SPARC 2000

2nd GENERAL ASSEMBLY OF THE WCRP PROJECT SPARC

Stratospheric Processes and their Role in Climate

Programme and Abstracts

Mar Del Plata, Argentina
November 6-10, 2000

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Dear Colleagues,

We are delighted that you have come to Mar del Plata to participate in the 2nd General Assembly of the WCRP Project "Stratospheric Processes and Their Role in Climate".

Here, during this week, you will enjoy doing science in a quite unforgettable area. And if you have time after the meeting, perhaps you will be able to explore more of this beautiful country and enjoy the scenery, the culture and traditions of Argentina, which have many agreeable surprises.

We welcome you and wish you all a rewarding and pleasant stay
Sincerely,

Alan O'Neill	Pablo O. Canziani	Marie-Lise Chanin
Chair of the SOC	Chair of the LOC	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

CNES	Centre National d'Etudes Spatiales - France
CNRS	Centre National de la Recherche Scientifique - France
CONAE	Comision National de Actividades Espaciales - Argentine
COSPAR	Committee on Space Research
EC	European Commission
ESA	European Space Agency
ESF	European Science Foundation
GAW	Global Atmosphere Watch
GLCC	Great Lakes Chemical Corporation
IAGA	International Association of Geomagnetism and Aeronomy
IAMAS	International Association of Meteorology and Atmospheric Sciences
ICSU	International Council of Scientific Union
IOC	International Ozone Commission
IUGG	International Union of Geodesy and Geosphysics
NASA	National Aeronautics and Space Administration - USA
NASDA	National Space Development Agency of Japan - Japan
NOAA	National Oceanic and Atmospheric Administration - USA
SCOSTEP	Scientific Committee on Solar Terrestrial Physics
SMN	Servicio Meteorologico Nacional - Argentina
UNEP	United Nations Environment Programme
UBA	Universidad de Buenos Aires - Artentina
WCRP	World Climate Research Programme
WMO	World Meteorological Organization

SPARC 2000 GENERAL ASSEMBLY ORGANIZING COMMITTEES

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Local Infrastructure

Horizonte del Sol Conference Center and Beach resort.

PROGRAMME AT A GLANCE

PROGRAMME

Monday 06th of November

Session 1 : Stratospheric Processes and their Role in Climate

09.00: A. O'Neill — Introduction to Assembly

09.30: T. Shepherd — Introduction to Session 1

Subsession 1-1: Chemistry

09.40: A. Ravishankara — ***Invited talk***
"Gas, heterogeneous and multiphase chemistry of the lower stratosphere and the upper troposphere". *(O/1-1.1)*

10.15: S. Meilinger — "Heterogeneous chemistry in the tropopause region" *(O/1-1.2)*

10.35: R.A. Cox — "Heterogeneous reaction HOBr + HCL on ice" *(O/1-1.3)*

10.55: Coffee Break

11.15: H. Oelhaf — "On the partitioning of nitrogen species in the Northern Hemisphere: balloon-measurements and 3D CTM calculations" *(O/1-1.4)*

11.35: M. Gauss — "3D CTM model calculations of chemical and dynamical processes in the lower stratosphere" *(O/1-1.5)*

Subsession 1-2: Transport

11.55: P. Haynes — ***Invited talk***
"The extratropical tropopause as a transport barrier" *(O/1-2.1)*

12.30: R.K. Scott — "Isentropic transport and mixing rates across the tropopause" *(O/1-2.2)*

12.50: H. Fischer — "Seasonal variation of cross-tropopause transport into the northern middle and high latitude lowermost stratosphere" *(O/1-2.3)*

13.10: R. Garcia — "Extratropical control of tropical upwelling in the lower stratosphere " *(O/1-2.4)*

13.30: Lunch

15.00: S. Pawson — "Model study of the sources of upper tropospheric ozone over the Atlantic, with emphasis on inter-hemispheric asymmetries" *(O/1-2.5)*

15.20: K.U. Grossmann — "High spatial resolution trace gas measurements in the stratosphere by CRISTA" *(O/1-2.6)*

15.40: C.M. Volk — "Transport in the tropical tropopause region from *in situ* tracer measurements on board the M55 GEOPHYSICA aircraft" *(O/1-2.7)*

16.00: S.J. Lin — "Age-of-air, tape recorder, and vertical transport schemes" *(O/1-2.8)*

16.20: L. Bruhwiler — "Simulated correlation of atmospheric trace species and implications for lower stratospheric transport" *(O/1-2.9)*

16.40: H. Kanzawa — "Isolation of the polar vortex estimated by the time threshold diagnostic" *(O/1-2.10)*

17.00: T. Shepherd — Introduction to Focused Discussion Sessions 1-1, 1-2, 1-3

Focused Discussion Session

(all posters of Session 1 will remain up Monday and Tuesday)

Tuesday 07th of November

Session 1: Stratospheric Processes and their Role in Climate

Subsession 1-3: Clouds and Water Vapour

09.00: T. Peter	***Invited talk***
	"Subvisible clouds at the tropical tropopause" *(O/1-3.1)*
09.35: F. Hasebe	"Initial results from SOWER/Pacific 1998-2000 campaigns" *(O/1-3.2)*
09.55: X. Zhou	"Variability of the tropical cold point tropopause and its implication for stratospheric water vapor" *(O/1-3.3)*
10.15: S. Sherwood	"Evidence of rapid dehydration and mixing within a tropical tropopause layer" *(O/1-3.4)*
10.35: A. Gettelman	"An analysis of convection penetrating the tropical tropopause" *(O/1-3.5)*

10.55: *Coffee Break*

11.15: D. Kley	"SPARC water vapor assessment report" *(O/1-3.6)*

Subsession 1-4: Gravity Waves

11.35: T. Tsuda	***Invited talk***
	"A global morphology of gravity wave activity in the stratosphere" *(O/1-4.1)*
12.10: R.A. Vincent	"Outcomes of the SPARC gravity wave radiosonde initiative" *(O/1-4.2)*
12.30: J.A. Whiteway	"The Aberystwyth EGRET experiment: gravity waves, filamentation and turbulent mixing in the tropopause region" *(O/1-4.3)*
12.50: D.C. Fritts	"Dynamics of turbulence and mixing in the stratosphere" *(O/1-4.4)*

13.10: Lunch

15.00: K. Sato	"Layered disturbances associated with low potential vorticity revealed by high-resolution radiosonde observation in Japan" *(O/1-4.5)*
15.20: M.J. Alexander	"Gravity wave forcing of the stratospheric circulation" *(O/1-4.6)*

Subsession 1-5: Tropical Oscillations

15.40: L.J. Gray	"Equatorial influence on the inter annual variability of the stratosphere" *(O/1-5.1)*
16.00: A.A Scaife	"Quasi-biennial oscillations in a realistic simulation of the global climate" *(O/1-5.2)*
16.20: N. McFarlane	"Resolved wave driving of tropical oscillations in a GCM" *(O/1-5.3)*
16.40: M. Hitchman	"On the relationship between the stratospheric quasi-biennial oscillation and tropical deep convection" *(O/1-5.4)*
17.00: T. Shepherd	Introduction to Focused Discussion Sessions 1-4, 1-5, 1-6, 1-7

Focused Discussion Session

(all posters of Session 1 will remain up Monday and Tuesday)

Focused Discussion Session 1
(Monday November 06 - Tuesday November 07)

Subsession 1-1: Chemistry

K. Sudo	"Modelling study on stratospheric effect on the distribution and budget of tropospheric ozone, and its annual variation" *(P/1-1.1)*
F. Sassi	"Climate of the stratosphere, mesosphere and lower thermosphere using interacting dynamics and chemistry in a GCM" (presented by R.R. Garcia) *(P/1-1.2)*
D. Kinnison	"The climate impact of polar ozone chemical processes: using a GCM that contains interactive dynamics and chemistry representative of the stratosphere, mesosphere, and lower thermosphere" *(P/1-1.3)*
A. Jonsson	"Assessment of the Canadian Middle Atmosphere Model simulation of temperature and chemical tracers using satellite observation" *(P/1-1.4)*
H. Teyssedre	"Coupling the arpege GCM to the stratospheric/tropospheric MOCAGE CTM: climate studies" *(P/1-1.5)*
T. Reddmann	"3D model simulation of SF6 with mesospheric chemistry" *(P/1-1.6)*
B. Bregman	"3D model calculations of heterogeneous chemistry on sub-visible ice clouds in the lowermost stratosphere" *(P/1-1.7)*
S. Prasad	"A new source of NOX: potential role in basic atmospheric chemistry and climate change" *(P/1-1.8)*
S. Prasad	"A new heterogeneous sink of nitrous oxide (N_2O) and surface chemistry on aerosols" *(P/1-1.9)*
R. Taccone	"Theoretical analysis of the relative reactivity of chloroethenes with O(3P), CL(2P), BR(2P) and OH, NO3 radicals" *(P/1-1.10)*
G. Arguello	"Photochemistry of fluorinated compounds. Kinetic of the reaction between CF3CF2 and FCO radicals" *(P/1-1.11)*
H. Leroy Miller	"Investigation of observed fluctuations in column OClO over Greenland during the 1994-95 and 1995-96 winters" *(P/1-1.12)*
B. Klumov	"Meteoroid fall into ocean: impact on stratospheric ozone" *(P/1-1.13)*
R.B. Rood	"Evaluation of the upper-tropospheric and lower-stratospheric ozone profiles from a global ozone data assimilation system" *(P/1-1.14)*
F. Fierli	"High horizontal resolution ozone assimilation" *(P/1-1.15)*

Subsession 1-2: Polar Processes and Transport

F. Fierli	"Transport of chemically activated air to middle latitudes in the Northern Hemisphere stratosphere" (*P/1-2.1)*
A. Hauchecorne	"Estimation of the transport and mixing of chemical constituents in the lower stratosphere using the high resolution transport model MIMOSA" (presented by F. Fierli) *(P/1-2.2)*
M. Marchand	"Effect of the Arctic erosion vortex on the transport of ozone loss toward the mid-latitudes" *(P/1-2.3)*
K. Krueger	"The sensitivity of streamers on planetary wave activity in the Berlin CMAM" *(P/1-2.4)*
M. Mueller	"Polar stratospheric clouds and mesoscale dynamics" *(P/1-2.5)*
G. Bianchini	"Measurement of O_3, HNO_3, N_2O, and CLO in the Southern polar stratosphere by far-infrared limb-sounding from high altitude aircraft" *(P/1-2.6)*
D. Gibson-Wilde	"Observations of the polar stratosphere from ALOMAR (69N)" *(P/1-2.7)*
C. Basdevant	"Simultaneous laminae in water vapour and aerosols profiles during SESAME experiment" *(P/1-2.8)*

H. Oelhaf	"Denitrification and mixing in the 1994/1995 Arctic vortex – MIPAS-B observations and modelling" *(P/1-2.9)*
J.A. Karhu	"Ozone, temperature and wind profile measurements at Marambio, Antarctica during APE-GAIA campaign in September-October 1999" *(P/1-2.10)*
H. Nakajima	"Meridional transport of minor species at the time of break-up of polar vortex observed by ILAS" *(P/1-2.11)*
L.L Pan	"Dehydration inside of the arctic polar vortex observed by ILAS" *(P/1-2.12)*
W. Choi	"High-latitude variations of the stratospheric tracers in the Southern Hemisphere spring" *(P/1-2.13)*
S. Yoden	"Chaotic mixing and transport barrier in an idealised stratospheric polar vortex" *(P/1-2.14)*

Subsession 1-3: Mid-latitude and Tropical Transport

E. Shuckburgh	"Inter-annual and longer-timescale variations in transport and mixing in the upper troposphere and lower stratosphere" *(P/1-3.1)*
H. Smit	"Ozone and humidity distribution inside the polar jet over the North-Atlantic obtained from the MOZAIC program: identification of a local circulation across the tropopause" *(P/1-3.2)*
A. Zahn	"Ozone-carbon monoxide correlation in the tropopause region from caribic flights 1997-2000" *(P/1-3.3)*
F. Chane-Ming	"A climatology of laminae in ozone sonde data in the upper troposphere and lower stratosphere at La Réunion island" *(P/1-3.4)*
Y. Tomikawa	"An origin of the laminated structure of ozone in the lower stratosphere" *(P/1-3.5)*
Y.J. Rao	"Stratosphere troposphere exchange: Indian MST radar observation" *(P/1-3.6)*
D. Lu	"Study on LS/UT processes in mid-latitude East Asia" *(P/1-3.7)*
T. Portafaix	"Isentropic exchanges through the southern dynamical barrier of the tropical stratosphere" *(P/1-3.8)*
H. Bencherif	"A case study of sporadic transport across the southern boundary of the tropical stratospheric reservoir" *(P/1-3.9)*
V.E. West	"Tropical STE interfered from modelled and observed trace gases" *(P/1-3.10)*
K. Nissen	"The tape recorder signal in the tropical stratosphere – Effects of different transport schemes" *(P/1-3.11)*
P. Simon	"Sensitivity of the MOCAGE CTM to the representation of large-scale and convective transport" *(P/1-3.12)*
T. Iwasaki	"Diagnosis for Lagrangian mean circulation based on pressure-isentrope hybrid vertical co-ordinate" *(P/1-3.13)*
B. Bregman	"Chemistry-transport model comparison with ozone observations in the mid-latitude lowermost stratosphere" *(P/1-3.14)*

Subsession 1-4: Clouds and Water Vapour

M. Ridal	"Water vapour isotopes in the stratosphere" *(P/1-4.1)*
L. Sauvage	"Influence of the ageostrophic circulations on the formation and maintain of cirrus clouds at tropopause level at mid latitudes" *(P/1-4.2)*
F. Cairo	"Observation of thin subvisible clouds at the tropical tropopause" (presented by G. Di Donfrancesco) *(P/1-4.3)*
L. Stefanutti	"APE-THESEO tropical campaign" (presented by M. Volk) *(P/1-4.4)*
J.C. Gille	"Investigating the role of stratospheric processes in climate with HIRDLS" *(P/1-4.5)*
H. Teitelbaum	"Critical level, mixing layer and hygropause formation during CEPEX and TOGA-COARE experiments" *(P/1-4.6)*
J. Fortuin	"Analyses of new observations at Paramaribo station, in Suriname" *(P/1-4.7)*
M. Van Weele	"Year-round spectral UV measurements at tropical Paramaribo, Suriname" *(P/1-4.8)*
M. Rivas	"Wavelength dependence of the optical depth of multicomponent aerosols in the north of Chile" *(P/1-4.9)*

C. Colberg	"Thermodynamic studies of single (NH4)2SO4/H2SO4/H2O-aerosols" *(P/1-4.10)*
D. Guzzi	"Stratospheric-tropospheric transport through PSC-cirrus combined presence at Dumond d'Urville (Antarctica)" *(P/1-4.11)*

Subsession 1-5: Gravity Waves

T. Kerzenmacher	"Importance of convection in generating gravity waves" *(P/1-5.1)*
Z. Eitzen	"Analysis of numerically simulated gravity waves generated by convection" *(P/1-5.2)*
Z. Chen	"Numerical simulation on stratospheric gravity waves above mid-latitude deep convection" *(P/1-5.3)*
H.Y. Chun	"Updated theory and parameterisation of convectively forced gravity wave drag" *(P/1-5.4)*
H.Y. Chun	"Global distribution of gravity wave drag as a residual of momentum budget calculated using UKMO assimilation data" *(P/1-5.5)*
J. H. Beres	"Forcing of the stratospheric circulation by convectively generated gravity waves: the role of tropospheric wind shear" *(P/1-5.6)*
T. Birner	"Climatology of stratospheric gravity-wave activity based on radiosonde data" *(P/1-5.7)*
M. Geller	"Some gravity wave characteristics from analysis of U.S. high resolution radiosonde data for 1998" *(P/1-5.8)*
I.-S. Song	"Characteristics of gravity waves revealed in high-resolution radiosonde data at Pohang; Korea" *(P/1-5.9)*
H. Moldovan	"Wave breaking and critical levels for propagating inertial gravity waves in the lower stratosphere" *(P/1-5.10)*
M.A. Pulido	"The vertical wave number power spectrum resulting from the propagation of a gravity wave spectrum under non-linear advective interactions" *(P/1-5.11)*
M.A. Pulido	"The convective instability in a non-linear gravity wave approach" *(P/1-5.12)*
R. Tailleux	"Influence of 3-dimensional and non-hydrostatic effects on the representation of subgrid-scale orography in GCMS" (presented by F. Lott) *(P/1-5.13)*
M. Charron	"A time and space dependent parameterised gravity wave source distribution in the MPI/MAECHAM model" *(P/1-5.14)*

Subsession 1-6: Climate Variability

R. Bernardi	"Changes in the polar vortex circulation associated to SST anomalies in the Pacific Ocean. Observed patterns and simulation with a GCM" *(P/1-6.1)*
L.S. Hingane	"Synoptic tracing OG migration of ozone minima from West Pacific to Tibet" *(P/1-6.2)*
P. Canziani	"A study of the impacts of tropospheric synoptic processes on the genesis and evolution of extreme total ozone anomalies" *(P/1-6.3)*
P. Canziani	"Variability in the temperature profiles over Lauder, New Zealand" *(P/1-6.4)*
E. Cordero	"An examination of low ozone events over Australia during 1997" *(P/1-6.5)*
P.K. Vigliarolo	"Southern Hemisphere ozone behaviour during 1994 austral winter" *(P/1-6.6)*
R. Huth	"Classification of hemispheric monthly mean potential vorticity fields" *(P/1-6.7)*
H. Sheng	"Diagnostic study of a stratospheric sudden warming during the winter of 1994-1995" *(P/1-6.8)*
M.A. Giorgetta	"Wave mean-flow interaction in the tropical middle atmosphere in MAECHAM4" *(P/1-6.9)*
C. McLandress	"Equatorial oscillations in a middle atmosphere GCM" (presented by T. Shepherd) *(P/1-6.10)*
S. Sitnov	"Characteristics of the QBO in ozone, temperature, and wind derived from ozone sonde data" *(P/1-6.11)*
K. Mohanakumar	"Biennal oscillation in temperature and monsoon activity" *(P/1-6.12)*
A.V. Shirochkov	"The solar proton events influence on the changes of the thermal regime of the Antarctic stratosphere" *(P/1-6.13)*
L.N. Makarova	"The solar wind, the stratosphere and the ground surface as the elements of the unified global electric circuit" *(P/1-6.14)*
R.K. Scott	"The effect of extratropical wave forcing on tropical upwelling" *(P/1-6.15)*
V. Wirth	"Diagnosing the impact of stratospheric Rossby wave breaking in a linear model" *(P/1-6.16)*
R. Aroche	"The stratospheric aerosols and their influence on the weather and the climate in the Great Caribbean" *(P/1-6.17)*

Subsession 1-7: Recent Ozone Loss

K. Kreher	"Sources of Southern Hemisphere mid-latitude ozone depletion during winter diagnosed with a Lagrangian box model" *(P/1-7.1)*
B. Connor	"Mapping of active chlorine and bromine in the Antarctic vortex for studies of ozone loss" (presented by K. Kreher) *(P/1-7.2)*
R. de Zafra	"Measurements of stratospheric descent rates in the Antarctic vortex core, and estimates of NOy removal during the polar winter" *(P/1-7.3)*
J. Damski	"A model study of northern hemispheric winter and spring 1997-1998" (presented by L. Tholix) *(P/1-7.4)*
M. Rex	"The evolution of chemical ozone loss in the arctic stratosphere over the last eight years as observed by MATCH" *(P/1-7.5)*

Wednesday 8th of November
Session 2 : Stratospheric Indicators of Climate Change

09.00: V. Ramaswamy	Introduction to Session 2
09.10: W. Randel	***Invited talk***
	"Updated trends in stratospheric circulation and trace constituents" *(O/2.1)*
09.45: M. De Mazière	"Analysis of a 15 years series of ground-based FTIR O3 measurements above the Jungfraujoch: Origin of the observed variations" *(O/2.2)*
10.05: G. Bodeker	"The origins of trends in vertical ozone profiles measured at Lauder, New Zealand from 1986 to 2000" *(O/2.3)*
10.25: P. Canziani	"Characterisation of total ozone fields over the Southern Hemisphere" *(O/2.4)*
10.45: J. Russell III	"HALOE observations of lower stratosphere and troposphere H_2O and CH_4" (presented by J. Anderson) *(O/2.5)*

11.05: Coffee Break	

11.25: H. Clark	"Can trends be determined in upper tropospheric water vapor from UARS MLS?" *(O/2.6)*
11.45: K. Rosenlof	"Comparisons of water vapor measurements and derived quantities in the UT/LS: A summary from the SPARC water vapor assessment" *(O/2.7)*
12.05: P. Keckhut	"Temperature trends in the stratosphere and mesosphere: Tidal inferences" *(O/2.8)*
12.25: G. Beig	"Assessment of temperature trends in the mesosphere and upper stratosphere along with resulting chemical changes" *(O/2.9)*
12.45: L. Thomason	"Aerosol variability in SAGEII version 6.0" *(O/2.10)*

13.05: Lunch	

15.00: L. Goldfarb	"A climatological study of cirrus clouds measured by lidar at OHP" *(O/2.11)*
15.20: D. Gaffen	"Climatological characteristics of the tropical tropopause as revealed by radiosondes" *(O/2.12)*
15.40: G. Reid	"The tropical tropopause: Intraseasonal, interannual and long-term variations" *(O/2.13)*
16.00: L. Hood	"The solar component of long-term stratospheric variability: the possible role of solar-modulated QBO" *(O/2.14)*
16.20: M. Salby	"Interannual changes of the stratospheric circulation: Relationship to total ozone and tropospheric structure" *(O/2.15)*
16.40: H-F Graf	"Coupled variability modes of atmospheric circulation, climate change and detection" *(O/2.16)*
17.00: V. Ramaswamy	Introduction to Focused Discussion Session 2

Focused Discussion Session

(all posters of Session 2 will remain up Wednesday and Thursday)

Focused Discussion Session 2

(Wednesday November 8 - Thursday November 9)

Subsession 2-1: Observational Platforms and Measurements

T. Wehr	"The European Space Agency's Future Atmospheric Chemistry Missions" *(P/2-1.1)*
A. Miller	"The use of ATOVS-AMSU data and the effect on detection of climate change in the stratosphere" (presented by C. Long) *(P/2-1.2)*
U. Cortesi	"The APE-GAIA campaign: Airborne Polar Experiment - Geophysica Aircraft in Antarctica" *(P/2-1.3)*
E. Oriol-Pibernat	"Status of the METOP-1 Program at ESA" *(P/2-1.4)*
F. Valero	"TRIANA - The first deep space climate observatory" *(P/2-1.5)*
C. Marquardt	"GPS-based global atmospheric sounding with low Earth orbiters" *(P/2-1.6*)
M. Tsutsumi	"A new NF radar at Syowa station, Antarctica" *(P/2-1.7)*
A. Goede	"GREENSKY - Greenhouse gas measurements from satellite observations for Kyoto protocol application" *(P/2-1.8)*
C. Rafanelli	"The Brewer ozone sampling in Ushuaia and Belgrano II" *(P/2-1.9)*
H. Smit	"Assessment of the performance of ozone sondes to measure long term changes of ozone in the upper troposphere and lower stratosphere" *(P/2-1.10)*
N. Kawano	"MU radar, temperature sheets and interferometry observation; A first report for MUTSI experiment" *(P/2-1.11)*
J. Wickert	"GPS radio occultation with CHAMP - Algorithms and data processing" (presented by C. Marquardt) *(P/2-1.12)*
J.P. Pommereau	"Winter Arctic Stratospheric Temperature Accuracy in Meteorological Models from Long Duration Balloon Measurements" *(P/2-1.13)*
P. Taalas	"Long-term spaceborne monitoring of ozone, UV and trace gases: EUMETSAT satellite application facility on ozone" *(P/2-1.14)*
L. Suarez Salas	"Analysis of the Ozone Column and Profiles of Ozone over Huancayo Peru" *(P/2-1.15)*

Subsession 2-2: Changes in Species (non-ozone)

J. Antuna	"SAGE II measurements of Mount Pinatubo aerosols: Tropical and mid-latitude validation with a lidar network" *(P/2-2.1)*
D. Guzzi	"Evolution in aerosol loading at mid-latitudes" *(P/2-2.2)*
B. Gonzalez	"Observations of cirrus clouds with lidar in Camaguey: Statistical analysis and their relationship with the tropical tropopause" *(P/2-2.3)*
C. Schiller	"Total hydrogen budget in the stratosphere and long-term changes" *(P/2-2.4)*
J. Bauman	"Stratospheric aerosol climatology derived from satellite solar occultation and infrared emission measurements" *(P/2-2.5)*
J.W. Elkins	"Trends of trace gases, total chlorine, and total bromine in the lower stratosphere from 1991 through 2000". *(P/2-2.6)*

Subsession 2-3: Changes in Ozone

L. Nunez	"The characterisation of ozone and temperature profiles over Marambio, Antarctic Peninsula" *(P/2-3.1)*
R. Piacentini	"Intercomparison between TOMS/EP and Southern Cone Ozone Project (SCO3P)/WMO ground-based ozone data" *(P/2-3.2)*
J. Karhu	"Ozone over Marambio (64°23'S, 56°72'W), Antarctica during 1987-1999" *(P/2-3.3)*
F. Zaratti	"An ozone anomaly over the Andean highland" *(P/2-3.4)*
A. Pazmino	"Study of the Antarctic ozone depletion over Marambio" *(P/2-3.5)*

E. Chapman	"Relationships between total ozone amount and upper air data in Cuba" (presented by R. Estevan or B. Gonzalez) *(P/2-3.6)*
L. Fook Sze	"Effects of Asian monsoons and ENSO on atmospheric ozone in Malaysia" *(P/2-3.7)*
S-R. Chung	"Variability in stratospheric ozone at Pohang, Korea" *(P/2-3.8)*
R. Kivi	"Trends in the vertical distribution of ozone and temperature above northern Finland for the years 1989-1999 based on balloon sonde measurements" *(P/2-3.9)*
O. Zyryanova	"The regional variations of total ozone and tropospheric ozone in the south of Kazakhstan" *(P/2-3.10)*
P. Canziani	"Tropopause height / total ozone relationships over Argentina" *(P/2-3.11)*
A. Sarkissian	"Trends in total ozone measured by SAOZ network at polar circles, mid-latitudes and tropics" *(P/2-3.12)*
A. Meier	"Observation of trace gases from Australia (34S) by means of ground-based solar FTIR spectroscopy, Part 1): Seasonal cycles of 20 species" *(P/2-3.13)*
A. Meier	"Observation of trace gases from Australia (34S) by means of ground-based solar FTIR spectroscopy, Part 2): Isotopic signals in N2O, CH4, O3, H2O and HCl" *(P/2-3.14)*
A. Torres Contador	"Study of the Instability of the Ozone Antarctic Hole and their Consequences in the South Cone of America" *(P/2-3.15)*

Subsession 2-4: Changes in Temperature

S. Bischoff	"A climatology of the tropopause height and temperature over Argentina" *(P/2-4.1)*
M.A. Salles	"Global analysis of MSU CH4 temperatures: Patterns of different spatial structures" (presented by R. Compagnucci) *(P/2-4.2)*
R. Compagnucci	"Global analysis of MSU CH4 temperatures: Regionalization of distinct temporal behaviours" *(P/2-4.3)*
S. Sherwood	"Trends and variability in upper troposphere / lower stratosphere temperatures" *(P/2-4.4)*
C. Cagnazzo	"Seasonal and interannual variability of stratospheric temperatures based on TOVS satellite data: 1987-1995" *(P/2-4.5)*
Y. Koshelkov	"Updated estimates of temperature trends in the arctic stratosphere" *(P/2-4.6)*

Subsession 2-5: Data Analysis and Model Studies

E. Chapman	"The persistence against a statistical model as tool for the forecast of total ozone at the Caribbean" *(P/2-5.1)*
N. Muthama	"Total ozone as a stratospheric indicator of climate variability and change over an African tropical region" *(P/2-5.2)*
J.G. Esler	"Inferring chemical loss in Arctic polar vortex air from tracer-tracer scatterplots" *(P/2-5.3)*
A. Engel	"On the influence of age on stratospheric chlorine trends - predicting the return to pre-ozone hole chlorine levels" *(P/2-5.4)*
H. Teitelbaum	"Strong late summer episodes of low stratospheric ozone unrelated to ozone hole chemistry" *(P/2-5.5)*
M. Yela	"Seasonal evolution of NO2 and O3 outside, at the edge, and inside the Antarctic polar vortex: Comparisons with the SLIMCAT model" *(P/2-5.6)*
S. Ramachandran	"Radiative impact of the Mt. Pinatubo volcanic eruption: Lower stratospheric response" *(P/2-5.7)*
N. Andronova	"Study of a relationship between interannual climate variability and interannual variability of ozone in the stratosphere and troposphere" (presented by E. Rozanov) *(P/2-5.8)*
C. David	"Polar stratospheric cloud formation in Antarctica: A possible feedback, in response to a stratospheric temperature decrease" *(P/2-5.9)*
T. Halenka	"Long term global stratospheric circulation analysis by spectral expansions" *(P/2-5.10)*

G. Braathen "Meteorology of the polar vortices" *(P/2-5.11)*

L. Da Silva Matus "Analysis of the Atmospheric Dynamic during the Depletion of the Ozone Column over the West Coast of South America" *(P/2-5.12)*

Thursday 09th of November

Session 3 : Modelling and Diagnosis of Stratospheric Effects on Climate

09.00: S. Yoden Introduction to session 3

Subsession 3-1: Climatology

09.10: M. Chipperfield ***Invited talk***

"The interaction of stratospheric processes and climate" *(O/3-1.1)*

09.45: T. Horinouchi "A GRIPS GCM intercomparison of tropical cumulus convection and vertically propagating waves" (Presented by S. Pawson) *(O/3-1.2)*

10.05: R. Kawa "Simulating observed ozone loss in the Northern Hemisphere winter" *(O/3-1.3)*

Subsession 3-2: Internal Variations in S-T Coupled System

10.25: D. W. Waugh "Persistence of the lower stratospheric polar vortices" *(O/3-2.1)*

10.45: I. Hirota "Interannual variations of planetary waves in the Southern Hemisphere stratosphere" *(O/3-2.2)*

11.05: Coffee Break

11.25: M. P. Baldwin "Propagation of annular modes from the mesosphere to the earth's surface" *(O/3-2.3)*

11.45: A. O'Neill "The structure and evolution of the arctic oscillation in the stratosphere and upper troposphere" *(O/3-2.4)*

12.05: J. R. Holton "A mechanistic model of the coupled troposphere-stratosphere annular mode oscillation" *(O/3-2.5)*

12.25: D. T. Shindell ***Invited talk***

"Northern Hemisphere winter climate response to greenhouse gas, ozone, solar and volcanic forcing" *(O/3-2.6)*

13.00: J. Austin "Climate model simulations of past stratospheric ozone, temperature and water vapour trends" *(O/3-2.7)*

13.20: Lunch

Subsession 3-3: Responses to Forcings

15.00: J.D. Haigh ***Invited talk***

"The response of tropospheric climate to perturbations in the heat balance of the tropical lower stratosphere" *(O/3-3.1)*

15.35: W.A. Norton "The influence of the QBO on the UTLS region" *(O/3-3.2)*

15.55: K. Tourpali "A coupled GCM - chemical model study of tropopause height response to solar forcing" *(O/3-3.3)*

16.15: A. Robock "Tropospheric responses in GCM simulations of the impact of the 1991 Mt. Pinatubo eruption" *(O/3-3.4)*

16.35: V. Ramaswamy "Changes in trace species and stratospheric temperature variations/trends" *(O/3-3.5)*

16.55: S. Yoden Introduction to Focused Discussion Sessions 3-1, 3-2, 3-3

Focused Discussion Sessions

(all posters of Session 3 and Session 4 will remain up Thursday and Friday)

Friday 10th November

Session 4 : UV Observations and Modelling

9.00: R. McKenzie	"Introduction to Session 4" and "Satellite-retrievals of UV compared with ground-based measurements" *(O/4.1)*
9.20: S. Madronich	"Effect of air pollution on surface UV radiation and photolysis rates" *(O/4.2)*
9.40: A. Bais	***Invited talk***
	"On the present status of solar ultraviolet radiation measurments" *(O/4.3)*
10.15: C.S. Long	"Using the UV index forecasts to independently validate and intercompare surface ultraviolet radiation observations in the United States" *(O/4.4)*

10.35: Coffee Break	

10.55: G. Seckmeyer	***Invited talk***
	"Ways to establish a UV climatology – Ground based and satellite approach" *(O/4.5)*
11.30: P. Taalas	"Past and future UV changes" *(O/4.6)*
11.50: O. Torres	"A satellite climatology of ultraviolet aerosol properties" *(O/4.7)*
12.10: G. Bernhard	" Changes in Antarctic UV levels in relation to ozone hole characteristics" *(O/4.8)*
12.30: H. Fuenzalida	"Latitudinal gradient of UV radiation along Chile (33-53°S)" *(O/4.9)*
12.50: S.B. Diaz	"A multiregression model for the determination of biologically effective irradiances from ozone total column and an indicator of cloud cover" *(O/4.10)*

13.10: Lunch

Session 3 : Modelling and Diagnosis of Stratospheric Effects on Climate

Subsession 3-4: Trends

15.00: D. Karoly	***Invited talk***
	"Detection and attribution of a stratospheric role in climate change: an IPCC perspective" *(O/3-4.1)*
15:35: J.A. Pyle	"A model study of ozone trends in the middle latitudes: the importance of dynamical processes" *(O/3-4.2)*
15.55: U. Langematz	"Radiative and dynamical contributions to the observed stratospheric temperature trend" *(O/3-4.3)*
16.15: B. A. Boville	"Stratospheric water vapor in climate change simulations with NCAR CSM-1" *(O/3-4.4)*
16.35: P. Simon	"Ozone-climate interactions simulated by the French GCM ARPEGE" *(O/3-4.5)*
16.55: V. Ramaswamy	Introduction to Focused Discussion Session 3-4
: R. McKenzie	Introduction to Focused Discussion Session 4

Focused Discussion Session
(all posters of Session 3 and 4 will remain up Thursday and Friday)

Focused Discussion Session 3

(Thursday November 09 - Friday November 10)

Subsession 3-1: Climatology

A. 3-1-1 GCMs

S. Pawson	"Status of the SPARC-GRIPS initiative" *(P/3-1.1)*
U. Langematz	"The radiation-intercomparison project for GRIPS" *(P/3-1.2)*
G. L. Roff	"Intercomparison of polar vortex simulations in GRIPS GCMs" *(P/3-1.3)*
B. Theodore	"The MSDOL project: Sequential assimilation of satellite measurements of stratospheric ozone in a 3D chemistry-dynamics-transport model" *(P/3-1.4)*

A. 3-1-2 Chemistry and Transport

E. Manzini	"Residual circulation and transport in interactive chemistry-climate simulations" *(P/3-1.5)*
A. R. Douglass	"Comparison of climatologies from HALOE and ER-2 with fields from three dimensional models" *(P/3-1.6)*
J. A. Pyle	"Quantification of the polar contribution to mid-latitude ozone loss by numerical modelling" *(P/3-1.7)*
H. Akiyoshi	"Development of stratospheric chemical transport model based on CCSR/NIES AGCM" *(P/3-1.8)*
P.K. Vigliarolo	"Extreme year-to-year differences in ozone mean distribution over Southern Hemisphere winter" *(P/3-1.9)*
E. C. Cordero	"An analysis of 1997 low ozone in the Southern Hemisphere middle latitudes" *(P/3-1.10)*
T. Halenka	"On the sensitivity of RegCM2 to ozone incorporation" *(P/3-1.11)*
G. Koch	"Dynamical causes for deviations of ozone profiles in Switzerland" *(P/3-1.12)*

A. Gabriel	"An examination of the dynamical components of the ozone variability based on a dynamical-chemical coupled 2D circulation model" *(P/3-1.13)*
D.B. Considine	"Sensitivity of upper stratospheric constituents to mixing processes and perturbations in the residual circulation" (presented by D. Waugh) *(P/3-1.14)*

Subsession 3-2 Internal Variations in S-T Coupled System

A. 3-2-1 Annular Modes

S. Zhou	"A diagnostic study of stratospheric dynamical effects on the troposphere" *(P/3-2.1)*
Y. Orsolini	"Signatures of the arctic oscillation on stratospheric ozone" *(P/3-2.2)*
M. Sigmond	"The downward propagation of the arctic oscillation" *(P/3-2.3)*
B. Christiansen	"Model studies of the dynamical connection between the stratosphere and the troposphere" *(P/3-2.4)*
J.C. Fyfe	"The influence of the stratospheric circulation on the annular modes of climate variability in a middle atmosphere model" (presented by E. Manzini) *(P/3-2.5)*
H. Koernich	"Interpretation of the arctic oscillation in dependence on stationary wave forcing" *(P/3-2.6)*
D. Ortland	"Coupling of the stratosphere and troposphere in a 2D quasi-linear vacillation model" (presented by M. Baldwin) *(P/3-2.7)*

3-2-2 Other Intraseasonal and Interannual Variations

S. Yoden	"A numerical experiment on intraseasonal and interannual variations of the troposphere-stratosphere coupled system" *(P/3-2.8)*
J. Perlwitz	"Characteristic features of the dynamical coupling of troposphere and stratosphere in the Northern Hemisphere" *(P/3-2.09)*
A. O'Neill	"Quantification of mass and water vapour transport across the dynamical tropopause" *(P/3-2.10)*
M. H. Hitchman	"Effect of Rossby wave breaking near the tropopause on constituent distributions" *(P/3-2.11)*
K. Mohanakumar	"Role of Asia Pacific Wave on stratosphere-troposphere exchange" *(P/3-2.12)*
S. Solman	"Synoptic processes and the response in total ozone" *(P/3-2.13)*
M. Richman	"On the use and abuse of eigentechniques for stratospheric analyses" *(P/3-2.14)*

Subsession 3-3 Responses to Forcings

A. 3-3-1 QBO and ENSO

Y. Naito	"The QBO effects on the stratospheric and tropospheric circulation in the Southern Hemisphere" *(P/3-3.1)*
A. S. Huesmann	"Climatological structures of the QBO in the NCEP reanalyses and possible tropospheric relationships" *(P/3-3.2)*
E. Echer	"QBO and solar cycle signals on total ozone at tropical Brazilian stations" *(P/3-3.3)*
A. Gettelman	"ENSO as a natural experiment for understanding the tropical tropopause region" *(P/3-3.4)*
J. Fochesatto	"South America ENSO teleconnection coherence patterns and their impacts to tropospheric parameters over Buenos Aires" *(P/3-3.5)*

A. 3-3-2 Solar Forcing

K. Kodera	"The GRIPS initiative to study the impact of solar forcing" (presented by S. Pawson) *(P/3-3.6)*
K. Shibata	"Simulations of the effect of solar variability on the troposphere and middle atmosphere with MRI/JMA98 GCM" *(P/3-3.7)*
K. Weber	"The impact on the atmospheric circulation of the 11-year solar cycle – A study with the Berlin climate middle atmosphere model" (presented by U. Langematz) *(P/3-3.8)*
M. Nakamoto	"Solar cycle variability and stratospheric ozone" *(P/3-3.9)*
J. Austin	"Model simulations of the impact of solar variability on stratospheric ozone and climate" *(P/3-3.10)*
K. Georgieva	"North-south solar asymmetry, QBO and climate" *(P/3-3.11)*

E. Rozanov — "Sensitivity of the UIUC stratosphere/troposphere GCM with interactive photochemistry to the observed increase of solar UV radiation" *(P/3-3.12)*

1) 3-3-3 Volcanic Aerosols

E. Rozanov — "Study of the effects of the Pinatubo volcanic eruption using the UIUC stratosphere/troposphere GCM with interactive photochemistry" *(P/3-3.13)*

G. Stenchikov — "Radiative forcing and stratospheric responses in GCM simulations of the impact of the 1991 Mt. Pinatubo eruption" *(P/3-3.14)*

J. Al-Saadi — "Multi-annual simulations during the UARS period with a 3D coupled general circulation and chemistry model" *(P/3-3.15)*

D. Chartrand — "Perturbation and recovery of chemical species due to the Mount Pinatubo eruption as modelled by the Canadian Middle Atmospheric Model" (presented by T. Shepherd) *(P/3-3.16)*

P. Hamill — "The stratospheric aerosol: the return to background levels" *(P/3-3.17)*

R. Estevan — "Stratospheric aerosol new background conditions measured with lidar over Camaguey, Cuba" *(P/3-3.18)*

M.A. Parodi — "Artificial neural networks in the analysis of atmospheric events: The Southern Hemisphere ozone depletion after the Mt. Pinatubo eruption" *(P/3-3.19)*

Subsession 3-4 Trends

1) 3-4-1 Trend Studies

C. A. Smith — "Radiative effects of trends in stratospheric water vapour derived from UARS HALOE" *(P/3-4.1)*

J. E. Rosenfield — "Effects of increasing CO2 on ozone recovery studied with an interactive 2D model" *(P/3-4.2)*

T. Egorova — "Simulation of the effects of the Montreal Protocol using the UIUC stratosphere/troposphere ACTM driven by the UKMO-assimilated winds" (presented by E. Rozanov) *(P/3-4.3)*

M. J. Mills — "A microphysical analysis of stratospheric aerosol response to climate change" *(P/3-4.4)*

F. Stordal — "Radiative forcing due to changes in stratospheric ozone" *(P/3-4.5)*

M. Van den Broek — "A model assessment of ozone destruction by man made compounds" *(P/3-4.6)*

A. K. Weiss — "Contributions of NAO, QBO, solar activity and aerosol loading to ozone variability and residual anthropogenic trends over Switzerland" *(P/3-4.7)*

P. Fabian — "Morphology and thermal structure of the Antarctic ozone hole: 1958 until present" *(P/3-4.8)*

A. 3-4-2 Climate Change Simulations

D. T. Shindell — "Accelerated global warming and delayed ozone recovery due to increased stratospheric water vapor" *(P/3-4.9)*

T. Hirooka — "Interannual variations of the general circulation and polar stratospheric ozone losses in a general circulation model" *(P/3-4.10)*

W.A. Lahoz — "Northern Hemisphere winter stratospheric variability in the UKMO unified model" *(P/3-4.11)*

M.D. Schwarzkopf — "Relative roles of greenhouse gas changes in recent stratospheric temperature trends" *(P/3-4.12)*

N. Butchart — "Changes in the stratospheric climate and Brewer-Dobson circulation due to increasing greenhouse gas concentrations" *(P/3-4.13)*

J. de Grandpré — "Middle atmosphere response to CO2 doubling with the Canadian Middle Atmosphere Model (CMAM)" (presented by N.A. McFarlane) *(P/3-4.14)*

P. Braesicke — "Inter-annual variability in an unified model integration using a parameterized ozone and AMIP II SSTs" *(P/3-4.15)*

C. Bruehl — "Feedback processes between chemistry and meteorology with focus on lower stratospheric polar vortices, simulations with a coupled GCM" *(P/3-4.16)*

Focused Discussion Session 4

(Thursday November 09 - Friday November 10)

M. Blumthaler	"Effect of varying albedo on solar UV irradiance" *(P/4.1)*
B. Lapeta	"Clouds influence on the ground level of UV radiation – Study for three polish stations" *(P/4.2)*
N. Chubarova	"The influence of cloud and total ozone on biologically active UV interannual variability during the 20th century in different geographical regions" *(P/4.3)*
E. Echer	"UV-B and ozone anticorrelations at low and high latitudes" *(P/4.4)*
R. Piacentini	"Solar ultraviolet irradiance incident on the Atacama desert region" *(P/4.5)*
D. Lu	"Monitoring of surface UV spectral radiance over Beijing since 1997" *(P/4.6)*
M.V.R. Murti	"Statistical analysis of UV radiation and stratospheric ozone depletion over India with TOMS Data" *(P/4.7)*
S.L. Jain	"Spectral measurements of UV-B radiation over Hanle, Delhi and Antarctica" *(P/4.8)*
D. Heath	"Improvements in UV radiometric calibration accuracy and measurements of column ozone from zenith sky observations" *(P/4.9)*
P. Jungwirth	"The impact of enhanced UV radiation on the chemistry of sea-salt aerosols" *(P/4.10)*
C. S. Weiler	"Dissertations initiative for the advancement of limnology and oceanography" *(P/4.11)*
C. Rafanelli	"UV green model and SUV 100 & BREWER spectra: an intercomparison in Ushuaia" *(P/4.12)*
J.P. Veefkind	"The ozone monitoring instrument (OMI)" *(P/4.13)*
N. J. Muthama	"Modelling ultraviolet radiation using DOBSON spectrophotometer" *(P/4.14)*
S. Cabrera	"Erythemal UV dose in Santiago, Chile (33°S)" *(P/4.15)*
H. Schwander	"Application of neutral network technique for UV monitoring" *(P/4.16)*
J. Sabburg	"Corrected UV irradiances from the U.S. EPA/NUVMC network of BREWER spectroradiometers and comparisons of DUV values with satellite data" (presented by Meltzer) *(P/4.17)*
P.M. Udelhofen	"Comparison of measurements of surface UVR and TOMS satellite data over Australia: Health implications" *(P/4.18)*
Ashraf Saber Zakey	"Modelling of UV radiation over Cairo part 1: Statistical method" *(P/4.19)*
C. Lovengreen	"Calibration of UV filter radiometers against UV spectroradiometers: Error assessment" *(P/4.20)*
V.I. Vasilyev	"Empirical model for the investigation of the intradiurnal variations UV-B radiation" *(P/4.21)*
R. Piacentini	"Solar UV risk in Argentina. First tests of the ISUVN index" *(P/4.22)*
S-K Baek	"UV-index forecasts and observations in Korea" *(P/4.23)*
C. Casiccia Salgado	"Simultaneous UV-B radiation and ozone measurements at Punta Arenas, Chile, during appearances of the ozone hole" *(P/4.24)*
F. Zaratti	"UV measurements at high altitude locations" *(P/4.25)*
E. Echer	"A comparison of direct and global UV-B X ozone anticorrelations" *(P/4.26)*
A.A. da Silva	"BREWER spectrophotometer UV-B measurements for aerosol optical thickness determinations during biomass burning" *(P/4.27)*
P. Eriksen	"Measurements of UV radiation at Thule, Greenland" *(P/4.28)*
A. Rosales	"Global spectral UV-radiometer with automatic shadow band" *(P/4.29)*
L. Petcoff	"Total ozone measurements in Mar del Plata, Argentina" *(P/4.30)*
G.R. Casale	"An investigation of high and low frequency ozone and UV variations" *(P/4.31)*
G. Palancar	"Ultraviolet radiation studies in Cordoba, Argentina" *(P/4.32)*
P. J. Neale	"Twenty-five year record of spectral UVB in the mid-atlantic region, USA" *(P/4.33)*

J.R. Slusser	“Comparison of USDA UV-MFRSRUV irradiance measurements with TOMS retrievals under various aerosol and cloud conditions abstract” *(P/4.34)*
R. Piacentini	“Ozone profiles and its influence on solar UVB irradiance incident over Buenos Aires, Argentina” *(P/4.35)*
M. Vernet	“Enhanced ultraviolet-B radiation in natural ecosystems as an added perturbation due to ozone depletion” *(P/4.36)*
L. Suarez Salas	“UV-B radiation over the Central Andean Region of Peru” *(P/4.37)*
H. Fuenzalida	“Underwater UV spectra from measurements with multichannel profilers” *(P/4.38)*
E. Cuevas	"The RACRUV narrow-band ultraviolet radiation network: preliminary results" *(P/4.39)*
M. Cisneros	"Halon Alternative Development Program: An Historical Perspective" *(P/4.40)*
A. Webb	"Towards the derivation of spectral UV actinic fluxes from irradiance measurements: an experimental campaign*". (P.4.41)*

ABSTRACTS

ORAL PRESENTATIONS

MONDAY, NOVEMBER 06, 2000

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-1: Chemistry

Subsession 1-2: Transport

O/1-1.1

Gas, heterogeneous and multiphase chemistry of the lower stratosphere and the upper troposphere

A.R. Ravishankara[1] and The Department of Chemistry and Biochemistry, Univ. Colorado, Boulder[2]

1) NOAA Aeronomy Lab - Boulder CO - USA

2) The Department of Chemistry and Biochemistry, University of Colorado - Boulder, CO - USA

The composition of the lower stratosphere and the upper troposphere is affected by the chemistry that takes place in the gas phase (free radical reactions and photochemistry) as well as the reaction in/on the condensed medium. The synergistic effect of these processes is what leads to the determined or projected composition. It is critical to evaluate all these processes together in understanding the composition of the atmosphere. I will briefly review the most recent findings in the area of the photochemistry, free radical chemistry, heterogeneous chemistry, and multiphase chemistry of this region. These discussions will highlight the role of laboratory studies along with some of the field measurements and their interpretations.

O/1-1.2

Heterogeneous chemistry in the tropopause region

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1) Air Chemistry Department, Max Planck Institute for Chemistry - 55020 Mainz - Germany

2) Swiss Federal Institute of Technology LAPETH, Hoenggerberg HPP - Swizerland

We examine the response of net ozone production rates on heterogeneous chemistry involving liquid aerosol and ice particles under conditions representative for the midlatitude upper troposphere and lowermost stratosphere.

We demonstrate that heterogeneous effects are controlled by nitrogen oxides and by the location of the air masses relative to the tropopause. The net effect of heterogeneous chemistry is to decrease net ozone production below the tropopause (via heterogeneous HO_2 loss) and to cause ozone destruction above the tropopause (via heterogeneous chlorine activation).

However, in the upper troposphere, gas phase chemistry due to non-methane hydrocarbons can become as important for ozone chemistry as heterogeneous reactions, and removal of HO_2 by particles can become more important than changes of HOx through heterogeneous bromine chemistry.

If chlorine activation becomes sufficiently large, ozone depletion occurs at all conceivable values of NOx. Heterogeneous reactions become important for dilute (water-rich) droplets and ice particles, with the greatest impact occurring under cold and rather humid conditions in the lowermost stratosphere, where ozone loss rates might reach values up to 0.4/m3/s for dilute droplets and 2/m3/s for ice particles.

O/1-1.3

Heterogeneous reaction HOBr + HCL on ice

R.A. Cox, J. Mossinger, R. Hynes

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Activation of Cl and Br may occur *via* heterogeneous reactions on the surfaces of cirrus clouds at temperatures higher than type II PSCs. To characterise the reaction at higher temperatures we have measured uptake of HCl, HOBr alone and in the presence of each other on laboratory ice surfaces, using a fast flow system with mass spectrometric detection.

The reactive uptake coefficient, g, of HCl on ice was measured between 200-235 K as a function of HCl concentration (0.6 to 4.10^{12} molecules cm-3). Between 215-235 K time dependent uptake of HCl on ice was observed with an initial value of g = 0.003±0.0004. The surface coverage of HCl was calculated to be two monolayers. Below 212 K HCl is taken up continuously into the ice. The observed loss rate of uptake of HCl on the ice film was found to be diffusion controlled. Thus only an approximate lower limit of g ~ 0.1 was obtained from the data.

The reactive uptake coefficient, g, of HOBr on ice was also measured between 204-230 K. HOBr is permanently lost to the surface and the reaction was found to be independent of HOBr (0.8 to 12.10^{12} molecules cm-3). A strong temperature dependence was observed with g = 0.0021±0.0004 at 230 K, g = 0.0087±0.002 at 223 K g = 0.01±0.004 at 216 K and g ~ 0.1 at 204 K.

