as $ClONO_2$. The present study aims to probe the chlorine activating surface reaction between HCl and $ClONO_2$, in isolation and in competition with $HNO_3$, with a view to establish parameterisations for the rate of Cl activation under conditions of the Upper Troposphere. Experimentally, this study is carried out using a coated-wall flow-tube coupled to an electron impact mass spectrometer. Frozen film ice surfaces are prepared by inserting a wetted Pyrex sleeve in to the pre-cooled flow tube. A sliding injector controls the exposure of reactant gases to the ice surface. Experiments are carried out in the temperature range 210-230 K and with partial pressures of reactants 0.3 x $10^{-6}$ Torr.

**P-2-19**

TRANSIENT SIMULATIONS OF THE NEAR PAST WITH INTERACTIVE MIDDLE ATMOSPHERE CHEMISTRY CLIMATE MODELS

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**Abstract:** The fully coupled chemistry climate model MAECHAM4/CHEM has been applied for a transient simulation from 1960 to 2000 using observed sea surface temperatures and concentrations of chemically active and greenhouse gases. The Quasi Biannual Oscillation is assimilated from observations, the 11-year solar cycle and major volcanoes are included. We show that the model is able to reproduce most of the observed features of ozone and temperature in the stratosphere, including trends and interannual variability. For a shorter period in the 1990s stratospheric and mesospheric results of the new more comprehensive middle atmosphere version of ECHAM5/MESSy (Modular Earth Submodel System) are compared with MAECHAM4/CHEM using the same constraints. We also show 14CO as a diagnostic tool for stratospheric tropospheric exchange in both models.

**P-2-20**

DECADAL VARIABILITY OF THE UPPER TROPOSPHERE/LOWER STRATOSPHERE WATER VAPOUR, OZONE AND TEMPERATURE FROM HALOE DATA

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**Abstract:** Solar modulation of the seasonal cycle in troposphere-stratosphere exchange of water vapour, revealed by multiple regression analysis of data from the Halogen Occultation Experiment (HALOE) on UARS satellite for the period October 1991-March 2003, is interpreted as an additional indirect mechanism for solar influence on climate. A key role in this process belongs to water vapour, accumulated at solar maximum in boreal winters just below the tropopause due to the increased saturation vapour pressure and a colder tropopause - preventing $H_2O$ transport into the stratosphere. Additionally the $NO_x$-limited regime of the Upper Troposphere (UT) leads to increased ozone production and more warming (up to 1-3K) of the tropical Upper Troposphere-Lower Stratosphere (UT/LS).

The solar modulation of UT/LS temperature regime offers an explanation for quasi-decadal variations of QBO equatorial winds, reported by Salby and Callaghan 2000, and described briefly as follows. Enhanced T gradients at subtropics (due to warmer tropics) strengthens tropical easterly winds below the tropopause, which on its turn damps westward propagating Rossby and gravity waves, allowing free vertical propagation of the waves with eastward phase. Taking into account that the QBO period is strongly sensitive to the vertical flux of horizontal momentum u'w' (increase of momentum flux decreases the period of QBO - Plumb 1977) shortens of westerlies may be expected, as obtained by Salby and Callaghan 2000 near solar maximum.

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**P-2-21**

# ASSESSMENT OF OZONE ASSIMILATION AND PREDICTION IN THE NCEP GLOBAL FORECAST SYSTEM

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**Abstract:** For several years, near real-time measurements of SBUV/2 ozone profile and total column ozone have been assimilated within the global data assimilation in the NCEP Global Forecast System (GFS). Ozone concentration is also a prognostic quantity in the operational model, which interacts with model physics, *i.e.* radiation and affects temperature and circulation. Based on NCEP s model output, synoptic, statistical and diagnostic analyses are performed to assess the skill and bias of ozone assimilation and prediction. The results show that the NCEP GFS is able to predict the total column ozone pattern up to at least 5 days with reasonable skill. This is particularly demonstrated by the successful 5-day forecast of the unprecedented ozone hole split in September 2002. On the other hand, the NCEP model forecast has a bias in global total ozone. The low ozone bias occurs in both the tropics and extratropics, mainly in the upper stratosphere. Numerical experiments and diagnostics indicate that the low ozone bias is in part due to the parameterisation of the ozone production and loss terms, and in part due to forecast errors in the model s transport circulation. Future plans to improve ozone assimilation system and ozone chemistry parameterisation are discussed.

**P-2-22**

# MEASUREMENTS AND MODEL CALCULATIONS OF NITROUS OXIDE: IMPLICATIONS FOR STRATOSPHERIC TRANSPORT

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**Abstract:** The Airborne Sub-millimeter Radiometer ASUR operates in a tuning frequency range from 602 to 664 GHz. The receiver is equipped with two spectrometers, the Acousto Optical Spectrometer (AOS) and Chirp Transform Spectrometer (CTS). The sensor is flown onboard an aircraft to avoid signal absorption due to tropospheric water vapour. The AOS has a total bandwidth of 1.5 GHz, a resolution of 1.5 MHz, whereas the CTS has a resolution of 300 kHz. The AOS is used for stratospheric and the CTS is used for mesospheric observations. A range of stratospheric constituents is measured using the AOS including Ozone and Nitrous oxide. The instrument measures thermal emissions from rotational lines of the observed molecules. The altitude information comes from the pressure broadened lines of the emitting species. Optimal estimation is employed to retrieve the mixing ratio profiles. SCIA-VALUE is the SCIAMACHY validation campaign performed onboard the German research aircraft Falcon in September 2002 and February - March 2003. Numerous measurements of stratospheric molecules are performed by ASUR during the campaign. The observations spanned a latitude band from 5°S to 80°N. The campaign enabled to survey the latitudes twice in two seasons. The measured profiles of stratospheric Nitrous oxide are compared with a simple global Chemical Transport Model (CTM). Important features of stratospheric transport are studied using the measurements and CTM simulations. An overview of the instrument, the data set, the CTM and the results of the study will be presented.

**P-2-23**

# POLAR STRATOSPHERIC CLOUD SIMULATIONS WITH THE CHEMISTRY-CLIMATE MODEL ECHAM5/MESSy

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**Abstract:** A Polar Stratospheric Cloud (PSC) module has been developed for the coupled troposphere-stratosphere chemistry-climate model ECHAM, version 5. Microphysical processes that lead to the formation of Supercooled Ternary Solutions (STS), nitric acid trihydrate (NAT), and ice particles in the polar stratosphere are modelled as well as heterogeneous chemical reactions of halogens and dinitrogen pentoxide on liquid and solid aerosol particles. Denitrification and dehydration due to sedimenting solid PSC particles are calculated for each grid box depending on particle size, pressure and temperature. For validation purposes the ECHAM 5 model is run in a nudged mode, *i.e.* its meteorology is driven by ECMWF analysis data. The PSC model results can thus be compared to measurements in the corresponding time period. This poster concentrates on the evaluation of the PSC microphysics and sedimentation routines.

**P-2-24**

# ASSIMILATION OF OZONE DATA IN THE ECMWF INTEGRATED FORECAST SYSTEM

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**Abstract:** Ozone is a prognostic variable in the ECMWF operational model and has also been included in the ECMWF data assimilation system. Currently, ozone retrievals from the MIPAS instrument on ENVISAT and from SBUV/2 on NOAA-16 are assimilated in the operational 4D-Variational ECMWF assimilation system. TOMS total column ozone data and SBUV/2 ozone layers were assimilated in the ECMWF 40-year reanalysis project, which used 3D-VAR.

This talk gives an overview of the ECMWF ozone assimilation system and presents results from the assimilation of ozone retrievals in 3D-VAR and 4D-VAR. We will show that the assimilation of MIPAS ozone profiles has a positive impact on the ECMWF ozone field. A new formulation of the ozone analysis is being developed at ECMWF. This formulation uses a normalized ozone control variable and better accounts for variations of ozone in the vertical. Examples showing the performance of this new ozone analysis will be presented.

**P-2-25**

EVOLUTION OF THE ATMOSPHERIC STATE DURING 1975-2000 SIMULATED WITH A CHEMISTRY-CLIMATE MODEL: AN ATTEMPT TO EVALUATE THE ROLE OF DIFFERENT FORCING MECHANISMS

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**Abstract:** The atmospheric state during the last 25 years of the 20$^{th}$ century has been simulated with the Chemistry-Climate Model SOCOL extending form the ground up to 80 km. We have carried out six 25-year long transient runs. For the first simulation only the time evolving SST/SI is prescribed. For the second and third simulations we have added the time evolution of the Greenhouse Gases (GHG) and Ozone Destructing Substances (ODS). In the forth simulation we consider the forcing due to the both GHG and ODS. The volcanic and solar forcing have been added for the fifth and sixth runs. This sequence of the runs allows to validate the simulated time evolution of the atmospheric state against available observations and to elucidate the contribution of the different forcing mechanisms. The obtained time evolution of the temperature and ozone fields for the sixth run is closer to the observation data than the results of all other runs. The model captures the formation of the ozone hole over the southern high-latitudes, cooling and ozone depletion in the upper stratosphere and warming in the troposphere and at the surface. The model simulates an increase of the stratospheric water vapour mixing ratio by of about 0.7 year, which seems to be a reflection of the tropospheric warming and subsequent increase of the water vapour in the upper troposphere.

**P-2-26**

INTERANNUAL VARIABILITY OF POLAR CONTRIBUTIONS TO THE LOWER STRATOSPHERE MIDDLE LATITUDE OZONE AND OZONE TREND

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**Abstract:** Previous studies have estimated polar contributions to spring-time middle latitude ozone loss to be approximately 50% in the Northern Hemisphere. The magnitude of the polar contribution to middle latitude ozone loss was also found to be strongly dependent on the relative disturbance of the polar vortex. However, it was uncertain if these seasonal impacts would contribute to the negative ozone trend as ozone could be replenished over the summer months. This study will expand earlier work and investigate the differences in the polar contributions to middle latitude ozone loss between the Northern Hemisphere and the Southern Hemisphere. The study will focus on the comparison between the Arctic winters 1999/2000, 2002/2003, and the Antarctic winters 2000 and 2002, which include extrema in both hemispheres. The 3D chemical transport model, SLIMCAT, has been integrated from the start of each winter for a whole year in each case. Possible contributions to middle latitude trends were investigated with the inclusion of ozone budgeting tracers to follow net ozone change by geographical origin relative to the vortex and the individual chemical cycles responsible for the ozone change.

**P-2-27**

## MIDDLE ATMOSPHERE MODELLING OF OZONE AND CLIMATE

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**Abstract:** The ability of chemistry-climate models to address ozone change issues relies on the models' capabilities to correctly represent the current state of the ozone layer. The ozone distribution and its evolution depend upon dynamical, radiative and photochemical processes which are strongly coupled and difficult to represent. The Canadian Middle Atmosphere Model (CMAM), which is based on the state-of-the-art CCCma GCM, includes the necessary processes and interactions to address ozone change issues. The approach is comprehensive and includes the necessary coupling between the troposphere-stratosphere-mesosphere regions. In this study, various aspects of the general circulation and the climatology of constituents from the CMAM will be compared with observations in order to characterise the model's capabilities and limitations. This model evaluation effort will be used to identify various aspects of the model which may need improvement in order to to address the full complexity of interaction between ozone and climate change.

**P-2-28**

## A CASE STUDY OF GRAVITY WAVE MOMENTUM DEPOSITION ESTIMATION USING AN ADJOINT MODEL

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**Abstract:** Although the importance of gravity wave momentum deposition effects on the general circulation is well recognised, there is still a big uncertainty about the actual wave forcing field. In this work, a technique to estimate the wave forcing from three-dimensional middle atmosphere observations is discussed. It uses an adjoint model and four-dimensional variational assimilation principles. The technique performance is evaluated in theoretical experiments where the model is evolved with a prescribed analytical drag. We show that this technique can capture the nonlocal effects of wave forcing, in other words it can effectively trace back the evolution of the atmosphere and estimate the prescribed wave forcing. It is also shown that the technique does not need observations of the wind field, temperature observations are enough. This makes the technique specially suitable for middle atmosphere studies where only satellite temperature observations are available.

A case study for 1-5 July 2002 observations is presented. The zonal and meridional components of the 3D wave forcing are estimated with the variational technique. Important departures from zonal symmetry are observed. The strongest forcing is found between 1.0-0.1 mb, which is associated with the cold-pole problem, peak values are -30 m/(s day).

**P-2-29**

## THE INTERACTION BETWEEN CHEMISTRY AND DYNAMICS IN A CLIMATE MODEL DURING ANTARCTIC OZONE DEPLETION EVENTS.

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**Abstract:** The Canadian Middle Atmosphere Model (CMAM) is a general circulation model with a top at 95 km with comprehensive on-line stratospheric chemistry. As part of the WMO report (Austin *et al*., 2003) we have made several 20 year time slice runs for current and future atmospheric and ocean surface conditions. These simulations were designed to examine the impact of changing $CO_2$ and CFC's upon both the expected high latitude ozone loss over the period of the current Chlorine peak and putative recovery expected over the next few decades.

We have analysed these time slices scenarios with a view to characterising the variability of the timing and magnitude of Antarctic stratospheric ozone. We find that the dynamical influences are important and can alter the modelled ozone depletion in a significant fashion. Our analysis points to the need for a better characterisation within all models of the actual wave forcing (planetary waves and gravity waves) for the time period of the climate being represented so that the model can reproduce the right vortex evolutionary character and hence ozone loss, for the right reasons: the vortex evolution and, thus, the ozone loss modelled is sensitive to the details of these waves.

More rigorous and hence realistic definition of the atmospheric forcing (via SST's and model generated wave forcing of planetary and gravity waves for example) is, thus, required to correctly simulate the complex interactions between dynamics, chemistry and physics which occur to produce specific ozone loss episodes. If we can understand the changing forcing and prescribe the changes accurately, this would result in an improved simulation of both the mean state and its variability and hopefully in a more realistic ozone loss.

**P-2-30**

## BACKGROUND ERROR STATISTICS FOR MIDDLE ATMOSPHERE DATA ASSIMILATION

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**Abstract:** The 3D variational (3D-var) assimilation system of the Canadian Meteorological Centre (CMC) provides operational weather analyses using 6-hr forecasts of the Global Environmental Multi-scale (GEM) model. This 3D-var assimilation system has been adapted for use with the Canadian Middle Atmosphere Model (CMAM) with a hybrid-eta vertical coordinate system and a ceiling of approximately 97 km. The CMAM background error statistics have been derived following the same choice of analysis variables and covariance representation as used operationally with GEM. The variances vary in latitude and along the vertical direction, while the correlations are set as spatially homogeneous and isotropic but non-separable. As alternative to the lagged-forecasts method, the background error 6-hr forecast statistics applied during the first data assimilation experiments have been estimated from statistics derived from a time series of 6-hr differences for individual months of a climate run. Statistics from both methods are presented and compared. The impact of gravity wave parameterisation on the middle atmosphere statistics is investigated. Single observation experiments demonstrate the sensitivity of the middle atmosphere increments to observations in the lower stratosphere and troposphere. Sources of this sensitivity are identified and corresponding adjustments are applied to the correlations and variable transformations.

**P-2-31**

## GREENHOUSE GASES INDUCED COOLING AND OZONE RADIATIVE FEEDBACK

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**Abstract:** The Canadian Middle Atmosphere Model (CMAM) has been used to examine the details of radiative and photochemical processes under current and 2x$CO_2$ conditions. The CMAM contains an interactive photochemical module, which includes the processes necessary to represent the complexity of the interactions throughout the stratospheric and mesospheric domain. Different scenarios have been performed with and without interactive chemistry to determine the importance of the radiative feedback through ozone on the 2x$CO_2$ cooling signal. The interactive model results show a maximum cooling of 10 K at the stratopause, which reaches 12-15 K in the polar regions. In association with this cooling, the ozone mixing ratio increases throughout much of the model domain with a 15-20 % maximum in the upper stratosphere. In the lower mesosphere the ozone increase is rather uniform and is generally 10-15 % up to 0.03 hPa (70 km). Results from the non-interactive simulations show that the magnitude of the cooling is significantly overestimated when the ozone radiative feedback is not considered. We have developed a procedure to analyse the complex model chemistry response using the odd oxygen budget equation. The details of our analysis indicating the various aspects of the temperature sensitivity of the main photochemical processes will be presented. The analysis reveals that, despite the complexity of the ozone chemistry, the ozone increase can be understood primarily as a result of the negative temperature sensitivity of the ozone recombination reaction. Although this reaction is not a net production or loss mechanism for odd oxygen, it indirectly affects odd oxygen loss rates by controlling the atomic oxygen concentration in the stratosphere.

**P-2-32**

## LOWER STRATOSPHERIC $N_2O$ DISTRIBUTIONS IN THE EARLY AND LATE ARCTIC VORTEX BREAKUP YEARS

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**Abstract:** It is well known that there are large interannual variations in the timing of the Arctic vortex breakup. This makes an interannual variation in $N_2O$ distribution in the lower stratosphere. Holton (1986) and Mahlman *et al*. (1986) showed a clear relationship among the annual mean meridional tracer slope, advection and horizontal diffusion. In this paper, the year-to-year lower stratospheric $N_2O$ distributions with a 3-D model are analysed in the early and late vortex breakup years with the probability distribution function (PDF) technique. The isentropic diffusion coefficient (Kyy) and the vertical advection are calculated to quantify the effects of horizontal diffusion and vertical advection on the $N_2O$ concentration. The data are from a Center for Climate System Research/National Institute for Environmental Studies (CCSR/NIES) nudging chemical transport model (CTM), which used NCEP data for the nudging processes, for 45 years from 1958 to 2002.

Results showed that there are clear differences in the $N_2O$ distribution in spring and early summer between the early vortex breakup years and the late years. In the early breakup years, the $N_2O$ concentration in the north of 45N on 600K isentropic surface is lower than that in the late years. The $N_2O$ distribution shows large dispersion after the vortex breakup, which is related to the strong vertical advection and large Kyy in the middle and high latitude lower stratosphere. In the late breakup years, the $N_2O$ distribution is more uniform than that in the early years, with smaller vertical advection and smaller horizontal diffusion.

**P-2-33**

# A CTM STUDY OF LOWER STRATOSPHERIC OZONE DESTRUCTION DUE TO BROMINE SPECIES INSIDE/OUTSIDE THE ARCTIC POLAR VORTEX

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**Abstract:** In this study we focus on the Arctic ozone destruction processes due to bromine species in 1995, 96, 97 and 2000. The model used is the CCSR/NIES nudging CTM, which was developed by Akiyoshi *et al.* (J. Meteorol. Soc. Jpn., 2002; J. Geophys. Res., 2004). The temperature and horizontal wind velocities of the CTM were nudged to the ECMWF data. The model includes heterogeneous reaction scheme for STS, NAT and ICE. Sulfur chemistry was introduced into the model for calculating $H_2SO_4$ concentration and STS amount. Concentrations of OCS and $SO_2$ were specified at the surface of the model. In order to examine the effects of bromine species on ozone destruction, three numerical experiments were made: (1) with bromine species and with heterogeneous reactions, (2) without bromine species and with heterogeneous reactions, and (3) with bromine species and without heterogeneous reactions, using the T42 horizontal resolution (2.8 degree by 2.8 degree in grids). The results are analysed by taking an inside/outside vortex mean at each latitude belt to see the sensitivity of bromine species to the sunlight. In the first run, a large amount of BrCl is formed within the polar vortex. The effects of the BrCl formation and the contribution of the $BrO_x$, $ClO_x$, $HO_x$ and $NO_x$ catalytic cycles on ozone destruction are discussed inside/outside the polar vortex in the winters and springs of these years, considering the year-to-year variation of the Arctic polar vortex.

**P-2-34**

# WAVE-LIKE OZONE VARIABILITY IN THE NORTHERN HEMISPHERE SUMMER STRATOSPHERE

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**Abstract:** Stratospheric minor constituent data obtained by the Improved Limb Atmospheric Spectrometer (ILAS) on board the Advanced Earth Observing Satellite (ADEOS) and the Polar Ozone and Aerosol Measurement II (POAM II) are analysed to examine ozone variability in the summer lower stratosphere of Northern Hemisphere high latitudes. It is shown that the ozone variability propagates westward with wave-like structures of zonal wavenumber 1-2 after the final breakup of the polar vortex until mid summer. In order to see dynamical features associated with these wave-like structures in the ozone field, we investigate ozone and meteorological data derived from a chemical and dynamical coupling general circulation model (GCM) developed in Kyushu University. It is confirmed that westward travelling waves of zonal wavenumber 1-2 are dominant in the GCM ozone field almost every Northern Hemisphere summer and have a characteristic period of 2-3 weeks, which are consistent with the observational results. Similar wave-like structures are also seen in the geopotential height field and are identified with normal mode Rossby waves on the basis of their three-dimensional structures. Moreover, ozone perturbations show in-phase spatial structure with temperature perturbations related to normal mode Rossby waves. This implies that wave-induced ozone advection associated with normal mode Rossby waves is important to the ozone variability in the summer lower stratosphere.

**P-2-35**

OZONE/TEMPERATURE CORRELATIONS DURING THE CRISTA 2 FLIGHT

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**Abstract:** Temperature and ozone observations from the second flight (August 7-17, 1997) of the Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA) instrument exhibit correlations which are out of phase above 40 km where photochemical timescales dominate the behaviour and are in phase below 30 km where dynamical timescales are most important. In the photochemically dominated region the correlation can be fitted empirically and a parameter closely related to the reactions involved in the photochemistry determined. As reported previously, the character of the correlations agree more closely with photochemical equilibrium calculations than previous analyses with other satellite data. In this paper we report on the latitudinal and temporal variation of these correlations during the mission. The CRISTA data are of sufficient quality and resolution and variations in this correlation are statistically significant. It is found that the form of the correlation varies with latitude with the empirical parameter maximizing at midlatitudes when the full mission data set is considered. This latitudinal variation is strongest early in the mission and decreases during the mission. Temperature perturbations in this data are smallest in equatorial regions and, as a result, the uncertainty in the value of the derived constant at these latitudes is greatest. These results are interpreted using simulations using the Rose model. Chemical fields are initialised with equivalent latitude distributions of the species of importance for ozone photochemistry derived from CRISTA data. UKMO or ECMWF fields for the CRISTA mission time period provide the dynamical forcing for the model, and the constituents are advected by the associated wind fields. The model constituent fields are sampled and analysed in the same manner as the CRISTA data and the derived correlations compared to the observations.

**P-2-36**

CLOUD PROPERTIES OF SYNOPTIC PSCs AND UPTAKE OF $HNO_3$:
MIPAS-B OBSERVATIONS AND MICROPHYSICAL MODEL CALCULATIONS

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**Abstract:** Balloon flights with the Michelson Interferometer for Passive Atmospheric Sounding balloon borne version (MIPAS-B) were carried out in the arctic winters 2000/2001 and 2002/2003. Recorded data have been analysed in order to study the potential of limb emission spectroscopy for deducing cloud properties of PSCs, as well as to investigate removal of gaseous $HNO_3$ by the cloud particles. The flights were performed under meteorological situations that were favourable for formation of synoptic-scale PSCs. Spectra have been analysed for cloud properties, such as composition, number density and mean particle size, as well as for the abundances of gaseous compounds, such as $H_2O$, $HNO_3$ and $ClONO_2$. In January 2001, MIPAS-B observations in PSC-free areas could be used as reference, while in December 2002 MIPAS-Envisat data provided the reference for the $HNO_3$ distribution prior to the onset of PSC formation.

In January 2001 a substantial uptake of $HNO_3$ by the PSC particles was observed in broad agreement with the assumption that most of the $HNO_3$ was in condensed form in liquid STS particles, while in December 2002 the situation appeared more unclear. Both situations were characterised by an almost complete conversion of $ClONO_2$ into active forms of chlorine. A detailed microphysical model is run on backward trajectories applying the ECMWF analysis. The model calculates the time dependent changes in size distributions of liquid sulphate and STS particles, NAT, ice, and SAT solid particles together with changes in gas phase $HNO_3$ and $H_2O$, using the basic vapour diffusion equation, applying a full kinetic approach. Measurements vs. model comparisons are utilized for evaluating the nucleation processes implemented in the microphysical model.

**P-2-37**

CHEMISTRY CLIMATE MODELLING OF THE MIDDLE ATMOSPHERE: DYNAMICAL FEEDBACKS IN A TRANSIENT SIMULATION

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**Abstract:** It is of great concern to simulate the evolution of the atmosphere of the last century for identifying causes of variability and change and for validating the comprehensive models to be used in predictions of the future atmosphere as its composition changes. Within this context, results from a 40 year transient simulation performed with the MAECHAM4/CHEM chemistry climate model are presented. The transient simulation cover the 1960 to 1999 period. External forcing includes observed sea surface temperature, an assimilated Quasi-Biennial Oscillation (QBO) in zonal wind, perturbations by volcanic eruptions, and the 11-year solar cycle. The main topic addressed is the dynamical response of the middle atmosphere in the transient simulation and its consistency and/or novel results with respect to the dynamical response from earlier simulations done with the same model but for constant forcing, respectively for the near past and present conditions. In particular, the role of the QBO and of sea surface temperature variations on the winter stratospheric circulation are considered.

**P-2-38**

SOME DIAGNOSES IN THE STRATOSPHERE USING CMAM-DA ANALYSES

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**Abstract:** Eliassen-Palm flux (EP flux) and the residual mean meridional circulation are two important tools in understanding the wave-mean flow interaction, ozone transport, and the age of air in the stratosphere. They are computed in this work using the analyses produced by the Canadian Middle Atmosphere Model Data Assimilation (CMAM-DA) system. In the system CMAM is used as the forecast model. Wind, temperature, moisture variables, and surface pressure are assimilated using the 3DVAR assimilation system. Conventional observations and satelliate observations (AMSUA) are used in the assimilation.

The impact of the analyses on the EP-flux will be examined by comparing analysed EP-flux with the EP-flux based on the CMAM climate run. The implication of the difference will be discussed. The impact of the analyses on the residual mean meridional circulation, as well as the impact of the residual mean meridional circulation on ozone transport, will also be discussed.

**P-2-39**

FIRST RESULTS OF ASSIMILATING OZONE DATA INTO CMAM WITH CMC'S 3D VAR

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**Abstract:** The Canadian Middle Atmosphere Model (CMAM) is a 3-D spectral climate model with hybrid vertical coordinate system up to about 96 km and incorporates fully interactive chemistry, dynamics and radiative transfer. In the model 49 species or families are advected and 95 gas-phase and heterogeneous chemical reactions are calculated. In order to force the model state closer to observations, we are extending the Canadian Meteorological Center (CMC)'s 3D VAR system to assimilate various chemical families from a variety of observation sources. As a first step, experiments are conducted in which ozone data is assimilated into the model and an attempt is made to evaluate the model bias and observation bias, as well as the impact of the data. The results of assimilating total column ozone observations (GOME level-2 and TOMS level-3) and ozone profile observations (OSIRIS, SBUV/2) will be presented and the impact on dynamic fields will be examined.

**P-2-40**

PROGNOSTIC GREENHOUSE TRACERS IN THE CCCma ATMOSPHERIC GCM

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**Abstract:** Improvements to the Canadian Centre for Climate Modelling (CCCma) atmospheric GCM, as part of ongoing work within the Canadian Global Coupled Carbon Climate Modelling (CGC3M) project, are described. Specifically, a prognostic tracer scheme has been introduced for methane and nitrous oxide, including parameterised chemical loss of both species and methane oxidation as a source of water vapour in the stratosphere. Results and sensitivity tests of ten-year climate simulations forced with climatological SSTs, sea ice, ozone, and specified surface concentration distributions of the tracers are presented. Zonally-averaged distributions are compared with UARS (HALOE/CLAES) climatology for the years 1992 to present. The model is able to reproduce the observed latitude-height distributions and seasonal variations of these radiatively important species with an accuracy sufficient for long-term transient climate simulations.

**P-2-41**

IMPACT OF CLIMATE CHANGE ON OZONE DEPLETION AND UV RADIATION EFFECTS

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**Abstract:** The effect of some human activities like the use of CFCs on ozone layer depletion and associated adverse UV radiation effects for human health and environmental degradation have been widely studied and protective measures including CFCs phase out have been instituted. However, the climate change involving temperature, humidity, cloud cover, etc. can also have additive (physiological) contribution to UV-B radiation effects on humans, in particular the skin cancer (UV carcinogenesis) under prevailing conditions and future projections. In this paper we present a quantitative estimation of UV-B enhancement due to such variables as temperature, humidity, wind, clouds and UV-A under different conditions relevant to the human skin cancer. It is found that the climatic contribution can be particularly serious in the tropical region.

**P-2-42**

IMPACT OF THE OCTOBER 2003 SOLAR PROTON EVENT ON THE COMPOSITION OF THE MIDDLE ATMOSPHERE: MEASUREMENTS AND MODEL STUDIES

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**Abstract**: On October 28, 2003 one of the largest solar eruptions of the current solar cycle occurred that was associated with the emission of energetic solar protons with energies exceeding 100 MeV. The solar proton event (SPE) was preceded by a smaller one on October 27, 2003. Another, weaker event followed on November 3/4, 2003. The highly energetic protons interact with the Earth's atmosphere in different ways. They lead, *e.g.*, to the production of $HO_x$ through complex chemical processes involving ionic-reactions, as well as to the formation of $NO_x$. Both families can lead to significant $O_3$ depletion as a consequence of the SPE.

We use stratospheric and mesospheric $O_3$ density profiles derived from limb scattering observations performed with SCIAMACHY (Scanning Imaging Absorption spectroMeter for Atmospheric CHartographY) on the European Space Agency's ENVISAT to quantify the immediate $O_3$ depletion caused by short-lived excess $HO_x$ in the upper stratosphere and the mesosphere. Within the polar cap region $O_3$ is found to be decreased by up to 60% in the lower mesosphere, and by a smaller amount in the upper stratosphere. Due to the short life-time of $HO_x$, a partial recovery of $O_3$ is observed between October 30, and the following SPE on November 3/4, when significant depletion occurred again.

The measurements are complemented by model simulations with a global 2-D chemistry, transport and photolysis model of the stratosphere and mesosphere. Model runs are carried out covering all three events, modelling the impact of high-energetic particle precipitation on the chemical composition of the mesosphere and stratosphere. The simulations are found to be in very good quantitative agreement with the stratospheric/mesospheric SCIAMACHY $O_3$ measurements.

**P-2-43**

A DIAGNOSTIC BALANCE IN EQUATORIAL FLOW

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**Abstract**: Current analyses of stratospheric horizontal wind fields are of poorer quality in the tropics than in the extratropics. Analysed winds often exhibit significant departures from observations, and various analysis products tend to disagree considerably near the equator, even in a zonal mean. In this study a scale analysis of the governing equations is performed, in an effort to derive a simple dynamical balance, which could be employed in data assimilation schemes, as a theoretical constraint on the zonal velocity. A relation similar to the traditional linear balance is proposed, exploiting the anisotropy of the flow, *i.e.* the small ratio of meridional scales of motion compared with zonal scales. The dynamical lengthscales are systematically characterised as a function of pressure, based on spatial correlations of horizontal velocities from numerical simulations using the Canadian Middle Atmosphere Model (CMAM), as well as analyses from the Met Office and the Canadian Meteorological Centre. This ratio is shown to become smaller as higher zonal wavenumbers are filtered out. Additionally, the CMAM allows for a careful comparison of all the terms involved in the equations of motion. The proposed balance, examined in the context of the above data sets, is reasonably robust in the tropics, especially in the lower and middle stratosphere. Significant departures from balance still appear, however, in regions of high wave activity.

**P-2-44**

THE 5-DAY WAVE IN ATMOSPHERIC ANALYSES AND IN CMAM, AND ITS EFFECTS ON LATE-SUMMER CHEMICAL VARIABILITY

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**Abstract:** The MANTRA campaign measures stratospheric chemical species relevant to ozone through a balloon launch every other year in late summer in Vanscoy, Saskatchewan (52°N). While large-scale dynamical variability in the stratosphere is very limited in late summer, it nevertheless exists and has an impact on chemical species. It is therefore important to characterise this variability in order to assess the representativeness of the measurements, and isolate long-term changes.

To this end, climate simulations from the Canadian Middle Atmosphere Model (CMAM), a fully interactive chemistry-climate model, are analysed to quantify the nature of the stratospheric late-summer dynamical variability and its relation to variations in various chemical species. In order to ensure that the model behaviour is realistic, the dynamical variability is compared with that found in various analysis products. The dominant features in both CMAM and the analyses are the propagating diurnal tide and the so-called 5-day wave. The amplitude of the 5-day wave exhibits considerable interannual variability. While it has a clear effect on long-lived species, the nature of the effect depends strongly on altitude. These features should be taken into account when interpreting the MANTRA measurements.

**P-2-45**

## UPTAKE OF C1 - C5 MONOCARBOXYLIC ACIDS ON AMMONIUM NITRATE AS A FUNCTION OF TEMPERATURE AND RELATIVE HUMIDITY

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**Abstract:** The uptake of C1 - C5 monocarboxylic acids on ammonium nitrate (AN) has been investigated as a function of temperature and relative humidity using a Knudsen cell flow reactor coupled with FTIR-Reflection Absorption Spectroscopy (FTIR-RAS). Initial uptake coefficients and coverages were determined over the temperature range 200 to 240 K. The uptake of the C1 - C4 acids was quite efficient but temperature dependent, with larger coverages and uptake coefficients being observed at lower temperatures. The uptake coefficients and coverages were also dependent on the carbon chain length, with the shorter chain acids displaying larger coverages but smaller uptake coefficients at a given temperature. Valeric acid (C5) did not adsorb onto ammonium nitrate under any of the conditions studied. Infrared spectra revealed that the acids ionized on the surface, despite the fact that the ammonium nitrate films were effloresced.

The initial uptake coefficients were analyzed using a precursor-mediated adsorption model to determine Hads and Sads values for each species. Adding small amounts of water vapour (RH 4 to the chamber resulted in unlimited uptake and dramatically increased the coverages and intial uptake coefficients. Higher relative humidity resulted in further increases of both values. The IR spectra again revealed that the organic acids ionized on the surface. Furthermore, the IR spectra revealed that a liquid layer is formed when many of the acids adsorbed onto the film at RH 20 These liquid water features were not observed at a similar relative humidity in the absence of the acids. These studies suggest that uptake of organic acids on AN dramatically increases the water uptake properties of the inorganic salt.

**P-2-46**

## SOLAR TERRESTRIAL INFLUENCES ON OZONE TRANSPORT PROCESSES

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**Abstract:** The concentration of ozone in the stratosphere varies accordingly with the 11-year solar cycle and induces changes in the net heating to the troposphere and stratosphere, and, thereby, affects the global circulation. However, the largest changes in the global circulation induced by solar variability have been observed in the Northern Hemisphere winter stratosphere, which does not experience any direct sunlight. We have used mechanistic two and three-dimensional models to demonstrate that planetary and gravity wave processes amplify the influence of solar forcing on the global transport processes, thereby significantly increasing the variability of ozone in the Northern Hemisphere stratospheric winter.

**P-2-47**

## TEMPERATURE VARIABILITY IN THE STRATOSPHERE AND LINKS WITH OZONE CHANGE

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**Abstract:** To investigate the role of ozone change on stratospheric temperature and dynamical fields, two ensemble of 5 model simulations have been considered (Unified Model, Metoffice and University of Reading). In the first one, AMIPII ozone climatology, representing conditions prior to ozone depletion (control run), was considered. In the second one, zonal and monthly mean ozone trends, calculated from Langematz (2000), have been considered as input of the simulations (ozone run). Stratospheric temperature trends for the period 1980-2000 have been determined using a multiple linear regression model (AMOUNTS) to separate the effect of the major sources of atmospheric temperature variability from a long-term linear trend. They have been compared with observed trends, obtained from satellite and radiosonde measurements (three different datasets). Results confirm the role of the ozone decreases in contributing to the temperature trends in the upper stratosphere and lower stratosphere. While a general good agreement between observations and ozone run is found in the middle and upper stratosphere, in the lower stratosphere trends are, however, still underestimated by the ozone run. The March cooling in the Arctic lower stratosphere is captured by the ozone run, but not entirely reproduced. Significant changes in the wave activity entering the lower stratosphere, estimated through the vertical component of the EP-flux, are obtained when considering the ozone run.

In the first part of our presentation, we will show temperature trends and discuss the stratospheric variability related to the Quasi-Biennial Oscillation (QBO), the El Nino Southern Oscillation (ENSO), the 11-yr Solar cycle and the Arctic Oscillation (AO). In the second part, we will compare model and observation results and then analyse the effect of the stratospheric ozone decrease on the thermal and dynamical structure of the stratosphere.

**P-2-48**

## EVALUATION OF THE STRATOSPHERE IN THE CHEMISTRY-CLIMATE MODEL LMDzT-INCA

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**Abstract:** The troposphere general circulation model with interactive photochemistry LMDzT-INCA has been extended to the stratosphere. A multiannual integration for present-day conditions has been performed. Firstly, we present an evaluation of both chemical and dynamical fields. In particular, we focus on the ability of the model to simulate the polar ozone depletion.

Secondly, in order to investigate the interactions between chemistry and climate in the middle atmosphere, this model integration will be compared to a simulation simply forced by an ozone climatology and to another one including a linearised ozone photochemistry.

**P-2-49**

ASSIMILATION OF OZONE PROFILES IN A GLOBAL TROPOSPHERIC AND STRATOSPHERIC CTM

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**Abstract**: Ozone is a key trace component of the atmosphere, notably due to its radiative impacts. It is monitored from space since a few decades but the number of remote-sensing instruments providing global coverage of ozone profiles and columns is increasing. In the perspective of chemical weather forecasting, as well as of using the information contained in ozone observations to improve meteorological numerical weather prediction, there is growing interest in the field of ozone data assimilation. We use here the MOCAGE comprehensive multiscale tropospheric and stratospheric Chemistry and Transport Model of Météo-France and the PALM data assimilation software of CERFACS to test and compare techniques of ozone profile assimilation. Precisely, two variationnal assimilation schemes are used to assimilate retrieved ozone profiles from SCIAMACHY and GOME nadir-viewing spectrometers: 3DFGAT and 4DVAR with a background correlation modelling using a generalized diffusion equation.

A particular attention will be paid to the choice of the linearised tangent model used for the backward integration needed to computation of the 4DVAR gradient. The role of backward dynamic and linear chemistry will be shown through the comparison of the two assimilation schemes. Examples showing the performance of this ozone analysis using GOME and/or SCIAMACHY and the impact on MOCAGE forecasts (global resolution is 2 degrees) will be then presented.

**P-2-50**

ASSIMILATION OF RADIO OCCULTATION MEASUREMENTS IN THE UT/LS

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**Abstract**: GPS based radio occultation measurements, such as those obtained by the GPS/MET, CHAMP and SAC-C satellite are well known to provide high vertical resolution temperature profiles in the stratosphere. Radio occultation data is also considered to be a potentially useful new data source for Numerical Weather Prediction. 1DVar information content studies suggest that the largest impact of the assimilation of this data type can be expected in the upper troposphere and lower stratosphere.

The Met Office has, therefore, developed the capability of assimilating these measurements. We performed forecast impact trial experiments with CHAMP measurements from May/June 2001 and September 2002 using the Met Office's new dynamics operational forecast model and 3D-Var assimilation system. With CHAMP providing 160 to 200 vertical refractivity profiles per day, this results in assimilating 40-50 measurements in each 6 hours assimilation cycle.

This presentation will outline the results from the impact trials in the upper troposphere and lower stratosphere. By comparing analyses with and without radio occultation data assimilated with other observations, we show that the analysis quality is indeed improved in the upper troposphere and lower stratosphere, with largest impacts in the lower stratosphere in the tropics and on the Southern Hemisphere.

**P-2-51**

## ON THE USE OF DATA ASSIMILATION TO HELP IDENTIFY MODEL ERRORS IN THE CANADIAN MIDDLE ATMOSPHERE MODEL

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**Abstract**: The Canadian Middle Atmosphere Model (CMAM), a three-dimensional climate GCM incorporating interactive chemistry, has been coupled with a 3DVAR data assimilation system developed at the Meteorological Service of Canada. Assimilation of only dynamical variables (temperature, winds and water vapour) leads to a much-improved prediction of global ozone patterns, but the magnitudes (both column profiles and total column) are incorrect. This can be corrected by initialising the run with a more realistic ozone field, however, even though the columns agree well with observations at the start of the run, there is an evident drift of ozone values in the model as the run progresses (particularly in the lower stratosphere).

To investigate the cause of this drift, the CMAM assimilation results are compared to the output from the MIMOSA model, a three-dimensional chemical transport model using a semi-Lagrangian transport scheme and potential temperature as the vertical co-ordinate. Three different MIMOSA runs are compared: a MIMOSA run initialised from REPROBUS and forced by ECMWF assimilated winds, a run initialised from REPROBUS forced by CMAM assimilated winds, and a run initialised with the same file as CMAM and forced by CMAM assimilated winds. For long-lived species (for example $CH_4$) differences between the results highlight transport differences, and once these are known, differences between short-lived species are considered to investigate chemical differences. The results can help us to identify sources of CMAM model error as being due to transport, chemistry or a combination of both.

**P-2-52**

## INVESTIGATIONS OF STRATOSPHERE MESOSPHERE COUPLING WITH WINDII AND OSIRIS DATA.

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**Abstract**: Mesospheric temperature variability at equatorial and tropical latitudes and planetary-scale perturbations are studied using daytime temperature data from the Wind Imaging Interferometer (WINDII) on the Upper Atmosphere Research Satellite (UARS). This study examines the latitudinal and longitudinal variability of the annual variation of mesospheric temperature from 70 to 90 km height. Tidal perturbations are also evaluated and accounted for in the determination of the global temperature variability in the vicinity of the mesopause. A seven-year climatology is presented revealing a signature of temperature decrease with amplitude of 25 K below the annual mean during the equinox periods.

Stratospheric and mesospheric temperatures can be derived from OSIRIS/ODIN Rayleigh-scattering observations. The OSIRIS instrument onboard the ODIN satellite is an optical spectrograph and infrared imager system, which makes daytime limb measurements of solar radiation scattered by the atmosphere, over a spectral range from 280 nm to 800 nm wavelength for tangent heights from 10 km to 100 km. These scattered radiation measurements are used in the retrieval of atmospheric temperature in the height range 30 to 90 km. Absolute temperature profiles are calculated using a technique derived from established Rayleigh lidar retrieval methods assuming that the atmosphere is in hydrostatic equilibrium. Comparisons with temperature climatologies derived from the SME and WINDII satellite experiments, as well as ground-based Rayleigh-scattering lidar observations are presented.

An extreme case of stratosphere mesosphere coupling is found from ground-based measurements at Resolute Bay (74°N), for a stratospheric warming event where the mesosphere changes are detectable two weeks in advance of the event. The mesospheric response at the time of final warming in the stratosphere is also demonstrated.

**P-2-53**

## THE EFFECTS OF INTERACTIVE CHEMISTRY IN SIMULATIONS OF THE MIDDLE ATMOSPHERE

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**Abstract:** We present numerical simulations with the WACCM model using interactive chemistry and heating calculations to 120 nm. A simulation with fully interactive chemistry is shown to have a realistic climatology both in the dynamical, thermodynamical structures and in the chemical composition. Two simulations are further investigated where the ozone field used in radiative calculation is replaced by a climatology: in one simulation, ozone from an observed data set is used, and in the final simulation a climatology of ozone from the interactive numerical calculation is used. Dynamical properties and transport characteristics are contrasted among these simulations.

**P-2-54**

## RADIATIVE-DYNAMICAL PROCESSES MODULATING THE VERTICAL STRUCTURE OF THE STRATOSPHERIC POLAR VORTEX

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**Abstract:** Several authors showed a quasi-periodic vacillation of the zonal wind in the Northern winter polar stratosphere. This vacillation is documented both in observations and in GCM simulations. Such a vacillation is reproduced by simplified mechanistic models involving a dynamical interaction between zonal mean zonal wind and planetary waves. On the other hand, experiences with 'Fixed Dynamical Heating' models show that ozone depletion may cause a heating in the polar upper stratosphere and a cooling in the lower stratosphere.

In the present work we explore the impact that ozone anomalies associated with the polar vortex strength may have in the vertical structure of the vortex. We performed correlation analysis on both intraseasonal and interannual timescales. Using monthly means, the correlation between ozone anomalies and vortex strength is negative with maximum absolute value for zero lag, and the shear of zonal wind in the upper stratosphere shows the highest correlation when the ozone anomalies lead by a month.

**P-2-55**

## PRELIMINARY INVESTIGATION OF CHEMISTRY-CLIMATE FEEDBACK ON STRATOSPHERIC CHEMICAL COMPOSITION

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**Abstract:** Multi-decadal simulation of stratospheric chemical using the GSFC chemical transport model (CTM) has quantitatively reproduced many features of ozone and other constituents in comparison to data from TOMS, SAGE and HALOE. This model simulation was driven by meteorological fields from a 50-year integration of the Finite Volume General Circulation Model (FVGCM). Motivated by the fact that the most important features of the observed stratospheric behaviour (*e.g.* seasonal cycles, horizontal gradients, ozone column amounts, winter polar ozone) are captured by the CTM, its photochemical scheme has been implemented online into the FVGCM. One objective of this is to isolate impacts in the coupling of predicted ozone with the atmospheric radiation field, and hence with the general circulation. In this study, we will present comparisons between the simulated and observed stratospheric ozone distributions while examining any differences between the online and offline implementations. Additionally, relevant analyses of meteorological diagnostics from the coupled model will be presented to isolate the feedbacks in the coupled chemistry-climate system.

**P-2-56**

## FUTURE TIME SLICE EXPERIMENTS WITH A NEW COUPLED CLIMATE-CHEMISTRY MODEL

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**Abstract:** Coupled climate-chemistry modelling studies have been performed as part of the Norwegian AerOzClim project. One of the main objectives of AerOzClim is to improve our understanding of chemistry-aerosol-climate interactions by further developing and applying global models in combination with analysis of observations for the processes involved. Detailed process studies have been performed with the Oslo CTM2 model, which includes two extensive schemes for the troposphere and the stratosphere ozone chemistry, respectively. These integrations have been used as benchmarks in the development of simplified parameterisations of tropospheric and stratospheric chemistry, which are being included in the NCAR CAM2 general circulation model. Previously, a tropospheric chemistry scheme was successfully implemented in the NCAR CCM3 model. The work presented here is an extension of that effort, including both tropospheric and stratospheric chemistry in the new NCAR CAM2 model. CAM2 features a higher resolution than CCM3, and the cold bias is reduced with respect to earlier versions. First results from the coupled climate-chemistry runs covering both the troposphere and the stratosphere are shown, focusing on future interactions involving the extent and timing of the ozone recovery expected for the 21$^{st}$ century.

**P-2-57**

## SENSITIVITY OF THE FVGCM TO CHANGES IN OZONE

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**Abstract:** We have carried out an experiment with the finite volume general circulation model (FVGCM). This experiment consisted of two different imposed changes in the climatological ozone fields assumed in the radiation code. The first was a simulation using an ozone distribution for conditions with no significant ozone hole. This distribution was obtained from a 50-year simulation of the full stratospheric ozone chemistry, with a time-dependent chlorine loading, done with our off-line chemical transport model (CTM). Three years (1978-1980) of this simulation were averaged to form a monthly, zonal-mean ozone distribution that was used in the 20-year integration of the FVGCM for unperturbed conditions. The second 20-year GCM integration included a fully-developed ozone hole. This ozone distribution was from three years, 1998-2000, from the same CTM simulation. The goal of this work is to determine the coupled response of the chemistry and dynamics of the stratosphere. These experiments are the first step in understanding the coupled response. An important initial question concerns the significance of the signals: if 20-year integrations turn out to be too short, the runs will be extended.