The reactive uptake coefficient, g, of HOBr on HCl doped ice was measured between 204-216 K with an HOBr concentration of $0.8.10^{12}$ molecules cm-3 and an HCl concentration of 8.10^{12} molecules cm-3. On exposure of HOBr to HCl doped ice surfaces at 204 K and 216 K BrCl production was observed. At both temperatures the reaction was found to be diffusion controlled. Thus only an approximate lower limit of g ~ 0.1 was obtained.

O/1-1.4

On the partitioning of nitrogen species in the Northern Hemisphere: balloon-measurements and 3D CTM calculations

H. Oelhaf[1], R. Ruhnke, G. Wetzel, M Stowasser, F. Friedl-Vallon, A Kleinert, W Kouker, G. Maucher, O. Trieschmann, H Fischer[2]

1) Institut für Meteorologie und Klimaforschung (IMK), Forschungszentrum Karlsruhe - 76021-Karlsruhe
2) Atmospheric Chemistry Department, Max Planck Institut for Chemistry - 55020 Mainz - Germany

The partitioning of reactive nitrogen controls the ozone budget, directly *via* catalytic cycles involving NOx, and indirectly by linkages with the hydrogen, chlorine, and bromine families. In the winter hemisphere the partitioning is controlled by highly variable heterogeneous chemistry, and small amounts of sunlight while at mid-latitudes in summer the situation is much more steady and dominated by gas-phase photochemistry.

Since winter 1994/95 several balloon flights with the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS-B) were carried out covering different geophysical conditions of the stratosphere. Vertical profiles of the major components of the nitrogen family (NO_2, HNO_3, HNO4, N_2O5, and $ClONO_2$) were measured simultaneously at night along with the source gas N_2O. From these data sets the partitioning of the major components of the reactive nitrogen is derived for winter and spring Arctic vortex air as well as for the late spring/early summer mid-latitude stratosphere.

3-D model calculations were performed with the chemistry-transport-model KASIMA (Karlsruhe Simulation model of the Middle Atmosphere). The vertical domain extends between 10 and 120km pressure altitude. The 6 hourly analyses of the European Centre for Medium-Range Weather Forecast (ECMWF) are interpolated in space and time to the model environment up to a pressure of 10 hPa. Above 10 hPa a prognostic meteorological model is used. The model calculations were interpolated in space and time to the MIPAS measurements.

This study presents for different geophysical conditions comparisons of the ratios of X/NOy (with X = NO_2, HNO_3, HNO4, N_2O5, $ClONO_2$) derived from the observations and the model calculations. While a high degree of agreement is found in the mid-latitude cases, the picture is not that clear at high latitudes. Possible causes of the discrepancies like gas phase rate constants, efficiency of heterogeneous processes and photolysis rates will be discussed.

O/1-1.5

3D CTM model calculations of chemical and dynamical processes in the lower stratosphere

M. Gauss, B. Rognerud, I. S.A. Isaksen

University of Oslo, Department of Geophysics - Oslo -Norway

Model studies of processes affecting ozone distribution and trends in the lower stratosphere have been performed. The model is specifically designed to study processes, which occur in the tropopause region. The studies focus on the chemical loss through reactions involving heterogeneous processes in the lower stratosphere and on tropospheric / stratospheric exchange of ozone and chemical compounds affecting the ozone distribution in the lower stratosphere. The model tool is a new 3-D chemical transport model (Oslo CTM-2) developed at the University of Oslo, which includes extensive chemical codes for processes in the troposphere and lower stratosphere. The model extends from the surface and up 30 hPa. The transport and physics parameters used, are supplied from ECMWF forecast data. Heterogeneous chemistry on aerosols and polar stratospheric clouds is calculated using a microphysical module.

Estimates of changes in the total ozone distribution and changes in stratospheric profiles are in agreement with observations. Heterogeneous chemistry, which is function of lower stratospheric temperatures, is found to have a significant impact on the stratospheric ClO distribution and on the ozone loss process due to chlorine reactions. Estimates of the impact on ozone for different years (e.g. different temperatures) are performed showing significant variations in the ozone loss. The model studies of the impact of ozone transport from the stratosphere to the troposphere show that there is an impact on the tropospheric ozone budget that has a distinct seasonal and latitudinal behaviour.

O/1-2.1

The extratropical tropopause as a transport barrier

P. Haynes

DAMTP, University of Cambridge, Cambridge - UK

There are strong analogies between the tropopause and the polar vortex edge in that both appear to act as partial barriers to transport of chemical species in an environment that is otherwise strongly stirred by waves or eddies. This talk will describe various numerical simulations designed to investigate the analogy. Two different numerical models have been used. The first is a multi-level primitive-equation on a sphere. The second is a multi-level quasi-geostrophic model in a beta-plane channel. In both the flow is relaxed towards a state that is baroclinically unstable and a statistical equilibrium is achieved which has an active field of eddies. A characteristic feature of both models is that transport properties show a rapid transition in the vertical. At upper levels there is a transport barrier (at mid-latitudes in the case of the first model). At lower levels there is no transport barrier and the eddies essentially mix across the entire extent of the flow. In the first model the transport barrier is analogous to the subtropical tropopause and the height of the transition is analogous to the height of the mid- and high-latitude tropopause.

The variation of the location and strength of the barriers and the height of the transition has been explored in both models with the aim of developing understanding of the factors that control the shape and position of the extratropical tropopause and of possible future variation and consequences for chemical distributions.

O/1-2.2

Isentropic transport and mixing rates across the tropopause

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We consider the isentropic transport of air across the tropopause, with particular emphasis on the transport of ozone rich stratospheric air into the upper tropical troposphere, using multiyear contour advection simulations with ECMWF analysed winds and potential vorticity. In particular, we consider how diagnostics of the contour advection can be used to estimate mixing and transport rates.

On the one hand, contour lengthening rates give an indication of the seasonal and interannual variation of mixing rates and these are compared with recent results by other contributors obtained using effective diffusivity calculations.

On the other hand, when contour surgery is applied repeatedly the resulting "coarse graining" provides an estimate of the isentropic area transported in both directions across the tropopause. Attention is given to the sensitivity of such estimates to the particular value of potential vorticity chosen for the isocontours. Where possible, we use additional data from MOZAIC flights crossing the upper tropical troposphere over the Atlantic to verify particular mixing events and their representation by the simulations. An important aspect of the study is the inclusion of a crude representation of the relatively strong diabatic processes present in the upper tropical troposphere by using a pseudo diabatic contour advection scheme, in which the large scale potential vorticity fields from the analyses are regularly compared with the advected fields.

Finally, from a dynamical systems perspective, we consider how both particle advection and the concept of distinguished hyperbolic trajectories can provide information about the stable and unstable manifolds in this region and we investigate the extent to which lobe dynamics can be used to evaluate the associated transport.

O/1-2.3

Seasonal variation of cross-tropopause transport into the northern middle and high latitude lowermost stratosphere

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We present an analysis of trace gas budgets in the lowermost stratosphere. *In situ* aircraft measurements of CO, N_2O, NOy and O_3, obtained during two STREAM campaigns in March 1997 and July 1998, have been used to investigate the role of isentropic cross-tropopause mass exchange. Mixing of tropospheric air into the lowermost stratosphere has been identified by enhanced ratios of NOy/NOy* and NOy/O_3, respectively, and from scatter plots of CO versus O_3. At altitudes above a potential temperature level of approximately 325 K in March 1997 and 355 K in July 1998, purely stratospheric air was found with NOy/NOy* ratios close to unity, NOy/O_3 on the order of 0.003 to 0.006 and CO mixing ratios as low as 20 ppbv. Most probably, these air masses were transported to the lowermost stratosphere *via* diabatic descent from the overworld. Enhanced levels of CO, NOy/NOy* and NOy/O_3 were found in a mixing layer between the local tropopause and the 325 K potential temperature level in the winter/spring season, indicating isentropic troposphere to stratosphere exchange. In the summer season the mixing layer extended to much higher potential temperature levels, up to 350 K.

O/1-2.4

Extratropical control of tropical upwelling in the lower stratosphere

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The role of extratropical forcing of the upwelling circulation in the tropical lower stratosphere is studied by means of data analyses and numerical modelling. Estimates of the extratropical residual circulation derived from the thermodynamic and momentum budgets are in reasonably good agreement throughout much of the year. In addition, the zonal mean temperature in the tropics correlates well with extratropical wave forcing over a broad range of time scales. Together, these findings suggest a major role for extratropical forcing of the tropical upwelling circulation. Implications for the transport of water vapor into the stratosphere and its secular variability are discussed.

O/1-2.5

Model study of the sources of upper tropospheric ozone over the Atlantic, with emphasis on inter-hemispheric asymmetries

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Measurements of ozone and aerosols from ships transecting the Atlantic Ocean reveal considerable interhemispheric asymmetries in the vertical structure of the ozone distribution. There is much more upper tropospheric ozone to the South of the Equator than in the Northern Hemisphere. These profiles suggest that the air in the southern hemispheric tropics and subtropics has a source in the stratosphere, while that in the Northern Hemisphere originates in the boundary layer.

A model experiment designed to investigate this problem will be discussed. They are based on a new general circulation model, developed in the DAO at NASA GSFC in collaboration with NCAR; the model is based on a Finite-Volume dynamical core (formulated by Lin and Rood) and the physical parameterisations from the Community Climate Model at NCAR. The model simulates a climatological state in reasonable agreement with observations, comparable to other contemporary climate models, but has a much more accurate transport capability than most other present-day models.

The experiment involves using a suite of tracers, designed to highlight air from different source regions. Some of these (water vapor and ozone) represent real atmospheric quantities, while others are markers, which indicate whether the air originates in the stratosphere, the boundary layer, or has traversed regions of convection (for example). The experiments were run for periods of up to one month, initialised from snapshots from a long climate integration of the model. A sample of results will be presented, chosen to illustrate the different sources of air in the upper troposphere and the physical mechanisms by which these air parcels arrived there.

O/1-2.6

High spatial resolution trace gas measurements in the stratosphere by CRISTA

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Trace gas distributions were measured on a high-density grid in the middle atmosphere by CRISTA [CRyogenic Infrared Spectrometers and Telescopes for the Atmosphere] during its two missions of about one week duration each in November 1994 and in August 1997. At medium to large scales the data show pronounced dynamically driven features in a number of gases. Assimilation of the trace gas fields with the NCAR-ROSE model driven by UKMO temperature and wind fields allows detailed studies of stratospheric transports. Modelled NOy species are consistent with the respective observations if the appropriate aerosol loading is used in the model. At smaller spatial scales gravity wave signatures are extracted from the CRISTA temperature measurements. In addition to orographically generated waves (lee-waves) other gravity waves are found which seem to originate from deep convection systems in the tropics. A correspondingly high variability in the concentration of ozone in the middle stratosphere is found. Ozone fluctuations of up to 1.4 ppm at 30 km are seen between measurements taken within 10 min and separated by only a few hundred kilometres in a region which otherwise shows now horizontal concentration gradients.

O/1-2.7

Transport in the tropical tropopause region from *in situ* tracer measurements on board the M55 GEOPHYSICA aircraft

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During the APE-THESEO campaign based out of Mahé/Seychelles (5°S) in February/March 1999 a variety of tracer measurements were made during 7 flights of the Russian high altitude aircraft M-55 Geophysica in the tropical upper troposphere and lower stratosphere. The observations cover latitudes from 1°N to 19°S and longitudes from 46° to 60°E at altitudes up to 21 km. The Geophysica's ability to fly stable at all altitudes allowed an extensive coverage also below 20 km that has not been achieved by the NASA ER-2 aircraft due to its operational constraints. A large number of measurements were taken during horizontal legs within 1 km of the tropopause and during vertical legs at slow ascent/descent rates of 5 m/s. The data provide for the first time a detailed picture of the upper tropospheric part of the ITCZ and the lowest part of the stratospheric 'tropical pipe'.

The University of Frankfurt's High Altitude Gas Analyzer (HAGAR) provided measurements of N_2O, CFC-12, CFC-11, halon-1211 every 90s, SF_6 every 45s, and CO_2 every 15s during 6 successful flights out of Mahé. Ozone was measured at high resolution by two instruments, the Electochemical Ozone Cell (ECOC) and the Fast Ozone Analyzer (FOZAN).

Vertical profiles of the tracers' mixing ratios show no systematic decrease in the upper troposphere, indicating that mixing of stratospheric air into this region is insignificant at least at the time and place of the observations. However, an apparent latitudinal gradient in the upper troposphere for F12, SF_6, and H-1211 is in accord with suggestions that horizontal mixing within the ITCZ is not rapid enough to completely homogenise interhemispheric surface gradients by the time tropical air enters the stratosphere. We also examine cross-correlations of tracers with differing source/sink structures whose slope is a reliable indicator for the recent origin of the sampled air masses.

O/1-2.8

Age-of-air, tape recorder, and vertical transport schemes

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A numerical-analytic investigation of the impacts of vertical transport schemes on the model simulated age-of-air and the so-called "tape recorder" will be presented using an idealised 1-D column transport model as well as a more realistic 3-D dynamical model. By comparing to the "exact" solutions of the "age-of-air" and the "tape recorder" obtainable in the 1-D setting, useful insight is gained on the impacts of numerical diffusion and dispersion of numerical schemes used in global models. Advantages and disadvantages of Eulerian, semi-Lagrangian, and Lagrangian transport schemes will be discussed. Vertical resolution requirement for numerical schemes as well as observing systems for capturing the fine details of the "tape recorder" or any upward propagating wave-like structures can potentially be derived from the 1-D analytic model.

O/1-2.9

Simulated correlation of atmospheric trace species and implications for lower stratospheric transport

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Simultaneous observations of atmospheric trace species such as CO_2, N_2O, and water vapor have been shown to provide important constraints on the rates at which air enters the tropical stratosphere and is transported polewards. In particular, it has been argued that the observed tight correlations between N_2O and CO_2 in the lower stratosphere imply a timescale of a few months for transport from tropical to mid and high latitudes. The GFDL SKYHI general circulation model has been used to simulate the temporal evolution of N_2O, CFC11, CO_2 and SF_6. The calculated correlations between N_2O and CO_2 agree reasonably well with observed correlations, although they tend to exhibit somewhat more scatter. The agreement between the model and observations improves with the addition of a gravity wave drag parameterisation, which results in a stronger and more realistic meridional circulation. Poleward transport of trace species in the stratosphere is significantly modulated by the QBO (quasi-biennial oscillation) such that during easterly phases, transport out of the tropical troposphere is enhanced, while during the westerly phase meridional eddy transport out of the tropics increases in importance. Since N_2O and CFC11 have photochemical sinks in the tropical stratosphere, they decrease with altitude while SF_6 has a weaker vertical gradient. Correlations between CO_2 and SF_6 and CFC11 calculated with a version of SKYHI that includes a parameterized QBO are shown to be a potentially useful diagnostic of QBO effects on lower stratospheric transport.

O/1-2.10

Isolation of the polar vortex estimated by the time threshold diagnostics

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A new method, named time threshold diagnostics (TTD), was developed by Sugata (2000) for estimating effective flux of air parcels across given boundaries.

The method considers the motion of an air parcel passing through a given surface, and defines an effective passage if the residence time of the parcel on one side of the surface (before the passage) and that of the other side (after it) are both larger than a specified time threshold.

The TTD method is applied to the problem of isolation of the polar vortex in the 1996/1997 Northern Hemisphere winter, when the vortex was maintained until the beginning of May 1997. ECMWF analysis data (2.5 * 2.5 degrees, twice daily) are used. The polar vortex edge is defined as the surface of $3.3*10^{-5}$ K m^2/kg/s of modified potential vorticity [power of 5 (not 4.5) with reference of 475 K potential temperature]. The upper boundary is set at 700 K and the lower boundary is at 475 K.

The TTD method is applied to the parcels with these boundaries with the time threshold of 7 days. The effective flux toward the outside of the edge is 0.3 %/day (0.1 %/day) and that toward the inside is 0.3%/day (0.2 %/day) in February/March 1997, where the percentage is defined against the total volume of the polar vortex air with these boundaries.

The characteristic vortex filling time in the "horizontal" direction is thus estimated to be ~ 11 months in February and over 1 year in March, which indicates strongly isolation of the polar vortex. The estimated exchange in the vertical direction, the robustness of the results, and further investigations for Arctic vortices of other years and for Antarctic vortices will be discussed.

ORAL PRESENTATIONS

TUESDAY, NOVEMBER 07, 2000

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-3: Clouds and Water Vapour
Subsession 1-4: Gravity Waves
Subsession 1-5: Tropical Oscillations

O/1-3.1

Subvisible clouds at the tropical tropopause

T. Peter, B.P. Luo, Ch. Kiemle, H. Flentje, M. Wirth, S. Borrmann, A. Thomas, A. Adriani, F. Cairo, G. Di Donfrancesco, L. Stefanutti, V. Santacesaria, K.S. Carslaw, A.R. MacKenzie, T. Koop

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The impact of subvisible cirrus clouds on the upper tropospheric and lower stratospheric water budget is still largely unknown. As homogeneous nucleation of ice requires a supercooling of 3-4 K, subvisible cirrus particles could influence the onset of dehydration of air masses during their passage from the troposphere to the stratosphere despite their very low condensed phase density. Particularly thin subvisible cirri with a vertical thickness of only 100-300 m but horizontal extent of thousands of square kilometres have been detected at the tropical tropopause around 17 km altitude during the APE-THESEO campaign. The cloud layers have been characterised by measurements on board of two aircraft: the Russian high-flying research aircraft Geophysica, which performed *in situ* measurements of the cloud layers; and a German Falcon research aircraft flying up to 13 km altitude and directing the Geophysica into these clouds, which remained invisible for the Geophysica pilot even during level flight within the layer.

Both *in situ* and remote measurements suggest that the condensed phase volume ranges between only 1 and 5 µm3cm-3. The corresponding condensed mass in the ppb-regime together with their extensive and relatively homogeneous appearance suggests that these clouds do not consist of water ice. The possible composition of the clouds and speculations on their impact on the water budget are discussed.

O/1-3.2

Initial results from SOWER/pacific 1998-2000 campaigns

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Soundings of Ozone and Water in the Equatorial Region/Pacific.

Mission (SOWER/Pacific) is initiated to improve our understanding on the distribution and variations of the ozone and water vapor in the stratosphere and troposphere of the equatorial Pacific.

The mechanism of mass exchange across the tropical tropopause, the chemical ozone depletion due to biogenic halogen compounds in the tropical eastern Pacific, the climatology of the ozone profile in the tropics are some of those subjects included in the scope of SOWER/Pacific.

What is specific is that SOWER/Pacific is trying to have co-ordinated, year-round ozone and water vapor soundings on a scale across the Pacific paying special attention to the east-west contrast along the equator. The base stations are San Cristobal, Galapagos in Ecuador (0.90 S, 89.62 W), Christmas Island of Republic of Kiribati (2.00 N, 157.38 W), and Watukosek in Indonesia (7.57 S, 112.63 E). The spatial gaps between these stations will be filled by sondes launched from research vessels cruising the central to the eastern Pacific.

Due to the limited fund available, the initial effort has been to undertake spontaneous campaign observations under two extreme atmospheric conditions; the boreal winter (summer) when tropical tropopause is cold (warm) and high (low) reflecting the extratropical pumping activity in the Northern middle and high latitudes. The two periods also correspond to the local rainy season and dry season, respectively. What was unexpected, the record strong El Nino took place in 1997-1998 switching quickly to La Nina in the latter half of 1998. This paper will present some of the important findings on the tropospheric ozone distributions and the water vapor budget in the lower stratosphere obtained from the campaign observations in Galapagos and Christmas Island from 1998 to 2000.

O/1-3.3

Variability of the tropical cold point tropopause and its implication for stratospheric water vapor

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Air entering the stratosphere across the tropical Cold Point Tropopause (CPT) is dehydrated to the saturation-mixing ratio of water vapor at the CPT temperature. Thus, the tropical CPT plays an important role in determining the observed low concentration of stratospheric water vapor. The climatology of the tropical CPT has been investigated using sounding observations and ECMWF reanalyses.

The CPT exhibits interannual variability associated with both the equatorial stratospheric QBO and with ENSO. The influence of the QBO on the tropical CPT is mainly zonally symmetric. However, the ENSO signature in the tropical CPT has East-West dipole and North-South dumbbell features. Both the QBO and ENSO signatures propagate upward as "low-frequency tape recorders". A cooling trend in the tropical CPT temperatures has been found, which in the absence of other changes would be expected to lead to a negative trend in stratospheric water vapor. Thus, the observed positive trend in stratospheric water vapor is probably caused by dynamical changes.

O/1-3.4

Evidence of rapid dehydration and mixing within a tropical tropopause layer

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We discuss a recent hypothesis on the dehydration and transfer of air from the tropical troposphere into the stratosphere. The hypothesis is based on the existence of a thick "tropopause layer" in which vertical and horizontal mixing are both significant. Air is rapidly dehydrated upon entering this layer in vigorous convective overshoots, then slowly ascends through the layer before fully entering the stratosphere. Dehydration and genuine entry into the stratosphere are separate processes that happen on much different time scales. The dynamics of this hypothesis are consistent with recent estimates of net downward mass flux at tropopause levels over the maritime continent. We present *in situ* data that support the existence of rapid dehydration and vertical mixing within the TTL. We also present results from numerical simulations of overshooting convective events in a tropical environment.

O/1-3.5

An analysis of convection penetrating the tropical tropopause

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We present a global analysis of convective cloud tops that are colder than the analysed tropical tropopause. The analysis is based on high-resolution global imagery of cloud brightness temperatures from satellites and reanalysis tropopause temperatures for 3.5 years. The focus of the study is to understand how convective processes affect the tropopause region (from 14-18km) and the direct role of convection in stratosphere-troposphere exchange.

The analysis reveals a strong annual cycle in the frequency and spatial distribution of convective events that penetrate the tropical tropopause.

The annual cycle of these events exhibits year-to-year variability. Results indicate that deep convection over tropical landmasses does not penetrate the tropopause as frequently as over tropical oceans, and affects the tropopause region differently.

The net global effect of these penetrating clouds on stratosphere-troposphere exchange is discussed and quantified to elucidate the importance of direct injection of air and trace constituents by convection into the tropopause region and the tropical lower stratosphere.

O/1-3.6

SPARC water vapor assessment report

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Water vapor plays a fundamental role for chemistry, dynamics and the radiation budget of the atmosphere. It is the single most important greenhouse gas, contributing more than 80% to the total greenhouse effect. Yet the distribution of water vapor, its climatology and the short and long-term variability of the water vapor concentration in the upper troposphere (UT) and lower stratosphere (LS) are not known with sufficient accuracy

to keep calculated radiative balance uncertainties on the same order as the radiative effect of doubling the CO_2 concentration.

Because of its importance and the fact that there has never been an assessment of the state of knowledge of H_2O vapor, the international SPARC Office sponsored a study called Water Vapor Assessment Study or WAVAS, to determine what is known about its distribution, variability and trends throughout the range from the troposphere to the mesopause. The emphasis of the study is on the upper troposphere and lower stratosphere region. Scientists from many countries have participated in the study.

The first chapter of the SPARC Water Vapor Assessment Report discusses ground-based, balloon, airborne and satellite measurement techniques, their spatial resolution, their accuracies and limitations. Chapter 2 focuses on the data quality, how well measurement systems intercompare with one another, limitations of the data sets and gives guidance on combining data sets e.g. for trend studies. The last chapter describes the H_2O, variability and trends.

We will present the summary of the SPARC Water Vapor Assessment Report and discuss the findings in the context of the importance of water vapor as a climate gas.

O/1-4.1

A global morphology of gravity wave activity in the stratosphere

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Using temperature profiles obtained by the GPS/MET (GPS Meteorology) experiment from April 1995 to February 1997, we have extracted mesoscale temperature perturbations with vertical wavelengths ranging from 2 to 10 km and background

Brunt-Vaisala frequency squared. For each occultation event, we can evaluate a potential energy, Ep, which is assumed to be caused by atmospheric gravity waves. The monthly mean values of Ep at 15-20 km around Japan showed an annual variation with an enhancement in winter, which is consistent with the climatological behaviour of the kinetic energy of gravity waves observed with the MU (middle and upper atmosphere) radar (34.9N, 136.0E) from 1985 to 1989. We have then derived the global distribution of Ep at 20-30 km during Northern Hemisphere winter (from November to February).

Our analysis shows that the largest Ep values are generally centred around the equator between 25N and 25S with considerable longitude variations. Longitudinal variations of Ep at 20-30 km in a latitude range of 30-60N are also analysed, resulting in larger Ep values over the continents than over the Pacific ocean. Using GPS/MET data without anti-spoofing, latitudinal variations of Ep are determined in 15-45 km. Although large Ep values are concentrated near the equator at 20-30 km, Ep tends to become larger at midlatitudes at 30-40 km and higher altitude regions. At midlatitudes, Ep is found to be larger in winter months in both hemispheres. Height variations of Ep indicate a decrease at 25-30 km, and a monotonic increase above 30 km.

O/1-4.2

Outcomes of the SPARC gravity wave radiosonde initiative

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The SPARC radiosonde initiative was established to use high-resolution (~50-m) radiosonde observations to construct a climatology of gravity wave activity on as global a scale as possible. Results from over 100 stations located in North America, Europe, Asia, the Pacific, Australasia and the Antarctic, and analysed by over 20 participants in the project, are summarised. The procedures used to ensure standardisation of the analyses are discussed. Significant commonality is found for seasonal variations in a range of wave parameters, including wave amplitude and propagation directions, especially in the lower stratosphere.

O/1-4.3

The Aberystwyth EGRET experiment: gravity waves, filamentation and turbulent mixing in the tropopause region

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An airborne campaign to investigate mixing in the tropopause region (8-15 km) has been conducted at Aberystwyth during May 2000. This has made use of the Australian high altitude research aircraft - The Egrett - in concert with the extensive ground based facilities at Aberystwyth: MST radar, balloons and lidar. The main goal of the experiment is to observe the manner in which gravity waves cause turbulence and to determine if the associated mixing has significant consequences for the vertical distribution of ozone and water vapour. Particular emphasis will be placed on the mixing that affects exchange between the stratosphere and troposphere. The experiment will also address the role of lateral filamentation and the interaction of this with turbulent mixing. Other experimental objectives are to study the variability of gravity wave activity with respect to meteorological patterns and fundamental aspects of gravity wave spectra. The significant findings from the experiment will be presented.

O/1-4.4

Dynamics of turbulence and mixing in the stratosphere

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Turbulence arises in the stratosphere *via* wave breaking and shears instability processes. Both processes are being investigated using very high-resolution direct numerical simulations (DNS). Results of these simulations reveal the mechanisms accounting for turbulence generation and allow detailed analyses of turbulence structure and anisotropy throughout the flow evolution. Because of the high Reynolds numbers and broad inertial-range of turbulence achieved, results also allow an assessment of the implications for mixing and transport for each flow. Turbulent mixing and transport depends strongly on the environment in which turbulence arises, with shear instability leading to vigorous mixing and fluid homogenisation at one level and wave breaking leading to less complete mixing but more effective transport within each event.

O/1-4.5

Layered disturbances associated with low potential vorticity revealed by high-resolution radiosonde observation in Japan

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Horizontal wind and temperature data obtained from operational high-resolution radiosonde observation over Japan have recently been available. By analysing the data over 4 years, it is discovered that clearly layered and long lasting structure in horizontal winds appears frequently in winter at several stations simultaneously. The layered disturbances are dominant in the height region of 8-16 km. An EOF analysis for time series of the layered disturbance amplitudes indicates that there are two dominant principal components. The first component (EOF1) is characterised as disturbances dominant in the middle of Japan (30-37N), and the second one (EOF2) is as in the south of Japan (23-30N). Using both radiosonde data and NCEP reanalysis data, the background field preferred by the layered disturbances was examined.

One of the most interesting results is that EOF2 disturbances are dominant when the background potential vorticity is almost zero or negative even in the relatively high latitude region. This suggests that EOF2 disturbances are due to inertial instability. The frequency of negative potential vorticity is higher than 20 % in the zonally elongated region at 23-29N in the western Pacific on 345K surface (an about 10km altitude) in winter. It is interesting that such a high frequency of negative potential vorticity is not observed at other longitudes in this latitude regions. To see the origin of this anomalous potential vorticity, we made a backward trajectory analysis. The negative potential vorticity air for EOF2 disturbances can be traced back to the equatorial region south of Japan within 3 days. This is due to a strong northward blanch of Hadley circulation associated with strong convection on the Maritime continent.

On the other hand, the background potential vorticity is low but not negative for EOF1 disturbances. Air parcels reaching EOF1 stations are traced back to far west because of the existence of strong westerly jet. Thus, it is inferred that the EOF1 disturbances are due to inertial gravity waves trapped in a duct of the westerly jet core.

O/1-4.6

Gravity wave forcing of the stratospheric circulation

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Wave dissipation gives rise to a force on the background flow that drives the zonal-mean transport circulation and the quasibiennial (QBO) oscillation in the equatorial lower stratosphere zonal winds. The importance of planetary-scale wave forcing of these circulations in the stratosphere is well established and can be reasonably well quantified using global observations and assimilation products of the stratospheric general circulation. Conversely, the role of gravity- wave forcing in these stratospheric circulations has only more recently been appreciated and is currently only poorly quantified.

We will describe constraints on gravity wave forcing of the stratospheric transport circulation, the QBO, and the semiannualoscillation (SAO) based on 6 years of observations from the Upper Atmosphere Research Satellite. These constraints are derived indirectly by inferring the total wave-driven force then subtracting the resolved planetary-scale force. The constraints are important to global models seeking to parameterise the effects of gravity waves. In addition to constraints on forcing, we apply a model of gravity wave propagation and dissipation in the stratosphere to infer constraints on the characteristics of the gravity wave spectrum that are important to the stratospheric circulation. Specifically, these characteristics include the phase speed spectrum of the waves, their horizontal wavelengths, and the momentum flux they carry across the tropopause.

O/1-5.1

Equatorial influence on the inter annual variability of the stratosphere

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Various factors influencing the inter-annual variability of stratospheric temperatures and dynamics at high latitudes in Northern Hemisphere (NH) winter will be discussed. The role of equatorial influences, especially the quasi biennial and semi-annual oscillations, will be examined.

A recent data study using equatorial rocketsonde data that extended to 60 km suggests a strong correlation of NH winter temperatures with the upper stratosphere equatorial wind direction. Those results will be summarised. Model studies to simulate this result and explore the mechanism for the influence will be described.

A series of very long integrations of a 3-d stratosphere-mesosphere model has been run in which the role of each of these factors is examined both separately and together. Results so far have reproduced this upper stratospheric influence and highlight the influence of the equatorial wind direction above ~35 km. There is no evidence of a Holton-Tan relationship (i.e. equatorial easterlies associated with warm disturbed winters and vice versa) when observed equatorial winds are imposed between 16km (the bottom of the model) and 32 km.

However, when equatorial winds are imposed all the way to 60 km (using the rocketsonde data) there is a strong H-T correlation. This good correlation is lost if the equatorial winds are imposed only above 30km, suggesting that the whole QBO and SAO height region is important. The correlation is also very sensitive to the timing of the SAO relative to the QBO. Early results, in which the influences of the solar cycle are included, will also be presented.

The study will also be extended to examine whether a full 3-d GCM displays the same sensitivity to upper stratospheric equatorial winds and initial results of this study will be reported.

O/1-5.2

Quasi-biennial oscillations in a realistic simulation of the global climate

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The tropical quasi-biennial oscillation is absent from almost all-general circulation models because much of the required forcing for the oscillation comes from unresolved gravity waves.

Here we show that when a spectrum of these missing waves is parameterised in a comprehensive numerical model of the atmosphere, a realistic quasi-biennial oscillation is simulated. Both the amplitude and period of the oscillation are within the range found in observations and the asymmetry between east and west wind phases of the oscillation is close to that observed. Using a transformed Eulerianmean budget for the zonal wind tendency we show that the oscillation is forced by both resolved and parameterised waves.

We also examine the effect of the parameterised gravity waves at other latitudes. Both the direct effect of the waves on the extratropical flow and the remote effects of the QBO will be discussed.

O/1-5.3

Resolved wave driving of tropical oscillations in a GCM

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Atmospheric general circulation models (GCMs) have historically failed to produce realistic tropical oscillations such as the semiannual oscillation (SAO) and the quasibiennial oscillation (QBO). Both the SAO and QBO rely on wave driving by tropical waves which can, in large part, be resolved spatially by GCMs. Recent studies have identified two factors required to correctly model the resolved tropical-wave driving in GCMs. The first factor is related to the temporal characteristics of the latent heating (LH) produced by parameterized moist convection (PMC) schemes, which represents the dominant source of tropical waves. Because of their unrealistically weak high-frequency variability, some commonly used PMC schemes give rise to unrealistically weak tropical wave forcing (Ricciardulli and Garcia, 2000). The second factor is related to the vertical resolution used to model the tropical waves' interaction with the basic-state flow. Through idealised GCM simulations Horinouchi and Yoden (1999) have demonstrated that unusually high vertical resolution is required in the stratosphere to correctly model the tropical-wave mean-flow forcing in a GCM.

In this study an ensemble of climate simulations is used to evaluate the sensitivity of simulated tropical oscillations to these two factors. The simulations employ the Canadian Middle Atmosphere Model (CMAM) and use the PMC scheme of Zhang and McFarlane (1995). The temporal variability of the LH associated with this PMC scheme is made to systematically vary by adding a trigger condition to the standard closure conditions. Sensitivity to the vertical resolution in the stratosphere is examined by varying the vertical grid increment in this region down to 0.5km. It is shown that production of a spontaneous realistic QBO requires both high vertical resolution in the stratosphere and realistic high-frequency variability of the LH. The production of a realistic SAO in the model appears to depend primarily on the temporal variability of the LH.

O/1-5.4

On the relationship between the stratospheric quasi-biennial oscillation and tropical deep convection

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Global meteorological and satellite radiance data are employed to investigate the relationship between the stratospheric quasi-biennial oscillation (QBO) and tropical deep convection. More than 40 years of NCEP reanalyses highlight the structural changes in meteorological quantities, which occur near the tropopause during different phases of the QBO. The QBO signal in tropopause temperature and tropopause pressure exhibits strong zonal symmetry, with a meridional node near 20 latitude. An exception is the Tibetan High of the northern summer, which is significantly higher and colder during QBO westerly shear.

Time series of outgoing longwave radiation (OLR) and highly reflective cloud data (HRC) exhibit good agreement with each other and show a significant geographical shift in tropical convection between the two phases of the QBO. We investigated Bill Gray's hypothesis regarding more and stronger Atlantic hurricanes during QBO westerly years.

We find that during QBO westerly periods the tropopause Poleward of 20N is somewhat higher and colder, which could support hurricane growth in the later stages of their life cycle. A strong relationship is found between QBO westerlies and reduced wind shear in the 70-150 hPa layer (confirming Gray's proposed mechanism), and reduced inertial stability at outflow level near 100 hPa, in the Atlantic hurricane region.

ORAL PRESENTATIONS

WEDNESDAY, NOVEMBER 08, 2000

Session 2

Stratospheric Indicators of Climate Change

O/2.1

Updated trends in stratospheric circulation and trace constituents

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Long records of stratospheric temperatures, derived circulation statistics, and constituent data are available from satellite measurements beginning in 1979. These data show evidence of stratospheric cooling and decadal-scale trends in a number of trace constituents. These updated measurements will be reviewed, and inferred changes in stratospheric circulation discussed in light of the constituent measurements. Evidence of the 11-year solar cycle and stratosphere-troposphere coupling will be discussed in detail.

O/2.2

Analysis of a 15 years series of ground-based FTIR O_3 measurements above the Jungfraujoch: origin of the observed variations

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The ozone total column abundance above the Jungfraujoch has been monitored continuously by ground-based Fourier transform infrared spectrometry since 1985. The International Scientific Station of the Jungfraujoch is located at 3580m altitude in the Swiss Alps (46.8°N, 8.0°E). It is part of the primary Alpine station of the Network for the Detection of Stratospheric Change.

The FTIR O_3 time-series has been re-analysed and homogenised recently. Significant variations can be discerned, on several time scales. In particular on the long term, the total ozone abundance appears to decrease in the eighties and early nineties, and to increase again since the middle of the last decade. It is investigated whether correlations with other indicators of stratospheric changes, e.g., the tropopause altitude, can be detected unambiguously. It is investigated also whether systematic changes can be observed in the vertical distribution of ozone and of dynamical tracer gases like HF and, if possible, N_2O. This is done by using recently developed algorithms based on the Optimal Estimation Method developed by C. Rodgers (1976).

The goal is twofold: (1) to verify the vertical profiling capabilities of the FTIR technique, in particular for O_3 by comparing the results with data from nearby O_3 sondesand from SAGE-II, and (2), to extract some information that may help answering the question of long-term changes in the radiative and dynamical properties of the atmosphere.

O/2.3

The origins of trends in vertical ozone profiles measured at Lauder, New Zealand from 1986 to 2000

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Regression analysis was performed on vertical ozone profiles from ozonesonde flights made at Lauder (45.04S, 169.684E), the Southern Hemisphere mid-latitude charter site for the NDSC, from 1986 to 2000. Ozone number densities were interpolated onto 100 pressure levels from the surface (969hPa, 370m) to 12.1hPa (approximately 30.1km), and approximately 300 geopotential meters apart, to provide input to a linear least squares regression model, which includes basis functions for a seasonally dependent long-term trend, annual and semi-annual variability, the Quasi-biennial Oscillation (QBO), the El Niño Southern Oscillation (ENSO), the solar cycle, the influence of tropopause pressure variability, and the influence of the Mt. Pinatubo volcanic eruption. Residuals from this analysis (measurements minus regression estimates) were investigated more closely to better understand the causes of long-term trends. Residuals at each analysis level were examined to determine whether the trends result from changes in the frequency of anomalously high or low ozone events from some unchanging background, e.g. export of increasingly low ozone to mid-latitudes following the break-up of the Antarctic vortex, or whether the background ozone levels themselves are changing. A Lagrangian box model was used to investigate the chemical and dynamical origins of a number of the highest and lowest ozone anomalies on a case study basis. Together with a long-term climatology of trajectories (also generated using the Lagrangian model), these results can be used to explain some of the variability in vertical ozone profiles at Lauder over the past 15 years.

O/2.4

Characterisation of total ozone fields over the Southern Hemisphere

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The combined TOMS total ozone record covers now a sufficient period of time that advanced climatology studies can be carried out. Observation of the TOMS daily or monthly total ozone fields shows that basic field patterns are more frequent than others. Furthermore the distribution of these patterns has changed over the years, in particular due to the evolution of the ozone 'hole' and its sequels after the break-up of the polar vortex.

Using PCA analysis techniques, the monthly mean total ozone fields are characterised in order to understand in a systematic fashion its spatial variability and trends. The behaviour and changes in ozone field are discussed under the light of these results. Comparisons with similar analysis of other variables will be carried out.

O/2.5

HALOE observations of lower stratosphere and troposphere H_2O and CH_4

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The Halogen Occultation Experiment (HALOE) has been operating on the Upper Atmosphere Research Satellite for almost nine years collecting atmospheric vertical profiles of H_2O, CH_4, O_3, HCl, HF, NO, NO_2, aerosols and temperature. The archived data set covers the altitude range from near the tropopause to, in some cases, 140km. The HALOE team has been working on new, innovative approaches to extend the H_2O, CH_4 and O_3 measurements downward well into the troposphere to ~6 km altitude. Some of the main challenges in doing this are signal saturation due to high pressures and mixing ratios in the troposphere, the presence of O_2 and H_2O continuum absorption and aerosol and cloud interference. We recently determined that tropospheric H_2O can be retrieved using signals from the stratospheric HF channel. This channel is well suited for this application because spectral lines in the HF region (2.5mm) are much weaker than in the main H_2O channel at 6.6 mm. Thus signal saturation is not a problem. Also, major sources of spectral interference like the O_2 continuum are avoided. Another advantage is the HF channel uses Gas Filter Correlation Radiometry (GFCR) which virtually eliminates the effects of aerosols, thin clouds and the H_2O continuum because they have broad spectral signatures. Similarly, we have been testing CH_4 retrievals using the HCl GFCR channel, which contains considerably weaker CH_4 lines. Consequently, we can extend these data into the troposphere as well.

We will present a series of comparisons of our new retrievals with coincident balloon, aircraft and ground-based Raman lidar data (for H_2O) to demonstrate the validity of results. Next we will show lower stratosphere/upper troposphere pressure versus latitude and pressure versus longitude cross sections. The scientific implications of these new retrievals and cross sections will be discussed.

O/2.6

Can trends be determined in upper tropospheric water vapor from UARS MLS?

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Measurements of both water vapour mixing ratio and relative humidity in the upper troposphere are available from the Microwave Limb Sounder (MLS) on the Upper Atmosphere Research Satellite (UARS). Data span the time period from September 1991 to June 1999 and three versions are available. The data are compared with analyses from the European Centre for Medium Range Weather Forecasts. We analyse time-series to determine whether the dataset is suitable for the diagnosis of trends. We discuss the occurrence of high clouds, the bias of the measurements towards the beginning of the time-series, and the impact of instrument operations such as the satellite yaw manoeuvre, on the interpretation of trends.

O/2.7

Comparisons of water vapour measurements and derived quantities in the UT/LS: a summary from the SPARC Water Vapour Assessment

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For the data comparison chapter of the SPARC Water Vapour Assessment (WAVAS), a number of instruments using both *in situ* and remote techniques for measuring water vapour in the upper troposphere and stratosphere were assessed. Using both direct and indirect comparisons, it was found that most instruments gave agreement to within +/-10%.

Additionally, comparisons were made among estimates of seasonal cycle amplitudes, stratospheric entry values, and long term changes from various instruments. Long term changes computed from a number of time series covering the past 40-50 years strongly suggest that the water vapor increases seen in recent measurements made since 1980 have been taking place over a considerably longer period of time. Results will be presented, and implications will be discussed.

O/2.8

Temperature trends in the stratosphere and mesosphere Tidal interferences

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A review of several studies on the analysis of some long-term series will be presented including rocket, lidar and satellite data. Despite the discontinuities due to the use of different type of sensors and corrections, rocketsondes, launched on a routine basis by the United States and Japan at several locations since 1969, have been re-analysed using a least square fitting method with a multi-parameter function. This model include some linear functions to represent trends, natural cyclic variability (Seasons, Solar Activity, equatorial QBO wind) and instrumental changes. Rayleigh lidar is also a well-adapted instrument for monitoring absolute temperature in the middle atmosphere in a long-term commitment. Lidar data obtained since 1979 in France (OHP) in the frame of the NDSC (Network of Detection of Stratospheric Changes) have been also analysed. Comparisons between lidar data and NCEP data interpolated from the global analyses to the lidar location reveal temperature differences. It appears that some bias caused by tidal influences may appear in temperature series. While temperature trends from various sources will be presented, tidal interferences on trend will be discussed.

O/2.9

Assessment of temperature trends in the mesosphere and upper stratosphere along with resulting chemical changes

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The stratospheric temperature trend is now better understood and receiving appropriate attention after Assessment initiative undertaken by SPARC by establishing Stratospheric Temperature Trends Assessment (STTA) group and results indicate good consistency between model simulated and observed trends. However, the analysis of systematic changes in temperature trend in the mesosphere and thermosphere has not been as comprehensive as the above and there is a need to interpret and resolve outstanding questions about the global change induced radiative forcing (forcing from troposphere), especially, at the mesospheric level. In this work, an attempt has been made to review the temperature trends in the mesosphere (which is an initial outcome of the initiative undertaken by the joint working group of IAGA /ICMA /SCOSTEP on the assessment of mesospheric temperature trends) and upper stratosphere. The following general observations can be made from the assessment study: (1) the observations clearly indicate a mostly negative temperature changes in the atmosphere above the tropopause, (2) there appears to be a latitudinal effect in the temperature changes (Note: the vast majority of observations is for mid-latitudes and data for lower latitudes are very limited) (3) the rate of cooling increases with height in the stratosphere and the thermosphere but cooling rates in the mesosphere are more complex. That is, a steady increase in the cooling trend continues in the lower mesosphere and is the strongest between 60-80 km above which this negative trend weakens and (4) the mesopause is region wherein no clear trends exist

We have attempted to answer some of the unresolved question using an interactive radiative-dynamical-chemistry model of the stratosphere and mesosphere by considering the actual growth rates of forcing parameters like CO_2, CH_4, N_2O, CFCs and NOx etc at the ground during the 1970-1998 period as an input to the model. The effect due to variation in solar activity is filtered. Model calculation reproduces a negative trend (up to -10°k) in the lower middle atmosphere that drops significantly around mesopause and again shoots-up in the thermosphere. The most debated observed dip in temperature near the mesopause (almost no trend) could only partially be explained if non-LTE (Local Thermal Equilibrium) approach in the 15mm CO_2-band and turbulent structure at the mesopause level is adopted. As a result of change in temperature and several other neutrals, model shows that the ratio of two principal ions (log NO^+/O_2^+) consistently declining with time for past 3 decades which is broadly consistent with observations. Finally, the relative importance of anthropogenic and natural activities (solar flux cycle, etc) on the distribution of stratospheric and mesospheric chemical species is made.

O/2.10

Aerosol variability in SAGE II Version 6.0

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The Stratospheric Aerosol and Gas Experiment (SAGE) II was launched aboard the Earth Radiation Satellite in October 1984. As of mid-2000, the instrument continues to operate well and produce data of near nominal quality. With this nearly 16 year-long record, it has been possible to observe the decay of the stratospheric volcanic event of the 1900's (Mt. Pinatubo) and observe the stratosphere during periods with little or no volcanic signature.

In this presentation, Version 6.0 of the processing algorithm has had a significant impact on the quality of the aerosol data. We will examine changes in both primary (e.g., extinction and aerosol optical depth) and inferred products (e.g., surface area density and effective radius). We will discuss the temporal and geographic variability that has been observed between 1984 and the present. We will examine the relatively clean periods to determine if non-volcanic background levels have been obtained and if it possible to determine trends in the aerosol background level. We will also look at interesting seasonal and other time-scale variability in extinction. For instance, in the most recent clean period (1997-present), an annual cycle in extinction can clearly be observed in the lower tropical stratosphere.

O/2.11

A climatological study of cirrus clouds measured by lidar at OHP

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Cirrus clouds cover between 20-30 % of the earth,s surface. These clouds impact climate and may affect ozone concentrations in the upper troposphere/lower stratosphere (UT/LS), but quantifying the contribution of cirrus to these processes has been acknowledged as major source of uncertainty (*Aviation and the Global Atmosphere*, IPCC 1999). Identifying past trends in cirrus occurrences is an important step in reducing this uncertainty.

We have constructed a climatology of cirrus clouds over the Observatoire de Haute Provence (44° N, 6° E) from ground-based lidar measurements taken between 1997 to 1999. During this time the Rayleigh-Mie lidar collected nearly 400 nights of measurements and cirrus profiles are detected in about half of these cases. Subvisible cirrus (< 0.03) constitute a substantial portion (~40 %) of the calculated mean optical thickness. Our high-resolution (75 m vertically and 3 minutes temporally) results will be compared to satellite studies.

O/2.12

Climatological characteristics of the tropical tropopause as revealed by radiosondes

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A temporally and spatially comprehensive depiction of the tropical tropopause is presented, based on a radiosonde data from 83 stations. Climatological statistics for 1961-90 are computed for three levels: the conventional lapse rate tropopause (LRT); the cold-point tropopause (CPT); and the 100hPa level. Mean values, and seasonal and interannual variations, of temperature, pressure, height, potential temperature, and water vapor saturation mixing ratio at these levels are compared. The tropopause is higher, colder, at lower pressure, and with lower saturation mixing ratio, in the Northern Hemisphere (NH) than in the Southern Hemisphere particularly in NH winter. The locations of minimum tropopause temperature differ from those of maximum height and minimum pressure: In NH winter, the tropopause is highest and at lowest pressure over Central America, but it is coldest over the western tropical Pacific warm pool region. The height of the tropopause reflects the temperature of the underlying troposphere, and it increases with decreasing atmospheric stability, suggesting a response to convection. Tropopause temperature, on the other hand, shows little association with tropospheric characteristics but is significantly correlated with the temperature and pressure of the lower stratosphere, showing evidence of the quasi-biennial oscillation and the warming following major volcanic eruptions. The utility of the radiosonde data for detection of trends in the tropopause is limited by changes in instrumentation. Taking these into account, we find some evidence for the following trends in the tropopause in the deep tropics during 1978-97: an increase in height of about 20 m per decade, a decrease in pressure of about 0.5 hPa per decade, a cooling of about 0.5 K per decade, little change in potential temperature, and a decrease in saturation mixing ratio of about 0.3 ppmv per decade. Using four decades of saturation mixing ratio data, we also investigate the implications of choice of observational data period for the Œstratospheric fountain' hypothesis.

O/2.13

The tropical tropopause intraseasonal, interannual and long-term variations

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The complex interplay of local convection and large-scale dynamical forcing have impeded our understanding of the tropical tropopause, yet such understanding is vitally important from the point of view of troposphere-stratosphere exchange, and the distribution of such trace species as ozone and water vapor in the stratosphere. This paper will discuss the interannual and intraseasonal variations in the tropopause over the tropical and subtropical Pacific, with emphasis on the effects of the ENSO cycle, the QBO, and the Madden-Julian oscillation. Data sources for the study include the radiosonde record from reliable tropical stations and the NCEP reanalysis data. The results demonstrate the importance of both localised convection and global-scale forcing, and show evidence for decadal-scale trends that appear to be more pronounced in the subtropics than in the equatorial region.

O/2.14

The solar component of long-term stratospheric variability: the possible role of solar-modulated QBO

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Observational evidence for a significant solar component of long-term variability in the lower and upper stratosphere has been reported by a number of analysts. The amplitude of this variability component in lower stratospheric records of geopotential height, temperature, and ozone has generally been larger than predicted by stratospheric models that account for known variations in solar ultraviolet flux and associated derivative effects on ozone, temperature, and wind fields.

In most previous studies, solar forcing has been assumed to be independent of the quasi-biennial wind oscillation that is responsible for much of the interannual variability of the lower stratosphere.

However, a recent study by Salby and Callaghan (J. of Climate, 2000) suggests that equatorial winds below 30mb may vary slightly on the solar cycle time scale. Although the QBO is dominantly driven by wave forcing originating in the troposphere, some GCM simulations have indicated that a solar modulation of the QBO may result from downward propagation of direct solar forcing effects at higher levels. In this paper, an independent analysis is reported of equatorial wind fields, column ozone, and meteorological fields at low latitudes to investigate further the QBO modulation hypothesis. Evidence is obtained that equatorial easterlies near the 50mb level tend to reach larger maximum amplitudes under solar minimum conditions. This modulation increases the vertical wind shear during the transition to westerlies at upper levels, thereby modulating the QBO-induced meridional circulation in the subtropics.

Associated effects on column ozone amounts in the subtropics are evident in long-term records. These results lead to the provisional conclusion that any accurate simulation of solar forcing of climate through the stratosphere must include a simulation of the QBO and its superposed solar modulation. Results also imply that accurate modelling of the solar cycle variation of stratospheric ozone must include this forcing component.

O/2.15

Interannual changes of the stratospheric circulation: relationship to ozone and tropospheric structure

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Interannual changes of dynamical structure and ozone have been studied in observed variations over the Northern Hemisphere during the 1980s and 1990s. The structure of interannual changes is consistent with a strengthening/weakening of the residual mean circulation of the stratosphere, which regulates polar temperature and ozone. Systematic changes, which underlie trends of temperature and ozone over the two decades, have the same structure. Two central mechanisms account for almost all of the interannual variance of temperature and ozone. Interannual changes of EP flux transmitted upward from the troposphere by planetary waves, along with changes of equatorial wind associated with the QBO, represent nearly all of the observed variation of wintertime polar temperature. Supported by changes of stratospheric aerosol and chlorine, which represent about 20% of the interannual variance, the same conclusion holds for ozone.