**P-2-58**

## STRATOSPHERE-TROPOSPHERE INTERACTIONS IN THE NEW GISS MODEL E GCM

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**Abstract:** We present results from the newly completed Goddard Institute for Space Studies (GISS) model E GCM. This state-of-the-art model incorporates a well-resolved stratosphere and our best representations of physical and chemical processes within a single unified framework. As the primary climate model of the institute, simulations have and are being performed of the climate response to various forcings using several representations of the oceans (*e.g.* prescribed SSTs, mixed-layer oceans, and fully coupled oceans). A fully interactive model of chemistry in both the stratosphere and troposphere has also been incorporated into the model. In a comparison with global datasets, the climate model substantially outperforms all earlier GISS models. We will discuss the response of the coupled stratosphere-troposphere system to forcings, such as increasing greenhouse gases, volcanic eruptions, solar variability and ozone depletion. The influence of coupled chemistry and coupled oceans will also be presented. Results from an ensemble of volcanic simulations already completed show an enhanced Arctic Oscillation/NAO during the two winters following large tropical eruptions. The response agrees qualitatively with the older generation GISS GCM, but matches the spatial pattern derived from meteorological and proxy-data much better at regional scales. Stratosphere-troposphere exchange of ozone is significantly enhanced in response to increasing greenhouse gases in the coupled chemistry runs.

**P-2-59**

## CAN ASSIMILATION OF SATELLITE OZONE DATA CONTRIBUTE TO THE UNDERSTANDING OF THE LOWER STRATOSPHERIC OZONE?

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**Abstract:** We study the quality of lower stratospheric ozone fields from a three-dimensional global ozone assimilation system. Ozone in this region is important for the forcing of climate, but its global distribution is not fully known because of its large temporal and vertical variability. Modelled fields often have biases due to the inaccurate representation of transport processes in this region with strong gradients. Accurate ozonesonde or satellite occultation measurements have very limited coverage. Nadir measurements, such as those from the Solar Backscatter Ultraviolet/2 (SBUV/2) instrument that provide wide latitudinal coverage, lack the vertical resolution needed to represent sharp vertical features. Limb measurements, such as those from the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS), provide a finer vertical resolution. We show that assimilation of MIPAS data in addition to SBUV/2 data leads to better estimates of ozone in comparison with independent high quality satellite, aircraft, and ozone sonde measurements. Other modifications to the statistical analysis that have an impact on the lower stratospheric ozone will be mentioned: error covariance modelling and data selection. Direct and indirect impacts of transport and chemistry models will be discussed. Implications for multi-year analyses and short-term prediction will be addressed.

**P-2-60**

## STRATOSPHERIC FORECASTING WITH THE NOGAPS (NAVY OPERATIONAL GLOBAL ATMOSPHERIC PREDICTION SYSTEM) GCM

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**Abstract**: The Navy Operational Global Atmospheric Prediction System (NOGAPS) GCM has been extended to include the middle atmosphere. The extended system includes ozone transport with parameterised ozone chemistry. Forecasts out to 10 days are compared with independent stratospheric analyses and soundings. Experiments initialised before known stratospheric warmings show the ability of the extended NOGAPS GCM to capture warming events. Experiments run with different horizontal resolutions show the ability of the higher resolution runs to capture tracer filaments produced during warming events.

**P-2-61**

## POLAR PROCESSES IN A 50-YEAR SIMULATION OF STRATOSPHERIC CHEMISTRY AND TRANSPORT

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**Abstract:** The unique chemical, dynamical, and microphysical processes that occur in the winter polar lower stratosphere are expected to interact strongly with changing climate and trace gas abundances. Significant changes in ozone have been observed and prediction of future ozone and climate interaction depends on modelling these processes successfully. We have conducted an off-line model simulation of the stratosphere for trace gas conditions representative of 1975-2025 using meteorology from the NASA finite-volume general circulation model. The objective of this simulation is to examine the sensitivity of stratospheric ozone and chemical change to varying meteorology and trace gas inputs. This presentation will examine the dependence of ozone and related processes in polar regions on the climatological and trace gas changes in the model. The model past performance is base-lined against available observations, and a future ozone recovery scenario is forecast. Overall the model ozone simulation is quite realistic, but initial analysis of the detailed evolution of some observable processes suggests systematic shortcomings in our description of the polar chemical rates and/or mechanisms. Model sensitivities, strengths, and weaknesses will be discussed with implications for uncertainty and confidence in coupled climate chemistry predictions.

**P-2-62**

## THE TOTAL OZONE RECORD AS A CLIMATE DIAGNOSTIC

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**Abstract:** Analysis of the ozone field in the Northern Hemisphere, using both TOMS and Dobson data, has shown that the total ozone field can be separated into three distinct regimes, delineated by the upper tropospheric subtropical and polar fronts and the polar vortex.

The change in ozone within each regime for the period January 1979-May 1991, a period of rapid total ozone change, was studied.

Previous studies had observed an overall linear trend of -3.15 per cent per decade for the latitude band 25-60 °N. When the ozone field is separated by regime, much smaller linear trends (-2.1, -1.7, and -1.7 % per decade for the polar, midlatitude, and tropical regimes, respectively) are observed. The trend in the overall total ozone is larger because the relative areas of the regimes also changed over the same time period. The relative area of the polar regime dropped by about 20 % the tropical regime increased by about 20 %. The change in the relative areas is attributed to a northerly movement of the mean latitude of the subtropical and polar fronts, 2.6 plus or minus 0.3 and 4.8 plus or minus 0.6 degrees, respectively. A movement of the subtropical and polar fronts implies a change in the weather patterns associated with these fronts, *i.e.* a climate change. In essence, the total ozone record can be used as a climate diagnostic.

Methods have been devised to obtain the relative movement of the subtropical and polar fronts from both the TOMS and Dobson data sets over the entire period 1964 to 2004. The analysis of the movement of the polar and subtropical fronts will be presented and compared with climate indices.

**P-2-63**

## THE ROLE OF THE QBO IN THE CLIMATE AND CHEMISTRY OF THE STRATOSPHERE IN A TRANSIENT CHEMISTRY-CLIMATE SIMULATION FOR THE PERIOD 1960 TO 2000

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**Abstract:** From statistical analysis is it known that the distributions of ozone, water vapour, methane and other constituents in the stratosphere correlates with the QBO, *e.g.* as given by the zonal wind at Singapore at 20 hPa. The QBO contributes to the variance and, if non-linearities are important, also to the temporal mean of *e.g.* water vapour or methane in the stratosphere. However, chemistry-climate simulations often do not include the QBO, but show instead weak easterlies without significant vertical shears in the QBO domain, with consequences for the transport of chemicals by the residual circulation. This work investigates the role of the QBO for the climatology of tracer distributions, temperature and the residual circulation in the stratosphere in chemistry-climate simulations based on a transient simulation for the years 1960 to 2000, which, by assimilation, includes the observed QBO. This experiment shows for example a decreased bias in lower stratosphere methane compared to similar time slice experiments without a QBO.

**P-2-64**

# THE MID-LATITUDE SUMMERTIME STRATOSPHERE: A COMPARISON BETWEEN MANTRA BALLOON CAMPAIGN MEASUREMENTS AND THE CANADIAN MIDDLE ATMOSPHERE MODEL

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**Abstract:** The MANTRA (Middle Atmosphere Nitrogen TRend Assessment) series of high-altitude balloon flights is being undertaken to investigate the changing chemical balance in the mid-latitude stratosphere, with a focus on nitrogen compounds. Three balloons have been launched to date from Vanscoy, Saskatchewan (52°N, 107°W), each carrying a suite of instruments to measure vertical profiles of stratospheric trace gases from a float altitude of about 35 km for one day. These flights have occurred in late August or early September of 1998, 2000 and 2002, when dynamical variability is minimized. A fourth flight is planned for August 2004.

In this presentation, MANTRA measurements are compared with the Canadian Middle Atmosphere Model (CMAM), a fully interactive chemistry-climate model. The objectives of this comparison are to help validate CMAM under conditions where the stratosphere is largely under photochemical and radiative control, and to use the model to complement the measurements to study the nitrogen partitioning at mid-latitudes during summertime. In particular, CMAM can help assess the representativeness of the measurements and the possible impact of dynamical variability. There are some discrepancies for the shorter-lived species. For example, our results suggest that CMAM forecasts larger $NO_2$ concentrations for sunset while reproducing the $NO_2$ measurements made during sunrise. However, overall we show that CMAM reproduces the MANTRA scenario well, with the model output for temperature, ozone, and the long-lived species in very good agreement with the measurements.

**P-2-65**

# MAINTENANCE OF POLAR STRATOSPHERIC CLOUDS IN A MOISTER STRATOSPHERE: WHAT ARE THE LIMITS?

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**Abstract:** Recent work by the author and others has shown the potential for a moister stratosphere, and increased polar stratospheric clouds, to help account for the extreme polar warmth of the Eocene period. However, in those studies, a moister stratosphere was assumed to be associated with a slower stratospheric overturning circulation. This reduced overturning would reduce the flux of water vapour to the polar regions in winter. Since PSCs represent a sink of stratospheric water due to sedimentation, this reduced flux might make sustained polar stratopsheric cloud cover implausible.

To investigate this difficulty, we model the fall-out rate of water ice from PSCs in a simplified model that includes treatment of cloud radiative effects and particle growth sensitivity to relative humidity and temperature. We show that water vapour mixing ratio has a strong impact on stratospheric temperatures via cloud formation, and that cloud-radiation interactions increase markedly at higher-than-present stratospheric moisture.

**P-2-66**

# A MULTIPLE LINEAR REGRESSION ANALYSIS OF THE 65-YEAR TROMSÖ TOTAL OZONE SERIES

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**Abstract:** The Tromsö total ozone series is the second-longest in the world and was started in autumn 1935. After 4 years of operation with a Fery spectrograph, a Dobson spectro-photometer was put into operation, and continued until 1972. Only in 1984, measurements were resumed and continued until 1999. After a 5-year overlap (since 1994) a Brewer instrument took over ozone monitoring at the near-by site of And ya. This unique, though fractionised, data series has recently been re-evaluated, and as far as possible been homogenised. The resulting monthly mean ozone series was analysed by means of multiple linear regression analysis tools, similarly to the Arosa total ozone series and the Hohenpeissenberg total ozone series. As regression parameters we included a quasi-linear trend/EESC, stratospheric aerosol load, QBO, solar activity, 30-mbar level temperature, and all significant tele-connection patterns in the respective months as given at the NOAA-CPC web site.

The most pronounced feature in most of the months analysed (February October) is the quasi-linear trend starting in 1979. Quasi-linear means that in years with an early stratospheric warming and no re-establishment of the polar vortex, *e.g.*, 1998 and 1999, the linear trend was set to zero. As to be expected, the (always negative) trend decreases throughout the spring months. Less expected is the presence of the trend also in July and August, but not in June. The quasi-linear term is most frequently accompanied by a contribution of stratospheric aerosols, which also is negative. The second-most pronounced parameter is the 30-mbar level temperature, especially in autumn, but also in spring, but not in summer. The quasi-biennal oscillation plays a significant roll in the summer months. The tele-connection patterns show a large variability from month to month, both in number of significant patterns and most prominent pattern. In contrast to mid-latitude stations, the NAO is not especially prominent, except in the months of March and May. In the spring and autumn months, the East Atlantic patterns (EA-JET, EA, EAWR) are prominent, while in summer remote patterns like the Pacific Transition, the North Pacific and even the Asian Summer Patterns are of importance. In contrast to mid-latitude stations, the tele-connection patterns do not contribute significantly to trends in the Tromsö series. The solar activity component is of minor importance.

**P-2-67**

# RESOLVING UNCERTAINTIES IN THE RADIATIVE FORCING OF HFC-134a

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**Abstract:** HFC-134a is the most rapidly growing hydroflurocarbon in terms of atmospheric abundance. It is currently used in a large number of household refrigerators and air-conditioning systems and its concentration in the atmosphere is forecast to increase substantially over the next 50-100 years. Previous estimates of its radiative forcing per unit concentration have differed by over 20. This work, initiated by SPARC, uses a two-step approach to resolve this discrepancy. In the first step six 20 different absorption cross section datasets are analysed to produce a best estimate absorption cross section. In the second step this absorption cross section was used in 6 different radiative transfer models to calculate the HFC-134a radiative forcing efficiency. Using this approach we are able to reduce and understand the uncertainties involved in this important calculation.

**P-2-68**

EVIDENCE THAT NITRIC ACID INCREASES RELATIVE HUMIDITY IN LOW-TEMPERATURE CIRRUS CLOUDS

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**Abstract:** *In situ* measurements of the relative humidity with respect to ice (RHi) and nitric acid ($HNO_3$) were made in both natural and contrail cirrus clouds in the upper troposphere. At temperatures lower than 202K, RHi values show a sharp increase to average values over 130% in both cloud types. These enhanced Rhi values are attributed to the presence of a new class of $HNO_3$-containing ice particles (Delta-ice). We propose that surface $HNO_3$ molecules prevent the ice-vapour system from reaching equilibrium by a mechanism similar to that of freezing point depression by antifreeze proteins. Delta-ice represents a new link between global climate and natural and anthropogenic nitrogen oxide emissions. Including Delta-ice in climate models will alter simulated cirrus properties and the distribution of upper tropospheric water vapour.

**P-2-69**

OBSERVATIONS OF GAS- AND CONDENSED-PHASE $HNO_3$ IN THE TROPICAL UPPER TROPOSPHERE AND LOWER STRATOSPHERE

**P. Popp**

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**Abstract**: Nitric acid ($HNO_3$) serves as the primary reservoir species for nitrogen oxides, which are directly involved in the photochemical production of tropospheric ozone. Gas- and condensed-phase $HNO_3$ were observed for the first time in the tropical upper troposphere and lower stratosphere onboard the NASA WB-57F high-altitude research aircraft during the NASA Pre-Aura Validation Experiment. Vertical profiles of $HNO_3$ in the UT/LS show a minimum of 50-100 pptv near the tropical tropopause. Condensed-phase $HNO_3$ was also observed above and below the frost point in the tropopause region. The implication of these results will be discussed.

**P-2-70**

TOWARD THE MORE REALISTIC SIMULATION OF THE ANTARCTIC OZONE HOLE BY USING A CHEMISTRY-CLIMATE MODEL

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**Abstract**: Antarctic ozone hole is one of the most prominent phenomena in the middle atmospheric chemistry, and it should be properly represented in every Chemistry-Climate Model (CCM). The Antarctic ozone hole simulated in several CCM, however have some problems. As to our CCM, the delay (about one month) of the seasonal march of the simulated Antarctic ozone hole in comparison with the observation is the largest problem. One of the supposed causes of the delayed ozone hole is a too stable polar vortex in connection with the polar cold bias problem in the Southern Hemisphere in our CCM. Too stable polar vortex prolongs the duration of chemical ozone destruction in the lower stratosphere over the Antarctica in the springtime. It also causes an insufficient downward transport of the $Cl_y$ species down to the lower stratosphere in the polar vortex, which weaken the ozone destruction by $ClO_x$ species. Neglect of the solar incidence from large Solar Zenith Angle (SZA) can bring weak ozone destruction at the beginning of the Antarctic ozone hole (August and September). These things can make the Antarctic ozone hole simulated in our CCM to be reasonable in size but delayed in time compared with the observation.

In order to eliminate these problems from our CCM, a non-ornographic Gravity Wave Drag (GWD) parameterisation was introduced and the effects of solar incidence from the SZA larger than 90 degrees were considered. The latter can advance the beginning of the ozone destruction in the Antarctic region. The influence of GWD parameterisation on the ozone hole is highly dependent on the employed parameter setting, and we are now making a trial to get the optimum parametersetting through the analysis of the GWD represented in a very high-resolution AGCM.

**P-2-71**

## HEATING OF THE MIDDLE ATMOSPHERE BY THE SOLAR WIND INDUCED ELECTRIC CURRENTS

**L. Makarova**

Arctic and Antarctic Research Institute, St Petersburg, Russia

**Abstract:** It was turned out that the Earth's atmosphere and climate are connected with energy of the solar wind. A new mechanism of connection of the solar wind with the near-Earth space is proposed for explanation of high correlation between the atmospheric and solar wind parameters. In accordance with this mechanism, energy of the solar wind passes, in the Earth Space as energy of electric field generated during contact of the solar wind with Earth s magnetosphere. Effects of this process can be see also in middle stratosphere (altitudes 20-30 km) where a permanent layer of heavy ion-clusters is produced by the galactic cosmic rays and by some other sporadically occurring sources. Quantitative evaluations showed that the temperature of stratosphere could change due to effects produced by this mechanism. Including this mechanism in a global circulation model of the atmosphere demonstrated that temperature regime of stratosphere can change on several degrees in some regions. Dynamics of atmosphere and concentration of ozone change essentially too. Suggestion is made that the energy of the solar wind could be one of the reasons, which change climate of the Earth. Satellite measurements revealed high values of the energy of the solar wind during 30 years of the last millennium. Warming climate observed in this time could be connected with influence of the Sun particle emission.

**P-2-72**

## POSSIBLE MECHANISMS OF THE SOLAR WIND ENERGY INFLUENCE ON THE OZONE LAYER DYNAMICS

**A. Shirochkov** and L. Makarova

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**Abstract:** The experimental data show that the total ozone content (TOC) decreases during disturbances of the solar wind, which are the fluxes of the charged particles of solar origin with frozen in interplanetary magnetic field (IMF). The drop in the TOC values is closely connected with increase of atmospheric electric field magnitude. It seems that these relations could be explained in framework of the global electric circuit model. Electric currents of this global electric circuit change temperature and the dynamics of the atmosphere. Re-arranging of the atmosphere dynamics can lead to the TOC variations. The calculations made by the authors show reality of this mechanism. However, it is possible to mention another mechanism of connection between the total ozone content and disturbances of the solar wind. Atmospheric electric field, which is induced by the solar wind variations, influences the rates of chemical reactions via enhanced ion-neutral collision frequency. This process could lead to formation of the additional odd nitrogen molecules. Total ozone content will decrease due to this process also. Authenticity of these two mechanisms is discussed.

**P-2-73**

## EFFECT OF HAZE ON THE SURFACE LEVEL SOLAR UV-B RADIATION AND TEMPERATURE

**A. Pandy**

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**Abstract:** Parts of South-East Asia experience haze almost every year due to man-made forest fires in Sumatra and Kalimantan (Indonesia). In this work, the severe haze episodes of 1994 and 1997 have been used as a case study to investigate the effect of haze on the surface level air temperature and solar UV-B radiation. *In situ* measurements at Penang (5.34°N, 100.30°E) of air temperature, surface level ozone concentration and broadband solar UV-B radiation together with related meteorological parameters are used to study the haze effect.

During very hazy episodes, the solar UV-B radiation was found to be as low as 2 percent of clear sky day values. Mean daily total radiation and noon time half-hourly flux ratios of UV-B to global radiation shows marked decreases (6.7 percent and 3.6 percent in 1994, and 40.3 percent and 39.6 percent in 1997). Enhanced levels of hourly surface level ozone concentration were recorded during hazy conditions. We associate the enhanced UV-B absorption to increased level of surface ozone and also scattering and absorption by aerosol particles. The slight increase in the surface air temperature can be attributed to higher concentrations of greenhouse gases.

# POSTER PRESENTATIONS

## TUESDAY AUGUST 3, 2004

**P-3-01**

## CASE STUDY OF TROPOSPHERE - STRATOSPHERE TRANSPORT ASSOCIATED WITH A SUMMER EXTRATROPICAL LOW: MOZAIC AIRCRAFT MEASUREMENTS ANALYSIS AND MODELLING.

**J. Brioude**[1], J.-P. Cammas[1], P Mascart[1], J. Duron[1], H. Wernli[2], and P. Nedelec[1]

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**Abstract:** Analysis of ozone, water vapour and carbon monoxide measurements from MOZAIC aircraft (**http://www.aero.obs-mip.fr/mozaic/**) show troposphere to stratosphere case studies associated with dynamics of extratropical lows. Results of a case study during July 2002 over the western North-Atlantic are presented. The case study involves the mixing between two airstreams, the dry and stratospheric-origin air stream and the maritime boundary layer-origin air in the warm conveyor belt, followed by irreversible upward transport into the lower stratosphere in the outflow region of the low. Backward trajectories and Reverse Domain Filling techniques are used to infer, with transport as resolved by ECMWF analyses, the origins of particules along the aircraft path. Contributions from advection, convection, turbulence and mixing processes involved in the irreversible intrusion into the stratosphere are further analysed with mesoscale modelling.

**P-3-02**

## CHARACTERISING UT/LS AEROSOLS OVER THE WIDER CARIBBEAN UNDER VOLCANIC BACKGROUND CONDITIONS

**J.-C. Antuna**, B. Barja , and R. Esteban

Camaguey Lidar Station, Camaguey Meteorological Center, Camaguey, Cuba

**Abstract:** Using SAGE II (Stratospheric Aerosol Gas Experiment II) instrument measurements the mean features of the UT/LS aerosols over the wider Caribbean have been studied. The study has been conducted for the unperturbed conditions in the stratosphere before and after Mt. Pinatubo eruption in 1991. Two stratospheric aerosols background periods of the cloud-free SAGE II extinction profiles, at 1.02 m and 0.525 m, were then selected: December 1987 to April 1991 and December 1996 to April 2000. Mean seasonal profiles of the aerosol extinction have been obtained. For all season mean aerosol extinction values at 0.525 m are two times the ones at 1.02 m. During winter and spring two maxima are present at both wavelengths. They belong to the UT/LS aerosols, below and above the tropopause respectively. For the summer and fall only one maximum is present around the tropopause. AOD in the column between 5km and 40 km is one order of magnitude higher at 0.525 m than at 1.02 m, showing a maximum value in spring at both wavelengths. AOD in the whole layer, at each of the wavelengths, have almost the same values the rest of the seasons. AOD in the layer 15.5 to 30 km, covering the LS, show almost no seasonal variation, while in the layer 5 to 15 km AOD values have a maximum in spring, associated with the intense and deep convection, which dominates in the region during that season. Results are in agreement with the well known existence of more stratospheric aerosols with diameters around 0.525 m than at 1.02 m under background conditions and at the same time reveals the same feature for UT aerosols. Also have been determined that under such conditions the main contributors to the AOD seasonal variations are the UT aerosols.

**P-3-03**

ANTARCTIC OZONE TRANSPORT AND DEPLETION IN AUSTRAL SPRING 2002

**P. Siegmund**, H. Eskes, and P. van Velthoven

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**Abstract:** The ozone budget in the Antarctic region during the stratospheric warming in 2002 is studied, using ozone analyses from the KNMI-TM3DAM ozone assimilation model. The results show during this event a strong poleward ozone mass flux south of 45°S between about 20 and 40 hPa, about five times as large as the ozone flux in 2001 and 2000, that is dominated by eddy transport. Above 10 hPa there exists a partially compensating equatorward ozone flux, which is dominated by the mean meridional circulation. During this event, not only the ozone column but also the ozone depletion rate in the Antarctic region, computed as a residual from the total ozone tendency in and the ozone mass flux into this region, is large. The September-October integrated ozone depletion in 2002 is similar to that in 2000, and larger than in 2001. Simulations for September 2002 with and without ozone assimilation and parameterised ozone chemistry indicate, that the parameterised ozone chemistry alone is well able to produce the evolution of the ozone layer in the Antarctic region in agreement with observations.

**P-3-04**

DIAGNOSTIC STUDY ON THE RELATION BETWEEN OZONE
AND POTENTIAL VORTICITY

**A. Gahein**

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**Abstract:** A diagnostic analysis of a Mediterranean system and the associated tropopause folding for the period 27 February to 10 March, 1987 is presented. Geopotential height, Potential Vorticity (PV) and relative humidity distributions were diagnosed. The analysis indicates clear correlation between the development of the cut-off low and the tropopause folding. A series of vertical cross-sections at the ends of the jet streaks demonstrated that a fold could be captured using potential vorticity and relative humidity. Q-vectors were employed to investigate vertical motion in the vicinity of the fold and showed the exact positions of descent corresponding to the fold along the entire length of the jet streak. The analysis also shows that the strong correlation between total ozone and column integrated potential vorticity holds well for all levels. As both quantities are integrals through the atmosphere this results is consistent with, but does not prove, a high independent linear dependence between ozone and PV. More case studies are needed to assure the high linear dependence between ozone and potential vorticity PV. The maximum transport of ozone from the stratosphere to the troposphere is coinciding with the maximum developing system, and also with the maximum values of PV.

**P-3-05**

A NEW PSC ALGORITHM FOR GLOBAL CHEMISTRY CLIMATE MODELS:
$NO_Y$ REDISTRIBUTION IN THE ARCTIC WINTER

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**Abstract:** One of the major uncertainties for future stratospheric ozone changes is the sensitivity of polar ozone to decreasing temperatures. The representation of Polar Stratospheric Clouds (PSCs) is the key issue in this respect, but is crudely described in current Chemistry Climate Models (CCMs). Most CCMs currently treat NAT particles using a bulk approach, and by assuming that equilibrium exists between the solid and gaseous forms of $HNO_3$. However, recent *in situ* observations have demonstrated that such treatment is no longer valid due to the detection of large NAT particles throughout the polar vortex (with diameters commonly 15 micrometer). Therefore, growth and evaporation of the NAT particles should be calculated explicitly and particles should be treated as transported tracer species. We have developed an algorithm that includes the recently developed parameterisation of Carslaw *et al.* (2002) to account for particle growth, evaporation and sedimentation and which transports the particles in distinct size bins. This algorithm has been incorporated and subsequently evaluated in the 3D Chemistry-Transport-Model, TM5. Here we present our first results and discuss the implications for modelling $NO_y$ redistribution. Moreover, we will demonstrate that results obtained using the new algorithm agree with observations to a greater degree than those obtained with a simple 'equilibrium' approach.

**P-3-06**

## MODEL ANALYSIS OF MASS AND OZONE CROSS-TROPOPAUSE TRANSPORT

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**Abstract:** Net mass flux from the stratosphere to the troposphere can be computed from the heating rate along the 380K isentropic surface and the time rate of change of the mass of the lowermost stratosphere (region between the tropopause and 380 K isentrope). Given this net mass flux and the cross tropopause diabatic mass flux, the residual adiabatic mass flux across the tropopause can also be estimated. These fluxes have been computed using meteorological fields from a free-running general circulation model (FVGCM) and two assimilation data sets, FVDAS, and UKMO. The data sets tend to agree that the annual average net mass flux for the Northern Hemisphere is about $10^{10}$ kg/s. There is less agreement on the Southern Hemisphere flux that might be half as large. For all three data sets, the adiabatic mass flux is computed to be from the upper troposphere into the lowermost stratosphere. This adiabatic flux into the lowermost stratosphere is up to five times larger than the diabatic mass flux into the stratosphere across the tropical tropopause. The analysis method is extended to estimate the ozone flux across the midlatitude tropopause by convolving the FVDAS computed diabatic mass fluxes with ozone mixing ratios from the Goddard 3D CTM. The ozone fields have been separated into tropospheric and stratospheric components based upon where the ozone is produced. A relatively large adiabatic flux of tropospheric ozone from the tropical troposphere into the extratropical lowermost stratosphere dilutes the air of stratospheric origin. Thus, a significant fraction of any measured cross tropopause flux of ozone may not be ozone produced in the stratosphere. The results also show a phase difference in the annual cycles of ozone and mass flux. The concentration of ozone available for transport is just as important as the dynamics in governing the magnitude and seasonality of the ozone flux cycle. This implies that a simplified calculation of ozone STE mass from air mass and a mean ozone mixing ratio may introduce a large uncertainty.

**P-3-07**

## $NO_2$ PROFILE RETRIEVAL USING AIRBORNE MULTIAXIS DIFFERENTIAL OPTICAL ABSORPTION SPECTROMETER (AMAX-DOAS) DATA

**M. Bruns**[1], S. A. Buehler[1], J. P. Burrows[1], K.-P. Heue[2], U. Platt[2], A. Richter[1], A. Rozanov[1], T. Wagner[2], and P. Wang[1]

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**Abstract**: A recent development in ground-based remote sensing of atmospheric constituents by UV/visible absorption measurements of scattered light is the simultaneous use of several horizon-viewing directions in addition to the traditional zenith-sky pointing. The different light paths through the atmosphere enable the vertical distribution of some atmospheric absorbers, such as $NO_2$, BrO or $O_3$ to be retrieved. This approach has recently been implemented on an airborne platform. The novel instrument called Airborne MultiAXis Differential Optical Absorption Spectrometer, AMAX-DOAS, has been flown for the first time.

In this study retrieved $NO_2$ profiles from 2 airborne campaigns in 2002 and 2003 will be presented. Further Sensitivity studies of synthetic data will be presented. These studies were performed for a variety of representative measurement conditions including two wavelengths, one in the UV and one in the visible, two different surface spectral reflectances, and various lines of sight (LOS).

**P-3-08**

## CLASSIFICATION OF HALOE DATA BY METEOROLOGICAL REGIME

**M. Follette**, R. Hudson, and M. Andrade

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**Abstract:** It has been shown that the Northern Hemisphere total ozone field can be separated into three distinct meteorological regimes. These regimes are defined as (1) the tropical regime between the equator and the subtropical front, (2) the midlatitude regime between the subtropical and polar fronts, and (3) the polar regime between the polar front and the polar vortex. Within each regime, the monthly mean total ozone is relatively constant. Rawinsondes, ozonesondes, and data from the Stratospheric Aerosol and Gas Experiment (SAGE) show that each regime is also characterised by a distinctive tropopause height. In addition, the atmospheric noise is clearly reduced within each regime, as compared to the noise observed when the data is classified by latitude alone. Preliminary analyses, using data from the Halogen Occultation Experiment (HALOE), will be shown. All seven chemical species from HALOE are classified by regime, using total ozone data from EP-TOMS, and by latitude.

**P-3-09**

## VARIATIONS OF THE TROPOPAUSE AND THEIR INFLUENCE ON OZONE IN THE UT/LS OVER BEIJING DISTRICT

**G. Wang**, Q. Kong, H. Chen, and Z. Gu

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**Abstract:** In recent years, more and more attention has been paid to the tropopause layer in view of the Troposphere-Stratosphere Exchange (TSE). That is because the tropopause looks like a transition region where some special processes on transport, chemistry and radiation take place. Thus, the tropopause region is particularly crucial for better understanding the TSE. Till now, the most studies were spent to the tropical tropopause rather than the extratropical one due to its key role in air mass transported into the stratosphere. Actually, there are even more open problems remaining to be studied for the extratropical tropopause due to a rather complicated coupling pattern in the region.

Among the most trace species, the ozone is likely a convenient one to be used for differentiating stratospheric air from tropospheric air. So variation of ozone abundances in the tropopause region may be used as a criterion for better understanding TSE characteristics and, in turn, the role of the tropopause in climate-chemistry interactions. To understand how well does the variation in tropopause height correlate with ozone content over the Northern mid-latitudes area, variations of the tropopause height and ozone variations in UT/LS over Beijing district are analysed and discussed in this paper based on ozonesonde data. Analysis of the two-year ozonesonde data (170 vertical profiles) shows that annual average tropopause and ozonepause height is about 11.1 km and 10.2 km respectively, showing that the ozonepause is always located below the tropopause height over Beijing area. A similar seasonal variation behaviour for both tropopause and ozonepause was found that is higher in the summer, lower in the winter. Amplitude of seasonal variation for both tropopause and ozonepause height is about 1.5 km.

One point should be noted in view of dynamics and ozone transport in the tropopause region, that is, seasonal variations in tropopause and ozonepause height are notably not parallel. The larger vertical distance between them appears in spring, while in winter and summer the tropopause and ozonepause heights are getting closer. Two-year ozonesonde data verify once again the negative correlation between the tropopause height and total ozone amount in the mid-latitudes area, especially in the summer and winter. Moreover, analysis of integrated ozone concentration in each individual atmosphere layer shows a largest seasonal variability of about 90% ozone content in the layer of 10.5-18.5 km, while in layers of 1.5-10.5 km and 18.5-27.0 km the corresponding ozone variability is about 32 and 22 respectively. In addition, seasonal variation in ozone content in the lowermost stratosphere appears in negative correlation with the tropopause height, while in the upper troposphere the correlation between the tropopause height and ozone content exhibits remarkably positive.

**P-3-10**

# CHEMISTRY AND TRANSPORT IN THE LOWER STRATOSPHERE

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**Abstract:** Over the past few years, several campaigns have taken place to study the transport and chemistry in the polar Lower Stratosphere (and Upper Troposphere) (UT/LS). Stratospheric observations show that significant springtime ozone loss has occurred in both the Antarctic and Arctic polar vortices and it is likely that this loss contributes to the observed mid-latitude trends. Here we use the 3-D chemical transport model (CTM) SLIMCAT to study chemical and dynamical mechanisms controlling the ozone distribution in the UT/LS for different regions during 1999-2004.

SLIMCAT is an 'off-line' 3-D model in which meterological fields (winds, temperature and humidity) are specified from analyses (UKMO or ECMWF). The model is formulated in a hybrid sigma-isentropic vertical coordinate and by default vertical motion is calculated from heating rates using the MIDRAD radiation scheme. Chemical tracers are advected by conservation of second-order moments. The model has a detailed gas-phase stratospheric chemistry scheme, as well as a treatment of heterogeneous chemistry on liquid and solid aerosols.

Using the multiannual simulation of SLIMCAT, we also compare the model results with a set of observations in the lower stratosphere for different campaigns (*e.g.* APE-GAIA in Antarctic 1999 and VINTERSOL in Arctic 2002/3) to investigate how well the model reproduces the observations in the polar regions. We will also show that SLIMCAT performs well in simulating the unusual 2002 Antarctic Ozone Hole during the sudden warming event and compare it with similar calculations for other years (1999, 2000 and 2003). We will also compare the chemistry/transport processes in 2002/03 Arctic winter with 1999/2000 and 2003/04 winter under different conditions.

**P-3-11**

# HIGH-RESOLUTION LIMB-OBSERVATIONS OF TRACE CONSTITUENTS AND CLOUDS IN THE UT/LS REGION

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**Abstract:** Despite the great importance of water vapour, other trace constituents, and clouds in the UT/LS region for the climate system, the distribution of these quantities is far from being well understood. This is a result of the existing lack of global observations with sufficiently high vertical and horizontal resolution. The CRyogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA) instrument made a number of snapshots of the UT/LS during its two Space Shuttle missions (STS 66 and STS 85) and demonstrated the potential of the IR limb viewing technique to provide information on several trace constituents and subvisible cirrus clouds (SVC) with comparably high spatial resolution.

The presentation gives an overview of CRISTA observations in the UT/LS, with emphasis on a comparison of observed water vapour values with corresponding ECMWF data in the extratropical UT/LS. In addition, two follow-on instruments with enhanced UT/LS measurement capabilities are briefly introduced: (1) CRISTA-NF, which is currently integrated for operation on the Russian high-flying M55-Geophysica research aircraft during the European SCOUT-tropics field campaign; (2) The GlObal limb Radiance Imager for the Atmosphere (GLORIA) instrument, proposed by FZ Jülich and FZ Karlsruhe in response to DLR’s call for a new German Earth observation mission.

**P-3-12**

ISENTROPIC OZONE TRANSPORT ACROSS THE TROPOPAUSE

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**Abstract:** Estimates of the isentropic cross-tropopause ozone transport based on the potential vorticity mapping of Stratospheric Aerosol and Gas Experiment II ozone measurements and contour advection calculations using the NASA Goddard Space Flight Center Global and Modeling Assimilation Office analysis for 1990 and 1999 have been made. The annual isentropic stratosphere-to-troposphere ozone flux is calculated to be approximately twice the flux that is directed from the troposphere to the stratosphere. The net effect is that approximately 92x109 kg/yr and 118x109 kg/yr of ozone are transferred globally via isentropic transport from the extratropical lower stratosphere into the subtropical upper troposphere between 330 and 370 K in 1990 and 1999 respectively. In the Northern Hemisphere, the isentropic ozone fluxes are found to occur preferentially over the eastern Atlantic Ocean and northwest Africa in winter and over the Atlantic and Pacific Oceans in summer and they are shown to be associated with Rossby wave breaking events. This research suggests that isentropic transport is important for determining ozone levels in the subtropical upper troposphere especially in summer.

**P-3-13**

DIAGNOSIS OF MERIDIONAL OZONE TRANSPORT BASED ON MASS WEIGHTED ISENTROPIC ZONAL MEANS

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**Abstract:** Transport equation based on mass weighted isentropic zonal means applies to diagnosis for meridional ozone transport in the troposphere and stratosphere. The mean and eddy ozone fluxes are estimated from global distributions of the temperature, wind and ozone. In comparison with conventional Eulerian mean and Transformed Eulerian Mean (TEM), the isentropic diagnosis takes an important advantage to simply and exactly represent eddy transport terms. Adiabatic eddy flux is separated from diabatic eddy flux, which is parallel to isentropic surface. The analysis shows that the eddy flux is almost adiabatic except that it is significantly affected by diabatic effects near the lower troposphere. Another advantage lies in the mean meridional circulation. Although it is almost similar to the TEM, significant differences can be found near the Antarctic polar vortex due to nongeostrophic effects. Furthermore, the isentropic diagnosis expresses strong equatorward flux near the lower boundary, while the TEM hardly do it because of inadequate treatment of the lower boundary conditions. The life cycle of ozone can be understood through the exact estimation of the transport terms. Although the stratospheric meridional transport is mainly performed by Brewer-Dobson circulation, strong poleward eddy ozone flux is caused by planetary wave breaking especially in the winter hemisphere. The ozone is subsided in the extratropical troposphere by the mean downward motions, mainly diffused to lower latitudes probably due to strong baroclinic waves and effectively lost through chemical processes in the lower troposphere.

**P-3-14**

## QUASI-PERIODIC VARIATIONS OF THE POLAR VORTEX IN THE SOUTHERN HEMISPHERE STRATOSPHERE DUE TO WAVE-WAVE INTERACTION

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**Abstract:** The winter polar vortex in the Southern Hemisphere stratosphere is characterised by prominent quasi-stationary planetary wave of zonal wavenumber 1 (Wave 1) and eastward travelling Wave 2. Quasi-periodic variations of the polar vortex are investigated in terms of the wave-wave interaction between Wave 1 and Wave 2 with both the NCEP/NCAR Reanalysis dataset from 1979 to 2002 and a spherical barotropic model. A typical case shows that the transient Wave 1 generated by the wave-wave interaction has a comparable amplitude to those of the stationary Wave 1 and the travelling Wave 2, and has a node. The transient Wave 1 travels eastward with the same angular frequency as that of the travelling Wave 2. The polar night jet also vacillates with the same frequency such that it has its minimum when the stationary Wave 1 and the transient Wave 1 are in phase at the polar side of the node. The vacillation is basically due to quasi-periodic variations of the wave driving by the interference between the stationary Wave 1 and travelling Wave 1. Similar periodic variations of the polar vortex are obtained in our model experiment in the circumstance that stationary Wave 1 generated by surface topography has a comparable amplitude to eastward travelling Wave 2, which is generated by the barotropic instability of a forced mean zonal wind. The winter polar vortex shows large interannual variability. The quasi-periodic variations due to wave-wave interaction often occurred for the 24 years in late winter when the transient Wave 2 was vigorous.

**P-3-15**

## UT/LS WATER VAPOUR MEASUREMENTS IN Ny-ALESUND, SPITSBERGEN

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**Abstract:** Since winter 2002/2003, several stratospheric water vapour soundings have been performed in Ny-Alesund, Spitsbergen (78°N, 12°E), using balloon-borne frostpoint hygrometers built at NOAA-CMDL. The measured vertical $H_2O$ profiles allow case studies with focus on the Arctic UT/LS region.

In the lower stratosphere, the Arctic water vapour distribution is affected both by phase aggregation due to the formation of Polar Stratospheric Cloud (PSC) particles, and by dynamical effects of the polar vortex. Clear differences of the water vapour concentration in polar vortex and mid latitude air are found. In fact, the analysis of a water vapour profile observed in February 2003 reveals that a distinct bite-out was not linked to dehydration caused by sedimenting PSC particles, but to filamentary structures of mid-latitude air at the vortex edge, proving water vapour a valuable tracer for dynamical processes in the polar stratosphere.

Another focus is put on the tropopause region. In the Arctic, certainly no efficient upward transport through the tropopause is expected. Yet, above the tropopause we find a smooth decrease of moisture before reaching typical stratospheric values at the hygropause, indicating the existence of a transition layer between troposphere and stratosphere, which may be caused by diffusion of water vapour through the smeared polar winter tropopause.

We plan to continue stratospheric $H_2O$ soundings in the future to realize long-term observations and climatological studies.

**P-3-16**

## INFLUENCE OF THE TIBETAN HIGH ON THE DISTRIBUTION OF COLUMN OZONE IN THE SOUTHERN HEMISPHERE

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**Abstract:** A new hypothesis is described regarding a teleconnection between the boreal summer and austral winter: the distribution of ozone in the Southern Hemisphere is controlled primarily by outflow from the top of the northern Asian monsoon (Tibetan High). The anthropogenic ozone hole, which appears each September and October over Antarctica, is surrounded by a croissant-shaped ozone maximum in the 40-60°S latitude band, characterised by a broad maximum of larger column ozone amounts centred south of Australia and lower amounts over the South Atlantic. No previous explanation has been offered for this preferred longitudinal distribution of column ozone. Observational analysis and theory will be described which illuminate the process by which the ozone croissant is established.

A major current of air flows out of the Tibetan High across the Indian Ocean, where it deforms the Southern Hemisphere winter subtropical jet. Outflow surges occur in pulses lasting several days, with southwestward flow generating an anticyclone over the Indian Ocean/Australian sector. The pulsed flow excites a train of Rossby waves, which propagates eastward. These breaking Rossby waves cause extensive mixing, with poleward and downward ozone transport in the UT/LS occurring preferentially in this longitude band. Dilution with low-ozone air accounts for the eastern end of the ozone croissant. This mechanism couples the two hemispheres chemically and dynamically, providing for deeper understanding of interannual variations and global change issues.

**P-3-17**

## SHORT-PERIOD DISTURBANCE OBSERVED IN THE ANTARCTIC STRATOSPHERE

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**Abstract:** Radiosonde data at Syowa Antarctic station (39.6°E, 69°S) in June 2002 was analysed in detail. A short-period disturbance with a period of 12-15 h was observed above 22 km. ECMWF operational analysis data showed that it has a horizontal wavelength of about 2000 km and a phase velocity of about 40 m/s, which is equal to the background wind speed at the zero meridional gradient of potential vorticity. The largest amplitude was observed slightly poleward of the potential vorticity minimum. Its structure is consistent, in some aspects, with the neutral wave in a barotropic shear flow. In our talk, the possibility of barotropic instability and the effect of anomalous flow configuration in 2002 will be discussed further.

**P-3-18**

## THE EXTRATROPICAL TROPOPAUSE INVERSION

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**Abstract:** The finescale structure of the extratropical tropopause region is explored by means of vertical high resolution (about 30 m) radiosonde data from 92 stations over the contiguous United States for the years 1998-2002. The radiosonde profiles are averaged by means of a recently introduced method, which utilizes the tropopause height as a common reference level of all profiles within the mean, *i.e.* profiles are averaged with respect to the local, time-dependent tropopause height. This method and the high vertical resolution of the data uncover a pronounced inversion in the vertical temperature gradient at the tropopause throughout the investigated extratropics in the mean. This tropopause inversion translates into a layer with maximum values in the static stability parameter just above the tropopause. The thickness of this layer increases towards the pole and averages nor in coarsely resolved data. Seasonal differences, as well as some implications, are discussed.

**P-3-19**

## DETERMINING THE TROPOPAUSE HEIGHT FROM GRIDDED DATA

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**Abstract:** A method is presented to determine tropopause height from gridded temperature data with coarse vertical resolution. The algorithm uses a thermal definition of the tropopause, which is based on the concept of a threshold lapse-rate. Interpolation is performed to identify the pressure at which this threshold is reached and maintained for a prescribed vertical distance. The method is verified by comparing the heights calculated from analyses of the European Centre for Medium-Range Weather Forecasts (ECMWF) with the observed heights at individual radiosonde stations. Despite the coarse vertical resolution of the analyses, errors in the calculated tropopause heights are generally small. RMS errors range from 30-40 hPa in the extratropics to 10-20 hPa in the tropics. The largest deviations (up to 60 hPa) occur in the subtropics, where the tropopause has strong meridional gradients that are not adequately resolved by the coarse-resolution input data.

**P-3-20**

## DECADAL AND YEAR-TO-YEAR VARIATIONS OF THE ARCTIC LOWER-STRATOSPHERIC TEMPERATURE IN MARCH AND THEIR RELATIONSHIP WITH EDDY HEAT FLUX

**D. Joon Kim** and W. Choi

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**Abstract:** The lower stratospheric polar temperature in March for the recent 40 years was investigated based on NCEP/NCAR reanalysis data in the relation to the strength of the stratospheric eddy heat flux in the preceding months. Both polar temperature and the eddy heat flux show significant variations in the year-to-year and the decadal time scales. Year-to-year variation of the polar temperature in March at 70 hPa is highly correlated with the eddy heat flux in February and March around 65°N, and this correlation explains most of the total variation of the polar temperature and eddy heat flux in the lower stratosphere. The decadal-scale variation of the 70-hPa polar temperature, however, shows high correlation with eddy heat flux at higher latitudes than 65°N, and the region of this high correlation is confined to the narrower latitudinal range of 70 –80°N. Examining stationary and transient eddy heat fluxes separately, we showed that the year-to-year variation of the lower-stratospheric polar temperature in March is highly correlated with the intensity of stationary eddy heat flux, whereas the decadal-scale variation of the lower-stratospheric polar temperature is strongly governed by the intensity of the transient eddy heat flux in the polar stratosphere.

**P-3-21**

## LIMB-SOUNDING TOMOGRAPHY OF THE UT/LS

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**Abstract:** The Upper Troposphere and Lower Stratosphere (UT/LS) region is characterised by strong horizontal and vertical gradients in temperature and constituents. Conventional limb-sounding retrieval schemes are able to retrieve profiles with high vertical resolution but assume that the atmosphere is spherically-symmetric and are, therefore, limited in recovering true horizontal variability. The tomographic approach dispenses with the assumption of spherical symmetry, models radiative transfer in two dimensions and uses multiple limb-scans simultaneously to produce a 2-D cross-section of the atmosphere. This method can achieve higher horizontal resolution for water vapour and other trace gases in the UT/LS than is possible for conventional limb sounding retrievals.

The MASTER instrument concept is being developed by ESA to sound the global distributions of trace gases in the UT/LS at high fidelity by measuring limb-emission spectra in three millimetre-wave frequency bands. By limb-scanning in the orbit plane with comparatively small vertical and horizontal spacings between adjacent tangent-points, a given airmass can be viewed from several different directions, enabling a tomographic approach to be used.

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) observes infra-red limb emission viewing rearwards from ESA's Envisat platform. One of the MIPAS special operating modes has been devised to sound the structure of the UT/LS in greater detail by scanning with finer vertical and horizontal spacing, at the expense of reduced spectral resolution compared to the nominal mode. These measurements, therefore provide the first opportunity to apply the principles of tomographic limb-sounding to real satellite measurements.

In this paper, the potential for retrieving UT/LS constituents from satellite limb-sounding instruments will be illustrated with results based on simulations and real data.

**P-3-22**

## CLASSIFICATION AND SCALES OF ANTARCTIC POLAR STRATOSPHERIC CLOUDS USING WAVELET DECOMPOSITION

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**Abstract**: Polar Stratospheric Clouds (PSCs) observed with a lidar over the French Antarctic station of Dumont d'Urville (DDU 66°S, 140°E) in 1996 are classified using backscatter and depolarisation ratio diagrams. Some Type 1 PSCs, called here intermediate type PSCs, exhibit lidar signals, which do not to fit the two distinct groups, Type 1a and 1b, of the standard classification. A wavelet decomposition analysis of backscatter and depolarisation ratio profiles is performed in order to study the vertical scales of the various PSCs layers.

This analysis reveals the presence of small-scale structures in the lidar vertical profiles, which are typical of mesoscale processes associated with the propagation of waves such as gravity or mountain waves, into the winter stratosphere. When these small-scale structures are filtered out of the lidar profiles, most of the intermediate type PSCs detected in the original data disappear, indicating that the layers of intermediate type PSCs must be relatively thin, possibly embedded into wider synoptic type 1a or 1b layers. This suggests that intermediate type PSCs observed over DDU in 1996 tended to form during rapid and small-scale perturbations associated with mesoscale processes. The lidar signal of intermediate type PSCs may simply reflect the sampling of rapidly evolving PSCs, supporting the view of these intermediate type PSCs as transition type PSCs. It is worth noticing that the vertical scale of theses processes cannot be fully resolved in meteorological analysis or satellite data. High resolution data are required to investigate these transition type PSCs.