Changes of dynamical structure operating coherently with the residual circulation share certain features with the Arctic Oscillation (AO). Both are marked by a prominent signature of the polar-night vortex, but the signature associated directly with changes of upward EP flux is 2-3 times stronger. Those changes operate coherently with interannual changes of the tropospheric circulation, specifically, with an amplification/weakening of the ridge over the eastern Pacific and a contraction/expansion of the North Atlantic storm track. The observed decline of upward EP flux during the 1980s and early 1990s mirrors a similar trend in the AO. Both are consistent with a decline of the residual circulation and a commensurate decline of temperature and ozone.

O/2.16

Coupled variability modes of atmospheric circulation, climate change and detection

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Climate can be defined by the probability density function (PDF) of few natural coupled variability modes - climate change by variations thereof - plus noise. These few fundamental variability modes are based on physical mechanisms arising e.g. from the transmission-refraction behaviour of quasistationary planetary waves in the atmospheric circulation field. They are especially meaningful in boreal winter if the coupling between stratospheric and tropospheric circulation is considered. Many classical climate parameters can be traced back to these modes. Due to the strong filtering effect of the vertical wind field for the propagation of shorter waves, the signal to noise ratio is much improved in the stratosphere for climate variations. This includes a small number of degrees of freedom and smoothed structures. Since the physical mechanism behind the troposphere-stratosphere coupling includes a bifurcation point (the critical Rossby velocity) climate change develops non-linearly. Therefore linear statistical techniques applied to tropospheric variables are sub-optimal for early detection of climate change. It can better be detected by searching for changes in the behaviour of the coupled variability modes in the stratosphere and projection onto tropospheric variables.

ORAL PRESENTATIONS

THURSDAY, NOVEMBER 09, 2000

Session 3
Modelling and Diagnosis of Stratospheric Effects on Climate

Subsession 3-1: Climatology
Subsession 3-2: Internal Variations in S-T Coupled System
Subsession 3-3: Responses to Forcings

O/3-1.1

The interaction of stratospheric processes and climate

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Stratospheric ozone depletion has been one of the major manifestations of human influence on the atmosphere. Research over the past 10-15 years has provided us with a good understanding of the processes, which lead to ozone depletion at both at high and mid latitudes.

Now that the stratospheric chlorine loading should start to decrease, the ozone layer is expected to recover. However, changes in other parameters (e.g. temperature, water vapour, and circulation) could delay this recovery, or result in recovery to a different state.

Depletion of ozone itself can also influence the climate, for example through the radiative role of ozone.

I will use results from three-dimensional chemical model studies to illustrate the interaction of ozone depletion and climate.

In particular I will discuss the current and future roles of chemistry and transport in determining ozone abudances in the polar regions. Chemical depletion could be enhanced by stratospheric cooling and by possible increases in H_2O. Dynamical changes may also exert a strong influence on Arctic O3 levels.

I will also discuss the interaction of ozone depletion and climate at mid-latitudes.

O/3-1.2

A GRIPS GCM intercomparison of tropical cumulus convection and vertically propagating waves

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It is easily imagined that there is considerable variation in the forcing and vertical propagation of tropical waves among a number of currently used middle-atmosphere GCMs. These waves may affect the model climatology in different ways. For example, differences in wave forcing and propagation may explain the fact that a few models produce QBO-like oscillations in the tropical lower stratosphere while the majority do not. The present paper reports on the first attempt to carry out a comprehensive and quantitative comparison of resolved tropical waves using suitable diagnostic tools. For this task, we have collected 3-hourly output for all grid points between 30N and 30S from GCMs that are participating in the GCM-Reality Intercomparison Project for SPARC (GRIPS) and some additional models. Spectral analyses were conducted for various quantities including precipitation, a proxy for the cumulus forcing of waves that propagate into the middle atmosphere.

The frequency-zonal wave number analysis of the EP flux provides a number of useful insights. It is found that, for all models, the high wave number and frequency waves (relative to the conventional "equatorial waves") collectively account for the bulk of the momentum flux, even in the lower stratosphere. Second, the amplitude of the momentum flux differs among the models examined by more than an order of magnitude. There are also significant variations in the spectral distribution, thus indicating variations in the phase velocity distribution of the waves as well. The spectral distribution of the EP flux resembles that of precipitation, suggesting that the momentum flux is primarily controlled by the transient features of cumulus heating. These spectral features are characteristic of the cumulus parameterisation employed in each model.

These results suggest that cumulus parameterisation is an important aspect of the climatology of simulated equatorial middle atmosphere.

O/3-1.3

Simulating observed ozone loss in the Northern Hemisphere winter

S.R. Kawa, A.R. Douglass, L.R. Lait, D.B. Considine, J.G. Anderson, D. Baumgardner, J.W. Elkins, D.W. Fahey, E.C. Richard, H. Jost, M. Rex, G.C. Toon, C.R. Webster

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Ozone amounts observed at high northern latitudes in late winter and early spring have been relatively very low in 4 of the last 6 years. On the face of it, this decline appears similar to that observed in the Antarctic in the mid-1980's in spite of the fact that the abundance of stratospheric chlorine is currently steady or decreasing. In order to predict the extent to which this change represents a trend, and to understand what combination of factors produces the low ozone, we need to accurately simulate these observations with models. In this presentation, we focus on the winter of 1999-2000, which exhibited some of the lowest ozone ever recorded in the Northern Hemisphere.

It also contained the largest-ever assembled set of atmospheric measurements and modelling activities in the SAGE III Ozone Loss and Validation Experiment/Third European Stratospheric Experiment on Ozone (SOLVE/THESEO). We use SOLVE/THESEO observations in comparison with the Goddard 3-D global model of stratospheric chemistry and transport to explore the model's capability to simulate the evolution of ozone and other species through the winter. We will discuss advective transport and mixing, chlorine activation, and denitrification, which are key processes to accurately simulating wintertime ozone. Preliminary results show that, although the model tracer transport and chlorine activation compare relatively well with observations, the magnitude of observed ozone loss is difficult to achieve in the model. Calculated ozone loss is sensitive to denitrification, which presents a major challenge to parameterisation in a global model. Simulation requirements and uncertainties will be evaluated.

O/3-2.1

Persistence of the lower stratospheric polar vortices

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The persistence of the Arctic and Antarctic lower stratospheric vortices is examined over the period from 1958 to 2000. Three different vortex-following diagnostics (two using potential vorticity and one based solely on the zonal winds) are compared and are shown to give very similar results for the break-up date. The variability in the timing of the break-up of both vortices is qualitatively the same:

There are large interannual variations together with smaller decadal-scale variations and there is a significant increase in the persistence since the mid-1980s (all variations are larger for the Arctic vortex). Also, in both hemispheres, there is a high correlation between the persistence and the strength and coldness of the spring vortex, with all quantities having the same interannual and decadal variability. However, there is no such correlation between the persistence and the characteristics of the midwinter vortex. In the Northern Hemisphere, there is also a high correlation between the vortex persistence and the upper tropospheric/lower stratospheric eddy heat flux averaged over the 2 months prior to the break-up. This indicates that the variability in the wave activity entering the stratosphere over late winter to early spring plays a key role in the variability of the Arctic vortex persistence (and spring polar temperatures) on both interannual and decadal timescales. However, the extreme values of Arctic vortex coldness and persistence during the 1990's are not echoed as a similar extreme in the eddy heat flux. This suggests that the recent increase in vortex persistence is not solely due to changes in the wave activity entering the stratosphere.

O/3-2.2

Interannual variations of planetary waves in the Southern Hemisphere stratosphere

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A statistical analysis is made of interannual variations of planetary waves in southern hemisphere winter for 20 years (1979-1997) with the aid of NCEP/NCAR reanalysis data-set in terms of the dynamical coupling between the stratosphere and troposphere.

It is found that the year-to-year variability of stratospheric planetary waves in the Southern Hemisphere is considerably higher than that of the Northern Hemisphere in their location (phase angle of monthly-mean stationary waves), suggesting that the excitation mechanism in the lower atmosphere and vertical propagation characteristics are quite different between the two hemispheres.

In order to see the planetary-scale forcing in the upper troposphere, variance of transient waves in winter months with the time-scale less than 7 days is examined. In general the maximum variance appears over the Indian Ocean, and its variability seems to be well correlated with the activity of stratospheric planetary waves.

Discussions are extented to the connection with the interannual variation of the polar-night jet in the Southern Hemisphere stratosphere as pointed out by Shiotani et *al*. (1993).

O/3-2.3

Propagation of annular modes from the mesosphere to the Earth's surface

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"Annular modes" are deep, longitudinally symmetric patterns, which dominate the circulation variability of both hemispheres from the Earth’s surface to the mesosphere. These ring-like patterns are characterised by fluctuations in pressure of one sign over the polar caps and the opposite sign at low latitudes. The Northern Hemisphere surface annular mode is also called the Arctic Oscillation. The simple structure of the annular modes appears to be a fundamental fluid dynamical consequence of the Earth's size and rotation rate. More than two decades of global satellite observations allow us to examine of the time-height development of the annular modes. We discuss the first observations that show that fluctuations in the annular modes often begin in the lower mesosphere and propagate downward, over a period of up to three months, to affect surface weather and climate patterns. These results provide observational evidence that perturbations and trends in the circulation of the stratosphere and mesosphere, which may be caused by natural variability, increasing greenhouse gasses, ozone depletion, volcanic eruptions, or 11-year solar variability, could have larger effects on surface weather and climate trends than has been recognised.

O/3-2.4

The structure and evolution of the Arctic oscillation in the stratosphere and upper troposphere

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The Arctic Oscillation was first identified by Wallace and Thompson (1998) as the leading mode of variability of the extratropical Northern Hemisphere. In the stratosphere, the AO has been referred to as an "annular mode" on account of its strong zonal symmetry. This paper describes the three-dimensional structure and evolution of the AO in the stratosphere and upper troposphere. The relationship of the AO to stratospheric sudden warmings will be described, and explanations offered for the apparent connections in AO activity between the stratosphere and upper troposphere, in particular for the apparent downward propagation of the AO signal. It will be argued that the AO cannot be considered to be an annular mode of variability, and that zonal asymmetries are essential for its evolution.

O/3-2.5

A mechanistic model of the coupled troposphere-stratosphere annular mode oscillation

J.R. Holton, S. Eichelberger

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The Arctic Oscillation (AO) is an annular mode of variation that consists of a meridional seesaw in the temperature and zonal mean wind extending from the surface to the upper stratosphere. In its Œhigh index, phase the oscillation is associated with a polar vortex that is stronger and colder than normal, leading to enhanced westerly winds at high latitudes extending from the surface to the upper stratosphere. The trend observed during the past several years is one in which the AO is spending more time in the high index state. Whether this is a result of natural variability or represents a trend related to greenhouse warming or ozone depletion is not yet known. We have developed a mechanistic dynamical model that provides a simple analogue of the AO. The model represents the interaction between the zonally symmetric flow and planetary waves for two meridional modes of variation. Variations in the second meridional mode qualitatively resemble those of the observed AO. The sensitivity of the oscillations in the model to parameters such as the amplitude of the planetary wave forcing at the surface, and the pole to equator gradient of radiative forcing, will be discussed in the context of the observed AO.

O/3-2.6

Northern Hemisphere winter climate response to greenhouse gas, ozone, solar and volcanic forcing

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There is considerable observational and modelling evidence that the stratosphere and troposphere are dynamically coupled. This coupling is strongest in each hemisphere during winter months when planetary waves can propagate up into the stratosphere most effectively. Perturbations to the stratosphere may therefore affect surface climate, perhaps *via* planetary waves. General circulation models have been used to study the interactive radiative, dynamical, and chemical impacts of increasing greenhouse gases, polar ozone depletion, volcanic eruptions, and solar cycle variability. In the GISS model, changes in the model,s Northern Hemisphere winter surface climate take place largely through enhancement of existing variability patterns, with greenhouse gases, polar ozone depletion and volcanic eruptions primarily affecting the Arctic Oscillation (AO) pattern. Other GCMs that have simulated the climate response to volcanic eruptions find similar results. Perturbations descend from the stratosphere to the surface by altering the propagation of planetary waves coming out of the troposphere, in accord with observations. The results support the conclusion that the dynamical coupling between the stratosphere and the troposphere plays a crucial role in recent surface trends. In other GISS climate model, while ozone depletion is significant, greenhouse gas forcing is the only one capable of causing the large, sustained increase in the AO observed over recent decades. This suggests that the AO trend, and a concurrent strengthening of the stratospheric vortex over the Arctic, are likely anthropogenic in origin.

O/3-2.7

Climate model simulations of past stratospheric ozone, temperature and water vapour trends

J. Austin, N. Butchart, J. Knight

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The stratosphere has cooled unambiguously over the last twenty years (WMO, 1999, Chapter 5) and both water vapour and ozone changes have contributed significantly. However, while ozone is fairly well understood, the observed changes in water vapour during the last few decades are so far unexplained.

Modelling capability has now reached the stage where simulations of past stratospheric trends are both more reliable and likely to produce benefits in understanding the tropospheric climate system.

In this paper, results will be presented from The Met. Office coupled chemistry-climate model, which has been developed further to produce the most realistic simulations for the period 1980 to 2000 currently attainable. This model has 64 levels from the ground to 0.01 mbar and contains a complete range of stratospheric chemical reactions allowing representation of all the main ozone formation and destruction processes. By resolving the whole of the stratosphere and most of the mesosphere the model is able to simulate possible dynamical feedbacks, such as changes in global mean meridional circulation, important for ozone and water vapour transport. External parameters of the model (GHG concentrations, long-lived chemical species and sea surface temperatures and ice amount) are supplied from observations. The trends in ozone, temperature and water vapour will be compared with observations. These will be contrasted with previous results from a dynamics-only simulation, which revealed cooling rates in the upper stratosphere some 30% lower than observed. Reasons for any differences will be explored.

O/3-3.1

The response of tropospheric climate to perturbations in the heat balance of the tropical lower stratosphere

J.D Haigh, S.-D. Ibbotson, S. Djavidnia

Blackett Laboratory, Imperial College of Science, Technology and Medicine - London - UK

We have used two completely different general circulation models [1] to study the impact on the lower atmosphere of variations in solar UV and solar-induced stratospheric ozone. Very similar patterns of response in tropospheric temperature and wind fields are found, especially at low latitudes and across the summer hemisphere, with a weakening of the winter Hadley cell. From this we conclude that the pattern is (a) a robust response to solar variability and (b) not dependent on details of wave propagation into the middle atmosphere. We now assess whether these patterns might be found in response to other factors, which affect the heat balance of the lower stratosphere (e.g. QBO, volcanic aerosol) by conducting a set of sensitivity studies with The Met. Office Unified Model in which heating rates in the lower stratosphere are perturbed. The structure of the imposed perturbations is determined from analysis of radiosonde and satellite observational records.

The results of the model runs will be presented and analysed concentrating on variations in the tropical tropopause region and how these affect the general circulation of the troposphere.

[1] GCMs used were a 19-level spectral model (UGAMP UGCM) with limited resolution in the stratosphere and a 58-level grid-point model (UKMO UM) extending up to 0.1hPa. The two models also use entirely different "physics" routines.

O/3-3.2

The influence of the QBO on the UTLS region

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Atmospheric Physics, University of Oxford - Oxford, Oxon - UK

Introducing the Hinds gravity wave drag scheme into a middle atmosphere version of the UK Met Office Unified Model produces a realistic QBO in the tropical stratosphere. The role of gravity wave drag and resolved equatorial waves in forcing this QBO is examined. Barotropic instability is shown to occur in the tropical stratosphere as a result of the QBO.

The influence of the QBO on the vertical ascent rates and isentropic mixing in the tropical lower stratosphere is compared with transport simulations using ECMWF analysis. The QBO produces variability in tropical tropopause temperatures and water vapour concentrations entering the stratosphere. Possible changes in convection in the upper tropical troposphere induced by the QBO are examined.

O/3-3.3

A coupled GCM - Chemical model study of tropopause height response to solar forcing

K. Tourpali, R. van Dorland, B. Steil, C.J.E. Schuurmans

Institute for Marine and Atmospheric Research Utrecht (IMAU), Utrecht University - Utrecht - The Netherlands

The global three-dimensional dynamic-chemical model MA-ECHAM4/CHEM is used to study climate effects due to variations in solar UV forcing. The General Circulation Model used, the Middle Atmosphere ECHAM4 (MA-ECHAM4), an extended upward version of ECHAM4 with the top at 0.01 hPa, has been interactively coupled to the tropospheric and stratospheric chemistry module CHEM. The coupled model employs interactive photochemistry and includes heterogeneous reactions on PSCs and sulphate aerosols. Preliminary results on lower stratospheric and upper tropospheric changes will be presented, derived from experiments with different initial conditions (warm and cold stratospheric winters). Emphasis will be on the annual cycle of the tropopause, and on tropopause height changes in response to the 11-year solar cycle, resulting from the interactive stratospheric ozone changes as simulated in the model.

Results will be compared also to observations, using the NCEP reanalysis data set, taking into account changes due to other mechanisms.

O/3-3.4

Tropospheric responses in CGM simulations of the impact of the 1991 Mt Pinatubo eruption

A. Robock, G.L. Stenchikov, V. Ramaswamy, S. Ramachandran

Rutgers University, Dept. of Environmental Sciences - New Brunswick, New Jersey - USA

The response of stratospheric GCMs to aerosols from the 1991 Mt. Pinatubo eruption is an excellent and rigorous model test, involving radiation, dynamics, chemistry and transport. It was a large, episodic event, with well observed forcing and response. Here we compare the responses of different GCMs participating in PINMIP, the Pinatubo Model Intercomparison Project. During the winter in the Northern Hemisphere following every large tropical eruption of the past century, surface air temperatures over North America, Europe, and East Asia were warmer than normal, while they were colder over Greenland and the Middle East. This pattern and the coincident atmospheric circulation correspond to the positive phase of the Arctic Oscillation. Using the Max Planck Institute ECHAM4 and the Geophysical Fluid Dynamics Laboratory SKYHI GCMs, we have successfully simulated this response following the 1991 Mount Pinatubo eruption. We describe these results and compare them to results from other GCMs that have used the same aerosol forcing. In ECHAM4 and SKYHI, the tropical lower stratospheric heating from the volcanic aerosols produces an enhanced pole-to-equator temperature gradient that forces a stronger polar vortex. This stronger jet stream produces a characteristic stationary wave pattern of tropospheric circulation resulting in winter warming of Northern Hemisphere continents. This indirect advective effect on temperature is stronger than the radiative cooling effect from volcanic aerosols that dominates at lower latitudes and in the summer. This result will allow us to produce better seasonal forecasts for the Northern Hemisphere winter following the next large tropical eruption. It also shows that stratospheric forcing of the climate system must be considered along with sea surface temperature anomalies when making seasonal forecasts, especially in mid and high latitudes in the winter.

O/3-3.5

Changes in trace species and stratospheric temperature variations/trends

V. Ramaswamy, M.D. Schwarzkopf

NOAA/ GFDL, Princeton University, Princeton, NJ -USA

It is now well understood that changes in radiatively active trace species' concentrations over the course of the past two decades must have introduced corresponding changes in the stratospheric radiative heating. Utilising the observed changes of well-mixed greenhouse gases, ozone, water vapor and stratospheric aerosols, and incorporating them into the GFDL "SKYHI" ~3-degree version GCM with fixed sea-surface temperatures and predicted clouds, we simulate the resultant changes in the global lower-to-upper stratospheric temperatures. In the case of the trace gases, the trend over the past two decades is investigated. We compare the model responses with the variability of temperatures obtained from long-term (50-year) "unforced" integrations with the same model, and thus determine the statistical significance of the simulated temperature trends, focussing in particular on the responses in the mid-to-high latitudes. In the case of the Pinatubo volcanic aerosols, we perform an ensemble of 2-year GCM perturbation runs (1991-1993), and investigate the evolution of the temperature response in the low and high latitudes during this time period. For both the trace gases and aerosol cases, we also conduct comparisons of the simulated temperature changes with those observed, and examine the extent to which the effects of the trace species' changes are potentially manifest in the observed temperature record.

ORAL PRESENTATIONS

FRIDAY, NOVEMBER 10, 2000
09.00 - 13.10

Session 4

UV Observations and Modelling

O/4.1

Satellite-retrievals of UV compared with ground-base measurements

R.L. McKenzie[1], G. Seckmeyer[2], A. Bais[3], S.Madronich[4]

1) Nat. Inst. for Water & Atmospheric Res., NIWA Lauder - Pb 50061 Omakau, Central Otago - N. Zealand
2) Institute for Meteorology and Climatology, University of Hanover - Hanover, Germany
3) Laboratory of Atmospheric Physics, Aristote University of Thessaloniki - Thessaloniki - Greece
4) Atmospheric Chemistry Division, Nat. Center for Atmospheric Research - Boulder, Colorado - USA

In recent years, estimates of UV radiation at the Earth's surface have been obtained from satellite retrievals. These retrievals have been compared with ground-based measurements at a few sites, but so far there have been few comparisons from unpolluted sites. The current study compares differences between satellite-derived estimates of UV and ground-based measurements at a clean air site in the Southern Hemisphere and with more polluted sites in the Northern Hemisphere to investigate the extent to which differences boundary layer extinctions are taken into account by the satellite retrievals. It is found that the hemispheric differences inferred from the ground based measurements are much larger than those derived from the satellite retrievals. Since international intercomparison campaigns have shown the ground-based spectrometers to be in agreement, it is concluded that differences in tropospheric extinctions (e.g. by ozone and aerosols) are not adequately taken into account in current satellite retrievals of UV radiation.

O/4.2

Effect of air pollution on surface UV radiation and photolysis rates

S. Madronich

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Air pollution in urban areas can have significant effects on the local UV radiation field. Two effects must be distinguished: Scattering, mostly by aerosol particles, and absorption by both aerosols and pollutant gases (e.g. O_3, SO_2, NO_2, and organics). The effects of aerosol particles often dominate those of the local gaseous pollutants. In the presence of aerosols, the radiation incident on horizontal surfaces is usually reduced, while the radiation on horizontal surfaces can actually increase, due to the greater amount of scattered radiation. Scattering aerosols (e.g. sulfate) can also increase the UV radiation levels above the surface, leading to more active photochemical processing of polluted air and resulting in stronger photochemical ozone production. In contrast, absorbing aerosols (e.g. soot) can reduce the radiation at all altitudes, and slow the local generation of photochemical smog. The net result is very sensitive to the aerosol optical properties, in particular the single scattering albedo, wo, which depends on the chemical composition of the particles. Data on wo at UV wavelengths are still relatively sparse, and current estimates are based mostly on model calculations. Two locations, Los Angeles and Mexico City, will be contrasted.

O/4.3

On the present status of solar ultraviolet radiation measurements

A. Bais

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Monitoring programs of solar ultraviolet radiation are currently established in many locations around the globe using ground-based instrumentation. A few of these programs have started already in late 1980's, offering now data sets of more than 10 years of continuous observations. Due to the large spatial and temporal variability of the UV field, imposed mainly by clouds, these datasets are representative mainly of the locality of the measuring site. A unique opportunity to achieve global coverage of the UV fields is offered through the use of satellite products, a field that has gained considerable attention in the last few years. Several studies have been conducted to investigate the variability of solar UV radiation using either ground-based or satellite-derived UV data sets.

Spectrally resolved measurements contain a lot of information and are best suited for the assessment of the effects and interactions of UV radiation with the environment. Strict quality control and efficient quality assurance methodologies are under development in parallel with the improvement of the measurements'; technology, in order to enhance the quality of the acquired measurements and to maintain long-term consistency and comparability amongst measurements at different locations. Key topics in the field of UV measurements, which currently attract the scientific interest, include the estimation of uncertainties, improvement of the absolute calibration methods, the detection and correction of measurement errors, and standardisation and homogenisation of measurements. Substantial effort has been put in these issues during the last decade through international co-operation in the form of intercomparison campaigns, comparisons of measurements with model calculations, laboratory investigations but also through individual research activities. Results from two important activities in the field of solar ultraviolet radiation, the SUSPEN intercomparison of UV spectroradiometers and the International Photolysis Frequency Measurement and Modelling Intercomparison (IPMMI), will be presented and discussed in association with other relevant international activities.

O/4.4

Using the UV index forecasts to independently validate and intercompare surface ultraviolet radiation observations in the United States

C.S. Long

NOAA, Nat. Weather Service, National Centers for Environmental Prediction - Camp Springs, Maryland -USA

The NOAA/National Weather Service (NWS) has been issuing a next day UV Index forecast for locations within the United States since the summer of 1994. The UV Index forecast incorporates satellite observations of the earth's ozone field, a radiative transfer model, and atmospheric parameters from a numerical weather forecast model. As with all other NWS forecast products, the UV Index must be validated. At nearly the same time, several U.S. governmental agencies have established surface ultraviolet radiation observation networks. The UV Index forecasts are validated against these observations.

In addition to providing validation information to the NWS, this process is unique in that it combines all of the different networks' observations and compares them against an independent source. In the past, this has lead to uncovering calibration and characterisation problems with specific instruments and an entire brand of instrument. Subsequently, these calibration and characterisation issues have been addressed and correction values are made available to the user community.

Finally, the UV Index data could also be another source of comparison and validation of satellite derived surface UV radiation estimates.

As the NWS strives to improve the accuracy of the UV Index, it remains an excellent independent source of comparison for surface UV observations.

O/4.5

Ways to establish a UV climatology - Ground based and satellite approaches

G. Seckmeyer

Institute for Meteorology and Climatology, University of Hannover - Hannover - Germany

The establishment of an UV climatology in combination with investigations on potential long-term changes in ultraviolet radiation is a major goal of the UV research community. The changes could arise from a combination of shifts in the concentration of atmospheric ozone and alterations in the amount of cloudiness, atmospheric aerosol loading or the Earth's reflectivity (albedo). Changes in ozone, cloudiness or albedo may also be induced as a result of climate change due to a further increase of greenhouse gases in the Earth's atmosphere. As with climate, the wider impact of UVR can only be studied effectively with access to large amounts of routine measurements made at many different and widely spaced sites covering time periods of decades. An added complication with the analysis of UVR is the difficulty in obtaining data of consistent quality. The formidable technical obstacles encountered in the measurement of spectral UV irradiance mean that data, even when available, are often of variable or uncertain quality. The EDUCE project - funded by the European Commission - is designed to overcome many of the problems that are currently limiting progress in the investigation of the UVR climate at the Earth's surface. An overview to this large research project, that integrates the UV research from 22 institutes in 11 European states, is given. Furthermore it is shown why and how such studies are the prerequisite for the evaluation of satellite derived UV levels. The importance to validate the data derived from satellites is illustrated by examples of the deviations between ground based measurements to those obtained by different satellite methods. It is found that such deviations are usually quite large, especially on smaller time scales. Possible reasons for these large deviations are discussed and ways to overcome the difficulties will be presented.

O/4.6

Past and future UV changes

P. Taalas, J. Kaurola, W. Josefsson, J. Borkowski, A. Kylling, D. Shindell, R. Sausen, J. Herman

FMI - POB 503, 00101 Helsinki - Finland

Past UV changes may be estimated by using direct UV measurements or modelling based techniques. Spectral UV datasets are so far rather short for trend analysis. Longer broadband records exist, but their reprocessing may be elemental before trend estimates may be made. Spaceborne modelling methodologies exist, and they may allow global UV estimates since e.g. late 1970's. It is also possible to use global radiation, total ozone and meteorological observations as input parameters for radiative transfer models in order to produce UV estimates. The usefulness and compatibility of these three techniques will be presented.

While estimating possible future UV changes information on future stratospheric climate and halogen concentrations are needed. UV scenarios based on three different GCM-CTM model runs and climatological estimates of cloudiness, albedo and aerosols will be presented. Some of the results indicate a potential of a doubling of springtime erythemal UV doses in the Arctic and at Antarctica during the coming decades. These scenarios and their limitations will be presented.

O/4.7

A satellite climatology of ultraviolet aerosol properties

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The multiyear record of satellite observations of backscattered radiances in the 331-380 nm range by the TOMS series of instruments, has been used to produce a long term global climatology of aerosol properties. The TOMS aerosol DataBase contains information on optical depth and aerosol absorption in the UV over both the oceans and the continents. The main features of the TOMS aerosol climatology will be discussed.

O/4.8

Changes in Antarctic UV levels in relation to ozone hole characteristics

G. Bernhard

Biospherical Instruments Inc., Biospherical Instruments Inc. - San Diego, California - USA

The United States National Science Foundation's UV Monitoring Network for Polar Regions is currently in its thirteenth year of operation. Antarctic network sites include South Pole, McMurdo and Palmer Stations. The data series from these stations are now sufficiently long to investigate changes of Antarctica's UV climate in relation to ozone depletion beyond year-to-year variability. UV changes are related to several characteristics of ozone depletion including lowest ozone value, maximum yearly ozone hole area, and date of disappearance of the ozone hole. Absolute changes in UV appear to be largest in late November and early December, when the sun is considerably higher in the sky than in October; the month with the lowest total column ozone. At Palmer Station, located on the Antarctic Peninsula, the highest UV levels occur in late November when the ozone hole starts to disperse and ozone depleted air masses from the Center of the hole move towards lower latitudes.

O/4.9

Latitudinal gradient of UV radiation along Chile (33-53°S)

H. A. Fuenzalida, C. Lovengreen, S. Cabrera, V. Valderrama and A. Dahlback

Departamento de Geofísica, Universidad de Chile - Santiago - Santiago

The decrease in total ozone depth has developed since the beginning of the 1980's. As a consequence an increase in UV radiation is expected especially in the Southern Hemisphere. During spring and early summer the ozone hole collapse influences the southern cone of South America.

Starting in 1995 UV radiation measurements are in progress at three Chilean sites: Punta Arenas (53ºS), Valdivia (40ºS) and Santiago (33º S) with the same type of filter radiometers with temperature control. This equipment has been calibrated with a common protocol and compared with spectroradiometric measurements.Results show a latitudinal gradient of UV radiation especially during winter and autumn. In spring and early summer the gradient is also observed but in addition rapid variations due to two factors are important. First, short lived episodes of UV radiation increases correlated with Antarctic ozone hole changing shape. These events were observed in the two southern cities but no over Santiago. The duration of them goes from one day up to three days. A second important variation relates to cloud cover changes, which normally weaken the incoming flux but under some conditions can increase the UV radiation. This happens when scattered cumuliform clouds add lateral reflections to the ground based observations.

Acknowledgements: The Norwegian government donated three GUV-511 radiometer to Chile authorities. This research has been partially funded by IAI under Project "Enhanced Ultraviolet-B Radiation in Natural Ecosystems as an added Perturbation due to Ozone Depletion"

O/4.10

A multiregression model for the determination of biologically effective irradiances from ozone total column and an indicator of cloud cover

S.B. Diaz, G. Deferrari, C. Camiliòn

CONICET, CADIC - Ushuaia, T. del Fuego - Argentina

After the discovery of the " Ozone Hole" the use of instruments to perform monitoring of UV radiation became more common, although in some regions, for example: South America, they are still a few.

Nevertheless, ozone total column has been determined worldwide by satellite since late seventies and, before that, since late fifties, there were several sites were ozone measurements were performed, mainly with Dobson photometers. Also, in many locations broadband measurements of solar radiation have been carried out for a while.

In this paper we introduce a methodology that, based on a multiregression model, would allow to infer biologically effective irradiances from ozone total column and irradiances in a band independent of ozone, as a proxy for cloud cover.

The irradiances used to develop the model are from the NSF UV Radiation Monitoring Network and were provided by Biospherical Instruments Inc., while ozone total column was obtained by the instruments TOMS, and provided by NASA/GSFC.

ORAL PRESENTATIONS

FRIDAY, NOVEMBER 10, 2000
15.00 - 17.00

Session 3

Modelling and Diagnosis of Stratospheric Effects on Climate

Subsession 3-4: **Trends**

O/3-4.1

Detection and attribution of a stratospheric role in climate change: an IPCC perspective

D. Karoly

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The Intergovernmental Panel on Climate Change (IPCC) carries out regular assessments of the science evidence for climate change. In its 1995 assessment, the conclusion that "the balance of evidence suggests a discernible human influence on global climate" attracted considerable public attention and some criticism. This conclusion came from the chapter on detection of climate change and attribution of causes.

The IPCC assessment process is in full swing again, preparing for the publication of its Third Assessment Report early in 2001. In this report, there has been greater recognition of the possible roles of stratospheric processes in climate and climate change.

A brief review will be presented of evidence for stratospheric influences on climate change, based on the IPCC assessment. This will include an overview of the necessary components of a study on the detection and attribution of climate change, including observational data, estimating internal climate variability and natural and anthropogenic climate forcings and simulated responses.

The focus will be on stratospheric forcing processes that are likely to influence climate, including natural forcing variations, such as solar irradiance and stratospheric volcanic aerosols, and anthropogenic variations such as in greenhouse gases or stratospheric ozone.

Qualitative and quantitative comparisons of observed and modelled climate change will be assessed. Finally, some limitations of current modelling and observational studies will be highlighted.

O/3-4.2

A model study of ozone tends in the middle latitudes: the importance of dynamical processes

J. Pyle, A. Jrrar, P. Hadjinicolaou

Department of Chemistry, University of Cambridge - Cambridge, Cambridgeshire - UK

We have used a chemical transport model, SLIMCAT, forced with ECMWF analyses between 1979 and 1998, to study ozone trends in middle latitudes. The Cariolle ozone scheme is used in the model. This simple treatment does not include changing chlorine levels within the parameterisation but a simplified polar ozone loss due to PSCs is included. Thus, calculated trends are simply due to changes in transport, and how those changes affect the chemistry.

The model agrees well with observations of total ozone. For example, very low ozone is modelled in 1992/93, in excellent agreement with TOMS measurements. The low ozone has, at least in part, a dynamical cause. Twenty-year monthly mean anomalies of modelled and observed middle latitude ozone also agree quite well. We conclude that a significant component of the observed middle latitude ozone trend is dynamically induced. We also note that the modelled trend is greatest from the mid-1980s onwards, suggesting an important connection with the strengthening of the Arctic vortex in the same period. The correlation between the modelled trend and the Arctic oscillation index, and other dynamical indicators, will be discussed.

O/3-4.3

Radiative and dynamical contributions to the observed stratospheric temperature trend

U. Langematz, K. Krüger, S. Leder

Institut für Meteorologie, Freie Universität - Berlin - Germany

Concurrent decreases in stratospheric ozone and temperature measured since the late 1970's have led to the assumption of a direct radiative impact of the ozone losses on the thermal structure of the stratosphere. Model simulations of different complexity have confirmed this for the Antarctic lower stratosphere in spring, where the magnitude of the measured temperature decrease can be explained by the ozone observed depletion. In contrast, in Northern Hemisphere winter and spring the observed stratospheric temperature trends could not be reproduced by model simulations, which used observed ozone changes since 1980. Other reasons for the NH temperature trends might be the additional increases in greenhouse gases, such as carbon dioxide and water vapor, long-term natural variability of the atmosphere or an indirect dynamical effect of the changed ozone content. In the study presented here the relative roles of radiative and dynamical processes are studied by using model data and observations. Three multiyear simulations of the Berlin Climate Middle Atmosphere Model with different ozone and CO_2 fields representative for the years 1980 and 2000 respectively will be used, as well as offline radiation calculations using the same radiation scheme and gas distributions. The results will be compared with trends inferred from the Berlin and NCEP stratospheric analyses. In particular, the impact of the ozone and CO_2 changes on stratospheric dynamics will be studied.

O/3-4.4

Stratospheric water vapor in climate change simulations

B.A. Boville

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This paper will focus on the processes controlling the evolution of water vapor in the upper troposphere and stratosphere during climate change simulations with the NCAR Climate System Model (CSM-1). CSM-1 is a coupled ocean-atmosphere general circulation model, which has been used for simulations of the period from 1870-2100. The observed trace gas record was specified up to the 1990s and several scenarios have been used for future trace gas changes. CO_2 was assumed to be well mixed in each scenario, but only the surface concentrations of CH_4, N_2O, CFC11 and CFC12 specified. The distributions of the latter gases were internally determined, by advection and specified stratospheric loss frequencies, and the stratospheric water source from methane oxidation was included.

The changes in stratospheric water vapor in response to changes in tropical tropopause temperatures and in methane concentrations were comparable in magnitude. The relative importance of the two effects depends primarily on the methane scenario. The atmospheric component of CSM-1 is the NCAR Community Climate Model (CCM3), configured with 18 levels for tropospheric simulation. This model does not adequately resolve the upper tropical troposphere and lower stratosphere. The sensitivity of the results to the vertical resolution of the model has been examined using the 52 level middle atmosphere version of CCM3 driven by sea surface temperatures and sea ice distributions from the coupled model.

O/3-4.5

Ozone-climate interactions simulated by the French GCM ARPEGE

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CNRM, Météo-France - Toulouse - France

A 100-year simulation (period 1950-2050) has been made at METEO-FRANCE using the atmospheric climate model ARPEGE coupled with the OPA ocean model. The version of the atmospheric model used for this simulation is a tropospheric-stratospheric version, with 45 levels from the ground up to the stratopause, and it is run at T63 truncation in the spectral space. In addition to the horizontal wind, temperature and humidity, the ozone mixing ratio is also a variable of the model, with a simplified parameterisation of its photo-chemical source and sinks, following the "linearized" approach of Cariolle and Déqué (1986). A simplified representation of heterogeneous chemistry has also been introduced in the model, using ozone destruction rates computed with the CTM REPROBUS, also developed at METEO-FRANCE. The 3D ozone distribution computed by the model is then used as a input for the radiative calculation package (Fouquart-Morcrette radiation scheme), achieving a full representation of the radiation-dynamics-chemistry interactions. Greenhouse gases (CO_2, CH_4, N_2O, CFCs) concentrations are prescribed to the model according to IPCC historical data (for the period 1950 to present) and scenario (for the second half of the simulation). A control simulation is also done for the same period, in which the GHG remain constant.

In this presentation, we will show the first results of this simulation, with a special attention to climate changes in the stratosphere: changes in the ozone concentration and chemistry, and related temperature and general circulation changes, and their links with changes in the troposphere.

FOCUSED DISCUSSION SESSIONS

MONDAY, NOVEMBER 06, 2000
TUESDAY, NOVEMBER 07, 2000

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-1: Chemistry
Subsession 1-2: Transport
Subsession 1-3: Clouds and Water Vapour
Subsession 1-4: Gravity Waves
Subsession 1-5: Tropical Oscillations
Subsession 1-6: Climate Variability
Subsession 1-7: Recent Ozone Loss

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-1: Chemistry

P/1-1.1

Modelling study on stratospheric effect on the distribution and budget of tropospheric ozone, and its annual variation

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Tropospheric ozone is not only one of principal greenhouse gases, but also the most important chemical specie for the tropospheric photochemistry. Understanding of present budget of tropospheric ozone is very important for future prediction of tropospheric ozone, related gases, and climate.

The source of tropospheric ozone is partly due to stratospheric influx and partly due to photochemical production in the troposphere. This study is focused on the role of stratospheric ozone in the distribution and budget of tropospheric ozone, and tropospheric photochemistry.

In this study, a global three-dimensional photochemical model is used. The model has been developed based on CCSR/NIES atmospheric GCM. In its present configuration, the model calculates the global distribution of 28 chemical species, and includes surface emission and dry deposition, chemical and photochemical processes, and wet scavenging process. The model represents the comparable distribution of tropospheric ozone with observations, and well reproduces the seasonal cycle of tropospheric ozone in comparison with ozone soundings.

In standard (climatological) run of the model, influx from the stratosphere is estimated at 962 $Tg(O_3)$/yr, while net production (Production(O_3)-Loss(O_3)) in the troposphere is estimated at 110 $Tg(O_3)$/yr. This indicates that the direct contribution of stratospheric ozone to the budget of tropospheric ozone is significant, and some other model simulations also show similar results of ozone budget.

We also conducted simulations on tropospheric ozone change during the El Nino events of 1994 and 1997 when pronounced enhancements of total and tropospheric ozone were observed in the Asian tropical region.

Our model simulations show that these enhancements of ozone are mainly due to extensive forest fire, and partly due to enhanced transport of ozone from the stratosphere. The increase of upper tropospheric ozone in midlatitude was also observed during the El Nino events of 1994 and 1997, and our model result is generally comparable with the observation.

P/1-1.2

Climate of the stratosphere, mesosphere and lower thermosphere using interacting dynamics and chemistry in a GCM

F. Sassi, D. Kinnison, B.A. Boville, R.R. Garcia, R. Roble

NCAR/CGD, National Center for Atmospheric Research - Boulder, CO - USA

A General Circulation Model, extending from the ground to the lower thermosphere with interacting dynamics and chemistry, is used to study the climate of the middle and upper atmosphere. The model includes detailed ozone chemistry in the stratosphere and relevant ion chemistry in the mesosphere and lower thermosphere.

The solar spectrum shortward of 200nm is considered, including Lyman-alpha and extreme ultraviolet radiation; heating from auroral processes in the lower thermosphere is also included. Non-LTE processes are taken into account to treat the 15 micro-meter band of CO_2 above approximately 70 km. The climate of the stratosphere, mesosphere and lower thermosphere is studied in a multi-year simulation in which sources of relevant chemical constituents are specified at current levels. The model climate is compared to available observations and to a simulation without stratospheric ozone chemistry. We study the impact that interactive ozone chemistry has on the circulation and, particularly, on the stratospheric polar vortex. We calculate the Transformed Eulerian Mean circulation and determine its relation with the transport of passive tracers using an age of air calculation. Age of air in the polar vortex is older due to dynamical isolation at high latitudes, but that isolation is partly attenuated in wintertime by quasi-horizontal mixing due to breaking planetary waves.

Wave propagation and absorption is diagnosed using Eliassen-Palm fluxes and is examined in conjunction with the strength of the wintertime polar vortex. Inter-annual variability of the vortex, acting co-operatively with changes in the thermal structure and with ozone removal by heterogeneous processes, is a key to the climate of the lower stratosphere.

P/1-1.3

The climate impact of polar ozone chemical processes using a GCM that contains interactive dynamics and chemistry representative of the stratosphere, mesosphere, and lower thermosphere

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A new General Circulation Model (GCM) has been developed at NCAR that addresses the impact of dynamical and chemical couplings relevant to the stratosphere, mesosphere, and lower thermosphere. This model currently includes 50 chemical species and approximately 150 photochemical reactions, along with a detailed representation of heterogeneous processes on sulfate aerosols and polar stratospheric clouds (Type 1a, 1b, and 2). Polar denitrification and dehydration processes are also represented. Photolytic processes are derived shortward of 750 nm, down to the Lyman-alpha spectral region. Auroral production of key constituents in the lower thermosphere (e.g., nitrogen oxide production) that will affect ozone chemistry in the stratosphere is also represented.

An initial study has been conducted that examines the impact that polar heterogeneous processes have on the present day climate. This is examined by conducting two simulations; one including the full polar heterogeneous chemistry package, the other without. In both cases the model-derived ozone abundance is interactive with the GCM dynamics. Results from this study are the first step to quantifying the importance that levels of ozone depleting substances (i.e., chlorine and bromine radicals) have on the present and future climate states of the lower stratosphere.

P/1-1.4

Assessment of the Canadian middle atmosphere model simulation of temperature and chemical tracers using satellite observations

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A ten-year climatology calculated by CMAM (Canadian Middle Atmosphere Model) has been compared to the CIRA-86 climatology and observations obtained by the CLAES, ISAMS, MLS and HALOE instruments onboard the UARS satellite. CMAM is a modern GCM/CTM, stretching from the ground to about 95 km. 44 species solved individually.

In this poster the authors have focused on assessing the model simulation of temperature and chemical tracers.

The modelled temperature is mostly in good agreement with the observations (±10 K), except at high latitudes. During the equinox months the modelled temperature in the tropical middle mesosphere is up to 25 K colder than the CIRA-86 climatology. The UARS data set supports the CMAM temperature simulation. Because of the UARS/CIRA discrepancy the validity of the CIRA-86 mesospheric temperatures is questioned. The modelled N_2O mixing ratio is mostly within ±20 % of the observations, except for some local regions at high latitudes or high altitudes.

P/1-1.5

Coupling the arpege GCM to the stratospheric/tropospheric MOCAGE CTM: climate studies

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MOCAGE is a new global 3D Chemical-Transport Model (CTM) which includes details descriptions of both stratospheric and tropospheric chemistries. Thus for tropospheric chemistry, the model takes into account surface emissions and depositions, while stratospheric chemistry involves heterogeneous processes occurring on solid and liquid aerosols. This CTM can be coupled to the atmospheric General Circulation Model (GCM) ARPEGE, which extends up to 80 km of altitude, with a rather fine vertical and horizontal resolutions. This GCM computes winds and temperature that are provided to the CTM.

Then, the CTM computes chemistry for a large number of chemical species such as ozone and other greenhouse gases that are used for radiative calculation of the GCM. This allows to take into account the effect of atmospheric chemistry upon the meteorology of the GCM and to evaluate its impact. Thus, the impact of surface emissions and tropospheric chemistry could be taken into account in the modelled climate, with a special attention to ozone.

P/1-1.6

3-D model simulation of SF_6 with mesospheric chemistry

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Multiannual integrations with the Karlsruhe Simulation model of the Middle Atmosphere (KASIMA) have been performed, using meteorological analyses for vorticity and divergence up to 10 hPa, to analyse the influence of a simplified SF_6 mesospheric chemistry on estimation of mean age of air and to compare observed profiles of SF_6 mixing ratios in the stratosphere with model simulations. The chemical degradation scheme includes electron attachment of SF_6 and subsequent reactions of SF_6 as photodetachment and charge transfer with ozone. Several combinations of reaction rate constants and electron profiles have been tested. Good agreement with observations is found for inert SF_6 transport. However, when mesospheric loss is included in the model significant deviations are found for polar winter observations above 25 km. Chemical loss by electron attachment without reactions yielding SF_6 again is not compatible with observations. The atmospheric lifetime of SF_6 spans 400 to 10000 years, depending on the assumed loss mechanism and the value for the electron density in the stratosphere.

P/1-1.7

3-D model calculations of heterogeneous chemistry on subvisible ice clouds in the lowermost stratosphere

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Utrecht University,IMAU -Utrecht - The Netherlands

Heterogeneous chemistry on subvisible ice cloud particles are included in a global three-dimensional chemistry transport model. The model transforms seasonal mean observed subvisible cloud frequency occurrences in a three dimensional field that is updated every 6 hours. The consequences for chemical ozone loss in the lowermost stratosphere will be presented. Some uncertainties, including the location of the clouds and uptake of important trace species on the ice cloud particles and their effect on chemical ozone loss will be discussed

P/1-1.8

A new source of NOx, potential role in basic atmospheric chemistry and climate change

S.S. Prasad

Creative Research Enterprises - Pleasanton, California - USA

The talk will discuss a new stratospheric chemical processes related with highly excited transient species (internal energy around 6 eV and lifetime of the order of 10 ps). This process could possibly have an important affect on our understanding of the climate change and may provide a reprieve from the current under-predictions of the NOx/NOy ratios by atmospheric models. Empirical theoretical considerations suggested and laboratory experiments have verified that the excited $O_2(B)$ reacting with N_2 produces NO efficiently *via* the Woodward-Hoffman forbidden reaction $O_2(B) + N_2 \rightarrow NO + NO$. Atmospheric modelling suggests this reaction has the potential to produce NO in the stratosphere at a rate comparable to or exceeding the rate of production from the classical $N_2O + O(1D) \rightarrow NO + NO$ reaction. It is thus possible that the missing element in our current understanding of the gas-phase or photolytic processes alluded to by various researchers might be this new NOx source. For this reason alone this new source is of importance in understanding climate change. More directly, the new NOx source is likely to add a new facet to understanding of the solar cycle modulation of the stratospheric O_3. The observed positive correlation of the stratospheric O_3 in the 20 to 60 km region is thought to be a result of the enhance O production due to enhanced radiation in the SR bands and Herzberg continuum. However, now we have to deal with the concurrent production of NOx resulting from the new reaction over and above the 'classical" change in NOx production due to change in O_3. This is an important development, in the context of SPARC, since the impact of solar variability on climate depends on the modulation of the stratospheric O_3.

P/1-1.9

A new heterogeneous sink of nitrous oxide (N_2O) lends further support to N_2O formation from excited ozone

S.S. Prasad

Creative Research Enterprises - Pleasanton, California - USA

Based on a laboratory experiment, the paper will explain that N_2O is efficiently destroyed on quartz surfaces exposed simultaneously to UV radiation and O_3. This new heterogeneous sink of N_2O lends an important additional support to the formation of N_2O from highly excited O_3. It does this by explaining why the formation of N_2O from highly excited O_3 is seen in one experiment (Zipf and Prasad, Geophys. Res. Lett., 25, 4333, 1998) but not in other experiments (Marie & Burrows, J. Photochem. Photobio. A: Chem, 66, 291, 1992). This development is important since the production of N_2O from excited O_3 occurs mostly in the troposphere, and with a magnitude that may be significant in the source-sink budget.

P/1-1.10

Theoretical analysis of the relative reactivity of chloroethenes with O(3P), CL(2P), BR(2P) and OH, NO_3 radicals

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Atom and free radical addition reactions to alkenes have been widely studied for their theoretical and experimental interest in the participation of these compounds in combustion processes and atmospheric chemistry [1]. The reactivity of alkyl ethylenes series correlate strongly with the ionisation potential (I.P.) [2]. We analysed the reactivity of the chloroethenes series with different electrophiles of tropospheric and stratospheric interest. The reactions studied were CH2=CHCl; CH2=CCl2; cis-CHCl=CHCl; trans-CHCl=CHCl; CHCl=CCl2 and CCl2=CCl2 with O(3P), Cl(2P), Br(2P) atoms and with OH and NO_3 radicals.

The geometry of reactants, the HOMO energy and the transition state were calculated using the semi-empirical methods AM1 and PM3 from the MOPAC 7.0 program and ab-initio calculations at the HF and B3LYP levels of theory with 6-31G** basis set, using the Gaussian-94 suite of programs. Also, the I.P. were obtained at the same level of calculation and it was observed that the PM3 method agreed better with the experimental values. These last calculations were considered to compare the frontier orbital energies. The rate constants were measured in our laboratory and taken from the literature.

It is possible to observe that as the chlorine atom substitution increases in the ethylene, the overall rate constant decreases and the I.P. also decreases. This applies in general, for all the electrophiles studied. This trend however is opposite to that observed with the non-chlorinated alkenes [3]. The energy and the carbon-carbon p-bonding form of the HOMO change by adding chlorine atoms as substituents to the carbon-carbon framework of the alkenes. For the reactions here studied the complete interaction HOMO-SOMO was considered and a good correlation with the experimental values was obtained. The activation energies for the addition reactions of different electrophiles to the chloroethenes were also calculated.

[1] R. Wayne, Chemistry of Atmospheres, 2nd Ed., OUP, 1991.
[2] R.J. Cvetanovic, Advances in Photochemistry, 1963, Vol. I, 115.
[3] J.P.D. Abbatt and J.G. Anderson, J. Phys. Chem. 1991, 95, 2382.

P/1-1.11

Photochemistry of fluorinated compounds. Kinetic of the reaction between CF3CF2 and FCO radicals

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Due to the replacement of CFCs by the less harmful HFCs, a huge body of information about the chemistry of these fluorinated compounds has been published and is currently of paramount importance. The radicals produced by these molecules involve mainly the families known as "CF_3Ox" and "FCOx". The FCO radical is thus involved in many degradation reactions.