**P-3-23**

CLIMATOLOGY OF UT/LS OZONE AND THE RATIO OF OZONE AND POTENTIAL VORTICITY OVER NORTHERN EUROPE

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**Abstract:** In the recent past, there has been a growing interest in exploring the ozone in the Upper Troposphere and Lower Stratosphere (UT/LS) region for various reasons. They include among others: 1) Changes in ozone content, with a possible climatic consequence, resulting from the direct injection of ozone precursors, particularly $NO_x$, by aviation aircraft that normally fly between 8-12 km; 2) The ozone trends are opposite in sign, at least in northern mid- and high- latitudes, in the troposphere and stratosphere, with a transition somewhere in the UT/LS region; 3) It is now well known that the maximum chemical ozone loss occurs in the lower stratosphere, which includes the upper part of the UT/LS region. It is, thus, of primary importance to monitor the vertical distribution of ozone in the troposphere and lower stratosphere on a long-term basis. However, we are only aware of a few reports on the climatology of ozone from the European Arctic. Furthermore, the data used in those studies are limited to only about 2-3 years. Thus, we focus our attention to construct a climatology of ozone in the troposphere and lower stratosphere with the help of long-term ozone measurements at 7 European Arctic stations and to study the annual and interannual variations of ozone at these stations.

The ratio between ozone and PV is useful to initialise chemistry transport models through modelled potential vorticity fields and to calculate the ozone fluxes from PV fluxes. In the present study, the correlation between ozone and PV is studied in more detail and climatology of ozone/PV ratio is constructed for 3 Northern European stations using 8 years of ozonesounding data. The ozone/PV ratio in the middle troposphere and lower stratosphere varies significantly during the course of the annual cycle and the variation is similar to that of ozone mixing ratio. The ozone/PV ratio for each month is nearly the same at the stations of interest indicating that a single ozone/PV ratio (as a representative for that month) can be used to convert global PV fluxes to ozone fluxes. The ratio between ozone/PV is estimated for several case studies and compared with the climatological ratio for validation of the climatological ratio. A fairly good comparison is found between the estimated value in the fold and the climatological value.

**P-3-24**

ENTROPY AND THE SIMULATED TEMPERATURE OF THE EXTRATROPICAL UT/LS REGION

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**Abstract:** There is some evidence that the upper troposphere / lower stratosphere at high latitudes is too cold in the climate simulated by many GCMs. An attempt has been made to explain this systematic error using an entropy argument. Numerical diffusion in atmospheric models mixes air across isentropes and so is a spurious aphysical source of entropy. In a simulated state without drift there must be a corresponding sink and the theory is that the observed cold bias develops to provide this sink by an increased loss of entropy to space by radiation. It is now accepted by the computational mathematics community that entropy is indeed created by numerical schemes. However, the magnitude of the source has never been directly calculated in a full atmospheric numerical model. To address this, a systematic study has been performed to quantify the entropy source due to numerical mixing in an otherwise adiabatic dynamical core model at the University of Reading. Results are presented over a range of diffusivities with the general conclusion that the entropy source due to spurious cross-isentrope mixing is indeed of the size required by the above theory: the same magnitude as the smaller fluxes in the observed atmospheric entropy budget.

**P-3-25**

## COLOR INDICES FROM SAOZ OBSERVATIONS AS POLAR STRATOSPHERIC CLOUDS DETECTION FLAGS

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**Abstract:** The SAOZ (Système d'Analyse par Observation Zénithale - Analysis System by Zenith Observation) network includes 10 stations. Three of them are located within the Arctic Circle: Scoresby-Sund (70°N, 22°W), Sodankyl (68°N, 27°E) and Zhigansk (67°N, 123°E). They are used to test daily detection of Polar Stratospheric Clouds (PSC). SAOZ is a UV-Visible spectrometer mainly devoted to column $O_3$ and $NO_2$ measurements. Observations, based on differential optical absorption, are made at sunrise and sunset, in any weather conditions, all over the year. Correction of the absorption from various chemical components gives access to scattering properties of the atmosphere (Rayleigh/Mie). A Colour Index (CI) at a given solar zenith angle (SZA) is the ratio of the solar light flux at 550 nm to those at 450 nm. The CI is defined as the ratio of the CI at 93 SZA to those at 90 SZA. Normalisation at 90 SZA allows avoiding tropospheric contribution and CI only depends on the stratospheric contribution. The whole data bases (started in 1990) from the three Arctic stations have been reprocessed, after algorithm improvements. On the rough CI data sets, 1991 to 1995 observations presented CI significantly lower than for the other years, due to Mt. Pinatubo aerosols impact. A method of slope detection was applied and three distinct periods appeared. Successive linear fits for these three periods were made to get data corrected from Mt. Pinatubo contribution. At this stage, CI values outside a range of threshold values can be used as PSC detection flag. More comprehensive information on PSC characteristics could be reached through interpretation of reddening or blueing, using a radiative transfer model.

**P-3-26**

## CHARACTERISTICS OF TROPOPAUSE FOLDS OVER AN ARCTIC STATION

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**Abstract:** The exchange across tropopause plays a pivotal role in controlling the ozone budget of the troposphere and lower stratosphere. At the extratropical tropopause the exchange depends mainly on small scale near tropopause processes, such as tropopause folds, cutoff lows, streamers, etc. Although these processes are strongly linked with one another, they are often described as separate processes in the literature. Further, the vertical structure of cutoff lows and streamers are often neglected and much emphasis is given to the horizontal structure of these systems. However they do possess a vertical structure in the form of tropopause folds (though not necessarily always). Tropopause folds have been monitored and studied since long by means of *in situ* aircraft measurements and remote sensing instruments (such as Lidar and radar). Most of these observations of tropopause folds have been made at mid latitudes. However, tropopause folding also occurs in the baroclinic zones beneath subtropical and arctic jetstreams. To the authors knowledge there exists only a few observations of tropopause folds at Arctic latitudes and certainly no observations exists using remote sensing instruments (particularly with a radar). Thus an attempt has been made to explore and characterise the tropopause folds over an Arctic station using a VHF wind profiler. Note the tropopause folds that we study need not be necessarily Arctic folds, which appear beneath the Arctic jet, but could also be folds under polar jetstream during the poleward migration of polar jet. In other words, they are folds observed over an Arctic station. In the present study, two interesting cases of tropopause folds are discussed in detail with the help of data from ESRAD (Esrange RADar), radio- and ozone-soundings and meteorological analysis. General characteristics of tropopause folds with a special emphasis on turbulence are discussed using the compilation of many such folds observed with ESRAD. Making use of continuous measurements of ESRAD for over 6 years, the annual cycle of tropopause folds has been studied over ESRANGE. The fold statistics have been discussed in light of other fold climatologies available in the literature.

**P-3-27**

## MODEL SIMULATIONS OF THE IMPACT OF THE 2002 ANTARCTIC OZONE HOLE ON MIDLATITUDES

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**Abstract:** The 2002 Antarctic winter was characterised by unusually strong wave activity. The frequency and intensity of the anomalies increased in August and early September with a series of minor stratospheric warmings and culminated in a major stratospheric warming in late September. A three-dimensional high resolution chemical transport model is used to estimate the effect of the exceptional 2002 Antarctic winter on chemical ozone loss at midlatitudes and in polar regions. An ozone budget analysis is performed using a range of geographical and chemical ozone tracers. In order to highlight the unusual behaviour of the 2002 winter, the same analysis is performed for the more typical 2001 winter. The ability of the model to reproduce the evolution of polar and mid-latitude ozone during these two contrasted winters is first evaluated against ozone sonde measurements at middle and high latitudes. The evolution of the model-calculated 2002 ozone loss within the deep vortex core is found to be somewhat similar to that seen in the 2001 simulation until November, which is consistent with a lower stratospheric vortex core remaining more or less isolated even during the major warming. However, the simulations suggest that the wave activity anomalies in 2002 enhanced mixing well before the major warming within the usually weakly mixed vortex edge region and, to a lesser extent, within the surrounding extra-vortex region. As a result of the increased permeability of the vortex edge, the export of chemically activated vortex air is more efficient during the winter in 2002 than 2001. This has a very noticeable impact on the model-calculated midlatitude ozone loss with destruction rates being about two times higher during August and September in 2002 compared to 2001. If the meteorological conditions of 2002 were to become more prevalent in the future, Antarctic polar ozone depletion would certainly be reduced, especially in the vortex edge region. However, it is also likely that polar chemical activation would affect mid-latitude ozone earlier in the winter.

**P-3-28**

## CLIMATOLOGICAL CHARACTERISTICS OF TROPOSPHERE-STRATOSPHERE OZONE FROM REUNION ISLAND (21°S 55°E) USING *IN SITU* (OZONESONDE AND LIDAR) AND SATELLITE (HALOE AND TOMS) MEASUREMENTS

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**Abstract:** Ozone is produced and destroyed naturally in our atmosphere, resulting ozone variations as a function of altitude, latitude and time are not easily separated from changes due to man. The upper tropospheric ozone, which has both tropospheric and stratospheric source due to exchange processes, contributes to the ozone budget.

The present study focuses on climatological characteristics of troposphere and stratosphere ozone from Reunion Island (21°S-55°E) using *in situ* (Ozonesonde and Lidar) and Satellite (UARS-HALOE and TOMS) measurements. We use ozone measurements from ozonesonde (10 years September 1992 to September 2002), tropospheric ozone lidar (5 years June 1998 to January 2003), HALOE satellite (11 years January 1991 to December 2002) and TOMS satellite (7 years July 1996 to December 2002). The results obtained from the present study are as follows. The constructed height profile of ozone from lidar and ozonesonde are found to be in good agreement during April to August and November to December and a little difference in the magnitude but with similar trend observed during January to March and September to October. Similarly, the ozone measurements from ozonesonde and HALOE for the height range of 15-30 km are also found to be in close agreement between each other for all the months. Climatological/Seasonal variation of ozone measurements by lidar shows a high ozone concentration at 5.5-9.5 km and at 11.5-15.0 km during January-February and at 5.5-10.0 km during September-October. The ozonesonde measurements recorded a high ozone values at 6-15 km during April-May and then by September-November and at 15-30 km during January-April and October-December.

The HALOE measurements show a maximum ozone concentration at 28-37 km and 1 ppmv of ozone decrease is recorded for February and May-August. The integrated ozone value at troposphere (0.75 km to tropopause), lower stratosphere (tropopause to 30 km) and total ozone measurements show a similar trend with maximum during September to October. On and before 1995, there was an increase in ozone concentration of 20 DU, which represents the Mt. Pinutabo volcanic eruption and also provides the information that the eruption causes a subtend change in the stratospheric ozone concentration in comparison to the tropospheric ozone. The stratosphere to troposphere ozone peak position shows a three months shift between them representing downward propagation.

The calculated ozone tropopause found to be located at 14.5-18.0 km with exhibiting annual oscillation. The correlation analysis between ozone concentration and potential temperature show a positive/high value up to 30 km and negative/low value for above 36 km.

**P-3-29**

## AGE OF AIR SIMULATIONS WITH A STRATOSPHERE/TROPOSPHERE CTM

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**Abstract:** Studies of the long-term changes in stratospheric ozone require models with a realistic representation of the slow, meridional (Brewer-Dobson) circulation. In recent years the 'stratospheric age-of-air' has become a useful diagnostic for testing this aspect of models. Moreover, comparisons with age inferred from observations show that models often do not perform well.

We have used a recently updated combined version of the SLIMCAT/TOMCAT off-line chemical transport model (CTM) to investigate the modelled mean age in a series of sensitivity tests. The model extends from the surface to about 60 km with different possibilities for the vertical coordinate. The vertical tracer transport can also be derived from analyses (like the model temperature and horizontal winds) or from diagnosed heating rates. We will discuss the effect of the modelled age of air of a range of sensitivity studies, which vary the vertical coordinate (pressure v. theta levels), the method of vertical advection (diagnosed heating rates v. analysed divergence), the tracer advection scheme and the analyses (UKMO or ECMWF ERA40) used to force the model.

Generally, more realistic stratospheric ages of air are obtained with isentropic stratospheric levels and/or diagnosed heating rates. Other model formulations tend to give ages, which are too young.

**P-3-30**

## CHANGES OF TEMPERATURE, OZONE, AND HUMIDITY IN THE UT/LS LAYER OVER CENTRAL EUROPE

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**Abstract:** The balloon-borne radio-sounding *in situ* measurements of temperature, humidity and ozone are so far the most accurate measurements in the atmosphere. On long-term series of qualified data the changes and trends can be studied. The study has been performed on the base of balloon-borne long-term measurements of temperature, humidity and ozone. The temperature trends over Poland have been analysed for two time series, 1966-2003 and 1979-2003. Accelerated cooling in the stratosphere, opposite to the warming in the troposphere, with the UT/LS transition layer, have been stated during the years. Special attention has been devoted to the particular points in the UT/LS layer, the tropopause and ozonopause. The relationship between the ozonopause and tropopause heights has been examined statistically on the series of ozone soundings from Legionowo for 1979-2003. On average, ozonopause is located about 600 m below the tropopause, with minor changes over the year. The individual soundings show both the subtropical advection (ozonopause above the tropopause) and the polar advection (ozonopause below the tropopause). In extreme cases, dispersed throughout the year, the ozonopause descends to 4-6km. Selected cases of the stratospheric ozone intrusions into the troposphere have been studied. On the base of the ECC ozone sounding series 1993-2003, the correlation between ozone and humidity has been examined. The results show negative correlation, what may indicate sink reactions of ozone in the UT/LS region.

**P-3-31**

## POTENTIAL UNCERTAINTIES IN USING THE HODOGRAPH METHOD TO RETRIEVE GRAVITY WAVE CHARACTERISTICS FROM INDIVIDUAL SOUNDINGS

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**Abstract:** Low-frequency gravity waves are an important component of the dynamics of the upper-troposphere and lower-stratosphere region. They affect processes that are sensitive to temperature fluctuations, such as the formation of PSCs, and contribute, when wave-breaking occurs, to mixing and turbulence.

Observational studies of low-frequency waves have largely relied on the hodograph method to retrieve characteristics (intrinsic frequency, vertical and horizontal wavelength) of individual gravity waves from profiles of the horizontal winds. The method is based on the linear theory of gravity waves on the background of a fluid at rest. In order to estimate the uncertainties of this method, we have analysed meso-scale numerical simulations of a gravity wave event in which a quasi-monochromatic inertia-gravity wave packet is present. Single vertical profiles are extracted from the simulations, analysed using the hodograph method, and the derived wave characteristics are compared to the reference values determined from the four-dimensional simulated fields. Although the conditions favour the use of the hodograph method, the derived wave parameters possess significant uncertainties.

**P-3-32**

## ANTARCTIC OZONE HOLE IN 2002 AND SST ANOMALIES IN THE SOUTH OCEANS

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**Abstract:** Analysis of the monthly mean (September) variations of the total ozone and lower stratospheric zonal wind is conducted for 1979-2002. It is shown that the total ozone increases over Antarctic in 1988 and 2002 are tightly associated with strong easterlies in 50°S-60°S especially over South America in according with findings of Jadin (1995). The separation of the dynamical and chemical forcing on the ozone hole development during 1979-2002 showed that their contributions are comparable. The mechanism of the wave hypothesis of the interference of the topographic source (Rockies and Andes) and thermal excitation of stationary planetary waves (Sea Surface Temperature - SST anomalies) can explain both of the natural fraction of the ozone layer variations and the climate changes associated with the Arctic and Antarctic Oscillations.

**P-3-33**

## GENERATION OF DEEP CONVECTION BY FOREST FIRE

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**Abstract:** Both satellite and *in situ* data show that smoke from forest fires can be carried well into the mid-latitude stratosphere by deep convection. An intriguing question is whether the forest fires contribute to the production of this very deep convection, or whether the smoke observed is simply passively transported by convection that would have occurred whether the fire was there or not. In this analysis, we seek to determine the relationship between mid-latitude forest fires and deep convection. To determine this, we use measurements of surface fires and deep convection made by the Moderate Resolution Imaging Spectrometer (MODIS) onboard NASA's Terra satellite. We will show that there does appear to be a statistically significant increase in the occurrence of deep convection near forest fires.

**P-3-34**

# STRATOSPHERIC WATER VAPOUR LAMINAE OVER SODANKYLA IN WINTER 2004 DURING LAUTLOS CAMPAIGN.

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**Abstract:** During the LAUTLOS campaign, balloonborne high-resolution *in situ* measurements of water vapour content in the UT/LS were performed over Sodankyla (67.4°N, 26.6°E) in February 2004. Different types of hygrometers have been used for intercomparison of results in UT/LS region.

We present the water vapour vertical profiles obtained by using the balloon optical hygrometer (FLASH-B) inside the polar vortex, outside the vortex and in the vortex edge region. The obtained results at the heights about 20 km confirmed higher water vapour mixing ratios inside the polar vortex (5.5 ppmv) relative to mid-latitudes (4.5 ppmv).

The vertical profile of the water vapour in the vortex edge region exhibits the laminated structure with amplitude exceeding 1 ppmv. Since there were no low enough temperatures for dehydration and further rehydration at lower altitudes, the most probable reason for such structure is the differential advection. To examine this, the trajectory model has been used. Potential Vorticity (PV) calculated on the base of ECMWF data was used as a proxy tracer. Reverse Domain Filling (RDF) calculations showed that such laminated structure is caused by the vortex filamentation. PV vertical profile reconstructed by RDF over Sodankyla demonstrates the structure similar to the water vapour profile. Such good agreement between model results and observations shows that the intrusions of air masses with the different origin in the vortex edge region provide the laminated structure of tracers.

**P-3-35**

# INERTIA-GRAVITY WAVES GENERATED DURING POLEWARD ROSSBY WAVE BREAKING EVENTS OVER NORTHERN GERMANY IN WINTER

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**Abstract:** Inertia-Gravity Waves (IGW) can be generated during Rossby wave breaking events. They propagate regionally and play a significant role in exchange processes of the upper troposphere and lower stratosphere. In this study the generation and propagation processes of IGW during poleward Rossby wave breaking events are examined over Northern Germany in winter.

The mean winter (DJF) circulation was studied using reanalysis ERA40 data (1991-2001) of ECMWF. Over Northern Germany the mean zonal wind shows a value of 15 m/s around the tropopause region and increases up to 70 m/s with height. Based on the dispersion relation good conditions for IGW propagation occurred. By counting Rossby wave breaking events for the winters 1999-2003 we found that during more than 40 percent of winter days Northern Germany were under the influence of Rossby wave breaking events that means that also in the upper troposphere localized strong jet streaks often appeared.

During the field campaigns we measured the intrinsic frequency by the radiosondes and the fixed-observer-frequency by a VHF-radar and estimated the horizontal wavelength of the IGW over the Doppler shifting equation. The gathered campaign-data were further analysed with standard methods in order to estimate energy spectra and phase diagrams. Closer inspection of the campaigns in December 1999 (P2 event with strong polar vortex) and March 2003 (P2 event without polar vortex) showed IGW with 600-900 km horizontal wavelength, 2-4 km vertical wavelength and intrinsic periods of 12-14h. The waves are generated at the exit of tropospheric jet by geostrophic adjustment and the energy is propagating upward and downward but upstream.

The nonlinear evolution of such IGW during these Rossby wave breaking events was simulated with the mesoscale model MM5. The Rossby wave evolution was included in an area of 5000 km extend, the IGW were resolved with a spatial resolution of 8 km horizontally and 0.1 km vertically. We run the model also for the above mentioned two campaigns (December 1999 and March 2003) and found IGW with parameters: 200-900 km, 2-9 km and 6-12h. For a run without orography, moisture and surface friction we found long IGW too, which confirms the active role of the jet stream in the generation process. It is also shown, that shorter IGW (about 200 km) excited by orography and deep convection travel faster in the troposphere and stratosphere. During these Rossby wave breaking events we found an enhancement of wave energy and of vertical momentum flux by a factor of five.

**P-3-36**

ATMOSPHERIC ANGULAR MOMENTUM BALANCE FOR THE SOUTHERN HEMISPHERE DURING THE POLAR VORTEX BREAK-UP OF SEPTEMBER 2002

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**Abstract:** On the basis of ECMWF analysis data the evolution of the axial component of the Atmospheric Angular Momentum AAM vector has been calculated for each day of September 2002. The components of the conservation equation of AAM have been calculated for southern hemispheric polar caps in order to examine the AAM balance during the unexpected break-up of the polar vortex.

It is found that the AAM tendency for the polar cap, defined by longitudinal, vertical and latitudinal (90°S - 60°S) integration, oscillates with a period of 5 days until the break-up of the polar vortex. In average we found an increase of AAM until day 16, followed by a strong decrease to day 25, the day of vortex splitting in the upper stratosphere, and a final increase to the end of September. The positive (negative) imbalance between mountain torque and the divergence of relative AAM fluxes causes the increase (decrease) of AAM. The mountain torque changes are determined by shifts of surface pressure in relation to the orography of Antarctica. The changes of AAM fluxes are mainly determined by the evolution of momentum fluxes due to transient Rossby waves in the upper troposphere and lower stratosphere. The polar friction torque induced by katabatic winds is weakly positive and nearly constant in comparison with that of middle latitudes. Especially during the polar vortex break-up event the balance between mountain torque and the divergence of relative AAM fluxes is negatively disturbed for more than 10 days.

For the Southern Hemisphere polar vortex break-up event the evolution of the AAM tendency and that of different torques as well as their connection to atmospheric circulation changes will be discussed.

**P-3-37**

THE TROPOSPHERIC ORIGIN OF THE MAJOR WARMING EVENT OVER ANTARCTICA IN SEPTEMBER 2002

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**Abstract:** In late September of 2002, the first-time recorded major event of sudden stratospheric warming occurred over Antarctica, leading to a sudden breakdown of a cold polar vortex and the collapse of the ozone hole. A diagnosis of a Rossby wave propagation as a zonally-confined wave packet before and during the warming reveals that the warming was caused by an upward propagating wave packet emanated locally from a prominent tropospheric blocking ridge over the South Atlantic. The blocking developed as a component of an eastward propagating Rossby wave train, which had been forced by anomalously active cumulus convection over the southwestern subtropical Pacific in mid-September.

**P-3-38**

## A SEASONAL PERSPECTIVE ON THE TROPOSPHERIC INFLUENCE IN THE LOWERMOST STRATOSPHERE

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**Abstract:** We present airborne *in situ* measurements of various trace gases, which were performed between November 2001 and July 2003 during the SPURT-project (SPURen-stofftransport in der Tropopausenregion, trace gas transport in the tropopause region). A total of eight measurement campaigns was performed in different seasons with each mission covering the UT/LS region over Europe from 35°N to 75°N.

The measurements on a quasi-regular basis allowed an overview on the trace gas distribution in the tropopause region during different seasons to investigate the influence of transport and mixing across the extratropical tropopause on the lowermost stratosphere. The CO distribution indicates that transport and sub-sequent mixing of tropospheric air across the extratropical tropopause predominantly affects a layer, which closely follows the shape of the local tropopause. Both, horizontal gradients of CO on isentropes as well as the phase shift of the $CO_2$ seasonal cycle in the tropopause region reveal that the influence of quasi-horizontal transport and subsequent mixing weakens as a function of distance to the local tropopause.

However, at large distances from the tropopause, a significant influence of tropospheric air is still evident. The relation between $N_2O$ and $CO_2$ indicates that a significant contribution of air from the (sub-)tropical tropopause contributes to the background air in the extratropical lowermost stratosphere. A combination of the short- and longlived tracers allows to estimate a mass balance for the lowermost stratosphere accounting for the tropical, as well as the extratropical fraction of air.

**P-3-39**

## WATER VAPOUR VERTICAL DISTRIBUTION INSIDE, OUTSIDE AND AT THE EDGE OF THE POLAR VORTEX OVER SODANKYLA, FINLAND IN WINTER 2004 DURING LAUTLOS-WAVVAP CAMPAIGN.

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**Abstract:** During January/February 2004 in the frame of LAUTLOS-WAVVAP campaign a series of balloon water vapour soundings were performed at the Arctic Research Center of Finnish Meteorological Institute, Sodankyla (67.4°N, 27.6°E). The campaign was aimed at intercomparison of water vapour lightweight instruments. 5 instruments of different types took part in the intercomparison. Among them the Lyman-alpha FLASH-B hygrometer developed at Central Aerological Observatory, Russia, was running. The instrument is based on fluorescent method, which implies $H_2O$ molecule photodissociation when exposed to radiation at a 121.6 nm wavelength (L-alpha - hydrogen emission). The excited OH radical fluoresces within 308 -316 nm range. The detector of OH fluorescence is a photomultiplier run in photon counting mode. Thus, the intensity of the fluorescent light, as well as the instrument readings, is directly proportional to the water vapour mixing ratio under stratospheric conditions. FLASH-B is a light-weight (0.980 kg) and small size (150 mm x 200 mm x 350 mm) instrument with total uncertainty estimated to be not more than 10.

During the LAUTLOS campaign 11 water vapour profiles were obtained using FLASH-B instrument among them 3 inside the polar vortex, 5 on the edge of the vortex and 3 outside the vortex. The polar vortex of February 2004 appeared to be a weak one with generally warm temperatures encountered in it. Therefore, no PSCs have occurred during that period.

The acquired measurements clearly demonstrate typical differences of water vapour vertical distribution in the lower stratosphere inside and outside the vortex. As an example, for 20 mBars the difference reaches 1.4 ppmv. Also it has been pointed out that water vapour profiles obtained at the edge or close to the edge of vortex have generally some filamentary structure in it, which could be explained by differential advection of air masses originating from inside and outside the vortex.

FLASH-B water vapour measurements were compared to those of NOAA-CMDL frostpoint hygrometer. The comparison reveals good agreement between the instruments. The reliable and reproducible results acquired using FLASH-B instrument could be a base for regional empirical model of water vapour in UT/LS.

**P-3-40**

HOW CAN WE QUANTIFY THE EFFECT OF MIXING ON THE TRANSPORT AND CHEMISTRY IN THE STRATOSPHERE? CLaMS - CHEMICAL LAGRANGIAN MODEL OF THE STRATOSPHERE.

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**Abstract:** Mixing processes in the vicinity of the polar vortices and in the mid-latitude surf zones play the essential role in the distribution of the chemical species in the middle and lower stratosphere. Although evidence of mixing is often observed, quantifying its effect has been proven to be a significant challenge. Using the recently developed 3D version of the Chemical Lagrangian Model of the Stratosphere (CLaMS) substantial progress could be achieved towards quantifying the effect of mixing on the chemical composition of the stratosphere. CLaMS is based on a Lagrangian formulation of the tracer transport and, unlike Eulerian CTMs, considers an ensemble of air parcels on a time-dependent irregular grid that is transported by use of the 3d-trajectories. The isentropic and cross-isentropic advection in CLaMS is driven by ECMWF winds and heating/cooling rates derived from a radiation calculation, respectively. The irreversible part of transport, *i.e.* mixing, is controlled by the local horizontal strain and vertical shear rates with mixing parameters deduced from observations. Thus, mixing is strongly inhomogeneous and anisentrop with respect to the local wind because it occurs only in those parts of the grid that experienced sufficiently high deformations rates. We show results derived from several case studies (SOLVE/THESEO, SOLVE2/VINTERSOL, Antarctic split in September 2002) where the simulated CLaMS distributions of tracers and ozone give a realistic description of the underlying small-scale transport and chemistry processes. The comparison of the simulated tracer distrubutions with *in situ* and satellite observations confirms the Lagrangian concept of strongly inhomogeneous and anisotropic mixing. In particular, the permeability of the vortex edges is quantified indicating that, despite strong wave activity, the well-isolated, ozone-depleted vortex remnants may “survive” until the onset of the summer circulation. We discuss the spatial distribution, the lifetime and the influence of such remnants on the mid-latitude ozone budget.

**P-3-41**

DIAGNOSTICS OF STRATOSPHERE-TROPOSPHERE EXCHANGE BY MEANS OF THE MECHANISTIC MODEL KASIMA AND THE CHEMISTRY CLIMATE MODEL DLR/E39C

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**Abstract:** A new method for the analyses of complex surfaces based on the triangulation of the space has been developed and applied to the analyses of stratosphere-troposphere exchange (STE). The tropopause (TP) is here dynamically defined as the locally lower surface of 3PVU field of the Ertel's potential vorticity (EPV) and the 380 K potential temperature (theta). The results presented are twofold:

1. By means of case studies of actual meteorological scenarios with KASIMA the method is verified by comparison with earlier studies (Wirth and Egger, 1999, QJRM, Gettelman and Sobel, 2000, JAS and Beuermann *et al*., 2002, GRL).

2. Climatologies are provided by statistical analyses of data of multiannual simulations with KASIMA and DLR/E39C. A validation of the CCM regarding this diagnostic is provided.

For this study, KASIMA runs as a prognostic primitive equation model which is confined to actual meteorological analyses by a Newtonian cooling term, nudging the model temperature to the analyses. The quasibiennial oscillation is modelled by nudging the zonal mean zonal wind towards the analyses in the tropical lower stratosphere.

For all cases the diagnostics concentrate on the computed cross tropopause mass fluxes (CTF). Whereas the case studies (1) indicate a reasonable result compared the studies of the original papers, it turns out that the CTF is significantly downward in the heavy rain regions of the Indian summer monsoon and over Indonesia.

A 1$^{st}$ hypothesis for this behaviour can be summarized as follows:

In these regions the tropopause is defined by the PV criterion. Theta is used only at a very tiny band around the equator. It is checked until the assembly whether the heavy rainfall in this area causes an irreversible latent heat release in the upper troposphere, which provides, together with an almost adiabatic lower stratosphere, a negative vertical gradient of the net heating rate around the TP, which is in turn a sink in the EPV.

**P-3-42**

# THE USE OF AN ADAPTIVE MESH REFINEMENT TRANSPORT CODE TO STUDY THE 2002 ANTARCTIC POLAR VORTEX EVOLUTION

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**Abstract:** A new Adaptive Mesh Refinement transport code is used for the first time to model the Southern Hemisphere stratosphere during a highly perturbed period that led to the unprecedent Antarctic sudden warming event during 2002. This warming led to the splitting of the vortex/ozone hole system. Nevertheless this splitting process is only very distinct at the top and bottom of the region considered, *i.e.* in the middle stratosphere and the lowermost stratosphere. The AMR code is capable of reproducing the fine structure of the system under study, in good agreement with the GOME assimilated total ozone and the broad fine structures detectable in PV calculations from the NCEP reanalysis. The model results were able to detect the significant mixing process between the vortex and the surrounding atmosphere. Finally, the evolution of the vortex in the lowermost stratosphere confirms the influence of synoptic scale perturbations in the dynamics of the region.

**P-3-43**

# TROPOSPHERIC SYNOPTIC SCALE DISTURBANCES AND THE DEFORMATION OF THE ANTARCTIC POLAR VORTEX

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**Abstract:** The aim of this paper is to demonstrate the influence of synoptic scale disturbances, on evolution of the Antarctic polar vortex/ozone hole. The synoptic scale perturbations can propagate from the troposphere, and reach the lower stratosphere. A study was carried out to determine the presence and characterisation of synoptic perturbations at different heights so as to understand their vertical structure. Such an analysis required the use of spectral filters in space, separating the perturbations as a function of their spatial wave properties. Daily values were used so as to preserve the non-linear time relationships. The conditions for penetration/propagation of these systems into the lower stratosphere were evaluated. The impact of such synoptic systems upon the vortex and ozone hole dynamics was then analysed. Geopotential height dynamics was used to follow the ozone hole dynamics.

A case study covering the months of October and November 1990 was chosen, and this was compared with independent data from NASA’s Goddard Space Flight Center (potential vorticity) and NOAA (wind and temperatures).

Summing up, the confirmation of the role of synoptic scale perturbation contribution to the polar vortex deformation is a contribution towards the understanding of the processes involved in the dynamics of this phenomenon.

**P-3-44**

## INTRUSIONS OF THE TROPOSPHERIC AIR INTO THE MIXING LAYER ABOVE POLAR TROPOPAUSE: AIRCRAFT OBSERVATIONS OF WATER VAPOUR AND OZONE

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**Abstract:** The results of water vapour and ozone measurements on board of high-altitude M-55 Geophysica aircraft during the Arctic campaign under the ENVISAT validation project in winter 2003 are presented.

One of the flights was carried out on 02.02.2003 at high latitudes in Arctic above tropopause. Special attention has been devoted to the leg of the flight performed at the altitude of about 11,5 km corresponding to the 330 K potential temperature level. Typical water vapour mixing ratio at that potential temperature level is about 4 ppmv and ozone mixing ratio is 2 ppmv. However, at the beginning of this leg water vapour mixing ratio achieved values up to 6,5ppmv and ozone mixing ratio about 0,3 ppmv. These values, which are typical of the upper troposphere, were measured during a quite long part of the flight (the longitude changed from 23°E to 13°E and the latitude was about 75°N). Then water vapour and ozone mixing ratios changed to their normal stratospheric values quite abruptly at the fixed potential temperature level 330 K.

To examine the origin of air masses arriving to the location of measurements we used trajectory-chemistry model and trace correlations. ECMWF data were used to calculate backward trajectories from several points of the leg. The analysis of the backward trajectories demonstrates simultaneous water vapour increase and ozone decrease three days before the measurements. The results of the measurements and their analysis demonstrate diabatic air masses transfer in UT/LS polar region. The obtained results show the presence of air masses with different origin in the mixing layer just above tropopause due to tropospheric intrusions.

**P-3-45**

## AN ALTERNATIVE MECHANISTIC MODEL OF THE ANTARTIC POLAR VORTEX

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**Abstract:** A quasi-3D global atmospheric model was developed to study the dynamics of the Antartic polar vortex.

The atmospheric system is represented by shallow water equations system together with thermodynamics, from a classical point of view. The integration of the equations on the horizontal plane was made using a Hough harmonic base. These conform an orthonormal system, which is the eingensystem of the shallow water operator of the linearized system of equations. The non linearities were retained in the forcing terms of the equations. Thus, the model uses the non linear shallow water systems of equations. In the vertical, the model was adjusted at each time step using a spline base to fit the solution between two consecutive model layers, on isentropic surfaces. This mechanistic model is forced from below at the lower boundary (near the tropopause) with the temperature from NCEP reanalysis, while the upper boundary is free.

The model was developed to study the dynamical behaviour of the Antartic polar vortex, in particular the interaction with synoptic scale disturbances of tropopsheric origin. The model was able to reproduce observations that show that synoptic scale perturbations of tropospheric origin can penetrate sufficiently into the lower stratosphere and can, thus, significantly contribute to the deformation of the polar vortex.

**P-3-46**

## OBSERVATIONS AND NUMERICAL SIMULATIONS OF INERTIA-GRAVITY WAVES AND SHEARING INSTABILITIES IN THE VICINITY OF A JET STREAM.

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**Abstract:** The SCATCAT (Severe Clear-Air Turbulence Colliding with Aircraft Traffic) experiment occurred during February 2001, operating from Hawaii. This experiment utilized NOAA's Gulfstream-IV aircraft, which made *in situ* measurements and high-resolution dropsonde deployments in the vicinity of jet streams and upper-level fronts. On February 18 2001, the Gulfstream-IV measurements elucidated the detailed structure of an intense jet stream, an upper-level front, and the inertia-gravity waves and clear-air turbulence associated with the developing system. This paper presents the observations for this case, and a very high-resolution simulation of the event.

The close spacing (40 km) of the dropsondes allowed coherent gravity wave structures to be identified above the jet core. The numerical simulations show that the generation of these inertia-gravity waves coincides with rapid upper-level frontogenesis, and the development of a deep tropopause fold. As these inertia-gravity waves propagate through the highly sheared flow above the jet stream, they perturb the background wind shear and stability, and create bands of reduced and increased Richardson number. These bands of reduced Richardson number are regions of likely Kelvin-Helmholtz instability, and coincide with enhanced turbulent kinetic energy in the simulation. This gravity-wave induced instability is a possible source of the clear-air turbulence that was observed, and is responsible for localized vertical mixing. Finally, the dropsondes are analyzed for inertia-gravity waves using the hodograph method. The analysed wave properties show some consistency with the inertia-gravity waves in the simulation.

**P-3-47**

## A VERY LARGE, SPONTANEOUS STRATOSPHERIC SUDDEN WARMING IN A SIMPLE AGCM: A PROTOTYPE FOR THE SOUTHERN-HEMISPHERE WARMING OF 2002?

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**Abstract**: An exceptionally strong stratospheric sudden warming (SSW) that spontaneously occurs in a very simple stratosphere-troposphere AGCM is discussed. The model is a dry, hydrostatic, primitive-equation model without planetary stationary waves. Transient baroclinic wave-wave interaction in the troposphere, thus, provides the only source of upward propagating wave activity into the stratosphere. The model's SSW is grossly similar to the Southern-Hemisphere major SSW of 2002: it occurs after weaker warmings precondition the polar vortex for breaking, it involves a split of the polar vortex, and it has a downward-propagating signature. These similarities suggest that the Southern-Hemisphere SSW of 2002 might itself have been caused by transient baroclinic wave-wave interaction. Our simple model also provides some insight into how often such extreme events might occur. The frequency distribution of SSWs in the model have exponential, as opposed to Gaussian, tails. This suggests that very large-amplitude SSWs, though rare, might occur with higher frequency than might be naively expected.

**P-3-48**

EVALUATION OF THE DISTRIBUTIONS OF OZONE, NITROGEN OXIDES AND WATER VAPOUR IN THE UT/LS IN THE CHEMISTRY CLIMATE MODEL LMDzT-INCA

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**Abstract:** In this study, we present a rigorous evaluation of the simulated distributions of ozone, nitrogen oxides and water vapour concentrations in the extratropical UT/LS region of the Northern Hemisphere. The methodology adopted was elaborated in the framework of the European project TRADEOFF (Brunner *et al*., 2003). We find that the mean values, as well as the variability of water vapour concentrations, are correctly reproduced by the model. The general pattern of ozone distribution (seasonal and geographical variations), as well as daily-time scale variations, are relatively well captured by the model. However, the numerical diffusion of the transport scheme leads to an overestimation of ozone in winter. We show also that the model tends to underestimate the ozone concentration and its variability in summer because of a bias in the altitude of the tropopause in summer. The reasons for these discrepancies and the impact of the vertical resolution model on our results are discussed. The agreement between simulated and measured $NO_x$ concentrations is good in term of seasonal and spatial variations of mean values. However, we show that the short-time scale variability, which involves the convection and lightning, is poorly captured by the model. The sensitivity of modelled ozone production to future $NO_x$ variations is also examined and is compared to analysis derived from measurements campaigns.

**P-3-49**

LAPBIAT UPPER TROPOSPHERE/LOWER STRATOSPHERE WATER VAPOUR VALIDATION PROJECT (LAUTLOS WAVVAP): FIRST RESULTS

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**Abstract:** The focus of this project is the improvement of water vapour measurements technique in the UT/LS. Routine measurements of water vapour with high accuracy at these altitudes are an unsolved problem up to now despite many activities in the past ten years.

The idea of the LAUTLOS-WAVVAP was the comparison/validation experiment, which brings together lightweight hygrometers developed in different research groups, which could be used as research-type radiosondes in the UT/LS region. These include: Meteolabor Snow White hygrometer, NOAA frostpoint hygrometer, CAO Flash-B Lyman alpha hygrometer, Lindenberg FN sonde (a modification of the Vaisala radiosonde), and the latest version of the regular Vaisala radiosonde with the humicap-polimer sensor.

The experimental plan of LAUTLOS-WAVVAP was based on regular launches of multi-sensor payloads at Sodankyl in January-February 2004. The campaign was hosted by FMI via LAPBIAT transnational Access to Research Infrastructure program and assisted by Vaisala Oyj who will provide their newest operational radiosonde generation and the expertise to evaluate the data. LAUTLOS WAVVAP campaign belongs also to the commitments of Finnish (Vaisala Oyj) participation to COST 723 action where one important goal is to develop soundings methods for upper troposphere-lower stratosphere measurements.

During the field campaign 30 balloon flights were conducted. In addition to balloon borne instruments, University of Bern operated its ground based 22 GHz microwave instrument MIAWARA at Sodankyla and a smaller airborne version from Lear Jet of Swiss air force. The obtained results are presented and discussed.

**P-3-50**

## SAGE III TROPOSPHERIC OZONE MEASUREMENTS

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**Abstract:** The Stratospheric Aerosol and Gas Experiment (SAGE) II is the most recent addition to a series of successful satellite-borne occultation instruments designed for making measurements of aerosol, ozone, water vapour, and other trace gases in the Earth's atmosphere. Launched in December 2001, SAGE III has been conducting routine data collection operations since March 2002. The recent release of the Version 3 data set now includes profile measurements below 10 km down to cloud top. This paper will present an overview comparison study of SAGE III tropospheric ozone measurements with ozone observations from SAGE II, POAM III, ozonesondes and the MOZAIC project.

**P-3-51**

## THE NCAR INITIATIVE ON INTEGRATED STUDY OF DYNAMICS, CHEMISTRY, CLOUDS AND RADIATION OF THE UT/LS

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**Abstract**: We present the science plan of a UT/LS initiative at NCAR. Identifying and understanding the dynamical, chemical and physical processes that control water vapour, ozone, aerosols, and clouds and their impact on the radiative balance in the UT/LS is necessary to advance reliable predictions of trends in climate or global change. The goal of the UT/LS initiative is to plan and to conduct integrated studies of these issues using the new high altitude research aircraft, NSF HIAPER, in conjunction with the large scale observations from satellite platforms, those from the NASA A-Train satellites in particular, and with NCAR modelling tools. We present current plans and the status of the project to promote collaborations with the scientific community of SPARC. At the current stage of planning, key UT/LS issues are grouped into four interrelated themes: (1) Tropical UT/LS water vapour, clouds, microphysics, and radiation; (2) Two-way Stratosphere-Troposphere Exchange (STE) processes; (3) Chemistry that controls the budgets of ozone and radical species in the UT/LS; and (4) Composition of aerosol and cloud particles in the UT/LS. Each theme will involve integrated use of field experiments, satellite measurements and state-of-the-art modelling tools.

**P-3-52**

## INVESTIGATIONS OF THE POLAR VORTEX STRUCTURE WITH THE OSIRIS OZONE PRODUCT

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**Abstract:** Three years of ozone data have been processed using the Flittner 3 wavelength algorithm. The OSIRIS ozone data is on the web as orbital slices. TOMS like maps have been formed at 2 km intervals from 10 km to 42 km by mapping the OSIRIS ozone product onto polar map projections. This mapset allows investigations of the vertical structure and evolution of the vortex. The downward motion in the vortex is clearly demonstrated by aerosol maps, which show a clean vortex due to the descent within the vortex.

The Antarctic vortex and the Arctic vortex are investigated using the OSIRIS ozone product. Data is available from Oct 1, 2001 to April 30, 2004 as maps at 2km intervals from 10 km to 42 km. An example is demonstrated using the split vortex event of September 25, 2002 the split extends from 14 km up to 42 km.

However, the 10 km and 12 km levels showed no vortex during the split. A comparison of the features of the Arctic and Antarctic vorticies was conducted. The Antarctic vortex usually extends from 10 km up to over 42 km, whereas in the Arctic the vortex is only obvious from 16 km to 42 km. The main hemispheric differences seem to be in the lower stratosphere, where ozone depletion usually occurs in the Antarctic vortex.

**P-3-53**

LIDAR MEASUREMENTS OF THE SEASONAL VARIATION OF WATER VAPOUR IN THE TROPOSPHERE AND LOWER STRATOSPHERE FROM A MIDLATITUDE STATION

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**Abstract:** Lidar measurements of water vapour mixing ratio in the troposphere and lower stratosphere have been made on a regular basis from the Delaware Observatory outside of London, Ontario (42.9°N, 81.4°W) since 1999 using the vibrational-Raman-scattering technique. Due to the high power-aperture product of the Purple Crow lidar, these measurements extend to altitudes greater than 15 km for integration periods of about 6 hours, with a vertical resolution of 250 m. The measurements are calibrated nightly using routine radiosonde measurements of water vapour from Detroit, Michigan and Buffalo, New York. We will show the seasonal and annual changes in the observed water vapour mixing ratio determined from these measurements.

**P-3-54**

FAST VERTICAL TRANSPORT OF HUMID AIR INTO THE UPPER TROPOSPHERE IN EXTRATROPICS: M-55 GEOPHYSICA WATER VAPOUR OBSERVATIONS.

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**Abstract:** We present some results of humidity measurements by FLASH (gaseous phase) and FISH (gaseous and condensed phase) hygrometers on the board of M-55 Geophysica aircraft obtained during the flight performed on 17 October 2002 in Italy. Two instruments are in good agreement in case of cloudless. During the flight leg on the fixed aircraft altitude (230 mb) in the upper troposphere the significant increase of water vapour (from 30 ppmv to 80 ppmv) has been measured by both instruments. FISH has registrated at that time the condensed phase of water as well. The temperatures were above the dew point, hence the condensation during the measurements can be excluded.

Applied trajectory analysis showed that this increase was caused by fast transport of humid air from the boundary layer into the upper troposphere. This is typical example of warm conveyor belt, which provides the presence of air masses with different chemical composition near the tropopause. ECMWF humidity data interpolated to the route of the aircraft also exhibit the rapid change of humidity in that region.

**P-3-55**

ANALYSIS OF THE FEBRUARY 2002 STRATOSPHERIC WARMING USING SABER DATA

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**Abstract:** The Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument began acquiring data in January 2002. The Version 1.04 Level 2A temperature data have been compared with correlative data sources (*e.g.* satellite experiments, lidar, and falling spheres). These results generally show very good agreement in the stratosphere. Synoptic temperature distributions have been generated from the SABER data using a sequential estimation technique, which was developed for use with the NIMBUS 7 LIMS data. From these temperature distributions, corresponding synoptic fields of geopotential height can be calculated from which geostrophic winds can be derived. The evolution of the lower stratosphere of the Northern Hemisphere during the warming of February 2002 will be analysed using these SABER data. The fidelity of the SABER analysis will be evaluated by comparisons with assimilated data fields for the same period.

**P-3-56**

## ANALYSIS OF WATER VAPOUR LIDAR MEASUREMENTS DURING THE MAP CAMPAIGN: EVIDENCE OF SUB-STRUCTURES OF STRATOSPHERIC INTRUSIONS

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**Abstract:** This paper presents the analysis of dehydration in the free troposphere measured by Raman lidar in the Northern-Italy during the Mesoscale Alpine Programme (MAP). Two case studies presenting horizontal dry layers were analyzed using Lagrangian techniques. These events are related to upper-tropospheric Potential Vorticity streamers crossing the Alpine ridge and were interpreted as small-scale features of stratospheric intrusions associated to the PV ridge during its break-out phase. The water vapour concentration also indicates dilution processes of dry stratospheric air in the troposphere. The Lagrangian simulation approach allowed to successfully reproduce the observed water vapour distribution and the air parcel histories confirmed the stratospheric origin of the dry layers.

**P-3-57**

## A STATE OF THE SOUTHERN SUBTROPICAL BARRIER DURING THE 2003 AUSTRAL WINTER, DEDUCED FROM ERTEL POTENTIAL VORTICITY AND CHEMICAL TRACER MEASUREMENTS

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**Abstract**: The subtropical dynamical barrier, located in the lower stratosphere on the edge of the Tropical Stratospheric Reservoir (TSR), controls and limits exchanges between tropical and extratropical stratospheres. The concentration of species varies strongly depending on whether measurements are performed in or out of the TSR.

From ECMWF data reanalysis (Potafaix *et al* 2003) have shown that in the Southern Hemisphere, the subtropical barrier is located in the 15-30 latitude range and have found a steadily seasonal variations well modulated by the equatorial quasi-biennale oscillation.