CF_3 and FCO radicals are obtained when CF_3COF is photolyzed. Both radicals react to give C_2F_6, CO, CF_2O and also regenerate the precursor molecule thus giving a quantum yield of CF_3COF disappearance lower than unity (=0.4). $CF_3CF_2C(O)F$ is a suitable source to generate the title radicals allowing to determine whether a longer chain can modify either the photolysis mechanism or the rate constant with respect to the CF_3COF. We performed the photolysis of $CF_3CF_2C(O)F$ either pure or in presence of c-C_6H_{12} and $(FCO)_2$ (oxalyl fluoride), following the concentration of the different species by FTIR spectroscopy. In the photolysis of the pure precursor, the products formed were C_4F_{10}, CO and CF_2O in accordance with the case of $CF_3C(O)F$.

When enough ciclohexane is added, the radicals formed in the initial step (C_2F_5 and FCO) are trapped and the recombination reactions between these species are suppressed. It is observed that the rate of reactant consumption is faster than without c-C_6H_{12}. This suggests that in the photolysis of pure CF_3CF_2COF, the reaction between C_2F_5 and FCO radicals takes place. This was corroborated by the photolysis of $CF_3CF_2C(O)F$ in the presence of $(FCO)_2$ (i.e. in presence of excess of FCO radicals). Here again, we observed the variation in the rate of disappearance of CF_3CF_2COF. The rate constant of the reaction C_2F_5 + FCO (CF_3CF_2COF) was obtained through a simulation using both, our experimental data and bibliography data available. The value found is similar, within experimental error, to the rate constant obtained for CF_3 and FCO radicals; therefore the length of the chain does not affect the mechanism.

P/1-1.12

Investigation of observed fluctuations in column OClO over Greenland during the 1994-95 and 1995-96 winters

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OClO and NO_2 vertical column abundances have been derived from ground-based measurements performed in the Arctic (Kangerlussuaq, Greenland, at 67.0°N, 51.0°W). These data illustrate the seasonal timing of autumnal chlorine activation and the springtime disappearance of active chlorine in the Northern Hemisphere during the winters of 1994-95 and 1995-96. The availability of sunlight and the activation of chlorine by heterogeneous processes are key factors in the catalytic cycles of stratospheric ozone depletion. Using a two-dimensional stratospheric chemical/dynamical Eulerian model, the role of several factors in determining the seasonal cycles of column OClO have been probed. This study indicates that observed cold temperatures and reactions on liquid sulfate aerosols play a key role in producing the timing of the observed OClO seasonal cycle in the Arctic. While the general characteristics of the seasonal cycle observations were reasonably well reproduced using the two-dimensional model, the observed short-term fluctuations were not. Details of these local fluctuations are examined using a recently developed three-dimensional model (CLaMS: Chemical Langrangian Model of the Stratosphere) from the Institute for Stratospheric Chemistry (ICG-1), Forschungszentrum Juelich.

P/1-1.13

Meteorid fall into ocean: impact on stratospheric ozone

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The fall of a large celestial body into the ocean causes a large number of compounds (for example, HCl, Cl, Br, Na, H_2O, OH, and NO) that destroy ozone molecules directly or indirectly to be ejected to stratospheric altitudes. The bleaching of the atmosphere in the UV range as a result of such ozone destruction creates negative feedback that restores the ozone. The characteristic time for such restoration in the stratosphere decreases sharply with altitude, ranging from several months at 30 km to several days at 20 km. Finally, we discuss the possible impact of this new effect on stratospheric ozone evolution.

P/1-1.14

Evaluation of upper-tropospheric and lower-stratospheric ozone profiles from a global ozone data assimilation system

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The Data Assimilation Office at NASA's Goddard Space Flight Center provides global 3-D ozone fields at six-hour time intervals. Data from TOMS and SBUV are used in the assimilation.

TOMS provide total column information and SBUV provides profile information, primarily above the ozone peak. Information below the ozone peak comes from the model. This paper will explore the realism of the assimilated ozone in the upper troposphere and lower stratosphere through validation with ozonesondes, HALOE, and POAM observations. This work is in preparation of using the assimilated ozone in the radiative calculation for the meteorological assimilation as well as in the derivation of tropospheric ozone.

P/1-1.15

High horizontal resolution ozone assimilation

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Assimilation of stratospheric chemistry measurements will be one of the main issues of the stratospheric studies during next years.

Current CTM's used for data assimilation, for which the horizontal scale is greater than the typical scale of cross isentrope transport, can be biased by an equivalent diffusivity greater than four orders of magnitude than the real one.

Recent results have shown that concentrations of chemical species relevant to stratospheric ozone balance can be greatly dependent on the resolution and then the values of the effective diffusivity used for the simulations.

We will present preliminary results of a high resolution 2D model of the atmosphere in order to perform passive assimilation of ozone data. It will be extremely useful in the quantification of the influence of small scale structures on the ozone depletion at the edge of the polar vortex and on the reduction of ozone at middle latitudes. Moreover the description of filamentary structures and small scale horizontal ozone variations would be greatly improved. The model is based on the transport scheme MIMOSA that is able to describe atmospheric horizontal scales with a resolution of 20 km.

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-2: Transport

P/1-2.1

Transport of chemically activated air to middle latitudes in the Northern Hemisphere stratosphere

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Transport of air from the Northern Hemisphere polar vortex could contribute to the ozone decline in the middle latitudes, observed since last 20 years. Polar Stratospheric Clouds lidar measurements in ALOMAR (69°N, 16°E) show the evidence for the presence of PSC outside the polar vortex in the coldest period of the winter. ECMWF analysis also indicates that temperatures, low enough for PSC formation, can be reached outside the vortex. The main geographical area subject to this phenomena is the northern Europe. So, where activated air will be transported? And how long chlorine is in activated form? We have chosen a high resolution dynamical approach to quantify the area covered by chlorine in the Northern Hemisphere and to evaluate the potential impact on the middle latitude chemistry. MIMOSA, high resolution transport model, has been adapted for advection of active tracers simulating the behaviour of activated radicals as ClO, BrO and OH. This approach allows us to analyse the activation outside the vortex and to estimate the timelife of the tracer inside the filaments. This has been done for three winters, 1995 to 1997 and will be extended for the SPARC workshop to the last 20 years.

The main features of the tropospheric circulation allowing the formation of PSC outside the polar vortex are also investigated. The presence of tropospheric geopotential ridge - trough structure above America is correlated with the polar vortex westward displacement. The Arctic stratosphere above Europe is outside the vortex and high pressure area at ground levels, related to the distortion of the polar vortex, lifts and cools air masses above Iceland. This tropospheric pattern is well parameterised by the NAO negative index.

P/1-2.2

Estimation of the transport and mixing of chemical constituents in the lower stratosphere using the high resolution transport model MIMOSA

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A negative ozone trend has been observed in the lower stratosphere during the last 20 years, not only in polar regions where heterogeneous chemistry in polar stratospheric clouds is active, but also at middle latitudes. The relative contribution to the mid-latitude trend of in-situ chemical destruction and transport phenomena is still not clear. In order to better quantify the meridional transport and the mixing of chemical species between different latitude bands, a global version of the MIMOSA high resolution model of the advection of potential vorticity on isentropic surfaces has been used. It allows to study the filamentation occurring at the vortex edge and at the subtropical barrier. The concept of effective diffusivity is applied to the potential vorticity fields generated by the model in order to quantify the effective meridional transport across dynamical barriers. A multi-year run of the model is made to estimate the year to year variability of the permeability of both Arctic and Antarctic vortices. The degree of isolation of the tropical reservoir as a function of the QBO phase will be looked out.

P/1-2.3

Effect of the Arctic erosion vortex on the transport of ozone loss toward the mid-latitudes

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The coupled MIMOSA-REPROBUS model is developed in order to quantify the effect of Arctic polar vortex erosion on the transport of ozone loss toward the mid-latitudes. This coupled model uses the high-resolution advection of potential vorticity from the MIMOSA transport model and the chemical scheme of the REPROBUS CTM. The interest of this coupled model is the high resolution of the dynamic scheme allowing the identification of vortex erosion processes. The coupled model allows thus to quantify the role of polar filaments on the transport of ozone loss toward the mid-latitude.

The comparison between the integrated ozone loss provided by the coupled model and by the REPROBUS CTM for the winter 2000 at 475K reveals that the high values of ozone loss follow well the filaments simulated by the coupled model, which are not reproduced in the REPROBUS simulation.

The potential vorticity of the ECMWF analysis is used to calculate the potential vorticity as a function of equivalent latitude. This relation is used for both models. The integrated ozone loss as a function of this equivalent latitude shows that the high values of ozone loss are extended toward the mid-latitude in the case of the coupled model. To quantify the transport of integrated ozone loss toward the mid-latitude from January to the end of the winter, the averaged percentage of integrated ozone loss is calculated during the winter for both models.

The high values of ozone loss are concentred in both models inside the vortex but in addition, the coupled model reveals at the end of the winter, an extrusion of high values of ozone loss up to the 30 equivalent latitude.

P/1-2.4

The sensitivity of streamers on planetary wave activity in the Berlin CMAM

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Stratospheric processes and their role in present and future climate modelling in particular to simulate the development of the future ozone layer are an essential aspect in climate change.

Besides the fundamental chemical processes, transport processes are a limiting factor determining the global distribution of atmospheric trace gases, such as ozone. The distribution of ozone at midlatitudes, influenced by subtropical tongues/streamers or transport through a leaking polar vortex edge, is still an open question.

In this sense, the occurrence of streamers through the transport barriers is analysed in detail with the Berlin Climate Middle Atmosphere Model, using a semi-Lagrangian transport scheme. Particular interest will be put on the winter and spring seasons, when planetary wave activity plays the dominant role on stratospheric dynamics. The sensitivity of both types of streamer events on planetary wave activity will be investigated with multiyear runs.

P/1-2.5

Polar stratospheric clouds and mesoscale dynamics

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Polar stratospheric clouds (PSC) provide particle surface for heterogeneous chemistry leading to chlorine activation and thus to ozone destruction in the polar stratosphere in spring. While the Antarctic, ozone hole ‰ is observed every year, the variability of the northern polar vortex and the resulting temperature distribution clearly influence the formation potential of PSC in the Northern Hemisphere.

Quite often, PSC are observed by different LIDAR systems while the synoptic scale temperatures are too high for particle formation. Those discrepancies can be explained by trace gas and temperature fluctuations due to mesoscale stratospheric dynamics. The involved processes may either be adiabatic cooling by mountain gravity waves which are induced at the Scandinavian mountain ridge and propagate upwards into the stratosphere, or differential advection at the polar vortex edge. In the latter case, Rossby wave breaking leads to a filamentary structure at the vortex edge, resulting in a filamentary distribution of trace gases like HNO_3 and H_2O. Thin filaments of enhanced water vapor mixing ratio originating from the vortex centre may lead to locally confined particle formation at the vortex edge by raising the critical temperature for PSC formation (TNAT).

Whether this increase of TNAT leads to a significant change in PSC occurrence at the vortex edge is analysed on the basis of LIDAR measurements at Ny-Ålesund, Svalbard (78°N,12°E), and Sodankylä, Finland (67°N, 26°E). In addition, the Contour Advection method is used to describe the filamentary transport between the mid-latitudes and the polar regions.

By combining experimental LIDAR data with stratospheric transport modelling, this study is an approach to merge microphysical theory with stratospheric dynamics.

P/1-2.6

Measurement of O_3, HNO_3, N_2O AND ClO in the southern polar stratosphere by far-infrared limb-sounding from high altitude aircraft

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Geographic variability of vertical VMR profiles of various compounds involved in stratospheric Ozone chemistry are derived from data acquired by the SAFIRE/A (Spectroscopy of the Atmosphere by using Far Infrared Emission/Airborne) instrument.

SAFIRE/A is a limb sounding far-infrared Fourier transform spectrometer that operated on board of the M55-Geophysica high altitude aircraft during the APE-GAIA campaign (Airborne Polar Experiment - Geophysica Aircraft In Antarctica, Ushuaia-Argentina, 16th September-15th October 1999).

The observed species include O_3, HNO_3, N_2O, ClO. The measurements have been performed crossing the antarctic polar vortex boundary. The VMR profiles, acquired in a region extending from 57 to 68 degrees of latitude, cover the low stratosphere (10-20 km) with a vertical resolution of about 1.5 km and an horizontal resolution of 1.5 degrees of latitude.

Chemical processes involving Ozone inside the polar vortex are evidenced in the presented data by correlation of the geographic and vertical variability shown in the VMR maps of Ozone and chemically active species like HNO_3 and ClO.

P/1-2.7

Observations of the polar stratosphere from ALOMAR (69N)

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During December 1999 an intensive measurement campaign was undertaken at the Arctic Lidar Observatory for Middle Atmosphere Research (ALOMAR, 69N), Norway.

Stratospheric measurements of temperature were obtained using the Rayleigh-Mie-Raman (RMR) lidar and associated horizontal wind measurements were obtained using the Doppler Wind and Temperature System (DWTS). Stratospheric ozone profiles were measured using an ozone differential absorption lidar (DIAL).

The unique combination of stratospheric lidar instrumentation available at ALOMAR, daytime observational capability, and excellent height resolution has led to comprehensive measurements of the polar stratosphere.

We will focus on the analysis and interpretation of stratospheric wind data during this period. Understanding of the dynamical situation, along with simultaneous DIAL ozone profiles, will then be used to investigate the transport of ozone in the vicinity of the arctic vortex.

P/1-2.8

Simultaneous laminae in water vapour and aerosols profiles during SESAME experiment

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A sounding launched from Kiruna during SESAME experiment show simultaneous decrease of water vapor and aerosols at two different stratospheric levels. We show that at the highest level (410K0) the air mass was trapped in the vortex edgeand processed some days before the measurement by a PSC causing the aerosol and water vapor decreases. The lowest air mass (364K) was found to be in the sub-vortex region. Although the back trajectories are more subject to caution, comparison of some characteristics at the measurement point and at middle latitude sites explain the decreases of aerosols and water vapor by the origin of the air mass.

P/1-2.09

Denitrification and mixing in the 1994/1995 Arctic vortex - MIPAS-B observations and modelling

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During the SESAME winter 1994/95 two balloon flights with the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS-B) were carried out on February 11 and on March 21/22 inside the Arctic vortex. The profile of total reactive nitrogen (NOy) and its correlation with the simultaneously measured N_2O indicate a strong vertical redistribution of NOy in February [1]. Denitrification is recognised as a prerequisite for strong ozone depletion. Though denitrification is a stratospheric phenomenon it is inherently linked to tropospheric processes through its pronounced temperature dependence. 3-D chemical transport models have not been able to reproduce the observed redistribution so far, but recently a quasi 1-D microphysical model was able to simulate the denitrification by suggesting that the sedimentation is predominantly caused by nitric acid trihydrate particles with small number densities which nucleate on ice particles [2]. The analysis of the balloon data recorded some 5 weeks later (March 21/22) had been delayed by time-consuming pre-processing made necessary due to reduced performance of the pointing system during that flight. These data have now been used along with the data of the February flight to achieve further insight into the issue of denitrification and mixing in the 1994/1995 Arctic winter.

Traditionally, the NOy/N_2O ratio has been used to diagnose denitrification. However, several recent studies have indicated that this method could overestimate denitrification as long as mixing processes are not considered (see e.g. [3] -[5]). On the basis of observed NOy/N_2O and CH_4/N_2O correlations as well as domain filling trajectory calculations we evaluate the uncertainty of the denitrification signal derived from the February flight, and investigate to what extent the denitrification was preserved 5 weeks later in the spring vortex. These results are compared to outputs of the 1-D sedimentation model that intrinsically neglects mixing and to calculations of the 3-D CTM KASIMA [6]. This work corroborates that there was deep, enduring denitrification in the 1994/95 Arctic winter.

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P/1-2.10

Ozone temperature and wind profile measurements at Marambio, Antarctica during APE-GAIA campaign in September-October 1999

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13 ozone soundings, 42 pTU-soundings and 25 total ozone measurements were made at Marambio (64°23' S, 56°72' W) during the 30 campaign days. Ozone soundings were timed to match the overpass of Geophysica, a high altitude atmospheric measurement laboratory, so that the same air mass was measured. Strong lamination can be seen in the ozone profiles from Marambio. The objective of this study is to investigate the origin and fate of these laminae using trace gas measurements from Geophysica and trajectory analysis in conjunction with an analysis of vortex situation. Comparison of ozone profile measurements with 1990-1998 climatology will be presented and discussed.

P/1-2.11

Meridional transport of minor species at the time of break-up of polar vortex observed by ILAS

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The Improved Limb Atmospheric Spectrometer (ILAS) onboard the ADEOS satellite made measurements of O_3, HNO_3, NO_2, N_2O, CH_4, H_2O, and aerosol extinction in both Arctic and Antarctic polar stratosphere from November 1996 to June 1997. We focused on time periods when polar vortices break-up in both hemispheres, i.e., November to December in 1996 for the Antarctic, and April to May in 1997 for the Arctic. We sorted all the measurements into the equivalent-latitude/potential-temperature co-ordinates. During the course of break-up of polar vortices, it was found that air, which contains higher mixing ratios of minor species (lower mixing ratio for H_2O), penetrates into the polar vortex through the polar vortex boundaries. Moreover, the altitudes where main bodies of minor species penetrate in are found to depend on species and hemispheres. For example, average altitudes for penetrations are found to be about 600K for HNO_3, 700K for aerosols, 800-900K for N_2O, CH_4, and H_2O, and 1000K for O_3 and NO_2, respectively. Also penetration altitudes at the times of break-up of polar vortices are found to be higher in the Southern Hemisphere than the Northern Hemisphere. Causes of inter-hemispheric differences in comparison with planetary wave activities and/or wind fields are discussed in the presentation.

P/1-2.12

Dehydration inside of the Arctic polar vortex observed by ILAS

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The Improved Limb Atmospheric Spectrometer (ILAS) onboard the Advanced Earth Observing Satellite (ADEOS) made measurements of a suite of trace gas species in the polar stratosphere from November 1996 to June 1997, which covers a NH winter season during which the Arctic polar stratosphere was extraordinarily cold. Dehydration of the Arctic polar stratosphere was identified using tracer-tracer correlations, and cases of significant dehydration were found inside the Arctic polar vortex for January 1997. These dehydration events were observed between 450 and 600 K potential temperature (approximately 25 km in altitude) and were well correlated with a region of low temperature (below 190 K). Using the correlation of H_2O and N_2O, we estimate that the water vapor value decreased as much as ~ 3 ppmv during the dehydration events. Potential vorticity and N_2O values for these measurements confirm that they were inside of the polar vortex. We have also found that the corresponding aerosol extinction values were elevated during the dehydration events. Comparisons are made with the dehydration events in the Antarctic polar region, also observed by ILAS, in June 1997. The general relationships between water vapor and PV, temperature, N_2O and the aerosol extinction during dehydration are similar for the NH and SH observations.

P/1-2.13

High-latitude variations of the stratospheric tracers in the Southern Hemisphere spring

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Temporal variations of methane, nitrous oxide, water vapor and ozone in the stratosphere was investigated based on observations by the Improved Limb Atmospheric Spectrometer aboard the Advanced Earth Observing Satellite. The zonal mean mixing ratio of methane and nitrous oxide at high latitudes in the Southern Hemisphere increased rapidly during November 1996. During the period the circulation pattern changed from the winter polar vortex to the summer pattern and was influenced by the periodic fluctuation of the planetary wave activities. The altitude on which the polar vortex broke down gradually changed from the upper stratosphere to the lower stratosphere. The vertical gradient of the zonal mean mixing ratio of methane showed positive value at the level of the rapid temporal increase of methane. The level of the positive vertical gradient is closely associated with that of the polar vortex breakdown. The variation of the methane mixing ratio was investigated with respect to the boundary of the polar vortex. The mixing ratios inside and outside of the polar vortex evolved with distinctive patterns with time. The evolution of the polar vortex and the shape of it have significant influences on the zonal mean mixing ratio of methane. The zonal mean methane mixing ratio periodically increased and decreased following the fluctuation of the planetary wave activities. It turned out that increase in the zonal mean mixing ratio of methane is associated with amplification of the planetary wave number two pattern, and decrease in methane is associated with amplification of the planetary wave number one.

P/1-2.14

Chaotic mixing and transport barrier in an idealised stratospheric polar vortex

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A high-resolution two-dimensional spherical model is used to investigate the fundamental process of large-scale horizontal mixing inside the circumpolar vortex in the winter stratosphere. Concept and analysis method of the chaotic mixing, which were first introduced to geophysical flow by Pierrehumbert (1991) with a simple kinematical model, are applied to some quasi-periodic and nonperiodic solutions obtained in the dynamical model.

Ishioka and Yoden (1995) obtained quasi-periodic and nonperiodic solutions in an idealised stratospheric model of two-dimensional non-divergent fluid with zonally symmetric zonal-flow forcing and Newtonian-type damping. The forced flow is a barotropically unstable polar-night jet and the obtained solutions mimic the eastward travelling planetary waves named "4-day wave" in the Southern Hemisphere upper stratosphere. Some of the typical solutions are analysed in details. Dispersion of lots of particles placed in a limited area in the chaotic region shows the characteristics of two-dimensionalization from large scales; fractal dimension (correlation dimension) is estimated to distinguish the time dependence of the mixing process in and out of the vortex quantitatively. Stagnation points in the stream function field in the co-moving frame with the dominant wave play an important role in the chaotic mixing. Finite-time Lyapunov stability analysis is also done to confirm the role quantitatively.

Through these analyses a new type of transport barrier was found inside the polar vortex. Some imperfectly isolated areas exit even in nonperiodic solutions. Poincare sections for several particles can be used to identify the transport barrier and the regions of chaotic mixing in quasi-periodic solutions. In order to investigate the applicability of the new type of transport barrier to the real atmosphere, dispersion of lots of particles placed in an limited area is computed with a UKMO analysed wind dataset on an isentropic surface for a period when the 4-day wave has large a amplitude.

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-3: Clouds and Water Vapour

P/1-3.1

Inter-annual and longer-timescale variations in transport and mixing in the upper troposphere and lower stratosphere

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A quantitative characterisation of the isentropic transport and mixing structure of the troposphere and stratosphere is presented. This has been produced by calculating the equivalent length diagnostic from tracer fields advected by analysed ECMWF winds using a chemical transport model. The equivalent length characterises the geometric structure of a tracer, which is most complex where the mixing is strongest. Equivalent length calculated both from an artificial tracer and from simulated N_2O reveals the vertical and latitudinal structure, and inter-hemispheric differences, of stratospheric barriers to transport at the vortex edge, the stratospheric tropical reservoir, as well as the barrier at the tropopause.

A 20-year calculation, using analysed winds from 1979 to present, has enabled inter-annual variability of the isentropic transport and mixing structure to be identified. This has highlighted the influence of the quasi-biennial oscillation (QBO) on mixing and transport in the stratospheric tropics and subtropics. When the QBO winds are easterly, mixing is inhibited in the tropics throughout the broad region occupied by the easterlies, whilst when the QBO winds are westerly, mixing is strongly inhibited within the narrow region occupied by the westerlies themselves, but is enhanced in the subtropics. Examination of zonal-mean quasi-geostrophic potential vorticity gradients and horizontal EP fluxes (broken down into contributions from different zonal wave numbers) suggests that, in the ECMWF analyses, barotropic shear instability of the westerly jet, as well as propagation of planetary waves from the extratropics, drives the subtropical mixing seen in the westerly phase. An influence of El Nino on the transport and mixing in the upper troposphere is noted, with weaker mixing associated with the monsoons in the northern hemisphere subtropics in El Nino years. The 20-year integration has also allowed examination of inter-annual variability and long-term trends in the strength of the barrier at the edge of the vortex.

P/1-3.2

Ozone and humidity distribution inside the polar jet over the North Atlantic obtained from the MOZAIC program identification of a local circulation across the tropopause

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Atmospheric dynamics in the region of the polar jet stream play a major role in stratospheric-tropospheric-exchange (STE). Ozone and water vapor measurements obtained from the MOZAIC (Measurement of Ozone and Water Vapor by Airbus In Service Aircraft) project were used to investigate STE in the region of the polar jet over the North Atlantic in a statistical study.

From a one-year record of more than 1000 transatlantic MOZAIC-flights cross-sectional distributions of ozone and relative humidity inside the polar jet are composed and analysed. A synoptical approach is employed, using daily weather analysis maps of the European Centre for Medium Range Weather Forecast, to develop a co-ordinate transformation method, which enables to position MOZAIC water vapor and ozone data relative to the jet-axis.

Inside the jet the cross sections of ozone and humidity show a local circulation across the tropopause with an indication of a net downward flux which is most pronounced in spring and has a minimum in autumn. The paper will discuss the observed circulation pattern inside the polar jet and its implications for stratospheric tropospheric exchange.

P/1-3.3

Ozone-carbon monoxide correlation in the tropopause region from caribic flights 1997-2000

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Regular flights using a passenger aircraft (Boeing 767 ER) equipped with an automated measurement container (project CARIBIC) have taken place since November 1997. (Measured are aerosols, ozone fast and standard, carbon monoxide and a range of trace gases and their isotopic composition). For a total of over 25 return flights from Germany to the Maldives and Colombo the ozone-carbon monoxide correlations have now been subjected to a detailed analysis, and the some important aspects will be discussed. The correlations rarely reflect a single process, like the formation of ozone in a biomass plume, and at 10 to 12 km a range of processes have to be taken into account. A strong seasonal cycle in the flux of ozone from the stratosphere near the subtropical jetstream is observed. The downward transport for May was estimated to be a factor of at least 3 higher compared to November. This transport caused an almost sinusoidal seasonal cycle of the ozone tropopause; it ranged from 75 nmole/mole in Mid November to 150 nmole/mole in mid May. Lowest carbon monoxide values observed for the lowermost stratosphere at mid latitudes are close to 40 nmole/mole.

P/1-3.4

A climatology of laminae in ozone sonde data in the upper troposphere and lower stratosphere at La Réunion Island

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A climatology of laminae induced by gravity waves and horizontal large-scale advection is investigated in the upper troposphere and the lower stratosphere at La Reunion island (20.8 S, 55.3 E) using ECC ozonesonde data and wavelet based methods.

The nature and the frequency of occurrence of these structures are analysed to provide some quantitative information about the role of such structures in vertical and horizontal transport processes and in mixing on both sides of the tropopause and the subtropical barrier. In fact dominant vertical short-scale structures with 1-5 km vertical wavelengths are observed in the troposphere and the stratosphere during Austral summer and winter. The coefficient R(z), which links the ozone and temperature perturbations produced by gravity waves allows us to distinguish signatures of gravity waves from those of horizontal large-scale advection up to about 21-25 km altitude. Laminae induced by gravity waves are mainly detected in the upper troposphere and the lower stratosphere in summer and from the middle troposphere up to the lower stratosphere in winter with dominant vertical wavelengths of about 2.4 km and 2.4-4.8 km respectively.

The frequency of occurrence shows that such structures are 1.3 times more numerous during winter. Those induced by the horizontal advection are mostly observed under the tropopause. They reveal to be more important and detected from 5 km below the tropopause to the lower stratosphere during winter.

Finally this climatology suggests some possible transport of air masses from both sides of the subtropical barrier, whose the origin depends on the season, and an important role of gravity waves in mixing more particularly during winter for which observed laminae induced by both of gravity waves and the horizontal advection are more frequent.

P/1-3.5

An origin of the laminated structure of ozone in the lower stratosphere

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An intensive observation of ozone, temperature, humidity and wind was conducted using ozonesondes, radiosondes and the MU (Middle and Upper atmosphere) radar at Shigaraki, Japan (35N,136E) between 16th and 24th April, 1998. While a synoptic scale disturbance in the troposphere passed over Shigaraki, a 2-4km thickness layered structure of ozone with large amplitude (peak-to-peak amplitude was about 100nb in the partial pressure), was observed in the lower stratosphere (17-22km) between 18th and 21st April, and propagated upwardly with time, whose thickness was about 2-4km. Although the wind data measured by the MU radar indicated that some inertial gravity waves were found at the same altitude region during the observation, their amplitude and period could not induce that layered structure. It suggested that this structure was not caused by the air oscillation at the observation point, but that it was probably due to the horizontal advection of ozone rich/air parcels.

In order to investigate the origin of the observed ozone rich/poor air parcels over Shigaraki, I carried out isentropic backward trajectory calculations. It showed that those ozone rich/poor air parcels were advected from the high/low latitude respectively. The analyses using the GANAL meteorological data suggested that the zonal wind shear and the meridional wind disturbance propagated from the troposphere differently advected the lower-latitude (ozone-poor) air at 21-22km altitude and higher latitude (ozone-rich) air at 18-19km altitude. We show that this differential advection often formed similar O_3 layered structure, and suggested this process may play a part in the mixing of lower and higher latitude air in the lower stratosphere.

P/1-3.6

Stratosphere troposphere exchange: Indian MST radar observations

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MST radar is a powerful tool to probe the atmosphere on near continuous basis. Direct measurement of vertical velocity is its unique capability, which can be used to monitor the vertical velocity during different meteorological conditions, to study the associated vertical transport. The capability of MST radar to detect atmospheric stable layers can be used to monitor tropopause. Analysis of vertical velocity in conjunction with the observed stable layer structures in the tropopause region may provide valuable information on STE. The VHF radar at Gadanki (13.45 N, 79.18 E), a tropical station in India, has been used to monitor stable layer structures including tropical tropopause and vertical velocity during different meteorological conditions. Stable layer structures associated with the tropical tropopause, are observed to be very prominent. These structures are noted to be disappear/weaken during passage of tropical convection. Such weakening of stable layer structures is associated with the enhanced vertical velocity across the tropical tropopause. Time series of vertical velocity do show oscillatory nature with significant mass-flux through the tropopause providing an evidence for STE at this tropical station. Several diurnal cycles of observations are analysed over a period of 4 years. Vertical wind variability during different meteorological condition is also presented. The observed vertical velocities are then used to compute mass-flux in the upper troposphere.

P/1-3.7

Study on LS/UT processes in mid-latitude East Asia

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For understanding the lower stratosphere/upper troposphere (LS/UT) exchange processes and their impact on regional and global climate/environment in the region of mid-latitude east Asia, a research project called "LS/UT Processes in Mid-Latitude east Asia"; was initiated in Lab. for middle Atmosphere and Global Environmental Observation (LAGEO). This project consists of both field campaign and numerical study. For field campaign, observations of LS/UT region are made with VHF/ST radar, ozone sounding, lidar, MW radar as well as other optical instruments, to reveal the dynamics and physical structure and ozone. In numerical study, analysis of temporal and spatial structure of tropopause in mid-latitude East Asia is made for its seasonal variation and long-term variability. Also the function of strong convective activities in mid-latitude summer to regional and global LS/UT exchange is paid attention by using numerical simulation and analysis of observation. The first period of field campaign has been conducted in the middle of April 2000 in Beijing area. The second period is planned in August-September 2000. In this paper, we will present some of research results.

P/1-3.8

Isentropic exchanges through the southern dynamical barrier of the tropical stratosphere

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Quasi-horizontal transport out of the tropics occurs with Rossby wave breaking events in which filaments of tropical air are stirred isentropically into middle latitudes where they are further mixed. Observations of a "tropical stratospheric reservoir" of aerosols from volcanic eruptions, of the potential vorticity fields and of different other chemical tracers, show the evidence of a subtropical eddy transport barrier isolating the tropical air mass from the surf zone and acting against transport along isentrope.

This work presents a preliminary study of the isentropic transport through the southern dynamical barrier of the tropical stratosphere, based on observations from Reunion Island (20.8S; 55.5E) NDSC site. This site is one of the rare southern tropical sites where regular and long term atmospheric measurements have been ensured.

A climatological survey of the subtropical edge of the tropical reservoir in the Indian Ocean area is first presented. This climatology is based on seven years of potential vorticity fields from the ECMWF assimilation system. Calculations have been performed on five different isentropic surfaces 400, 450, 500, 600, and 700 K. Reunion Island is, according to seasons, under the influence of equatorial or middle latitudes air masses.

The location of the tropical reservoir evidenced by the gradients of potential vorticity on isentropic surfaces display a seasonal variation with strong gradients at its southern edge in winter. This seasonal influence of the dynamical barrier increases with altitude.

Case studies of vertical profiles of ozone anomalies and PV contour of advection model analysis, further document the displacement of air masses *via* quasi-horizontal transport. Ozone anomaly profiles have been obtained from ECC radiosoundings performed at Reunion since 1992 and from stratospheric ozone LIDAR measurements available at this site since 2000.

P/1-3.9

A case study of sporadic transport across the southern boundary of the tropical stratospheric reservoir

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Eddy transport barriers, resulting from the contribution of horizontal shear and isentropic gradient of PV, separate the tropical stratospheric reservoir from the mid-latitude stratosphere [Holton et al., 1995]. Aerosol and trace gas steep gradients clearly materialise the edges of this reservoir [Grant et al., 1996]. Sporadic disruptions of these barriers are occurring through planetary wave breaking and the generation of laminae. Yet, the height-latitude structure of dynamical and chemical tracer fields is complex and disruption mechanisms controlling the release of material between the tropics and mid-latitudes are still under study. Furthermore, the respective narrowing of northern and southern boundaries through these exchanges is not clear.

To improve our understanding of the role of such transport processes, several co-ordinated project have been undertaken, such as the METRO project included in the THESIO program. Yet, due to the lack of ground-based measurements in the southern tropics and to the insufficient spatial and time accuracy of satellite data, investigations on transport across the southern boundary of the tropical stratospheric reservoir are not numerous.

We presently report the analysis of a laminae exchange from the tropics to mid-latitudes. Observations are based on lidar profiles of aerosol and temperature obtained at Durban (30°S, 32°E; South Africa) and ozonesonde profiles performed in the framework of SHADOZ (Southern Hemisphere ADditional OZonesonde) project. PV laminae advection on isentropic surfaces is linked to ozonesonde and aerosol profile laminae through a high-resolution model based on PV advection calculation using ECMWF meteorological analyses. Air masses are coming from the equatorial zone (around Panama), across the southern barrier of the tropical reservoir through laminae stretching and reach the southern subcontinent of Africa a few days later (5-6 days).

P/1-3.10

Tropical STE inferred from modelled and observed trace gases

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Understanding of transport into and around the stratosphere has greatly improved since the first observations of high level water vapour and ozone, and the establishment of the Brewer-Dobson circulation. However many questions still remain unanswered concerning the exact method with which water vapour and other trace gases enter the stratosphere from below. General Circulation Models are increasingly used to draw light on the subject.

We jointly study the transport of the tracers SF_6 and H_2O in the UKMO Unified Model and also look at observations of water vapour to gain further insight into the preferred times and areas of entry into the stratosphere of such trace gases, and the relative importance of processes such as convection, large scale advection and the strength of the stratospheric pump.

P/1-3.11

The tape recorder signal in the tropical stratosphere effects of different transport schemes

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The Unified Model is able to simulate characteristic features of water vapour in the tropical stratosphere like the "tape recorder signal". The existence of such a signal in the GCM shows that the model is able to reproduce tropical troposphere stratosphere exchange and the tropical pipe in a reasonable manner. We will analyse these phenomena in detail and compare them with UARS water vapour measurements.

Better insight can be gained into the drying and moistening processes at the tropopause. Results about the tropical pipe (i.e. the ascent rate of the tape recorder signal) are however strongly influenced by the advection scheme used in the model. We will compare different transport schemes and analyse the their effect on the water vapour distribution.

P/1-3.12

Sensitivity of the MOCAGE CTM to the representation of large-scale and convective transport

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MOCAGE is a new Chemistry-Transport Model (CTM) developed by CNRM/Météo-France, which includes a detailed representation of tropospheric and stratospheric chemistry. One original feature of the model is that, in addition to the standard global grid relevant for large-scale, long-term studies, several nested grids can optionally be activated for the study of more localised phenomena (continental or regional pollution).

The first version of the model uses a semi-lagrangian transport scheme, and a parameterisation of convective transport based on Tiedtke's scheme. In this study, we will present results from a sensitivity study showing how the model responds to changes in the formulation of the large-scale transport (SL, Prather and PPM schemes) or convective transport (Tiedtke, Kain-Fritsch, Bougeault schemes). In particular, attention will be focused on stratosphere-troposphere exchange, using ECMWF ERA40 windfields in a multi-year simulation of idealised tracers (age of the air for instance).

Consequences on chemically active species will also be investigated using a shorter integration of the model (seasonal scale).

P/1-3.13

Diagnosis for Lagrangian mean circulation based on pressure -isentrope hybrid vertical co-ordinate

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To consistently describe mean meridional transports of mass, angular momentum, heat, minor constituents, the author developed a diagnostic formulation of Lagrangian mean circulation and wave, mean-flow interactions based on the pressure-isentrope hybrid vertical co-ordinate. This was to generalise non-acceleration theorem toward finite-amplitude and/or nongeostrophic (fully primitive) expression.

The new analysis of the GCM shows the mean meridional circulation has only hemispheric single direct cell with a kink at the subtropics near the so-called tropopause folding in contrast with the well-known three cell structure in the conventional Eulerian mean circulation. For small amplitude eddies, the new analysis may be equivalent to with the TEM residual circulation. The former, however, seems to be more consistent with the observation of minor constituents and with trajectory simulation. The GCM analysis is well enough to show that differences in the wave, mean flow interactions between two hemispheres may cause a significant seasonal variation the global stratosphere-troposphere mass exchange rate.

Based on the pressure-isentrope hybrid vertical co-ordinate, the author further formulates atmospheric energy cycle between zonal mean and eddy components. Significant differences from conventional Eulerian mean view are that the zonal mean available potential energy does not directly transform with the eddy available potential energy but that the zonal mean kinetic energy does directly transform with the eddy available potential energy . The latter is contributed to by the vertical divergence of the form drag over isentropic surfaces, which is the major term of the Eliassen-Palm flux divergence.

P/1-3.14

Chemistry-transport model comparison with ozone observations in the mid-latitude lowermost stratosphere

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About 600 ozone sonde profiles and in-situ ozone observations on 2300 aircraft flights were compared with several three-dimensional global chemistry-transport models, in the midlatitude lowermost stratosphere during 1996. The models use the same top boundary conditions and parameterized ozone chemistry. The comparisons show that the models using GCM winds do not capture the seasonal ozone accumulation in the lowermost stratosphere.

The models using ECWMF winds overestimate ozone above this maximum, especially during spring. This overestimation increases with increasing latitude. In addition, among these models there are significant differences in the modelled ozone profiles, despite their common source (ECWMF) to calculate the transport. The reasons for these discrepancies are discussed. The use of a comprehensive stratospheric chemistry scheme results in only a small change in ozone in the lowermost stratosphere.

Close to the tropopause, the best agreement between models and observations is found during winter, and the worst during summer, where all models underestimate the mean ozone concentration. This underestimation is caused by too strong meridional mixing between air from the (sub)tropics and midlatitudes, and is more pronounced above Asia then above the Atlantic. A 'non-diffusive' advection scheme is required to simulate ozone in the lowermost stratosphere, but can not prevent ozone underestimation during summer. In addition, the results seem relatively insensitive to vertical resolution. To improve the model performance further in this region, the horizontal resolution need to be higher than 2.5°.

Experience varies directly with equipment ruined

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-4: Gravity Waves

P/1-4.1

Water vapour isotopes in the stratosphere

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Measurements and modelling of less abundant water vapour isotopes, such as HDO and H218O, can be important tools in the study of certain aspects of the dynamics of the stratosphere. The exchange between the troposphere and the stratosphere in the tropics and at mid-latitudes are areas where this might be useful. An air parcel entering the stratosphere from below is very much depleted in isotopes, compared to a standard mean, due to the lower vapour pressure of the heavier isotopes. Water vapour produced inside the stratosphere, on the other hand, will reflect the isotopic ratio of atmospheric oxygen and methane, since the oxidation of methane is the primary source of water vapour within the stratosphere.

In this study, a one dimensional, chemical/dynamical model is used in a first attempt to model HDO in the stratosphere. The model is designed for the tropical region, with large inputs of water vapour following a seasonal cycle and a large scale ascending motion. The studies have been performed to estimate what might be expected from measurements by the Odin satellite, which will be launched in December 2000. ODIN will be able to measure water vapour as well as HDO, H218O and H217O.

P/1-4.2

Influence of the ageostrophic circulations on the formation and maintain of cirrus clouds at tropopause level at mid latitudes

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Cirrus clouds play a key role in the radiative balance of the atmosphere. But till the 50's, their precise observations were difficult to conduct due to the height of these clouds. Airborne observations in the 50's showed a correlation between the occurrence of cirrus and the vicinity of jet streams. More recently, Mace (1995) describes the formation of cirrus decks during a strong polar jet stream event.We have conduct several observations of cirrus by lidar during polar jet streaks at the Palaiseau site near Paris from 1994 to 1999. Several cases indicate the presence of cirrus cloud layers up to 14.5 km above the thermal winter tropopause in some occasions.

We will present a case study observed in 1994. We show from lidar and radiosoundings data, the presence of a cirrus layer in the core of the jet stream and the close elevation of the cirrus tops with an increase of the tropopause height when crossing the jet axis from the cyclonic side to the anticyclonic side. By using ECMWF reanalysis data, we show the ageostrophic circulations associated with the wind flow changes lead to strong upwellings in the upper part of the troposphere. We then describe the close link between these upward motions and the formation of cirrus clouds.

P/1-4.3

Observation of thin subvisible clouds at the tropical tropopause

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Observation of subvisible clouds at the tropical tropopause have been made both by satellite and ground-based or airborne lidars. These persistent structures do not seem to form at midlatitudes, so their origins may be envisaged in the relative abundance of moisture deposited near the tropical tropopause, either by deep convection or synoptic uplifting of air, and to the extremely cold tropopause in the tropics. Subvisible cirrus clouds are gaining increasing attention due to the role they may play in the mechanism of dehydration of the tropical lower stratosphere, and their forcing on the radiative budget of the middle atmosphere.

On October 22, 1999 the stratospheric research aircraft "GEOPHYSICA"; on a flight crossing the Inter Tropical Convergence Zone, from Recife to Isla do Sol, detected in many occasions thin layers of subvisible clouds around the local tropopause. Optical observations of those clouds have been made by the multiwavelength backscattersonde MAS, which was part of the aircraft's scientific payload. The acquired data consist of backscattering coefficients at 532 nm and 830 nm, and depolarisation ratio at 532 nm.

Those observation are here presented and discussed, together with a meteorological synoptic analysis and a study on the possibles mechanisms of formation of those clouds.

P/1-4.4

APE-THESEO tropical campaign

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APE-THESO campaign, supported by the European Commission, in the frame of THESEO program was held from 15 February to 15 March 1999 from the Seychelles in the western Indian Ocean. The principal goal of the campaign was the study of the tropical upper troposphere and lower Stratosphere. Tropics and in particular the regions around the ITCZ have a fundamental role in the general circulation of the atmosphere. In this region is localised the upward branch described in the Dobson-Brewer theory. In particular the campaign aimed to get information on what controls the low water content of the stratosphere, on the mechanism of the cloud formation in the tropical tropopause region and the impact they have on ozone depletion on UT-LS exchange and on radiative budget.

Two aircraft were used simultaneously in order to perform remote and *in situ* measurement. They were the high altitude research aircraft M-55 Geophysica, which can fly up to 21 km and the Falcon a tropospheric aircraft belonging to DLR.

A very cold temperature at the tropopause has been observed during the campaign and a detailed analysis of the relationship among tropopause, ozonopause and hygropause has been performed. Ultra thin clouds at the tropopause were observed during several flights, also in this case their composition and the mechanism of their formation is not yet clear and is under investigation.

We have also performed some meridional transect flights that provided useful in formation on the study of the distribution of long-lived trace gases in the tropical lower stratosphere.

P/1-4.5

Investigating the role of stratospheric processes in climate with HIRDLS

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The High Resolution Dynamics Limb Sounder (HIRDLS) experiment is being developed to acquire unique data with which to address many of the questions at the focus of SPARC. This presentation will briefly describe how HIRDLS will obtain measurements of temperature and the concentrations of ozone, water vapor, aerosols and 8 other species in the upper troposphere and lower stratosphere (UT/LS) with unprecedented zonal and vertical resolution. The standard zonal resolution for global coverage is 5 degrees in both longitude and latitude, which will be combined with a vertical resolution of 1 km or better. This allows the resolution of evanescent synoptic scale waves in the UT/LS, and a direct measurement of their transports. The zonal resolution is commendable, to allow smaller features to be seen where desired.

These capabilities will allow, among other things, global depiction of the transport of water vapor and ice from the troposphere into the stratosphere in the tropics. Preliminary planning calls for an international aircraft and balloon campaign to provide detailed in-situ observations in conjunction with the satellite measurements, to better study these important transports, as well as to validating the HIRDLS measurements. HIRDLS will also be able to provide data for the study of the isentropic exchange of ozone and water vapor between the troposphere and stratosphere in mid-latitudes. Results from a simulation of HIRDLS sampling of real data show these data will be able to observe transports up to and beyond wave number 15 with high fidelity.

P/1-4.6

Critical level, mixing layer and hygropause formation during CEPEX and TOGA-COARE experiments

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During the CEPEX and TOGA-COARE experiments from November 1992 to March 1993 the brightness temperature derived from GMS showed that very strong convection occurs to the west of the dateline, and that this is not the case to the east of the dateline. From the temperature, wind ozone and humidity provided by CEPEX and temperature and wind provided by TOGA-COARE we studied two phenomena related to this difference. On one hand the strong convection generates waves, which encounter a critical level inducing mixing layers clearly seen in ozone and potential temperature profiles. On the other hand we found that a very simple mechanism can explain the hygropause formation in this region. This mechanism is based on the existence, during periods of intense convective phenomena, of an uplift of the tropopause inducing a cooling of its temperature. We indeed find in these circumstances, very low water vapor values at the same level as the temperature minimum. After the end of the intense convection episode, the minimum temperature level is re-established at a lower altitude while the hygropause remains positioned in the lower stratosphere but with a lower value for the water vapor mixing ratio.

P/1-4.7

Analyses of new observations at Paramaribo station, in Suriname

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Under the project RADCHiS (Research on Atmospheric Dynamics and Chemistry in Suriname) an observation site has been installed on the premises of the Meteorological Service of Suriname (MDS) in Paramaribo, the capital of Suriname. The observation program consists of total ozone, UV and Umkehr measurements with a Brewer MKIII spectrophotometer (since March 1999), and weekly balloon sondes measuring ozone, temperature, humidity and wind profiles (since September 1999). A web camera was also installed in September, taking wide-angle pictures of the sky every two minutes. These pictures are used to compliment the Brewer and sonde observations and, when compiled into animations, give insight into cloud turbulence processes and transport. The station is located at 5.81°N 55.21°W, at the northern coastal shores of the South American continent, and lies about in the middle of the latitudinal migration range followed by the Inter-tropical Convergence Zone (ITCZ) in this area. The sonde observations started with the onset of the long dry season (September to November, south-east trade winds dominating), and show its transition into the short wet season (December to January) when the ITCZ passes overhead, followed by the short dry season (February to April, north-east trade winds) and the long wet season. An overview of these sonde observations will be presented, showing the distinctive effects of the migrating ITCZ on ozone, temperature, humidity and wind fields. Also, signatures in the observations coming from dynamical processes like deep convection and equatorial waves are discussed, along with their possible role on stratosphere-troposphere exchange, the QBO and the large-scale circulation.

P/1-4.8

Year-round spectral UV measurements at tropical Paramaribo, Suriname

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Spectral surface UV measurements are made on a continuous basis at the site of the Suriname Meteorological Service (MDS) in Paramaribo, (5.8 N; 55.2 W) with a Brewer MKIII spectrophotometer.

The Brewer #159 was installed at the MDS in March 1999 and has been operated successfully since. Absolute, wavelength and ozone calibrations have been performed after one full year of operation. Instrument performance is checked daily and specific care is taken for the possible instrumental effects of tropical conditions with high humidity. The year-round measurements have been checked extensively against accurate discrete-ordinate radiative transfer calculations for their stability, the wavelength alignment (by using solar spectra) and the internal consistency of the data set.

Using radiative transfer modelling the Brewer spectral UV measurements have been related to the total ozone measurements of the Brewer #159, and also with satellite data of GOME and TOMS.

Weekly ozone sondes give information on the local vertical temperature and ozone profile and its variability around the year.

A webcam at the site is continuously recording the sky above the measurement site, and this gives valuable information on cloudiness. In this presentation the year-round UV climatology for Paramaribo is discussed, and some representative days are selected to further discuss tropical UV exposure and its seasonal variability.

P/1-4.9

Wavelength dependence of the optical depth of multicomponent aerosols in the North of Chile

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In this work, we present the first results of measurements of UV- Absorbing aerosols made by an automatic CIMEL Sunphotometer installed by NASA in Agreement with University of Tarapacá Arica-Chile.

We analyse spectral measurement of tau from 340-1020 nm obtained from a ground based Aerosol Robotic Network Radiometers AERONET, which is located in Arica (Lat.: 18º 29´S, Long.: 70º19´W, h=25 m). Desert dust aerosols are present, at this location due to the proximity of the Atacama Desert (the world´s driest), and fine mode aerosols are also present.

Aerosol size distribution retrieval analyses are also presented. The data show that in some days there is curvature in the ln (tau) vs ln (lambda) plot, which is related to the dominance of yhe accumulation mode aerosols. In this case a second order polynomial fit to the ln (tau) vs ln (lambda) provided in Arica provides a good agreement with the measurements. Satellite TOMS estimates of optical depth for this region were also obtained.

P/1-4.10

Thermodynamic studies of single (NH4)2SO4/H2SO4/H_2O-aerosols

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Due to their scattering and absorbing properties aerosols in the stratosphere and upper troposphere (UT) can intensely affect the radiative balance of the Earth. Furthermore they can act as cloud condensation nuclei for cirrus clouds *via* heterogeneous freezing. However, the exact role of aerosols in cirrus formation mechanisms and the associated microphysical processes are insufficiently understood. The net radiative effect of a cirrus cloud may be either to warm or cool the Earth. Hence the contribution of aerosols and cirrus clouds to radiative forcing is a main uncertainty in quantifying the global radiation budget [Intergovernmental Panel on Climate Change, IPPC 1999].

The influence of solid species of the $(NH_4)2SO_4/H_2SO_4/H_2O$ system on the cirrus formation are poorly understood. Existing thermodynamic models are mainly based on experimental data obtained at room temperature. Furthermore these models cannot make predictions about efflorescence points, since nucleation is a statistical process.

In order to obtain a better understanding we perform laboratory measurements of single levitated $(NH_4)2SO_4/H_2SO_4/H_2O$ droplets in an electrodynamic particle trap. Thermodynamic and kinetic aspects are studied. The particle radii are determined from Mie phase function measurements and the DC voltage is used as a measure for their mass. The chemical composition of liquid and solid particles is examined with Raman spectroscopy.

Measurements show that pure $(NH_4)2SO_4/H_2SO_4/H_2O$ droplets with different stoichiometries can be supersaturated immensely and might not crystallize at ambient relative humidities (RH > 15%). However, if efflorescence is observed letovicite [$(NH_4)3H(SO_4)2$] is a occurring phase. The atmospheric relevance of letovicite has not been discussed sufficiently so far.

Besides, deliquescence points of solid ammonia containing sulfates at different water partial pressures and further uptake of gaseous water into liquid aerosols are studied. Cooling of these droplets along the ice/liquid coexistence line shows that they can be supercooled massively.