The present work examines the southern subtropical barrier location in the lower stratosphere during the 2003 austral winter, from June to September. Position of the barrier is obtained from the original code DYBAL (DYnamical BArrier Location, Portafaix *et al.*, 2003) applied to a conservative tracer field and using surface coordinates. Nakamura diagnostic tools (Nakamura *et al.*, 1996) - tracer gradient and equivalent length of the tracer contour - are used simultaneously in DYBAL. Dynamical and chemical tracer fields are both used to obtain barrier localisation and results are compared. Ertel Potential Vorticity (PV) calculated from ECMWF reanalyses is used and combined with observational chemical field retrieved from instruments on board ENVISAT or ODIN satellite.

In addition to the barrier location in the winter hemisphere, where quasi-horizontal exchanges may take place because of the wave activity increase, this work allows us to assess and to extend the classical approach based on PV fields computed from assimilated data.

**P-3-58**

## INFLUENCES OF INERTIA GRAVITY WAVES ON ANTARCTIC POLAR STRATOSPHERIC CLOUDS AND CHEMICAL OZONE DEPLETION

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**Abstract:** Polar Stratospheric Clouds (PSCs) were observed by a Rayleigh lidar at Davis, Antarctica (69°S, 78°E) during the austral winters from 2001 to 2003. The clouds were detected between June and September each year, and showed considerable variation in their day-to-day characteristics and altitude range. Daily altitude-time images of 532 nm backscatter ratio often revealed persistent wavy laminated structures, with phase fronts that predominantly propagated downwards. PSC sedimentation histories were modelled using the Danish Meteorological Institute microphysical PSC model and the British Atmospheric Data Centre trajectory model. The range of vertical particle velocities obtained from this analysis was about an order of magnitude smaller than inferred vertical velocities of the laminated PSC structures, suggesting that sedimentation was not the major controlling influence on these features. A wavelet technique was used to infer the vertical location and characteristics of inertia gravity waves from concurrent high resolution radiosonde measurements. Based on the characteristics of the waves, it is shown that they are probably generated by synoptic scale processes in the UT or LS. Where temperatures were between the expected frost points of water ice and nitric acid trihydrate, a close association was observed between the location of cloud features and wave packets, showing that rapid decay and growth of particles associated with type I PSCs can be driven by the gravity wave field. The implications of this result for chemical ozone depletion is investigated using a series of concurrent lidar and ozonesonde measurements made at Davis during 2003.

**P-3-59**

## THE IMPACT OF AEROSOLS AND MESOSCALE GRAVITY WAVES ON CIRRUS CLOUDS AT MIDLATITUDES

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**Abstract:** We use a Lagrangian microphysical aerosol-cloud model to study cirrus clouds along trajectories at Northern Hemisphere midlatitudes. We focus on the role of mesoscale gravity waves in ice formation and the indirect effect of heterogeneous Ice Nuclei (IN) on cirrus clouds. The presentation will address the following findings:

(1) Most cirrus form in synoptic cold pools, but with microphysical properties determined by mesoscale variability in vertical velocities; (2) The key effect of IN is a reduction of the number of ice crystals in cirrus. IN present in concentrations probably typical for northern midlatitude background conditions (about 0.01 pcc) significantly modify cirrus properties but do not control cirrus formation; (3) At high concentrations (above 100 pcc), IN become the controlling factor in cirrus formation, diminishing the role of homogeneous freezing; (4) IN with freezing thresholds near ice saturation are capable of introducing very strong changes of cloud properties, even at low concentrations; (5) Changes in upper tropospheric cooling rates and ice-forming aerosols in a future climate may induce changes in cirrus occurrence that are comparable in magnitude to observed decadal trends in global cirrus cover.

Concerns have been raised that IN could influence cold clouds and thereby contribute to climate change. This study narrows the ranges of freezing conditions and number concentrations of IN to exert a significant indirect effect, and provides quantitative estimates of IN-induced changes in cirrus and coverage. Although significant progress has been made in the treatment of cirrus clouds in global (climate) models, a final assessment is not yet possible owing to the lack of knowledge about distribution and freezing properties of IN.

**P-3-60**

# OPERATION OF BACKSCATTER LIDAR AT BUENOS AIRES (34.6°S-58.5°W) FOR THE RETRIEVAL AND ANALYSIS OF THE ATMOSPHERIC PARAMETERS IN CIRRUS CLOUDS, TROPOSPHERIC HEIGHT AND AEROSOLS LAYER

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**Abstract:** Since August 1995 a backscatter lidar station was implemented at Buenos Aires (34.6°S, 58.5°W) for climate application and regional process studies taking place at southern mid-latitudes. The latest objective is to monitor the cirrus cloud properties, aerosols layer presence and atmospheric boundary layer (ABL) structure on the long term. The lidar operates at 532 nm, making a direct comparison of the optical properties with other data bases available around the world. Since August 2000 the backscatter lidar station was improve adding another small telescope to extend the dynamic range. The new system can sense simultaneously the atmospheric parameters located in the whole troposphere, starting from 50 m above the ground into the low stratosphere (less than 27 km). The lidar signal lets us measure in real time the: tropospheric aerosols (optical parameters and radiative properties), stratospheric aerosols presence, tropopause height and cirrus clouds evolution (backscatter coefficient and optical depth statistics) and the time series evolution of the atmospheric boundary layer (ABL). Finally we present different measurements of cirrus clouds, tropopause height and aerosols layer, under different climatologically conditions.

**P-3-61**

# ANALYSIS OF UT/LS TRANSPORT BASED ON DATA ASSIMILATION OF MIPAS MEASUREMENTS

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**Abstract**: The transport behaviour in the UT/LS dynamical barriers is analysed from the MIPAS assimilated water vapour and ozone. The approach is based on the isentropic transport model (MIMOSA) the combination of the high resolution tracer fields and satellite measurements allows to better quantify the tracer distribution and follow continuously its evolution. We present an assessment on the potential of this approach for the study of the dynamical barriers behaviour and a further analysis of meridional dry air transport between middle latitudes and tropics.

**P-3-62**

## A 15-YEAR CLIMATOLOGY OF STREAMERS AND CUTOFFS AND THEIR RELATION TO CROSS-TROPOPAUSE MASS EXCHANGE

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**Abstract:** Stratospheric streamers are extrusions of stratospheric air (*i.e.* air with potential vorticity larger than 2 pvu) towards the south. Often these streamers completely cut off from the stratospheric reservoir and then exist as isolated regions with stratospheric air within a tropospheric surrounding (so-called stratospheric cutoffs). In an analogous way, tropospheric streamers and cutoffs can be defined.

Streamers and cutoffs indicate regions with enhanced dynamics near the tropopause (so-called Rossby wave breaking), and are, thus, in themselves of great interest. Additionally, they are often associated with other processes. Stratospheric streamers, for instance, are often linked with heavy precipitation events to the south of the Alps, and they often induce cross-tropopause mass exchange (STE) through their boundaries.

In this study, a 15-year climatology of streamers and cutoffs is presented (based upon the ERA-15 data set). They are identified on isentropic surfaces from 290 K to 360 K. The resulting geographical distributions show a pronounced seasonal and zonal variability. The position of the maxima shifts also in dependence of the isentropic surface. At 320 K, for instance, a clear winter maximum is found over the Mediterranean and near the west coast of northern America. In the subtropics (at 360 K) a pronounced band of stratospheric cutoffs extends from the Mediterranean to the east coast of Asia.

A detailed analysis of the lifecycles of individual streamers and cutoffs reveal their source and sink regions. For instance, the many summer cutoffs in the subtropics are form to the east of Asia and are then advected by easterlies towards the west up to the Mediterranean region. Finally, a detailed investigation of the surrounding of each streamer in the immediate future allows estimating how often a streamer really cuts off or is reabsorbed into the stratospheric reservoir.

In a final step, the streamer and cutoff climatology is used to estimate their importance for STE. For that aim, a 15-year climatology of STE (based upon a Lagrangian approach) with equal temporal resolution (6 hours) is considered. It is then checked whether any streamer or cutoff occurs in the near vicinity (temporal and geographical) of an STE event. This approach yields a simple count statistics for the link between the two dynamical features. The resulting high percentages of STE events with a nearby streamer or cutoff (up to 50 %) indicate the eminent importance of streamers and cutoffs for cross-tropopause exchange.

**P-3-63**

## LAGRANGIAN TURBULENT DIFFUSION IN THE LOWER STRATOSPHERE

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**Abstract:** A stochastic Lagrangian transport model is used to reconstruct the small scale structure of chemical tracers in the lower stratosphere. Unlike standard deterministic reconstructions this procedure yields results that converge in time. The comparison with airborne measurements of $O_3$ and $N_2O$ performed by the NASA ER-2 during SOLVE campaign provides an estimate of turbulent diffusivity within and around the polar vortex based on a roughness measure and on the profile of well identified structures like the edge of the vortex or filaments. The resulting estimates for the diffusivity are usually of the order of 0.01 $m^2$/s or less, except in the shear zone of the vortex edge. It is also observed from the evolution of filaments that large variations of Lagrangian diffusion occur at the mesoscale that cannot be accounted by variations of the Lagrangian strain, and are perhaps associated with breaking gravity waves. We hope to present additional results from the CRYSTAL-FACE campaign in the subtropics.

**P-3-64**

## IDENTIFYING TRANSPORT MECHANISMS OF AIR INTO THE SUBTROPICAL MIDDLEWORLD DURING THE SUMMERTIME

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**Abstract:** Different pathways that transport air into the subtropical middleworld are identified using *in situ* measurements of various chemical tracers along with back trajectories. We use measurements of water vapour, ozone, nitric oxide, total odd nitrogen, and carbon monoxide obtained during the Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE) campaign during July of 2002. We focus this study on the middleworld, the region in the stratosphere bounded from below by the local tropopause, which was found around the 360 K isentrope over Florida during the month of July, and from above by the 380 K isentrope, which nominally corresponds to the tropical tropopause. The high spatial and temporal resolution that *in situ* measurements provide allow us to develop a time series containing both the strength and the region of influence within the middleworld of various transport mechanisms of air. Correlation plots of tracers with respect to water vapour in clear air show evidence of three major transport mechanisms that bring air into the subtropical middleworld, namely equatorward transport of stratospheric air from high latitudes, poleward transport of upper tropical tropospheric air, and convectively driven transport from both local and non-local events. The first mechanism is observed to bring air to the entire region throughout the month of July, the second mechanism is observed to affect the upper part of the region (370 K to 380 K) during the end of the month only, and the third mechanism is evident throughout most of the region during the entire month of July. The transport mechanisms identified by tracer: water vapour correlations are checked against 3D back trajectories, which show consistency in both the origin of the air sampled over Florida and the timing of the dominant large-scale transport. These results provide new insights into the spatial and temporal resolution of the dynamics of the subtropical middleworld during the summertime. Understanding the dynamics of this region of the atmosphere is crucial for predicting the radiative and chemical impacts of long-term changes in ozone and water vapour in the stratosphere.

**P-3-65**

## SAGE II LOWER STRATOSPHERIC/UPPER TROPOSPHERIC OZONE CLIMATOLOGY

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**Abstract:** The Stratospheric Aerosol and Gas Experiment (SAGE) II satellite mission has been providing high quality profile ozone measurements since its launch in October 1984. The measurements extend downward through the middle atmosphere to cloud top with a vertical resolution of better than 1 km. These observations (Version 6.2) are used to describe the monthly zonal-mean variation of the ozone in the upper troposphere and lower stratosphere at mid latitudes. In general, the climatology reveals the presence of a strong vertical gradient across the tropopause that follows its latitudinal variation in the Northern Hemisphere. Weak enhancements in the upper troposphere are also observed near 40°N in spring (March-June). The distribution in the Southern Hemisphere differs with a weaker ozone gradient across the tropopause and greater enhancements in ozone found below it in spring. A focus of this study is on a comparison of the SAGE II climatology with observations from the ozonesonde and MOZAIC data sets and on Northern Hemisphere/Southern Hemisphere differences.

**P-3-66**

## A CLIMATOLOGICAL STUDY OF THE ARCTIC UT/LS REGION, WITH SPECIAL EMPHASIS ON NORTHERN SCANDINAVIA

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**Abstract:** In collaboration with research groups from Germany, Sweden and Finland, the Arctic Upper Troposphere/Lower Stratosphere (UT/LS) project has started in 2003. The main objectives of this study are to further characterise the Arctic tropopause trends, using the most recent comprehensive meteorological dataset from the European Centre for Medium-Range Weather Forecast (ECMWF) and local meteorological measurements from radiosondes, ozonsondes, lidar and radar at high-latitude stations, and to achieve understanding of the processes leading to the high variability of the Arctic tropopause and Arctic UT/LS temperatures in the last decade. Besides improving the quality of trend studies, the 1990s/early 2000s data set will be utilized to investigate Arctic stratosphere-troposphere coupling processes based on the thermal structure throughout the UT/LS region, with emphasis on their dependence on hemispheric circulation patterns and wave propagation conditions. Furthermore, an investigation of meso-scale tropopause properties including stratosphere-troposphere exchange processes in the vicinity of the Scandinavian mountain ridge is planned.

Here, we present a general overview of Arctic UT/LS projects and first geophysical outcomes. From the newest subset of re-analysed (ERA40) data from the ECMWF, covering the time period between 1990 and 08/2002, thermal tropopause fields for the Arctic region north of 60°N have been generated. These data, as well as *e.g.* pressure fields on 2 PV surface, have been further analysed to see whether the data from the 1990s and early 2000s show trends in tropopause properties, and how they compare with reported trends from before 1990. Further, we investigate the question whether the tropopause in the Scandinavian mountain ridge region shows a systematic bias compared to zonally averaged characteristics due to regional peculiarities. Here we present case studies from periods with potentially strong coupling, *e.g.*, strong wave activity and a cold lower stratosphere/strong vortex during winter, and periods with rapid changes in tropopause characteristics, *e.g.*, late summer when the sub-Arctic tropopause rises from typically 10 to 12 km altitude or even more. Data from MST radars located in Northern Scandinavia (Kiruna/Andenes) and, for comparison on Svalbard, are utilised for this investigation.

**P-3-67**

## STRATOSPHERE-TROPOSPHERE EXCHANGE IN EAST ASIA: SEASONAL VARIATION AND MAJOR PROCESSES BY USING NCEP DATA

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**Abstract:** To understand quantitatively the Stratosphere-Troposphere Exchange (STE) and those major processes, computation of cross tropopause flux (CTF) are made based on NCEP data. The results show that the East Asia region play important role to the global STE. For example, for the whole year of 2000, the annual mass exchange over the region of east Asia (30-60°N, 100-150°E) is about -1.7x10^17kg, *i.e.*, strong transport from the stratosphere to the troposphere. This value accounts for 29% of the net exchange of the whole Northern Hemisphere in that year, but the area of this region only accounts for 5.6% of the Northern Hemisphere. In this paper, we will present the detailed analysis about the seasonal variation of STE in the East Asia, the function of east Asia monsoon, the regional difference of STE, the major process relating to the upward transports (from troposphere to stratosphere) and the downward transports (from stratosphere to troposphere). These results will be discussed with numerical simulation and other observation data.

**P-3-68**

## EFFECTS OF THE BAROCLINIC ACTIVITY ON THE TROPOPAUSE STRUCTURE

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**Abstract:** The nature of the tropopause and which mechanisms could effectively maintain and modify this atmospheric region are interesting issues for an accurate comprehension of the climate system. Moreover, the tropopause height has been considered, recently, as useful fingerprint for the global climate change. In this framework, we analyse the global observed tropopause structure relating the observed features with a theory of baroclinic adjustment and focusing on the effects of the baroclinic eddies on the mean tropopause height. To investigate the effects of this kind of perturbations in terms of the mean tropopause, we introduce an appropriate global index to determine events of high baroclinic activity in winter periods. By using this index we individuate in which days baroclinic waves develop and decay in the winter periods. So, we compare the tropopause mean structure before and after a baroclinic event. We find out that baroclinic disturbances cause, in the mean, a rise in the zonally averaged midlatitude tropopause of both hemispheres and also influence the eddy field of the midlatitude tropopause structure, particularly in the Northern Hemisphere.

**P-3-69**

## STRATOSPHERIC CHEMISTRY OF THE ANTARCTIC WINTER 2002: GOME OBSERVATIONS EXPLAINED BY A 3D-CTM

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**Abstract:** The GOME observations allow retrieval of $O_3$ and $NO_2$ vertical column densities, as well as OClO and BrO slant column densities. These global measurements have a high temporal and spatial resolution, allowing a detailed study of the chemical evolution of the stratosphere during the unusual winter 2002 in the Southern Hemisphere.

BASCOE, a 4D-VAR assimilation system developed for analysis and forecast of the stratospheric chemistry, is built around a three-dimensional chemistry-transport model with 57 chemical species and complete modelling of microphysical processes related to Polar Stratospheric Clouds. We have implemented a GOME observation operator into this 3D-CTM, to compare quantitatively its output with GOME observations, taking into account fast chemical processes and slant column geometry for BrO and OClO.

The excellent agreement confirms that a complete chemical model is able to forecast the evolution of lower stratospheric chemistry several months in advance, as long as it is driven by operational analyses of the wind fields. This ability is not limited to the ozone column: the model reproduces correctly chlorine activation as indicated by OClO slant columns, and the peculiar evolution of the $NO_2$ vertical column during the 2002 splitting vortex event.

**P-3-70**

STRATOSPHERIC AND UPPER TROPOSPHERIC WATER VAPOUR OBSERVATIONS AT SODANKYLÄ, FINLAND

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**Abstract:** In Sodankylä (67.4°N, 26.6°E) altogether thirty-five balloon flights of several light-weight water vapour sensors took place during the period January 29 - February 26, 2004. This research was motivated by the need to improve the quality of water vapour measurements in the UT/LS by balloon-borne instruments. The payloads included RS80-A, RS-90 and RS-92 radiosondes manufactured by Vaisala Oy, FN- sonde (a modified version of RS-90 radiosonde by Lindenberg Observatory, Germany) and a chilled mirror hygrometer by Meteolabor, Switzerland (SW-sonde). 12 larger payloads included RS80-A, RS80-H, RS-92, FN-sonde, SW-sonde, NOAA or CFH frost-point hygrometer and FLASH-B Lyman alpha hygrometer. In this study we focus on the performance of two relatively new instruments: FLASH-B hygrometer and RS-92. Data from both instruments are compared with the measurements by NOAA frost-point hygrometer and the chilled mirror hygrometer manufactured by Meteolabor, all flown in the same payload. RS-92 is the newest radiosonde type by Vaisala Oy, the manufacturer of the majority of operational radiosondes. Wider use of this instrument is expected to improve the UT humidity measurements by radiosonde network in the future. FLASH-B is a Lyman-alpha fluorescence hygrometer that has been developed by the Central Aerological Observatory in Moscow, Russia. In Sodankylä 14 flights of the instrument were performed and the results indicate that the instrument is capable of good measurements in the stratosphere.

**P-3-71**

OBSERVATIONS AND EXPLICIT SIMULATIONS OF EXTRATROPICAL SOURCES OF MIDDLE-ATMOSPHERIC MESOSCALE GRAVITY WAVES ASSOCIATED WITH TROPOSPHERIC BAROCLINIC JET-FRONT SYSTEMS

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**Abstract**: Mesoscale gravity waves originated from baroclinic jet-front systems have important implications to stratospheric dynamics and ozone chemistry. Compared to commonly observed orographic gravity waves, these waves are less studied in literature, especially in the upper troposphere and lower stratosphere. In this study, we will first present the generation of gravity waves during the life cycle of an idealised baroclinic wave through multiply-nested mesoscale numerical simulations with horizontal resolution up to 3.3 km. Long-lived vertically-propagating mesoscale gravity waves with horizontal (vertical) wavelengths about 150 (2.5) km and intrinsic phase speed of about 8 m/s simulated originating from the exit region of the upper-tropospheric jet streak. The imbalance diagnosis and model simulations suggest that balance adjustment, as a generalization of geostrophic adjustment, is likely responsible for generating these mesoscale gravity waves. It is hypothesized that, through balance adjustment, the continuous generation of flow imbalance from the developing baroclinic wave will lead to the continuous radiation of gravity waves.

The significance of the baroclinic jet-front systems to the variability of the middle-atmospheric gravity waves in the real atmosphere is analyzed with observations from the NOAA AMSU-A (Advanced Microwave Sounding Unit-A) radiance measurements over North America and the Atlantic Ocean during January of 2003. Analyses of these observations provide detailed information on the horizontal variations of middle-atmospheric gravity waves: besides the geographical modulation especially above regions of significant topography, these middle-atmospheric gravity waves are strongly correlated with the intensity and location of the tropospheric baroclinic jet-fronts systems.

A state-of-the-art mesoscale model has been used to explicitly simulate several episodes of enhanced gravity wave activities identified from the above observations (*e.g.*, January 7-10 and January 18-20, 2003). The simulated middle-atmospheric gravity waves compared qualitatively well with the satellite observations. Moreover, high-resolution explicit simulations allow us to identify four likely source mechanisms of middle-atmospheric gravity waves associated with extratropical tropospheric baroclinic jet-front systems: (1) topographically-forced waves due to jet streaks incepted by large terrains, (2) adjustment-forced waves due to strong flow imbalance associated with the upper-tropospheric jet streaks, (3) diabatically-forced gravity waves due to moist convection induced by baroclinic waves and, (4) frontally-forced gravity waves due to frontal collapse near the surface. The last three mechanisms are transient in nature and often inseparable from each other. Explicit simulations also enable us to assess qualitatively the momentum fluxes from different sources and their relative importance.

**P-3-72**

# DEHYDRATION IN WINTER ARCTIC TROPOPAUSE REGION

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**Abstract:** Recent work has shown that limited amounts of tropospheric air can penetrate as much as 1 km into the lowermost stratosphere during the arctic winter. This, coupled with temperatures that are cold enough to produce saturation mixing ratios of less than 5 ppmv at the tropopause, results in stratospheric cloud formation and upper tropospheric dehydration. Even though these cold outbreaks occupy only a small portion of the area in the arctic (a few percent), their importance is magnified by an order of magnitude because of the air flow through them. This is reinforced by evidence of progressive drying through the winter measured during the NASA SOLVE field experiment in the 1999-2000 winter. The significance of this process lies in its effect on the upper tropospheric water content of the middle and high latitude tropopause region, which plays an important role in regulating the earth's radiative balance. Notably, there appears to be significant year-to year variability in the incidence of these cold outbreaks.

This work has two parts. First, we describe case studies of dehydration taken from the SOLVE and SOLVE-II aircraft sampling missions conducted by NASA during the Arctic winters of 2000 and 2003 respectively. Trajectory based microphysical modelling is employed to examine the sensitivity of the observed dehydration and particle size distributions to microphysical parameters and the nature of sub-grid-scale temperature fluctuations along the trajectories. Second, we examine the year-to-year variations in potential dehydration using trajectory climatologies.

**P-3-73**

# TOTAL OZONE TRENDS WITHIN METEOROLOGICAL REGIMES: THE SOUTHERN HEMISPHERE

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**Abstract:** It has been shown previously that the Northern Hemisphere total ozone field can be classified by meteorological regimes. Satellite and sonde data indicate that each regime is characterised by relatively constant total ozone and tropopause height. A similar approach has been followed to classify the total ozone field for the Southern Hemisphere where global ozone data from TOMS instruments have been used to locate the upper level jets and, therefore, the regimes boundaries. In this case, however, vertically integrated potential vorticity from the reanalysis data from NCEP/NCAR and ECMWF have been used to estimate the first guess for the ozone boundary values. The results are validated by the use of rawinsondes and SAGE data.

For the period Jan/79-May/91, ozone trend analysis shows that the decadal trends within each regime are smaller than the overall trend between 25 and 60°S when the analysis is performed without any classification. The analysis also shows changes in the relative areas of the tropical and polar regimes during this period of time. Both processes, changes in total ozone within each regime, as well as changes in their contribution to the 25-60°S band, are responsible for the overall trend in that region. The results for the period indicate, as in the case of the Northern Hemisphere, that the upper-level jets have migrated poleward during this period of time.

**P-3-74**

EVIDENCE OF THE EFFECT OF SUMMERTIME MIDLATITUDE CONVECTION ON THE SUBTROPICAL LOWER STRATOSPHERE FROM CRYSTAL-FACE TRACER MEASUREMENTS

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**Abstract:** Trace gas and particle measurements taken during the Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE) mission are used to examine mixing in the summer subtropical lower stratosphere. Vigorous convection in the central and eastern U.S. injected a significant amount of tropospheric air into the lower stratosphere, which was subsequently advected over the region sampled during the CRYSTAL-FACE mission. The coincident occurrence of a large number of forest fires in the western U.S. and eastern Canada contributes to the analysis by providing evidence of convective injection of tropospheric air into the lower stratosphere. The circumstances of the large-scale flow pattern in the upper troposphere and lower stratosphere, vigorous summertime convection, abundant forest fires and the downstream sampling allow a unique view of mixing in the lower stratosphere. We calculate the fractions of midlatitude tropospheric air in the sampled lower stratosphere and mixing rates based on consistency between a number of tracer-tracer correlations. The tropospheric endpoints to the mixing estimates give an indication of midlatitude continental convective input into the lower stratosphere. We will also discuss the possible impact of summertime midlatitude convection on the composition of the stratosphere as a whole.

**P-3-75**

SEASONAL CYCLE AND VERTICAL STRUCTURE OF CROSS-TROPOPAUSE TRANSPORT DETERMINED FROM SAGE II DATA

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**Abstract**: Analysis of ozone and water vapour data from the Stratospheric Aerosol and Gas Experiment II (SAGE II) show the seasonal variations and vertical structure of cross-tropopause transport in the midlatitudes and subtropics. Using the ozone and water vapour tracer qualities in the tropopause region and their inherently different abundances in the stratosphere and the troposphere, we identify air that crossed the tropopause by searching for air with stratospheric concentrations in the troposphere and tropospheric concentrations in the stratosphere. The results reveal spatial and temporal characteristics of Stratosphere-Troposphere Exchange (STE) processes. Results show active stratosphere to troposphere transport particularly in the winter and spring hemisphere with a minimum in the summer. This is attributed to the relatively high activity of baroclinic systems during winter and spring. Troposphere to stratosphere transport is more active in the Northern Hemisphere particularly during the summer. Greater STE activity was observed along the region influenced by the meandering polar jet than by the relatively stable subtropical jet. Vertical structure shows that the troposphere to stratosphere transport peaks at the 350 K potential temperature surface and continues to be observed at higher altitudes while the stratosphere to troposphere transport peaks at the 330 K surface and continues to be active at 300 K. All the results complement general knowledge as well as specific findings reported in the literature. In this paper, the data analysis approach, results and interpretations of this investigation will be discussed.

**P-3-76**

## MEASUREMENTS OF TRACE CONSTITUENT PROFILES USING SCIAMACHY

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**Abstract:** SCIAMACHY (Scanning Imaging Absorption spectrometer for Atmospheric CHartographY) is a national contribution from Germany, The Netherlands and Belgium to the European Space Agency ENIVSAT platform. The latter was launched into a sun synchronous low earth orbit with an equator crossing time of 10:00 a.m. SCIAMACHY observes scattered light from the atmosphere between 220 and 2380 nm. Its measurements when suitably inverted yield profiles of $O_3$, $NO_2$, BrO, OClO, $H_2O$ and $CH_4$. This presentation will describe results from SCIAMACHY limb and occultation measurements of relevance to stratospheric chemistry.

**P-3-77**

## TROPOSPHERE-TO-STRATOSPHERE TRANSPORT AND ITS IMPACT ON LOWERMOST STRATOSPHERIC $NO_Y$ AND $O_3$

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**Abstract:** In the framework of SPURT (trace gas transport in the tropopause region) high resolution measurements of $NO_y$, NO and $O_3$ beside other trace gas species were performed. 36 mission flights were seasonally distributed between November 2001 and July 2003 and covered a broad latitudinal range from 30-75°N over Europe. The established data set allows investigating the role of dynamical and chemical processes shaping the structure of the extratropical tropopause region.

We present analyses of the new data set including comparisons with former measurements, model calculations and tracer correlations between $NO_y$, $N_2O$, and $O_3$. The correlations between $NO_y$ and $N_2O$, as well as between $O_3$ and $N_2O$ reveal pronounced seasonal cycles but no latitudinal dependence, whereas the slope of the correlation between $NO_y$ and $O_3$ is variable from year to year. Their slopes are controlled in winter and spring by downward transport of aged stratospheric air, whereas in summer and autumn the influences through troposphere-to-stratosphere transport by isentropic and diabatic mixing mechanisms gain in importance. While in winter/spring TST tends to decrease $NO_y$-mixing ratios due to the lower $NO_y$ loading of tropospheric air, in summer/autumn it results in a significant increase, possibly due to in-mixing of air affected by lightning. Both cases are leading to strong deviations from expected correlations as generally found in the stratosphere. Reactive nitrogen plays, however, a pivotal role in the local $O_3$-chemistry influencing the radiative budget of the atmosphere and, hence, the related climate change. A main focus is therefore, the assessment of $NO_y$ sources other than stratospheric $N_2O$ degradation, namely aircraft emissions, lightning-induced production, or convectively transported polluted planetary boundary layer air and subsequent mixing into the stratosphere and their influence on local $O_3$ production or loss.

**P-3-78**

## AIRBORNE *IN SITU* OBSERVATIONS IN THE 2002/2003 ARCTIC VORTEX: ANALYSIS OF DESCENT, MIXING AND OZONE LOSS

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**Abstract:** During the VINTERSOL/EUPLEX and the ENVISAT Arctic Validation Campaigns the M55 Geophysica aircraft performed 15 flights inside and outside the Arctic Vortex from Kiruna, Sweden, between mid January and mid March 2003. The University of Frankfurt's High Altitude Gas Analyser (HAGAR) simultaneously measured $N_2O$, F11, F12, H1211, $CH_4$, SF6, $H_2$, and $CO_2$ on board the aircraft. Ozone was measured by the Fast Ozone Analyser (FOZAN). An early winter reference for ozone and various tracer profiles is provided by a balloon flight of the Mark-IV instrument launched from Kiruna in mid December 2002 during the NASA SOLVE II campaign.

We analyse descent, mixing and ozone loss in the Arctic vortex up to mid March 2003 using the airborne data. The observed $N_2O$ mixing ratio as a function of potential temperature is used to distinguish between true vortex air and extra-vortex air for each flight. Vortex descent can be derived to first order from the evolution of the vertical tracer profiles inside the vortex. Mixing-in of extra-vortex air or mixing within an inhomogeneously descended vortex manifests itself in changes of non-linear tracer correlations. Such changes are clearly observed in *e.g.* the F11-$N_2O$ correlation, particularly after the vortex split into two pieces and reformed in late February. Cumulative ozone loss is derived from the $O_3$-$N_2O$ and $O_3$-$CO_2$ relations and compared with that from the winter 1999/2000.

**P-3-79**

## EVALUATION OF UT/LS LOSS PROCESSES OF PEROXYNITRIC ACID ($HO_2NO_2$)

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**Abstract:** Nitrogen containing compounds ($NO_x$ and $NO_y$) play an important role in the chemistry of the troposphere and stratosphere. Peroxynitric acid ($HO_2NO_2$ PNA), an $NO_y$ species, is a reservoir for both $NO_x$ (=NO and $NO_2$) and $HO_x$ (=HO and $HO_2$). Therefore, PNA plays an important role in the atmosphere.

Association of $NO_2$ with the hydroperoxyl radical ($HO_2$):

$HO_2 + NO + M \leftrightarrow HO_2NO_2 + M$ (1, -1)

is the source of PNA in the atmosphere. PNA is removed from the atmosphere by thermal decomposition (reaction (-1)), photolysis (UV and IR) and reaction with

OH (reaction with OH is also a sink for $HO_x$):

$HO_2NO_2 + h\nu \rightarrow HO_2 + NO_2$ (2a)

$\rightarrow OH + NO_3$ (2b)

$OH + HO_2NO_2 \rightarrow H_2O + O_2 + NO_2$ (3a)

$\rightarrow$ Other products (3b)

In the upper troposphere and the lower stratosphere (UT/LS), the PNA concentration is significant due to its slow thermal decomposition, reaction (-1) at the colder temperatures of this region. The ability to model PNA in the UT/LS has been limited by the uncertainties associated with the various PNA loss processes. We have recently addressed the uncertainties in the loss processes through a series of quantitative laboratory studies.

The results of our studies on the kinetics of OH radicals with PNA in the gas-phase as a function of temperature, the branching ratio for reaction (3), the rate coefficients for the thermal decomposition of PNA, and the UV and IR photolysis will be presented. The atmospheric implications will be discussed.

**P-3-80**

## OZONE INTRUSION EVENTS AND THEIR EFFECT ON CLIMATE OVER THE EASTERN MEDITERRANEAN

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**Abstract**: Analysis of Ozone measurements during 1994-2003 from commercial flights within the EC MOZAIC (Measurement of OZone and water vapour by Airbus In-service airCraft) programme has revealed considerably high Ozone values in the summer UT/LS region over the Eastern Mediterranean. The connection of these events with both the Asian Monsoon and transatlantic transport is examined, as well as their significance on the climate within the study area.

**P-3-81**

## MODELLING OF TROPOSPHERIC DYNAMICAL FORCING LEADING TO ISENTROPIC MIXING IN THE STRATOSPHERE: A NEW APPROACH

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**Abstract**: One aspect relevant to possible climate change is the transport and mixing of mass and chemical species in the stratosphere. Over the past ten years, there has been increasing recognition of the heterogeneous nature of stratospheric transport and mixing. Especially, there exist partial barriers to transport that may be quasi-permeable at least some of the time. Transport processes across these barriers are controlled by breaking of planetary wave disturbances originating from the troposphere leading to the production of tracer filaments at scales that are not fully resolved by either meteorological analyses or global 3-D numerical models. On the other hand, high-resolution transport models on isentropic surfaces are well adapted to simulate the formation and the evolution of fine-scale filaments linked with the large-scale structure of the horizontal wind field.

In the present work, we report on a new approach based on the COupled Mimosa Msdol Interactive Dynamics (COMMID) model, which comprises the MSDOL global 3-D mechanistic model coupled with the MIMOSA high-resolution advection contour model of potential vorticity (PV) on isentropic surfaces. MSDOL allowing for realistic simulations of the stratospheric large-scale circulation with a tropospheric dynamical forcing from NCEP meteorological analyses delivers the driving wind data for MIMOSA. In order to identify barriers to transport and mixing regions, we then apply the effective diffusivity diagnostic, which has been found to work better to estimate the mixing properties of tracers with the PV advected by MIMOSA than with the true PV.

Application of this approach to the modelling of the impact of planetary waves on an event of isentropic transport across the Southern subtropical barrier observed in July 2000 is also presented.

**P-3-82**

## QUANTIFYING STRATOSPHERIC OZONE IN THE UPPER TROPOSPHERE USING *IN SITU* MEASUREMENTS OF HCL

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**Abstract**: Precise *in situ* measurements of hydrochloric acid (HCl) have been made using a new Chemical Ionization Mass Spectrometry (CIMS) technique. In aircraft measurements at tropical and subtropical latitudes, minimum HCl values found in the Upper Troposphere (UT) approach zero, indicating that background HCl values are much lower than an average global estimate. However, significant abundances of HCl were observed in many UT air parcels as a result of stratosphere-to-troposphere transport events. A method for diagnosing the amount of stratospheric ozone in these UT parcels was developed using the compact linear correlation of HCl with ozone found throughout the Lower Stratosphere (LS). No other reliable method exists to quantify the stratospheric contribution to ozone in the upper troposphere with similar high precision and accuracy. Expanded use of this method will lead to improved quantification of cross-tropopause transport events and validation of global chemical transport models.

# RAPID MIXING ACROSS THE EXTRA-TROPICAL TROPOPAUSE AS OBSERVED DURING A CARIBIC BOEING 767 FLIGHT

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**Abstract:** The CARIBIC (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrumented Container, **www.caribic-atmospheric.com**) project seeks to investigate atmospheric chemistry and dynamics in the upper troposphere and the lowermost stratosphere on the basis of the measurement of variety of trace gases, aerosol, and isotopic ratios using a Boeing 767 passenger aircraft. From November 1997 to April 2002, 47 flights have been performed from south of India, southern Africa, and Caribbean Sea to Germany. In June 2004, regular flights with an Airbus A340-600 will commence.

Here we present results from one flight from Maldives to Germany, June 2000, which provided an excellent opportunity to investigate dynamic processes in the tropopause region in the mid-latitude, based on the measurement of reactive trace compounds, in particular, non-methane hydrocarbons (NMHCs). Along the flight track we observed large variability of the mixing ratios of CO, $O_3$, NMHCs, halocarbons, and ultra-fine aerosol particle (UFP) concentrations. This occurred primarily due to the frequent excursion of the aircraft between two characteristic regimes near the tropopause, the upper troposphere (UT) and the lowermost stratosphere (LS), as is shown by means of good correlations among the compounds that exhibit characteristic end-members in both regimes. Even between the alkanes (C2- C5) the one-to-one relationships exist, indicating the occurrence of rapid mixing across the tropopause. However, there are outliers with the short-lived alkanes (C4 - C5) well above the one-to-one relationship. The elevated short-lived alkanes are likely to come from the polluted boundary layer by moist deep convection as sharp increase of CO and UFP, and decrease of $O_3$ were also observed simultaneously. Taking advantage of the capture of deep convective air masses, we estimated the age of air in the tropopause region to be approximately 26 days. This estimate is the same as the age of UT air within the uncertainty. Therefore, the one-to-one relation of the alkanes and the fact that the ages of air in the UT and in the tropopause are similar suggest an occurrence of rapid mixing of air masses in the vicinity of the tropopause in the range of day or less.

# POSTER PRESENTATIONS

## THURSDAY AUGUST 5, 2004

**P-5-01**

OBSERVATIONS OF EXTREMELY LOW COLD POINT TROPOPAUSE (CPT) TEMPERATURE OVER INDIAN TROPICAL REGION DURING SUMMER MONSOON MONTHS: POSSIBLE IMPLICATIONS FOR STRATOSPHERIC WATER VAPOUR

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**Abstract:** Tropical tropopause height and temperature play an important role in Stratospheric-Tropospheric Exchange (STE). The freeze dry mechanism is generally believed to occur when the Cold Point Tropopause (CPT) temperature is lower than the critical temperature (Tc191K). This mechanism could limit the transport of water vapour from Troposphere into Stratosphere and, thus, it can be one of the factors responsible for the observed dehydration of the Stratosphere. One of the areas where such mechanism is expected to play a significant role is west Pacific region around Indonesia and there is some observational evidence to support the same. However, there are only a limited number of investigations, which examines the characteristics of tropical Tropopause over Indian region from this particular angle.

In present study observations from three campaigns carried out from number of stations in Indian Tropical region are examined. These campaigns have been carried out using Radiosonde/GPS sonde during summer monsoon and post-monsoon seasons. The observations carried out during these campaigns have provided clear evidence of the existence of CPT temperature lower than the critical temperature (Tc) of 191K. Such temperatures are observed over a wide area of 5°x5° in latitude and longitude. The coldest CPT temperatures are observed more often around local midnight hours. It is also observed that for the days, when Tcpt Tc, the temperature at CPT level is lower by 8K than what is predicated by the atmospheric model for the Indian tropical region. The lapse rate just below the CPT level for these days is also noted to be closer to dry adiabatic lapse rate indicating a rapid cooling in a narrow height range. The observations, thus, provide unambiguous evidence that freeze dry mechanism could be operating over wide area, which includes the Indian tropical region. Simultaneous UARS satellite measurements are also examined to study the change in stratospheric humidity, if any, following the observations of very cold CPT temperatures.

**P-5-02**

VHF RADAR OBSERVATIONS OF TROPICAL TROPOPAUSE AND ITS TEMPORAL VARIABILITY ASSOCIATED WITH GRAVITY WAVE ACTIVITIES

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**Abstract**: Entrance of various chemical compositions and minor constituents from troposphere to stratosphere and vice-versa take place through tropical tropopause, which play a significant role in the troposphere-stratosphere exchange/dynamics. This makes the study of temporal and spatial variation of tropical tropopause so important for understanding these processes. Generally height of tropopause is determined from radiosonde measurements, but these measurements are limited in time resolution (12 hrs) *i.e.* twice a day (0000 GMT & 1200 GMT). Thus, the studies related to short period variability of tropical tropopause, which are important for the small-scale stratosphere-troposphere exchange, are not possible using the conventional radiosonde method. It is very difficult to obtained radiosonde observation during convection and cyclone period, as the balloon would drift and such meteorological conditions play a key role in Stratospheric-Tropospheric Exchange (STE). In these situations, detection of tropopause height by using remote-sensing techniques, such as atmospheric radar, which is applicable in any of the above-mentioned weather conditions can be adapted.

In presence two different methods are utilized for the determination of tropopause height by using a VHF-radar and compare each of them with the conventionally detected tropopause height derived from Radiosonde. These methods show consistency for both diurnal and day-to-day variation in the tropopause height.

These two radar methods are utilized to examine the diurnal variations of cold-point tropopause (CPT) height over the tropical station, Gadanki (13.5°E, 79.2°N). One of the radar methods is also used for studying the short period variability of CPT tropopause height with a period of 2 to 4 hrs. These fluctuations in tropopause height are identified as oscillations due to the passage of gravity waves. The role of tropopause in the propagation of these waves is examined. The implication of the variability of tropopause in the response of gravity waves on mass and momentum flux from troposphere to stratosphere is also discussed, which opens up a new exciting area.

**P-5-03**

LONG TERM VHF RADAR OBSERVATIONS OF VERTICAL VELOCITIES AND CROSS TROPOPAUSE MASS FLUX OVER GADANKI (13.5°N, 79.2°E)

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**Abstract**: Long term vertical velocity observations over tropical region are necessary to understand various atmospheric processes such as Stratosphere-Troposphere Exchange (STE), diabatic heating convection phenomena etc. Further, the studies of cross-tropopause mass flux are very essential for understanding the transport of mass between the stratosphere and troposphere. These transports modify the budget of chemically reactive minor constituents in the lower stratosphere and upper troposphere. Thus, it is very important to study seasonal and intra-seasonal variations of such transports.

In this paper, long term vertical velocities measured by the MST radar are presented. The data collected with the MST radar during the years 1996 - 1999 have been used for the present study. Emphasis has been given to study the tropopause height variations and cross-tropopause mass flux and seasonal and intra-seasonal variations of the same are also presented.

**P-5-04**

INFLUENCE OF TROPOSPHERIC TELECONNECTION PATTERNS ON THE STRATOSPHERE IN WINTER

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**Abstract:** In polar winter, the ozone distribution in the statosphere is governed by chemical loss and dynamical redistribution. Dynamical redistribution and net supply of ozone to high latitudes is largely controlled by the propagation and dissipation of waves with tropospheric origin, which are subject to tropospheric climate variability. Our study focuses on the impact of such variability, as deduced from NCEP/NCAR monthly mean reanalyses from 1948-2002, on the circulation and ozone distribution in the stratosphere. The dominant tropospheric teleconnection patterns were identified by applying rotated EOF-analyses to the geopotential height at the 500 hPa level. The Principle Components (PC) of the individual EOF patterns are used as indices of tropospheric climate variability. We show significant correlations between individual PCs and the geopotential height, temperature, and wind fields on various stratospheric levels, clearly showing the impact of tropospheric variability on the stratosphere. For some of the teleconnection patterns, *i.e.* the Polar Eurasian, Pacific North American, Scandinavian, and the North Atlantic Oscillation, it turns out that the correlations vary with season. In some cases significant correlations appear when the stratospheric data is lagged by one or two months, typical time scales for processes that involve changes in the stratospheric residual circulation. A better insight into the underlaying coupling processes is provided by analysing the relation between individual patterns of tropospheric climate variability and the strength and meridional direction of the EP-flux into the stratosphere. We have split our analysis into four separate time periods: 1948-2002, 1948-1977, 1978-2002, 1990-2002. It is remarkable that generally the correlations are stronger for the period 1990-2002 than for any other period.

**P-5-05**

A TROPOPAUSE MOIST POOL OVER ARID ASIA MINOR: UPPER TROPOSPHERIC AND LOWER STRATOSPHERIC MOISTENING IN THE ASIAN SUMMER MONSOON REGION

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**Abstract:** Previous studies have highlighted the Northern Hemisphere monsoon systems as dominant hydrators of the upper troposphere. In this study, we examine in more detail the distribution of upper tropospheric and lower stratospheric water vapour in the Asian Summer Monsoon (ASM) Region. Satellite and reanalysis data show the presence of a summertime moist pool shifted to the west of the main monsoon convection, extending from 150 mb to 70 mb, over the arid Asia Minor region (Iraq to Western Pakistan). Water vapour is constrained by the strong anticyclone, aggregating to the south and is sourced from a warm moist region at 150 mb to the north-west of India. Above this, the pool is independent of the deep convective regions. The pool is observed to propagate cross-isentropically from 370 K to a water vapour minimum at 440 K. It is proposed that the heat for ascent comes from turbulent diffusion incited by the baroclinicity across the anticyclone. Changes in the transient moisture flux from lower levels and the structure of the anticyclone create high intraseasonal variability in the characteristics of the moist pool. At 70 mb, water vapour leaked from the anticyclone may have large impacts on stratospheric humidity, temperature and chemistry. This work forms the first section of a larger investigation into the global significance of the moistening effect of the ASM on the upper troposphere and lower stratosphere.

**P-5-06**

## RESPONSE OF THE STRATOSPHERE-TROPOSPHERE SYSTEM TO IMPULSIVE TOPOGRAPHIC FORCING

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**Abstract:** It has been suggested that downward propagating stratospheric anomalies might be used to extend weather predictions beyond current time scales and to explain certain aspects of climate change. In order to understand the dynamical mechanisms by which the troposphere might respond to changes in the stratosphere, we employ a relatively simple general circulation to explore the transient response of the stratosphere-troposphere system to impulsive topographic forcing. Using a simple topographic forcing over a period of ten days, we generate upward propagating planetary waves that, upon breaking, produce stratospheric anomalies, which then propagate downwards and can be detected in the troposphere at lags of 30-100 days. A large ensemble of 100-day long experiments is created to obtain robust results. We find that the timing of the downward response is controlled by (1) initial anomalies in the stratospheric polar vortex, and (2) by the initial strength of the lower stratospheric eddy drag. These two criteria are found to be sufficient to predict the surface response of the stratosphere- troposphere system 50-100 days after the application of the forcing.

**P-5-07**

## THE STRATOSPHERIC POLAR VORTEX AND TROPOSPHERIC TELECONNECTIONS IN NORTHERN HEMISPHERE WINTER

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**Abstract:** Teleconnections of North Atlantic mid to upper tropospheric geopotential height are examined separately for the strong and weak regimes of the polar vortex in northern winter. In both cases the major teleconnection patterns have north-south dipole structures with opposing centers of action in subpolar and subtropical latitudes. The strong polar vortex case is characterised by a single pattern over the central North Atlantic, whereas there are two patterns in the weak vortex case: one over the western and one over the eastern North Atlantic. The growth of the stream function anomalies related to these teleconnection patterns reveals to be characterised by different dynamical processes. In the weak vortex regime, the growth is mainly driven by transient eddy fluxes, whereas, in the strong vortex regime, forcing resulting from interaction of low frequency transients (periods larger than 10 days) with stationary eddies is equally important. Composites of the North Atlantic storm track and monthly mean precipitation are dependent on both, the teleconnection pattern and its polarity. Hence, a considerable part of tropospheric variability cannot be explained in the classical framework of NAO without considering the strength of the polar vortex in the stratosphere.

**P-5-08**

## OZONE AS THE PREDICTOR OF EXTREME WEATHER EVENTS

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**Abstract:** Relations of the interannual variations between the total ozone and surface air temperature are investigated using the monthly mean (December-March) TOMS and NCEP/NCAR reanalysis datasets in 1979-1994. It is shown that the geographical regions with strong negative total ozone trends correspond well to those with large climate warmings. On the interannual time scales, increase (decrease) of the total ozone occurs also over those regions where cooling (warming) is observed in the wintertime. Strong non-local correlations indicated between the total ozone variations over England in January and surface air temperature changes in the western Siberia, southern Russia and Azore in February in 1979-1994. These results can be used for the extended-range forecast of extreme cold/warm winters (on 10-40 days onward) using the total ozone data as the predictor in the future. Possible mechanisms of this non-local linkage and its relation to the Arctic Oscillation are discussed.