P/1-4.11

Stratospheric-tropospheric transport through PSC-cirrus combined presence at Dumont d'Urville (Antarctica)

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Since 1989, a backscattering lidar has been in operation at the Antarctic station of Dumont d'Urville. The data elaborated from 1989 to 1998 have provided us with a wide climatology for Polar Stratospheric Clouds (PSC).

Analyses of the mid-cloud height and temperature, PSC cloud top and bottom, and the optical parameters such as backscattering and depolarisation for each cloud layer, together with their evolution during the year have been briefly reported. The midcloud, top and bottom altitude have been analysed with regard to the evolution in PSCs during the year. During the winter, an increase in the midcloud temperature and a decrease in midcloud altitude were observed. Starting from these observations a special study was carried out on PSC events characterised by low mid-cloud altitude. This study has shown the presence, usually during the late August-early September period, of low PSCs. These were usually placed above the tropopause, together with the presence of cirrus or high clouds just below the PSC bottom, that were situated in the tropopause or in high troposphere. At least one of these events has been observed at Dumont d'Urville every year, with the exception of the 1994 winter when no such phenomena was detected. This was probably due to bad meteorological conditions, which prevented lidar measurements. Nothing can be said for the 1992-1993 post-Pinatubo period, when the volcanic cloud hid this phenomenon. The evidence of these phenomena every winter may be a proof of the mechanism of denitrification and dehydration of the Antarctic stratosphere, since PSC particles, rich in nitric acid and water, can reach the highest levels of the troposphere, thanks to the presence of cirrus or high tropospheric clouds placed just below the PSC bottom.

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-5: Gravity Waves

P/1-5.1

Importance of convection in generating gravity waves

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Gravity waves in the atmosphere can be generated by deep convection as well as by orography. Radiosonde data form the basis of a study to find whether convectively generated gravity waves are energetically important in the midlatitudes. Several months of data from stations in the UK are used. Convective available potential energy (CAPE) is used as an indicator of the likely occurrence of deep convection. Gravity waves are detected through their effect on the ascent rate of radiosondes and by examining the hodograph (u-v diagram) using the Stokes parameter technique for finding the polarisation properties. Cases of correspondence between high values of CAPE and the existence of waves in the stratosphere are described. Shear is determined for the ascents. In the resulting climatology it is found that high values of CAPE occur in about 50% of all the gravity wave cases in the radiosonde ascents.

The energy content of gravity waves is determined using a spectral analysis. Using the total data set it is found that the energy content of gravity waves on average is at least as important during convection as during strong shear events. This can also be seen in the associated calculations of the momentum transfer. Values for the momentum transfer and the respective value for shear will be given.

These two results suggest that convectively generated gravity waves represent a physical process in the midlatitudes that should not be neglected.

P/1-5.2

Analysis of numerically simulated gravity waves generated by convection

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Convectively generated gravity waves have recently been identified as a source of momentum flux that affect the mean flow in the stratosphere and higher levels. The waves are easily identified in the stratosphere, but difficult to discern in the troposphere due to the much larger amplitude of the convection. In this study, we examine a simulation of squall line convection that produces vertically propagating gravity waves. Trajectory and empirical orthogonal function (EOF) analyses are applied to the velocity and thermodynamic fields simulated by the model, obtaining separation of wave and convective motions. Momentum fluxes are calculated for both convective and gravity wave motions in the troposphere, and are compared to fluxes in the stratosphere. One of the goals of this research is to develop improved parameterisations of convectively generated gravity waves for large-scale models.

P/1-5.3

Numerical simulation on stratospheric gravity wave above mid-latitude deep convection

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Troposphere is an important source region for gravity wave generation. The convection activity, especially deep convection is an important gravity wave generation mechanism. Observations suggest that it is at least as equally important as topographic forcing.

In this presentation, the authors initiated a set of 3D numerical simulation on a slowly moving intense deep convection case occurred in mid-summer season at mid-latitude in northern China. In-situ radar detection showed that the updraft of the storm could penetrate into the tropopause to about 16km above surface. The research was performed by using a 3D non-hydrostatic compressible atmospheric model, and was incorporated with a rather detailed bulk cloud microphysics parameterisation scheme. The model region and resolution in the two horizontal dimension is of 60km and 1km respectively, and in the vertical dimension of 25km and 0.5km respectively.

The simulated morphology and moving of the storm fit reasonably to the radar observation. Through evaluating the statistics of model output, the temporal and spatial characteristics of flux and spectrum of the lower stratospheric gravity wave due to convection was examined. It was confirmed that in the realistic atmospheric condition the wave propagation is of 3D characteristics. Secondly, convection induced lower stratospheric gravity wave is closely related to the thermal state of the upper troposphere. Comparative examination test shows that while a rather weaker stable layer exists beneath the tropopause in real situation, it can protect the convection originated from the mid-troposphere resulting to a secondary upwelling with a rather strong forcing of 20m/s/day on unit mass upon tropopause. Finally, our results are also consistent with the work of other people. For example, the momentum flux in the lower stratosphere reveals the "mechanical oscillator effects".

P/1-5.4

Updated theory and parameterisation of convectively forced gravity wave drag

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An updated theory of gravity wave drag forced by cumulus convection (GWDC) is proposed by considering the 2-dimensional, steady-state, linear response of a stably stratified shear flow to diabatic forcing which represents the latent heating of cumulus convection. The basic state consists of a 2-layer structure with a constant shear with a critical level in the lower layer and a uniform wind above, and piecewise constant buoyancy frequencies in each layer. Using the solutions of perturbation horizontal and vertical velocities, the horizontally averaged momentum flux at the cloud top is obtained analytically. It is shown that the magnitude of the momentum flux is inversely proportional to buoyancy frequency and basic-state wind speed at the cloud top for given parameters in the forcing region. The effects of vertical shear appear to be negligible in the formulation of the cloud-top momentum flux except for low Richardson number flows ($Ri<4$). The dependency of buoyancy frequency on the momentum flux is different from that of the uniform basic-state wind and stability case by Chun and Baik (1998). The magnitude of the momentum flux at the cloud top in the present theory is larger than that in our previous theory by a factor of a fractional ratio between buoyancy frequencies in the lower and upper layers.

A parameterisation scheme of GWDC based on the updated theory is proposed for use in GCMs. We will present the effects of GWDC on zonal mean flow and planetary waves through GCM simulations (YONU AGCM) including the new parameterisation scheme, in comparison with the results using our previous parameterisation scheme.

P/1-5.5

Global distribution of gravity wave drag as a residual of momentum budget calculated using UKMO assimilation data

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The global distribution of gravity wave drag (GWD) is estimated by calculating a residual of momentum budget. For this, 7-year assimilation data set archived from the UKMO is used, which has horizontal resolutions of 2.5 degree latitude and 3.76 degree longitude and 22 vertical levels from 1000 hPa to 0.316 hPa. We will present the latitudinal and height structure of zonal mean GWD and its variance. Especially, the seasonal variance of GWD in the upper stratosphere will be discussed by analysing each term of the momentum equation.

P/1-5.6

Forcing of the stratospheric circulation by convectively generated gravity waves: the role of tropospheric wind shear

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The knowledge of the spectrum of gravity waves entering the stratosphere is crucial in determining the stratospheric gravity wave mean-flow forcing. More specifically, the knowledge of gravity wave phase speeds is essential in determining their breaking levels, whereas the amount of momentum flux carried by the waves is necessary to predict the mean-flow forcing. Global Circulation Models (GCMs) often assume that convection generates waves isotropically, propagating equally in all directions. In this work we show that this assumption is most likely erroneous, and we propose a method of estimating the anisotropy in waves generated by tropical convection based on the structure of tropospheric wind shear and tropospheric heating.

In this study, tropospheric convection is simulated using a two and three dimensional cloud resolving model. Numerous simulations are performed with varying shear of the horizontal wind at different levels of the troposphere. It is concluded that the storm-relative phase speed spectrum of waves generated by convection is primarily determined by the vertical extent of tropospheric heating and is modified by the storm-relative mean flow.

P/1-5.7

Climatology of stratospheric gravity-wave activity based on radiosonde data

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This study contributes to the co-operative 'SPARC Gravity Wave Initiative' co-ordinated by R.A. Vincent of the University of Adelaide, Australia. It deals with high vertical resolution radiosonde data of routine soundings from Munich (48N, 12E) and Stuttgart (49N, 9E) close to the northern baseline of the Alps. A number of stratospheric gravity-wave parameters are derived over the ten year period from 1990 to 1999. A standard analysis follows the methods used for the global climatology of gravity-wave spectral parameters presented by R.A. Vincent. It is critically compared to own evaluations in order to classify the different excitation mechanisms of gravity waves by flow over orography, fronts, etc. Maximum wave energies are found to be connected to intense frontal passages. Orographically induced gravity waves have typical potential energies of about 12 Jkg^{-1}, whereas the highest observed potential energy due to a frontal passage has a value of about 82 Jkg^{-1}. The dependency of the magnitude of these wave energies on tropospheric wind conditions is investigated. Especially, the horizontal drift of the balloons is taken into account in order to specify the area where the individual stratospheric observations were made. Balloons, drifting into mountainous terrain might measure an additional energy due to the mountains below them. Such effects come into play primarily if the tropospheric wind speeds are sufficiently large. This longer-term data analysis leads to a better classification of the different sources of gravity-wave energy and constitutes a new contribution to the world-wide co-operation under the auspices of SPARC.

P/1-5.8

Some gravity wave characteristics from analysis of U.S. high resolution radiosonde data for 1998

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More than 50 high resolution (~30 m), out of a total of 105 available, United States radiosonde stations have been analysed for gravity wave activity for the year 1998. The analysis techniques closely follow methods previously used by Allen and Vincent (1995) and Vincent *et al*. (1997). In agreement with those earlier Australian studies, it is found that lower stratosphere gravity wave energies decrease Poleward in the subtropics and extratropics; are stronger in winter than in summer; and have a dominant vertical wavelength of about 2.5km. New results from our study are that gravity wave energies in the lower stratosphere are greater in the vicinity of the Rocky and Appalachian Mountains in winter and spring, but not in the summer and fall; show ground-based phase velocities near zero in mountainous areas; and have day-to-day variations that show good correlations over wide geographical areas; and that periods of large gravity wave energies are highly correlated with the passage of jet streaks. Some preliminary analysis results are suggestive about source mechanisms. For instance, approximately 50% of the tropospheric wave energy show upward energy propagation while there is about 80% upward propagation in the lower stratosphere. It is also interesting that the poleward decrease in lower stratospheric gravity wave energies exist even over the Arctic environment of Alaska.

P/1-5.9

Characteristics of gravity waves revealed in high-resolution radiosonde data at Pohang, Korea

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Characteristics of gravity waves observed by radiosonde at Pohang, Korea for the year of 1998 are investigated. From the wave energy analysis, it is shown that perturbations in the stratosphere can be considered as gravity waves, while those in the troposphere consist of other components. The seasonal variation of wave activity, stronger in winter and weaker in summer, is also shown. Despite the effects by other components, the spectral analysis for normalised temperature perturbation can identify saturated gravity waves both in the stratosphere and troposphere except for in July. The dominant vertical scales of gravity waves are 3.2 km and 4.0 km in the stratosphere and the troposphere, respectively. Horizontal wind hodographs generally have anticyclonically rotating components with height in the stratosphere. The rotary spectra analysis shows that a large portion of inertia gravity waves transports wave energy upward in the stratosphere.

The seasonal variation of wave propagation direction is also detected. The westward propagation is dominant in winter and the meridionally propagating waves are strong compared with the zonally propagating waves in summer. The intensification of wave energy and the decrease of vertical scales of waves are observed just above the tropopause in the height distribution of gravity wave energy and vertical wavenumber spectra. These results support the wave supersaturation theory near the enhanced stability region. It is also noticeable that the critical level above the tropopause can intensity wave energy and decrease vertical wavelength below that level. In July, however, the energy and vertical wavelength of gravity waves near the tropopause seem to be controlled by other mechanisms.

P/1-5.10

Wave breaking and critical levels for propagating inertial gravity waves in the lower stratosphere

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This work analyses and interprets the formation of mixed layers due to propagating inertio-gravity waves observed during the FASTEX experiment. The data used are the high vertical resolution soundings, launched from different sites located in the North-Atlantic sector. In agreement with other studies, attributing the origin of the inertio-gravity waves to the adjustment of the jet-stream near fronts, the largest waves observed are often located in the vicinity and above frontal bands. The amplitude of these waves is large enough that they break in the lower stratosphere, and give rise to narrow mixed layers. These observations witness the likely importance of inertio-gravity waves in the vertical exchanges that occur in the stratosphere. By analysing with details the characteristics of the waves, we can distinguish when the mixing results from an interaction with a critical level and when it results from wave breaking independently of critical levels.

P/1-5.11

The vertical wavenumber power spectrum resulting from the propagation of a gravity wave spectrum under non-linear advective interactions

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The non-linear advective interactions between components of a atmospheric gravity wave spectrum are investigated. Starting from the gravity wave equations we show that the power spectrum of a continuous (in wavenumber space) wave packet has a -3 power law in the spectral tail while, as it is known, a monochromatic wave propagating in a shearing background has a -1 power law. The energy exchange to other parts of the spectrum maintains the amplitude within the tail in the range of the observed amplitudes.

P/1-5.12

The convective instability in a non-linear gravity wave approach

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A non-linear theoretical approach is used to study a gravity wave, which becomes unstable convectively. An understanding of the physical processes is obtained under this approach. We see that the energy exchange with the background occurs at very thin layers where contact discontinuities appear in the solution. The results show that the universality of the spectrum can not be explained by the linear instability theory at least in its present stage of development.

P/1-5.13

Influence of 3-dimensional and non-hydrostatic effects on the representation of subgrid-scale orography in GCMS

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We present a parameterisation scheme for mountain gravity waves that allows to deal with 3D trapped lee-waves and 3D directional critical levels using an extension of WKB theory. The scheme presented is spectral, providing a step toward a unification of orographic and non-orographic gravity waves drag schemes.

The scheme is tested in a version of the LMD-GCM with 50 vertical levels and extending up to 75Km.

P/1-5.14

A time and space dependent parameterized gravity wave source distribution in the MPI/MAECHAM model

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The aim of this work is to evaluate the impact of varying in space and time the parameterized tropospheric gravity wave (GW) source distribution on the middle atmospheric circulation of the Max-Planck-Institut MAECHAM model using the Hines Doppler-spread parameterisation scheme. Two lines of thought are followed. The first stage consists in determining how the seasonal and latitudinal subgrid scale mid-latitude GW source distribution can be affected by front climatology obtained from an independent dataset. Data from the ECMWF analysis at resolution T319 and sampled twice a day for the years 1998-1999 are used to establish a tropospheric frontal activity depending on latitudes and seasons. This is then interpreted as a proxy for GW emission, and the parameterized rms GW winds and anisotropy at the source region are taken to be modulated by this distribution. First results show that the tilt of the Southern Hemisphere middle atmospheric jet in July is increased and closer to observations than when using a uniform and constant isotropic GW source.

The second stage consists in linking the subgrid scale GW source due to fronts to the resolved flow in the model troposphere, instead of using a climatological forcing as in stage one. Since fronts are poorly resolved in the model at resolutions T30 and T42, a space and time dependent field producing horizontal isotherm compression due to flow deformation and convergence is calculated and used as a precursor to frontogenesis and as an indicator of subgrid scale GW emission in the model. The model middle atmosphere response to this GW forcing will be shown. We restrict our study to mid-latitude fronts, other GW source mechanisms being left for later examination.

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-6: Climate Variability

P/1-6.1

Changes in the polar vortex circulation associated to SST anomalies in the Pacific Ocean observed patterns and simulation with a GCM

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Years of extreme SST anomalies at the equatorial Pacific Ocean show changes in the circulation patterns of the stratospheric polar vortex in the Southern Hemisphere.

During austral spring, a vortex anomaly resulting on a "shift" towards higher latitudes is observed during the EN years to the Southwest of South America. This is shown through correlation fields between El Niño Indexes and zonal wind at 50 hPa, as well as with composites of zonal wind at 50 hPa during ENSO events.

We simulate this process by using the UCLA-GCM with two ensembles of 5 simulations each one, with different SST temperatures. One ensemble has the climatologic SST (CLI) for October. The other ensemble, the SST of October 1997 (EN97).

Results show increased westerlies (50 hPa) in the southern part of the vortex and decreased westerlies in the northern part between 40ºE and 100ºE for the EN97 ensemble, in agreement with observations. The statistical significance is larger than 95% at the t-Student test in that region. These anomalies can also be seen at 200hPa in high latitudes, which is consistent with a certain barotropic equivalence of the atmosphere at these latitudes.

For precipitation, the difference between ensembles shows, in the equatorial Pacific Ocean, a positive precipitation anomaly eastward of the highest climatologic precipitation region for the EN97 ensemble. In adjacent regions to this positive anomaly there are anomalies of opposite sign (although of less intensity than in observed cases). This simulated precipitation results substantially agree with those associated to EN events at the central Pacific, which allows us to adequately represent anomalous forcing of tropical troposphere.

In order to study this polar vortex alteration dynamics, we use Hoevmoller diagrams at different levels, E-P fluxes and potential vorticity analysis.

P/1-6.2

Synoptic tracing OG migration of ozone minima from West Pacific to Tibet

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Globe's minimum ozone generally prevails over the equatorial west Pacific almost throughout the year (except the period of occurrence of ozone-hole over Antarctica). This low splits sometime in the month of May and one part of it start moving towards north-west and settles down over the Tibet and neighbouring parts of India for about two months i.e. in August and September. After that, the same low again starts moving back and merge with the original west Pacific low by the month of November. Initial investigation revealed that the migration of ozone low is a manifestation of dynamical feature of typical monsoon circulation. In view of this, influential meteorological parameters are analysed.

The analysis showed that when monsoon circulation starts developing over the Asia in the month of April, the moisture-rich intense low-level convergence coupled with large and homogeneous upper-air divergence which normally prevails over equatorial west Pacific starts moving toward north-west via. Malaysia, Thailand, Burma and becomes semi-permanent over Tibet and neighbouring part of India during the months of June to September. It is seen that core thunderstorm activities producing stratospheric fountain are associated with the movement of this large scale system. The association is clearly seen in the elevation of tropopause height, cooling of lower stratosphere (in fact, this is coolest region of the globe's atmosphere) and contours of moist static energy. Obviously these extraordinary meteorological activities lead to the reduction in columner ozone (mainly due to the overshooting of tropospheric air in to the stratosphere through intense thunderstorm activities).

P/1-6.3

A study of the impacts of tropospheric synoptic processes on the genesis and evolution of extreme total ozone anomalies

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The relationship between total ozone anomalies and tropospheric processes has been known for many years now, due to Dobson's seminal work. Over the years the topic has been analysed a number of times. The so-called total ozone 'mini-holes' issue rekindled the topic. It is now well known that extreme low ozone events can be frequently observed, particularly during winter at mid to high latitudes. Furthermore most studies have focused on Northern Hemisphere events.

During May 1997 extreme low ozone events occurred at mid to low mid-latitudesover the South Cone of South America (Argentina, Chile and Uruguay). The lowest ever total ozone values were observed at the Buenos Aires Dobson Station (211DU).

This sequence of low ozone events that extended from late April till mid June, was associated with a sequence of extreme tropospheric perturbations, basically very strong blocking events.

The study of the genesis and evolution of these low ozone events and the associated synoptic processes has been useful in shedding light upon the mechanisms that can affect the ozone column in this spatial scale. It shows that these events can be originated by different dynamic processes in the troposphere and lower stratosphere, even though the simple observation of the ozone anomalies may not show distinct differences between the source processes involved.

P/1-6.4

Variability in the temperature profiles over Lauder, New Zealand

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Radiosonde/ozonesondes have been regularly launched from Lauder, Central Otago, New Zealand, since 1986. These temperature and ozone profiles have been stored in high resolution, thus allowing for valuable studies of trends and variability studies in this area. Multivariate statistical methods are applied to almost 14 years of data to determine patterns of variability and trends in the temperature profiles from the surface up to 30 km. The changes in the temporal behaviour and the vertical structure of the profiles are studied. The results provide interesting insights on the coupling between the troposphere and the lower stratosphere as well as on the behaviour of the tropopause region and the middle stratosphere, during the period 1986-2000.

P/1-6.5

An examination of low ozone events over Australia during 1997

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Observations from the Total Ozone Mapping Spectrometer (TOMS) indicate record low ozone column densities between 20S and 50S throughout 1997. The monthly averaged record shows that measurements from 1997 are lower than both the TOMS climatological mean (1979-1996) and measurements from 1998 and 1999 by up to 20 Dobson units. From June through December, monthly averaged total ozone values over Southern Australia were also significantly below the range of values observed by TOMS. To better understand the processes responsible for the low ozone observed in 1997, a detailed examination of ozone variability over Australia is conducted using various observations and modelling tools. Australian ground-based observations indicate numerous occurrences of rapid declines in ozone column densities, which last up to several days. These events occurred from winter through till early summer. We use a 3-D analysis of ozone compiled from satellite and ground based observations to describe the structure and evolution of these low ozone events during different seasons. Although there is evidence of vortex filamentation during winter and early spring, other low ozone events may be due to either tropical/midlatitude exchange or vertical movements in the tropopause. A discussion of how these events contribute to the monthly averaged ozone fields will be presented.

P/1-6.6

Southern Hemisphere ozone behaviour during 1994 austral winter

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In this paper, ozone synoptic-scale fluctuations and their relationship with the atmospheric circulation are comprehensively explored over Southern Hemisphere middle and high latitudes during 1994 austral winter. For that purpose, NCEP four times daily reanalyses of standard meteorological variables were utilised, as well as ozone data from SBUV/2-NOAA9 and TOMS-Nimbus 7.

1994 July ozone mean field was characterised by the typical ring-like-structure of maximums at around 40-60º S with a relative minimum over south western South America (SA). This minimum was related to a quasi-stationary ridge with a coherent-vertical structure located over the same region. In addition over south western Pacific and nearby SA, relative maximums of both storm and ozone-tracks were evident.

During the second week, an ozone mini-hole started to develop over southern SA lasting for about six days and maintaining values below 240 DU along the evolution. Furthermore, at both upstream and downstream sides of the mini-hole region, ozone values were dramatically increased for more than 100 DU respect to the minimum. The analysis of the atmospheric fields showed a clear correspondence between ozone relative minimum (maximum) and ridges (troughs), lowered (enhanced) tropopause pressure values and relative maximum (minimum) of potential vorticity at isentropic surfaces, thus indicating that atmospheric activity drove ozone distribution. Moreover, atmospheric synoptic-scale waves presented an equivalent-barotropic structure with a maximum near the tropopause and significant amplitudes even at 10-hPa level.

SBUV/2 data revealed that over the region where the ozone mini-hole was detected, the contribution to local ozone-maximum variations came from the 125-62.5 hPa layer, with secondary contributions coming from both 62.5-37 hPa and 250-125 hPa layers. In addition, evaluation of the different terms of the transport equation for ozone mixing ratios pointed out the relevance of the meridional transports in the determination of maximum ozone local changes, with minor contributions from the vertical advection term.

P/1-6.7

Classification of hemispheric monthly mean potential vorticity fields

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Classification methods are a widely used tool in meteorology and climatology, but have so far been applied only scarcely in stratospheric studies. The aim of the contribution is to provide a classification of monthly mean potential vorticity fields on selected isentropic surfaces. The data source is NCEP/NCAR reanalyses where isentropic levels of 400, 450, 550 and 650 K are available. The classification method used is principal component analysis in T-mode, which has been successfully applied to tropospheric circulation on continental scales. The monthly mean PV patterns are classified separately for both hemispheres. The types identified (i.e., the typical, recurrent patterns) are compared between the hemispheres as to their characteristic features and frequency of their occurrence. The relationships between the NH and SH types are also investigated, i.e., we investigate whether there is a preference for some NH and SH types to occur simultaneously. The seasonality of the types is also examined.

P/1-6.8

Diagnostic study of a stratospheric sudden warming during the winter of 1994-1995

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This study investigates the mechanism of stratospheric sudden warming occurred in the 1994/1995 Northern Hemisphere winter by examining several key diagnostic quantities, such as Eliassen-Palm (EP) flux, isentropic potential vorticity (IPV) and refractive index. The data came from the UK Meteorological Office assimilation data, which is different from retrieval data in the previous study. Comparison with the previous study of stratospheric sudden warming, this diagnostic study should be more objective and realistic. The results show: 1) The wave impact in the upper stratosphere is earlier that those in the middle and lower stratosphere, which consists with that the sudden warming in the upper stratosphere is earlier than that in the middle and lower stratosphere, 2) Clearly there exists a wave train structure of EP flux convergence and divergences from the tropics ti high latitude in the upper and middle stratosphere. It seems that the wave activity originated from the tropics in the upper stratosphere precedes and is more important the wave activity originated in the troposphere during the sudden warming, 3) the wave converge to the zero wind line not ionly from the tropics in the upper stratosphere and upward from the troposphere as in previous study, but also downward from upper stratosphere at polar cap. 4) Inspecting isentropic potential vorticity, the smallest area of main vortex is the precondition of major warming. However a double jet structure in the troposphere is not a necessary condition for major warming.

P/1-6.9

Wave mean-flow interaction in the tropical middle atmosphere in MAECHAM4

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Currently a number of experiments are carried out to investigate the explicit simulation of the QBO and the SAO, this means to find a model configuration which generates these equatorial oscillations without considering gravity wave drag (GWD) parameterisations.

A well-known condition is a sufficient vertical resolution. While the standard vertical grid of MAECHAM4 has 39 layers (L39) over a vertical range from surface to 0.01 hPa, the current experimental version is used with 88 layers over the same extent, so that the layer thickness is 700 m over a large part of the grid. This leads for instance to the generation of westerlies in the QBO domain, though without starting an oscillation.

A second modelling problem concerns the control of wave mean-flow interaction by the horizontal diffusion, as given in a spectral model by the hyper-Laplacian operator. The selection of the time scale has consequences for all scales in the tropical waves. A strong damping on the small scales leads to high spectral power in the large scales, while a strongly reduced damping reduces the large scale power in favour of intermediate scales. Thus without modifying the convective parameterisation, which is the tropical wave generator one obtains clearly different results in the equatorial middle atmosphere.

A MAECHAM4 (L39) experiment with weak horizontal diffusion, but without GWD parameterisation shows a well defined downward propagation of the SAO which is not found at normal horizontal diffusion, though the amplitude is only 50% of that achieved in the standard configuration including the GWD parameterisation. However, at high vertical resolution the directly forced SAO shows a realistic amplitude.

P/1-6.10

Equatorial oscillations in a middle atmosphere GCM

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Long period zonal mean wind oscillations in the tropics are generated in the Canadian Middle Atmosphere General Circulation Model using a spectral gravity wave drag parameterisation.

The sensitivity of the oscillation to the (unresolved) gravity wave source spectrum and the relative roles of resolved and unresolved wave driving are examined. Results from two longer integrations are analysed to determine the impact of the oscillation on extratropical planetary waves and the frequency of sudden stratospheric warmings.

P/1-6.11

Characteristics of the QBO in ozone, temperature, and wind derived from ozone sonde data

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On the basis of ozonesonde data in the period 1965-1998 the anomalies of ozone, temperature, and wind related to the equatorial quasi-biennial oscillation (QBO) were extracted and analysed. The anomalies having the time scales 24-32 months; QBO effects were obtained from the earth's surface till the heights 30-34 km at 22 stations located in North America (7), Europe (7), Japan (4), Australia (2), Antarctica (1) and at Hawaii (1). One of the most noticeable feature of the QBO effects in ozone is that that the layers with the well developed QBO effects are alternated with the layers with the ill defined QBO effects where the phases of the QBO effects are changed abruptly. In high and middle (low) latitudes the maximum ozone anomalies of 3-5 nbar are noticed at heights about 20 (21-25) km. The patterns of the ozone anomalies in the region 15-25 km are similar at all the stations. There are negative anomalies in this region in the period of the 50 hPa equatorial zonal wind E-W phase reversal and positive ones at the lags +/- 12 months relative the reversal. The ozone QBO effects in this region often reveal the downward time-height dynamics. The amplitudes of the QBO effects in temperature are 0.5-0.7;. At a number of stations the temperature anomalies are also characterised by the well-pronounced downward phase dynamics. In Europe (in the high latitudes of the North America) in the region 15-25 km the temperature anomalies lead (lag) the ozone anomalies. At the rest of the stations the QBO effects in ozone and temperature in this region are in phase. The amplitudes of the QBO effects in the zonal and meridional winds are 1-2 m/s. Their height dependencies reveal local maxima in the vicinity of the tropopause and in the middle stratosphere.

P/1-6.12

Biennial oscillation in temperature and monsoon activity

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Radiosonde measured temperature field over the near equatorial Indian station, Thumba (8.5 N, 76. 8 E) for the period 1971-1992 shows the signal of biennial oscillation with periods ranging from 20-32 months in the troposphere. The phase of the tropospheric biennial oscillation (TBO) in temperature does not vary with height from the surface to the level of tropopause and is associated with the intensity of the Indian summer monsoon rainfall. Temperature over Thumba shows Quasi- Biennial Oscillation (QBO) in the lower stratosphere. Phase of the QBO and TBO in temperature meet at tropopause level or just above 15km altitude. Where they meet, phases of the QBO and TBO are unsynchronised during 1971-1981 and synchronised during 1982-1992 periods.

Recent studies reveal the existence of biennial time scale variability in Indian Monsoon activity. Indian monsoon activity is strongly modulated by biennial time scale variability caused by atmosphere-ocean coupled processes occurring in Indian and Pacific Oceans, Convective activity is strong (weak) over the Indian Ocean area during strong (weak Indian monsoons. During the active monsoon years (1975, 1983 and 1988), the temperature TBO is found to be in its positive phase and during the weak monsoon years (1972, 1982 and 1987) the biennial oscillation in temperature is in negative phase. The stratospheric zonal wind QBO is in westerly phase during the active monsoon years and easterly phase during weak monsoon period.

P/1-6.13

The solar proton events influence on the changes of the thermal regime of the Antarctic stratosphere

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The changes in the thermal regime of the Antarctic stratosphere at levels 50-200 hPa (altitudes 10-20km) as well as phenomenon of the spring shifting of the sign of the vertical temperature gradient are considered. The data of atmospheric balloon soundings Antarctic stations Vostok, Mirny, Molodezhnaja, Novolazarevskya and Bellingshausen in 1957-1980 were taken for this study. It was demonstrated by using statistical methods that the solar proton fluxes penetration in the Antarctic stratosphere cause a notable intensification of the process of changing of the vertical temperature distribution. As an indicator of the solar proton fluxes precipitation appearances of the polar cap absorption events recorded by the riometers at the same stations were chosen

It was found that the spring shift of the direction of vertical temperature gradient is observed in 2-3 weeks earlier than usually if the solar proton fluxes affect the Antarctic stratosphere in spring months (September, October). The effects of the solar protons are more pronounced in the upper part of this altitude range and at the more higher geomagnetic latitudes. One of the possible explanations of this phenomenon could be transformation of the profile of the stratosphere heating due to absorption of the solar UV radiation by the ozone layer. Decrease of the ozone concentration during the solar proton events causes decreasing of the maximum of this absorption with excessive warming of atmosphere and correspondingly - acceleration of the spring change of circulation.

P/1-6.14

The solar wind, the stratosphere and the ground surface as the elements of the unified global electric circuit

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It was found from analyses of reliable experimental data that the solar wind disturbances (primarily its dynamic pressure enhancements) have a direct notable response at various atmospheric altitudes. For example, stratospheric temperature at levels 30-50 hPa is closely coupled with the solar wind parameters under the solar UV radiation level (correlation coefficient between them is as high as 0.85). Similar connection is found between the stratospheric ozone density and the solar wind parameters (correlation coefficient is close to 0.75). The solar wind dynamic pressure enhancements cause warming of stratospheric layers at altitudes 18-28 km while the ozone concentration at these altitudes decreases. It was found also that the anomalies of atmospheric pressure at ground surface in the region of Iceland depression taken for winter periods of 1965-1995 are correlated with the extremes of the solar wind dynamic pressure for the same period (correlation coefficient is close to 0.7).

These connections could be explained in the framework of unified global electric circuit where its external EMF generator driven by the solar wind energy is located at the dayside magnetopause of the Earth magnetosphere. The ionosphere, stratosphere and ground surface are the elements of this circuit.

Futher evidences of correctness of this idea were obtained through analysis of experimental measurements of the atmospheric electric fields and ozone concentration at Vostok Station in Antarctica.

P/1-6.15

The effect of extratropical wave forcing on tropical upwelling

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We consider the relation between extratropical wave forcing and the low-latitude residual circulation, or tropical upwelling, using an axisymmetric primitive equation model with prescribed zonal forcing and heating. Specifically, we consider to what extent classical downward control is applicable, or must be modified, in the low-latitude regions where angular momentum contours deviate significantly from the vertical. Two cases are investigated in detail: the first uses zonal forcing and heating that are constant in time; the second uses zonal forcing and heating that have a time varying seasonal cycle, crudely approximating the seasonal cycle in wave induced zonal forcing and radiative heating in the real stratosphere.

In the first case, the dependence of the tropical upwelling on the latitudinal location of the extratropical zonal forcing is presented. For forcing that extends to sufficiently low latitudes there is significant upwelling throughout the tropics and well into the opposite hemisphere. The spreading of the upwelling response is explained by considering the angular momentum distribution, and the change induced in this by the zonal forcing. In particular, as the forcing amplitude is reduced the spreading of the upwelling response diminishes, approaching the limit of linear downward control.

In the second case, the time averaged response to seasonally varying forcing and heating indicates an increase in the upwelling compared with the steady state response to the time averaged forcing and heating. The increase is attributed to the non-linear correlation of the time variation of the residual circulation with the time variation of the angular momentum distribution. The relative contributions to the latter term induced both by the zonal forcing and by the heating are considered.

Finally, tests with different model resolutions suggest that model hyperdiffusion is not responsible for the low latitude spreading of the upwelling responses.

P/1-6.16

Diagnosing the impact of stratospheric Rossby wave breaking in a linear model

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In the past, linear quasi-geostrophic theory has proven successful in modelling the vertical and meridional propagation of stationary planetary waves in the stratosphere. Since in such models the wave solution does not sensitively depend on the wave damping, the latter was usually implemented as relaxation with a simple damping coefficient. As far as the damping is concerned, this is likely to be unrealistic since it does not account for the locally enhanced dissipation arising from stratospheric Rossby wave breaking.

In the present study, a parameterisation for Rossby wave breaking (Garcia, 1991) is applied to obtain an improved representation of wave damping throughout the stratosphere.

Although solving for the wave turns into a non-linear problem, the model remains linear in the sense that both the basic state zonal wind and the wave at the tropopause level are specified and kept fixed.

The divergence of the Eliassen-Palm flux and the steady-state residual circulation are computed in order to diagnose the impact of the waves on the mean flow. Both quantities depend sensitively and in a complex manner on the given basic state zonal flow. The model is applied to different scenarios representing the different phases of an idealised QBO.

The dependence of the wave forcing on the phase of the QBO is consistent with results from previous studies. The current model allows a clear attribution of differences in wave mean-flow interaction to differences in the basic flow.

P/1-6.17

The stratospheric aerosols and their influence on the weather and the climate in the Great Caribbean.

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A priori knowledge on the future behaviour of the weather and the climate in a given region, in the event of the presence of Stratospheric Aerosol (SA) of volcanic origin, it is of crucial importance, due to the multiple repercussions that the same exerts on a great diversity of socio-economic and ecological activities.

It is widely known that the most likely global and direct response expected of the radiative forcing, by SA, is the warming in that zone of the atmosphere, and cooling in the land surface. However, to regional scales, the hydrothermodynamic adjustments to which are submitted the different components of the climatic system, induce several types of responses; particularly through those designated feedbacks related to the atmospherical circulation, that at the same time modify the rest of them.

Tropical cyclones (TC), Easterly Waves (EW) and Atmospherical Fronts (AF), appear between the principal synoptic systems, that with their frequency, intensity and trajectories, conform the weather and climate of the Great Caribbean, and certify on a large part of their variability, under their specific interactions with the Intertropical Convergence Zone, the Subtropical Anticyclone of the Azores and the Polar Continental Anticyclone of North America.

In the present work was analysed the historical behaviour of the TC, EW and AF, applying the method of the integral curves of the modular coefficients, in long chronological series of annual frequencies, 1886-1999, 1967-1999 and 1916-2000, respectively. Furthermore, through the methods of the disturbances and that of superposed epoch, it could be determined the degree of influence of the Volcanic Eruptions (EV) from 1869 to 1999, generating of SA, on the occurrence of such atmospherical systems, the one which, upon depending on the such eruptions intensity, the geographical location on the same, as well as on the conditions on the Stratospheric transport in the moment of their occurrence, for these reasons was necessary to stratify the information of the sample according to:

- The magnitude of the Volcanic Explosivity Index (VEI).

- The discrimination in two types of Volcanic Eruptions, the Tropical (TVE) and the Extratropical (ETVE).

Occurrences of the eruptions in the first or in the second semester of the year.

The most general aspects of such influence are:

- Each type of VE causes the greater anomaly on the frequency of that synoptic system, whose genesis elapses in the region of the eruption occurrence.
- For a given synoptic system, response to both types of VE, elapses generally in counterphase, though they can be distinguished the following regularities.

Both types of VE generate, predominantly, negative anomalies in the frequency of the TC, particularly during the first three seasons, with the greater anomaly in the second.
Both types of VE generate, predominantly, positive anomalies in the frequency of the AF, particularly during the first four seasons, with the exception of the ETVE, which generate the greater negative anomaly and occurs in the first seasons. The TVE cause positive anomalies to the beginning (two first seasons) and negative finally (the last to season), while the TVE make inverse.

Session 1
Stratospheric Processes and their Role in Climate

Subsession 1-7: Recent Ozone Loss

P/1-7.1

Sources of Southern Hemisphere mid-latitude ozone depletion during winter diagnosed with a Lagrangian box mode

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Analysis of ozone trends at Lauder, New Zealand indicate large negative trends in summer, weaker but significant negative trends in winter, and barely significant negative trends around the equinoxes. Export of ozone poor air from the Antarctic stratosphere following the break-up of the vortex is thought to contribute significantly to the summertime negative trends. The sources of the wintertime decreases are less well understood. A potential source is export of ClO from the Antarctic stratosphere during the period when Antarctic stratospheric temperatures are sufficiently low for polar stratospheric cloud (PSC) formation but the polar vortex is not yet well formed enough to prevent transport from high to midlatitudes. Elevated midwinter ClO levels have been observed by satellites and are thought to cause observed midwinter ozone depletion between 60S and 70S at the sunlight edge of the polar vortex.

The purpose of this paper is to investigate to what extent export of ClO from the Antarctic vortex during midwinter contributes to the observed midwinter decrease in ozone over New Zealand. ClO concentrations in the Antarctic stratosphere are based on a combination of MLS ClO data and a mapping procedure described by Connor et al., these proceedings. The permeability of the Antarctic vortex is diagnosed and ensemble forward trajectories from regions of activated chlorine during periods when the Antarctic vortex is weak are calculated. A Lagrangian box model is then used to calculate the ClO time evolution along those trajectories that terminate at midlatitudes. Potential impacts of these ClO levels on ozone concentrations are discussed.

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P/1-7.2

Mapping of active chlorine and bromine in the Antarctic vortex for studies of ozone loss

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Photochemical models tend to underestimate polar ozone loss rates when rates are relatively high and the sun is low. Modelling heterogeneous processes is fraught with difficulty (e.g. uncertainties regarding PSC phase, composition, and formation temperature) which may cause substantial uncertainty in the predicted loss rates. One way of mitigating this problem is to specify active chlorine and bromine (hereafter Cl* and Br*) and supply these as inputs to simpler homogeneous chemical models.

In this paper we make use of time series of ClO and BrO measured at Scott Base, Antarctica (78 S, 167 E) to estimate Cl* and Br* throughout the Antarctic vortex. ClO profiles have been measured at Scott Base with a microwave radiometer since 1996. BrO slant columns have been measured with a UV spectrometer since 1995.

The slant columns are combined with a climatological profile shape to estimate the vertical profile of BrO. For Cl*, we first convert ClO to local time series of Cl* using a simple photochemical model. A regression analysis is performed on the measured time series to model them in terms of meteorological variables. From the regression coefficients and standard meteorological analyses, Cl* can then be extrapolated to other locations and times. A similar process is applied to BrO and Br*. The accuracy of the resulting distributions of Cl* and Br* is assessed by evaluating their sensitivity to assumptions in the analysis and by comparisons to available measurements and the results of a 3-D model calculation.

P/1-7.3

Measurements of stratospheric descent rates in the Antarctic vortex core, and estimates of NOy removal during the polar winter

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There has been debate whether the Antarctic winter vortex acts as a 'continuous flow' chemical processor, or as a 'containment vessel' within which vortex air is trapped for a significant period during the winter. The rate of descent of air in the winter vortex is the key in this debate. Moreover, descent alters the proportions of various chemical species found at a given altitude, and through changes in ambient pressure and temperature, affects reaction rates and subsequent partitioning. Various theoretical analyses have been carried out to determine rates of vertical transport from observed meteorological data fields, and satellite observations of various tracers (e.g., methane, NO_2) have been used to quantify descent. In the present analysis, we use mm-wave spectroscopic measurements of various species over prolonged periods in the winter vortex core over the South Pole to determine rates of core descent. Observations of NO_2 serve to determine rates in the lower stratosphere, while new measurements of CO categorise injection and descent of air from the mesosphere into the upper and mid-stratosphere. Derived descent rates will be compared with those from other studies, including those from our own measurements of mid and upper stratospheric ozone and HNO_3 in 1993, 1995, and 1999. These descent rates favour the 'containment vessel' view of the Antarctic vortex. Finally, we show from observations of descent and conversion of NOy to HNO_3, followed by condensation into PSCs and gravitational subsidence, that cryogenic removal of up to 3-4x10^8 kg of stratospheric NOy may occur over Antarctica each winter.

P/1-7.4

A model study of Northern Hemispheric winter and spring 1997-1998

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According to the various ozone measurements, the northern hemispheric winter and spring 1997 was quite different from the winter and spring of 1998. During 1997 both space-borne, and ground based measurements exhibited relatively long-lasting areas of low ozone throughout the season. The next season, winter and spring 1998, however, was quite different, since only few events of low total ozone were observed during the season.

In this study we present results from a global middle atmospheric simulation of 1997-1998 using FinROSE-CTM-model. Our objective is to study the differences between 1997 and 1998, particularly from the 'transport versus chemistry' point of view. Our preliminary results suggest that the role of transport is of primary importance to the high-latitude winter/spring middle atmospheric ozone distribution due to the year to year differences in large-scale middle atmospheric circulation.

While during winter-spring season 1997 the low values of the total ozone were rather clearly connected to the chemical processing, the winter-spring season of 1998 was more transport driven, even though significant chemical processing of ozone was present.

The overall performance of the FinROSE-CTM-model, and the general importance of the constituent transport scheme functioning will be also discussed.

P/1-7.5

The evolution of chemical ozone loss in the Arctic stratosphere over the last eight years as observed by MATCH

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The chemical ozone loss in the Arctic stratosphere during winter has been measured with the MATCH approach since 1991/92. The Match technique uses Lagrangian ozone measurements that are achieved by the co-ordinated launches of several hundreds to more than thousand ozonesondes per winter from a network of 30-40 closely co-operating stations. By using a Lagrangian approach, the chemical ozone loss is isolated from the strong dynamical variability of the ozone layer during Arctic winters. The spatial distribution and temporal evolution of the chemical ozone loss during the last eight Arctic winters is presented and discussed in the context of Antarctic ozone loss observations. It is shown that the stratospheric ozone loss is extremely sensitive on the stratospheric temperature evolution. Up to 60-70% local chemical ozone destruction has been observed during the coldest Arctic winters (e.g. 1994/95,1999/00) but no measurable loss was found in winters when temperatures stayed consistently above the threshold for the formation of Polar Stratospheric Clouds (e.g. 1998/99). The combined effect of transport and chemistry on the evolution of Arctic ozone columns during the last decade is presented.

FOCUSED DISCUSSION SESSIONS

WEDNESDAY, NOVEMBER 08

Session 2
Stratospheric Indicators of Climate Change

Subsession 2-1: Observational Platforms and Measurements
Subsession 2-2: Changes in Species (non-ozone)
Subsession 2-3: Changes in Ozone
Subsession 2-4: Changes in Temperature
Subsession 2-5: Data Analysis and Model Studies

Session 2
Stratospheric Indicators of Climate Change

Subsession 2-1: Observational Platforms and Measurements

P/2-1.1

The European Space Agency's Future Atmospheric Chemistry Missions

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Space-borne instruments are essential tools for atmospheric measurements on a global scale. The European Space Agency is engaged in space-borne observations of land, ocean, cryosphere and atmosphere. Atmospheric chemistry sounding instruments are playing an important role in ESA's Earth observation strategy. The presently operating GOME instrument on ERS-2 will be followed by an improved version onboard the Metop satellites.

Envisat, ESA's largest Earth observation satellite so far, which is due to be launched in 2001, will carry ten scientific instruments, including three atmospheric chemistry sounders. In the future, atmospheric composition sounding missions can be realised within the Agency's new concept for Earth observation, the Living Planet

Programme. Within this programme, two types of mission are possible, namely the operational Earth Watch Missions and the research/demonstration Earth Explorer Missions, which are driven by user needs. Two classes of Explorer Missions exist, namely the larger, ESA-led Core Missions and the smaller Opportunity Missions with a fixed funding limit. Two Core and two Opportunity Missions have already been selected. A call for ideas for future Core Missions is expected.

In preparation of potential future missions, ESA is conducting scientific and technical studies related to atmospheric science. These deal, for example, with observation equirements for an atmospheric chemistry mission, data retrieval and data assimilation techniques, millimetre and sub-millimetre spectroscopy, OH profiling by FIR limb sounding and an airborne simulator for a millimetre-wave limb sounder.

P/2-1.2

The use of ATOVS-AMSU data and the effect on detection of climate change in the stratosphere

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The Stratospheric Sounding Unit (SSU) on-board the NOAA operational satellite series has been the major source of satellite stratospheric temperature information since about 1979. This era, however, is coming to a close as the last of these instruments was launched on NOAA-14 in 1996. While this instrument continues to function, ultimately it will be replaced by the Advanced Microwave Sounding Unit (AMSU) instrument first flown on the NOAA-15 polar orbiting environmental satellite in June 1998.

AMSU instruments are scheduled to operate on all NOAA polar satellites for at least the next 10 years. As the AMSU provides radiometric information from 6 stratospheric channels as opposed to 3 SSU channels, we may expect positive impact on the stratospheric temperature retrievals. The purpose of this paper is to illustrate the anticipated effects of this change and the impact it will have on detection of the temperature change in the stratosphere.

P/2-1.3

The APE-GAIA campaign: Airborne Polar Experiment - Geophysica Aircraft in Antarctica"

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A research campaign of the M55-Geophysica high-altitude aircraft has been carried out from the base of Ushuaia (Argentina; lat 54°S; long. 68°W) in the period 15th September - 15th October 1999, to study the chemical and dynamical mechanisms involved in stratospheric ozone destruction between the end of the ozone depletion and the beginning of the recovery phase (APE-GAIA campaign, Airborne Polar Experiment - Geophysica Aircraft In Antarctica). The aircraft, equipped with remote-sensing and *in situ* instruments for observation of atmospheric chemistry and microphysics, performed five scientific flights over the Antarctic Peninsula investigating the mixing between mid-latitude and polar air masses, as well as specific events such as the formation of lee-waves induced PSC and extrusions of filaments out of the polar vortex.

A general overview of the APE-GAIA campaign is reported and the main operative and scientific results obtained during the mission are discussed.

P/2-1.4

Status of the METOP-1 Program at ESA

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The European Space Agency's mandate include to undertake research, development and demonstration of Earth Observation related space technologies. The Metop satellites, which prototype is planned for mid 2003, will be the European contribution to the world meteorological polar satellite system, replacing the "morning" satellites, provided by the U.S. until then. Metop will embark a NOAA payload, plus European advanced instruments. The satellites are being developed by ESA in co-operation with EUMETSAT, which has the overall responsibility of the European Polar System EPS, which main objective is to furnish data for operational meteorology. Some instruments on Metop, including one using occultation methodology (GRAS) will provide detailed information on the atmospheric temperature/humidity profiles, essential for weather forecasting and climate monitoring. Other parameters will be available from the scatterometer (ASCAT) and the global ozone instrument (GOME-2) continuation of the successful ERS series. The use of Metop data is expected to contribute to the improvement of meteorological and other applications, plus to Earth Sciences research. Industrial activities for the manufacturing of the satellites started in February 1998, under the leadership of MMS (F).

P/2-1.5

TRIANA - The first deep space climate observatory

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From its location in deep space, Triana will view the Earth in a different way - as an entire planet rather than a patchwork of regions of interest. It will uniquely acquire synoptic (all regions in the sunlit side seen simultaneously) sunrise to sunset, high time resolution data for most points on Earth using state of the art, highly accurate, in flight calibrated instruments.

Triana will collect information on the climate system combining atmospheric dynamics, cloud physics, aerosols, radiation and surface remote sensing. For example, the continuous measurement of the infrared radiation emitted by Earth in the direction of L-1, will provide a stable, highly accurate thermal emission reference parameter, that is thought to be correlated to the temperature at the surface. These measurements will be tested as a surrogate for surface temperature measurements in monitoring "global warming" and climate variability.

Ozone measurements will be used to study upper atmosphere circulation using ozone as a tracer. This is uniquely possible for Triana because it has the necessary synoptic view and temporal and spatial resolutions to allow the description and study of dynamic processes in the upper atmosphere.

Surface ultraviolet exposure estimates will be enhanced by the continuous daylight view, surface remote sensing (including the oceans and vegetation canopies) will be made possible by Triana's location near the direction of the opposition effect ("hotspot").

Measurements of solar wind magnetic field and plasma (density, velocity, and temperature) will provide data to study turbulence and solar corona heating and the slow solar wind. Solar wind events will be "seen" by Triana approximately 50 minutes before reaching the Earth's magnetosphere- providing enough time to issue warnings to protect sensitive systems (satellites, etc)

In the Educational front, views of the Earth spinning through the blackness of space, showing details of its surface and atmosphere, will be distributed to schools and the general public. These touching views of our world used as a teaching tool, will inspire the quest for knowledge, a quest that we will support with public and elementary to higher education outreach, teacher training and research opportunities for undergraduate and graduate students. TRIANA may well be the first Deep Space "climate satellite" and has the potential to prove the unique usefulness of deep space observation points such as L-1 or L-2, for Earth Sciences. TRIANA is scheduled for launch in early-mid 2001.

P/2-1.6

GPS-based global atmospheric sounding with low Earth orbiters

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Recent small satellites in low earth orbit, like the proof-of-concept experiment GPS/MET, the German satellite CHAMP (Challenging Mini-Satellite Payload for Geophysical Application), or the argentine SAC-C mission, utilise the bending of the radio signals of the Global Positioning System (GPS) on their path through the atmosphere as a mean for remote sensing the atmosphere's thermal structure. By measuring excess path delays of the GPS signals during occultation events stratospheric temperatures and tropospheric moisture abundance can be derived. The limb sounding geometry provides a vertical resolution of 1km or better; highest temperature accuracies are obtained in the lower and mid stratosphere. A single satellite like CHAMP provides about 150 - 200 daily profiles of stratospheric temperature and tropospheric water vapor.

In the framework of the CHAMP mission, additional products like geopotential heights, tropopause characteristics, and estimates of stratospheric gravity wave parameters will be provided. Detailed comparisons of available GPS radio occultation data with ancillary meteorological data from, e.g., the global radio sonde network and operational atmospheric analyses, will be presented in order to assess the quality of such data products derived from GPS remote sensing data using present day retrieval techniques.