**P-5-09**

STRATOSPHERIC PREDICTORS FOR EXTENDED-RANGE SURFACE PREDICTIONS

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**Abstract:** The predictability of 0.5-2 monthly mean surface meteorological fields in the Northern Hemisphere has been investigated, using lower stratospheric temperature and height anomalies as a predictor. The results are obtained using the 40 year ECMWF reanalysis dataset. The method is similar to that used by Baldwin *et al.* (Science, 1 August 2003), but with different predictors, predictants and averaging periods. Whereas the latter study uses the stratospheric Northern Annular Mode as a predictor, the present study uses the more easily computable and available average over the area north of 65°N. The predictants are surface pressure, wind, and temperature, both area averages and geographical distributions. Results are presented for a range of averaging periods.

**P-5-10**

MODELLING CONVECTIVE IMPACTS ON THE TROPOPAUSE TEMPERATURE

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**Abstract**: The energy budget near the tropical tropopause is important, because the temperature in that region is thought to control stratospheric water vapour and/or the prevalence of thin cirrus clouds. Both of these affect climate. Radiative transfer calculations indicate that a balance between radiative and convective energy transport is not actually achieved until some point above the cold point (temperature minimum at the top of the troposphere). Observations indicate that temperatures near tropopause level decrease during convective episodes, but it is not certain whether the observed cooling is due to convective, radiative or adiabatic effects. By using the Weather Research and Forecasting (WRF) model, we are attempting to clarify the above hypothesis. Preliminary results are encouraging. The convective flux at and below the cold point (which is at about 16.5 Km for our background sounding) appears to produce a small but significant tropopause cooling. The sensitivity of the simulated cooling to model resolution, geometric dimensions, lateral boundary conditions, sub-grid scale turbulence parameterisation and background state will also be discussed.

**P/5-11**

A TRAJECTORY-BASED STUDY OF THE TROPICAL TROPOPAUSE REGION

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**Abstract:** Large ensembles of 90-day backward trajectory calculations from isentropic surfaces in the tropical lower stratosphere are performed for NH winters 1997-98 and 1998-99 and summer 1997-98 and 1998-1999 and summer 1999. The calculations are based on ECMWF operational analysis data. The calculated trajectories are analysed to determine patterns of transport and encountered temperatures and implications for lower stratospheric water vapour. For each set of back trajectories a Troposphere-to-Stratosphere (TS) ensemble, originating below 355K, is identified. Trajectories in the TS ensemble sample the coldest regions of the tropical tropopause region very efficiently. (The coldest 15 per cent of temperatures are sampled). Corresponding water vapour concentrations are calculated using two simple dehydration models, one (Model 1) assuming instantaneous dehydration and the other (Model 2) taking some account of time delays associated with microphysical processes. Model 1 predicts average concentrations for the TS ensembles of 1.5 ppmv and 2.0 ppmv in the two NH winters and 3.8 ppmv in NH summer. Model 2 predicts concentrations that are about 0.5 ppmv larger. A quantitative method is described to assess the efficiency of sampling of cold regions, the roles played by different transport processes and differences between seasons or years. Both vertical transport (the 'stratospheric fountain' effect) and horizontal transport are shown to play important roles for dehydration, with the former more important in NH winter and the latter more important in NH summer. Differences in predicted water vapour between NH winter 1997-1998 (El Nino) and 1998-1999 (La Nina) are due to the warmer region of coldest temperatures in NH winter 1997-1998 than in NH winter 1998-1999, and to the less efficient sampling of cold temperatures by both horizontal and vertical circulations during the El Nino event.

The effect of temperature variability along the trajectories is studied by smoothing the temperature series at different timescales. Removing variability on timescales between 6 hrs and 1 day gives significant increases in water vapour (1.3 ppmv in NH winter, 2.4 ppmv in NH summer). The large temperature variability along trajectories is dominated by transport through strong temperature gradients rather than temporal variability of the temperature field.

**P-5-12**

STRATOSPHERE-TROPOSPHERE EXCHANGE NEAR TROPICAL CONVECTION: OBSERVATIONS, MESOSCALE AND GLOBAL ANALYSES

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**Abstract:** Recent studies have suggested that ozone transients in the tropics were associated with convective activity and that Stratosphere-Troposphere Exchanges (STE) can take place around tropical convection (cyclones, upper level depressions, ITCZ). Reunion Island is located in the southern subtropics in the Indian Ocean (55.5°E, 20.8°S), and is ideally located to observe dynamical mechanisms associated with the tropical convection during austral summer. Since 1992, around 300 measurements of ozone, humidity and temperature have been performed by radiosounding (Thompson *et al.*, 2003), and since 1998, around 150 measurements of tropospheric ozone by Lidar (Baray *et al.*, 1999). In this *in situ* database, several case studies of ozone enhancement in the upper troposphere have been detected in the vicinity of tropical convection. As example, Marlene cyclone (April 1995) was an exceptional case of ozone contamination, observed on radiosoundings launched from both Reunion Island and the Malcolm Baldridge INDOEX (Indian Ocean Experiment) ship. Mesoscale simulation carried trough the French mesoscale non-hydrostatic model Meso-NH allowed us to identify filamentation structures near the tropopause in the vicinity of the cyclone. Another system (Guillaume, February 2002) has been observed with several measurements made at two life stages (depression and intense tropical cyclone), and we saw that the evolution of Guillaume perturbation had a symbiosis with the propagation of a Rossby wave. Another case study in November 2000 taken in the South-African radiosounding database (Irene 28.2°E-25.9°S) showed that an original situation influenced by the ITCZ and the subtropical jet stream has been at the origin of an important ozone peak in the upper troposphere (170 ppbv at 12 km).

In this presentation, we will review the different case studies of STE near tropical deep convection areas in the Southern Hemisphere. A discussion about the role of deep convection and downward STE processes in order to improve our understanding of this phenomenon and detail the signatures of STE around tropical convection as function of the case study on chemical and dynamical tracers ($O_3$, $H_2O$, potential vorticity) will be possible through the dynamical analyses based on satellite data (Meteosat), global (ECMWF) analyses and mesoscale (Meso-NH) simulations. The understanding of the transport of trace chemical species between the stratosphere and the troposphere is necessary for global change prediction. Then these mechanisms of STE induced by tropical convection are important to identify and quantify since changes in the vertical distribution of ozone, a greenhouse gas, influence the atmospheric radiative balance.

**P-5-13**

QUANTIFICATION OF THE RATE OF TRANSPORT FROM THE UT TO THE LS *VIA* THE TROPICAL TROPOPAUSE LAYER USING A 3D CTM

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**Abstract:** A key uncertainty in our understanding of the stratosphere concerns how air is transported from the Upper Troposphere (UT) to the Lower Stratosphere (LS) in the tropics, and how this may change in the future. One of the main areas of uncertainty in estimating the impact of Very Short-Lived Substances (VSLS) on stratospheric ozone and climate lies in the physical and dynamical processes, which transport these substances to the stratosphere through the Tropical Tropopause Layer (TTL). In recent years there has been growing consensus that the tropical tropopause cannot be viewed as a simple barrier between the troposphere and the stratosphere. Instead, the notion of a more complex transitional layer called the Tropical Tropopause Layer (TTL) has been developing, which is at present poorly understood and ill defined. Currently there is a lack of understanding of processes which control transport through the TTL. For example, is TTL transport affected by interannual changes in the large-scale organisation of convective activity, such as from the El Nino Southern Oscillation (ENSO)? There is also a lack of understanding on how current 'state-of-the-art' global models represent transport in this region. We have evaluated the current treatment of transport in the TTL in different versions of a three-dimensional (3D) off-line Chemical Transport Model (CTM). We have used the TOMCAT/SLIMCAT 3D CTM, which can be used with different vertical coordinates (*e.g.* isobaric or isentropic levels) and different methods of diagnosing vertical transport (analyses or heating rates). We have performed simple tracer experiments to establish timescales for transport to the stratosphere by initial specification of surface values (ozone and carbon monoxide) and their lifetimes, comparison of CTM profiles with $O_3$ and CO observations and model sensitivity runs to investigate the effect of different model resolution and meteorological analyses. We will discuss whether the model reasonably represents transport from the surface to the stratosphere and whether seasonal and inter-annual variations in convective activity are realistically represented in the CTM. The findings from this evaluation of the CTM will be important in helping to determine the impact of VSLS on the stratosphere.

**P-5-14**

## AN IDEALISED MODEL OF THE SEASONAL CYCLE IN DEHYDRATION AND CIRRUS FORMATION NEAR THE TROPICAL TROPOPAUSE

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**Abstract**: An idealised model of dehydration and cirrus formation near the tropical tropopause is used to investigate the seasonal cycle in stratospheric water vapour and tropopause cirrus clouds. We use a 2D (height-longitude) trajectory simulation of the equatorial tropopause region (an extension of Holton and Gettelman, 2001), incorporating background temperature observations from GPS radio occultation measurements, and several background wind fields. The model can also include a variety of wave perturbations in temperatures and winds, and is inexpensive to run for several years. Water and cirrus fields are calculated by a series of simple (*i.e.* 100 % ice saturation) to more complex microphysical calculations, and model results are compared to observations from satellites, aircraft and balloons. Overall, the model produces a reasonable simulation of the observed seasonal cycles in water and cirrus clouds, although the detailed results depend on various model parameters. In particular, the amplitude and frequency of tropopause temperature perturbations have a large impact on model results.

**P-5-15**

## EXAMINING THE THERMAL MODES OF THE TROPICAL TROPOPAUSE LAYER WITH GPS RADIO OCCULTATION MEASUREMENTS

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**Abstract:** High-resolution observations of the temperature structure of the Tropical Tropopause Layer (TTL) are critical to diagnosing the relationship between water vapour saturation mixing ratio and stratospheric water vapour and, accordingly, the mechanisms for Stratosphere-Troposphere Exchange (STE). Global positioning system (GPS) radio occultation measurements offer a relatively new approach to examining the temperature structure of the TTL at high vertical resolution. EOF analysis of the GPS-derived temperature data yields the prevailing thermal modes of the TTL. These thermal patterns can provide new information to help assess the relative importance of small-scale structure in the context of regional patterns. In order to relate the prevailing thermal modes to the radiative and dynamical processes driving vertical motion in this region, EOF analysis is performed coincident with recent *in situ* measurements of water vapour and total water (*i.e.*, vapour, liquid, and solid phases) aboard the NASA WB-57 aircraft in the tropics. This sets the context for examining the mechanisms controlling water vapour entering the stratosphere.

**P-5-16**

## WATER VAPOUR AND CIRRUS IN THE TROPICAL TROPOPAUSE LAYER OBSERVED BY UARS

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**Abstract:** The Microwave Limb Sounder (MLS), an instrument on the Upper Atmosphere Research Satellite (UARS), is sensitive to water vapour in the tropical tropopause layer. We exploit a new dataset from MLS, which has enhanced vertical resolution and gives new insights into the vertical structure of water vapour between 215 and 56 hPa. The Cryogenic Limb Array Etalon Spectrometer, another of the instruments on UARS is sensitive to sub-visible cirrus formation in the region of the tropical tropopause. Cirrus clouds play an important role in the dehydration of this region and can contribute to the destruction of ozone. At 100 hPa, cirrus exhibit a longitudinal variability which is well correlated with upper tropospheric water vapour seen by MLS. The formation of cirrus is more prevalent over continental landmasses and over warm oceanic areas and the intraseasonal oscillation is evident. As we ascend through the tropical tropopause layer, the influence of convection on sub-visible cirrus weakens. Three dimensional trajectories show that by 68 hPa, cirrus form predominately in air which ascends at the rate of the zonal mean uplift except over the Indonesian region where a higher proportion are found in air which appears to be sinking. We discuss these observations in the context of stratosphere-troposphere exchange.

**P-5-17**

# THE INFLUENCE OF THE TROPOSPHERIC ANNULAR MODE ON THE POLAR VORTEX VACILLATIONS IN A SIMPLE GLOBAL CIRCULATION MODEL

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**Abstract:** The dynamical coupling between the extratropical troposphere and stratosphere consists of the downward propagation of a zonal wind anomaly from the stratosphere and the upward wave flux from the troposphere. Focussing on the latter, we examine how the tropospheric Annular Mode (AM) influences the vacillations of the stratospheric polar-night jet. While the Southern AM is driven by synoptic eddies alone, the zonally symmetric part of the Northern AM feeds back on the tropospheric stationary eddies. In this study, we show that these differences in the tropospheric AMs cause a different vertical coupling. In order to mimic the internal variability of the Northern and Southern Hemisphere, we use a simple global circulation model under perpetual January conditions. The model extends from the ground up to 60 km and produces a reasonable winter climate. In the model, the stationary wave forcing by orography and land-sea heating contrasts can be applied in different combinations. The dominant variability patterns are determined in terms of the empirical orthogonal functions for the geopotential at 1000 hPa and the stratospheric zonal mean zonal wind. Using a linear model version, we analyse the mechanisms of the tropospheric AMs and we interpret the contributions of the large-scale waves to the Eliassen-Palm-flux.

In all model experiments, the tropospheric AM leads the stratospheric vacillations by several days. This upward influence results from the Eliassen-Palm-flux, which is modified by the AM in the troposphere. Further studies with a constant-troposphere model show how the tropospheric AM induces different regimes of stratospheric variability. We find that the feedback process between the tropospheric AM and the stationary waves is essential for the strong stratospheric vacillations which are observed on the Northern Hemisphere.

**P-5-18**

# MECHANISMS FOR INTRASEASONAL VARIABILITY IN THE NORTHERN ANNULAR MODE

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**Abstract:** The mid- to high-latitude troposphere has been shown to be sensitive to variations in the stratospheric polar vortex related to the Northern Annular Mode (NAM). Studying this interaction on intra-seasonal timescales, we attempt to deduce the mechanisms responsible for current climate trends in the mid- to high-latitude troposphere and stratosphere.

Composite analyses are performed based on both the NAM index and its time derivative. Events during which the index undergoes significant change are binned according to the phase of the NAM. This allows a clear time evolution of build-up and decay for NAM events to be constructed for both positive and negative NAM phases.

Time evolution figures are shown for both the intensification and decline of the composited NAM event. Zonal-mean and three-dimensional eddy-flux diagnostics are used to examine the role of eddy-mean flow interaction in sustaining the anomalous winds characteristic of the NAM. Anomalous zonal wind tendencies are analysed in conjunction with the wave driving and Coriolis torque in an attempt to attribute eddy forcing to accelerations in the mean flow. Potential vorticity inversions are also used to determine the role of stratospheric anomalies in directly forcing the troposphere. Particular emphasis is devoted to the transition from a mature NAM event back to climatology in an attempt to determine the physical mechanisms behind such a transition.

**P-5-19**

PLANETARY WAVE PROPAGATION IN NORTHERN HEMISPHERE WINTER -- CLIMATOLOGICAL ANALYSIS OF THE REFRACTIVE INDEX

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**Abstract**: The frequency distribution of days per season with negative refractive index squared (FNRI) in a meridional plane is introduced as a simple but powerful method to evaluate the propagation of planetary waves. Northern winter (December, January and February (DJF) frequency distributions of negative are produced by counting the number of days with negative at each grid point of the meridional plane over the whole length of the data set and diving it by the total number of days. Thus, a 2D probability distribution of refraction of planetary waves is obtained. At places where the probability of negative is small, planetary waves have a good chance to propagate, while large probabilities indicate that planetary waves very probably will be reflected. NCEP/NCAR daily reanalysis data (1958-2000) are used as a substitute of observation. FNRI of wave number 1 wave indicates the different propagating probability in two regimes of Northern Hemisphere polar vortex - Weak Polar Vortex (WPV) and Strong Polar Vortex (SPV) (J. Perlwitz and H. Graf, 2001). In WPV, an obvious path from troposphere crossing the tropopause to stratosphere for vertical propagation of planetary wave exists around very high latitude, which shows the dynamic coupling between both atmospheric layers, while in SPV the propagation is weakened and has the different structure.

Many current climate models are biased towards a too strong polar winter vortex. Comparison between FNRI of observation and several models can also partly explain the bias of models. Therefore, this method can be applied to study the model dynamical and thermal structures in future work.

**P-5-20**

THE IMPACT OF HIGH RESOLUTION STRATOSPHERIC MODELLING ON THE TROPOSPHERE

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**Abstract**: Currently at the Met Office a high horizontal resolution model, with a poor representation of the stratosphere, is used to produce operational weather forecasts. However, stratospheric analysis is carried out using a model with a high vertical resolution, but a low horizontal resolution. Work is underway to merge these two configurations, producing a high resolution model used for both applications. Benefits from this new combined configuration are expected to be found in both the stratosphere and the troposphere, on a variety of timescales. Results from the preliminary trials will be presented, including the effect on month long tropospheric forecasts following a period of large stratospheric disturbance.

**P-5-21**

NONLINEAR CLIMATE RESPONSE TO ENSO AND STRATOSPHERIC WARMINGS

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**Abstract:** An increasing body of evidence suggests that the extratropical tropospheric climate responds to strong stratospheric circulation anomalies, such as Stratospheric Sudden Warmings (SSWs). Since the extratropical climate also responds to El Nino and Southern Oscillation (ENSO) variations among other forcings, it raises a question about the interaction of the response to these two forcings. In this study, we explore dynamical nonlinearity of climate response to ENSO and SSWs in two ways. A composite analysis of SSWs is made for warm and cold phases of the ENSO in a 50-year run of Whole Atmosphere Community Climate Model forced with observed sea surface temperatures. Idealised experiments with a dry, primitive-equation model are also conducted, where a zonally symmetric climate is perturbed by a tropical localized diabatic heating and/or extratropical stratospheric warming. Both results show additive non-linearity of the climate response to the two forcings the response to the stratospheric warmings is enhanced when the ENSO is in its warm phase or the tropical diabatic heating is imposed. We will further examine robustness of the results as well as underlying dynamical mechanism.

**P-5-22**

# DOWNWARD PROPAGATION OF DYNAMICAL SIGNALS IN THE MIDDLE ATMOSPHERE

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**Abstract:** Studies of the effect of changes in the middle atmosphere on the troposphere have suggested that there may be two distinct phases to the response to such changes. One is a downward propagation of the response in the stratosphere, and the second is an interaction between the lower stratosphere and the troposphere involving the natural modes of variability in the extratropical tropospheric circulation. The work reported here concentrates on the first phase.

A recent paper by Plumb and Semeniuk (2003) has shown how the extratropical stratospheric circulation (as represented by a Holton-Mass type wave mean flow model) naturally leads to downward phase propagation, but not 'real' downward propagation (*ie* - downward propagation of information), as a response to forcing at low level. They emphasise that in certain limits 'real' downward propagation can be ruled out. The emphasis here is on detecting 'real' downward propagation and in determining when it occurs and what physical mechanisms play a role in it. Two essential ingredients for 'real' downward propagation are continuing Rossby wave forcing at the bottom boundary and some degree of vertical non-locality in the dynamics of the mean flow (which is naturally present in the extratropics). The effect of the degree of non-locality of the velocity field on downward propagation, and the differences caused by using a WKB approximation for the Rossby Wave forcing are investigated, again using a Holton-Mass type model. Holton-Mass type models exhibit a bifurcation between a steady state regime and an oscillating regime. By applying a forcing in the upper stratosphere, or by changing the velocity field there, it is possible to cause a transition from steady to oscillating states, thus, having an effect on the whole stratosphere. This effect is quantified by determining how the amount of forcing needed (or amount of change needed to the velocity field) to cause this transition changes with respect to how high up in the stratosphere the changes are made and how far from the bifurcation between the two states the system is.

**P-5-23**

# THE DYNAMICAL IMPACT OF THE STRATOSPHERIC STATE ON THE TROPOSPHERIC FLOW DURING THE SOUTHERN HEMISPHERE MAJOR WARMING 2002

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**Abstract:** The dynamical links between the stratosphere and troposphere during the unprecedented stratospheric major warming in the Southern Hemisphere stratosphere during September 2002 have been extensively documented. While much attention has focused on the potential role of the troposphere in initiating this phenomenon there has been little attempt to understand the impact of the sudden warming on the subsequent tropospheric flow. In this study two 30-member 20-day forecasts of the stratospheric warming are run using the ECMWF IFS numerical weather prediction model. The first or nature forecast has initial conditions in the stratosphere and troposphere taken from ECMWF analysis. The second or non-nature forecast has the same initial conditions in the troposphere but has stratospheric initial conditions indicative of a strong polar vortex. The impact of the stratospheric warming on the tropospheric flow can be assessed by comparing the tropospheric evolution in the two forecast ensembles. The stratospheric flow is shown to have a statistically significant impact on the tropospheric flow at the time of the major warming. This impact is manifested as a local equatorward shift of the tropospheric storm track in the South Pacific sector. As the run progresses a subsequent statistically significant change to the tropospheric Antarctic Oscillation Index is observed. The second impact is manifested as a local equatorward shift of the tropospheric storm-track in the Atlantic sector. The 500 hPa geopotential height anomaly correlation for forecasts with observed stratospheric initial conditions is improved by 10 % around the time of the peak of the major warming.

**P-5-24**

## MEASUREMENTS OF WATER VAPOUR IN THE TROPICAL AND SUBTROPICAL TROPOPAUSE REGION WITH MIPAS/ENVISAT

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**Abstract:** Water vapour is an important gas in the atmosphere. Its significance for the natural green house effect requires the knowledge of the global distribution to assess its influence on the radiative budget. Additionally, water vapour in the tropopause region is a suitable tracer to observe transport processes from the troposphere to the stratosphere and vice versa.

The satellite borne Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) onboard the European research satellite Envisat provides global measurements of water vapour and other atmospheric state parameters. MIPAS is a high resolution limb sounding Fourier spectrometer measuring atmospheric emission spectra in the mid infrared from which vertical profiles of numerous trace species can be retrieved. In the standard measurement mode MIPAS provides profiles covering a nominal altitude range from 6 to 68 km.

Measurements covering the upper troposphere and the lower stratosphere are presented. Examples will be emphasized where large scale indications for exchange processes in the tropopause region can be seen. In the tropics the large scale ascent of very dry stratospheric air as a consequence of the Brewer-Dobson-Circulation is clearly visible.

In the subtropics measurements of enhanced water vapour volume mixing ratios above the thermal tropopause hint towards possible troposphere to stratosphere transport processes.

**P-5-25**

## DEHYDRATION AT THE TROPICAL TROPOPAUSE OVER THE INDIAN OCEAN

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**Abstract:** During the APE-THESEO campaign in February/March 1999 high-resolution *in situ* measurements were made from the Geophysica high altitude aircraft above the western equatorial Indian Ocean.

The height of the tropopause and the hygropause were highly variable for the investigated period. We attribute this to short and local perturbations to the seasonal cycle. The cold point tropopause was located at a potential temperature range from 365 403 K. Minimum temperatures were very low (183-194 K), leading to saturation mixing ratios at the tropopause of 1.1 8.4 ppmv. The hygropause was located on average 4 K above the tropopause with water vapour mixing ratios of 1.2 4.1 ppmv. These very low mixing ratios are comparable to those found in previous studies in the fountain region over Micronesia.

For 70 of the vertical profiles, ice saturation was found in a wide range around the tropopause. Predominantly, the saturation was corroborated by concurrently detected clouds up to the altitude of the cold point. We identify three common types of vertical profiles: coincident hygropause and cold point at relatively low potential temperatures, associated with a cirrus deck of a few kilometers thickness coincident hygropause and cold point at relatively high potential temperatures, associated with thin subvisible cirrus and unsaturated, cloud-free, profiles without a pronounced relationship between hygropause and cold point. Characteristics of the cirrus clouds such as their extension, number density, frequency distribution of relative humidity over ice were different for these categories, which allows to infer their different origin, but also their different impact on the $H_2O$ budget of the Tropical Tropopause Layer (TTL). The observed geometrically thicker clouds, located at relatively low potential temperatures, show only small supersaturations and are embedded in dry air. They are formed by injection of moist air from convective outflow into dry upper tropospheric air and thus moistening the TTL. In contrast, the observed geometrically thin clouds, located at higher potential temperatures, are formed *in situ*. They show large supersaturations and are embedded in much more humid air. The presence of these clouds up to the altitude of the hygropause is evidence of ongoing dehydration of air entering the stratosphere in the TTL over the western Indian Ocean.

**P-5-26**

# THE DYNAMICAL IMPACT OF THE STRATOSPHERE ON THE TROPOPSHERE IN A NUMERICAL WEATHER PREDICTION MODEL

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**Abstract**: Over the last few years there has been much interest in the impact of the stratospheric state on the tropospheric flow. While a number of studies have shown that making a permanent change to the stratospheric state results in an impact on the tropospheric flow there have been fewer studies which have examined the impact of a transient change to the stratospheric flow on the troposphere. In this study experiments are conducted with the ECMWF IFS model. This is a high horizontal and vertical resolution GCM primarily used for numerical weather prediction. Two ensemble forecasts of the model are compared which have identical tropospheric initial conditions and different stratospheric initial conditions. Stratospheric initial conditions have a statistically significant influence on the large-scale tropospheric flow after 15-20 days of the ensemble forecast. This impact is manifested as statistically significant changes to the local storm-track regions in the North-Atlantic and North-Pacific. Changes to the North-Atlantic are consistent in the three case studies examined and can be summarised as a southward shift of the North-Atlantic storm-track during weak stratospheric vortex conditions. Changes to the North-Pacific have similar magnitudes to those in the North-Atlantic but are different in each of the three case studies examined.

Over the three case studies comparison of tropospheric forecast accuracy for cases with correct stratospheric initial conditions and those with incorrect stratospheric initial conditions reveals a mean reduction of 10% 500 hPa anomaly correlation after 12 days for forecasts with incorrect stratospheric initial conditions. Comparison of the results of the model run with simple PV inversion experiments shows that the impact of the stratospheric initial conditions on the tropospheric flow observed in the model simulation cannot be understood purely in terms of a large-scale adjustment of the tropospheric flow to the stratospheric PV distribution.

**P-5-27**

# HOW SOLAR HEATING OF THE LOWER STRATOSPHERE INFLUENCES TROPOSPHERIC CLIMATE

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**Abstract:** Analyses of NCEP zonal wind data have shown a particular pattern of response to solar activity in which the sub-tropical jets weaken and move poleward when the sun is more active. GCM studies of the solar influence have managed to reproduce this pattern and have also shown an impact on tropospheric mean meridional circulation with a weakening and expansion of the tropical Hadley cells and a poleward shift of the Ferrel cells. In order to understand the mechanisms whereby these changes take place we have carried out experiments with a simplified global circulation model. The results show that any heating of the lower stratosphere results in a weakening of the sub-tropical jets and of the tropospheric mean meridional circulations. The positions of the jets, and the extent of the Hadley cells, respond to the distribution of the stratospheric heating with low latitude perturbations forcing them to move poleward and high latitude, or latitudinally uniform, perturbations forcing them equatorward. We present an analysis of the model runs in an attempt to identify a chain of causality for these effects. Our work demonstrates that perturbations to the heat balance of the lower stratosphere, such as brought about by solar or volcanic activity, can produce changes in the mean tropospheric circulation even without any direct forcing below the tropopause.

**P-5-28**

CLIMATIC RESPONSE TO HIGH LATITUDE VOLCANIC ERUPTIONS

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**Abstract:** Explosive volcanic eruptions cause large amounts of $SO_2$ to be injected into the stratosphere. The $SO_2$ is converted to sulfate aerosol over time, and they cause a significant radiative perturbation to the climate system. Previous work has generally been focused on the impact of tropical volcanic eruptions on climate. In this study we examine the climatic impact of high latitude volcanic eruptions using the Goddard Institute for Space Studies (GISS) model E GCM.

We simulated the climatic response to the Katmai (58°N) eruption, which occurred on June 6, 1912. We produced 20 ensemble members using the observed Katmai aerosol distribution (1x) and an additional 20 member ensemble of a 3 times (3x) Katmai eruption to explore how the climate is impacted by the strength of high latitude volcanic eruptions. The lower stratospheric zonal mean temperature response is strongest over the mid-latitudes with maximum warming of 1.5°C and 4.5°C for the respective simulations. The high latitude response shows a weakening of the stratospheric polar vortex in the 3x Katmai runs, but not in the 1x runs. Both cases result in continental cooling during the two summers following the eruption. In the winter, cooling dominates large areas of Asia and North America with warming over Greenland and Iceland. This winter response resembles the negative phase of the Arctic Oscillation, which is different than past studies of tropical volcanic eruptions. In the Katmai case the radiative, as well as the dynamical response, are working in the same direction.

**P-5-29**

THE EFFECT OF CONVECTION ON THE THERMAL STRUCTURE OF THE TTL

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**Abstract:** In this analysis, we investigate the impact of convection on the thermal structure of the TTL. We use temperature profiles measured by the Atmospheric Infrared Sounder (AIRS) onboard the AQUA satellite, and the time evolution of local convection determined by the National Centers for Environmental Protection/Aviation Weather Center (NCEP/AWS) half-hourly infrared global geostationary composite. The observations demonstrate that the TTL is cooled by convection, in agreement with previous observations and model simulations. By using a global data set, we are able to investigate the variations in this convective cooling by season and region, and these will be presented.

**P-5-30**

A CLIMATOLOGY OF PLANETARY WAVES AND SYNOPTIC SYSTEMS OVER THE SOUTHERN HEMISPHERE TROPOSPHERE AND LOWER STRATOSPHERE

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**Abstract:** The existence of synoptic scale disturbances of tropospheric origin in the lower stratosphere is strongly linked to the evolution of planetary wave activity, as shown in a number of case studies. A spatial spectral analysis of ECMWF geopotential height, spanning the period 1973-2002, is used to establish a dynamic climatology of the signatures of planetary waves and synoptic scale disturbances in the troposphere and lower stratosphere in order to understand the interactions between these two scales and how they can influence lower stratospheric dynamics. Evidence of downward control from the stratosphere on the tropopsheric dynamics is discussed, together with the changes and varaibility observed over the thirty year period.

**P-5-31**

## TROPICAL TEMPERATURE STRUCTURES BY RADIOSONDE, ECMWF AND NCEP REANALYSES

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**Abstract**: Characterising the atmospheric structure in the tropical tropopause region is very important for understanding the processes that determine stratospheric water vapour and its variation. Both radiosonde data and reanalyses are useful for this purpose. US high-resolution radiosonde data for more than 90 stations have been archived in the SPARC Data Center for 1998-2002. Thirteen of these radiosonde locations are located within 20 degrees of the Equator, nine within 15 degrees, and five within 5 degrees. Most of these (six) are clustered in the Warm Pool region, but three are in the Central Pacific, and four are in the Caribbean/Central American region. In earlier work, we compared the sounding profiles to NCEP-R and ERA-15 analyses during TOGA/COARE (1992-1993). We extend this work by doing comparisons for monthly mean profiles for more stations, and for ERA-40. We previously found that ERA-15 better represented the tropical temperature structure than NCEP-R during the TOGA/COARE period. It appears that the NCEP-R is improved for the later period. There still are systematic biases in the temperatures and altitude structure for all the reanalyses, however. These are characterised.

**P-5-32**

## THE EFFECT OF A TROPICAL CYCLONE ON THE TROPICAL TROPOPAUSE LAYER: MEASUREMENTS AND SIMULATIONS FOR THE DAVINA CYCLONE

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**Abstract:** Tropical cyclones may have a large impact on the exchanges process between stratosphere and troposphere. The case of TC Davina has been analysed using both data measured by the instruments on board of stratospheric airplane Geophysica and the simulations performed with the mesoscale model MM5V3. The MM5 configuration was chosen based on the results of sensitivity experiments presented in the poster session. The comparison of the observed total water content with the same parameter retreived by the MM5 and ECMWF analysis shows a possible underestimation by the GCM.

**P-5-33**

## TROPOSPHERIC RESPONSE TO STRATOSPHERIC COOLING IN A SIMPLE AGCM: IMPACT OF THE SEASONAL CYCLE

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**Abstract:** We investigate the response of the tropospheric circulation to stratospheric cooling in a relatively simple AGCM that consists of a dry hydrostatic primitive-equation model with zonally symmetric boundary conditions and analytically specified physics. Using a time-independent thermal forcing in the stratosphere, it is found that, as the polar-winter stratosphere is cooled, the tropospheric jet shifts poleward to a remarkable degree. Surprisingly, the troposphere takes a long time to adjust to the stratospheric cooling in this simple model, typically over 300 days. Naturally, then, one is lead to ask whether the tropospheric jet response would be observed in the presence of seasonally varying, instead of time-independent, thermal forcing. We address this issue by repeating the forcing experiments with a seasonal cycle in the forcing: specifically, we impose a thermal forcing in the stratosphere that only occurs in the winter months. We find that, even when the stratospheric forcing is applied with a seasonal cycle, the tropospheric jets shift poleward. Although the magnitude of this response is somewhat smaller than in the time-independent forcing case, the ratio of the tropospheric response to the stratospheric forcing is the same as in the time-independent forcing case, in the annual mean. In this sense, the response appears to be linear in the strength of the stratospheric forcing.

**P-5-34**

TROPOSPHERIC JET STRUCTURE AND THE DOWNWARD PROPAGATION OF STRATOSPHERIC ZONAL WIND ANOMALIES

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**Abstract:** An idealised primitive-equation general circulation model is used to investigate how the tropospheric jet structure affects the downward propagation of zonal mean flow anomalies from the stratosphere into the troposphere. Model forcing consists of Newtonian relaxation of the temperature field to radiative equilibrium values and a thermally driven Hadley circulation. Different tropospheric zonal mean states are created by varying the strength and latitudinal position of both a subtropical jet and a midlatitude region of enhanced baroclinicity. By varying these parameters we are able to create tropospheric wind profiles with either dual jets or a single tropospheric jet maximum. We find that the tropospheric jet structure affects the frequency of downward propagating events and the depth to which anomalies propagate into the troposphere. These results will be discussed in context of previous studies demonstrating the importance of wave reflection for downward propagation of zonal flow anomalies.

**P-5-35**

MESOSCALE NUMERICAL EXPERIMENTS OF THE TROPICAL CYCLONE DAVINA

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**Abstract:** Sensitivity experiments using MM5V3 (NCAR/PSU) have been performed to the aim of reproducing the best dynamic and thermodynamic structures of the TTL above the Davina tropical cyclone. The sensitivity experiments are performed to test the model description of the physical process: convection, microphysics and boundary layer. Two cumulus parametrisation (Kain-Fritsch and Betts & Miller), a few PBL schemes (MRF, ETA, Balckadar, etc.) and several microphysical descriptions are ranked by a skill score technique. The score is based on the measurement took onboard of the stratospheric plane Geophysica. The results allow in choosing the best configuration for the model aided analysis of the Davina cyclone.

**P-5-36**

STRATOSPHERIC IMPACT OF VARYING SEA SURFACE TEMPERATURES

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**Abstract:** The Finite-Volume General Circulation Model (FVGCM) has been run in 50 year simulations with the 1) 1949-1999 Hadley Centre Sea Surface Temperatures (SST), and 2) a fixed annual cycle of SSTs. In this presentation we first show that the 1949-1999 FVGCM simulation produces a very credible stratosphere in comparison to an NCEP/NCAR reanalysis climatology. In particular, the Northern Hemisphere has numerous major and minor stratospheric warmings, while the Southern Hemisphere has only a few over the 50-year simulation. During the Northern Hemisphere winter, temperatures are both warmer in the lower stratosphere and the polar vortex is weaker than is found in the mid-winter Southern Hemisphere. Mean temperature differences in the lower stratosphere are shown to be small (less than 2 K), and planetary wave forcing is found to be very consistent with the climatology. We then will show the differences between our varying SST simulation and the fixed SST simulation in both the dynamics and in two parameterised trace gases (ozone and methane). In general, differences are found to be small, with subtle changes in planetary wave forcing that lead to reduced temperatures in the SH and increased temperatures in the NH.

**P-5-37**

INSIGHTS INTO STRATOSPHERIC DEHYDRATION USING ISOTOPES OF WATER

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**Abstract:** An analytic model of transport and microphysics in the Tropical Tropopause Layer (TTL) is extended to include stable isotopes of water. The model, running along trajectories, is tested against *in situ* and satellite observations of HDO and $H_2$-18O. The model is able to reproduce the range of isotopic depletions observed in the data, and reproduce individual episodes that mirror or depart from Rayleigh fractionation processes. The results indicate that water substance in the upper troposphere does not follow a Rayleigh distillation model due to the presence of lofted ice in the TTL. Stratospheric abundances of stable isotopes of water can be understood based on known isotopic physics, convective lofting of ice and gradual dehydration.

**P-5-38**

CIRRUS CLOUD OCCURRENCE STUDIES BY USING LIDAR AND HALOE OBSERVATIONS

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**Abstract:** Cirrus clouds have been shown to be ubiquitous by lidar and satellite observations. Lidar observation based on Chung-Li (25°N, 121°E) shows that cirrus cloud has the highest occurrence in the summer months with a probability over 0.90. Detection of multilayer cirrus clouds is also frequent in the summer months with a probability of about 0.30. Mid-cloud height distribution is centralized at 14 km. A few cirrus clouds were measured above the tropopause.

Lidar measurement is compatible with HALOE data. The cloud occurrence is correlated with tropopause temperature and water vapour mixing ratio, for which HALOE measurements give the highest mixing ratio (6ppm) in the summer. In July the exceptional high probability of cirrus clouds formation deviates from the general trend of temperature and water vapour correlations, and there seems to require an additional mechanism.

By using the HYSPLIT back trajectory calculations, we found major part (3/4) of cirrus clouds can be traced back to the Tibet High Plateau region which is an elevated heat source and related to summer monsoon in Asia. A small part (1/4) of cirrus clouds are traced to the Pacific Ocean in the summer.

**P-5-39**

SOLAR INFLUENCE ON THE SPATIAL STRUCTURE OF THE INTERANNUAL VARIATION OF THE STRATOSPHERIC JET AND ITS IMPACT ON THE TROPOSPHERE

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**Abstract:** The 11-year solar cycle produces large dynamical effect in the stratopause region in early winter through change in a balance between the dynamical and radiative forcings. The transition from a radiatively controlled- to a dynamically controlled state can be characterised by two events, jet shift and subsequent stratospheric warming. Year-to-year variation of the timing of the transition period produces two modes of variability in the zonal-mean zonal winds in the stratopause during winter. The leading mode of the empirical orthogonal function (EOF) has a meridional dipole-type structure in early winter, which changes in mono-pole type in mid winter. The period of dipole-type anomalies lasts longer during the high solar activity. The meridional dipole-type structure in the stratopause region extends downwards from the stratosphere to the troposphere through interaction with planetary waves in Northern Hemisphere winter. The dipole-type anomaly in the tropospheric zonal winds produces a hemispherical pattern similar to the Arctic Oscillation in the surface pressure field.

**P-5-40**

# INTRASEASONAL VARIATIONS OF WATER VAPOUR AND CIRRUS CLOUDS IN THE TROPICAL TROPOPAUSE LAYER

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**Abstract:** Water vapour and cirrus clouds in the Tropical Tropopause Layer (TTL) affect not only the terrestrial radiative balance but also on the stratospheric water content. Space-time variations of water vapour and cirrus clouds associated with the IntraSeasonal Oscillation (ISO) are investigated using data from the Microwave Limb Sounder (MLS) and the Cryogenic Limb Array Etalon Spectrometer (CLAES) on board the Upper Atmosphere Research Satellite (UARS). Composite moisture and meteorological fields based on five ISO events selected in two boreal winters (1991-1993) are analysed using 20-80 day bandpass filtered data.

The moisture field in the TTL seems to be indirectly affected by convective activity through the dynamical response to the convective heating. Dry anomalies are observed over the Indian Ocean around the developing stage and over the eastern Pacific around the mature-to-decaying stage of the ISO. Cirrus clouds are frequently found over the cold region located to the east of the convective system. These structures around the tropopause level are closely related to the eastward moving Kelvin and Rossby wave responses to the convective heating with the equatorial cold anomaly and with the subtropical anticyclonic gyres. Between the two gyres the easterly wind blowing through the equatorial cold region may cause dehydration through cirrus formation when the convective system develops over the Indian Ocean and the western Pacific. As the northern gyre intensifies, tropical dry air is transported to the subtropical Pacific and eventually to the equatorial eastern Pacific. It is suggested that the temperature and flow variations due to the coupled Kelvin-Rossby wave structure play an important role in dehydrating air in the tropical and subtropical tropopause region.

**P-5-41**

# THE HIGH RESOLUTION DYNAMICS LIMB SOUNDER (HIRDLS) ON AURA: CAPABILITIES FOR UT/LS STUDIES, STATUS AND FIRST RESULTS

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**Abstract:** HIRDLS is scheduled for launch on the Aura spacecraft on the 17$^{th}$ June, 2004, with activation by mid-July. It is a 21 channel limb-scanning infrared radiometer, designed to measure the global vertical distributions of temperature, $O_3$, $H_2O$, $CH_4$, $N_2O$, $NO_2$, $N_2O_5$, $HNO_3$, $ClONO_2$, CFC11 & 12, and provide information on high level aerosols and clouds. These measurements will be obtained with horizontal and vertical resolutions of 500 km or less and 1 km or less, respectively, from the upper troposphere to the mesopause in some cases. It is expected to provide detailed information on the UT/LS in the absence of thick clouds. In particular, the data should provide a global and reasonably detailed look at the entry of air from the tropical troposphere into the stratosphere, and the mechanisms that maintain the low stratospheric humidity. We will show simulations of the HIRDLS measurement capabilities and the ways they can be used to address such questions. Finally, the up-to-the-minute status of Aura and HIRDLS will be described. We hope to present some initial results.

**P-5-42**

SOWER/PACIFIC - RESULTS AND A FUTURE PLAN

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**Abstract:** The Soundings of Ozone and Water in the Equatorial Region/Pacific Mission (SOWER/ Pacific) has been running on a campaign basis since 1998 to improve our knowledge on the ozone and water vapour distributions in the tropical Pacific region by making coordinated radiosonde observations at several equatorial places, the Galapagos Islands (Ecuador), Christmas Island (Kiribati) and Indonesia. In addition to establishing the climatology and variabilities in ozone and water vapour, we also intend to explore controlling dynamical/chemical processes for these species and to collect correlative data for satellite data validation. In this talk results from the SOWER campaigns so far will be summarized and a future plan of the coordinated campaign in coming December 2004 will be introduced. In this campaign we will focus on dehydration around the tropical tropopause layer using a trajectory-based match method by conducting water vapour observations at several stations.

**P-5-43**

THE ROLES OF THE HADLEY CIRCULATION AND DOWNWARD CONTROL IN TROPICAL UPWELLING

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**Abstract:** The magnitude and configuration of tropical upwelling of tropospheric air into the stratosphere plays an important role in determining tropical tropopause properties and in stratosphere-troposphere exchange. It is likely of great importance in understanding observed variations in stratospheric water vapour.

Here, we present several idealised models of tropical upwelling, which clarify the roles of the nonlinear Hadley circulation and extratropical wave driving in determining the circulation. In particular, we show that the Hadley circulation and wave-driven circulation interact to determine the nature of tropical upwelling.

With these models, we compare the mean meridional circulation driven by the interactions between these two effects to that circulation in the SHYHI model, showing the role of the different processes that determine the circulation. We are able to explain several features that are both observed and appear in the SKYHI model, such as maximum upwelling in the summer hemisphere and the annual variation of the upwelling. One feature that is seen in both the idealised models and the SKYHI model is equatorial downwelling in boreal summer. This helps to explain the nature of the observed tape recorder in tropical stratospheric water vapour.

**P-5-44**

STRATOSPHERE-TROPOSPHERE EXCHANGE AND THE QBO

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**Abstract:** Breaking planetary waves cause irreversible mixing along and across isentropic surfaces. When this occurs in the Middleworld (*i.e.* on isentropic surfaces that intersect the tropopause and, therefore, comprise both tropospheric and stratospheric air), rapid mixing of stratospheric and tropospheric constituents occurs. This process is known to be closely associated with the subtropical summer highs. Stratosphere-troposphere exchange also occurs diabatically (over a larger spatial and time scales) in the tropics and polar regions.

Planetary wave breaking (PWB) will be examined in the Middleworld, with particular emphasis on its three-dimensional structure and the effect of the stratospheric QBO. We present a new method of diagnosing planetary wave activity, and show how the QBO affects the wind and potential vorticity fields and, thus, PWB and stratosphere-troposphere exchange. Preliminary results show a reduction in the SH PWB maximum over the Pacific and a shift in the location of the NH PWB maximum over the Pacific, consistent with changes seen in the potential vorticity and wind fields.

**P-5-45**

STRATOSPHERIC INFLUENCE ON BAROCLINIC INSTABILITY: CONNECTION TO THE ARCTIC OSCILLATION

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**Abstract:** The possibility that the stratosphere might exert significant dynamical influence on the troposphere has recently attracted much attention. In this work we investigate how stratospheric conditions might alter the development of baroclinic instability in the troposphere. Starting from the LC1 paradigm of Thorncroft *et al*. 1993, we consider the evolution of baroclinic lifecycles resulting from the addition of a stratospheric jet to the LC1 initial condition. The synoptic evolution of the resulting lifecycles is compared to the reference case with no stratospheric jet. The evolution of the stratospherically influenced lifecycles is described, and the tropospheric response is mapped over the space of stratospheric jet parameters. Significant departures from the LC1 paradigm are observed over a large range of stratospheric jet parameters, with synoptic-scale differences to the surface geopotential, whose zonal averages in many cases exhibit meridional dipole structures that resemble the Arctic Oscillation.

**P-5-46**

MODULATION OF THE STRATOSPHERE-TROPOSPHERE COUPLING PROCESS OF THE NORTHERN HEMISPHERE ANNULAR MODE ASSOCIATED WITH THE ENSO CYCLE

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**Abstract:** Recent observational studies reveal some evidence that, in intraseasonal time scales, the downward propagation of zonal mean zonal wind anomalies in the stratosphere precedes the Northern Hemisphere annular mode (NAM) signal in the troposphere. In this study, interannual variability of this type of stratosphere-troposphere dynamical coupling in winter is examined by using NCEP/NCAR reanalysis and Met Office HadISST datasets. In particular, we will focus upon the dependence of the coupling on the ENSO phase (warm/cold phase).

The downward propagation of zonal wind anomalies in the stratosphere is evident irrespective of the ENSO phase, while the zonal WaveNumber (WN) of planetary waves responsible for the zonal wind anomalies is different: WN 2 (WN 1) component plays a primary role in the cold (warm) phase. The region where anomalous upward propagation of wave activity is observed also depends on the ENSO phase: the Eurasian (Pacific-North Atlantic) sector for cold (warm) phase. On the other hand, large tropospheric zonal wind anomalies followed by the stratospheric zonal wind anomalies appear only for the cold phase. Anomalous poleward propagation of wave activity of planetary waves with WN 2, as well as synoptic waves acts to reinforce the tropospheric zonal wind anomalies. We will also discuss a possible mechanism for the ENSO influence on the stratosphere-troposphere coupling.

**P-5-47**

ZONAL VARIABILITY OF THE HEAT BUDGET IN THE TROPICAL UT/LS

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**Abstract**: Temperatures around the tropical tropopause show distinct seasonal and spatial variabilities, with a strong cold anomaly over the western Pacific in Northern Hemisphere winter. These temperature anomalies have a significant impact on the dehydration of tropical Troposphere-to-Stratosphere Transport (TST). In addition, they may be associated with zonal variability in the diabatic mass flux across the tropopause.

The mechanisms that control temperatures at the tropical tropopause are subject of ongoing research. In particular, the relative importance of large scale dynamics, cooling through injection of cold air by deep convective cells, and radiation and its modulation through clouds and trace gas concentrations are not well established.

We use atmospheric soundings of temperature and trace-gas concentrations together with a radiative transfer model to provide a comprehensive overview of the seasonal and spatial variability of the radiative energy budget at the tropical tropopause and lower stratosphere. This analysis allows us to test several hypotheses related to tropical TST, which provides additional insight on the relative importance of the aforementioned processes.