P/2-1.7

A new NF radar at Syowa station, Antarctica

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An MF radar was installed at Syowa station, Antarctica (69S, 39E) and started continuous operation in late March 1999. Since then, it has been observing wind fields with a fairly good quality.

At times, echo returns from altitude as low as 50km are detected. The observed wind data reveals the behaviour of atmospheric gravity waves, tides and longer-period waves. The radar has been also operated as a meteor radar since May 1999. It can give wind information at least up to 110km altitude during night-time. Comparison of the wind values from the two methods suggests that some discrepancy still remains to be resolved. It must be noted that global collaboration with longitudinal chain of MF radars in Antarctica, TIMED satellite, and conjugate observations made in Arctic region are expected to work well in clarifying the wave dynamics in the polar upper atmosphere.

P/2-1.8

GREENSKY - Greenhouse gas measurements from satellite observations for Kyoto protocol application

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The GREENSKY project proposes to make better use of the forthcoming data from the ESA ENVISAT satellite (launch 2001), in particular SCIAMACHY and MIPAS data, complemented by the NASA EOS-Terra-MOPITT data (launched Dec 1999). The objective is to investigate the feasibility of an independent global observing system for monitoring the emissions of a number of important Kyoto Protocol greenhouse gases CO_2, CH_4 and N_2O. Complementary measurements of related, chemically reactive and/or highly variable tropospheric and stratospheric gases O_3, CO, NO_2, and H_2O and relevant physical quantities on albedo and cloud will also be carried out. The global measurements include emissions from remote regions and the potential sinks in oceans not covered by the measurements made by the limited set of ground based monitoring sites currently available. It also covers emissions from countries that are not signatories to the Kyoto Protocol. This is a necessary precursor for the assessment of global change and its anthropogenic component.

The GREENSKY project will pay special attention to regional and seasonal variations in the emission fluxes around the globe. In order to achieve this objective appropriate algorithm development for the retrieval of columns and altitude profiles of the amounts of the target gases will be carried out. Subsequently, these data will be assimilated into atmospheric chemistry transport models to establish surface fluxes (emission or deposition). A top-down approach or "inverse modelling" of emissions at the regional scale, derived from atmospheric space measurements is pursued. Similarly, radiation transfer models will be employed to assess implications of the GREENSKY measurements for both the Earth radiation budget and radiative forcing issues. The quality of the measurements is expected to lead to improved model performance. The project will establish a baseline for global emissions in the year 2002. The present status of the project will be presented at the SPARC 2000 conference.

P/2-1.9

The Brewer ozone sampling in Ushuaia and Belgrano II

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The activity of the National Italian Antarctic Project (PNRA) concerning the Ozone Hole studies culminated with the APE-GAIA Project campaign during the 1999 spring has utilised the two spec-trophotometers Brewer sited in the Argentinean territory, Ushuaia, and the Argentinean Antarctic base, Belgrano II respectively. The measure of total and vertical profile Ozone content with ground based instruments is very important for two kinds of reasons. The first, of course, is for knowledge of the local Ozone levels for studies about their effects on the biosphere. The second is to have a reference value for the satellite monitoring.

The paper shows some results about the Ozone trend in the two sites and, using the analytical model outputs during the APE-GAIA Campaign as reference, the influence of the cloudiness on the sampling, as total content and vertical profile both.

P/2-1.10

Assessment of the performance of ozone sondes to measure long term changes of ozone in the upper troposphere and lower stratosphere

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Up to an altitude of about 20 km ozone sondes constitute the single most important data source with long term data coverage for the derivation of ozone trends with sufficient vertical resolution, particularly in the important altitude region around the tropopause. Furthermore, in the lower/middle stratosphere up to 30-35 km altitude ozone sondes are of crucial importance to validate and evaluate satellite measurements for long term stability assessments.The paper will start with a brief overview of the major conclusions reported in the SPARC-Ozone Trend Assessment with regard to the performance of the vertical profiling capabilities of ozone sondes. In the scope of this assessment the paper will focus on the results of recent investigations about the instrumental performance of ozone sondes obtained from the different JOSIE (Juelich Ozone Sonde Intercomparison Experiment) experiments. Since 1996, several JOSIE-experiments have been conducted in an environmental simulation chamber at Forschungszentrum Juelich (Germany). The Juelich laboratory has been established as World Calibration Facility for Ozone Sondes (WCFOS). Its major role is the regular assessment of the performance of different types of ozone sondes which are commonly used within GAW (Global Atmosphere Watch), and NDSC (Network for the Detection of Stratospheric Change).

JOSIE-results will be discussed with regard to the influence of instrumental sonde factors and their uncertainties on the long-term trends derived from ozone sounding data. Special attention will be paid to the performance of Electrochemical Concentration Cell (ECC) sondes and the recent controversial issue of the change of the chemical composition of sensing solution which may cause a change of sensitivity of the ECC-sensor by evaporation during flight while its impact on the interpretation of ozone trends is not understood.

P/2-1.11

MU radar, temperature sheets and interferometry observation, a first report for MUTSI experiment

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The MU radar Temperature Sheets and Interferometry (MUTSI) project is the result of a co-operation between RASC (Radio Science Center for space and atmosphere, Kyoto, Japan), LSEET (Laboratoire de Sondages Electromagnetiques de l'Environnement Terrestre, Toulon, France), and SA (Service d'Aéronomie, Paris, France). It will consist in launching 10 small 'capsphere-type' balloons equipped with instrumented borne gondolas near the MU radar site (Shigaraki, Japan 34.85N, 136.10E). This original radar-balloon experiment aims to improve our knowledge in physics of radar measurements in different observational modes (-DBS-Doppler Beam Swinging, -FDI-Frequency Domain Interferometry, -SDI-Spatial Domain Interferometry) and to get information on the temperature field in the stratified lower atmosphere at small scale and their relationships with dynamics at larger scales.

The measurement campaign has been carried out on May 10-31, 2000.

P/2-1.12

GPS radio occultation with CHAMP - Algorithms and data processing

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Radio occultation measurements of the atmosphere's thermal structure utilising the Global Positioning System's (GPS) micro wave radio signals are a new and promising remote sensing technique with applications in the upper troposphere and lower to mid stratosphere. The main atmospheric products derived from GPS based limb sounding measurements are profiles of stratospheric temperature, tropospheric water vapor, and pressure. The German satellite CHAMP (Challenging Mini-Satellite Payload for Geophysical Application), launched earlier this year, is the first mission aiming at both a pre-operational data processing as well as a quasi-continuous monitoring of these quantities.

The POSTER gives an overview on the algorithms implemented in CHAMP's processing system, converting raw GPS signals and orbit information into the 150 - 200 atmospheric profiles CHAMP delivers daily. Methods to calculate additional products available from the CHAMP GPS radio occultation mission - like geopotential heights, estimates of stratospheric gravity wave parameters and regular validation statistics - are also discussed.

P/2-1.13

Winter Arctic Stratospheric Temperature Accuracy in Meteorological Models from Long Duration Balloon Measurements

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Long duration Infra-Red Montgolfier balloons carrying a variety of instruments have been flown in the winter Arctic vortex in 1997, 1999 and 2000. The flights, lasting for 7 to 22 days, have allowed the study of several ozone loss related processes. Among the results difficult to tackle by other methods is the evaluation of the accuracy of wind and temperature of global meteorological models in the stratosphere used to simulate the ozone loss. Night-time temperature (± 0.5 K accuracy) measured along the flights between 4 and 100 hPa have been compared to those of ECMWF 31 levels, DAO, NCEP, UKMO and the new ECMWF 50/60 levels now available. In the mid-stratosphere around 5ˆ10 hPa, unexpected large systematic biases of up to ± 25 K could be observed in all models except the new ECMWF, likely related to the SSU (Satellite Sounding Unit) temperatures used in their assimilation scheme since there is almost no soundings above 30 hPa in the Arctic. At lower altitude around 50-100 hPa, the systematic discrepancy reduces but a large dispersion of ± 4-5 K remains to which mesoscale are shown to contribute for only little (<0.7 K). A significant improvement seems to have been achieved by the new ECMWF 60 levels version assimilating radiances of the narrow vertical resolution AMSU (Advanced Microwave Sounding Unit) now in operation. Indeed, the deviation with the measurements on the whole altitude during a 18 days flight in 1999 reduced to + 0.2 ± 1.4 K.

Similar studies have been carried out for the wind by comparing actual and simulated trajectories. ECMWF trajectory errors larger than that of NCEP and UKMO in the past, have considerably reduced after introduction of a variational data assimilation scheme in 1996. As for temperature, they are now substantially smaller than that of other models.

P/2-1.14

Long-term spaceborne monitoring of ozone, UV and trace gases: EUMETSAT satellite application facility on ozone

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EUMETSAT has decided to widen its activities towards atmospheric chemistry and climate measurements from satellite instruments. The new polar orbiting satellite system of three consecutive satellites (EPS/METOP) will carry onboard GOME-2, HIRS 2/3 and IASI instruments, which allow retrieval of ozone (total and profiles), UV, NO_2, SO_2, OClO, BrO, HCHO and aerosols. METOP-1 will be launched in 2004, and the whole programme will last at least until 2018. The processed data is expected to be especially valuable for monitoring of long-term changes in ozone, UV and several stratospheric and tropospheric trace gases. Besides EPS EUMETSAT will launch geostationary Meteosat Second Generation in 2002 with e.g. SEVIRI instrument for ozone retrieval onboard.

Relevant algorithms for ozone, UV and trace gas retrieval are developed as a joint effort of nine European institutes. EUMETSAT is partially funding the Ozone SAF development work, which was started in 1997. Total ozone, ozone profile and UV products are planned to be validated operationally. Ozone and UV data will also serve operational end-users, like ECMWF. The expected products and research activities will be presented.

P/2-1.15

Analysis of the ozone column and profiles of ozone over Huancayo, Peru (12° 02'S, 75° 47'W)

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In this paper, in progress, are analysed the total ozone column and their corresponding profiles gotten starting from the Umkehr curves, particularly the year 1988, registered in the Huancayo Observatory (12° 02'S, 75° 47'W). A annual average curve was made considering 29 years, with the values of the total ozone column registered by the Dobson (station #110). The Umkehr curves was analysed in periods where the anomalies of the ozone column occurred, coinciding these anomalies with the registered for other authors. This advance paper shows the analysis of the behaviour of the Umkehr curves during periods of anomalies in the ozone column.

Session 2
Stratospheric Indicators of Climate Change

Subsession 2-2: Changes in Species (non-ozone)

P/2-2.1

SAGE II measurements of Mount Pinatubo aerosols: tropical and midlatitude validation with a lidar network

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During the first several months following the June 1991 Mount Pinatubo eruption, the largest of the 20th Century, discrepancies were reported between the optical depths measured from SAGE II and other instruments like AVHRR and the Mauna Loa Sunphotometer. We have collected global lidar data for that period, providing an independent dataset to investigate such discrepancies. Realistic extinction-to-backscattering coefficients have been derived using Mie theory and dustsonde- and UARS-derived particle size distributions. Aerosol optical depths derived from low latitude lidar are in better agreement with AVHRR and Mauna Loa Sunphotometer measurements than with SAGE II. We characterise the differences using lidar-SAGE II coincidence criteria, which, take into account the aerosol cloud variability. Vertical extinction profiles of individual coincident SAGE II-lidar measurements are also analysed. The importance of having complementary lidar measurements of aerosols to the limb-scanning satellite measurements under volcanic conditions is addressed.

P/2-2.2

Evolution in aerosol loading at mid-latitudes

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The evolution of stratospheric aerosol was analysed by using lidar data collected at mid-latitude sites. Data coming from stations in Germany (Garmish Partenkirkchen), France (Observatoire Haute Provence), Italy (Florence/Brasimone), New Zealand (Lauder) were used to monitor the changes in the aerosol characteristics over the past nine years. Results for two polar stations are shown for comparison. Integrated backscattering, mass content and the surface area density were evaluated for the green wavelength of the Nd-yag laser, with the decay time constant giving an indication of the size of the aerosol particles. The scattering ratio was used to monitor the evolution in the altitude of the aerosol layer during the period under investigation. Optical depth was computed for the 532nm wavelength.

After the last volcanic eruption, the climatological analysis showed an increase in the altitude of the aerosol layer and in its loading, and then the slow decrease to a background situation. This behaviour was confirmed by the increase in the integrated backscattering decay time constant and the decrease in the aerosol dimension during the 1994-1998 period. In fact the decay time constant measured in the 3-years period after the eruption was about 1 year and half and it increased up to about 4 years during the last 5 years. These values are consistent with particles having dimensions ranging from 0.8-0.9 micron for the 1992-1993 period to 0.06 micron or less for the recent period. Climatological results have been given to the scientific community for a global revaluation of ozone profiles and trends.

P/2-2.3

Observations of cirrus clouds with lidar in Camagüey. Statistical analysis and their relationship with the tropical tropopause

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The study of the cirrus clouds is of special interest for the scientific community, because it have been recognised they have a great influence on weather and climate trough their effect on the radiative energy budget in the Earth' Atmosphere system. The behaviour of tropical cirrus have not still been very well understood. This paper presents the geometrical properties of cirrus clouds (transparent or semitransparent) measured with radar laser (Lidar) in The Meteorological Center of Camagüey (21.40º N, 77.92º E) during the period of 1993 - 1999. The results show in general for the Cloud Base and Cloud Top average, the values of 10.72 and 13.78 km respectively. While for the rainy period these variables have the values of 10.61 and 13.91 km and for the dry period 11.12 and 13.59km.

The contribution by the cirrus clouds to the concentration of water vapor in the Upper Troposphere, is presently under depth scrutiny. The scientific community is trying to understand its role in the hydrologic cycle of the planet. A discussion is carried out on to the relationship of the Cirrus Cloud Top with the characteristic height of the Tropical Tropopause obtained starting from atmospheric characteristic sounding from the region of study.

P/2-2.4

Total hydrogen budget in the stratosphere and long-term changes

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A series of balloon-borne measurements of CH_4, H_2, and H_2O will be used to assess the hydrogen budget in the stratosphere. CH_4 and H_2 data from a cryogenic whole air sampler are available since 1975. H_2O is measured by the Lyman-alpha hygrometer FISH and a frost point hygrometer of LMD-CNRS since the early 90s. Further, recent H_2O and CH_4 data from the MIPAS balloon instrument are used. The quality of the data will be discussed, based on the findings of the SPARC Water Vapour Assessment. The quantities $2CH_4+H_2O$, the mean entry level of H_2O into the stratosphere and the H_2O yield will be presented and compared to data of other institutes. Long-term changes of each single trace gas and of the derived quantities will be determined considering the age spectra of the data, which are determined from SF_6 and CO_2 measurements.

P/2-2.5

Stratospheric aerosol climatology derived from satellite solar occultation and infrared emission measurements

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A global climatology has been produced on the stratospheric aerosol that spans nearly 15 years, from December 1984 to August 1999. The climatology includes values and uncertainties of measured extinction and optical depth from 0.385 μm to 12.82 μm, as well as retrieved particle effective radius *Reff*, distribution width *sg*, surface area *S* and volume *V*. As a basis for aerosol retrievals, a multi-wavelength Look-Up-Table (LUT) algorithm has been developed that uses a combination of 4-wavelength Stratospheric Aerosol and Gas Experiment (SAGE) II extinction spectra (0.385-1.02 μm) and the Cryogenic Limb Array Etalon Spectrometer (CLAES) 12.82 μm extinction measurements. The LUT matches SAGE II/CLAES extinction ratios to pre-computed ratios that are based on a range of unimodal lognormal size distributions. By varying *sg*, the uncertainties in measured extinction are propagated to corresponding uncertainties in *Reff*, *S* and *V*.

Aerosol retrievals show notable increases after most major volcanic eruptions, with increases in *Reff* lagging increases in other parameters. Post-volcanic increases in *sg*, indicative of broader size distributions, are consistent with sudden increases in both small and large particle sizes. After Pinatubo, retrieved *Reff* and *sg* took nearly 5 years to return to pre-eruption values, while slightly shorter recovery times are obtained for *S* and *V*. Seasonal variations in *S* and *V* are observed at high latitudes (with high values occurring in winter), but are less obvious in *Reff*. Latitudinal banding is often noted in retrievals in a layer just above the tropopause, with high values occurring in the tropics and at high latitudes. The overall uncertainty in retrievals is approximately ± 20% for *S* and *V*, with slightly smaller values for *Reff*. Results were compared to several previously developed stratospheric aerosols climatologies, and with few exceptions, agree well with these climatologies.

P/2-2.6

Trends of trace gases, total chlorine, and total bromine in the lower stratosphere from 1991 through 2000.

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In situ measurements of a number of trace gases including CFC-11, CFC-12, CFC-113, methyl chloroform (CH_3CC_{l3}), carbon tetrachloride, halon-1211, sulfur hexafluoride (SF_6), nitrous oxide (N_2O), and methane (CH_4) were made using airborne gas chromatographs (Airborne Chromatograph for Atmospheric Trace Species, ACATS, and Lightweight

Airborne Chromatograph Experiment, LACE) by NOAA/CMDL scientists starting in 1991 and continuing through SOLVE in 2000. These trace gases are plotted against time using surfaces of equal mixing ratios (isopleths) of N_2O that were corrected for its slow atmospheric growth. One of the most striking features is the quick propagation of the tropospheric peak of methyl chloroform in 1992 through the lower stratosphere within 2 years (to the 185ppb N_2O isopleth).

This peak is being propagated at a faster rate than transport models would predict and does so with a time scale that is shorter than the mean age of the air mass from simultaneous measurements of either CO_2 or SF_6. The peak broadens and diffuses out as it propagates into the lower stratosphere as models would predict. Using these *in situ* measurements and tracer-tracer correlations from the Whole Air Sampler and chemical models, unmeasured species containing chlorine and bromine can be calculated and used in the trends. The total organic peak of chlorine also propagates into the stratosphere within 2-3 years after the peak of tropospheric chlorine (between mid-1992 and mid-1994). Total organic bromine is increasing in the lower stratosphere throughout this time period because of the large reservoir of banked halons. If it does turn out that models have the chlorine and bromine budget decay incorrect, this will impact predictions of the recovery of the ozone layer.

Session 2
Stratospheric Indicators of Climate Change

Subsession 2-3: Changes in Ozone

P/2-3.1

The characterisation of ozone and temperature profiles over Marambio, Antarctic Peninsula

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Ozonesondes have been launched from the Argentine Antarctic Base Marambio (64°23' S, 56°72' W) since 1988, in Cupertino with the Finnish Meteorological Institute. These soundings are mostly made during the Antarctic ozone 'hole' season. One of the interesting aspects of measurements at Marambio is the fact that this station can be located within, on the edge of, or outside the polar vortex, depending on prevailing stratospheric conditions at the time of the ozonesonde launch.

With more than ten years of measurements it is now possible to attempt a characterisation of the ozone and temperature vertical profiles for the complete set of observations. The profiles are typified using the Principal Component Analysis method in the T-mode approach, i.e. the spatial analysis.

Once the model profiles are obtained these will be further discussed under the light of the position of the ozonesonde launch with respect to the polar vortex.

P/2-3.2

Intercomparison between TOMS/EP and southern cone ozone project (SCO3P)/WMO ground based ozone data

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In the present work we have extended the analysis of the relative difference between TOMS/EP total ozone data and the SCO3P stations placed in Argentina, Uruguay and Antarctica, in order to incorporate new data obtained at these stations and measurements done with AFO instruments, recently installed by WMO in Argentina. The calibration in Buenos Aires of the Dobson spectrometers with respect to the Boulder reference one made last December 1999, determined that all instruments, except Marambio one in some periods of time, agree within a mean of less than 1%. The analysis confirms the increase with latitude of the mean relative difference, from around 2-4% in the range 30º-50º S and greater than 5 % at higher latitudes. Particular attention is made to the comparison in Direct Sun conditions. Possible sources of these large relative differences are analysed, like change in satellite orbit, ozone hole and non ozone hole periods, before and after intercomparison of ground based instruments. The obtained results can be of importance in the *in situ* verification of the behaviour of ozone (fix and portable) instruments, the integration of ozone profiles and the definition of the extension and depth of the austral ozone hole.

P/2-3.3

Ozone over Marambio (64°23' S, 56°72' W), Antarctica during 1987-1999

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Long term ozone changes over Marambio have been studied using Dobson spectrophotometer total column measurements for the period of 1987-1999, and ozone mixing ratios at 435 K, 475 K and 550 K isentropic surfaces from ozone sonde measurements for 1990-1999. A classification of Marambios situation in relation to the polar vortex has been made using the potential vorticity and potential vorticity gradient analysis. Three classes have been selected: (i) inside vortex, (ii) outside of vortex and (iii) at the edge of vortex. The method is compared with some generally used other methods, and it seems that the method used in this study gives slightly better results. The classification for November, and for December is characterised by the fact that the vortex is normally in a state of breakdown during these months. During May, June and July there is markedly less data available than during the other months.

Eleven year (1957-67) means of total ozone at Argentine Islands (AI) (400 km SW from Marambio) are used as a pre-depletion reference. During months of January, February, March and April when there is no strong vortex the mean total column ozone at Marambio has been 277 Dobson units (DU), which is 6 % less than the long term mean at AI. There is no trend either in total ozone or in ozone mixing ratios at 435 K, 475 K and 550 K surfaces. During the August-December period the total column ozone outside the vortex in Marambio has been 305 DU, which is 9 % less than in AI during 1957-67. The Marambio total ozone inside the vortex has been on average 41% less than in AI. Statistically significant linear ozone trends inside the vortex are found in September at 435 K and 475 K surfaces (-10%/year) and in total ozone (-2 %/year), in October in total ozone (-3 %/year) and in November at 435 K surface (-6%/year).

P/2-3.4

An ozone anomaly over the Andean highland

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Analysing the ozone TOMS data, released by NASA, as function of latitude and longitude, a permanent anomaly for the total amount of ozone has been detected.

Actually the ozone column is found to be less than people would have expected just from considerations of latitude and altitude (Zaratti *et. al*., Nuovo Cimento C, Vol.22, N.2, pp. 145-152).

Surface instruments confirm these unexpected low ozone values over a region located at tropical latitudes between the two branches (East and West) of the Andes mountains, the so-called Altiplano.

Furthermore, an ozonesonde campaign, carried out in 1998, confirmed that the anomaly takes place at the stratosphere height. Moreover the ozone content in the troposphere was found to be as expected (10% of the total ozone column).

Some factors that may contribute to this result, for example atmosphere reduction, albedo, aerosols from forest burning are analysed, concluding that the most important factor should be the dynamical one.

P/2-3.5

Study of the Antarctic ozone depletion over Marambio

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During the last decades, special interest has been dedicated to the Antarctic ozone loss. Different stations were built to measure and develop their own statistical ozone database. In order to study the polar ozone decline, we present a statistical analysis of the ozone content over the Marambio Argentinean Antarctic station (64.2 S, 56.7 W) for the period 1997-1999. For this study, the position of the station with respect to the polar vortex is represented in a quasi-conservative space using the potential temperature and the equivalent latitude as an approximate vortex-following co-ordinate. This co-ordinate system frees the study from the dynamics of the polar vortex. The potential vorticity is computed from the ECMWF (European Center for Median Range Weather Forecasts) meteorological analyses. Besides, the inner and outer vortex borders are calculated from the potential vorticity second derivative as a function of equivalent latitude. Our study allows the polar vortex occurrences above Marambio to be identify and to determine whether the station is located inside, at the edge or outside the vortex, at various isentropic levels. The ground based ozonesondes measurements performed at Marambio as well as the SAGE and TOMS data over the station are then studied as a function of potential temperature and equivalent latitude in order to evaluate the springtime ozone loss. The seasonal variation of the ozone content in the different situations of the station with respect to the polar vortex is analysed as well as its interannual variability.

P/2-3.6

Relationship between total ozone amount and upper air data in Cuba

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Strong and significant statistical relations between total ozone amount and meteorological parameter of upper air has been good documented in middle and high latitudes. Recently statistical approaches have extensively used for short-term ozone forecasting in many countries of the world. The prediction of total ozone is required as a prerequisite for the calculation of the harmful solar UV radiation reaching the ground and consequently for the calculation of the UV Index.

However there are very few studies on the statistical relationships between total ozone and meteorological elements in low latitudes that found the use of the meteorological fields as good indicators for ozone in those locations where the day-to-day variability in the total ozone and weather tend to be smaller. In this paper the correlation coefficients of daily values of total ozone measured by TOMS and corresponding upper air data obtained from analysis have been investigated in La Habana, Cuba, during 1988-1992.In general it was obtained low values of the correlation coefficients between total ozone and the following meteorological parameter considered: temperature, temperature difference, gopotential height, thickness, zonal and meridional winds components, at the selected high standard pressure level (50, 100, 200, 500, 700hPa). From analysis of the TOMS overpass data series 1978-1993, version 7, was observed interdiurnal changes in the total ozone amount over Cuba seldom greater than about 10 per cent. It is show that the use of the upper air meteorological fields as predictors in a multiple regression model produce a forecast of total ozone in this Caribbean location not better than that obtained by a persistence forecast.

P/2-3.7

Effects of Asian monsoons and ENSO on atmospheric ozone in Malaysia

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The Malaysian Meteorological Service initiated its ozone monitoring programme in November 1991 commencing with the vertical ozone profile measurement, and following a year later with column ozone monitoring. The data set compiled is used to conduct a study on the effects of the Asian monsoons and ENSO on atmospheric ozone in Malaysia. Malaysia lies within the maritime continent of Southeast Asia, which is strongly influenced individually or interactively by the Asian monsoons and ENSO. The total column ozone exhibits marked seasonal variation, viz. two minima corresponding with the Northeast (Asian winter) and Southwest (Asian summer) monsoon whose vertical circulations serve to transport ozone to higher latitudes and two maxima, associated with the two transitional periods when the regional circulation is weak.

Interannual variations of ozone are strongly linked to the ENSO cycle. Concentration levels in both troposphere and stratosphere are enhanced in El Nino events because of weak or inactive monsoons and due to production of ozone associated with forest fires induced by El Nino, particularly the forest fire event of 1997. On the other hand, ozone concentrations are considerably reduced during near-normal ENSO conditions or in La Nina events because of relatively strong or active monsoon.

Surface ozone concentrations at a rural site were elevated during the 1997 severe haze episode when wind directions favoured the low level advection of ozone to the Peninsular Malaysia from forest fires in Sumatra. Under normal circumstances, ozone concentrations were similar to those found in regional air masses.

P/2-3.8

Variability in stratospheric ozone at Pohang, Korea

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The recent features of stratospheric ozone variability in Korea was investigated. Total and vertical ozone amounts have been measured at Pohang (36.0 N, 129.4 E) station using Brewer spectrophotometer and ozone-sonde for the period of 1995-1999. Strong negative ozone anomaly appeared at the layer of 17-25 km with the magnitude of 20-35 nano bar (nb) in December 1998-March 1999, while strong positive anomaly at 11-16km with 20-40 nb in December 1997-March 1998. The overall features of ozone anomalies are very similar with that of temperature anomalies in the stratosphere. In vertical, the maximum ozone amount - the ozone layer - is usually observed at 22-26 km, which has the highest value in February. There are quite large variabilities below and above the maximum ozone heights, up to 4 km below that the difference is about 50 nb, while up to 4 km above it is about 19 nb for January-May. Total ozone decreases at the rate of 6.0 DU/km in proportion to the increases of tropopause height. It means that the tropopause height changes might explain total ozone variations.

P/2-3.9

Trends in the vertical distribution of ozone and temperature above Northern Finland for the years 1989-1999 based on balloon borne sonde measurements

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Ozone profile measurements by ECC ozone sondes since 1989 are analysed for a high latitude site Sodankyla (67.4° N, 26.6° E). Careful attention is paid on the data quality issue, focusing on the pre-flight calibration records and comparative column data. The data set used for trend analysis forms one of the longest continuous series of ozone sonde profiles in the European sector of Arctic, by the end of year 1999 the time series covers one solar cycle. The soundings have been performed with the basic frequency of once per week throughout the year. During the winters additional soundings have been performed within stratospheric research campaigns. In this study statistical regression model is applied to ozone partial pressure. The model includes monthly means, seasonality, QBO, solar dependence and autoregressive term. Sensitivity of trends is tested for effects of tropopause height, Pinatubo aerosols and different sampling periods. Negative ozone trends are found in the lower stratosphere at and above ozone density maximum, while negative tendency increases with altitude. This feature is more pronounced in spring months. The analysed radiosonde temperature profiles over the 1990s from the same site indicate enhanced cooling in the lower stratosphere compared to available data from the earlier period, 1958-1990.

P/2-3.10

The regional variations of total ozone and tropospheric ozone in the south of Kazakhstan

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The background measurements of total ozone and tropospheric ozone were used in the paper. The observations were carried out in the Alatau mountain near Almaty-city. Spectrophotometer - ozonometer was used for measurements of total ozone. The observations of tropospheric ozone were carried out by the chemiluminescent ozonometer. The annual variations of total ozone were shown to have the maximum in winter months, minimum in summer months and the annual variations of tropospheric ozone have the maximum in summer, minimum in winter in this region. Such variations are typical variations for middle latitude in north hemisphere. Station of ozone monitoring is placed in zone with mountain - valley circulation. It is surrounded the city in the one side and mountain in other side. Comparison of total ozone and tropospheric ozone was carried out in period when pollution city smog comes to the ozone station. The tropospheric ozone value was shown to increase at noon in summer while variations of total ozone are insignificant. Such daily variations of total ozone and tropospheric ozone was not observed in winter. We concluded that in city photochemical smog of the Los-Angeles type presence in summer.

P/2-3.11

Tropopause height/total ozone relationships over Argentina

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In recent years a number of studies have shown links between variability and trends observed for the tropopause and the behaviour and changes in the ozone layer. Most studies have referred to Northern Hemisphere locations.

The aim of this presentation is to discuss what is happening over the Southern Hemisphere, and more specifically over Southern South America. The analysis is carried out using 3 Argentine radiosonde stations datasets covering the subtropics to mid latitudes in a narrow longitudinal band (~60W), Resistencia, Ezeiza, Comodoro Rivadavia, together with the Buenos Aires Dobson station dataset as well as the TOMS retrievals. The impact of trends and variability in tropopause height upon the total ozone and how this relates to total ozone trends in the latitude band under consideration will be discussed.

P/2-3.12

Trends in total ozone measured by SAOZ network at polar circles, mid-latitudes and tropics

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Permanent monitoring of ozone by the SAOZ (Systeme d'Analyse par Observation au Zenith) Network of ground-based UV-visible zenith-sky spectrometers has been conducted since 1988 in the Antarctic, since 1990 in the Arctic, since 1992 at mid-latitudes and at the Tropics. SAOZ spectrometer measure total ozone twice a day at twilight, even in cloudy conditions. We will present here results from monthly averaged total ozone available from 8 to 12 years series at 7 stations. Trends from these series are computed with a special attention to the homogeneity of the series following recommendation given by the NDSC (Network for Detection of Stratospheric Changes).

P/2-3.13

Observation of trace gases from Australia (34°S) by means of ground-based solar FTIR spectroscopy, Part 1 : Seasonal cycles of 20 species

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Observation of trace gases from Australia (34°S) by means of ground-based solar FTIR spectroscopy, part 1): Seasonal cycles of >20 trace gases Since 1996 high resolution infrared spectra have been recorded in solar absorption geometry at Wollongong, Australia (34.45°S, 150.88°E). Currently we operate the only NDSC (Network for the Detection of Stratospheric Change) FTIR spectrometer between 19.5°N and 45°S, which makes our measurements valuable in the validation of present and upcoming space borne instruments.

We are presently involved in CRISTA-2, TERRA, ENVISAT, and SAGE-3. This is the first presentation of such data from Australia. In this presentation we will give an overview of the seasonal cycles of all species currently analysed including HCl, HNO_3, HF, CFC-11, CFC-12, CFC-22, HCFC-142b, O_3, NO_2, NO, C_2H_2, C_2H_6, COF_2, CO, CO_2, CH_4, N_2O, HCN, and OCS. Though not all of these molecules are strictly stratospheric they are nevertheless relevant to atmospheric processes that concern the stratosphere (e.g. the slowing down of freon releases).

Our data will be discussed in comparison with observations from other sites and will highlight some special events identified in the data (volcano eruption, biomass burning).

P/2-3.14

Observation of trace gases from Australia (34°S) by means of ground-based solar FTIR spectroscopy, Part 2 :Isotopic signals in N_2O, CH_4, O_3, H_2O, and HCL

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Observation of trace gases from Australia (34°S) by means of ground-based solar FTIR spectroscopy, part 2): Isotopic signals in N_2O, CH_4, O_3, H_2O, and HCl In addition to the companion presentation on the seasonal cycles of conventional trace gases retrieved from ground-based FTIR spectra above Wollongong, Australia (34.45°S, 150.88°E), this contribution deepens the discussion into isotopic signals obtained from the same data set. The retrieval of isotopic ratios from atmospheric FTIR spectra is an exciting new field.

We will present symmetry-resolved isotopic ratios of N_2O and compare them to results from balloon-borne FTIR from the Northern Hemisphere and to the analysis of sampled air. Isotopic ratios of ozone will be compared against space borne observations from the ATMOS mission and against ground-based FTIR observations from the Northern Hemisphere. In both cases are mass-spectrometer based techniques incapable of distinguishing between positional substitutions. Spectroscopy offers the inherent advantage to separate e.g. 14N-15N-O and 15N-14N-O. HCl, CH_4 and (mostly tropospheric) H_2O will be discussed as well. We will assess the current uncertainties of the new technique, showing that one of its main limitations in solar spectra is given by the limited accuracy of the spectroscopic data base currently used (HITRAN96). The usefulness of isotopic signals as tracers will be discussed as well as implications for the underlying formation processes.

P/2-3.15

Study of the instability of the ozone Antarctic hole and their consequences in the South Cone of America

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The study of the instability of the ozone Antarctic hole and their consequences in the South Cone of America between 1993 and 1994, it demonstrates that ozone Antarctic hole owes their formation to the stratospheric vortex polar, and their displacement and oscillations are related with the section of this vortex, existing a tendency of projections of ozone-poor air masses coming from the vortex over the natural axis of the Antarctic peninsula, that during periods of maxim intensity presents an East-West oscillation associate usually to incursions of polar masses of ozone-poor air coming from the polar vortex, towards the South cone of America, occasioning events of ozone depletion in mid-latitudes. In order to study this phenomenon, it developed a model of profiles distribution of stratospheric ozone associates with the events of ozone depletion in middle latitudes in South America between 1993 and 1994. They were carried out campaigns of mensuration of total ozone in the South cone of America in 1993 an 1994, it results a high correlation between the data of ozone registered by satellite (TOMS) and the gotten registrations *in situ* for the ground stations. This fact is of great importance in the study of the phenomenon, due to one would can to know the events of ozone depletion in periods and zones where the ground stations didn't exist, this was possible in the construction of the profiles utilising potential vorticity (PV) on isentropic surfaces. Applied the model with the NCEP/NCAR Reanalysis Project data and contrasting these profiles with the existent registrations in ground, it result a high correlation between the model distributions with the satellite and the events of ozone depletion.

Session 2
Stratospheric Indicators of Climate Change

Subsession 2-4: Changes in Temperature

P/2-4.1

A climatology of the tropopause height and temperature over Argentina

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Understanding the behaviour of the tropopause is important both to Climate Change and variability studies, as well as for understanding the changes that have taken place in the ozone layer. One of the main sources of information about the tropopause remains the observations made with the upper-air network, i.e. radiosondes. Tropopause observations by radiosondes are also relevant for the validation of the reanalysis products. The Southern Hemisphere is particularly lacking in upper air observations due to the large oceanic expanses, low populations and budgets. Hence it is particularly relevant to analyse the data available.

In this study data from 3 Argentine stations, Resistencia, Ezeiza and Comodoro Rivadavia, covering the subtropics to midlatitudes, in a narrow longitudinal band (~60W) east of the Andes, are statistically analysed. Tropopause height and temperature for the period 1973-1993 are studied in order to identify their variability as well as the occurrence of multiple tropopauses (following WMO definitions), annual cycles and trends. The results obtained will be compared with some of the current reanalysis products available.

P/2-4.2

Global analysis of MSU CH_4 temperatures: patterns of different spatial structures

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The MSU Channel 4 temperature anomalies are analysed with the Principal Component Analysis methodology in order to determine the groups of fields with similar spatial characteristics. To reach this result the distance matrix between the spatial fields is analysed. Both the raw fields and fields weighted by latitude (cos(phi))**0.5 for covariance and correlation matrices are considered. These 4 sets of results are all different. Hence a discussion on the methodology and its results is carried out. It must be noted that despite the differences the complexity of the temperature anomaly fields in both hemispheres is of the same order. The different patterns are discussed, together with their physical meaning and their temporal relevance.

P/2-4.3

Global analysis of MSU CH_4 temperatures: regionalization of distinct temporal behaviours

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The aim of this work is to determine regions of distinct temporal behaviour by isolating gridpoints with coherent temporal behaviour. The matrix of the distances between the different time series of the gridpoints is analysed.

The analysis was carried out using both correlation and covariance matrices. In the case of the covariance matrix with the data matrix weighted by (cos(phi))**0.5 was also studied.

The main result is that when the covariance matrix is used, with or without weighted data, the T signature at low latitudes is not significant in the first 8 modes, which explain 86% of the total variance. When the correlation matrix is considered the low latitudes signature appears in the mode which explains the most variance. This signal explains the effects of El Chichon and Mt. Pinatubo eruptions.

Other results of great physical significance, as well as a comparison between the covariance and correlation methodologies are discussed. The characteristics of the observed temporal variability of the different regions is discussed, and the corresponding spectra shown.

P/2-4.4

Trends and variability in upper troposphere/lower stratosphere temperatures

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Previous estimates of temperature trends are not completely consistent with one another. This is largely due to the difficulty in analysing data that are collected irregularly in space and time in the presence of large amounts of natural variability. Here, trends since 1985 are estimated in radiosonde temperature data between 200 and 30hPa using a new method which statistically treats the natural variability, and (given this treatment) achieves maximum-likelihood estimation of the desired trends and the climatology. Uncertainty estimates are obtained using the bootstrap method. The results clearly reproduce the well-known cooling in lower stratosphere, and show its spatial distribution and uncertainty. Trends at the tropical tropopause are small and vary with location. Variability in shorter and longer time-scale bands is also produced by the estimation method, and shows (for example) that synoptic temperature variability at the tropical tropopause is greatest on the equator rather than in the off-equatorial convergence zones. Further results and discussion will be presented.

P/2-4.5

Seasonal and interannual variability of stratospheric temperatures based on TOVS satellite data: 1987-1995

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Global observations from the satellites of the TIROS-N series, equipped with the HIRS-2 (High resolution Infrared Radiation Sounder) and MSU (Microwave Sounding Unit) radiometers permit the determination of atmospheric temperature profiles up to 10 hPa (about 30 km). At present time, more than 8 years of TOVS data (Jan 87 - Aug 95) have been reanalysed using the Improved Initialisation Inversion (3I) developed at Laboratoire de Météorologie Dynamique. Mean layer temperatures for the layers 100-70, 70-50, 50-30, and 30-10 hPa are thus available on a day-by-day basis, and also averaged over pentads and over months, with a spatial resolution of 1 degree in latitude by 1 degree in longitude.

Comparisons between monthly-mean temperatures obtained by 3I and produced independently by the Free University of Berlin over the Northern Hemisphere will first be presented and discussed. Then, the influence of the QBO, the ENSO and the Pinatubo eruption on the temperatures will be examined.

Results will also be discussed in the view of previously-published studies based on microwave satellite measurements.

P/2-4.6

Updated estimates of temperature trends in the Arctic stratosphere

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The temperature time series for the Arctic stratosphere (100 and 50 hPa) have been prolonged up to 1999 and updated trends estimates of the mean zonal temperature calculated. In agreement with earlier findings (SPARC-1996), negative trends prevail in the updated series. Although, analysed were fields of temperature based on 58 radiosonde stations north of 65°N. In summer and autumn, when the trends are most reliably determined, the characteristic feature is a zonal asymmetry of the trends distribution during most of the month, with somewhat greater cooling in the Siberian sector of the Arctic as compared to other sectors.

Session 2
Stratospheric Indicators of Climate Change

Subsession 2-5: Data Analysis and Model Studies

P/2-5.1

The persistence against a statistical model as tool for the forecast of total ozone at the Caribbean

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Statistical forecast methods of the total column ozone content has extended its use in many countries of the world. Accurate total ozone prognose is required as a prerequisite for the calculation of the harmful solar UV radiation reaching the ground and consequently for the calculation of the UV Index. Strong and significant statistical relations between the short-term variations of total ozone and a number of stratospheric and tropospheric meteorological parameters have long been good documented in middle and high latitudes. However there are very few documentation on such relations at those locations where the day-to-day variations in the total ozone amount and weather tend to be smaller. In this paper the correlation between the daily values of ozone measured by TOMS over La Habana, Cuba, and some upper air parameter from analysis are studied. It was obtained low correlation coefficient of the total ozone during the course of the year with the meteorological parameter considered (temperature, temperature difference, geopotential high, thickness, zonal and meridional wind components) at the standard pressure levels (50, 100, 200, 500,and 700hPa).It is show that the use of this meteorological fields as predictor in a regression model produce a forecast of total ozone not better than that obtained using persistence.

P/2-5.2

Total ozone as a stratospheric indicator of climate variability and change over an African tropical region

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The climate system, encompassing complex interactions between the different subsystems such as the oceans, the land surface, and the ice coverage of land and oceans, incorporates many feedbacks. These account for the systems behaviour. The El Nino/ Southern Oscillation (ENSO) is an example of a natural irregular climate fluctuation that involves extensive interaction between atmosphere and ocean. El Nino influences climate in distant regions *via* teleconnections. This has been evidenced, for instance, by consistent changes in precipitation in specific areas of the globe. Droughts in South-east Asia, parts of Australia, Parts of Africa, and heavy rainfall and flooding in arid areas of South America and East Africa have been observed during El Nino years. ENSO events have a significant economic impact on developing countries in the tropics. East Africa is not an exception, primarily through effects on food production. In this regard, therefore, the present work presents an analysis of the temporal characteristics of the ENSO-Total ozone relationship over Kenya in East Africa.

Dobson spectrophotometer and Total Ozone Mapping System (TOMS) total ozone data, together with ozone sounding data are used in the study. Statistically significant relationships between $NINO_3$ and total ozone in the first half of the year are observed. The long rains season over Kenya (March to May) suggest a negative connection with NINO3. The period before the start of the October-to-November (short) rains, on the other hand, depicts a positive relationship.

Connection between convective activity and total ozone's temporal pattern is also investigated. METEOSAT Cold Cloud Duration (CCD) data show appreciable relationship with total ozone over the region. Distinct patterns for the two rainy seasons are evident. The relationships suggest possible significant association between convective activity and possible tropospheric ozone production and/or stratospheric ozone redistribution. The results seem to show signs of applicability of total ozone over East Africa as an indicator of climate variability and/or change.

P/2-5.3

Inferring chemical loss in Arctic polar vortex air from tracer-tracer scatterplots

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The extent of denitrification and ozone loss in Arctic polar vortex air exhibits large interannual variability due to the strong temperature dependence of the processes involved. Significant denitrification leads to an increase in the lifetime of ozone-depleting chlorine species (ClOx), and therefore to an increase in the extent of springtime Arctic ozone loss. Small uncertainties in analysed temperatures make quantitative modelling of denitrication subject to potentially large errors, and this makes it particularly important that denitrification can be inferred from direct observations.

Previous attempts to infer denitrification from aircraft and satellite occultation measurements have involved the use of tracer-tracer scatterplots between total reactive nitrogen (NOy) and an approximately conserved species, typically N_2O. Springtime vortex correlations are compared to reference correlations taken from the extratropics, and any reduction in NOy is attributed to denitrification. However, this approach generally relies on the assumption that no extratropical air is mixed into the vortex over the course of the winter. Recent evidence suggests that weak mixing may take place continuously throughout the winter (as opposed to in a single discrete event at the end), and that this mixing can alter the tracer-tracer correlations in the absence of denitrification, potentially distorting previous results. A method to overcome this problem is suggested, using a linear combination of several conserved tracers to infer denitrification, even in the presence of mixing.

Results will be presented using aircraft and satellite occultation data from the 1992-1993 Arctic winter as well as from several idealised chemical transport model experiments. Difficulties with diagnosing ozone loss directly from tracer-tracer scatterplots will also be discussed.

P/2-5.4

On the influence of age on stratospheric chlorine trends - predicting the return to pre-ozone hole chlorine levels

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The decrease in CFC emissions is clearly visible in tropospheric and also stratospheric data sets of CFC mixing ratios. The question as to when this reduction in emissions will result in stratospheric chlorine levels which are comparable to the those observed before the onset of the Antarctic ozone hole is subject to considerable. We use observations of SF_6 and N_2O in high and mid latitudes to derive typical vertical profiles of the mean age of stratospheric air. These profiles, in combination with tropospheric trends as observed from the monitoring networks are used to determine past trends in stratospheric total chlorine and to derive the amount of chlorine present in the stratosphere at the onset of enhanced Antarctic ozone depletion. Possible future trends are predicted for three scenarios: (1) the baseline scenario of WMO, (2) zero emissions and (3) for a scenario with constant emissions at the level assumed for the year 2000 by the WMO scenario. The same method based on SF6 derived age is used to calculate the propagation of these trends into the stratosphere.

For zero emissions a return to pre-ozone hole chlorine levels is predicted for about 2050. Recovery will take about 10 more years if the emissions from the WMO scenario are assumed. On the contrary, if the chlorine emissions were to stay at the levels predicted by WMO for 2000 the chlorine loading is calculated to stabilise at around 2.6 ppb and pre ozone hole levels would never be reached.

P/2-5.5

Strong late summer episodes of low stratospheric ozone unrelated to ozone hole chemistry

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Strong uplifts or downlifts of stratospheric air induced by planetary waves throughout the ozone layer do significantly affect the stratospheric ozone content just by dilation or compression effects, without any variation of the ozone mixing ratio of the displaced particles. This effect is common in September and October around the Antarctic, where from times to times it generates macro-filaments of low total ozone content linked to the polar vortex. We have found very large decreases of the ozone layer depth at middle latitudes in late summer. Such decreases are indeed due to dynamical adiabatic processes independent of the existence of a polar vortex and of the corresponding ozone hole. This means that even without ozone destruction by chemical reactions, there are always times and places where the decrease of the ozone shield is strong enough to yeld hazardous health conditions at middle and high latitudes in late summer, when the mean stratospheric ozone depth is low. Particularly we shall show such an episode and his dynamical causes in Mar del Plata

P/2-5.6

Seasonal evolution of NO_2 and O_3 outside, at the edge, and inside the Antarctic polar vortex comparison with the SLIMCAT model

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A long term monitoring program for NO_2 and O_3 column by visible spectroscopy in the Antarctic region was initiated in February 1994 by an Agreement between INTA (Spain) and DNA (Argentina). Three unattended scanning spectrometers operating in short spectral ranges for NO_2 and O_3 observations were deployed at Marambio station (64ºS, 56ºW), Ushuaia (55ºS, 68ºW) and Belgrano station (78ºS, 35ºW) between 1994 and 1995. The instrument is a scanning spectrometer operating in zenith view mode at twilight using DOAS technique. The 6-year spectroscopic dataset available for all three stations are analysed and compared with SLIMCAT model. Belgrano station remains during the winter and most of spring well inside the polar vortex. The NO_2 column displays a strong, photochemically driven, seasonal wave being the spring build-up delayed almost two months of what would be expected from photochemistry as result of the strong denitrification in the stratosphere. Differences between years are small. NO_2 distribution over Marambio station displays a very strong seasonal wave with very low values in winter. A sharply maximum occurs around the summer solstice. The asymmetry between fall and spring is not significant even though in spring. The ozone data set shows a great variability during the spring from year to year connected to the position of the vortex. Over Ushuaia the pattern broadly follows that of mid latitude with small influence of the vortex. The SLIMCAT CTM model reproduce well the NO_2 observations in spring and the diurnal variability (am/pm ratio) but underestimates the column evolution in autumn. Small-scale dynamical features are not seen in the model because of its rough grid size but episodes of changes in the column due to strong temperature fluctuations occurring in spring are accurately reproduced.

P/2-5.7

Radiative impact of the Mt Pinatubo volcanic eruption: lower stratospheric response

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Volcanic aerosols in the stratosphere produce significant transitory solar and infrared radiative perturbations, which warm the stratosphere and cool the Earth's surface. Tropical eruptions affect the global heat balance by altering the solar and longwave distributions of radiant energy. They warm the tropical lower stratosphere and set up a meridional thermal gradient between the equator and pole, thereby affecting stratospheric circulation.

In this study we investigate these effects for the June 15, 1991 Mt. Pinatubo eruption using the GFDL SKYHI General Circulation Model. The investigation is carried out using an updated version of a comprehensive monthly-and-zonal-mean Pinatubo aerosol spectral optical properties dataset.

We performed an ensemble of 2-year GCM integrations using predicted clouds and climatologically varying sea surface temperatures, one set with and one set without stratospheric aerosols. The calculations confirm that solar forcing in the near infrared contributes substantially to total stratospheric heating. Over the entire global domain, the longwave radiative heating of the lower stratosphere exceeds the solar component. In contrast, the magnitude of the solar perturbation in the overall surface-atmosphere radiative heat balance exceeds that due to the longwave.

The temperature of the tropical lower stratosphere increases by a statistically significant 3 K. There is a temporal evolution in the meridional gradient of the lower stratospheric thermal structure, with a substantially warmer tropics; the modelled tropical warming is directly correlated with the evolution of the aerosol optical depth. Detailed results obtained on the radiative forcing due to Pinatubo aerosols and the temporal evolution of the lower stratospheric thermal structure will be presented and discussed.

P/2-5.8

Study of a relationship between interannual climate variability and interannual variability of ozone in the stratosphere and troposphere

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To study relationship between interannual climate variability and variability of ozone in the stratosphere and troposphere we use the University of Illinois at Urbana-Champaign (UIUC) Stratosphere/Troposphere Atmospheric Chemical Transport Model (ACTM). The photochemical routine of the ACTM includes all of the principal gas-phase and heterogeneous reactions involved in the production and loss of ozone. The meteorological quantities from the UKMO assimilated dataset (from 1993-2000) and the University of Illinois at Urbana-Champaign (UIUC) Stratosphere/Troposphere Atmospheric General Circulation Model,s 10 year output are used individually to drive the ACTM,s advective transport and photochemistry and create time series for ozone evolution.

Empirical Orthogonal Functions (EOFs) are calculated for obtained set of atmospheric chemical compositions and given meteorological quantities to define the principal modes of ozone and climate variability in the stratosphere and troposphere. The sensitivity of the principal ozone modes to different scenarios for intensity of the ozone chemical sources and sinks is determined. The later allows to define an importance of chemical processes for the ozone variability. Comparison of the principal modes for ozone and climate variability with the use of the Singular Value Decomposition (SDV) analysis allows to define an importance of variability of the circulation field for the ozone variability.

P/2-5.9

Polar stratospheric cloud formation in Antarctica: a possible feedback, in response to a stratospheric temperature decrease.

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Polar Stratospheric Clouds (PSC) are known to play a key role in the ozone depletion phenomena in the polar regions. Their influence could become less important as the abundance of chlorofluorocarbons (CFC) in the lower stratosphere is going to decrease during the turn of the century. Nevertheless, even after a decay of CFC concentrations has started, the role of PSC will remain critical as nitric acid and water vapour partial pressures in the stratosphere may increase as a result of aircraft emissions, and because stratospheric temperatures could decrease in response to tropospheric warming.