Preliminary results suggest that variability in thick anvil clouds and trace gas concentrations tend to attenuate the effect of zonal temperature variabilities on diabatic mass flux at the tropopause, but are likely of secondary importance. Conversely, these clouds may lead to even more pronounced zonal variability of vertical mass flux in the tropical lower stratosphere. It, thus, appears that dynamical forcing plays a major role in the observed zonal temperature variability in the tropical UT/LS.

**P-5-48**

PREDICTABILITY OF STRATOSPHERE-TROPOSPHERE DYNAMICAL INTERACTION DURING STRATOSPHERIC SUDDEN WARMING EVENTS IN THE NORTHERN HEMISPHERE

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**Abstract:** Predictability of zonal-wavenumber (WN) 1 stratospheric sudden warming (SSW) events occurring in December 1998 and December 2001 is examined by the use of the operational one-month forecast data set provided by Japan Meteorological Agency (JMA). The triggering process for the occurrence of the SSW events in the troposphere and the dynamical influence on the tropospheric circulation during the SSW events are also investigated.

For the SSW in December 1998, the stratospheric warming in the polar region is predictable from one month in advance. The amplification of tropospheric planetary waves triggering the onset of the SSW is closely connected with weak vertical westerly shear near the surface around 60°N, in association with rather strong synoptic wave activity. Thus, the fair reproduction of the interaction between zonal-mean flows and synoptic waves in the troposphere is essential for the successful prediction of this event. We also point out prolonged predictability for the onset of a tropospheric blocking event occurring over Alaska just after the warming peak. The blocking is formed due to the poleward propagation of planetary waves causing the SSW event, which suggests a predictable downward control of the tropospheric circulation by the stratosphere after the SSW.

High sensitivity to the initial condition for the warming prediction prior to the onset of SSW event is detected by examining all ensemble members of the one-month forecast for the SSW in December 2001. The high sensitivity is related to a dipole pattern between 80°N and 60°N in tropospheric zonal mean flow anomalies among ensemble members. Moreover, the zonal flow anomalies are intimately connected with the enhancement of the tropospheric WN 1 component similar to the SSW event in December 1998, which suggests that the pattern of the tropospheric zonal flow anomalies is a key factor for the occurrence of the SSW events.

**P-5-49**

## 5-DAY VARIATION OF EQUATORIAL CONVECTIVE ACTIVITY OVER 100°-110°E AND ITS INFLUENCE ON THE UPPER TROPOSPHERE AND STRATOSPHERE

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**Abstract**: The 5-day disturbances in convective activity are examined by using data from *in situ* Radar and radiosonde observations over the tropical 100-110°E (Kototabang, Singapore and Kuching) during November-December 2001. The convective systems during the convectively active phase of the Madden-Julian oscillation (MJO) are characterised by two events of convection enhancement (CE) over equatorial 80-120°E and 10 days, and westward-propagating disturbances with a horizontal scale of 3000 km and an interval of about 5 days. The westward propagating disturbances, which be enhanced by cold surge of Asian winter monsoon and strong tropical westerlies meandering meridionaly, are identified with mixed Rossby-gravity (MRG)-type disturbances to the west of Sumatra and tropical depression (TD)-type disturbances to the east of Sumatra. A lag correlation of indices of convections with wind and temperature fields suggest a close relationship of convections with both tropospheric meridional wind anomalies propagating westward and stratospheric variations with a structure of the equatorial Kelvin waves during the CE events. An intriguing coincidence of cold anomalies of the Kelvin waves and the occurrence of tenuous cloud obtained from the Halogen Occultation Experiment (HALOE) emphasizes that convectively generated equatorial Kelvin waves can dehydrate in the Tropical Tropopause Layer (TTL).

**P-5-50**

## MST RADAR OBSERVATIONS OF VERTICAL VELOCITY AND DIABATIC HEATING RATES IN THE VICINITY OF TROPICAL TROPOPAUSE: POSSIBLE INFLUENCE ON STRATOSPHERE TROPOSPHERE EXCHANGE

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**Abstract:** Mesosphere-Stratosphere-Troposphere (MST) radar is a powerful tool to monitor atmosphere winds, stable layer structures and turbulence with fine height and time resolutions. Such high resolution measurements, in the vicinity of tropopause, are expected to provide better understanding of stratosphere troposphere interaction over different time scales. In the present study, high resolution measurements of vertical winds and stable layer structures, made using MST radar located at Gadanki (13.50°N, 79.20°E) a tropical station in India, have been analysed to study the variability of these parameters in the vicinity of tropical tropopause during different seasons, including during passage of Tropical Easterly Jet (TEJ) associated with the Indian summer monsoon. An attempt has also been made to monitor vertical wind variability during passage of Inter Tropical Convergent Zone (ITCZ). Analysis of MST radar observations of vertical velocity for the year 2002 clearly show net downward vertical wind during the period of monsoon, *i.e*. June-September, 2002.

An attempt has also been made to derive the diabatic heating rates in the troposphere, including the vicinity of tropical tropopause, by making use of first law of thermodynamics and MST radar observed vertical winds. The net rate of change of temperature can be expressed in Z coordinates as sum of local rate of change of temperature, horizontal advection of temperature and vertical advection of temperature.

By making appropriate assumptions for horizontal advection for a station and neglecting the local rate of change of temperature, the above equation is simplified and then by making use of thermodynamic energy equation ($dQ = Cp\ dT\ \alpha\ dP$, where dQ is heat exchanged, dT and dP and changes in temperature and pressure and CP and $\alpha$ are latent heat at constant pressure and specific volume respectively), the diabatic heating rate has been expressed in terms of vertical velocity and temperature lapse rate. Height profiles of diabatic heating rate, during different meteorological conditions, have been derived by making use of MST radar observed vertical winds and model temperature profiles for tropical region. Results clearly indicate that the heating rates derived from MST radar observed vertical velocities vary significantly during different meteorological conditions and also across the tropopause. Temporal and day-to-day variations of diabatic heating rates have also been studied.

**P-5-51**

## CIRRUS CLOUDS IN THE TROPICAL TROPOPAUSE LAYER: ROLE OF HETEROGENEOUS ICE NUCLEI

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**Abstract**: The role of heterogeneous Ice Nuclei (IN) in controlling the occurrence and properties of cirrus clouds in the tropical tropopause layer is examined with the help of a Lagrangian microphysical cirrus model that includes competition between insoluble and volatile aerosol particles during ice nucleation and temperature perturbations induced by small-scale gravity waves.

This study suggests that the mean values of ice supersaturation and the stratospheric entry level of $H_2O$ are only weakly altered by IN unless they are particularly potent or abundant, in which case additional IN-induced dehydration of up to 0.3 ppmv may occur. Our current knowledge about IN abundance and properties is insufficient to rule out such effects. In contrast, microphysical (and thus radiative) cirrus properties and global subvisible cirrus coverage are very sensitive to the presence of IN, even at low concentrations and modest freezing efficiencies. This strong sensitivity warrants further research.

**P-5-52**

## STRUCTURE AND VARIABILITY OF THE QUASI-BIENNIAL OSCILLATION

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**Abstract**: A Non-Linear Principal Component Analysis (NLPCA) is applied to the monthly-mean zonal winds of the equatorial stratosphere to determine the optimal representation of the Quasi-Biennial Oscillation (QBO) and investigate its spatial and temporal variability. The NLPCA is conducted using a 2-hidden-layer feed-forward neural network. This type of network alleviates the usual problems of over-fit and non-uniqueness plaguing non-linear techniques of principal component analysis.

The two non-linear principal components of the stratospheric zonal-winds dataset offer a clear picture of the QBO. In particular, the structure of this NLPC shows clearly the asymmetry between the QBO westerly and easterly phase and the difference in QBO variability between cold and warm seasons. It also shows that the QBO phase is modulated strongly by two cycles: the 11-year solar cycle and another cycle of longer period.

**P-5-53**

## TEMPERATURE TRENDS ESTIMATED WITH FINITE-LENGTH DATASETS AND EVALUATION OF THEIR SIGNIFICANCE WITH SOME IDEALISED MODELS

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**Abstract:** Spurious linear trend may exist in the estimation with short-length data that have natural internal variability. Statistical characteristics of such spurious trends are investigated theoretically and numerically. The probability distribution function (PDF) of spurious trend depends on the standard deviation and the kurtosis of the PDF of the natural variability. The PDFs of the natural variability are evaluated by long time-integrations of a simple global circulation model, and it is founded that spurious trend is approximately follows a normal distribution in the mid-latitudes with 20-year data. Thus, statistical significance of linear trends obtained from observed data is estimated by the t-test. A cooling trend in mid-stratosphere at the mid-latitudes in summer is shown to be highly significant.

**P-5-54**

## THE OCCURRENCE OF TENUOUS CLOUD IN THE TROPICAL TROPOPAUSE LAYER AS RELATED WITH THE EQUATORIAL KELVIN WAVES COUPLED WITH THE MJO

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**Abstract**: This study examines the occurrence of tenuous clouds associated with the short term variations in the TTL, using aerosol extinction coefficient (version 19) from the Halogen Occultation Experiment (HALOE) measurement from 20 to 28 January 1993 during the Madden-Julian oscillation (MJO) active phase. Temperature and wind fields are also taken from rawinsonde measurements over Singapore to validate the occurrence of tenuous clouds. The tenuous cloud height is here estimated both from vertical profile of 5.26 μm extinction coefficient and four spectral analysis.

Global measurements of aerosol extinction reveal that the occurrence of tenuous clouds in the tropical tropopause layer shows a large scale structure, which is connected with 1) convective anomalies of the below 200 hPa, and 2) Kelvin waves with horizontal wavelength of 10,000-20,000 km above 200 hPa. Eastward of the convective region (prior to the occurrence of active convection), tenuous clouds occur in the region of cold anomalies caused by adiabatic cooling and longwave cooling above MJO convections. At the westside of convection (after the occurrence of active convection), tenuous clouds are displaced downward by downwelling or sedimentation, and disappear as the air warms adiabatically. An excellent consistency of tenuous cloud top with the region of easterly and cooling anomalies explains that the occurrence of tenuous cloud is globally controlled by equatorial waves induced by convective heating or adiabatic upwelling. This result demonstrates the tight connection between the occurrence of tenuous clouds and planetary scale variation in the TTL.

**P-5-55**

## LIDAR AND MST RADAR OBSERVATIONS OF STRATOSPHERE TROPOSPHERE EXCHANGE OVER A TROPICAL INDIAN STATION

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**Abstract:** High resolution measurements of winds including vertical winds and aerosols have been carried out using Mesosphere-Stratosphere-Troposphere (MST) radar and Nd: YAG lidar system, respectively, to study the stratosphere troposphere exchange, at National MST Radar Facility (NMRF), Gadanki (13.5°N, 79.2°E) a tropical station in India. The capability of MST radar to monitor stable layer structures has been used to monitor characteristics of tropical tropopause. MST radar observations of winds including vertical winds have been used to study the vertical wind variability in the vicinity of tropical tropopause during different seasons including during passage of Tropical Easterly Jet (TEJ) associated with Indian monsoon. Results clearly show the reversal of vertical wind in the vicinity of TEJ and also variability of vertical winds during different seasons, suggesting the variability of vertical transport across the tropical tropopause over this tropical station. High power Nd: YAG lidar system at NMRF, operating at a wavelength of 532 nm, has been operated to study the characteristics of aerosols and cirrus clouds in upper troposphere and stratosphere including the vicinity of tropical tropopause. Lidar data include backscattered signals, in the form of photons, recorded separately by using two independent identical photomultiplier tubes (PMT) with co (P) and cross (S) polarisations. Altitude profiles of photon counts obtained from P and S channels have been converted into scattering and depolarisation ratios. These two parameters have been used to study the aerosol and cirrus cloud characteristics over Gadanki. Results show multiple layers of enhanced scattering ratio around tropopause during clear sky conditions. The scattering ratio also showed very large magnitude (2) coupled with enhanced depolarisation ratio indicating the presence of cirrus clouds in the vicinity of tropopause. The lidar observed scattering coefficients have been used to derive both aerosol and cloud optical depths. These high time resolution measurements have been used to study the temporal variation of optical depths around the tropopause. Lidar backscatter measurements have also been analysed in conjunction with MST radar observed vertical velocity to examine the transport of aerosols in the vicinity of tropopause. Results clearly indicate the potential of combined observations of MST radar and lidar to investigate the stratosphere troposphere interaction using both vertical wind and aerosols as tracers.

**P-5-56**

# SEASONAL FORECAST OF THE NORTH ATLANTIC OSCILLATION WITH A STRATOSPHERE-TROPOSPHERE MODEL

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**Abstract**: We have run the atmospheric general circulation model ARPEGE with a well-resolved stratosphere and observed initial- and boundary conditions to investigate whether we improve upon the predictability scores from the troposphere-only models presented in the European project called PROVOST (Prediction Of climate Variations On Seasonal to interannual Timescales). Results of how well our modelled seasonal NAO index compares to both the seasonal NAO index from PROVOST and the observed NAO index from the ERA-40 data set will be presented.

**P-5-57**

# A SIGNAL IN THE ENERGY DUE TO PLANETARY WAVE REFLECTION IN THE UPPER STRATOSPHERE

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**Abstract**: A study of the energetics of the planetary waves will be presented for high-winter in the Northern Hemisphere (January to March). The analysis was done by means of a 3-Dimensional normal mode expansion of the atmospheric general circulation, represented by the NCEP/NCAR reanalysis. The basic working physical hypothesis is a trapping of the energy associated with planetary waves of zonal wave number 1 in the troposphere and lower stratosphere, when the upper stratospheric circulation reflects these waves. The reflecting configuration of the upper stratospheric circulation is characterised by a negative shear of the zonal mean zonal wind.

We found more energy associated with the barotropic and lower baroclinic modes when the upper stratosphere has a reflecting configuration. These results add more new evidence of planetary wave reflection by the stratosphere.

**P-5-58**

## DOWNWARD WAVE PROPAGATION ON THE STRATOSPHERIC POLAR VORTEX

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**Abstract:** Using a novel separation of variables, a closed form Green's function solution for the compressible quasigeostrophic system is derived, which shows explicitly the spatial dependence of the streamfunction response to a general distribution of Potential Vorticity (PV). In particular, it is shown that the Green's function decays algebraically like 1/r above the source point, compared with exponentially in all other directions. The stronger upward influence of the PV source means that the upper levels of a finite volume vortex rotate faster than the lower levels, stabilizing the upper vortex and destabilizing the lower vortex. As a consequence, wave propagation on a finite vortex is preferentially downward. For ellipsoidal vortices the effect is particularly dramatic with all wave breaking occurring in the lower vortex levels.

The same preferential downward propagation is shown to be a feature of more general vortices, and, in particular, vortices resembling the stratospheric polar vortex in size and aspect ratio. On such vortices, a disturbance placed centrally almost always exhibits significantly stronger downward propagation than upward. The phenomenon is remarkably robust, occurring for a range of planetary wavenumbers, vortex shapes, and disturbance amplitudes.

In the presence of a lower boundary the Green's function is modified by the inclusion of a barotropic component that dominates the response as the lower boundary is approached. Close enough to the boundary the sense of the differential rotation is reversed, destabilizing the central vortex. At a critical distance the barotropic component is such as to cancel the differential rotation in the lower levels, stabilizing the lower vortex against wave disturbances. Interestingly, this critical distance corresponds roughly to the distance between the ground and the stratospheric polar vortex.

**P-5-59**

## ON THE PROPAGATION OF TRANSIENT ROSSBY WAVES ON THE EDGE OF STRATOSPHERIC POLAR VORTICES

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**Abstract:** The propagation of Rossby waves on the edge of the stratospheric polar vortices is studied analytically and numerically in a simple quasi-geostrophic f-plane model. In contrast to the traditional approach, we consider basic states with very sharp PV gradients, more representative of the actual state of the winter stratosphere. For waves generated by time-dependent topographic forcing, we derive linear analytic expressions for the total angular pseudo-momentum generated by a finite pulse of forcing. Nonlinear simulations reveal that these expressions are surprisingly accurate even up to large forcing amplitude, when large wave breaking occurs. We highlight the distinction between barotropic and baroclinic components of the evolution, which seem to have been overlooked in previous studies. The implications for understanding sudden stratospheric warmings are discussed.

**P-5-60**

DOWNWARD PHASE PROPAGATION IN A SIMPLE MODEL
OF EXTRATROPICAL ZONAL VARIABILITY

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**Abstract**: Observations have shown that anomalies in the stratospheric Arctic Oscillation (AO) tend to precede same-signed anomalies in the tropospheric AO (Baldwin & Dunkerton, 2001). The downward propagation of these anomalies suggests that the state of the stratosphere might influence the future state of the troposphere. Using a simple zonally averaged model with prescribed mechanical forcing and Newtonian cooling (*e.g.* Garcia, 1987), we investigate the possibility that such a signal could arise solely as the response to a mechanical forcing localized in the troposphere. In this case the apparent downward propagation of the stratospheric circulation anomaly is purely phase propagation, and the stratosphere acts passively to redden tropospheric variability rather than exerting an independent influence. This demonstrates that downward-propagating stratospheric anomalies may not necessarily indicate a degree of stratospheric control over the troposphere.

**P-5-61**

INFLUENCE OF TROPOSPHERIC $SO_2$ ON PARTICLE FORMATION
AND STRATOSPHERIC HUMIDITY

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**Abstract**: Stratospheric water shows a strong positive trend, which is only partly understood. We suggest a mechanism that links this trend to increasing anthropogenic $SO_2$ emissions. Our model simulations and trajectories indicate that the $SO_2$ increase in China, South East Asia and the tropics results in the formation of more sulfuric aerosol particles and, as a consequence, to more ice crystals of smaller size in the Tropical Tropopause Layer (TTL). The ascend in the TTL leads to an uplift of small ice crystals into the stratosphere. In addition, the infrared heating of the clouds increases the uplift of these clouds. Ice crystals with higher number densities but smaller diameter are uplifted more readily, leading to an increase in the stratospheric humidity. We calculate that the increasing $SO_2$ emissions from China, South East Asia and from the entire tropical belt since the mid-1950's caused a significant contribution of the currently unexplained stratospheric water vapour trend.

**P-5-62**

STRATOSPHERE TROPOSPHERE EXCHANGE DURING SOUTHWEST
AND NORTHEAST MONSOON IN INDIA

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**Abstract:** Indian summer monsoon is associated with torrential rains, strong wind and lot of depressions in the Bay of Bengal and Arabian Sea. Southwest monsoon in India usually starts in the month of May or June and it retreats from the country by September and northeast monsoon starts by October and retreats by December. Both monsoons are characterised by intense convection and occasional depressions and cyclones in the Bay of Bengal and Arabian Sea. During Southwest monsoon the tropical easterly jet over the subcontinent and during northeast monsoon the subtropical jet stream are found. During the monsoon periods experiments were carried out using the Indian MST Radar located at Gadanki (13.5°N, 79.2°E). From MST Radars we get the three components of wind with high time and altitude resolution. These data are used to calculate the mass flux transport and the zonal and meridional momentum flux transport. The preliminary results of this study will be presented in detail in the conference.

**P-5-63**

## IS STRATOSPHERIC VARIABILITY COMPLETELY DETERMINED BY TROPOSPHERIC FORCING?

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**Abstract**: Recently, the authors showed that coherent, internal modes of stratospheric variability, observed previously in highly truncated models, persisted also in relatively high resolution models that provide a more realistic representation of stratospheric dynamical processes. These internal modes of variability consisted of downward propagating patterns of zonal wind anomalies that closely resembled those found recently in observational data sets. The modelled internal variability is associated with large variability in the upward EP fluxes into the stratosphere, which occurs despite the fact that the troposphere has no variability of its own: here, the stratosphere essentially controls the amount of wave flux that can enter into it. This begs the question to what extent is the observed stratospheric variability controlled by its own internal variability, and to what extent is it simply forced by large tropospheric variability.

This question is addressed using a simple variation of the model configuration used to identify the original, internal modes of stratospheric variability. Instead of being time independent, the tropospheric wave forcing is now allowed to vary in a prescribed manner as a simple, controlled representation of natural tropospheric variability. Comparing the characteristics of the stratospheric variability obtained with and without tropospheric variability provides an estimate of the importance of the latter. Finally, including a troposphere that evolves according to its own, internal baroclinic dynamics indicate how these results may carry over into the more complicated situation of the full troposphere-stratosphere system.

**P-5-64**

## ARE PILEUS CLOUDS A SOURCE FOR TROPOPAUSE CIRRUS?

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**Abstract**: The July 2004 CRYSTAL-FACE field program, based from Key West, Florida, showed that thin tropopause cirrus (TTC) layers were often present above cirrus anvils. Ice crystals in the TTC were small (10 micrometers across) and fairly numerous (0.5 /cc). The TTC persisted or even thickened while the anvil cirrus dissipated beneath. Although the TTC had nearly identical horizontal dimensions to the convectively formed anvil, *in situ* tracers showed that the TTC was derived mostly from tropopause air with only a minor contribution from the convection itself. Compared to clear surrounding air, the TTC had embedded a monochromatic gravity wave with a wavelength of 2 km and an amplitude of several hundred meters. With supporting photographic evidence, we speculate that the tropopause cirrus had its origins as convectively forced pileus.

**P-5-65**

MEAN RADIATIVE ENERGY BALANCE AND VERTICAL MASS FLUXES IN THE EQUATORIAL UPPER TROPOSPHERE AND LOWER STRATOSPHERE

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**Abstract**: Upwelling in the tropical upper troposphere is claimed to be responsible for most of the air entering the stratosphere. The details of the mass transport from the troposphere to the stratosphere are determining the composition - *e.g.* the water vapour content - of the air reaching the stratosphere. The vertical mass fluxes near the cold point tropopause are still poorly quantified.

The mean energy balance of the equatorial atmosphere (10°S to 10°N) above 15 km altitude can be approximated as a balance between radiative heating and adiabatic cooling from upwelling motion. Therefore, radiative transfer calculations can be used to quantify vertical mass transport in the equatorial upper troposphere and lower stratosphere.

In this study radiative transfer calculations are based on temperature, ozone and water vapour profiles from balloon sonde measurements at five equatorial locations providing accurate information on the atmospheric composition with high vertical resolution. The resulting mean clear sky heating rate profile shows radiative cooling in the lower troposphere and radiative heating above 15 km up to the top of the calculated profile at 28 km. Above 15 km the profile is shaped like an S with a local maximum at the cold point tropopause (17 km) and a local minimum at 19 km. The influence of clouds is examined using a satellite climatology, providing an estimate of the mean full sky (including clouds) heating rate profile. Depending on the assumed vertical cloud distribution the transition from radiative cooling to heating may occur significantly lower than in the clear sky case, demonstrating the potential importance of clouds for processes in the upper troposphere, such as troposphere to stratosphere transport. The full sky heating rate profile is then used to diagnose mean vertical mass fluxes. The resulting profile shows a decreasing mean upward mass flux from 16 to 19 km. This result means that only a small part of the air ascending at 16 km can reach the equatorial stratosphere. But what is the physical reason for this upwelling? Above 19 km the vertical motion is a gentle non-divergent upwelling mass flux consistent with the idea of a Brewer-Dobson circulation driven by waves dissipating in the extratropical stratosphere. The results below 16 km depend strongly on the assumed vertical cloud distribution, including the possibility of a continuous divergence from 15 to 19 km, consistent with ECMWF analysis.

**P-5-66**

UPWELLING AND MIXING WITHIN THE TTL: AIRBORNE *IN SITU* MEASUREMENTS OVER THE INDIAN OCEAN

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**Abstract**: We analyse *in situ* tracer and ozone observations in the Tropical Tropopause Layer (TTL) above the Indian Ocean taken on board the M55 Geophysica aircraft during the APE-THESEO campaign based out of Mahé/Seychelles (5°S) in February/March 1999. The University of Frankfurt's High Altitude Gas Analyzer (HAGAR) provided measurements of $N_2O$, CFC-12, CFC-11, halon-1211, SF6 and $CO_2$ during 6 successful flights out of Mahé. Ozone was measured at high resolution by two instruments, the Electrochemical Ozone Cell (ECOC) and the Fast Ozone Analyzer (FOZAN). The observations cover latitudes from 1°N to 19°S at altitudes up to 21 km with the majority of the measurements taken during horizontal legs within 2 km of the tropopause and during vertical legs at slow ascent/descent rates. The data thus, provide an unprecedented, detailed coverage of tracers and ozone in the TTL between the maximum convective outflow (13 km) and the cold point (17 km), to both sides of the ITCZ.

We examine the data with respect to the principal transport processes acting within the TTL. As deep convection penetrating the TTL was rare during the measurement period, conclusions about the slower transport processes can be made from the observations. Vertical tracer profiles and correlations of tracers and ozone show one case of inmixing of extratropical air above the tropopause, but no detectable influence of stratospheric air below the tropopause. For tracers with an interhemispheric surface gradient (F12, SF6, and H-1211) a latitudinal gradient is observed throughout the TTL, suggesting meridional mixing to be slow within the TTL. Finally, in the absence of both convection and stratospheric inmixing, we use ozone as a photochemical clock to estimate the rate of upwelling throughout the TTL. This analysis suggests that the observed mean ozone profile must be the result of ascent rates that are significantly faster than predicted by radiation models.

**P-5-67**

CAN STRATOSPHERIC WARMINGS AFFECT THE EVOLUTION OF SYNOPTIC SCALE EDDIES?

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**Abstract**: We examine the role that wave and mean flow evolution in the stratosphere may influence the evolution of synoptic scale eddies in the troposphere through a series of mechanistic model experiments. A downward reflected stationary wave component can develop in the stratosphere from either a turning level at the bottom of a strong polar jet or from an over reflecting critical level that forms during a stratospheric warming. In these experiments, the presence of the downward reflected wave component in the troposphere combines with the upward component emanating from the wave source to produce an anomaly in the vertical EP flux. This wave flux anomaly, in turn, forces an annular mean flow anomaly, which then affects the synoptic scale momentum flux in a way that reinforces the mean flow anomaly.

**P-5-68**

INVESTIGATION OF THE MEAN TROPICAL TROPOPAUSE USING
GPS AND THE NCAR-NCEP REANALYSIS

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**Abstract**: Characteristics of the mean tropical tropopause were investigated using GPS pressure-temperature data and assimilated fields from the NCAR-NCEP reanalysis. We focused on a 14-month period from May 2001 to June 2002 and on the latitude range -20 degrees. Pressures and temperatures of the monthly mean, lapse rate tropopause from GPS data at high vertical resolution show well known annual features, which have been compared to values derived from the NCAR-NCEP reanalysis at much coarser vertical resolution. This comparison shows some of the stengths and weaknesses of using assimilated fields for deriving long term changes in the height and temperature of the mean tropical tropopause. Specifically, we are investigating the consequences of interpolation schemes for determining the lapse rate tropopause, limitations on the precision of the mean tropopause height, and effects from lapse rate changes in the upper troposphere/lower stratosphere.

**P-5-69**

SOLAR ACTIVITY IMPACT ON STRATOSPHERE-TROPOSPHERE
GLOBAL CIRCULATION PATTERNS

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**Abstract:** The long-term behaviour of global circulation structures and their connections to some helio-geophysical influence, especially solar and geomagnetic activity, has been studied for SOLICE Project recently. To represent the objective characteristics of circulation patterns the spectral structure of both stratospheric and tropospheric fields is analysed in terms of spherical harmonics coefficients of expansions for potential vorticity; NCEP/NCAR database of reanalyses is used for period 1948-2002 with monthly data. Temporal analysis of significant spherical harmonics is introduced as well as the comparison of their changes with respect to the changes of different sets of solar, geomagnetic and global circulation indices. A strong connection to a set of extraterrestrial parameters appears for some distinctive shapes of polar vortex as presented in composites for solar maximum and minimum in vertical structure. The natural variability connected to the extraterrestrial influence is studied as well as interannual variability, with the emphasis to the QBO and ENSO. The systematic review of the appropriate correlations and linear regression analysis are presented and decadal variability and long-term trends are pointed out for some of the wave numbers. Long-term changes in the variability of the circulation patterns are analysed by means of wavelet analysis as well.

**P-5-70**

# STATISTICAL ANALYSIS ON SIGNIFICANT EFFECTS OF THE QBO ON THE EXTRATROPICAL STRATOSPHERE AND THE TROPOSPHERE

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**Abstract:** We have been investigating effects of the QBO on the extratropical stratosphere-troposphere coupled system by performing numerical experiments and by analysing daily global data both from the long time integrations and from the real atmosphere. Statistical significant signals can be found when the number of samples is sufficiently large.

**P-5-71**

# CUBIC ICE IN THE ATMOSPHERE

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**Abstract:** The phase of emulsified aqueous solution droplets, which froze homogeneously, has been measured using x-ray diffraction.

The freezing and melting point, as well as other phase transitions, were measured by carefully controlling the temperature of the emulsified sample between 25 and -100$^{o}$C. Over this temperature range hexagonal ice (Ih) is the thermodynamically stable form, while cubic ice (Ic) is a metastable form. The proportion of Ic formed when the droplets (of around 10 m in size) freeze was measured as a function of solute concentration for NaCl, $(NH_4)^2SO_4$, $(NH_4)3H(SO_4)^2$ and $HNO_3$. In general the particles freeze to form close to 100 c below –80°C and above this temperature the Ic fraction is between 5 and 80 depending on the solute and solute concentration. $(NH_4)3H(SO_4)^2$ solutions always freeze to form 30 c, even when the concentration is close to zero wt $HNO_3$ solution droplets freeze to form just a small component of Ic for freezing points above –80°C. One of the more surprising results of this study is that pure water freezes to around 25 c when it freezes homogeneously. This suggests that the Otswald law of stages, which states that the metastable phase will nucleate in preference to the stable phase, applies to water. Our results also show that the stability of Ic is much larger than previously thought in fact Ic was observed at -20$^{o}$C.

The formation of Ic at low temperatures may have significant implications on the properties on the properties of ice clouds in the upper troposphere and lower stratosphere. Murphy (GRL, Art. N°. 2230, 2003) has shown that the formation of Ic in cirrus clouds may alter the particle size distribution sufficiently to influence the optical properties of ice clouds and the rate at which the cloud particles sediment. Increased sedimentation will significantly alter the water vapour distribution in the upper troposphere.

**P-5-72**

ON THE ORIGIN OF THE MERIDIONAL CIRCULATION AND THE SURFACE PRESSURE CHANGE ASSOCIATED WITH THE ARCTIC OSCILLATION AND COMPARISON WITH THE POLAR-NIGHT JET OSCILLATION

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**Abstract:** The Arctic Oscillation (AO) is a hemispheric seesaw variability between the polar cap and the mid-latitude. It appears throughout the year but it is very active in winter time. As the AO is the seesaw variability of the sea level pressure, the role of the meridional circulation is crucial for the mass exchange between the polar cap and the mid-latitude. In this study, eddy forced meridional circulation and corresponding surface pressure change associated with the AO is examined with the comparison of the similar variability associated with the Polar-night Jet Oscillation (PJO). Effect of the surface pressure change is diagnosed by means of the Eulerian mean zonal symmetric quasi-geostrophic model. It is found that the typical AO is mainly driven by the mechanical forcing of zonal-wavenumber 2 and high frequency transient eddies, which are almost confined in the troposphere. In contrast, the PJO is driven by the combination of the mechanical and thermal forcing of mainly zonal wavenumber 1, which are extended toward the upper stratosphere.

**P-5-73**

THE ROLE OF MONSOON CIRCULATIONS IN THE CHEMISTRY AND COMPOSITION OF THE TROPICAL AND SUBTROPICAL UT/LS

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**Abstract**: The relation of ozone and water vapour in the upper troposphere and lower stratosphere (UT/LS) is strongly influenced by the off-equatorial Asian and North American monsoons in boreal summer. Both regions experience hydration, presumably as a result of deep convection. This behaviour contrasts sharply with the apparent dehydrating influence of near-equatorial deep convection in boreal winter. There is also a striking difference in ozone between Asia and North America in boreal summer. Over Asia, ozone concentrations are low, evidently a result of ubiquitous deep convection and the vertical transport of ozone-poor air, while over North America, ozone concentrations are much higher. Since deep convection also occurs in the North American monsoon, it appears that the difference in ozone concentration between Asia and North America in boreal summer reflects a differing influence of the large-scale circulation in the two regions: specifically, (i) isolation of the Tibetan anticyclone versus (ii) the intrusion of filaments of ozone-rich air from the stratosphere over North America. During boreal summer, as in winter, near-equatorial concentrations of ozone and water vapour are low near the equator. The result of these geographical variations is a trimodal distribution of ozone and water vapour correlation. Our talk reviews the observational evidence of this trimodal distribution and possible dynamical and microphysical causes, focusing primarily on the quality and possible sampling bias of satellite and aircraft measurements. A key issue is the ability of HALOE to sample areas of ubiquitous deep convection. Other issues include the vertical structure of tracer anomalies, isentropic stirring in the UT/LS, horizontal transport of biomass burning products lofted by deep convection, and connections to the moist phase of the tropical tape recorder signal in water vapour.

# POSTER PRESENTATIONS

## FRIDAY AUGUST 6, 2004

**P-6-01**

## INDIAN MST RADAR AND LIDAR OBSERVATIONS OF QBO AND QBO-LIKE OSCILLATIONS IN LOWER AND UPPER ATMOSPHERES OVER GADANKI DURING 1995-2003

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**Abstract:** An attempt has been made to delineate the characteristics of Quasi-biennial oscillations and their effects on climate changes in lower and upper atmosphere over the Indian subcontinent. For this purpose, we used about eight years of wind measurements (3.6-20 km) obtained with Indian MST radar and about three years (2000-2003) of temperature (25 - 80 km) observations made with the lidar both collocated at Gadanki (13.5°N 79.2°E), a tropical station in India. Morlet wavelet analyses performed for the radar data indicate that QBO in zonal winds has significant amplitudes (maximum about 9 m/s) in the height range of 16-20 km during the period of 1996-1999, which includes the active El Nino period of 1997. After 1999, the time evolution of QBO amplitude shows that its strength is decreasing to insignificant values. Here it may be noted that El Nino during the year 2002 was weak and we see insignificant amplitude of QBO in zonal winds during this period. This observation may indicate that strong El Nino may occur following the year of strong QBO oscillations in the tropical upper tropospheric zonal winds. The wavelet analyses performed on the temperature data indicate that significant QBO-like (1.4 year periodicity) oscillations are present at almost all the heights from about 40 km to 80 km during the period of 2000-2003. This observation of QBO-like oscillation in the upper atmospheric temperature data is in agreement with the theoretical predictions by Hamilton *et al*. (2001) and Horinouchi and Yoden (1998). Along with other weather parameters, detailed analyses of the above mentioned data sets will be presented for this study of QBO in atmospheric parameters and its effect on lower atmospheric climate changes.

**References:**

K. Hamilton, R. J. Wilson, and R.S. Hemler, Spontaneous stratospheric QBO-like oscillations simulated by the GFDL SKYHI General Circulation Model, Journal of Atmospheric Sciences, 58, Nov., 2001.

T. Horinouchi, and S. Yoden, Wave-mean flow interaction associated with a QBO-like oscillation simulated in a simplified GCM. J. Atmos. Sci., 55, 502-526, 1998.

**P-6-02**

## INTERHEMISPHERIC TEMPORAL VARIABILITY OF LOWER STRATOSPHERE TEMPERATURE ANOMALIES.

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**Abstract:** Inter-monthly to interdecadal global variability of lower stratosphere temperature (LST) is studied in order to determine regions with similar patterns of temporal variability and to develop an inter-regional comparative analysis. The data used in this study correspond to monthly stratospheric temperature anomalies for January 1979 to December 2001 made with the TIROS-N satellite Microwave Sounding Units (MSUs). The Principal Component Analysis (PCA) with S-mode Varimax rotated PCA, spatial correlation fields and spectral analysis are applied. The equatorial-tropical zone and the subtropical area show the warming caused by the eruptions of El Chichon and Mt. Pinatubo volcanoes but both regions are divided into two components due to the influence of the Quasi-Biennial Oscillation (QBO). The LST in the northern polar region is in anti-phase with the equatorial behaviour and shows the influence of volcanic eruptions, absent in the high latitudes of the Southern Hemisphere. Mid and high latitudes of both hemispheres show different behaviour which indicates the lack of global teleconnection between these latitudes. The LST series present a negative trend in both hemispheres.

**P-6-03**

## DIFFERENCES IN THE VARIABILITY ASSOCIATED WITH ENSO IN THE MIDDLE ATMSOPHERE BETWEEN A GENERAL CIRCULATION MODEL (WACCM) AND REANALYSIS DATA (ERA-40)

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**Abstract:** The ENSO signal in the middle atmosphere temperatures has been isolated using the Whole Atmospheric Community Climate Model (WACCM). This GCM spans to the lower thermosphere and is forced with time dependent SSTs. It has neither QBO nor radiative forcing from volcanic aerosols, and so the only sources of variability are those related to internal variability and SSTs forcing. Nonetheless, ENSO is not absolutely independent from those other sources of variability, so the Reanalysis Project ERA-40, which exploits the maximum information from observational sources up to the lower mesosphere, has also been used to analyse the differences between ENSO signal in the middle atmosphere (associated to WACCM) and that associated to reanalysis data in which QBO and volcanic effects are not removed.

Monthly-mean temperatures from WACCM and ERA have been used to calculate longitude-height lag-correlation maps between them and Nino 3.4 index at different latitudes. Besides, composites of temperatures and zonal winds for the strongest ENSO events have also been analysed. The comparison of the results has been carried out for the period 1979-2000. On the whole, both datasets provide similar patterns for the ENSO signal in the middle atmosphere but several differences are noticed. The ENSO signal lasts longer in the WACCM model while it concentrates between 2 and 3 months around the maximum of Nino 3.4 in ERA. The vertical propagation of the signal is more effective in the WACCM model in the Northern Hemisphere while results in the Southern Hemisphere show a better agreement. These differences could be partly related to the differences observed in the zonal-mean zonal-wind regimes, which are known to have a strong influence on the vertical propagation of the Rossby waves, but also indicate the influence of other sources of variability. In the tropics, the signal shows a zonal-band pattern in both datasets, which seems to be related to anomalies in zonal meridional circulation. The analysis of the composites shows that the zonal-band ENSO signal in the stratosphere appears earlier and is stronger in observations.

**P-6-04**

## LONG-TERM CHANGES OF THE HORIZONTAL WIND PARAMETERS IN THE MIDDLE ATMOSPHERE OVER THE ROCKET STATION VOLGOGRAD

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**Abstract**: The wind data obtained from rocket and accompanying radiosonde measurements at the station Volgograd (48.7°N, 44.3°E) during 1969-1995 are analysed. Above 60 km, for the period of 1976-1995, wind data measured by radar tracking of a metallised chaff ejected from a rocket near the apogee are analysed too. The statistical analysis involving linear trend estimates of zonal and meridional winds within a height range of 0-80 km, with a 5 km step, is done for each month of the year. The results reveal significant changes in the prevailing wind parameters, especially in the upper stratosphere and lower mesosphere. These changes are smaller in summer months, but increase in winter, with a peak in December-January. However, in winter, long-term monthly trends of the prevailing zonal wind in the stratosphere and mesosphere have opposite sings: positive in October, January, February and March and negative in November and December.

**P-6-05**

## ALTERNATIVES TO LINEAR TRENDS FOR CHARACTERISING STRATOSPHERIC TEMPERATURE CHANGES

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**Abstract**: Historical changes in global atmospheric temperature are typically estimated using simple linear trends. We consider three alternative simple statistical models, each involving breakpoints (abrupt changes): a flat steps model, in which all changes occur abruptly, a piecewise linear model (with data segments defined by breakpoints) and a sloped steps model, incorporating both abrupt changes and slopes during the periods between breakpoints. Autoregressive models (both first and second order) are used in combination with each of the above to account for the high lag autocorrelation of global temperature anomalies. We evaluate the goodness of fit of the models with a Bayesian Information Criterion to objectively determine which better describe the observations. This criterion assesses the reduction in mean-squared error for a given model, with a penalty factor to account for the number of fitting parameters in the model.

We will focus on results from applying these models to global monthly stratospheric temperature anomalies from radiosondes and satellite Microwave Sounding Units. Breakpoints are identified at the times of major volcanic eruptions (when the stratosphere warms abruptly), and two years following each eruption (when objective statistical methods identify significant downward temperature shifts). We examine two data periods, 1958-2001 and 1979-2001, and two layers, 100-50 hPa for radiosonde data and MSU Channel 4. We consider both the complete time series as well as censored versions, in which the two-year periods following the eruptions are excluded. We have also examined global temperature observations at the surface and in the troposphere, with breakpoints identified at different times, and will present some results from those regions.

We find that the autoregressive components contribute the most toward explaining the variance of the models. For the stratosphere, in all cases, a linear fit was one of the two best choices, and the flat steps or sloped steps model was the other, with very small differences in the Bayesian Information Criteria. Thus two fundamentally different, but equally valid, descriptions of stratospheric cooling were found: gradual change vs. more abrupt ratcheting down of temperature concentrated in post-volcanic periods (with abrupt warming after the eruption and by larger, somewhat less abrupt, cooling about two years after eruption). Because models incorporating abrupt changes are as explanatory as simple linear trends, we suggest consideration of these alternatives in climate change detection and attribution studies.

**P-6-06**

## AN IMPROVED WATER VAPOUR PRODUCT FOR THE SAGE II VERSION 6.2 DATA SET

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**Abstract:** SAGE II (Stratospheric Aerosol and Gas Experiment) is a space-based solar occultation instrument that measures stratospheric profiles of ozone, $NO_2$, aerosol extinction at 4 wavelengths from 386 nm to 1020 nm, and water vapour. In version 6.2 of the SAGE II data set, the water vapour retrieval process has been updated and improved. This update is in response to known problems in older versions of SAGE II water vapour data, including strong sensitivity to enhanced aerosol and a large apparent dry bias near the hygropause for version 6.1. Version 6.2 reflects a new understanding of the instrument process, especially a shifted spectral response for the primary water channel near 935 nm. Water vapour is measured with the SAGE II instrument using a single filter-based channel, nominally at 935 nm. It is hypothesised that the spectral response of the filter underwent a significant change in the first few years after launch, broadening and shifting to longer wavelengths. Such a change in the channel response would affect not only the apparent strength of the water vapour feature but also the contributions of other components, such as ozone absorption and molecular scattering. Correcting for a single constant shift in the filter from January 1986 to the present has yielded a data set in which the measurement bias observed in previous versions has effectively been eliminated. The sensitivity to aerosol has been reduced so that the recommended upper limit on 1020 nm aerosol extinction for usable water vapour data is $3x10^{-4}$ $km^{-1}$, about an order of magnitude reduction from the cutoff for version 6.1. Furthermore, it is possible to

distinguish features in the version 6.2 water vapour record that previously had been nearly indistinguishable, such as the tropical tape recorder.

**P-6-07**

VARIATIONS OF THE RESIDUAL CIRCULATION IN NORTHERN HEMISPHERIC WINTER AND THE IMPACT ON ARCTIC OZONE

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**Abstract:** The zonal forcing from the dissipation of tropospheric waves causes net transport of mass towards the north pol and adiabatic change of pressure in the air below, which leads to net diabatic cooling at high latitudes. Due to variability in the tropospheric wave activity, the strength of the residual circulation has a distinct seasonal cycle and significant year to year variability. We use a reverse domain filling trajectory model based on ECMWF ERA-40 data to compile a multiannual time series of the strength and spatial structure of the residual circulation. Two different approaches are used in the trajectory routine to calculate the vertical movement of air. The first approach is based on the vertical velocity given by ERA-40, a quantity that is derived from the divergence of the horizontal winds and that tends to be noisy. Therefore, in the second approach we use a radiation transfer model to calculate the diabatic heating rates from the divergence of the net radiation flux. We compare the derived descent from both methods with measured tracer distributions from satellite data and Arctic field campaigns to assess which approach results in a more realistic vertical transport. The successful method is used to compile a climatology of the diabatic descent for the ERA-40 time period and to derive the meridional transport from the vertical profile of the calculated descent. Furthermore, the variability and long term change of the climatology will be analysed in geographical resolution. The implications for variability and changes of the total ozone column in the Arctic are discussed.

**P-6-08**

DISTRIBUTION OF HCL AND $NO_X$ OVER TIBET PLATEAU IN STRATOSPHERE

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**Abstract:** The HCl and $NO_x$ data observed by HALOE in UARS satellite from 1992 to 2002 are used to analyse their distribution and variation in stratosphere over Tibet Plateau and their differences from those over the same latitudes. Compare them with the distribution and variation of Ozone we probed the possible influence of HCl and $NO_x$ on Ozone over Tibet Plateau. The results show that:

(1) The HCl mixing ratio increased with altitude in stratosphere over Tibet Plateau. In the level near 100 hPa and below, the HCl mixing ratio is no more than $10^{-10}$ in the layer from 10 hPa to 0.1h Pa, it reached 2-3 $10^{-9}$ in order. There are two maximum values for $NO_2$ mixing ratio over Tibet Plateau. One is located at 300-200 hPa and the other is in the 10 5 hPa layer. The minimum value for $NO_2$ is located near 150-50 hPa. As to NO mixing ratio, it rapidly increases with height except in 100-50 hPa and above 5 hPa.

(2) There are obvious differences between HCl, $NO_x$ mixing ratio over Tibet Plateau and those over the same latitudes, but their differences in the same level are not similar. In summer, the HCl mixing ratio near the 200-40 hPa over Tibet Plateau is less than that averaged in the same latitudes, while NO and $NO_2$ mixing ratio over Tibet Plateau are much higher in this layer. In the layer from 25 hPa to 5 hPa, HCl mixing ratio is larger than that averaged in the same latitudes, but $NO_x$ mixing ratio is almost as much as that in the same latitude.

(3) The correlation is obvious between the variation of HCl, $NO_x$ and $O_3$ over the Tibet Plateau, and it changes with altitude. There is obviously inverse correlation between HCl and $O_3$ from 25 hPa to 5 hPa. In the layer from 70 hPa to 30 hPa, the correlation of HCl and $O_3$ is not clear, while the negative correlation between $NO_x$ and ozone is evident in this layer. That means both the hydrochloric acid and nitrogen-oxide may cause the ozone depletion over Tibet Plateau, while HCl is important in the layer from 25 hPa to 6 hPa, and $NO_x$ is more important in the layer from 70 hPa to 30 hPa.

**P-6-09**

# CROSS-EQUATORIAL WAVE PROPAGATION OVER AFRICA AS INFERRED FROM TOTAL OZONE

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**Abstract:** The main variations of the general circulation of the atmosphere can be characterised by the various modes of atmospheric mass redistribution. Interhemispheric exchanges of atmospheric mass, through the upper troposphere and lower stratosphere, occur with considerable regularity on seasonal and subseasonal time scales. Observational evidence from previous studies indicates that anomalous and persistent regional atmospheric mass distributions (*e.g.*, atmospheric blocking) may often be related to interhemispheric atmospheric mass exchange. The tropical atmosphere plays a critcal role in mass redistribution. 24 years of total ozone measurements from the Total Ozone Mapping Spectrometer (TOMS) over Africa are used to study the structure of the interhemispheric exchange patterns, subseasonal, seasonal and quasi-biennial oscillation (QBO) in total ozone over the African continent. Interannual variability of total ozone near the equator (5°S to 5°N) is dominated by the QBO. The equatorial ozone anomalies are independent of season and are significantly correlated with the equatorial zonal wind. Tropical patterns of the ozone QBO are identified by computing lagged correlations between the zonal-mean equatorial ozone and ozone elsewhere in the tropics. Correlations between equatorial and tropical ozone in both hemispheres are variable. There are nodes or phase shifts in the correlation patterns at 10 latitude. There are indications of a correlation between wave activity, as measured by the eddy variance of the total ozone field, and the QBO. Cross correlation analysis of total ozone data is used to study the symmetrical characteristics of Northern and Southern Hemisphere tropics. Latitudinal and longitudinal total ozone asymmetry is observed in each month of the year. August has the least asymmetry while March and December have the highest asymmetry. These further allude to the influence of wave activity in the region. Observational evidence of interhemispheric wave propagation through the equatorial African total ozone is found in the 24 years (1979 to 2002) of TOMS total ozone analyses. Using time mean, standard deviation, and one-point correlation fields of total ozone, it is found that waves associated with local fluctuations with periods between 30 and 60 days propagate from the Tropical Northern Hemisphere and continue into the Southern Tropical Hemisphere. This result is in agreement with hypotheses that claim regions of time-mean westerlies in the tropics act as ducts allowing extratropical Rossby waves to propagate into and through the tropics. Horizontal structure of the waves appears to change little during the course of the interhemispheric propagation.

**P-6-10**

# CONTRIBUTION OF STRATOSPHERIC COOLING TO SATELLITE-INFERRED TROPOSPHERIC TEMPERATURE TRENDS

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**Abstract:** Over the period from 1979 to 2001, global mid-tropospheric temperatures derived from the Microwave Sounding Unit (MSU) channel 2 (T2) show a near-zero (0.01 K/decade) or small (0.095 K/decade) warming, and the MSU-inferred lower-tropospheric temperature (T2LT) also indicates only a small warming (0.055 K/decade). The surface temperatures based on *in situ* observations, however, show a pronounced warming of 0.17 K/decade. The discrepancy between the surface and tropospheric trends remain an important unresolved issue since Global Climate Models (GCMs) forced by combined anthropogenic and natural factors project an increase in tropospheric temperature that is somewhat larger than the surface temperature increase. A recent alternative analysis of MSU data does suggest that the mid-troposphere is warming faster than near the Earth's surface, but this method has been called into question. Here we show that trends in MSU mid-tropospheric temperatures are weak because large stratospheric cooling trends cancel contributions to the T2 brightness temperature by tropospheric warming trends. When the stratospheric contribution is removed using MSU's stratospheric channel, the tropospheric temperature trend derived from satellite data is consistent with the

observed surface temperature trend. For the tropics, we find the tropospheric warming is 1.6 times the surface warming, following a moist adiabatic lapse rate.

**P-6-11**

MIDDLE ATMOSPHERE PARAMETER FLUCTUATIONS AS RELATED TO EDDY TRANSPORTS AND LONG TERM CIRCULATION CHANGES

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**Abstract**: Mixing ratios of $H_2O$, CFC11, and $O_3$ have been measured in the upper troposphere/lower stratosphere with high spatial resolution by the CRISTA instrument. The data have been assimilated by the NCAR-ROSE model and are used to derive meridional eddy fluxes and - by a K approach – eddy coefficients. These coefficients are in close agreement with the effective diffusivities of Haynes and Shuckburgh (JGR, 105, 2000) except for tropical latitudes. The climate change problem suggests that such eddy transports should be analysed to determine if they are stable in the long run. For this purpose temperature variances as measured by LIMS and CRISTA 1 have been compared. They show substantial changes over this 16 year time interval, that are systematic in altitude and latitude. Other variations will be discussed, such as an apparent increase of gravity wave activity at the mesopause (above the Wuppertal OH station). Changes in variances are mutually related to middle atmospheric circulation changes. Such changes are well documented by observations, as for instance by the change of summer duration. This is shown by more than 5 decades of NCEP or ECMWF data. It will be compared to multi-decade runs of the WACCM model (a) with greenhouse gases changed, and (b) with SST changed.

**P-6-12**

STRATOSPHERIC WATER VAPOUR: A CCM STUDY OF ITS POTENTIAL IMPACTS ON OZONE DEPLETION AND CLIMATE CHANGE

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**Abstract:** We have developed a new interactive Chemistry-Climate Model (CCM) for coupled studies of the stratosphere. The CCM is based on the U.K. Met Office Unified Model (UM) and the stratospheric full chemistry schemes used in the TOMCAT/SLIMCAT off-line chemical transport model. The CCM results have been tested using observations and long-term CTM output and performs well. We have used the CCM to perform a series runs to investigate the potential effects of increased stratospheric water vapour on ozone loss and climate change. The chemical and radiative effects of the stratospheric water vapour were derived seperately with different radiative coupling and the integrated effects on ozone and climate were then inferred. Initial model results show that on average, stratospheric $O_3$ mixing ratios at middle and lower latitudes decrease by about 50 ppbv due to chemical effects of increasing water vapour, but increase by a similar 50 ppbv or so due to the radiative effects of the same 2 ppmv $H_2O$ increase. In the Antarctic both the chemical and radiative effects of increasing water vapour increase $O_3$. In the Arctic, however, the chemical effect of increasing water vapour causes severe decrease in the ozone mixing ratios by maximum 0.2 ppmv, while the radiative effect leads to significant increase in the ozone mixing ratios by maximum 0.2 ppmv. Increasing stratospheric water vapour tends to cool the stratosphere both directly through radiative process and indirectly through its chemical feedback, except at the Antarctic where the temperature responses differently to increasing water vapour with cooling by radiative effect and warming by chemical effect. The radiation-related effects of increasing water vapour give rise to a significant cooling of the stratosphere in all latitudes ranging from 1 K to 4 K. Also the CCM results indicate that the radiative effects of increasing water vapour tend to increase tropopause temperature by about 0.5 to 1 K, while the chemistry-induced effects decrease tropopause temperature by about 0.1 to 0.5 K. Further details will be presented at the meeting.

**P-6-12**

## TEMPERATURE CLIMATOLOGY FOR 40-60 KM FROM SAGE II

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**Abstract:**. SAGE II (Stratospheric Aerosol and Gas Experiment) is a space-based solar occultation instrument that measures stratospheric profiles of ozone, $NO_2$, water vapour and aerosol extinction at wavelengths from 386 nm to 1020 nm. Recently, a self-consistent molecular density retrieval was developed that uses SAGE II transmittance data above 40 km altitude. Since at this altitude attenuation of solar radiation due to aerosols can be neglected, there is enough independent information in five SAGE II channels (386-600 nm) to separate the absorption due to ozone and nitrogen dioxide from Rayleigh scattering. Vertical inversion to obtain profiles of these quantities from 40 to 65 km proceeds as in the standard SAGE II algorithm. The density gradient information for daily averaged profiles is converted to temperature. The resulting zonal average profiles provide coverage in latitude from about 70°S to 70°N with a full sweep in latitude taking between 25 to 40 days. The data are sorted into 20° latitude bands, and the time series are fitted to provide a mean temperature climatology and long-term trend estimates. The climatology agrees well with published climatologies. Analysis of long-term variation finds no statistically significant trend. An upper bound on a possible cooling trend of 3 or 4 K/decade is derived for high and middle latitudes between 40 and 45 km altitude.

**P-6-14**

## VHF RADAR OBSERVATIONS ON PROMINENT FEATURES OF GRAVITY WAVES AND WEAKENING OF TROPOPAUSE ASSOCIATED WITH TROPICAL COVECTION

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**Abstract**: This paper discusses the vertical wind disturbances and possible signatures of gravity waves associated with tropical convection. High-frequency gravity waves generated by deep convective storms play an important role in the circulation of the middle and upper atmosphere. Continuous vertical velocity measurements using 53-MHz Indian MST Radar located at Gadanki (13.5°N, 79.2°E) during monsoon and post monsoon seasons have been used for the present study. The experiments were conducted as part of convection campaign during June 2000 (during monsoon) and October 2002 (post monsoon), both periods are highly convective over the station. The radar made observations only with zenith beams, since the buoyancy waves are much more evident in the vertical wind component.

With the aid of such data of high resolution, several characteristics of Gravity Waves can be discussed. Vertical velocity in the middle troposphere is of the order of 6-8 m/s and variation of radar reflectivity for the vertical beam with height and time shows the effect of convection. NCEP/NCAR reanalysis data of Geopotential height on 1000 hPa level and TRMM rain rate have also been used to supplement convective activity. Time- Height variation of vertical velocity, radar reflectivity and Doppler width were also discussed in the paper. Time-Series and Power spectrum analysis of the vertical velocity are also showing some signatures of short period gravity waves of periodicity 10 min and 24 min associated with tropical convection. The vertical wavelength and Amplitude-Height profile have also presented. The convective heating and moistening profile during the observation period were also analysed. An attempt has been made to discuss these characteristics of vertical velocity disturbances, turbulence and observable signatures of gravity waves associated with tropical convection and the results will be presented in more detail in the seminar.

**P-6-15**

## STRATOSPHERIC CHANGES OVER ANTARCTICA

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**Abstract:** Measurements of the stratosphere using radiosondes and the Dobson ozone spectrophotometer began at Halley station in Antarctica at the start of the IGY in 1956/57. In the 1980s the measurements lead to the discovery of the Antarctic ozone hole and today the measurements continue in essentially the same fashion as when the record started. Similar measurements have been made at what is now known as Vernadsky station (formerly Argentine Islands or Faraday) on the Antarctic Peninsula. In order to fully evaluate the trends shown by the data it is necessary to understand the limitations of the measurement techniques. In this presentation I will demonstrate the methods used for the measurements and their limitations, and then compare and contrast the time-series from the two locations.

**P-6-16**

## WATER VAPOUR IN THE TROPOPAUSE REGION AS A FORCING AND FEEDBACK COMPONENT IN CLIMATE MODEL SIMULATIONS

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**Abstract:** Distribution, variability and trend of water vapour in the upper troposphere and lower stratosphere are important for the climate system. The radiative forcing caused by stratospheric water vapour trends (evident in observations and climate simulations) may be of similar magnitude as the forcing due to ozone changes. However, neither the geographic pattern nor the origin of these water vapour trends is sufficiently well known from observational or model data. This talk uses sensitivity and scenario simulations with a climate model to illustrate the current knowledge on the role of water vapour changes in the tropopause region as a forcing and feedback component in the climate system. Correlations between tropopause temperature and stratospheric water vapour found in an interactively coupled chemistry-climate model, the influence of stratospheric water vapour feedbacks on climate sensitivity, and the consequence of systematic errors in near tropopause water vapour for the simulated temperature distribution are all discussed. Potentially important respective climate model improvements will be suggested.

P-6-17

MEASURING BY MOONLIGHT: STRATOSPHERIC TRACE GASES DURING THE 2003 ANTARCTIC WINTER

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**Abstract:** During the polar winter, chemical processes occur in the stratosphere that ultimately lead to ozone depletion in the spring. The lack of sunlight during this period, however, has largely prevented detailed studies of relevant trace gases by traditional spectroscopic methods. We present first-ever spectroscopic measurements of the chlorine reservoir species hydrogen chloride (HCl) obtained using the moon as a light source during the 2003 Antarctic winter. HCl is the primary reservoir for chlorine in the stratosphere, and it is only under the extremely cold conditions that prevail in the polar winter that chlorine is released on the surface of polar stratospheric clouds (PSCs) to form to more active and ozone-destroying chlorine species. An understanding of the timing and extent of HCl depletion, hence, helps us to better understand the priming that the polar stratospheric region undergoes during the winter period. Concurrent measurements of nitric acid ($HNO_3$), a nitrogen reservoir species and the primary component of PSCs, were also made. These measurements of $HNO_3$ are used to further develop our understanding of the conditions leading to HCl depletion during the winter months. Results from the 2003 field campaign will be presented and compared with model predictions of HCl and $HNO_3$.

P-6-18

PREPARATORY ACTIVITIES FOR FUTURE ATMOSPHERIC CLIMATE AND CHEMISTRY MISSIONS OF THE EUROPEAN SPACE AGENCY

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**Abstract:** The European Space Agency's Envisat mission is successfully observing the Earth's atmosphere since its launch in 2002 and provides the scientific community with an unprecedented wealth of research data. In particular, the three instruments GOMOS, MIPAS and SCIAMACHY contribute significantly to atmospheric climate and chemistry research. Furthermore, ESA's ERS-2 mission is still operational with limitations in data coverage, which carries the GOME instrument for atmospheric ozone and other constituent measurements.

The Agency is conducting preparatory activities for future missions beyond the life time of Envisat and ERS-2, including chemistry and climate missions. The next landmark mission to be launched in 2005, in cooperation with EUMETSAT, will be the Metop operational series of new low-Earth orbit weather satellites. Metop will carry the GOME-2 instrument and the GRAS instrument for L-band radio occultation for temperature and water vapour measurements.

Two future mission candidates focusing on water vapour measurements have completed their Phase A study. WALES uses four-wavelengths a dial laser (around 935 nm) for high-resolution water vapour measurements in the entire troposphere. ACE uses radio occultation in the L-band and K/X-band for tropospheric and stratospheric temperature and tropospheric/lowest stratospheric water vapour. By the time of the symposium, the selection decision will have been made.

Further preparatory study activities are taking place for a limb-sounding UT/LS mission. An airborne mm-wave limb sounder demonstrator has been developed by the Agency and will start test flights in March 2004. Tomographic, two-dimensional retrieval algorithms have been developed through ESA-sponsored studies, which will significantly improve the exploitation of UT/LS microwave and infrared limb-sounder observations.

ESA is conducting preparatory study activities for a future Earth Watch mission for operational atmospheric chemistry monitoring, which could be implemented in the framework of the GMES initiative of the European Commission. ESA is also actively supporting the Integrated Global Observing Strategy (IGOS) Partnership, which establishes requirements for future long-term observation and analysis/integration systems in various areas of Earth sciences and related applications. IGACO is the IGOS theme dedicated to atmospheric chemistry. The IGACO theme report is presently being drafted and will identify the major scientific and societal issues and establish the observational requirements, as well as assess the adequacy of existing instrumentation.

**P-6-19**

## SPACE AND TIME VARIATIONS OF TEMPERATURE TRENDS IN THE ARCTIC STRATOSPHERE

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**Abstract:** A long series of monthly mean temperatures at 58 aerological sites located north of 65°N was used, after a 3-month sliding averaging, to calculate the trend at the 100 and 50 hPa levels. The total time period was 1959-2000 for 100 hPa and 1961-2000 for 50 hPa. Also, to estimate temporal variations of the trend, the calculations were made for the first and the second parts of the total period (1959/1961-1979 and 1979-2000, respectively), as well as for the intermediate 20-year periods. The spatial distribution of the trends was seen from the respective trend maps. For the total 40-year period, in every month only negative trends have been obtained for each station (with the exception of nearly-zero positive trends in December at 3 stations). However, some zonal asymmetry has been found, with the Canadian sector cooling slower than the northern Eurasia. For the shorter periods, both time and space variations in the calculated trends are rather great. Especially striking are the differences in the trends between the first and the second parts of the total period. For months from February to July, the trends during the 1979-2000 period were much more negative than those for the 1959/61-1979 period. So the speed-up of the cooling of the Arctic stratosphere in the latest decades seems to have occurred mainly in late winter and spring, till early summer. On the opposite, the early winter was characterised in this period (80-90s) by the warming of the Arctic stratosphere, which followed the cooling during the 60-70s. The large difference in the zonal means of the trend magnitude in the winter season between the different 20-year periods makes it speculative to consider the trends determined from such rather short periods as characteristic for longer-time development of the winter stratospheric temperature regime in the Arctic. Such estimates on the basis of the radiosonde data seem to be reliable only for the summer-early autumn season (and mainly for the zonal mean trend, if quantitative estimates are looked for). The instability of the winter-time trend estimates is related also to marked spatial variability of the trends seen on the corresponding maps of the trends. The bulk of the large cooling of the Arctic stratosphere registered during the 80-90s in February to April has been centred over northern Siberia and adjacent regions. The earlier (in 60-70s) cooling in November and December was also located in roughly the same sector. The trends reveal certain annual variations, but their nature depends on a region considered over north Atlantic and northern Eurasia the trends are generally greater in winter than in summer, while the opposite result is obtained for northern Canada. Particularly high uncertainty appears again in case of the shorter-period trends.

**P-6-20**

## STUDIES ON CONVECTIVELY GENERATED GRAVITY WAVES OVER THE TROPICS USING INDIAN MST RADAR ATGADANKI

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**Abstract:** VHF radar is a promising tool to study convective systems and their dynamical effects. Atmospheric Gravity waves play a significant role in controlling the middle and upper atmospheric dynamics. A special campaign has been conducted during October-November 2002 and June 2003 with the Indian MST Radar located at Gadanki (13.5°N, 79.2°E) to study the convectively generated gravity waves in the lower atmosphere. Convection is one of the important source mechanisms for the generation of gravity waves in the tropics. The excitation and vertical propagation of gravity waves are found to display specific characteristics pointing convection as a main source. The important characteristics of gravity waves are enhancement of signal strength from near the ground to the lower troposphere and are coupled with increase in both vertical velocity and turbulence. We observed the convective phenomena within a time span of 3-4 hours on 17-18 October 2002. The vertical velocity during this period was found to be 6-8 m/s in the troposphere. Present results illustrate that the rapid growth in wind disturbances, which we infer to be gravity waves, is the result of a temporally growing and moving tropical convective system. The dominant wave periods and their height profiles of amplitudes are studied. The satellite cloud images exhibited temporal growth and movement of cloud clusters over the region of the radar site. The vertical wavelength and the propagation direction of gravity waves are determined and the detailed discussions and the results will be presented in the full paper.

**P-6-21**

ASSESSING THE IMPORTANCE OF MOMENTUM CONSERVATION IN THE PARAMETERISATION OF GRAVITY WAVE DRAG IN ATMOSPHERIC MODELS

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**Abstract:** It is widely accepted that a realistic simulation of the climate of the middle atmosphere requires the parameterisation of the torque exerted by internal gravity waves propagating from the troposphere. Models, which fail to account for the angular momentum transfer by dissipating internal gravity waves (Gravity Wave Drag, GWD), suffer from the so-called cold-pole problem (unreasonably low Antarctic wintertime stratospheric temperatures).

Due to the lack of observational evidence, the parameters of a GWD parameterisation are typically tuned to obtain a reasonable mean climate. The physical realism of the response of a tuned GWD parameterisation to a radiatively induced change (ozone depletion, changes in greenhouse gas distribution, solar variability) is an important question. Since a key question in climate change is the influence of the stratosphere and mesosophere on climate, it is important to distinguish between true and spurious downward influence. In this study, momentum conservation is shown to provide a key constraint on the downwelling (and consequent adiabatic warming) induced by GWD in atmospheric models. A GWD parameterisation is said to be momentum conserving if all of the vertical momentum flux through any level is absorbed by the large scale flow above that level. The response of different GWD parameterisations to radiative perturbations is assessed through idealised calculations with a zonal-mean model. Particular attention is paid to the possibility of spurious downward influence (as a consequence of non momentum conservation), which could be falsely interpreted as stratospheric and mesospheric effects on climate. Several GWD parameterisations are compared and contrasted with Rayleigh drag (which is not momentum conserving). The impacts of allowing momentum flux to escape through the model lid and allowing the GWD to interact with a model sponge layer are also investigated.

**P-6-22**

RAYLEIGH LIDAR OBSERVATIONS OF DOUBLE STRATOPAUSE STRUCTURE OVER NORTHERN AND SOUTHERN HEMISPHERE STATIONS

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**Abstract:** The lidar technique, employing Rayleigh backscatter from molecules for middle atmospheric density/temperature measurements, has emerged as an effective tool for the past two decades. The capability of the Rayleigh lidar for high time and height resolution measurements has offered a new approach for studying various aspects of the middle atmosphere dynamics (gravity waves, tides, equatorial waves and planetary/Rossby waves etc.), not possible by the radars. The present study of middle atmosphere temperature structure is based on the lidar data collected from both northern and Southern Hemisphere stations. From the Northern Hemisphere, we use the data from Gadanki (13.5°N, 79.2°E) and Ahmedabad (24.2°N, 73.5°E) and from the Southern Hemisphere, we use the data from Observatoire de Haute Provence (44°N, 6°E) and Reunion (21°S, 55°E). Since the location of above stations are placed at Northern and Southern Hemisphere region and also at mid- and low latitudes, the study can be considerable important for the scientific community, in terms of differences in dynamics between the two hemispheres as well with seasonal variability. An interesting feature of the temperature profiles is the observed double stratopause structure in the height range of 40-60 km (Raju *et al*., 2004). The systematic analysis is performed from the above stations, and observed characteristics of the double stratopause structure will be presented.

**P-6-23**

## CHANGES IN STRATOSPHERE/TROPOSPHERE EXCHANGE IN A DOUBLED $CO_2$ CLIMATE

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**Abstract:** A middle atmosphere version of the Unified Model coupled to a slab ocean is used to assess how climate change will affect: 1) the position of the tropopause, 2) transport of water vapour into the stratosphere, 3) transport of tropospheric source gases into the stratosphere, 4) transport of ozone into the troposphere.

Significant changes in composition are found associated with a strengthened Brewer-Dobson circulation. A new theory is put forward to explain why the Brewer-Dobson circulation strengthens with increased greenhouse gas loading.

**P-6-24**

## COMPARISON OF SAGE II VERSION 6.2 WATER VAPOUR WITH BALLOON-BORNE AND MULTIPLE SPACE-BASED INSTRUMENTS

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**Abstract**: A new version of the SAGE II data products was released in October 2003. The primary change to the algorithm dealt with improvements in the water vapour product such as eliminating the dry bias in the lower stratosphere and reducing the sensitivity to aerosol contamination. Results of an extensive comparison of SAGE II version 6.2 water vapour and various correlative measurement from balloon-borne and space-based instruments illustrate significant improvement over the previous version, v6.1. In general, the agreement was within 10% or less over an altitude range of 15-40 km, when compared with frost-point hygrometer, HALOE, POAM III, and ILAS, and 15-20% when compared to MkIV. Above 40 km, SAGE II water vapour profiles are often noisy, and show an increasingly positive bias. Based on comparison with HALOE, a basic screening criteria would consist of electing measurements where the aerosol extinction coefficient at 1020 nm exceeds $2x10^{-4}$ $km^{-1}$ and water vapour uncertainty exceeds 50%.

**P-6-25**

STUDIES ON GRAVITY WAVE CHARACTERISTICS INCLUDING SATURATION PROCESS AT A LOW LATITUDE USING LIDAR AND MST RADAR

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**Abstract:** Gravity waves (GW) play a major role in transporting the momentum and energy in the middle atmosphere. These waves, having their source at lower heights, propagate upwards and deposit energy through wave breaking and dissipation process in the mesosphere, thereby significantly altering its thermal structure and wind pattern. Rayleigh Lidar, providing high resolution temperature profiles for the height range of 30-80 km, offers a valuable means to study the propagation characteristics of the gravity waves in the middle atmosphere as well as their saturation, breaking and dissipation processes. The Lidar studies of middle atmospheric gravity waves have been made mostly at mid and high latitudes and hardly any at low latitudes.

The establishment of an MST Radar and a collocated Rayleigh lidar at the National MST Radar Facility (NMRF), Gadanki (13.5°N, 79.20°E), offers an unique opportunity for a systematic study of lower and middle atmospheric GW characteristics at a low latitude. The intent of the present study is to undertake a comprehensive study of GW characteristics in the lower and middle atmosphere (4 to 80 km) using simultaneous lidar and MST radar measurements. The primary emphasis of the study shall be to understand the saturation mechanism through frequency and wave-number spectra using the high-resolution lidar data. The MST radar data is to observe the GWs simultaneously in the troposphere with a view to relate them to the GW characteristics in the stratosphere and mesosphere.

Initially the fluctuation associated with GW will be extracted from the temperature profiles using lidar data and velocity profiles using MST radar data. The perturbations associated with the GWs in time domain will be obtained by subtracting the mean profile from the individual profiles, where as in the height domain, third order polynomial fit will be applied to the mean profile and the difference will be obtained from the individual profile. Then, the velocity and temperature fluctuations will be subjected to Fast Fourier Transform (FFT) in both time and height domains after removing the trend, to get frequency and vertical wave number spectra. The wave number spectra were computed for the different height ranges, covering the tropospheric height region (4-16 km), stratospheric height region (30-45 km), lower mesospheric height region (45-60 km) and the upper mesospheric height region (60-75 km). The time period of propagating gravity wave is found to be more than 7 hrs and their vertical wavelengths are in the range of 5-20 km. The seasonal dependence of gravity wave activity has shown equinox is a maximum and minimum during winter season. In addition, the gravity wave saturation spectra in frequency and wave number are constructed and found that the power index of 5/3 slope follows the measured one for the time periodicity less than 1 hrs and 3 slope follows for the vertical wavelength less than 2 km.

**P-6-26**

MULTI-DECADEL 3D CTM SIMULATIONS OF PAST OZONE VARIABILITY AND TRENDS

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**Abstract:** The study of the observed decrease in stratospheric ozone at mid-latitudes since 1980 is one of the major issues, which has driven recent stratospheric research. These decreases, and their seasonality and interhemispheric differences have not been quantitatively explained, though many possible contributing processes have been identified.

In the past 2D (latitude-height) models have been used to study the effect of increases in stratospheric halogen loading on mid-latitude ozone, and these studies indicate that the halogen increase is a likely explanation. However, some 3D dynamical studies have shown that dynamical variability will strongly affect mid-latitude ozone, and a trend in dynamics may even be responsible for part, or all, of the observed trend. A problem with reconciling these somewhat conflicting explanations is that a coupled study containing all of the relevant dynamical and chemical processes has not yet been performed.

Following recent developments in 3D atmospheric modelling, it is now possible to perform long 'full chemistry' simulations at moderate resolution. I will described recent experiments with the SLIMCAT/TOMCAT 3D off-line chemical transport models (CTMs) forced by UKMO and ECMWF ERA40 analyses. A number of simulations has been performed which address the role of chemistry and aerosol variations in driving stratospheric $O_3$ changes at mid (and high) latitudes.

**P-6-27**

GLOBAL MEASUREMENT AND MODELLING OF GRAVITY WAVE MOMENTUM FLUX

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**Abstract:** Absolute values of Gravity Wave (GW) momentum flux are obtained from temperatures measured by the CRISTA satellite instrument in August 1997 (CRISTA-2). Global distributions of GW momentum flux calculated with the Warner and McIntyre GW parameterisation scheme for the same period are compared to the distribution of CRISTA GW momentum flux and to CRISTA GW temperature variances. Horizontal structures of the CRISTA momentum flux are in much better agreement with the Warner and McIntyre momentum flux results than horizontal structures of the CRISTA temperature variance data are. The best agreement between CRISTA and model data is achieved if low model launch levels (below about 400 hPa) are used.

**P-6-28**

THE CONTRIBUTION OF LONG-TERM CIRCULATION CHANGES TO COLUMN OZONE TRENDS AT NORTHERN MIDLATITUDES

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**Abstract:** Long-term, climate-related changes in lower stratospheric circulation influence monthly mean column ozone amounts at middle latitudes in several ways. First, since transport of ozone by the residual circulation is the dominant source of ozone at middle to high latitudes, interannual variability in this circulation contributes significantly to midlatitude ozone variability and trends. The circulation is driven by tropospheric waves entering the stratosphere and can be characterised by the integrated planetary wave flux (or approximately by the eddy heat flux) as a proxy. Second, since the amplitudes and phases of quasi-stationary planetary waves dominantly determine the zonal distribution of ozone in winter-spring (Siberian maximum, North Atlantic minimum, etc.), interannual and long-term variability in these amplitudes and phases contributes significantly to ozone trends at a given geographic location. Third, interannual variability in planetary-scale wave breaking behaviour contributes significantly to monthly mean ozone variability and trends at a given latitude. For example, during a given month, a single large poleward wave excursion event can decrease the monthly zonal mean ozone at midlatitudes, while increasing it in the tropics. In extreme events, rapid upwelling over upper tropospheric anticyclonic disturbances results in the formation of so-called ozone mini-holes. Of these mechanisms, the first and third contribute substantially to zonally averaged midlatitude ozone trends. The first is described adequately by the Transformed Eulerian Mean ozone continuity equation and is, therefore, relatively straightforward to analyze. However, the third involves non-linear effects (*e.g.*, a tropopause that meanders latitudinally on a planetary scale resulting in injections of ozone-poor air from the tropical upper troposphere into the midlatitude lowermost stratosphere) and is not easily analysed using this formalism.

Here, we report an effort to estimate the relative contribution of both residual circulation changes and planetary wave breaking behaviour changes to monthly zonal mean column ozone trends at northern midlatitudes during the 1979-2002 time period. To characterise the influence of planetary wave breaking behaviour, we use Ertel's potential vorticity on the 350 K isentropic surface. Empirical predictions of ozone interannual variability using zonal averages of the latter quantity are found to be more successful, on average, than predictions based on time-integrated eddy heat flux. In February and March, when observed ozone trends at northern midlatitudes are largest (about -4.5 per cent per decade), we find that approximately half of the observed trend can be attributed to a combination of both of these dynamical processes. The analysis may underestimate the total dynamical contribution because it neglects more localized processes, such as rapid upwelling over tropospheric anticyclones.

**P-6-29**

# LONG-TERM CHANGES OF METHANE IN THE STRATOSPHERE IN THE PERIOD 1978-2003

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**Abstract:** We present a 25 years-long time series of stratospheric $CH_4$ for the period of 1977 - 2003 using balloon-borne data of $H_2$, $CH_4$ and $N_2O$ from the whole air samplers Bonbon and SACURA and subsequent gas chromatographic analysis. To eliminate short term variability attributed to dynamical processes, we have used $N_2O$ as a vertical coordinate. A correlation analysis for the individual years is used, and the $CH_4$ mixing ratios are interpolated to three different levels of $N_2O$, corresponding to altitudes of approximately 17, 23 and 29 km. For the investigated period we find an average increase for the three levels of 7.9 (0.6) ppb/yr, 6.6 (0.3) ppb/yr, and 5.3 (0.6) ppb/yr, respectively. Thus, the increase of $CH_4$ can only account for roughly 1/3 of the increase in stratospheric $H_2O$ of 1 % per year over the last decades derived from previous studies. The simultaneously measured time series for the stratospheric $H_2$ mixing ratios show no significant trend for the period 1988-2003.

**P-6-30**

# THE EVOLUTION OF TOTAL COLUMN OZONE AT SOUTHERN MIDLATITUDES 1980-2000

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**Abstract:** The rate of decrease of Total Column Ozone (TCO) over the Southern Hemisphere mid-latitudes (30-60°S) has diminished from the eighties to the nineties. In order to better understand this evolution, annual mean, January, June and October monthly means are analysed, both in latitude and longitude, and fitted with polynomial functions to describe their evolution. The results show significant different evolutions in longitude particularly south of 40°S, with areas of enhanced depletion and others with stable ozone levels or even recovery. The reasons for this decreasing trend, which considerably slowed down before the slowdown of chlorine loading, is discussed together with the evolution of the tropopshere and lower stratosphere. To do so, decadal differences for TCO, as well as for a set of tropospheric and stratospheric dynamic indicators, are carried out and compared. The results of the comparative study show that TCO decadal variations are in general more closely related to decadal dynamic changes during the nineties than during the eighties.

**P-6-31**

METHODS FOR VALIDATION AND INTERCOMPARISON OF REMOTE SENSING AND *IN SITU* ICE WATER MEASUREMENTS: CASE STUDIES FROM CRYSTAL-FACE AND MODEL RESULTS

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**Abstract:** Remote sensing observations, such as those from AURA, are necessary for understanding the role of cirrus in determining the radiative and humidity budgets of the upper troposphere. Using these measurements quantitatively requires comparisons with *in situ* measurements, which have previously been validated.

However, a direct comparison of remote and *in situ* measurements is difficult due to the requirement that the spatial and temporal overlap be sufficient in order to guarantee that both instruments are measuring the same air parcel. The CRYSTAL-FACE mission provided an opportunity for assessing how well such intercomparisons can be performed and for determining the type of flight plans that will be necessary for validation of future satellite instruments. During CRYSTAL-FACE, remote and *in situ* instruments were placed on different aircraft (NASA's ER-2 and WB-57), and the two planes flew in tandem so that the *in situ* payload flew in the field of view of the remote instruments. We show here, however, that even with this type of careful flight planning, it is not always possible to guarantee that remote and *in situ* instruments are viewing the same air parcel. We use ice water data derived from the *in situ* Harvard Total Water (HV-TW) instrument, and the remote Goddard Cloud Radar System (CRS) and show that agreement between HV-TW and CRS is a strong function of the horizontal separation and the time delay between the aircraft transects. We also use a cloud model to simulate possible trajectories through a cloud and evaluate the use of statistical analysis in determining the agreement between the two instruments. If available we will also present data from the April 2004 MidCiX mission.

This type of analysis should guide flight planning for future intercomparison efforts, whether for aircraft-borne or satellite instrumentation.

**P-6-32**

ODIN/SMR GLOBAL MEASUREMENTS OF WATER VAPOUR AND ITS ISOTOPES IN THE MIDDLE ATMOSPHERE

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**Abstract:** Water vapour, the strongest greenhouse gas, is not only a good tracer of the dynamics in the middle atmosphere, but is also linked to many chemical processes like the natural destruction of ozone (through the $HO_x$ family). Improving our knowledge of the amount of water and its variability in the stratosphere and in the mesosphere is, thus, of primary importance. The Sub-Millimetre Radiometer (SMR) onboard the Odin satellite, launched in February 2001, measures the thermal emission from the Earth's limb in the 485-580 GHz spectral range. In particular, two bands around 489 and 557 GHz are used to study water vapour and its isotopes, on the basis of 4 days per month. Using a forward model and an inversion code based on the OEM, vertical profiles of $H_2O$-16, $H_2O$-18, and HDO are retrieved between roughly 20 and 70km at 489 GHz, whilst $H_2O$-16 is retrieved from the mid-stratosphere to the lower thermosphere (35-100 km) at 557 GHz.

In addition to the interesting picture of water vapour provided in the entire middle atmosphere, the unique and original measurements of HDO and $H_2O$-18 between 20 and 70 km allow the study of isotopic depletion/enrichment of water, supplying information on the origin of air masses (tropospheric or stratospheric).

**P-6-33**

THE BREWER-DOBSON CIRCULATION IN THE STRATOSPHERE AND MESOSPHERE: IS THERE A TREND?

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**Abstract:** The Brewer-Dobson circulation brings greenhouse gases and sources of reactive gases ($CO_2$, $CH_4$, $N_2O$, CFCs) into the stratosphere, profoundly modifying stratospheric radiation and chemistry. Total ozone in Antarctica increases during the early winter, consistent with the descent and convergence that are part of the Brewer-Dobson circulation, and at one site the rate of increase doubled since the 1960s suggesting a major increase in Brewer-Dobson circulation. The calculated greenhouse effect in the Antarctic midwinter lower stratosphere due to increased stratospheric $H_2O$ disagrees with the measured small trend in temperature, but this could be resolved by less $CH_4$ oxidation due to an increased Brewer-Dobson circulation. The observed increase in stratospheric $H_2O$ since the 1950s disagrees with decreased tropical cold-point temperatures, but would be resolved by an increased Brewer-Dobson circulation if dehydration during $H_2O$ entry is incomplete. These suggestions of a trend are contradicted by other evidence, and models with increased greenhouse gases disagree in the sign of their predicted trend in winter.

**P-6-34**

GRAVITY WAVE ACTIVITIES AROUND BAROCLINIC WAVES IN AN AGCM SIMULATION

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**Abstract:** A numerical experiment is conducted using CCSR/NIES AGCM to investigate gravity wave activities around baroclinic waves in June. The resolution is T106L60 with the top boundary at about 50 km altitude. The thickness of the model layers is about 550 m through the upper troposphere to the lower stratosphere. No gravity wave drag parameterisation is used in this experiment. In order to extract gravity wave components, high-pass filter with a cut-off period of about 30 hours are applied to the data.

Gravity waves around the baroclinic instability are generated around the area of large lagrangian Rossby number, where the subtropical jet is distorted. Their horizontal and vertical wavelengths are about 700 (km) and 4 (km), and periods are 12-24 hours. Their intrinsic frequency is higher than the inertial frequency, and satisfy the dispersion relation of inertia-gravity waves. The intrinsic phase speed of these waves is negative, and propagates westward in a fluid. Most of them do not propagate till upper stratosphere due to negative vertical wind shear.

The Eliassesn-Palm flux is used to evaluate effects of gravity waves to large-scale circulation. Large EP flux convergence associated with short-period gravity waves is seen above the subtropical jet in the Southern Hemisphere. Values of convergence are -10 (m/s/month), and occupies 30-50% of total EP flux convergence there. This deceleration is due to gravity waves generated around baroclinic instability. We discuss the roles of non-stationary gravity waves explicitly resolved in the model.

**P-6-35**

LOWER STRATOSPHERIC TEMPERATURES IN ANTARCTIC WINTER: THE 40-YEAR RECORD CONFLICTS WITH MID-LATITUDE TRENDS IN STRATOSPHERIC WATER VAPOUR

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**Abstract:** Water vapour is a potent greenhouse gas, and the observed increases in water vapour in the stratosphere act to cool it. Trends in lower-stratospheric temperature within the core of the Antarctic vortex in winter should be a unique indicator of trends in stratospheric water vapour, because changes in neither $CO_2$ nor ozone have a large effect on temperature in the lower stratosphere in the dark. The character and magnitude of the long-term changes in temperature in midwinter at Halley (76°S) are similar at 100 hPa to 70 hPa and 50 hPa, similar whether corrected for sonde changes or not, and similar to other Antarctic sites.

There was no significant trend in temperatures at Halley between 1960 and 2000, inconsistent with the change calculated from the observed trend in lower-stratospheric water vapour. Between 1980 and 2000 at Halley, the change in temperature was -1.8 ± 0.6 K, in agreement with the change calculated from the observed trend in stratospheric water vapour. The differences between these periods could be caused by a variation in the rate of oxidation of $CH_4$ to $H_2O$ in the upper stratosphere between 1960 and 1980. Such a variation in oxidation rate was observed by satellite between 1992 and 1999, caused by the Mt. Pinatubo eruption.

**P-6-36**

THE BROAD EDGE REGION OF THE ANTARCTIC OZONE HOLE COULD ALLOW INCREASED GREENHOUSE GASES TO DELAY OZONE-HOLE RECOVERY

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**Abstract:** Stratospheric $H_2O$ is increasing, and may be responsible for a large part of the observed cooling of the lower stratosphere. Further cooling will lead to more PSCs in the edge of the Antarctic stratospheric vortex in spring, though not in the vortex core, which already becomes cold enough for near-continuous PSCs. An improved diagnostic of mixing, plus measurements of $H_2O$, show that the vortex edge is weakly mixed with the core until late in the spring. This isolation will allow any increase in PSCs to result in continued severe ozone loss, despite reduced chlorine due to the Montreal Protocol. The isolated edge region is half the area of the ozone hole. It frequently passes over southern South America late enough in the spring for major UV damage, and in summer the broken-up ozone hole contributes to significant hemisphere-wide ozone loss.

**P-6-37**

## ON THE DECAY OF STRATOSPHERIC POLLUTANTS: OBSERVATION OF THE LONGEST-LIVED EIGENMODE OF THE STRATOSPHERIC DISTRIBUTION OF A CONSERVED TRACER

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**Abstract**: Utilizing 3-D model results from MM II we demonstrate that the decay time of the lowest eigenmode of the stratospheric distribution of a conserved tracer, tau(1), can be derived from a 1-D diffusion analysis. tau(1) obtained from measured vertical profiles of the mean age of stratospheric air gamma(z) should, therefore, be applicable to the realistic three-dimensional stratospheric circulation. Two case studies (a,b) give tau(1,a)=3.8 yr (estimated error ee=0.8 yr) and tau(1,b)=5.3 yr (ee=1.1 yr). These semi-observational times are shorter than the observational eigentime, tau(1,HTO)= 7.7 yr (ee=2 yr), determined from the decay of the tritium content in stratospheric water vapour following the thermonuclear test explosions in the early 1960's. Re-examination and adjustment of the assumptions going into the determination of tau(1,HTO), especially the trend in stratospheric water vapour, leads to a lower value, tau(1,HTO)= 6.3 yr (ee=0.9 yr) for the time period 1975-1983. The remaining difference with respect to tau(1,a) and tau(1,b) can possibly be explained by a temporal trend in gamma and tau(1), which might be induced by global warming. Our estimate of the current tau(1,HTO,c) is 5.3 yr (ee=1 yr). This updated tau(1,HTO,c) remains significantly larger than the tau(1,3-D) from most current stratospheric models. The large observational tau(1) indicate that stratospheric transport is slower than predicted by most current models. As a consequence the predicted decay of the stratospheric chlorine perturbation is probably too fast.

**P-6-38**

## GCM SIMULATIONS OF THE STRATOSPHERIC GLOBAL TEMPERATURE RESPONSE TO REALISTIC 20TH CENTURY FORCINGS

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**Abstract**: The GFDL atmospheric model (AM2) has been employed to assess the transient stratospheric temperature response to realistic changes in atmospheric species over the 1950-2000 period. Separate calculations are made to evaluate the effects of changes in $CO_2$, other well-mixed greenhouse gases and ozone, as well as the combined effects of including all species changes. Transient ozone concentrations are obtained from the MOZART chemistry transport model. The vertical profile of the temperature changes and the interannual variability of temperatures is evaluated. Results are compared to previous time-slice calculations for 1979 and 1997 obtained with the GFDL SKYHI GCM.

**P-6-39**

BENCHMARK WATER VAPOUR MEASUREMENTS: REQUIREMENTS, MEASUREMENT TECHNIQUES AND VALIDATION

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**Abstract**: Figure 1 in the SPARC Assessment of Upper Tropospheric and Stratospheric water vapour (SPARC 2000) presents a summary of relationships between stratospheric water vapour measurements from different instruments. Quoting from the conclusion section of chapter 2 on data quality, with specific reference to this figure, 'For both the troposphere and stratosphere there is no single technique or instrument platform that is recognized as a standard to which other techniques should be compared, and thus comparisons were made relative to one another'. In other words, after about thirty years of instrument development, testing, validating, and intercomparing, it is unclear whether we are making water vapour measurements accurate enough to satisfy the needs of the scientific and global communities.

For example, a trend in stratospheric water vapour is thought to be a prominent indicator of climate change. Accordingly a reported increase of 1 % per year over a 45-year period must be taken seriously. Nevertheless, considering the volatility surrounding global climate change and proposed governmental responses to that change, and the state of water vapour measurements as reported in SPARC 2000, how much credibility can be given to the data sets used to determine that trend? Solutions to additional questions regarding testing strat-trop exchange mechanisms, measuring supersaturation in and around cirrus clouds, or predicting heterogeneous ozone loss in polar regions, require water vapour measurements with proven accuracy. This same requirement holds for validation of satellite-borne instruments. In either case, in order to avoid instrument dependent conclusions, a 'standard' or 'benchmark' water vapour instrument is required.

In this talk, we use recent *in situ* water data, validated by laboratory calibrations and in-flight intercomparisons, to address requirements for a benchmark water vapour instrument. We will outline the rationale for and progress in adding an infrared tunable diode laser hygrometer as a permanent part of both our laboratory calibrations and our flight instrumentation. Finally, we will use results from our instrument to illustrate procedures such that any interested party can duplicate the calculations that derive archived mixing ratios from the raw data.

**P-6-40**

ON GRAVITY WAVES NEAR THE TROPOPAUSE ASSOCIATED TO JET-STREAMS

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**Abstract**: Jets and fronts are known from observations to be major sources of gravity waves in the mid-latitudes. These waves are important for their impact on the middle-atmosphere circulation, but also for their contributions in the tropopause region to PSC formation, and to turbulence and mixing when wave-breaking occurs. However, the dynamical mechanisms that are responsible for the excitation of gravity waves by essentially balanced motions, such as jets, are still poorly understood. In investigations of interactions of balanced motions with gravity waves, the flow is generally thought of as a superposition of both types of motions. Yet balanced motions and gravity waves can be coupled in space and constitute 2 parts of the same motion. In order to illustrate and quantify this spatial coupling, we have analysed the normal modes of a linear vertical shear in the linearized primitive equations for a rotating stratified fluid over a rigid boundary. These modes consist of balanced motions near the surface that connect through an inertial critical level to gravity waves aloft. It is shown, analytically and numerically, that the amplitude of the gravity waves is exponentially small in the Rossby number and depends asymmetrically on the meridional wavenumber of the mode. The relevance of this coupling in a more realistic flow is analysed in normal modes of a two-dimensional jet obtained by numerical simulations using the Weather and Research Forecast (WRF) Model.

In a complement to this study, we have also used mesoscale simulations of idealised baroclinic wave development to identify the flow regions where gravity waves are generated, the possible generation mechanisms and the importance of the propagation of these waves in the complex flow background.

**P-6-41**

## THE TEMPORAL AND SPATIAL VARIABILITY OF MINOR CONSTITUENTS AS OBTAINED BY MIPAS-B MEASUREMENTS

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**Abstract**: The MIPAS-Balloon instrument is a cryogenic limb emission FTIR spectrometer with a spectral coverage between 5 and 14 microm and a spectral resolution of 0.035 $cm^{-1}$.

Two MIPAS-Balloon datasets have been investigated for this study: One was retrieved from a flight in mid-latitudes on April 30, 1999 covering three limb sequences of spectra before, at and 3 hours after sunrise allowing to investigate both the $NO_y$ partitioning, as well as the temporal evolution of the short-lived species $N_2O_5$ and $NO_2$ at sunrise.

The second has been recorded inside and at the edge of the polar vortex in March 2003 in a mode with very high temporal and spatial resolution for 5 hours. This dataset features a temporal resolution of about 5 minutes.

The dependency on the solar zenith angle of minor constituents, such as the short-lived $NO_y$ species as well as ClO, is analysed and compared to a chemical box model. The MIPAS-B data are also compared to calculations performed with the 3-D chemical transport model KASIMA. The deficits of the models will be highlighted, *e.g.* discrepancies between the global model and the measurements are found in the night-time built up of $NO_2$ in the lower stratosphere and in the temporal evolution of the $N_2O_5$ mixing ratio.

**P-6-42**

## PECULIAR BEHAVIOUR OF TROPOPAUSE OBSERVED IN TROPICAL AND EXTRA TROPICAL LATITUDES WITH CHAMP/GPS RADIO OCCULTATION MEASUREMENTS

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**Abstract:** The tropopause region, which is the transition zone between the turbulently mixed troposphere and the more stable stratosphere, has attained international interest as it was recognized as indicator for climate variability. Long-term radiosonde and NCEP (National Centers for Environmental Prediction) reanalysis show decreasing trend of the tropopause temperature in the tropics by 0.5 K/decade and an increase in tropopause height of about 20 m/decade. Recent research has shown that increases in the height of the tropopause over the past two decades are directly linked to ozone depletion and increased greenhouse gases.

However, using Global Position System data, for the first time a peculiar behaviour of tropopause is observed in tropical and extra tropical latitudes. A global analysis of structure and variability of tropopause is presented. The analysis is based on radio occultation measurements by CHAMP/GPS from May 2001 to December 2003 (123,923 occultations). Tropopause height defined by conventional lapse rate and cold point tropopause (LRT and CPT) is found to be increasing from tropics to extra tropical latitudes in contrast to earlier observations. This feature is more prominently observed in the Indian and Pacific oceans where large cumulous convection is expected to exist, and less observed in the parts of North and South America. Moreover, the height of the tropopause is found to be increasing significantly in winter hemisphere. Significant hemispheric differences were found both in the tropopause height and temperature. To elucidate the observed nature of the tropopause, we discuss the role of dynamical processes and their impact on chemical composition.

**P-6-43**

# MONITORING EAST ASIAN SUMMER MONSOON USING UPPER TROPOSPHERE HUMIDITY DATA FROM GEO-STATIONERY METEOROLOGICAL SATELLITES

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**Abstract**: In most of the geo-stationery meteorological satellites, viz., Japanese GMS, NOAA's GOES and EUMETSAT's Meteosat, a wavelength of 6.7 mm was employed to monitor distribution of global water vapour at regular intervals. So most of the radiation sensed by this channel comes from the atmospheric layer between 300 and 600 hPa. Earlier studies demonstrates that brightness temperature from this channel (T b6.7) is useful for not only qualitatively analysing the moisture transport but also quantitatively inferring Upper Tropospheric humidity (UTH) and precipitable water above 400 hPa. Thus, moisture information derived from this type of channels should be useful for understanding hydrological circulation.