The PSC formation is primarily linked to temperature. Two types of clouds are distinguished [Poole and McCormick, 1988; Hamill *et al*., 1988]: water ice clouds (Type II), which from at temperature lower than the frost point, and nitric acid clouds (Type I), which exist for temperature 5 to 7 K higher than the frost point. Since 1989, lidar measurements of PSC are available at the French Antarctic station of Dumont d'Urville (66°S, 140°E), together with a long serie of radiosonde temperature measurements provided by Météo France. The quantities derived from the lidar signals, which include backscatter and depolarisation ratios authorise the determination of the type of the observed PSC. Here we present a correlative study of the evolution of the PSC formation as derived from lidar data, together with stratospheric temperature trends from radiosondes, during the last decade. These trends are compared with the PSC observation frequency and with the occurrence frequency of each type of clouds, in order to detect a possible feedback between a possible decrease of stratospheric temperatures and PSC occurrence. Such a feedback may have an impact on the future prediction of stratospheric ozone levels, despite the decrease of CFC abundance.

P/2-5.10

Long term global stratospheric circulation analysis by spectral expansions

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To give an objective characteristics of circulation patterns the spectral structure of stratospheric fields is analysed to compare the long-term behaviour and connections to some extra-terrestrial influences and circulation patterns. Two sources of data became available for this study: reanalyses of geopotential and temperature fields from Free University in Berlin available at 50, 30 and 10 hPa levels covering unregularly the period of 1976-96 that we have analysed in terms of spherical harmonics, and the huge database of reanalyses from NCEP, where appropriate spectral coefficients are available for the period 1948-now, four times per day at 28 levels for vorticity, divergence, temperature, etc. 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. Quite strong connections to a set of extraterrestrial, parameters appear for four trough shape of polar vortex. The natural variability connected to the extraterrestrial influence is studied as well as the inter-annual variability with the emphasis on the QBO and ENSO. The systematic review of the appropriate correlation is presented and an attempt to find some special case-study is discussed. The influence on and connections to the tropospheric circulation are also discussed in terms of coefficients of spherical harmonics.

P/2-5.11

Meteorology of the polar vortices

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As part of the EU Project PVC (Polar Vortex Change) NILU has acquired the ERA-15 data set for several meteorological parameters. This data set goes from 1979 - 1994. The data are global fields at 31 levels from the ground to 10 hPa. For the time period 1994-present we use regular T 106 data that are acquired on a daily basis from ECMWF. This long time series of data can be used for several useful studies of the long term development of the polar vortex. Several "environmental indicators" for vortex change have been calculated, and a climatology, as well as trends, for these parameters will be presented. These indicators can act as yardsticks and will be useful for understanding future changes in the polar vortex. Examples of indicators are: vortex mean temperature, vortex minimum temperature, vortex mean PV, vortex area, vortex strength (PV*area), vortex break-up time, maximum wind speed, amount of air passing through regions where $T<T_{NAT}$.

In the north polar vortex there are, over the time period 1980-2000, significant trends in the PSC area, vortex area, vortex strength and minimum temperatures for the later part of the winter (March and April). There is no significant trend for January and February. Table 1 shows the trends for these parameters.

Table 1. Linear trends (% per year). Uncertainties are 1 σ

Parameter	Jan	Feb	Mar	Apr
Min. Temp	0.04±0.08	-0.02±0.10	-0.16±0.07	-0.10±0.05
Vortex Area	-0.8±1.5	0.7±1.5	4.7±1.9	9.6±4.5
Mean PV	-0.1±0.2	0.36±0.29	0.69±0.29	0.38±0.17
Vort. strength	-0.8±1.0	0.3±1.1	2.7±1.3	5.2±2.9
PSC Area	-0.5±3.1	0.9±3.9	14.0±5.9	no PSCs

It can be seen from the table that in March and April most of the trends are larger than 2 standard deviation. We can therefore say that these trends are significant with better than 93% confi-dence. A similar trend study will also be made for the Antarctic vortex. In addition to presenting results on vortex climatology the study also shows what is available at the NADIR data centre in terms of ERA-15 extraction tools, software for calculation of special products and routines for visualisation of the data.

P/2-5.12

Analysis of the atmospheric dynamic during the depletion of the ozone column over the west coast of South America

L. Da Silva M.

Data on the ozone column published by NASA since 1978 show a clear decrease every summer in the ozone column along the west coast of South America, extending form Ecuador southward to approximately 33° latitude in Chile. The occurrence of these seasonal declines is further supported by Dobson data from the Instituto Geofisico at Huancayo (12° 02'S, 75° 19'W), Peru, and UV solar radiation data from the observatory at El Tololo (33° 23'S, 70° 47'W), Chile. To determine the characteristics of this phenomenon, satellite data were used to obtain cross-sections of the ozone column. When graphed, they revealed a significant decline in teh concentration of the column in the form of a depleted strip flanked by asymmetic areas of normal concentration. To find the cause of this depletion, an analysis was made of the regional wind field velocities and their vorticities at different heights. This produced evidence that the ozone layer is being compressed by winds coming from above and winds moving upward from the troposphere, causing a redistribution in ozone density.

FOCUSED DISCUSSION SESSIONS

THURSDAY, NOVEMBER 09, 2000
FRIDAY, NOVEMBER 10, 2000

Session 3

Modelling and Diagnosis of Stratospheric Effects on Climate

Subsession 3-1: Climatology
Subsession 3-2: Internal Variations in S-T Coupled System
Subsession 3-3: Responses to Forcings
Subsession 3-4: Trends

Session 3
Modelling and Diagnosis of Stratospheric Effects on Climate

Subsession 3-1: Climatology

3-1-1 GCMs

P/3-1.1

Status of the SPARC-GRIPS initiative

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Data Assimilation Office, NASA GSFC, Code 910.3 - Greenbelt, MD 20771 - USA

The GCM-Reality Intercomparison Project for SPARC is an initiative designed to provide a comprehensive assessment of our ability to model the present-day climate and the impacts of different physical perturbations. This POSTER will show the different scientific experiments being conducted in GRIPS and include some summaries of the results.

The three concurrent aspects of GRIPS are: (1) studies of the climate and transient features simulated by the models; (2) examinations of different parametrizations and their impacts on the model climate; (3) studies of the impact of physical perturbations, such as solar forcing, volcanic aerosols and ozone change. Sample results from a number of these areas will be presented, with discussion of their implications for our ability to model the climate of the present and future atmosphere.

P/3-1.2

The radiation-intercomparison project for GRIPS

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One initiative of the SPARC-GRIPS project is to study the impact of the physical parametrizations used in the different Climate Middle Atmosphere Models on the model's climatology and variability. In particular, the impact of the formulation of the radiative schemes on the cold polar bias that most GCMs display in the lower stratosphere, is of interest. This issue is studied in a GRIPS subproject by means of an offline intercomparison of the participating radiative schemes performing defined experiments with standardized input data.

Here, the project will be introduced and an overview of its current status will be given. The analysis of a first set of experiments has revealed large differences in the solar- and in the IR-heating rates for January between the seven participating radiation schemes. To find out reasons, additional experiments are going to be performed, first results of which will be presented.

Additionally, the sensitivity of the radiation schemes to changes in trace gas distributions, e.g. ozone, will be discussed. For that purpose, the heating rates of one of the radiation schemes using climatological ozone will be compared with those of the same scheme using observed ozone trends.

P/3-1.3

Intercomparison of polar vortex simulations in GRIPS GCMS

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Diagnostic techniques are applied to climatology (NMC and UKMO analyses) and model (several GRIPS GCMs) outputs in order to compare the ability of models to simulate the 4D lifecycle of polar vortices. One of the techniques employed for this model intercomparison is *via* the application of elliptical diagnostics to the vortex simulations.

In order to apply elliptical diagnostics to the polar vortex simulations we calculate daily Ertel's potential vorticity (EPV) contours on isentropic surfaces, which span the vertical extent of the models. The polar vortex on each isentropic surface is then defined as the EPV contour, which has the maximum EPV gradient and an ellipse is fitted to this contour. The most informative daily diagnostics which then come from the fitted ellipse on each of the isentropic surfaces are: the areal size of the ellipse, indicating the horizontal extent of the vortex; the motion of the centroid of the ellipse, indicating motion of the vortex off the pole; and the aspect ratio of the ellipse, indicating the extent of any elongation of the vortex.

Examination of these elliptical diagnostics, eg as time - height plots, then enable a compact method for the model intercomparison as well as to compare the model simulations with those from climatology. The results from these comparisons will be discussed in this presentation.

P/3-1.4

The MSDOL project sequential assimilation of satellite measurements of stratospheric ozone in a 3-D chemistry-dynamics-transport model

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The MSDOL project has been developped in the frame of the preparation of the exploitation of ENVISAT data. It consists in the setting up of a tool allowing assimilation of vertical profiles of stratopsheric ozone obtained by satellite experiments. The assimilation indeed serves to optimally interpolate measurements that are irregularly located in space and time.

The whole MSDOL system including a 3D chemistry-dynamics-transport model and an assimilation algorithm based on the optimal interpolation technique will be presented. Various tests, using simulated measurements allowed to evaluate the performances of the assimilation algorithm.

The MSDOL tool is readily available for the assimilation of already existing data. Example of application to MLS data will thus be presented.

3-1-2 Chemistry and Transport

P/3-1.5

Residual circulation and transport in interactive chemistry-climate simulations

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Aspects of the middle atmosphere circulation as simulated by the MAECHAM4/CHEM model are evaluated. The model used extends form the surface to about 80km, it consists of the MAECHAM4 general circulation model and the CHEM chemical model for the evolution of ozone, H_2O, and relevant chemical species, and including heterogeneous chemistry. Two 15-year interactive simulations (among other coupling, the chemical species affect the radiative forcing) have been performed, respectively for typical present conditions and for recent past conditions. The intercomparison of these simulations as well as simulations with the MAECHAM4 model component only are presented.

Preliminary results have revealed that the upper stratosphere and mesosphere are most sensitive regions. Thereafter, the focus being on the implications for the residual circulation and transport in the lower stratosphere and upper troposphere.

Comparisons with reanalysis, tracer observations and with previous works are presented.

P/3-1.6

Comparison of climatologies from HALOE and ER-2 with fields from t hree dimensional models

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Atmospheric constituents which comprise total reactive nitrogen (NOy) affect ozone through gas phase photochemical reactions, through heterogeneous chemical reactions, and through condensation to form polar stratospheric clouds. Like ozone, reactive nitrogen species are produced and destroyed in the stratosphere and mesosphere. Also like ozone, transport plays an important role in determining the NOy distribution and seasonal cycle. A model is useful for assessment of the impact of changes in climate and atmospheric composition only if the photochemical and transport contributions to key atmospheric constituent distributions are represented realistically.

Here the simulationed O_3 and NOy from three dimensional chemistry and transport models are compared with observations. The model uses different meteorological data sets, from data assimilation systems such as the Goddard Earth Observing System Data Assimilation System, and from general circulation models. Simulated fields are compared with climatologies for NOy and O_3 developed from *in situ* observations from the ER-2, and with climatologies for O_3, CH_4, and sunset NO + NO_2 from the Halogen Occultation Experiment on the Upper Atmosphere Research Satellite. This analysis provides a means to untangle the transport and photochemical processes that affect NOy and ozone in the lower stratosphere. The comparison of modeled and observed fields also provides a critical evaluation of the balance between photochemical and transport as represented in the models.

P/3-1.7

Quantification of the polar contribution to mid-latitude ozone loss by numerical modelling

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A numerical model has been used to quantify anthropogenic (halogen-induced) ozone loss at the winter pole and at mid-latitude. This is compared with the loss due to "natural" cycles. The inter-annual variability of these processes is studied. Five winters in the 1990s have been chosen to investigate a variety of meteorological conditions in and around the polar vortex.

The Cambridge 3-dimensional off-line chemical transport model, SLIMCAT, was run at T31 resolution (3.75 degrees latitude by 3.75 degrees longitude) with UKMO analysed winds and temperatures for each winter. The contribution of polar processes to ozone loss at mid-latitudes was investigated with novel tracers mapped to potential vorticity equivalent latitudes. The polar vortex core and mid-latitude regions were defined as 90 degrees - 70 degrees N and 60 degrees - 30 degrees N respectively.

Novel tracers were included into SLIMCAT to follow ozone loss by reactions with Clx, Brx, NOx, HOx etc. and ozone production by oxygen photolysis and also to record the mass of ozone destroyed by location.

Analysis of the ozone loss tracers shows large inter-annual variability in the relative strengths of particular chemical loss mechanisms depending on the meteorology in a given year. The role of mixing also varies with the meteorological conditions. For example, in the winter of 1996/97, a winter with a well isolated vortex, by the end of March only about 15 % of the loss in the polar lower stratosphere (between 570 K and 330 K potential temperature levels, approximately 12 km to 21 km) originates south of 60 degrees N. In contrast, in 1998/99, a dynamically disturbed winter, about 50 % of the polar loss is of middle latitude origin. We also find that in this partial column, at mid-latitudes, halogen chemistry contributes about 50 % of the chemical ozone destruction throughout the winter.

P/3-1.8

Development of stratospheric chemical transport model based on CCSR/NIES AGCM

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A stratospheric Chemical Transport Model has been developed. The chemical scheme of 1-D coupled chemistry-radiation model developed in NIES was incorporated into CCSR/NIES AGCM. The model includes 13 heterogeneous reactions on Polar Stratospheric Clouds as well as 163 gas phase chemistry for the stratosphere. The heterogeneous chemistry computation routine of TOMCAT model was incorporated into the GCM. Zonal wind velocity, meridional wind velocity, and temperature of ECMWF data are assimilated into GCM with a nudging method. The nudging time scale of 1 day produced realistic fields of the horizontal wind and the temperature in the GCM. Above 10hPa, monthly CIRA data are used and interpolated linearly with respect to time. Vertical wind velocity and photolysis rates of chemical species are calculated from the continuity equation and the solar radiation flux in the GCM, respectively. Year-to-year variations as well as seasonal variations in ozone and other chemical species such as CFCs, CH_4, N_2O, and HNO_3 are shown. Effects of heterogeneous chemistry on ozone distribution will be discussed.

P/3-1.9

Extreme year-to-year differences in ozone mean distribution over Southern Hemisphere winter

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The ozone mean distribution over Southern Hemisphere during austral winter is characterized by maximum values at middle latitudes decreasing equatorward and poleward. Over the latitude-belt maxima, longitudinal ozone differences as large as 40 UD are typically found, with maximum values over the Indian Ocean and minimum over southern South America.

Besides, interannual variability in ozone mean winter field is of great significance. To address this issue, tempORAL eddy anomalies were analysed for the ECMWF daily analyses and for TOMS-Nimbus 7 ozone data for the period 1983-88. In that sense, zonal asymmetries were yearly calculated removing zonal averages of each individual winter mean. Then, temporal eddy anomalies were obtained subtracting out the long-term winter mean.

It was found that both 1987 and 1988 austral winters exhibit the major ozone anomalies in association with a wave number 1 structure. In addition, while 1987 shows a negative center at 75°E, 50º S and a positive one at 125°W, 45ºS, 1988 displays stronger anomaly centers at almost the same locations but with reverse sign. Strikingly similar and in-phase patterns are seen in 100-hPa potential temperature anomalies at middle and high latitudes for both years, suggesting an impact from dynamical forcing in the ozone distribution. Furthermore, 100-hPa geopotential-height anomalies indicate that eddy activity was greater during 1988 than 1987.

The explanation of such ozone anomaly interannual differences between those particular years is under current investigation. Although QBO effect cannot be discarded, an ENSO influence seems to be of mayor relevance. Particularly, during 1988-ENSO cold phase, maximum ozone anomalies appear to be related with a weakened subtropical jet over the Pacific Ocean and the occurrence of blocking events, which could allow vertical wave propagation deep into the stratosphere.

P/3-1.10

An analysis of 1997 low ozone in the Southern Hemisphere middle latitudes

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Ground-based and satellite instruments show record low ozone column densities between 20S and 60S throughout 1997. Monthly averaged total ozone values in 1997 compiled from Total Ozone Mapping Spectrometer (TOMS) observations are up to 20 Dobson units lower than any other year on record (1979-present). An analysis of ozone profiles from the UARS HALOE instrument indicates that the majority of ozone changes occur in the lower stratosphere. To better understand the mechanisms responsible for these low ozone densities we examine various diagnostics of tracer transport in the Southern Hemisphere. In particular, residual circulation statistics calculated from heating rates and United Kingdom Meteorological Office (UKMO) temperatures indicate that changes in the strength of the residual circulation can account for a significant portion of the midlatitude ozone anomalies observed in 1997. Indications for why the residual circulation was anomalous suggest a possible connection with the tropical quasi-biennial oscillation (QBO). UKMO statistics imply that the residual circulation is strongly influenced by the phase of the QBO. Further discussion of how the QBO may have influenced 1997 ozone values and accompanying model results will be presented.

P/3-1.11

On the sensitivity of RegCM2 to ozone incorporation

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Regional climate model RegCM2 is used for study of climate change impact on regional scales. The simple ozone profile parameterisation based on standard atmosphere composition neglecting the monthly and regional variability is prescribed in standard version of the model. Sensitivity tests for appropriate ozone changes both in troposphere and stratosphere with respect to possible antropogeneous changes are presented resulting in quite significant changes in radiative characteristics of the model. The great effect is usually connected with other parameters and variables of the model with important role of water vapour and cloudiness. For the purposes of this study the model top was moved up to 10 hPa and the resolution was increased in stratosphere. For the tests of validity of the model in real climate simulation modification of the model introducing TOMS data is presented. Real TOMS data can be used recovering the ozone profile by means of the analytical curve. Its parameters can be analysed on ozone profiles data and also their climatology, i.e. at least its monthly and latitudinal variability is available for real extrapolation. The comparison of such an inclusion of ozone profile into the RegCM2 based on TOMS climatology with the appropriate ozone profile based on day to day and point to point variable real ozone information from TOMS data is presented as well. It can be seen that the effect of the improvement of ozone profile incorporation into the model can be at least in some of model points quite significant mainly for radiative characteristics. Actually, for climate models without the chemistry of ozone we could hardly have proper detailed ozone data for long-term simulations, but it should be possible to include into such models better parameterisation of both seasonal and at least latitudinal ozone profile variability. For forecast models GOME measurements could be good source of ozone profile data.

P/3-1.12

Dynamical causes for deviations of ozone profiles in Switzerland

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An improved understanding of the variability in ozone profiles is essential to describe dynamical contributions to long-term trends and will allow better estimates of anthropogenic ozone destruction.

Detailed diagnostic studies were performed with ozone profiles provided by balloon-soundings at Payerne, Switzerland. Deviations of single ozone profiles above the tropopause from monthly means were analysed using 10-day backward trajectory analysis.

One major cause for the deviations was found to be connected to advection of the air masses from different origins. Transport of ozone poor air from regions south of 30 N was observed.

In addition tropopause pressure has an impact on the profile. A high tropopause often leads to reduce ozone at heights between about 200 and 100 hPa, which is sometimes accompanied by an ozone surplus between 50 and 20 hPa particularly in September and October. These two different effects were separated with case studies. Also seasonal characteristics for the Payerne profiles are presented.

Further, the analysis is extended to explain interannual variability.

P/3-1.13

An examination of the dynamical components of the ozone variability based on a dynamical-chemical coupled2D circulation model

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In recent years, several investigations have been focussed on interpretation of the observed interannual ozone variability from different viewpoints. Basically, the observed temperature variability, the QBO and/or the lower stratospheric large-scale planetary wave variability of given time periods were introduced as external forcings in climate-chemistry model calculations. The aim of this work is to examine the influence of tropospheric and stratospheric eddy heat and momentum fluxes on the ozone variability based on a zonal mean dynamical-chemical coupled 2D-circulation model. The 2D model is a 2D version of a standard 3D GCM (ECHAM) with a coupled complex photochemistry model, and it includes the troposphere and the stratosphere. Model calculations were carried out with observed and with parameterized zonal mean transient and stationary eddy fluxes. The results provide a detailed analysis of the different contributions of the eddy-forced meridional mass circulation, the temperature fluctuations, the tropospheric-stratospheric mass exchange, and several important trace gases and reaction cycles to the ozone variability. Several related feedbacks between the ozone chemistry and the climate system *via* the ozone-induced radiative transfer are examined, revealing their important influence to the ozone variability.

P/3-1.14

Sensitivity of upper stratospheric constituents to mixing processes and perturbations in the residual circulation

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A number of observed constituents in the upper stratosphere exhibit interesting low frequency variations (interannual variability and trends), the causes of which are not currently clear. These constituents include CH_4, H_2O, HCl, and HF, all of which are measured by the HALogen Occultation Experiment (HALOE) on board the Upper Atmosphere Research Satellite (UARS). We use 2D model simulations of these constituents to show that upper stratospheric CH_4 is sensitive to small stratospheric residual circulation changes such as could be caused by changes in planetary wave forcing of the stratosphere due to tropospheric climate change or radiative heating of the lower stratosphere due to volcanic aerosols. This sensitivity is caused by its relatively strong vertical gradients in the upper stratosphere.

In contrast, the species HCl, HF, and H_2O are not sensitive to such changes in the upper stratosphere due to their weak vertical gradients. We show from simulations of HF and HCl that the observationally-inferred upper stratospheric total chlorine time series is not consistent with the simple expectation that upper stratospheric total chlorine will follow near ground abundances time-lagged by the mean age of air. Stratospheric mixing processes can explain some of the discrepancy because they reduce the expected peak upper stratospheric total chlorine amounts so our model estimates are in good agreement with observations. However, our simulations are unable to explain the apparent peak in inferred total chlorine which occurred in 1997, 2 years before the time suggested by the ground observations and the estimated mean age of upper stratospheric air.

Session 3

Modelling and Diagnosis of Stratospheric Effects on Climate

Subsession 3-2: Internal Variations in S-T Coupled System

3-2-1 Annular Modes

P/3-2.1

A diagnostic study of stratospheric dynamical effects on the troposphere

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It has been a controversy whether, and how, stratospheric changes have a direct effect on tropospheric weather and climate. In this study, we mainly focus on the dynamical links of Northern Hemisphere stratosphere and troposphere. In particular, we examine downward propagation of stratospheric anomalies of polar temperature and height in the winter-spring season, using past 22 years of National Centers for Environmental Prediction (NCEP) meteorological data. We find that, on the synoptical time scale, the stratosphere behaviours sometimes like a "conductor" which allows a warm or cold anomaly to propagate from upper stratosphere to troposphere, and sometimes like a "resistor" which prohibits downward propagating. The Arctic Oscillation is more clearly seen in the "conducting" atmosphere. To understand what dynamical conditions dictate the stratospheric "conductivity", we select those upper stratospheric episodes with very large anomalies (such as sudden warming) and divide them into two groups according to their downward propagating features. We use E-P diagnostics to examine characteristics of wave-mean flow interactions in the two different groups. We find that wave forcing must be large enough to reverse polar zonal flow, then dynamically induced anomalies will descend as the "critical line" descends. Otherwise, an upper stratospheric anomaly will hardly propagate down.

P/3-2.2

Signatures of the Arctic oscillation on stratospheric ozone

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One of the primary mode of wintertime extratropical variability, the North Atlantic Oscillation (NAO) has recently been argued to be part of a more global pattern, termed the Arctic Oscillation (AO), which extends from the surface upwards into the stratosphere (1, 3). The AO emerges as a statistical linkage between the stratospheric and tropospheric circulations, especially in winter.

In this study, we examine the signature of the AO on the ozone layer. Analysis of satellite column ozone observations indicates a strong signature of storm tracks in ozone (2), with marked asymmetries between the Pacific and Atlantic storm tracks. The storm track modulation by the NAO/AO over the Atlantic is hence expected to strongly influence ozone transient variability over the Atlantic and Europe.

A set of multi-year satellite ozone data over extended winter periods is analysed to extract an AO-induced signal. A long-term record of column ozone observations in Tromso (Norway), extending back to the 1940's, is also examined for signature of the AO.

Finally, we discuss whether a persisting trend in the AO amplitude could strengthen column ozone transients over Europe.

References:
(1) Thompson and Wallace, GRL, 25, p1297, 1998.
(2) Orsolini et al., GRL, 25, p2413, 1998.
(3) Hartman et al., Proc Acad Sci, 97, p1412, 2000.

P/3-2.3

The downward propagation of the Arctic oscillation

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For the winter of 1988-89 the Arctic Oscillation has been diagnosed from ECMWF Re-Analysis (ERA-15) data. The results show a downward propagation of variations in the polar cap averaged stratospheric zonal wind.

This propagation has been analysed by considering the temporal dependence of the different terms of the zonally averaged momentum equation. The goal of this work is to investigate a possible mechanism of the downward propagation of the Arctic Oscillation signal.

P/3-2.4

Model studies of the dynamical connection between the stratosphere and the troposphere

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The dynamical connection between the stratosphere and the troposphere during the Northern Hemisphere winter is investigated both with a general circulation model (GCM) and with a highly truncated quasi-geostrophic model. In the GCM the stratospheric variability is strongly dominated by vacillations on a time-scale of about 100 days. The vacillations are well described by a few empirical orthogonal functions (EOFs). The leading EOF describes a standing oscillation of the stratosphere while the two next describe the vertical and horizontal propagation. In the troposphere the leading EOF shows the characteristic circumpolar structure of the Arctic Oscillation. One-point correlation maps of the zonal mean zonal wind anomaly reveal the characteristic downward propagation of the stratospheric disturbances. Poleward of 60 N significant disturbances penetrates deep into the troposphere with a lag of 10-20 days compared to 10 hPa.

Singular value decomposition of the covariance matrix between stratospheric and tropospheric fields shows that a considerable part of the tropospheric variability can be related to the downward propagating anomalies. The pattern of surface pressure anomalies found in this way describes 20-30 % of the total variance and strongly resembles the pattern of the AO.

The quasi-geostrophic model is an extension of the Holton-Mass model (Holton and Mass 1976) which now includes several zonal and meridional modes. While the original single mode Holton-Mass model simulates the stratospheric vacillations the representation of the troposphere requires additional meridional modes (Kodera and Kuroda 1999). The present model also includes wave-wave couplings and allow for changes of the vertical profile of the static stability. With this model the dynamical connection between the stratosphere and the troposphere will be studied in detail. In particular, the sensitivity of the troposphere to perturbations in the radiative equilibrium and the static stability will be studied as function of the altitude of the perturbation.

P/3-2.5

The influence of the stratospheric circulation on the annular modes of climate variability in a middle atmosphere model

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The annular modes, also known as the Arctic and Antarctic Oscillations, or the AO and AAO, are spatially the largest and dynamically the most fundamental modes of climate variability spanning the troposphere and stratosphere, yet questions remain as to their maintenance and transition mechanisms, especially in the stratosphere. Towards understanding the influence of the time-mean stratospheric circulation on the annular-mode-related variability we take a modelling approach and analyse two middle atmosphere model simulations, which, by virtue of differing gravity wave treatments, have differing time-mean stratospheric circulations. In a simulation where the Northern Hemisphere winter circulation is quite realistic, we find that the AO is well reproduced in zonal-mean zonal wind and temperature and that it's positive phase is characterised by:

1) Upward and equatorward planetary wave propagation from the troposphere into the stratosphere;

2) Upper stratospheric planetary and gravity wave westward zonal-mean zonal wind driving and

3) Negative zonal-mean zonal wind and positive zonal-mean temperature time-tendencies in the polar stratosphere.

The latter are hypothesised to contribute to the transition to the negative phase of the AO. In a simulation where the Northern Hemisphere winter stratospheric circulation is unrealistically weak, the AO signal is also weak and the role of upward propagating planetary waves in providing for the transition severely limited. Similar comparisons are made for the AAO.

Finally, we explore the connection between major stratospheric sudden warmings and extreme negative phase AO.

P/3-2.6

Interpretation of the Arctic oscillation in dependence on stationary wave forcing

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The Arctic Oscillation (AO) is one of the most dominant atmospheric variability patterns and plays an important role in the dynamical coupling of the stratosphere and troposphere.

In this work we try to understand how this variability mode develops in an idealised troposphere-stratosphere GCM. Several model runs were carried out under perpetual January conditions, where different combinations of stationary wave forcing, i.e. orographic or thermal, were tested. It is shown that the stationary wave forcing determines the poleward extension of the stratospheric residual circulation.

In the following, variability patterns on different height levels have been identified in terms of empirical orthogonal functions (EOF). As concerns the surface pressure, an AO-like pattern can be found regardless of the stationary wave forcing. In the upper troposphere and stratosphere the situation is contrasting. There, a zonally symmetric and barotropic variability pattern, resembling the AO, depends crucially on the strength and composition of the stationary wave forcing. Furthermore, the signature of this variability pattern in the residual circulation and the Eliassen-Palm-flux is demonstrated.

Finally, an interpretation of variability patterns on the basis of dynamical coupling of the troposphere and stratosphere is given.

P/3-2.7

Coupling of the stratosphere and troposphere in a 2D quasi-linear vacillation model

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We explore the dynamical connection of stratospheric warmings to the Arctic Oscillation. A new breed of vacillation model has been developed for this purpose. This 2 dimensional model extends from the surface to the mesopause and represents the interaction of the mean flow and one or more waves. The wave is forced at the tropopause in order to represent the fluxes from baroclinic waves residing in the troposphere. This aspect of the model allows the vacillation dynamics to modulate the forcing strength. Effects propagating downward all the way to the surface and producing a surface pressure response are observed. The elements of the dynamics of this model will be explained and related to observations.

3-2-2 Other Intraseasonal and Interannual Variations

P/3-2.8

A numerical experiment on intraseasonal and interannual variations of the troposphere-stratosphere coupled system

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A numerical experiment on the dynamical coupling between the troposphere and the stratosphere is done with a global circulation model (T21 truncation and 42 levels) with some idealisations; it is a dry-atmosphere model with a Newtonian-type radiation scheme for meridional differential heating. An idealised surface topography of zonal wavenumber one is introduced to make zonal asymmetry and its height is changed from 0 to 3 km for 10 runs as an experimental parameter. Non-linear interactions among zonal mean zonal flow, planetary waves forced by the topography, and baroclinic disturbances produce irregular fluctuations in the troposphere and also in the stratosphere with multiple time-scales from intraseasonal to interannual variations. For each run, time integrations are done for 100 years with a periodic annual forcing of the meridional differential heating.

Even in the run with no surface topography, the model response shows (small) interannual variations in the polar stratosphere. If the topographic height is small (around 500 m), the polar stratosphere shows large variability in spring. On the other hand, the variability is large in winter for medium topographic heights (around 1000 m). These results remind us of the variations in the Southern Hemisphere and the Northern Hemisphere, respectively. The dynamical coupling is inevitably two-way. Large stratospheric events are mainly caused by vertically propagating planetary waves from the troposphere, while circulation changes in the stratosphere influence upper and middle troposphere for a time scale of a month.

Such coupling is significant in the season when the interannual variations are large, depending on the topographic height. The dynamical vertical link is also analysed from the viewpoint of Arctic Oscillation, which was found recently as a deep signature of modulations in the strength of the polar vortex from the mid-stratosphere down to the surface on the intraseasonal and interannual time scales.

P/3-2.09

Characteristics features of the dynamical coupling of troposphere and stratosphere in the Northern Hemisphere

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In this paper, the Single Wave Analysis (SWAN) approach for studying the dynamical coupling of troposphere and stratosphere is introduced.

Using SWAN, key-features of this coupling are isolated in Northern Hemisphere geopotential height fields. We study the vertical propagation of wave-like anomalies and the relationship between the strength of the stratospheric polar winter vortex and both the single tropospheric wave fields and the North Atlantic Oscillation.

Our analysis reveals that winter seasons characterised either by an anomalously strong or weak polar winter vortex exhibit different tropospheric circulation regimes because only in the case of a strong polar vortex a downward control of the tropospheric climate occurs. From our analysis, we conclude that the forecast potential of the strength of the stratospheric polar winter vortex does not result from the change in the zonal mean zonal wind but from modifications of the structure of tropospheric waves. We also found that a forecast potential for the phase of the mid-tropospheric North Atlantic Oscillation only exists, when changes in the strength of the stratospheric polar winter vortex are related to a modification of the transmission-refraction properties for waves of zonal wave number one.

P/3-2.10

Quantification of mass and water vapour transport across the dynamical tropopause

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The contour advection technique is used to quantify the quasi-horizontal, isentropic transport of water vapour across the dynamical tropopuase between the tropical upper troposphere and the extratropical lower stratosphere. The calculations are based on ECMWF analyses for 1997 and 1998. It is shown that the annually integrated isentropic net mass flux is directed from the stratosphere into the troposphere, though the exchange is a two-way process. The isentropic mass fluxes are of the same order of magnitude as the upward vertical mass fluxes across the tropical tropopause. The isentropic flux of water vapour from the troposphere to the stratosphere is largest during summer, and is more than enough to account for the observed summertime increase in specific humidity in the lowermost stratosphere. The isentropic flux of water vapour into the stratosphere of the Northern Hemisphere is about an order of magnitude larger than that in the Southern Hemisphere, and explains why the extratropical lower stratosphere is moister during northern summer than during southern summer. There is more moisture transport into the lower stratosphere of both hemispheres during El Nino conditions.

P/3-2.11

Effect of Rossby wave breaking near the tropopause on constituent distributions

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Global meteorological and satellite constituent data, together with *in situ* data and a high-resolution model, are employed to investigate the effects of synoptic wave breaking on climatologically significant constituent distributions in the upper troposphere and lower stratosphere. A climatological study of Rossby wave breaking at 350 K along the subtropical tropopause, using a decade of ECMWF data, shows that stratosphere-troposphere exchange at this level maximises over the summer oceans, poleward and downstream of the tops of the seasonal monsoon anticyclones. Synoptic waves travelling in westeries on the poleward flank of the monsoons modulate divergent pulses of air out of the monsoon tops. Their baroclinic life cycles are consistent with theory, with wave activity refracting from the East Coast of continents upward and equatorward into the tropopausal surf zones over the summer oceans.

These surf zones help control the chemical and radiative properties of the tropical upper troposphere and extratropical lower stratosphere, are a useful conceptual model for interpreting observations, provide a mixing pathway, and a mechanism for generating layered structures.

Synoptic Rossby waves stir the lower stratosphere near Alaska throughout most of the year. During NASA's POLARIS campaigns in the northern summer of 1997 we employed the University of Wisconsin Non-hydrostatic Modelling System (UW-NMS) to study ozone transport in support of ER2 and balloon flights. We found that layered structures in the lower stratosphere and total column ozone varied with synoptic wave features. The decline of stratospheric column ozone, which occurs across the northern summer, is partly due to a seasonal change in transport.

Since the import of ozone by planetary waves from the tropics ceases during summer, but synoptic Rossby wave breaking in the lower stratosphere continues to mix ozone into the troposphere, there is a net flux of ozone out of the high latitude stratosphere all summer.

P/3-2.12

Role of Asia Pacific wave on stratosphere-troposphere exchange

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Analysis of the NCEP/NCAR reanalysis wind data shows the presence of a stationary wave train extending into the lower stratosphere during summer. This wave train is seen prominently upto 70hPa level, confined between 10 N and 50 N latitudes and has a zonal wave number of 6 or 7. It is an extension of the Asia Pacific Wave of the troposphere reported by the earlier studies into the stratosphere. Above 200 hPa level this wave shows a phase shift of 20 degree longitude between deficient and excess Indian summer monsoon rainfall years. Amplitude of this wave is maximum around 200 hPa and decreases both above and below. The large amplitude portion of this wave is thus situated in the break region of the tropical and subtropical tropopause around 30 N latitude. The large amplitude Asia Pacific Wave (APW) is found to exchange the tropical and subtropical airmasses through the tropopause break and thus the APW is also seen in the satellite monitored total ozone (TOMS data).

P/3-2.13

Synoptic processes and the response in total ozone

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It is a well-established fact that upper tropospheric disturbances are reflected in the total ozone content. Already Dobson postulated in the late twenties and early thirties the link between total ozone and upper tropospheric pressure.

Recent studies of particular events (Canziani *et al*., this conference) that over the Southern South America very strong quasi-barotropic perturbations caused by a sequence of blocking events could result in very significant total ozone anomalies.

Furthermore this particular sequence of events showed that the response of the ozone column dependent on the 'mix' of processes involved (vertical tropopause displacements, advection and divergence of the flow).

This contribution presents the results of a study of upper tropospheric synoptic scale perturbations during the Southern Hemisphere winter (June, July, and August) over Southern South America and adjacent oceans and total ozone perturbations over the same region. The variability of the response of the total ozone is compared with the variability observed in the synoptic perturbations at upper leves in the troposphere during the years 1979-1992 and 1997-1998 where there is adequate coverage by the TOMS family of instruments. The behaviour of variability of both the upper troposphere and total ozone is discussed. Preliminary results suggest that periods characterised by high (low) spatial variability of total ozone, in terms of deviations from the zonal mean are related to high (low) variability of upper tropospheric synoptic scale activity.

P/3-2.14

On the use and abuse of eigentechniques for stratospheric analyses

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Eigenanalysis has become ubiquitous as a tool for analysing climate data. With the advent of new stratospheric datasets this trend has continued and an increasing number of publications purporting to represent physically important processes have appeared in recent months. In fact, the output of such analyses may ultimately be used to form policy decisions. Consequently, it is important to document, in a systematic fashion, the specific decisions that are made in any analysis as well as scrutinise those decisions on their ability to transmit the underlying physical processes as captured in the data.

This work will provide insight into the likelihood that various decisions, which must be made at each step of an eigenalaysis, will ultimately reflect the variability in the data. To facilitate this endeavour, a two-step process is employed. In the initial analyses, known patterns are eigendecomposed in both the spatial (S) and temporal (T) modes. The effects of various similarity matrices and methodological decisions within the eigenalaysis are documented in a Monte Carlo framework and each is quantitatively related to the original data for their ability to minimise distortions or bias. Subsequently, the knowledge gained in this stage is then applied to analysis of MSU Channel 4 temperature anomalies. The veracity of the eigenpatterns is tested against the data to insure the relationships arise from the data and are not an artefact of the statistical process. Moreover, techniques that allow specific lines of investigation will be presented. Accordingly, the lower stratosphere temperature can be filtered into the dominant spatial and temporal patterns.

Session 3
Modelling and Diagnosis of Stratospheric Effects on Climate

Subsession 3-3: Responses to Forcings

3-3-1 QBO and ENSO

P/3-3.1

The QBO effects on the stratospheric and tropospheric circulation in the Southern Hemisphere

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A statistical analysis on the relationship between the equatorial QBO and the interannual variability of the stratospheric circulation in the Southern Hemisphere (SH) is made by using the NCEP/NCAR reanalysis data. We focus on the planetary wave propagation from the troposphere.

In November (spring, which is the season with the largest interannual variability of the stratospheric circulation in the SH), the polar-night jet tends to be stronger in the easterly phase (E) than in the westerly phase (W) of the QBO. It means that the deceleration is larger in the E before November. This tendency is consistent with the convergence of the Eliassen-Palm (EP) flux, which is larger in the E from August to October. The larger convergence is contributed by the stronger upward propagation of the planetary waves from the troposphere.

Furthermore, the equatorward component of the EP flux in the troposphere is examined. It has an opposite tendency of the upward one to the stratosphere; larger in the W than in the E from August to October. The predominant wavenumber is around 4-6, which implies the baroclinic disturbance rather than the planetary-scale rossby waves. Also the tropospheric zonal wind is associated with the QBO. The positive composite difference of the zonal wind has a tropospheric "tail" extended down to the surface throughout spring months. It is also statistically significant instead of its small magnitude. This signal of the tropospheric wind may be causable of the difference of the upward and equatorward EP-flux components, and hence the difference of the stratospheric wind, while the tropospheric signal is inseparable from the stratospheric one.

P/3-3.2

Climatological structures of the QBO in the NCEP reanalyses and possible tropospheric relationships

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Global quasi-biennial variation in the lower stratosphere and tropopause region is studied using primarily the National Centers for Environmental Prediction (NCEP) reanalyses. A total of 41 years (1958-1998) of horizontal wind, temperature, constant pressure level height, and tropopause data are used. The long time series of data allows for the clear detection of even very subtle quasi-biennial oscillation (QBO) signals, such as that of the secondary meridional circulation, for which the first direct observation-based evidence is presented. Also, a novel QBO index is presented which allows for clearer distinction between "westerly" (W) and "easterly" (E) phases; this technique may be useful to other investigators. The vertical and meridional structure of the zonal average QBO is examined in three ways: (a) with simple oscillation amplitudes, (b) through the use of phase differences (i.e., W anomaly minus E anomaly) to emphasise spatial patterns and the descent of the QBO, and (c) through the use of "composite phases" to show the time progression of the QBO. High latitude effects (caused by wave dynamics) are apparent in the tropopause and stratospheric fields. The "phase lock" with the annual cycle is demonstrated, with the zonal wind anomaly near the tropopause changing sign preferentially during the Southern Hemisphere winter. The relationship between the stratospheric QBO and tropospheric phenomena such as ENSO and the Walker circulation will also be examined. The NCEP reanalyses agree qualitatively with theory and previous observational studies, but there are quantitative discrepancies: the overall amplitudes are often weaker, and the asymmetry between the W and E shear zones is less pronounced. Perhaps more difficult to resolve is a "transition" at around 1978 (when satellite observations became the dominant input of the model), when many fields exhibit a step-function discontinuity and their QBO amplitudes change.

P/3-3.3

QBO and solar cycle signals on total ozone at tropical Brazilian stations

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Long-term measurements of total ozone have been carried out by The National Institute for Space Research, INPE, at Natal (5.8oS, 35.2oW) and C. Paulista (23.1oS,45W), since 1978 and 1974, respectively, using two Dobson spectrophotometers. A spectral analysis was applied on these time series, using the Multiple Taper Method, the Maximum Entropy Spectral Analysis and an Iterative Regression Model. The time series were the yearly averages, 12 months (12m) and 36 months (36m) running means. Using these time series, the main periodicities found were 2.45 and 10 years for Natal, and 2.45 and 7 years for C. Paulista, associated to the quasi-biennial oscillation (QBO) and to the 11-year solar cycle. The amplitudes of these periodicities were close to 1% of the averages. Using 36m the QBO signal was eliminated (r2 = 0.01 between total ozone and the zonal wind index, for Natal) and the solar cycle signal could be more easily seen. It was observed that ozone at Natal has a variation in-phase with the sunspot number, while at C. Paulista an out-of-phase variation was observed, with a lead for ozone of about 2 years. To study the QBO signal the difference between 12m and 36m time series was calculated, removing the longer periods. In this time series, the correlation between total ozone and zonal wind index was higher (r2=0.49 for Natal).

P/3-3.4

ENSO as a natural experiment for understanding the tropical tropopause region and stratosphere troposphere exchange of water vapor

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Changes to the tropical atmosphere as a result of the El-Nino Southern Oscillation (ENSO) are used to better understand the processes governing water vapor in the tropopause region. Coupling between convection, the large-scale wind field and water vapor is observed to change between warm and cold phases of ENSO. This variability is used to refine our understanding of the stratosphere-troposphere exchange of water vapor.

The redistribution of tropospheric heating associated with ENSO causes significant changes in the thermodynamics and dynamics of the upper troposphere and the tropopause. These interannual changes, which are analysed using objective analysis techniques in upper tropospheric winds, tropopause diagnostics, convection, cirrus clouds and water vapor, provide a natural laboratory for understanding processes important in the tropical 'tropopause region' between 14-20km.

The variability and coupling between these fields is examined during ENSO cold and warm events at various levels. A transition in the tropopause region between tropospheric (convective) control and stratospheric (non-local) control is evident. The coupling of tropopause diagnostics for several definitions of the tropical tropopause with convection, with the large-scale circulation and with water vapor is examined. These relationships are crucial for determining the transport of water vapor into the stratosphere, and how such transport might change over time. These diagnostics and linkages revealed by analysing observations are also used as a means of testing the performance of climate models (and model parameterisations) in this region.

P/3-3.5

South America ENSO teleconnection coherence patterns and their impact to tropospheric parameters over Buenos Aires

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Large Scale Meteorological Coupling is studies between the South America Total Cloud Cover and ENSO (El Niño Southern Oscillation) phenomena in its different phases (Niño, Niña and Normal) situation. Based on a Singular Value Decomposition technique we compute the Heterogeneous Correlation Pattern for South America Region from 1980 to 1999. Clustering the same nature events we identify the teleconnection coherence zone and their influence regions for each types of events. Finally, for the last Niño Event (1997/1998) we compute the local incidence pattern in Buenos Aires where we operate a Lidar Station and Radiometry (34°36'S, 58°, 26'W) as a correlation between regional variables, affected by these Large Scale Coupling, and the local variables measured in Buenos Aires, Argentine.

3-3-2 Solar Forcing

P/3-3.6

The GRIPS initiative to study the impact of solar forcing

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One initiative of the SPARC-GRIPS project is to study the impacts on the atmospheric circulation of 11-year variations in solar irradiance. Previous studies have shown the importance of the ozone response to solar UV changes, since the two factors together determine the change in radiative heating rates in the upper stratosphere. The thermal response to these heating rate anomalies initiates zonal wind perturbations in the subtropical stratopause region, whose downward and poleward propagation over the winter can lead to late-winter changes in the lower stratospheric circulation which correlate with the 11-year solar cycle.

Model studies of these phenomena are in their infancy, but already it is clear that even the response of the ozone to the UV changes is uncertain. In this study, the dynamical response of several models to imposed changes in incoming solar irradiance and the ozone distribution is analysed. The ozone changes are taken from model studies at NASA GISS and Imperial College. Solar UV anomalies are specified as a function of wavelength. The development and propagation of circulation anomalies over the winter is examined and discussed.

P/3-3.7

Simulations of the effect of solar variability on the troposphere and middle atmosphere with MRI/JMA98 GCM

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The effects of solar maximum and minimum on the climate is investigated with an MRI/JMA98 GCM.

As forcings on the model resulting from solar variability, solar irradiance in UV range and ozone climatology are changed. The UV change of original dataset in 119-420 nm (Lean *et al*., 1997) is used only for a longer wavelength region (200-420 nm). Two different ozone dataset are used. One is based on Imperial College 2-D chemical model, and the other is based on GISS 2-D chemical model, which includes 3-D temperature effect through 3-D dynamics. The model used in this study is a T42L45 GCM with a top height at 0.01 hPa. The model is integrated for 21 years under standard conditions to yield a control run, in which weak easterly winds blow in the lower equatorial stratosphere. The model is also integrated for 24 years under solar maximum and minimum conditions (experiment runs).

Since there are two ozone datasets, there are four experiment runs in total. For solar maximum experiment, mid-winter responses are different (opposite in February) for GISS and Imperial College ozone data.

However, slowly descending modes can be seen in both experiments. For solar minimum experiment, responses are very similar for the two ozone data. The slowly descending modes are clearly identified. Ensemble average of 4 members under an assumption of linear response demonstrates that the solar maximum impact induces stratospheric cooling in northern high-latitudes in winter, and vice versa.

P/3-3.8

The impact on the atmospheric circulation of the 11-year solar cycle - A study with the Berlin climate middle atmosphere model

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11-year variations in solar irradiance have been shown to impact the mesosphere and upper stratosphere by changing the radiation budget of the atmosphere. Associated temperature changes may lead to changes in atmospheric circulation. In the lower stratosphere and troposphere, a mechanism for the observed high correlation of meteorological parameters with the 11-year solar cycle is more difficult to find. Recent simulations with Climate Middle Atmosphere Models discussed the possibility of an indirect dynamical response of the lower atmosphere to the radiative forcing of the upper atmosphere, but details of the simulations are still controversial.

Here, results of two multi-year simulations with the Berlin Climate-Middle-Atmosphere-Model will be presented. The model was run with implied changes in spectral solar irradiance and ozone for solar minimum or solar maximum conditions respectively. The prescribed changes were the same as defined for the GRIPS solar forcing initiative thus enabling the intercomparison of the model results with similar studies.

The model's thermal and dynamical response to the solar forcing will be discussed and compared with results from observational analyses. In particular, the impact on the tropospheric circulation will be addressed.

P/3-3.9

Solar cycle variability and stratospheric ozone

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Solar has variation of the 11year-sunspot cycle. The corresponding variation in the solar constant is small (0.1%). The change in the ultraviolet radiation of the sun is much greater than that of visible radiation.

Recently, it has begun to do quantitative analysis of the relationship between solar activity and a long-range change of stratospheric temperature, ozone. So, satellite observations show that the ozone content grows by 2% from sunspot minimum to maximum, and the temperature difference in the stratosphere between minimum and maximum of the 11-year cycle reaches 1.8K.We performed numerical experiments using a CCSR/NIES AGCM with coupled chemistry for the middle atmosphere. The AGCM has a horizontal resolution of T21. There are 33 layers from the surface to 70km in the vertical. Integration years are 20years for each at solar maximum and minimum.

Numerical results and the comparison with observations will be presented.

P/3-3.10

Model simulations of the impact of solar variability on stratospheric ozone and climate

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Variations of several percent in the UV part of the solar spectrum occur in response to the 11-year solar activity cycle and also due to the 27-day solar rotation. These give rise to a similar variability in ozone and possible feedback effects through radiation and transport. Analyses of stratospheric temperature trends indicate that the impact of the solar cycle is a significant fraction of the decadal trend due to greenhouse gas increases. Hence it is important to quantify and understand the influence of solar variability on ozone and climate.

Results will be presented from simulations of The Met. Office coupled chemistry-climate model. The model has 64 levels from the ground to 0.01 mbar and contains a complete range of chemical reactions allowing representation of all the main ozone formation and destruction processes. By resolving the whole of the stratosphere and most of the mesosphere, and in three dimensions, the model is able to simulate possible dynamical feedbacks, such as changes in global mean meridional circulation, important for ozone transport. Improvements to the model have been made to simulate the effects of solar variability on both photodissociation and radiative heating rates. Two experiments will be described. In the first a 27-day oscillation is included with an amplitude spectrum determined using data from UARS SOLSTICE.

Preliminary results with 2-year simulations show that the model correctly captures the observed tropical ozone sensitivity and downward phase propagation. The second experiment involves two 10-year simulations, with top of the atmosphere solar fluxes corresponding to the maximum and minimum of the 11-year solar cycle. The model response in ozone and temperature will be compared with observations.

P/3-3.11

North-South solar asymmetry, QBO and climate

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One of the main problems in solar-climatic influences is the instability of the relations found. Different authors have reported both positive and negative correlations between solar activity and surface air temperatures. We have performed a detailed study making use of global, hemispheric and zonal temperature estimations, as well as of data from individual meteorological stations with long measurement records, to show that the sign of the correlation changes regularly in consecutive centennial solar cycles and seems determined by the North-South asymmetry of solar activity: the correlation is positive when the Northern solar hemisphere is the more active one, and negative when more active is the Southern solar hemisphere. On the other hand, the sign of the correlation between solar activity and different climatic elements reveals a similar dependence on the phase of the quasibiennial oscillation of stratospheric winds (QBO). QBO signals have been identified in a number of geophysical parameters, e.g. sea level pressure, ozone distribution, Earth's rotation, and its existence has been shown in solar activity parameters as sunspot numbers, solar radio flux at 10.7 cm, green coronal activity, solar neutrino flux, etc. In the present paper we show that QBO exists in solar North-South asymmetry as well, and discuss the relation between the quasibiennial oscillation in solar asymmetry and in stratospheric zonal winds, and its possible implications on climate.