Recently Fasullo and Webster (2002) proposed a diagnostic criteria based on large scale hydrological cycle (HOWI) to assess the onset and withdrawal dates of the Indian Monsoon. Based on the similar type index East Asian summer monsoon onset and withdraw dates are determined using ECMWF re-analysis data. In this paper the relationship between HOWAI and UTH derived from the GMSS-5 water vapour channel (UTH6.7) is studied for the year 1998. It is found that UTH6.7 represents a significant variations of HOWI and, hence, can be used in monitoring summer monsoon evolution studies.

**P-6-44**

# DETECTION OF THE SECONDARY MERIDIONAL CIRCULATION

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**Abstract**: The Multi Taper Method-Singular Value Decomposition (MTM-SVD), a multivariate frequency-domain analysis method, is applied to detect and reconstruct the quasibiennial oscillation (QBO) signal in stratospheric zonal and meridional wind, temperature and geopotential heigth fields. The data used has been extracted from the NCEP reanalysis to analysed significant and spatially coherent narrowband oscillations during the second half of the 20$^{th}$ century (1958-2001). After the QBO is found as the most intense signal in the stratospheric zonal wind, the MTM-SVD method is used to determine the patterns induced by the QBO at every stratospheric level and data field. In the obtained patterns, the secondary meridional circulation associated with the QBO (SMC) is identified. This circulation is characterised by negative (positive) temperature anomalies associated with adiabatic rising (sinking) motions over zones of easterly (westerly) wind shear and over the subtropics and midlatitudes, while meridional convergence and divergence levels are found separated by a level of maximum zonal wind shear. These vertical and meridional motions form quasi-symmetric circulation cells over both hemispheres, though less intense in the Southern Hemisphere.

**P-6-45**

# ENHANCEMENT OF GRAVITY WAVE ACTIVITY OBSERVED DURING MAJOR SOUTHERN HEMISPHERE STRATOSPHERIC WARMING BY CHAMP/GPS MEASUREMENTS

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**Abstract**: Using GPS occultations we have analysed the gravity wave activity during the major sudden stratospheric warming event that occurred in the Southern Hemisphere in the late winter/spring of 2002, and which for the first time split the polar vortex into two parts. The vertical temperature profiles measured by CHAMP/GPS are used to analyse the dynamics and structure of the unusual SSW, while the corresponding gravity wave energy (using potential energy, Ep) is estimated using temperature fluctuations. The observed temperatures show a rapid poleward moving increase with a maximum of about 45-50 K with respect to the undisturbed winter conditions, and a reversal of the latitudinal gradients at 30 km and below within 15 days (September 15-30). During this time gravity wave energy is observed to be 3 times higher than usual. This enhancement is observed near the edge and outside the cold polar vortex, but not inside the vortex. For a comparison with other years, CHAMP/GPS temperatures during 2001 and 2003 are also analysed. Before the warming, four strong minor warmings (8-15 July, 2-10 August, 20-28 August, and 1-10 September) with a frequency of one week are observed from mid-July 2002 onwards until mid-September 2002. After the warming, the temperatures dropped by some 10 K lower than during the other 2 years analysed. Remarkable latitude and longitudinal variations of the warming were found. We discuss the observed event with potential interaction of gravity waves, planetary waves and the mean circulation during the stratospheric warming. We also discuss the global variations of stratospheric gravity wave activity.

**P-6-46**

# THE TEMPORAL TREND OF $CO_2$ AND THE MEAN AGE OF STRATOSPHERIC AIR DERIVED FROM BALLOON BORNE WHOLE AIR SAMPLES

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**Abstract**: Mean age of stratospheric air can be derived from the observation of long lived tracers with neither sources nor sinks in the stratosphere. The age of stratospheric air at a given stratospheric location is a time scale summarising the ability of the atmosphere to transport material to that location from the troposphere and thus a diagnostic tool of stratospheric transport. Mean age is particularly sensitive to the strength of the advective circulation. Changes of mean age of stratospheric air are, thus, a very suitable indicator of possible changes of stratospheric circulation, which could be induced *e.g.* by climate change.

We present a series of balloon borne observations of stratospheric $CO_2$ mixing ratios that was started in 1977 and has been extended until the present to investigate possible long term changes in mean age. Data from the cryogenic whole air samplers operated at the University of Frankfurt (Germany) and Tohoku University (Japan) are combined. The analysis is performed both for high and mid latitudes. We also compare mean age derived from $CO_2$ with mean age derived from SF6 for a series of about 10 observations performed between 1995 and 2003. As the vertical gradient of mean age gets very small above a certain altitude level, we group the $CO_2$ data above this level and derive a single mean age value for each flight. Different grouping criteria are compared and discussed. Inside the uncertainties arising from the observations and from the determination of mean age, no statically significant trend can be observed.

**P-6-47**

## GRAVITY WAVE ACTIVITY OVER THE SOUTH WEST INDIAN OCEAN BASIN

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**Abstract:** Daily radiosonde observations made at Seychelles (4.66°S, 55.53°E) and Tromelin Island (15.53°S, 54.31°E) in the Southern Indian Ocean, over 4-year period (December 1998- December 2003), are used to characterise the activity of gravity waves in the lower stratosphere. With the experimental observations of La Réunion Island (20.8°S, 55.3°E) the study provide a global view of gravity wave activity over the South West Indian Ocean basin within the southern tropical belt at the longitude of about 55°E. The islands are located in an active convective region more particularly in austral summer. A previous work (Chane-Ming *et al*., GRL 2002) has determined some gravity-wave parameters during the passage of Cyclone Hudah from 11 March to 30 April, 2000 near Tromelin island. An extension of this work has provided a climatology of gravity-wave parameters over Tromelin Island during December 98-July 2002 (12th conference of the middle atmosphere, AMS 2002) in relation to the convective activity (OLR, TMI rain rate, WLD/NNN index), the QBO in comparison with that of Coco Islands (12°S, 97°E) (Vincent and Alexander, 2000). The background convective activity was observed to be the major source of gravity waves in the lower stratosphere over Tromelin Island with mesoscale structures such as tropical cyclones. This present study aims at contributing to the cooperative effort in producing climatologies of wave parameters in a global scale.

**P-6-48**

## FORCING MECHANISMS OF THE SEMIANNUAL OSCILLATION

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**Abstract**: Oscillations of the mean zonal wind in the tropical stratosphere and mesosphere with 6 months period are known as the SemiAnnual Oscillation (SAO). It is also well known that the zonal momentum forcing by the meridional wind and the eddy momentum deposition by large-scale waves and gravity waves play an important role in the SAO.

In this study, forcing mechanisms of the SAO are investigated by using Met Office UK assimilated data (1992-2003) and GCM experiments. The GCM developed at Kyushu University is used in this study. The resolution is T21L55 with the top boundary at about 150 km altitude. The gravity wave drag parameterisation and QBO-like forcing in the lower stratosphere are introduced to our GCM. We investigated the effect of QBO oscillation on the SAO. The momentum balance is diagnosed by using the TEM momentum equation.

In the stratopause SAO, the zonal wind acceleration of large-scale waves and gravity waves is mainly influenced by the lower stratosperic QBO. In the GCM experiments, the westerly momentum deposition due to the gravity waves drag is stronger during the easterly phase of the QBO than during the westerly phase of the QBO. In the mesopause SAO, gravity wave drag is also very important to the SAO-QBO interaction.

**P-6-49**

EQUATORIAL GRAVITY WAVES IN A GENERAL CIRCULATION MODEL

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**Abstract:** Gravity waves have an important role in the equatorial lower stratosphere. In the present study, equatorial gravity waves are analysed in a general circulation model with high horizontal and vertical resolution. The model is a CCSR/NIES general circulation model. The horizontal resolution is T106 with grid difference about 120km. So, gravity waves with horizontal wavelength larger than several hundreds km can be analysed. Vertical resolution is about 550 m in the upper troposphere and lower stratosphere with top boundary about 50km. Convective parameterisation is Arakawa-Schubert scheme. The model has no gravity wave drag parameterisation in order to see gravity waves in the model atmosphere. Output data are one hour from June 10 to June 16.

A third-order polynomial is fitted to the data to give the mean fields, and the deviation from this fit gives the perturbation profiles, which are defined gravity waves of short-vertical wavelength. There are equatorial gravity waves in the lower stratosphere. The dominant vertical wavelength is about 5 km. Rossby-gravity waves are seen around African regions. Kelvin waves are dominant around Indian Ocean and equatorial Western Pacific regions. Eastward moving gravity waves of n=0 are also seen around Eastern Pacific.

These gravity wave activities of short-vertical wavelength are different from those of short period (30 hours) in the equatorial lower stratosphere (cf. Kawatani *et al*. 2003). Short-period gravity waves are distributed locally. For instance, they are generated by a strong diurnal cycle of convection, especially around the Bay of Guinea, the Indochinese Peninsula and South America.

**P-6-50**

STRATOSPHERIC WATER VAPOUR ANALYSIS AT ECMWF

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**Abstract:** Stratospheric water vapour in the ECMWF model is determined by transport and a source/sink term for methane oxidation. Since there are no operational observations of water vapour in the stratosphere, water vapour has so far been left unaffected by data assimilation in the stratosphere. Experiments have now started with the assimilation of stratospheric water vapour information from the MIPAS instrument. A new formulation of the humidity background errors, which has already been shown to make the humidity analysis more accurate in the troposphere, will be evaluated for the stratosphere. Particular attention will be paid to changes in the lower stratosphere, and interactions between the troposphere and stratosphere introduced by the stratospheric water vapour observations.

**P-6-51**

A QUANTITATIVE COMPARISON OF GRAVITY WAVES SIMULATED
BY A HIGH-RESOLUTION GCM TO THOSE CALCULATED
WITHIN THE DOPPLER SPREAD PARAMETERISATION

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**Abstract**: Internal gravity waves play important roles for the general circulation of the middle atmosphere. A number of parameterisations for non-orographic gravity waves have been developed and used in climate models. However, our knowledge for global distribution and temporal variation of the gravity waves has been limited due to difficulties in observations. This study estimates global distribution and seasonal variation of the gravity waves by use of a T213L250 GCM, which can resolve waves as small as 250 km x 600 m, in horizontal and vertical respectively. Wave momentum flux explicitly simulated by the GCM is compared to those calculated within the Doppler spread parameterisation by Hines (1997), in which the same background wind and wave sources as derived from the GCM simulation is used.

**P-6-52**

MOMENTUM FLUX IN THE TROPOSPHERE AND LOWER STRATOSPHERE DURING THE MAP EXPERIMENT

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**Abstract:** The Mesoscale Alpine Experiment took place from September to November 1999. In the area of Laggo Maggiore a UHF and VHF wind profiler were set up and ran continuously. The VHF wind profiler is a five-beam radar. The VHF radar measurements have been used to estimate momentum flux of gravity waves in the troposphere and lower stratosphere. Three methods have been used: one using three beams (one vertical and two obliques), a second one using four beams (two pairs of oblique beams symmetrically offset from the vertical), and the last one, the hybrid method using the vertical beam and a pair of radial beams. At first the different waves present in the data set are determined. Then, a comparative study is carried out as a function of the wave period and permit to test the robustness of the results.

**P-6-53**

SEASONAL AND INTERANNUAL VARIATIONS OF GRAVITY WAVES IN EQUATORIAL AFRICA

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**Abstract**: The present study focuses on the variability of gravity waves in equatorial Africa area. Two different sets of data are used and are complementary. The first one is the ozone data set, obtained by sondes launched in the tropical belt in the framework of SHADOZ (Southern Hemisphere ADditional OZonesondes) campaign. Thompson *et al*. (J. Geophys. Res., 2003) showed that the interannual variation of stratospheric ozone in the Southern Hemisphere is characterised by a quasi-biennial oscillation (QBO) informing about atmospheric transport. The signatures of gravity waves are observed and analysed in temperature and ozone profiles. The second set of data is the radiosonde data, which complemented the first one with wind profiles.

Gravity waves are characterised with both sets of data from January 1998 to December 2003 period for four stations located in a belt ranging between 15° of latitude. Gravity wave parameters are determined in the upper and the lower stratosphere. The sources and their variability are also examined in relation with convection, monsoon and QBO.

**P-6-54**

ACTIVITY OF GRAVITY WAVES ABOVE LA RÉUNION ISLAND (21°S, 55°E)

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**Abstract:** La Réunion island, located in the South-west part of Indian Ocean, is a secondary site of the NDSC network since 1994 providing measurements, such as lidar and ozone data, for the survey of the stratosphere. In 1999, a Raman scattering lidar system has been implemented. Our study on gravity waves (GW) takes advantage of Raman lidar technique and is based on continuous temperature data set in the troposphere and the lower stratosphere during four years from January 1999 to December 2003. Monthly and seasonal variability of spectral wave parameters are examined using nightly-averaged temperature profiles. The data set is completed with radiosonde measurements. Possible sources of GW, such as convection and the subtropical jet are examined in addition with others geophysical phenomena: the quasi-biennial oscillation (QBO). A comparative study is also investigated with observations of another sites, such as Tromelin Island (15°S, 54°E) and Seychelles (4°S, 55°E) located at the same longitude in the southern tropical belt.

**P-6-55**

## THE RESPONSE OF MESOSPHERIC OZONE TO THE SOLAR STORM OF OCTOBER 28, 2004 AS SEEN BY OSIRIS ON ODIN

**E. Llewellyn**, D. Degenstein, R. Gattinger, N. Lloyd, J. Truitt Wiensz, and A. Bourassa

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**Abstract**: The largest solar proton event in the past thirty years took place during October 28, 2003, and had a significant impact on the Earth's atmosphere. These energetic protons produced both $HO_x$ (H, OH, $HO_2$) and $NO_x$ (N, NO, $NO_2$) constituents in the mesosphere at polar latitudes (60° geomagnetic) in both hemispheres. The OSIRIS instrument on the Odin satellite measured the effects of this event on October 28/29 and again on October 31/November 1, 2003. On October 28/29 the oxygen infrared atmospheric band emission in the dayglow was decreased to less than 1/3rd of its normal value for altitudes above 54 km in the southern auroral zone, Northern Hemisphere measurements are limited in October as the Odin orbit is in darkness at that time. The ozone loss, which is reflected in the measured dayglow signal, closely maps the expanded auroral oval and provides direct evidence of the mesospheric effect of the solar proton event. The close identification of the ozone loss with the auroral oval is possible as OSIRIS is used with a tomographic retrieval algorithm. While OSIRIS operates only in a limb observing mode, there is some evidence of an enhanced NO-gamma band emission above 60 km. On October 31/November 1, when OSIRIS was again in an atmospheric observation mode, the oxygen infrared atmospheric band dayglow brightness had returned to normal values. This provides direct evidence that the $HO_x$ reaction scheme that is responsible for ozone depletion is extremely rapid and that mesospheric recovery from ozone depletion is fast.

**P-6-56**

## REMOTE SENSING OF THE UT/LS VIA GPS RADIO OCCULTATION

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**Abstract**: GPS radio occultation are active limb soundings, which can provide accurate measurements of atmospheric refractivity and Total Electron Content in the Ionosphere. By tracking the coherent occulting signal transmitted by the Global Positioning Satellite system, GPS occultation can offer vertical profiling of the atmosphere with very high vertical resolution, making it apt to capture gravity waves and tropopause structure. In this presentation we discuss an introduction to the technique, current limitations, lines of progress in the retrieval technique, data availability, and illustrate a couple of scientific applications.

**P-6-57**

## SEASONAL GRAVITY WAVES DRAGS ON THE UPPER STRATOSPHERE DUE TO NORTHWESTERN PACIFIC TYPHOONS

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**Abstract:** In a recent study of the first author and his co-authors (Z. Chen, P. Preusse, M. Jarisch, M. Ern, and D. Offermann, 2003), it has been revealed that a northwestern Pacific typhoon can generate stratospheric gravity waves with the horizontal scales ranging from 500 km 1000 km, and carrying a magnitude of 0.001 Pascal of momentum flux into the upper stratosphere Statistics indicates that the annual mean number of typhoon in the Northwestern Pacific is about 32, most of them happen in summer.

In this presentation we show that a parameterisation scheme is developed to derive the magnitude of the momentum flux of the waves from operational satellite observations that can scale the intensity of a typhoon (*e.g.* the brightness temperature observations from the GMS-5 satellite), and operational meteorological data analysis. The seasonal effect of the Gravity Wave Drags due to the typhoons in the area is derived.

**P-6-58**

## IMPACT STUDIES ON ATMOSPHERIC CHEMISTRY OF FUTURE SUPERSONIC AIRCRAFT FLEET.

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**Abstract**: The objective of the European project SCENIC is the study of the atmospheric impact of possible future fleets of supersonic aircraft and the possibility of reducing this environmental impact in changing the aircraft design. Several atmospheric research institutes and aviation industry representatives are involved in the project to use the most realistic emissions scenario within different numerical models of the atmosphere.

Two periods are studied: 2025 and 2050, both of them with a pure subsonic fleet or a mixed fleet (sub supersonic). The emissions of $NO_x$ and water vapour, as well as the production of sulfate aerosols, are taken into account to calculate the supersonic feet emissions impact on the chemistry.

For the 2050 period, due to the higher supersonic aircraft number in the mixed fleet, some alterations (within the range of the industry possibilities) of the super-sonic fleet design, such as flight altitude, number of aircraft or Mach number, are also investigated.

**P-6-59**

## GRAVITY WAVE CHARACTERISTICS OBTAINED FROM RADIO OCCULTATION SOUNDINGS: OBSERVATIONAL FILTER AND CLIMATOLOGY

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**Abstract:** Retrievals of GPS-based radio occultation soundings provide stratospheric temperature profiles with high vertical resolution. Consequently, data from *e.g.,* the GPS/MET, CHAMP and SAC-C missions have been used to infer characteristics of the global distribution of gravity waves and vertical wave number spectra in the stratosphere.

The standard dry temperature retrieval, however, suffers from high sensitivity to measurement noise. This requires filtering of the raw measurements, which reduces resolution. The distinction between gravity wave signal and instrumental noise is also difficult.

We present a variational (1DVar) retrieval of radio occultation data allowing the estimation of gravity wave parameters. Averaging kernels provide the observational filter of radio occultation measurements. We show that the smoothing required due to noise levels in raw phase measurements of currently operating GPS receivers is the main limiting factor in vertical resolution, which strongly depends on altitude. Implications for the interpretation of gravity wave climatologies obtained from radio occultation data are discussed.

**P-6-60**

GRAVITY WAVE GENERATION BY SMALL-SCALE TRANSIENT CONVECTION: A MODEL STUDY AND COMPARISONS TO OBSERVATIONS AND A PARAMETERISATION

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[2]National Center for Atmospheric Research, Boulder, USA; [3]Bureau of Meteorology Research Center, Altaneda, USA

**Abstract**: Convection is an important source of gravity waves, particularly in the tropics. Such waves carry momentum vertically, and through breaking and dissipation they contribute to driving the important quasibiennial and semiannual oscillations in tropical zonal winds. Global circulation models of the middle atmosphere include these effects of small-scale gravity waves via parameterisation. The parameterisations require input properties of the gravity waves, such as their horizontal wavelengths and phase speeds. Previous work has shown that the properties of the waves generated by convection can be sensitively dependent on the spatial and temporal scales of the latent heating in convection.

We describe a model study of latent heating and gravity wave generation based on precipitation radar observations during the Darwin Area Wave Experiment (DAWEX). Because the wave properties are sensitive to the details of the latent heating, our model study includes realistic spatially and temporally varying latent heating derived from volumetric precipitation radar retrievals. The field of gravity waves generated by this latent heating in the model are analysed and compared to other DAWEX observations for validation. The modelled wave properties are also compared to a parameterisation of convectively generated gravity waves that is based on linear theory of wave generation by a thermal forcing. The sensitivity of the wave properties to the background wind profile and the scales and variability in the latent heating field will be discussed.

**P-6-61**

TREND COMPARISONS BETWEEN GPS OCCULTATION, ECMWF, NCEP REANALYSIS, AND THE MICROWAVE SOUNDING UNIT

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**Abstract**: The Microwave Sounding Unit (MSU) aboard the NOAA TOVS series satellites provide the longest satellite-based record of tropospheric and stratospheric temperatures to date. Their measurements of an absorption line of a well-mixed gas, started in 1979, are well calibrated, are mostly insensitive to clouds and have global coverage, but recently three independent analyses concluded in conflicting temperature trends for the mid-troposphere. Their discrepancy is explained from the corrections for orbital decay and non-linear change in the detector response. GPS occultation provides an independent data set, whose absolute calibration properties offer the potential to resolve that discrepancy.

We use the JPL-occultation archive using GPS/MET data from 1995-97, and the CHAMP and SAC-C experiments from 2001 to the present, to simulate the MSU stratospheric temperature channel. Stratospheric brightness temperatures at each occultation profile were calculated with a radiative transfer code, mapped globally using Bayesian interpolation, and compared directly to maps of MSU stratospheric temperature.

The GPS-based value suggests a larger cooling trend and smaller seasonal cycle, with NCEP midway between. The gap is largest during boreal summer in the Northern Hemisphere, where radiosondes constraint the reanalysis. ECMWF exhibits differences that might be related to the assimilation of raw rather than pre-processed MSU data. We examine the sensitivity of the inter-annual trend difference to seasonal and latitudinal bias arising from misperception of the 60-GHz oxygen absorption lines and the climatology missing in the static weighting function.

**P-6-62**

STRATOSPHERIC GRAVITY WAVES GENERATED BY TYPHOON-
A NUMERICAL SIMULATION STUDY

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**Abstract:** In this presentation the results of a numerical simulation study focusing on investigating the typhoon effect of generating stratospheric GWs will be presented. By applying the PSU/NCAR mm5 model for a northwestern Pacific typhoon (Winnie, 05-23 August 1997), the critical features of the typhoon (comparing with the brightness temperature observations from GMS-5 satellite) and the mean state of the background circulations (comparing with the temperatures observations of the stratosphere from the CRISTA II mission) were captured by the simulation.

Detailed investigations revealed that significant stratospheric GWs were triggered by the typhoon. A Typhoon related Gravity Waves Active Area (hereafter referred to as TGWAA) was defined. Momentum flux spectrum with respect to the zonal wave number and frequency in the TGWAA was calculated. Results indicated that the GWs dominant modes were those propagating in the upstream of the background flow (Easterly wind) with a spatial scale ranging from 500 km to 1000 km in the horizontal, and from 7 km to 10 km in the vertical. The temporal scale was rather monotonic with the periods concentrated at 15 hr. The averaged momentum flux in the TGWAA was 0.001 Pascal at 19 km altitude, 0.0008 Pascal at 25 km altitude, indicating that the waves effect on the mean flow should be paid more attention.

**P-6-63**

STRATOSPHERIC OZONE EVOLUTION AT OHP (43.9°N, 5.7°E) DURING 1985-2003
BASED ON MULTIPLE REGRESSION ANALYSIS

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**Abstract**: By means of a multiple regression model, the evolution of stratospheric ozone measured by DIAL lidar at Observatoire de Haute-Provence from 1985 to 2003 is analysed. The present study provides the statistical relationship of solar flux and several dynamical parameters (Quasi-Biennial Oscillation, North Atlantic Oscillation and Eliassen-Palm flux) to changes in vertical profile of ozone. Solar flux and QBO explain 5 to 20% whole period ozone variation, while NAO and EP flux have negligible relationship. However, NAO and EP flux have significant correlation with monthly ozone variation. Deseasonalised ozone variation is regressed with these 4 explanatory parameters and trends of its residual are calculated. Considered measurement errors and vertical profile of ozone concentration, trends results indicate a decrease of ozone depletion.

**P-6-64**

# A COMPARISON OF CTM GENERATED TOTAL OZONE WITH THE NIWA HOMOGENISED TOMS/GOME DATA SET

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**Abstract**: Because of the importance of the ozone layer to life on Earth, it is vital that the processes affecting it are understood. One of the ways to provide insights into the processes responsible for the observed trends in ozone is to use a Chemistry-Transport Model (CTM). Offline CTMs (those which are run using pre-calculated circulation fields) have the advantage that they are relatively fast to run. However, in order to produce reasonable results with such a model, a high quality circulation data set is needed. The new ECMWF ERA-40 reanalysis data set may prove to be suitable for such use. Circulation data from the ECMWF ERA-40 reanalysis was used to drive the 3D CTM MEZON for the time period 1978-1998. The resulting distribution and concentration of ozone is compared with measurements, and with results of model runs driven by UKMO circulation data. Thus, an insight is provided into the ability of our model, driven by ERA-40 circulation data, to capture the variability in ozone.

**P-6-65**

# THE IMPACT OF STRATOSPHERIC OZONE DEPLETION AND $CO_2$ ON AAO TREND AND REGIONAL CLIMATE CHANGES AT SURFACE OF SOUTHERN HEMISPHERE: IMPLICATIONS FOR WATER RESOURCES IN AUSTRALIA

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**Abstract:** The CSIRO T63/L18 AGCM has been used within the framework of the Climate of the 20$^{th}$ Century Project to complete an extensive suite of experiments using ensemble approach. The AGCM has been forced with HadISST 1.1 sea surface temperature and sea ice dataset for period 1871 to 2003. In addition the relative role of solar variability, time varying $CO_2$ and stratospheric ozone have been eveluated in this setup.

The analysis of the CSIRO AGCM model results show that model simulated trend of mean sea level pressure (MSLP) for period 1971 to 2003 has very similar spatial distribution to the trend computed from ERA40 data. The model and observation show strong decrease in MSLP in high latitude of Southern Hemisphere and increase in mid-latitudes, with characteristic wave number three patterns present in both observation and model simulations forced by the observed SST, solar, $CO_2$ and ozone. The stratospheric ozone depletion has a strongest contribution to the trend in MSLP distribution during the all months, except for winter where the $CO_2$ effect is strongest.

The pereliminary results show a significant influence of stratospheric ozone depletion on the observed drying trends in coastal eastern Australia during the past decade. The effect of increasing $CO_2$ and ozone depletion on rainfall are in opposite direction in many regions of the globe, in particular eastern Australia and South Pacific Convergence Zone. This prolonged and persistent drought conditions lead to widespread water use restrictions in all major urban areas of eastern Australia in recent times.

**P-6-66**

# GEOPHYSICAL VARIABILITY IN V6.2 STRATOSPHERIC AEROSOL AND GAS EXPERIMENT II WATER VAPOUR MEASUREMENTS

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**Abstract**: The Stratospheric Aerosol and Gas Experiment (SAGE) II instrument has collected vertical profiles of stratospheric ozone, nitrogen dioxide, water vapour, and aerosol extinction at four wavelengths with high resolution since the program's inception in October, 1984. The previous version (v6.1) of SAGE II water vapour measurements in particular exhibit clear biases in comparisons with other instruments (notably HALOE), but were of sufficient quality to provide evidence of long-term stratospheric increases, in agreement with independent measurements. This bias has often been attributed to the inability to completely clear the effects of aerosols. In the latest version (v6.2), the SAGE II processing team has made great strides in characterising stratospheric water vapour by performing a single wavelength-shift and increasing the channel-width by 10 from 1986-present. These advancements have significantly reduced this bias except in the proximity of heavy aerosol levels. We present results characterising the geophysical variability in the new v6.2 water vapour retrievals. Analysis techniques include performing singular value decomposition on the covariances between the water vapour and QBO time series to characterise the inter-annual variability in the data and multiple linear regression analysis to reproduce the tropical tape recorder and near-global seasonal cycles. Comparisons with HALOE v19 data show dramatic improvements (compared to v6.1) in reproducing the near-global seasonal cycle patterns and the tropical tape-recorder.

**P-6-67**

# GRAVITY WAVES IN THE LOW STRATOSPHERE OF THE TROPICAL REGION OF THE SOUTH AMERICA - IMPACTS OF VERTICAL RESOLUTION

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**Abstract:** The present work aims to study numerically the process of energy transport between the troposphere and the low stratosphere in the tropical region of Brazil by gravity waves generated in situations of intense convective activity exploring the impact of the vertical resolution used in the model (RAMS-Regional Atmospheric Modelling System).

Observations show great alterations in the temperature and wind fields in 70-20 hPa in soundings near very intense convective systems and there are indications that the vertical resolution used in the numerical model can represent very significant differences (of the order of 5C) in the fields of temperature in the low stratosphere.

At this point we look at homogeneous simulation to make an evaluation of the process and its impacts. It is intended to study, which is the necessary vertical resolution in numerical models for foreacast in the tropical region.

**P-6-68**

## THE INTERACTION OF GRAVITY WAVES WITH STATIONARY WAVE/MEAN FLOW VACILLATION CYCLES IN THE STRATOSPHERE

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**Abstract**: Vacillation cycles spontaneously form in a model in which stationary waves are forced in the troposphere and propagate through a stratospheric mean flow maintained at climatological values through radiative relaxation and constant body forces. We examine what happens to the vacillation when the constant body force is replaced with gravity wave forcing computed using the Alexander-Dunkerton parameterisation. Gravity waves play multiple roles in the vacillation dynamics. First, they help keep the winter jet speed weak enough for stationary waves to propagate through it. Second, the gravity waves modify the planetary wave EP flux divergence, both through wave damping effects and through the mean meridional circulation that gravity wave forcing on the mean flow sets up. Finally, the quasi-stationary flow made up of the mean flow and planetary wave modulate the gravity propagation, thereby providing a three-way interaction, which we attempt to describe by examining these separate mechanisms individually.

**P-6-69**

## MIDLATITUDE TEMPERATURE CLIMATOLOGY OF THE MIDDLE ATMOSPHERE MEASURED BY RAYLEIGH LIDAR

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**Abstract**: A temperature climatology of the middle atmosphere has been derived from Rayleigh-scatter measurements using the University of Western Ontario’s Purple Crow Lidar (PCL). The lidar is situated near Western’s campus in London, Canada (42.9°N, 81.4°W). The PCL climatology includes calculations of monthly average temperature and temperature variability, as well as the amplitude and phase of annual and semi-annual oscillations.

The stratosphere climatology shows some significant differences from both the CIRA-86 and NRLMSIS-00 models. While CIRA’s stratopause altitude is typically within 1 km of the PCL climatology, its stratopause temperature is, for all months except January and February, up to 5 K warmer than the PCL climatology. The NRLMSIS-00 model’s stratopause temperature agrees more closely with the PCL climatology, however, from March through July it is also 5 K warmer than the PCL measurements. The NRLMSIS-00 stratopause altitudes are typically 1 to 2 km lower than those of the PCL climatology.

The PCL mesospheric climatology shows that the mesopause is up to 15 km lower than predicted by CIRA or MSIS models in spring and summer. The temperature of the PCL climatology mesopause is as much as 20 K warmer than that predicted by the models. However, the PCL climatology compares favourably to other mesospheric Rayleigh-lidar climatologies. Significant differences are apparent in the upper mesosphere and lower thermosphere both between the PCL climatology and climatologies determined by sodium-resonance-fluorescence lidar. Most of this difference appears to be geophysical.

**P-6-70**

PROGRESS TOWARDS ROUTINE SOUNDINGS OF UPPER TROPOSPHERIC AND STRATOSPHERIC WATER VAPOUR

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**Abstract**: Stratospheric and upper tropospheric water vapour is of great importance for the climate system, yet routine *in situ* soundings are done only at Boulder, CO. We will show intercomparison measurements of the NOAA/CMDL frost-point hygrometer with other balloon borne instruments and discuss to what level stratospheric water vapour is currently measured routinely. The University of Colorado Cryogen Frostpoint Hygrometer (CU/CFH) is a recent development, which overcomes some of the limitations of the NOAA/CMDL frostpoint hygrometer. This instrument will be discussed and first measurements are presented. It is planned to introduce this instrument for routine soundings at several sites covering all major climate regions.

**P-6-71**

TROPICAL CYCLONE AND ASSOCIATED STRATOSPHERE TROPOSPHERE EXCHANGE

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**Abstract**: Tropical cyclones are violent whirls spiraling up from the oceans to greater heights. In order to study the various characteristics of the atmosphere during the passage of a tropical cyclone several experiments were carried out using the Indian MST radar located at Gadanki (13.5°N, 79.2°E). In October 2001, there was an overhead passage of a cyclonic storm at this station. The depression formed in the Bay of Bengal on October 14 intensified into a deep depression by October 15 and developed further into a cyclonic storm by the same day evening. It passed over the station on October 16 morning. Special experiments were carried out at 1-hour interval from 0930 hours LT (October 15) to 1630 hours LT (October 16) and at 4 minute interval from 09.30 hours LT to 1200 hours LT on October 16. Wind characteristics during the storm are studied. The momentum flux exchange during the intensification and passage of the storm are also studied. Stratosphere Troposphere Exchange during other cyclone passages (during 1994-2003) is also studied. Gravity wave characteristics are also studied. These results will be presented in detail in the conference.

**P-6-72**

PARAMETERISING MEAN FLOW CHANGES ASSOCIATED WITH EQUATORIAL INERTIAL INSTABILITY

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**Abstract:** The zonal flows of the Earth's equatorial atmosphere are prone to inertial instability when the horizontal shear is non-zero at the equator. These instabilities have been observed in the upper stratosphere near solstice, although they are likely to occur elsewhere too.

For numerical modellers, the small vertical scale typical of inertial instabilities is challenging. In GCMs, the instabilities are often poorly resolved. Worse still, the instabilities can sometimes grow uncontrollably on the smallest resolved vertical scale, in which case they have to be artificially suppressed, perhaps by vertical diffusion. In either scenario, the dynamical effects of the instability are not resolved.

One strategy is, thus, to parameterise the nonlinear action of the inertial instabilities by somehow eliminating the cross-equatorial shear of the mean flow. Here, high resolution simulations of the nonlinear evolution of inertial instability are used to diagnose the typical form of this mean flow change. The effects of secondary Kelvin-Helmholtz instabilities and barotropic instabilities are taken into account. The parameterisation schemes introduced are based on a latitudinal adjustment for the potential vorticity, with a corresponding adjustment to the zonal flow. Both simple stepwise adjustments and smoothly varying adjustments are discussed.

**P-6-73**

ASSESSMENT OF VERSION 19 HALOE OZONE DATA

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**Abstract**: The Halogen Occultation Experiment (HALOE) on board the Upper Atmosphere Research Satellite (UARS) has been collecting measurements of ozone and several other trace gases in the middle atmosphere since October 1991. The Version 19 ozone data are of high quality, however, the retrieval process utilizes spectral line intensities in 10 micrometer wavelength region which are not the current recommendation of the spectral community. Using the current recommended line intensities will apply a bias to the profiles; however, by using an updated instrument spectral model and accounting for differences between line-by-line calculations and band model calculation some of this difference is diminished. We also will show results from a new diurnal gradient correction model, which will be applied in a forth-coming 4$^{th}$ public release of HALOE data.

**P-6-74**

OBSERVATIONS OF SHALLOW AND DEEP CONVECTION AND THEIR ROLE IN GENERATION OF GRAVITY WAVES USING INDIAN MST RADAR

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**Abstract**: An attempt is made to present the current understanding of the convection based dynamics revealed by the MST radar observations taken in the last few years at Gadanki, India. The results show different categories of time and spatial growth of the convection especially during wet season. During strong convection events, the impact of turbulence/convective updrafts is clearly seen up to tropopause and lower stratosphere, while during other weak convection events the impacts is confined up to middle troposphere. Efforts are made to categorize the convection systems and their role in the generation of gravity waves in the troposphere and stratosphere. Generation mechanism of these short scale waves (time period is of few tens of minutes and horizontal wavelengths is about 10-50 km) is studied and their detailed characteristics are shown.

**P-6-75**

THE 11-YEAR SOLAR CYCLE INFLUENCE ON THE ATMOSPHERE

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**Abstract**: A multiple linear regression analysis has been carried out using the ERA-40 dataset over the period 1979-2001 to study the influence of the 11-year solar cycle on the temperature and zonal wind structure of the atmosphere. The solar signal has been distinguished from other signals (volcanic, NAO, ENSO, trend, QBO) to reveal significant temperature signals not only in the mesosphere and the upper stratosphere, but also in the lower stratosphere and parts of the troposphere. The spatial pattern of annual zonal mean temperature response to the 11-year solar cycle is presented from 1000 to 0.1hPa and shown to have a maximum positive response of 1.75K in the equatorial upper stratosphere. Significant (seasonally dependent) negative responses of several Kelvins are found at high latitudes of both hemispheres in the upper stratosphere. In addition, the tropopheric solar response is also examined and reveals significant zonal wind responses in the subtropics, suggesting that the Hadley circulation is influenced by 11-year variations in solar irradiance.

**P-6-76**

GRAVITY WAVE GENERATION BY EQUATORIAL INERTIAL INSTABILITY

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**Abstract**: Gravity waves (GWs) and inertio-gravity waves (IGWs) are an important means of transferring momentum from the lower to the middle and upper atmosphere. Gravity wave breaking is responsible for closing off the mesospheric jets and for producing the summer-to-winter-pole mesospheric circulation. They also interact with atmospheric tides and affect other large-scale phenomena in the upper atmosphere. GWs are generally thought to be produced in the troposphere by a number of different processes, such as topographic generation, geostrophic adjustment, shear instability and convection. They propagate vertically to higher altitudes where, due to the reduction in density, the momentum they deposit can affect a large change in the background winds.

This paper will focus on a different generation mechanism of GWs, specifically IGW generation by equatorial inertial instability. Due to their slow vertical propagation, IGWs may deposit their momentum horizontally far from the region where they were generated. Therefore, IGWs generated in the tropics by inertial instability may affect the background winds at midlatitudes. A 3D primitive equations model will be used to study this generation mechanism. In this presentation we will focus on the spectra and launch altitudes of the IGWs and their effect on the mean flow. Also, because inertial instability occurs typically at the smallest resolvable scales, we will examine the robustness of the results to changes in resolution and small-scale diffusion, both of which can affect the scales and the strength of inertial instability.

**P-6-77**

THE UNUSUAL OCCURRENCE OF RECENT MAJOR MIDWINTER WARMINGS IN BOTH HEMISPHERES - AN INDICATOR OF POSSIBLE CLIMATE CHANGE?

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**Abstract**: This paper reports on the recent occurrence of unusual major midwinter warmings in both hemispheres: The current major midwinter warming in the Arctic winter 2003/04 has longer lasted than ever observed before since the 1950s, showing also a large impact on the tropospheric circulation. Another such unusual example was the midwinter warming in 2002 in the Antarctic, where a major stratospheric warming has never previously been detected since when observations began in the 1940s.

An overview of stratospheric dynamics will be given in the context of monitoring the stratosphere for over 50 years, concentrating on the occurrence of such unusual events in both hemispheres. The possible role of a changing climate in forcing such phenomena, *i.e.* in terms of changes in planetary wave activity, will be discussed.

**P-6-78**

CONSTANT PRESSURE BALLOON STUDIES OF GRAVITY WAVES IN THE TROPICAL AND EXTRATROPICAL LOWER STRATOSPHERE

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**Abstract**: Constant pressure balloons provide a unique method of studying the properties of gravity waves in the lower stratosphere. We describe observations made on long-duration flights launched from sites in South America and in the Arctic. Measurements of pressure, temperature and position using GPS techniques allow important wave parameters, including momentum fluxes, to be measured as a function of intrinsic frequency. Using wavelet techniques we show that it is also possible to obtain intrinsic phase speeds, which gives a complete picture of the wave field. Considerable spatial and temporal intermittency in wave activity is found and the results are related to possible wave sources.

**P-6-79**

TOTAL OZONE BEHAVIOUR IN THE CARIBBEAN

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**Abstract**: The natural fluctuations of the ozone include the synoptic and subsynoptic scales, the annual and semiannual variations and also those variations related with the QBO, the ENSO regional effects, the volcanic eruptions influence and the solar activity cycle. But the ozone total content fundamentally is determined for the transport and not for the photochemical processes. With the purpose of studying the ozone variability in the Caribbean the TOMS ozone data over different sites in the zone were selected. The study area is situated between the 5° and the 30°N. Also, TOMS daily gridded data are used with 1 x 1.25° step from November of 1978 to December of 1999. Of the ozone daily variation analysis it is obtained that in the region the variations are small and they rarely surpass 10. The variation coefficient (CV) is employed to determine the ozone seasonal variability. It is obtained that the biggest CV (19) are associated to instability conditions, on the contrary, minimum variations are observed associated to high pressures centres. Also the influence of the QBO and the 11-year solar cycle on total ozone is analysed.

**P-6-80**

DEVELOPMENT OF A LIGHTWEIGHT, FAST, AND ACCURATE HYGROMETER FOR USE ON BALLOONS AND AIRCRAFT

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**Abstract:** Long term, widespread, and accurate measurements of upper tropospheric and lower stratospheric water vapour are critical towards understanding changes in atmospheric dynamics, chemistry, and climate. For example, measurements inside ice clouds in the upper troposphere show supersaturations with respect to ice of 10 Cubic ice and nitric acid coatings on ice have been suggested as possible mechanisms to support the observed data. In addition, sources for the observed trends of tropopause water *vapour* are currently unknown. Unfortunately, measurements of water *vapour* in this region are complicated by low concentrations (ppmv), outgassing from instrument surfaces, and hysteresis effects. Existing radiosondes do not meet the strict requirements for use in understanding upper tropospheric and lower stratospheric trends of water *vapour*. High precision and accuracy measurements require instrumentation too heavy for use on anything besides large, research grade balloons and aircraft-based studies. Significant advances in these areas would be aided by a sensor with the capabilities of research grade instruments but also being lightweight and small enough for routine balloon measurements. To this end, a fast and sensitive prototype instrument for use on balloon-borne applications has been developed. The instrument uses a recently-developed Vertical Cavity Surface Emitting Laser (VCSEL) at 1850 nm. The water *vapour* absorption cross section at this wavelength is about 80 tronger than most distributed feedback (DFB) laser-based hygrometers near wavelengths of 1390 microns. The VCSEL-based hygrometer offers several advantages for use on balloon-based platforms. First, the VCSEL consumes lower amounts of power (15 mW).

Second, the 1850 nm VCSEL has a wide current turning range (15 $cm^{-1}$), enabling multiple water *vapour* absorption features to be probed and thereby increasing the dynamic range of the instrument. Third, the VCSEL is inexpensive to produce in mass quantities. Data acquisition and signal processing occurs through the use of digital signal processing boards which are lightweight and also consume little power. A compact optical cell of Herriott design is used with a 2 m pathlength. The size of the entire instrument is 10 x 12 x 16 cm. Overall, the instrument is powered by two AA batteries, weighs 9 oz. including batteries, and can scan over its tuning range at frequencies as high as 1.0 kHz.

The prototype instrument can measure the entire range of tropospheric and lower stratospheric mixing ratios by probing three water vapour absorption features of varying strength within its scanning range (1853.04, 1854.03, and 1856.73 nm). Based on results from a VCSEL hygrometer at 980 nm, where the water *vapour* absorption cross section is 100 times less than at 1850 nm, we expect the 1850 nm VCSEL hygrometer to have a precision of 0.05 ppmv and a minimum sampling frequency of 25 Hz. These features of the 1850 nm VCSEL hygrometer, along with future plans on calibrations and field testing, will be presented. The low cost, lightweight, and sensitive instrument may significantly aid in obtaining more accurate and more widespread water *vapour* measurements in the upper troposphere and lower stratosphere on both balloon-borne and aircraft-based platforms.

**P-6-81**

PROCESS STUDY OF THE DAY-NIGHT-VARIATION AND TWILIGHT CHEMISTRY OF NITROGEN- AND HALOGEN OXIDES IN THE LOWER AND MIDDLE STRATOSPHERE

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**Abstract:** The measurements of ClO, OClO, $NO_2$, and BrO by space borne, air plane, and ground based stations have been analysed with the help of a 1-dimensional chemical stacked box model. The analysis focuses on the day-night-variation and twilight chemistry in the lower and middle stratosphere. The model used gives the opportunity to compare the different measurement products and to validate our current understanding of the fast stratospheric photochemistry. In particular the coupling of the $NO_x$-, and $ClO_x$/$BrO_x$ destruction cycles is investigated.

In order to fully exploit the current measurements of SCIAMACHY and (AMAX)-DOAS under twilight conditions the retrieval have been improved. Under twilight conditions species with a clear diurnal cycle have large gradients in their concentrations along the line of sight. Therefore a set of simulated, SZA dependent a priori profiles have been use within the retrieval to account for the chemical enhancement factor. To quantify this improvement, a sensitivity study has been performed enclosing representative days in polar- and mid latitude regions.

**P-6-82**

RECENT ADVANCES IN THE HALOE 4TH PUBLIC RELEASE (v20) ALGORITHM

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**Abstract:** The Halogen Occultation Experiment (HALOE) has been operating essentially without flaw on the Upper Atmosphere Research Satellite since it was first turned on in orbit October 11, 1991. HALOE measures a suite of atmospheric vertical profiles including $O_3$, HCl, HF, $CH_4$, $H_2O$, NO, $NO_2$, aerosol extinction at four wavelengths and temperature versus pressure. Measurements of some of these parameters, *i.e.* $O_3$, $H_2O$, NO and temperature, extend well into the mesosphere and/or lower thermosphere. This study focuses on recent advances in the HALOE 4$^{th}$ public release (v20) algorithm development. This algorithm will provide the first HALOE $H_2O$ vertical profile data in the mid-to-upper troposphere and higher accuracy $O_3$ in the upper troposphere and lower stratosphere. It will also increase the vertical resolution of $CH_4$, HCl, HF and NO in the middle atmosphere by nearly a factor of two to 2.5 km. In addition, the use of newer line parameter data for many of the HALOE gases will increase the accuracy of the data set and further enhance its value as a correlative measurement source for recently launched and future satellites. We will present results of initial tropospheric $H_2O$ validation studies using correlative measurements and show preliminary long-term change results. Goals of this research are to develop and analyse tropospheric climatologies for $H_2O$ and $O_3$ and conduct studies to assess long-term changes in these parameters.

**P-6-83**

MODELLING WATER VAPOUR IN THE UPPER TROPOSPHERE
AND LOWER STRATOSPHERE

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**Abstract:** The distribution, transport and short and long term variability of water vapour in the upper troposphere and lower stratosphere (UT/LS) are analysed based on measurments from the HALOE and MLS instruments onboard the UARS satellite and the ECMWF ERA-40 reanalysis. The results are compared to a 25-years model simulation (1975-2000) with observed sea surface temperatures using the general circulation model CAM2. The simulated temperature and water vapour fields in the UT/LS region exhibit a realistic seasonal variation and distribution. However, the seasonal signal in the stratosphere, the so-called tape recorder signal, is propagating too fast, indicating a too fast Brewer Dobson circulation in the model. This is partly due to the low upper boundary at 10hPa. The temperatures in the UT/LS region are slightly too low, leading to a dry bias in the lower stratosphere. Two additional transport schemes are tested to investigate these problems.

A simple stratospheric methane oxidation scheme is implemented in the model, which greatly improve the results, as shown in the validation against HALOE data.

An increase in stratospheric water vapour has been observed during the last 50 years amounting to as much as 1% per year. 50% of the total increase can be attributed to methane oxidation as the anthropogenic emissions have increased in the same period. Our model simulations with observed sea surface temperatures suggest that the increase in sea surface temperatures alone can not account for the other half of the total water vapour increase.

# MODEL RESPONSE TO THE DOUBLING OF $CO_2$ AS SIMULATED BY THE CANADIAN MIDDLEATMOSPHERE MODEL

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**Abstract:** The Canadian Middle Atmosphere Model is a 3D GCM, which extends from the surface up to about 100 km and includes an interactive gas-phase chemistry scheme. This model has been used in a series of multi-year experiments to examine the middle atmosphere response to doubling of $CO_2$, with emphasis on the effect of changes in the surface conditions (SST's and sea ice). Changes in temperature, $O_3$ and $H_2O$ fields will be presented. The main effect of the $CO_2$ doubling in the middle atmosphere is a temperature decrease. This response is maximized near the stratopause with a value of about 10K, however its latitude-altitude distribution shows significant latitudinal structure with particularly weak temperature change near the polar summer mesopause. The cooling leads to ozone increase by 10-20 percent in the upper stratosphere and lower mesosphere. The main effects of the changes in surface conditions are a $H_2O$ increase in the middle atmosphere by up to about 20 % and significant temperature changes over the polar regions. The paper will also discuss changes in the radiative energy budget occurring in response to the doubling of $CO_2$.

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