P/3-3.12

Sensitivity of the UIUC stratosphere/troposphere GCM with interactive photochemistry to the observed increase of solar UV radiation

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The University of Illinois at Urbana-Champaign (UIUC) 24-layer stratosphere/troposphere GCM with interactive photochemistry has been used to estimate the changes of temperature, dynamics and photochemistry due to the observed increase of solar UV radiation from solar minimum to solar maximum. We have performed two 10-year steady-state model simulations with prescribed sea-surface temperature: (1) a control run with the observed average spectrum of solar radiation; and (2) an experiment with the observed increase in solar UV radiation from solar minimum to solar maximum added to the average spectrum of solar radiation. The increased solar UV radiation influenced both the solar heating rates calculated by the GCM's radiation code and the photolysis rates calculated by the GCM's photochemical code.

Analysis of the initial 3 years of the simulations reveals an increase in the ozone-mixing ratio by 2-8% in the middle and upper stratosphere due to the enhanced UV radiation and some changes in the dynamics. Increases in total ozone of up to 3% are found in low latitudes. Enhancement of the solar heating led to a 0.5-1 degree K warming in the middle and upper stratosphere in low latitudes. Propagation of the solar signal northward induced: (1) an increase in the geopotential height of the 30 and 100 hPa surfaces during boreal winter in northern high-latitudes, (2) a reduction of the intensity of the northern polar-night jet, (3) a 12-15% increase of total ozone inside the northern polar vortex; (4) a 5-7% decrease in total ozone over Canada, (5) a 4-6 degree K warming inside the polar vortex, and (6) a 3-4 degree K cooling over Canada in the lower stratosphere. Over the Southern Hemisphere some acceleration of the zonal wind during austral winter-spring led to the depletion of ozone over southern high-latitudes in October and enlargement of the ozone hole.

3-3-3 Volcanic aerosols

P/3-3.13

Study of the effects of the Pinatubo volcanic eruption using the UIUC stratosphere/troposphere GCM with interactive photochemistry

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The University of Illinois at Urbana-Champaign (UIUC) 24-layer stratosphere/troposphere GCM with interactive photochemistry has been used to simulate and evaluate the effects of the Pinatubo volcanic aerosol on atmospheric temperature, dynamics and photochemistry. The spatial and temporal distributions of the stratospheric aerosol during the 2 years following the Pinatubo eruption were retrieved from satellite data. The model was run for those 2 years separately with and without the observed aerosol. Comparison of the simulated and observed temperature anomalies shows that the structure of the lower stratospheric warming is captured rather well by the model. The first maximum of the simulated warming in November 1991 is slightly shifted to the north of the observed maximum. The second simulated maximum occurs in August 1992 at 20 degrees S that exactly coincides with the observations. The magnitude of the simulated warming is 1.5-2 degrees K larger than observed, but is closer to the observations than the results of the simulation with the same GCM without interactive photochemistry. This can be explained by the ozone depletion simulated by the interactive photochemistry. The simulated changes of reactive nitrogen and chlorine are found to be in reasonable agreement with theoretical predictions. The ozone concentration is decreased by the Pinatubo aerosol almost everywhere in the tropical and northern middle latitudes by up to 10%. The effect is more complicated in high latitudes where the ozone increases during the winter and decreases in summer. This can be explained by the changes in the dynamics, because the ozone in winter and early spring is very sensitive to the transport processes, while during the late spring and summer the photochemical destruction of ozone dominates.

P/3-3.14

Radiative forcing and stratospheric responses in GCM simulations of the impact of the 1991 Mt. Pinatubo eruption

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The Mt. Pinatubo eruption was the strongest eruption of the 20th Century and the best ever observed. Here we use this opportunity to test the ability of GCMs to correctly account for the effects of volcanic aerosols. We compare the radiative forcing and stratospheric responses of different GCMs participating in PINMIP, the Pinatubo Model Intercomparison Project. Using SAGE II, CLAES, and ISAMS satellite observations we have developed a spectral-, space-, and time-dependent set of aerosol parameters for two years after the Mount Pinatubo eruption on June 15, 1991. Using this data set, we calculate the aerosol radiative forcing and climate response using the GCMs with different spatial resolution and radiative schemes.

Radiative forcing of a volcanic aerosol cloud heats the lower stratosphere and cools the troposphere. The change of the Earth radiative balance reaches 5 W/m^2 and is significantly affected by clouds. The strongest perturbation of atmospheric radiative heating is in the tropical lower stratosphere and reaches 0.3 K/day. Calculations with radiative transport models with different spectral resolution consistently show that aerosol absorption of near-IR radiation produces about 1/3 of the heating effect in the lower stratosphere. Aerosol absorption of upward thermal flux produces the other 2/3 of the heating effect. The temperature anomaly caused by aerosols in the lower tropical stratosphere reaches 3-4 K in about 4 months after eruption, which is larger than in observations, although the global stratospheric temperature change is in good agreement with observations. The QBO and volcanically caused changes in ozone mixing ratio should be accounted for to produce the correct evolution of the spatial distribution of stratospheric temperature.

P/3-3.15

Multi-annual simulations during the UARS period with a 3D coupled general circulation and chemistry model

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Results of recent multi-annual integrations conducted with the NASA Langley Research Center IMPACT models are presented. The IMPACT model is a three-dimensional general circulation model (GCM) with coupled dynamics, radiation and chemistry. The ozone distribution predicted by the model is used in the calculation of stratospheric radiative heating. The chemistry component explicitly transports 24 chemical families and individual species, and includes parameterisations of heterogeneous chemical processes on sulfate aerosols and polar stratospheric clouds. The dynamics component includes explicit tropospheric physics with large-scale cloud and moist convection schemes. The model dynamical and transport characteristics are evaluated with respect to the observationally based objective criteria used in the recent Global Modelling Initiative intercomparison. The model is used to examine the dynamical and photochemical response of the middle atmosphere to a large tropical injection of volcanic sulfate aerosol, such as that following the June 1991 eruption of Mount Pinatubo.

The influence of enhanced aerosol on heterogeneous chemical processing is simulated using a three-dimensional climatology of surface area density developed using observations made from the HALOE, SAGE II, and SAM satellite instruments. Radiative effects of the enhanced aerosol loading are represented by monthly mean zonally averaged heating perturbations obtained from a study conducted with the ECHAM-4 GCM. The contributions of heterogeneous chemical processing and direct aerosol radiative effects to the stratospheric response are assessed with respect to the natural internal variability of the IMPACT model.

Model results are compared with observational data including TOMS total ozone and species observed by instruments on the UARS satellite. Finally, preliminary results from an updated version of the IMPACT model will be briefly presented.

P/3-3.16

Perturbation and recovery of chemical species due to the Mount Pinatubo eruption as modelled by the Canadian middle atmospheric model

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The eruption of Mount Pinatubo injected large amounts of SO_2 into the stratosphere, which subsequently was converted to stratospheric aerosols. The enhanced stratospheric aerosol number density cools the troposphere but it also results in increased stratospheric radiative heating rates and heterogeneous chemistry rates. The Canadian Middle Atmosphere Model (CMAM) is a fully interactive 3D model, which has been used to study both the short terms (a few months after the eruption) and long term (a few years) effects of the eruption of Mount Pinatubo on the atmosphere. The aerosol surface areas were derived from extinction coefficients from SAGE II observations. The model also includes important mid-latitude heterogeneous chemistry reactions.

Preliminary analysis shows that the total water in the stratosphere as diagnosed by the "tape recorder" effect was affected. The ratio of active to inactive ozone destruction catalytic species such as NOy and Cly were also impacted. Results will show the chemical effects of enhanced aerosol loading as well as the recovery of the atmosphere several years after the eruption.

P/3-3.17

The stratospheric aerosol: the return to background levels

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The stratospheric aerosol layer was highly perturbed by the eruption of Mt. Pinatubo in June 1991. The layer has slowly eroded, reaching the lowest levels in over 20 years of systematic observations. It now appears to have attained a steady state background condition. We speculate that this very tenuous layer is maintained by non-volcanic sources of sulfur bearing gases. We document the gradual return to background levels by considering the data obtained by the SAGE II and HALOE satellite borne instruments.

The similarity of these instruments makes it particularly easy to compare the two data sets. One can show by simple scaling arguments that sedimentation of the aerosol particles is the primary factor in the clearing of the aerosol layer. We have also carried out studies with a rather sophisticated model that includes all of the microphysical process that affect the aerosol layer, including the gas to particles conversion for sulfurous gases, such as the heteromolecular nucleation of new particles and the growth of particles by heteromolecular condensation. We also include coagulation and, of course, sedimentation. Our modelling studies yield results that agree well with the satellite observations.

P/3-3.18

Stratospheric aerosol new background conditions measured with lidar over Camagüey, Cuba

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Camagüey Lidar Station (CLS) have been in operation from late 1988, with several periods of interruption, but still enough to provide a series of measurements before, during and after Mt Pinatubo eruption. The authors describe the evolution of the integrated backscatter coefficient (IBC) between 16 and 31 Km in the periods 1988 to 1990 and 1995 to 1998. During the first one, before the Pinatubo eruption, the IBC has a mean value in the order of 10^{-4} sr-1; for the second, beginning almost four years after Pinatubo, the IBC has a mean value of 10^{-4} sr-1. This result is in agreement with recent reports both from lidar and satellite measurements that a new background condition have been reached for the stratospheric aerosol layer. This is the lowest IBC value measured over Camagüey. Several individual profiles from both periods are analysed. Some particularities are discussed. Lidar derived aerosol optical depths are compared with space coincident Sage II measurements for both periods.

P/3-3.19

Artificial neutral networks in the analysis of atmospheric events: the Southern Hemisphere ozone depletion after the Mt. Pinatubo eruption

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A regional ozone layer depletion which can be associated to the Mount Pinatubo eruption in June 1991, is analysed in 5 and 10 degree latitudinal bands on the Southern Hemisphere, from the Equator to 60º S, employing artificial neural networks (ANN).

The feed-forward multilayer networks were trained with the back propagation algorithm. Several architectures (6: 4: 1, 8: 3: 1 and 8: 4: 1) were checked out, and the best of them for each zone was selected.

In a first part, ANN were trained on monthly zonal averaged (area weighted) Nimbus-7 TOMS/NASA total ozone time series, from November 1978 up to May 1991. As a non-linear noise filter, a yearly (June 1990ˆMay 1991) cross validation interval was used. In all the numerical experiments, typical values of the average relative variance (i.e. the square of the ratio between RMSE and data standard deviation) over the cross validation interval were found ranging between 0.055 (30ºS-40ºS) and 0.13 (55ºS-60ºS).

Secondly, a multiple-step prediction was done over the testing period, from June 1991 to the end of the satellite data set, on March 1993. Since ANN learn the intrinsic dynamic of the ozone behavior, it makes a prediction of the ozone values during the Pinatubo eruption and subsequent atmospheric perturbation phase taking no account of the Pinatubo eruptive event. Then, by comparing the measured TOMS time series on this period against the corresponding ANN predictions, a remarkable depletion in the total ozone was observed all over the analysed zones, which can be attributed to such eruptive event.

Particularly, a depletion around 5% was found in the spring of 1992 at 55ºS-60ºS band, which is in rather good agreement with the depletion shown in the same period by the seasonal, solar and QBO adjusted TOMS data (WMO Ozone Assessment 1998).

Session 3
Modelling and Diagnosis of Stratospheric Effects on Climate

Subsession 3-4: Trends

3-4-1 Trend Studies

P/3-4.1

Radiative effects of trends in stratospheric water vapour derived from UARS HALOE

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The latest version (V19) of UARS HALOE water vapour data has been analysed for trends from Jan 1992 to April 1999. This shows an increase in stratospheric water vapour over this period although since 1996 the magnitude of the trend appears to have decreased, especially in the upper stratosphere. A seasonal analysis suggests that large increases in upper tropospheric water vapour in autumn are the source for the stratospheric increases. An analysis of trends in the seasonal amplitude supports this.

To estimate the radiative effects of these changes a two-dimensional atmospheric model of the lower and middle atmosphere that includes interactive radiative, chemical and dynamical fields is used. Experiments are carried out in which the water vapour in the radiative routines of the model is perturbed by the derived trends. The results show that the water vapour trends may have caused a stratospheric cooling in regions of increases and warming in regions of decreases. The cooling due to the water vapour increases is similar to that caused by stratospheric ozone loss indicating a possible additional cause of observed stratospheric temperature decreases. The derived radiative forcings are of comparable magnitude, but opposite sign, to published values for ozone. Thus radiative forcing due to lower stratospheric ozone and water vapour trends may have offset each other over the past decade.

P/3-4.2

Effects of increasing CO_2 on ozone recovery studied with an interactive 2D model

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The GSFC coupled chemistry-radiation-dynamics 2D model is fully interactive in temperature, ozone, and water vapour. It has a full gas phase chemistry scheme, as well as heterogeneous reactions on sulfate aerosols and polar stratospheric clouds. Previous simulations with the model showed that the stratospheric cooling calculated to result from doubling atmospheric CO_2 would lead, in the absence of a growth of other anthropogenic gases, to a decrease in upper stratospheric NOy. This work has been extended to examine the chemical and dynamical impact on O_3 of increases in CO_2, CH_4, N_2O, and CFCs during the time period 1980 to 2050. The stratospheric cooling due to increasing CO_2 feeds back on temperature dependent chemical reaction rates, affecting ozone loss rates both directly and indirectly. Indirect effects are changes in NOy and changes in the partitioning of the Ox family. As a result, increasing CO_2 is predicted to speed up the recovery of annually, globally averaged column ozone.

In low latitudes, column ozone is predicted to recover faster in all months of the year with increasing CO_2. In high northern latitudes, the increase in polar stratospheric clouds computed due to the CO_2 cooling slows down column ozone recovery during the spring and summer months. However, the simulations show high northern latitude column ozone recovering faster with increasing CO_2 during the fall and winter months.

P/3-4.3

Simulation of the effects of the Montreal protocol using the UIUC stratosphere/troposphere ACTM driven by the UKMO assimilated winds

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Depletion of the ozone layer is a major global scientific and environmental problem. One of the causes of ozone depletion is the increase in the atmospheric concentration of CFCs. It is well known that CFC,s are long-lived species that can reach the stratosphere and cause ozone depletion. To reduce the influence of anthropogenic ozone-depleting substances, the Montreal Protocol was agreed to by the world's governments in 1987. Recent measurements show a decreasing concentration of CFCs as a result of the Montreal Protocol (1987) and its amendments (1989, 1990, 1991, and 1992). Whether or not stratospheric ozone is recovering, as a result of the limitations on the production of CFCs by the Montreal Protocol is, however, unclear. This problem cannot be solved on the basis of the analysis of observed ozone trends alone, because the level of ozone in the stratosphere is controlled by many processes, including chemical destruction and production, and changes in temperature and circulation patterns. To identify what part of the observed ozone trend can be explained by changes in the concentrations of CFC,s in the atmosphere as a result of the limitations imposed by the Montreal Protocol, we have used the University of Illinois at Urbana-Champaign (UIUC) 24-layer Atmospheric Chemical Transport model (ACTM), driven by temperature and wind fields acquired from the UKMO assimilation dataset, to simulate the trends in ozone and other species from 1993 to 2000. We have made two simulations, one with the observed concentration of CFCs and another with a scenario for the concentration of CFCs in the absence of the Montreal Protocol. Preliminary results have shown that the limitations of the CFC,s production saved for the present day up to 2% and 5% of the total ozone for Northern (March) and Southern (October) Hemispheres accordingly.

P/3-4.4

A microphysical analysis of stratospheric aerosol response to climate change

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We have performed calculations with a microphysical model of stratospheric sulfate aerosol, integrated in the Garcia-Solomon 2D-dynamical/chemical model, designed to predict the response of stratospheric aerosol and related chemical species to a future doubling of CO_2. Our model shows that the predicted cooling of the stratosphere will result in increases in aerosol.

From the tropopause to the middle stratosphere, temperatures increase to the point where aerosol boils away to sulfuric acid vapour. The altitude of the top of the aerosol layer, near 40 km, is a strong function of temperature, and varies with season and latitude. Stratospheric cooling due to CO_2 doubling increases with altitude from about 2K in the lower stratosphere to 8-10K near 40 km. In a future CO_2-doubled atmosphere, aerosol is predicted to be present at higher altitudes than in the current atmosphere. At 40 km in the tropics, aerosol surface areas are calculated to increase by 2 to 3 orders of magnitude. We discuss the effect this is expected to have on stratospheric chemistry.

P/3-4.5

Radiative forcing due to changes in stratospheric ozone

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The role of changes in stratospheric ozone on the lower atmosphere in terms of radiative forcing is studied by means of observations and modelling. It is well known that changes in lower stratospheric ozone concentrations most critically determine the radiative forcing. On the other hand, ozone changes in this region are still somewhat uncertain. Calculations of radiative forcing have therefore been made based on several sources of stratospheric ozone change, ranging from observations by ozone sondes and satellites to chemistry transport modelling. The uncertainties in the radiative forcing are discussed in relation to the range in the trends in ozone from the different sources.

P/3-4.6

A model assessment of ozone destruction by man made compounds

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Declining ozone concentrations are found throughout the lower stratosphere, both at mid-latitudes and at higher latitudes. Causes may lie in changes in transport properties as well as chemical changes related to increased concentrations of ozone depleting species, which are due to man-made emissions.

The three-dimensional chemistry transport model TM3 is used to assess the impact of man-made emissions on chemical ozone production and destruction in the present day lower stratosphere. Lately, various revisions have been proposed in the chemistry governing HOx and NOx. The relative contribution of the hydrogen, chlorine, bromine and nitrogen species to ozone depletion has been calculated, using the newly observed reaction rates, both for a realistic atmosphere and for an atmosphere in which only natural sources of these families of species are taken into account. In both model calculations, a present-day global ozone concentration field was assumed, based on climatological profiles and satellite total column observations.

In a future atmosphere, man-made emissions of halogen compounds are expected to phase out in accordance with international agreements, whereas methane and nitrous oxide are expected to increase. Since the ozone depleting cycles involving NOx and HOx are partly buffering each others effect on ozone, ozone depletion is expected to decrease even when these species increase. Another model assessment of ozone depletion is made for these conditions.

P/3-4.7

Contributions of NAO, QBO, solar activity and aerosol loading to ozone variability and residual anthropogenic trends over Switzerland

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Ozone profile changes are of interest for stratospheric chemistry, UV-radiation, stratospheric dynamics and climate research. This statistical study with Swiss total ozone and ozone profiles separates anthropogenic (i.e., chemical) trends from dynamically caused ozone changes. In the Northern midlatitudes, dynamical changes show up in the troposphere and in the stratosphere. For description, the climatic variables Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) are used. They are found useful proxies to describe the dynamical influence on total ozone and ozone profile trends. The proposed physical mechanism is tested with another station (Iceland) and proved to be valid. The climatic variables are found to be linked with tropopause pressure, which in turn causes reversible ozone transport. Tropopause pressure variations affect the ozone content above the tropopause. These dynamical anomalies decay with height but are noticeable up to the middle stratosphere. Because dynamic variability is strongest in winter/spring, the dynamical effect on ozone is most prominent in this season.

Stepwise regression models are used to separate the contributions of different causes for long-term ozone variability. Tropopause pressure, the Quasi-Biennial Oscillation (QBO) and NAO (AO) are highly significant at certain seasons and heights, explaining a major part of observed ozone variability in the lower stratosphere. Aerosol content and solar flux are found to be significant in the layers above. The solar activity was found significant when only the positive QBO-terms were considered.

The anthropogenic contribution is modelled to depend nonlinearly on aerosol content and clorine loading. Different ozone balances have to be employed for at least three seasons and for the lower, middle and higher stratosphere, to correctly account for the different causes of ozone variability. The trend analysis in the lower and middle stratosphere is performed with the Swiss balloon sounding series. Furthermore, Umkehr measurements of Arosa and satellite overpass data are employed to extend the analysis to the upper stratosphere.

P/3-4.8

Morphology and thermal structure of the Antarctic ozone hole: 1958 until present

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Changes of the ozone distribution and thermal structure of the Antarctic stratosphere were investigated from pre-ozone hole until present conditions based on NCAR/NCEP and ECMWF temperature and TOMS and ground-based ozone data. Particular emphasis was devoted to seasonal transitions and Final Warmings, the influence of the QBO, the solar cycle and volcanic eruptions, relations to the anthropogenic greenhouse effect as well as thermal conditions for PSC formation. The results clearly shows that phase I (1958-1978), with stagnant or increasing stratospheric temperatures, differs distinctly from phase II (1979-1998) when stratospheric temperatures decrease along with increasing ozone depletion. While no significant QBO and solar cycle signals could be found in the data, strong effects of ElChichon and Mt.Pinatubo eruptions resulting in enhanced heterogeneous reactions on volcanic aerosol surfaces, can be quantified. For phase II, the areas of PSC formation potential show a significant growth, with high correlation of these areas with observed ozone depletion surfaces; over this phase the time of the Final Warming is delayed by 16 days. Ozone and stratospheric temperatures show significant correlations, which are highest over eastern Antarctica where the largest cooling rates are observed, too. This may point to a relief effect of the high elevation eastern compared to the lower western Antarctic.

3-4-2 Climate Change Simulations

P/3-4.9

Accelerated global warming and delayed ozone recovery due to increased stratospheric water vapour

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Recent observations suggest that stratospheric water vapour may be increasing, however, the measurements are extremely limited in either spatial coverage or duration. Such an increase would cool the stratosphere. Observations of stratospheric temperature trends extend back several decades, much longer than for water, and show very large decreases of 3-6 K from 30-50 km altitude. We argue here that only with the inclusion of an increase in stratospheric water vapour can these temperature trends be reproduced in a climate model. Furthermore, the required water vapour trend is too large to be accounted for solely by increased production within the stratosphere, suggesting that climate change may be altering the input from the troposphere. The calculated increase in stratospheric water vapour has a large positive contribution to global warming, ~24% of that due to the well-mixed greenhouse gases over the past two decades. If the stratospheric trend indeed arises from increased tropospheric injection, simulations show that it is likely to continue, increasing the predicted twenty-first century global warming by 10-15%, and impeding stratospheric ozone recovery.

P/3-4.10

Interannual variations of the general circulation and polar stratospheric ozone losses in a general circulation model

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Interannual variations of the general circulation and polar stratospheric ozone losses are investigated by using a general circulation model (GCM) developed at Kyushu University. The GCM includes simplified ozone photochemistry interactively coupled with radiation and dynamics in the GCM. Polar ozone depletion is brought about in the GCM by a parameterised ozone loss term which is activated under tuned conditions for dynamical fields and a solar zenith angle and added in the continuity equation for the ozone mixing ratio.

In the present experiment, we performed an 'ozone depletion experiment' over successive 20 years with stratospheric ozone losses formed over the Arctic and Antarctic polar regions, along with a 'control experiment' which is a simulation without the ozone loss term.

Results of the ozone depletion experiment show large interannual variations of the general circulation and polar ozone losses especially in the Northern Hemisphere winter and spring. It is found that the interannual variations are caused not only by dynamical conditions in the stratosphere, e.g., strength of the polar vortex and planetary wave activities, but also by interaction mechanisms between dynamical and ozone fields; the resultant interannual variability of the general circulation in the stratosphere becomes larger than that in the control experiment. Moreover, influences of the stratospheric ozone losses could extend to the troposphere; overall three-dimensional patterns of the interannual variations in dynamical fields seem to coincide well with those of the Arctic Oscillation.

P/3-4.11

Northern Hemisphere winter stratospheric variability in the UKMO unified model

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The ensemble approach is used to study the simulated northern winter stratospheric variability in a troposphere-stratosphere version of the UK Met Office Unified Model (UM). The runs are for December-March periods from 1979-80 to 1997-98: the ensemble for each winter has 9 members. We use observed sea surface temperatures (SSTs), a fixed ozone climatology and fixed greenhouse gases. This paper discusses the following questions: (1) Does the UM reproduce observed temperature trends with only SST variations and (2) Can any significant trend be attributed to SST variations? The results suggest that the answer to (1) is that the UM reproduces the observed trend with only SST variations. The temperature differences between the simulated 1990s and 1980s generally are not significant at 10 hPa, but are generally significant at 50 hPa at the 95% significance level. The results provide a first step toward answering question (2) by suggesting that SST variations alone may explain the cooling trend at 50 hPa. Because the model results show that there is no significant cooling trend at 10 hPa outside of natural variability, one cannot rule this out as an explanation.

A discussion of the elements required for a complete answer to question (2) will also be provided.

P/3-4.12

Relative roles of greenhouse gas changes in recent stratospheric temperature trends

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The GFDL SKYHI general circulation model is used to simulate the effects of observed changes in the well-mixed greenhouse gases and in stratospheric ozone and water vapour during the 1979-1997 and 1989-1998 periods. The relative importance of each change is ascertained using calculations in which changes in 1) ozone; 2) ozone + well-mixed gases; 3) ozone + well-mixed gases + water vapour over the specified time period(s) are added to the model climatologocal values of these species, and the GCM is allowed to obtain a new equilibrium state.

The ozone changes (supplied by W. Randel) include changes from the tropopause to ~50 km. Water vapour data (supplied by F. Wu) are annual means in the 100 - 0.3 hPa range.

Results demonstrate the importance of both ozone changes and changes in the well-mixed greenhouse gases in evaluating upper stratospheric temperature changes. For example, the sign of the temperature change in the tropics at ~10 hPa depends on the inclusion of the greenhouse gases. The results are compared to calculations in which only lower stratospheric ozone changes were included.

The relative importance of radiative and dynamical effects is evaluated using a parallel Fixed Dynamical Heating radiative calculation. Seasonal effects and changes in the model zonal wind field are also evaluated.

P/3-4.13

Changes in the stratospheric climate and Brewer-Dobson circulation due to increasing greenhouse gas concentrations

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The troposphere-stratosphere version of The Met. Office Unified Model has been integrated for the 60 years 1992-2051, assuming the Intergovernmental Panel on Climate Change IS92a scenario for greenhouse gas (GHG) concentrations. Sea surface conditions were taken from a separate coupled ocean-atmosphere experiment, using the same GHG scenario. Modelled temperature trends and decadal variability in the winter polar stratosphere will be presented. Northern Hemisphere ozone depletion in late winter and early spring is particularly sensitive to the occurrences of sudden stratospheric warmings. However it will be shown that changes in the frequency of occurrences of such events was unpredictable in our experiment because of internally generated decadal variability.

The response of the Brewer-Dobson circulation to the changes in GHG concentrations will be analysed using the transformed Eulerian-mean (TEM) residual circulation (v*, w*) as a proxy for the Lagrangian-mean motions in the model. In the tropical lower stratosphere the TEM vertical velocities will be compared to ascent rates inferred from the "tape recorder" signal in water vapour.

These diagnostics suggest that over the 60 years the annual mean up-welling in the tropical lower stratosphere could increase by as much as 30%. The reasons for this strengthening of the Brewer-Dobson circulation will be examined and its consequences for the "age-of-air" in the stratosphere and distributions of ozone and chemical species involved in ozone depletion will be discussed.

P/3-4.14

Middle atmosphere response to CO_2 doubling with the Canadian middle atmosphere model (CNAM)

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The middle atmosphere (MA) response to the increase of anthropogenic greenhouse gases is a complex phenomenon and a subject of concern about the future evolution of the climate system. Trend analysis of observations taken over the past few decades suggest that a significant cooling between 2-10K/decade has occurred in various areas of the MA. A major concern associated with such a cooling is the impact on the long-term evolution of the ozone layer and on the processes driving ozone depletion in polar regions.

The CMAM model has been used to study the response of the MA to a 'double CO_2' scenario. The model includes an interactive photochemical module to incorporate the coupling between ozone and temperature, which is an important source of uncertainties in such studies. The model has been run in both interactive and non-interactive mode to address specifically the nature of the feedback mechanisms involved. It has been run with a non-interactive ocean to produce a first estimation of the direct radiative response (cooling to space) due to the CO2 increase which is the most significant forcing mechanism leading to the MA cooling over tropical and mid-latitude regions. The results show the presence of a negative feedback between ozone and temperature, which reduce the magnitude of the cooling due to the doubled CO_2 concentration. Results also show small but significant changes in the ozone distribution throughout the MA associated with the CO_2 increase. This experiment is a first step toward a more comprehensive study that would include interactive ocean and transient sources of other greenhouse gases such as methane and nitrous oxide.

P/3-4.15

Inter-annual variability in an unified model integration using a parameterised ozone and AMIP II SSTS

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We have used a version of the UK Meteorological Office's Unified Model (UM), a state of the art climate model, to study changes in the stratosphere during the past twenty years. The UM is being integrated in conjunction with the Cariolle parameterisation for stratospheric ozone. The Cariolle scheme includes gas phase chemistry and a simplified treatment of PSCs using a "cold tracer" approach.

The calculated ozone is used instantaneously in the calculation of the radiative heating rates. As the lower boundary condition AMIP II SSTs were used.

The SSTs contain many signals, including the NAO and SO, which are likely to influence the atmospheric circulation, and hence the transport of ozone, in the model. Therefore special attention is paid to the inter-annual variability of ozone and temperature and their relationship to these phenomena. Notice that the Cariolle scheme does not include any change in stratospheric chlorine loading, or stratospheric aerosol. Thus any modelled ozone variability cannot be related to, for example, the increased role of chlorine compounds in ozone depletion. The variability must be related to changing stratospheric dynamics and the interaction between those changes and stratospheric chemistry. In this context, it is of special interest if the model displays a stratospheric circulation change between the 1980's and the 1990's, especially the formation of colder and more stable vortices in the 1990's. Various model diagnostics to investigate the stratospheric circulation will be presented, including planetary waves and EP fluxes.

P/3-4.16

Feedback processes between chemistry and meteorology with focus on lower stratospheric polar vortices, simulations with a coupled GCM

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Three 15-year simulations with the chemical middle atmosphere circulation model MA-ECHAM-CHEM with boundary conditions representative for the sixties, nineties and about 30 years in the future are evaluated. We focus on feedback processes between radiative heating, water vapour and ozone depletion at polar stratospheric clouds in the lower stratosphere of polar spring in both hemispheres. The simulations include analysis of the impact of changes in PSC particle sedimentation due to temperature and water vapour changes, changes of the mean circulation (large scale descent), stability of the polar vortices, changes in large scale wave patterns, and interannual variability. The presentation includes an intercomparison of the simulations for the nineties with 8 years of HALOE/UARS satellite data, and also intercomparison of modelled and observed (Berlin data) temperature trends in the Arctic lower stratosphere.

FOCUSED DISCUSSION SESSIONS

THURSDAY, NOVEMBER 09, 2000
FRIDAY, NOVEMBER 10, 2000

Session 4
UV Observations and Modelling

P/4.1

Effect of varying albedo on solar UV irradiance

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The intensity of solar UV irradiance at the earth's surface is influenced by several atmospheric parameters like ozone content, aerosol optical depth and cloudiness. Furthermore, the reflectivity of the surrounding ('albedo') is of importance, as soon as highly reflecting terrain is present. Experimental data of spectral albedo of various surfaces show that green vegetation has a very low albedo (below 1%) in the UV range, while it is higher than 20% in the visible range. The other extreme situation is snow covered terrain, where the albedo reaches values higher than 90%.

From model calculations it results that the amplification factor of global irradiance due to increasing albedo depends strongly on wavelength and it has highest values around 320 nm, even when the spectral albedo itself is assumed to be independent of wavelength. These model calculations use the so-called 'effective albedo', which assumes a constant value of albedo of the ground in an unlimited surrounding of the observation site.

The effect of varying albedo can be measured best at mountain stations, because there the expanse of snow-covered terrain is changing during the year according to the local meteorological conditions. During winter, spring and summer measurements at the high mountain station Jungfraujoch (3576 m above sea level, Switzerland) were analysed to derive the effective albedo. This is done by comparison of spectral measurements with model calculations, where the only unknown parameter is the albedo, whereas ozone and aerosol optical depths were determined independently. The temporal variation of effective albedo between 80% and 40% could be correlated clearly to the extent of the snow-covered terrain around the measurement station. The corresponding variation in enhancement of irradiance at 320 nm is in the range of 1.3 to 1.15, relative to a snow-free terrain.

P/4.2

Clouds influence on the ground level of UV radiation study for three polish stations

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UV Index dependence on clouds' amount and type has been studied on the base of the four year broadband UV (SL 501) measurement series for three Polish stations: Leba (54.75°N, 17.53°E), Legionowo (52.40°N, 20.97°E) and Zakopane (49.30°N, 29.97 °E). Cloud Modification Factor (CMF) defined as ratio between measured UV Index and corresponding clear-sky UV Index obtained from the multiple scattering radiative transfer model calculations has been used for the analysis. In the model computations, total ozone amount derived from NOAA/TOVS satellite data have been applied. Additional calculations have been made for Legionowo station taking into consideration the available total ozone amount measured by Dobson spectrophotometer at Central Geophysical Observatory in Belsk. Informations about cloudiness have been taken from the simultaneous observations.

The obtained results confirmed the well-known relationship between CMF and clouds' total amount (n). In the cases when clouds amount reached 8 octas, we have obtained the CMF value of 0.8. For all stations, a third degree polynomial has been found as the best fit for curves obtained. The influence of various clouds' type on UV Index has been also analysed. It has been shown that the thin clouds attenuate UV radiation less than the others. For instance, in case of Cirrus clouds the obtained CMF was higher than 0.7 for all n values. The enhancement of UV radiation due to broken clouds has not been clearly confirmed.

P/4.3

The influence of cloud and total ozone on biologically active UV interannual variability during the 20th century in different geographical regions

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UV irradiance coming to the surface is determined by many atmospheric factors, the most important of which are cloudiness and total ozone amount. Since ground UV network has been established not long ago, we estimated the long-term UV irradiance variations in different geographical regions by using historical records of cloud observations from the beginning of the 20th century and long-term ground measurements of total ozone amount.

Variations of UV radiation due to ozone and cloudiness changes are analysed separately in order to reveal the significance of each factor and to define the geographical regions where the interannual variability of UV irradiance is determined mainly by this or that parameter.

The proposed method has been verified by comparing with real variability of biologically active UV irradiance available for the last decade. The reliability of the method can be also proved by a good agreement between the UV variability reconstructed from ground ozone and cloud measurements, and variations of UV irradiance retrieved from TOMS satellite data.

Special attention was given to the geographical regions (if ground cloud and ozone measurements were available) where the regular spectral UV measurements are being carried out (for example NSF network and some others) during the last decade to compare the observed UV variability for the period of measurements with the reconstructed UV variability for much longer period of observations. For the region of Eastern Europe the long-term cloud variations were analysed together with the large-scale global circulation processes in order to reveal those of them, which led to decreasing or increasing of the UV irradiance. The periods with relatively high UV dozes, which can affect the dynamical balance of ecosystems, has been revealed.

P/4.4

UV-B and ozone anticorrelations at low and high latitudes

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An apparently low anti-correlation situation between UV-B radiation and ozone is investigated at two observation stations. Anti-correlations between ozone and global UV-B radiation were obtained for a tropical station, Cuiaba (15°S, 56°W) and a relatively high-latitude station, Punta Arenas (53.2°S, 70.9°W). For both stations, ozone and UV-B radiation data from Brewer ozone spectrophotometers, operated by The National Institute for Space Research, of Brazil (INPE) have been used. A full year of data, 1995, was analysed. The anti-correlation studies were made by using ozone daily average data, and measured UV-B radiation: the maximum daily value, and the observation at a fixed solar zenith angle. Spectral irradiance at two wavelengths, 305 nm with strong ozone absorption and 325 nm, with very weak ozone absorption, were used, and the irradiance ratio 305/325 was obtained in order to eliminate the noise effect of clouds. Four data sets were used: maximum daily with all data, maximum daily without cloudy days, measurements at a fixed solar zenith angle, and measurements at a fixed solar zenith angle with cloudiness removed. It was observed that at both stations spectral maximum UV-B values show very low correlation coefficients with total ozone, and only the irradiance ratio has a more significant correlation coefficient. It is only when the geometry sun-observer is removed that the correlations show. The measurements at a fixed solar zenith angle show much higher correlations. For example, the correlation coefficients for the signal ratio 305/325nm with the removal of cloudiness, and using the daily maxima, are only 0.05 for Cuiaba, and 0.14 for Punta Arenas; whereas for a fixed solar zenith angle, the correlations are 0.61 for Cuiaba, and 0.79 for Punta A

P/4.5

Solar ultraviolet irradiance incident on the Atacama desert region

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In the present work we made detailed radiative transfer model calculations of solar ultraviolet irradiances incident over the Atacama desert region around 18º S within a 6º latitudinal interval as function of altitude, from 0 to 7 km, in order to interpolate all possible situations in the region. The resulting irradiances weighted with the erythemal action spectra of McKinlay and Diffey are compared with ground based measurements done at La Quiaca, Argentina, (3459 m asl), and at Arica, Chile, (25 m asl) at the Pacific coast. Spectral irradiances for different months of the year and moments of the day are presented, considering typical as well as extreme values of the most significant geophysical variables (ozone, aerosol and albedo for ground surface with and without snow). A mean curve derived from results for all months normalised to the maximum value, gives a slope of 5.6 %/km for no snow and normal ozone conditions and 4.1 %/km for snow (high albedo) and low ozone. In this last case, the absolute value of the erythemal irradiance at the highest mountains picks are within the highest of the Earth. These mean values can be improved significantly if the altitude range is divided in three parts: 0-1km, 1-3km and 3-7km. The corresponding slopes are: 9, 5.9 and 3.9 %/km for the first (normal) case and 6.4, 4.4 and 2.8 %/km for the second (extreme) case.

P/4.6

Monitoring of surface UV spectral radiance over Beijing since 1997

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The monitoring of Surface UV spectral radiance over Beijing (40N, 117E) was begun in 1995. Quasi-continuous long-term monitoring is started in 1997. The instrument used is a hemispherical spectral radiometer in wavelength range of 290-450 nm and sampling interval of 0.1 nm.

Daily monitoring is made with consecutive observation with and without shadowed sphere, thus, total hemispherical radiance and only diffused radiance can be obtained. In addition to this instrument, a Dobson instrument made observation at the same site. There have been totally 572-day observation and about 16,000 spectral samples. About 35% of observation are made in clear days. In this paper, we will present the observation statistics, relationship with ozone and other atmospheric parameters, comparison with UV R-T model, and towards establishing surface UV climatology in northern China.

P/4.7

Statistical analysis of UV radiation and stratospheric ozone depletion over India with TOMS data

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Stratospheric Ozone reduction results in higher amounts of UV-B radiation reaching earth's surface and the health risks associated are skin cancer, damage to eyes and immune system. The most common effect is photokertitis. Chronic eye conditions likely to increase with Ozone depletion include cataract, carcinoma, ocular melanoma and a variety of conjunctivitis. Stratospheric Ozone values are near lowest point since measurements began and so current UV- B radiation levels are thought to be close to their maximum. The expected correlation between increase in the surface UV-B radiation and decrease in over head Ozone are evaluated for a period of 22 years from 1978 -1999 based on TOMS data in this paper.

The changes in Ozone and UV-B radiation can very well be monitored by using Earth Observation Satellite Data. Total Ozone Mapping Spectrometer (TOMS) on board the NIMBUS-7, Meteor- 3, ADEOS and Earth Probe satellites provide daily global coverage of Earth's total Ozone by measuring back-scattered ultraviolet sunlight in six 1 nm bands from approximately 308 to 380 nm. For total global Ozone and UV- B radiation TOMS level 3 data was used on a fixed 1-degree latitude by 1.25-degree longitude grid. With the help of this data, the total column of Ozone and Erythemal U.V. radiation are derived for selected cities of different regions of India viz., East Coast, West Coast, Central India, Northern India, Himalayan region and Desert region. The trends of Ozone and UV-B radiation are observed for the period of 22 years from 1978-1999. Statistical methods of analysis have been carried out for monthly mean ozone values and UV radiation over different regions of India. Best linear fit of Ozone data and U.V-B radiation have been carried out and the rate of Ozone depletion per month and per year and also the rate of percentage increase in U.V. radiation per month and per year are evaluated. Correlation coefficients between monthly mean Ozone values and corresponding U.V. radiation have been evaluated. The seasonal variations and correlation of different data sets for different regions have been worked out and results obtained are presented in this paper.

P/4.8

Spectral measurements of UV-B radiation over Hanle, Delhi, and Antarctica

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Ozone in the stratosphere is very important for the very survival of life on the earth as it protects us from harmful ultraviolet -B radiation coming from the sun. The ozone depletion within the earth's atmosphere is responsible for increase in the solar ultraviolet radiation reaching the earth surface. The harmful effects on human health, animals, plants and material are on increase due to high exposure to UV-B radiation, which is caused by ozone depletion. Solar ultraviolet radiation is also one of the important factor which controls the chemistry of stratosphere and troposphere. The UV-B radiation at Earth's surface is a function of latitude, altitude, season, solar zenith angle, aerosols and ozone concentration. Therefore monitoring of UV-B radiation level at various latitudes, altitudes and seasons is of great significance not only for scientific study but also for medical and environmental reasons.

Keeping above in view a highly sophisticated and hand held microprocessor based sun photometer, MICROTOP-II, has been used to measure the solar radiation at five wavelengths 300 nm, 305 nm 312 nm, 940 nm and 1020 nm using narrow band (2.5 nm FWHM) filters. These measurements were used to estimate total ozone, water vapour, aerosol optical depth etc. The measurements were carried out at Maitri an Indian Antarctica station (700 46' S, 130 44' E) from Jan. 1997 to Feb., New Delhi (280 38' N, 770 13' E) from April 1999 onwards and high altitude stations such as Leh (34°77' N, 77°36' E, 3311 meter a.m.s.l.), Hanle (Mount Saraswati), Jammu and Kashmir (India) (32° 43' N, 77°34' E, 4467 meter a.m.s.l.) during July 13-31, 19991998 on hourly basis on all clear days. The measurements were also carried out during voyage to Antarctica covering latitudes 150 N to 700 S during December 1996. It is found that the UV-B radiation is very low at polar latitudes due to more ozone in the stratosphere while UV-B was found to be very high at high altitudes. The UV-B radiation at New Delhi is in between. In the present communications the diurnal, seasonal and latitudinal variations of UV-B at various wavelengths will be discussed in detail.

P/4.9

Improvements in UV radiometric calibration accuracy and measurements of column ozone from zenith sky observations

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A multi-filter spectroradiometer (MFS) has been developed which is being used as a component of a calibration transfer standard spectroradiometer (CTSS) and for measurements of total column ozone amounts which are derived from zenith sky observations. The MFS utilises the newly developed ion-assisted-deposition narrow band interference filters, which are characterised by high in-band transmittance, extremely low out-of-band transmittance, and a nitrided silicon photodiode. These components have been shown to be insensitive to extremes of environmental conditions. The MFS instrument exhibits a radiometric stability, which appears to exceed that of national laboratory radiometric standard sources. The other component of the CTSS system is a small high precision double monochromator. Measurements of zenith sky radiances at the Dobson AD double wavelength pairs have been inverted to obtain total column ozone. On November 12, 1999 the MFS instrument yielded total column ozone values of 265.2 DU, SD=3.5 DU. The co-located NOAA Dobson instrument AD double wavelength pair direct sun observations yielded 260 DU, and the TOMS overpass value was 258.0. On November 13, 1999 the MFS zenith sky value was 252.4 DU, SD=2.6 DU compared to the TOMS overpass value of 248.0 DU. No Dobson instrument measurements were made on this date. This degree of comparability is similar to a series of 9 days of zenith sky observations made with SBUV-2 and the SSBUV instruments and co-located NOAA Dobson direct sun observations. The average zenith sky column ozone measurement was on the average 1 % higher than the Dobson direct sun measurements.

P/4.10

The impact of enhanced UV radiation on the chemistry of sea-salt aerosols

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Recent *in situ* measurements show the major role of sea-salt aerosols in radiative forcing in the marine troposphere. Understanding of the interaction of these particles with UV radiation and gaseous pollutants is, therefore, of prime importance. We have performed a concerted experimental, molecular dynamics, and kinetics modeling study of concentrated aqueous sodium chloride microparticles suspended in air with ozone and irradiated at 254 nanometers [1]. UV radiation triggers a cascade of chemical reactions leading to substantial changes in the composition of the sea-salt aerosols and to release of molecular chlorine from the particles into the atmosphere. Laboratory measurements of the observed gaseous chlorine product are explainable only if reactions at the air-water interface of the aerosols dominate. Molecular dynamics simulations show the availability of substantial amounts of chloride ions for reaction at the interface, and quantum chemical calculations predict that in the gas phase chloride ions will strongly attract hydroxide, which is the product of UV photolysis of ozone in humid air. Model extrapolation to the marine boundary layer yields daytime chlorine concentrations that are in excellent agreement with field measurements over the Southern Ocean and North Atlantic.

Thus, interactions at the surface of atmospheric particles may play as important role in the troposphere as in the stratosphere. Increased amounts of UV radiation will strongly influence photochemical reactions at the aerosol interfaces leading to changes in the global production of molecular chlorine, which is one of the major oxidants in the lower marine troposphere.

[1] E. M. Knipping, M. J. Lakin, K. L. Foster, P. Jungwirth, D. J. Tobias, R. B. Gerber, D. Dabdub, and B. J. Finlayson-Pitts: Science vol. 288, p. 301, 2000.

P/4.11

Dialog: Dissertations initiative for the advancement of limnology and oceanography

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Initiative for the Advancement of Limnology and Oceanography (DIALOG) Program was initiated in 1994 to promote understanding and collegial interactions across the aquatic sciences. The program consists of 3 parts:

1. Ph.D. Dissertation registry. All Ph.D. recipients are invited to submit an abstract of their Ph.D. dissertation research for inclusion in the DIALOG Dissertation Registry. These are posted on the ASLO website in a searchable format, and a hard copy is mailed to everyone who submits an abstract and to representatives of the various funding agencies.

2. Data base. Demographic information is collected with the dissertations in order to provide information on the characteristics of the recent graduates such as Ph.D.-granting institution, field, age, gender, citizenship and employment status.

3. Symposium: A symposium is held every other year to enhance interdisciplinary thinking and promote collegial interactions across the aquatic sciences. The fourth is planned for October, 2001 at the Bermuda Biological Station for Research.

Symposium expenses for this international program (air fare and on-site expenses) are covered by the sponsoring agencies (U.S. National Science Foundation, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration and Office of Naval Research and European Commission). This program is co-sponsored by the American Society of Limnology and Oceanography.

This POSTER will present an overview of the program and a profile of participants. The dissertation registry, an on-line form for submitting dissertation abstracts, and application instructions are available at <www.aslo.org/dialog.htm>.

P/4.12

UV green model and SUV 100 and Brewer spectra: an intercomparison in Ushuaia

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Within the activity of the Italian Antarctic Project (PNRA) from the 1994 is running in Ushuaia (Argentina) a spectrophotometer Brewer to study during the austral springtime the ozone depletion over the periantarctic region and its relations with the Antarctic "ozone hole". The activity is culminated with the flights of the APE-GAIA Project campaign during the 1999 spring time.

The same place is a node of the NSF UV Radiation Monitoring Network (USA) where a spectroradiometer SUV100 is present since 1990. Ushuaia is also a very suitable site to study the effects of aerosols and cloud cover on the UV-B radiation due to its climate situation. This paper shows the results of the intercomparison between the Green model outputs and UV-B experimental values by the SUV100 spectroradiometer and the Brewer. The semiempirical Green model is an efficient algorithm to calculate the middle ultraviolet radiation at ground. The calculated data have been implemented standardising the results to the instrumental outputs using a triangular function to fit the two slit functions. The Ozone measurements by the Brewer have been used as input to the model.

Furthermore the outputs of the model of some selected clear sky and cloudy days during the APE-GAIA Campaign are displayed.

P/4.13

The ozone monitoring instrument (OMI)

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The Ozone Monitoring Instrument (OMI) is a Dutch-Finnish contribution to the NASA EOS-AURA mission (formally called EOS-CHEM), which is scheduled for launch in December 2002. OMI is an imaging spectrometer that will measure the back-scattered Solar radiance between 270 and 500 nm. OMI will provide total columns of trace gases like ozone, NO_2, BrO and SO_2. Cloud coverage and height, as well as aerosol optical thickness and information on the aerosol size distrubtion and aerosol type will be derived from OMI data.

From these products, the UV-B flux at the surface can be derived. Given its high spectral and spatial resolution, OMI will make a major advance in our ability to estimate the UV flux from satellite measurements.

A special line of OMI data products will be available within three hours after the measurement. These so-called near real time products is intended for the operational weather forecasts, but can also be used for UV forecasts.

P/4.14

Modeling ultraviolet radiation using Dobson spectrophotometer

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Monitoring of ultra violet (UV) radiation reaching the earth's surface has gained a lot of interest in view of the documentation that 1% decrease in ozone brings about 1.2 to 1.5% increase in biologically harmful ultra violet (UV) radiation. No continuous monitoring of UV radiation is performed in the equatorial African region. This study presents an indirect methodology of determining UV irradiance at Nairobi.

A Dobson spectrophotometer located at Chiromo, Nairobi, Kenya has been acquiring ozone measurements since 1984 through a radiative methodology. In this study, a novice technique is presented of deriving UV-radiation from the raw data of the Dobson Ozone Spectrometer. Estimates of UV levels at three distinct frequencies in the UV-A (in the 400-315 nm spectral region) and UV-B (315 -290 nm) are thus theoretically generated.

A case study of UV patterns using six years of ozone data is presented. The generated UV levels seem to agree fairly well with the general patterns of UV-levels in the tropics using satellite data.

This methodology has a potential utility in all countries where such similar instruments are located in that it will enrich global Ultra-Violet data base and thus provide a better understanding of the climatological behaviour of UV globally.

P/4.15

Erythemal UV dose in Santiago, Chile (33°S)

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Ground-based UV irradiance measurements over Santiago-Chile have shown a significant increase during winter. Summer and spring are also increasing but at statistically non significant rates. Here the result of 8 years (1992-1999) of erythemal dose rate and daily dose calculated with the CIE action spectrum are presented.

The range of mean daily dose spans from 500 to 5200 Joule/m^2/day in winter and summer, respectively. Seasonal variations of daily dose prove to be non significant. The expected theoretical daily mean dose for clear-skies over Santiago is around 4.000 joule/m^2 but observed mean values are only 2.640 Joule/m^2. However, the absolute maximum daily dose in summer reached to 8.000 Joule/m^2. During midsummer (January) the calculated daily dose increased at a rate of one Minimal Erythemal Dose (200 Joule/m^2) every two years, corresponding to an increase of around 18-20% per decade. Causes for decreasing ozone at middle latitudes during spring and summer and the influence of urban pollution on UV are discussed.

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P/4.16

Application of neutral network technique for UV monitoring

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An approach for the monitoring of surface UV irradiance is presented. One the one hand benefit is taken of fast integral radiation measurements. On the other hand the results of a multiple scattering radiative transfer model are used. Both data are connected *via* neural network technique to give UV irradiance values with high spectral resolution. This approach allows the disposition of UV spectra for all sky conditions including broken cloudiness. The resulting UV data are free of any instrument properties, as slit function and deviations with respect to the cosine response. Chances for UV monitoring with high spatial and tempORAL resolution and the its accuracy will be discussed.

P/4.17

Corrected UV irradiances from the U.S. EPA/NUVMC network of brewer sperctroradiometers and comparisons of DUV values with satellite data

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A network of 21 Brewer spectroradiometers, operated by The U.S. Environmental Protection Agency/National UV Monitoring Center (EPA/NUVMC) is measuring UVB and UVA spectral irradiances throughout the United States. The database from these sites extends for periods ranging from two to seven years. Corrections to the raw data have now been implemented. The procedure for carrying out these corrections will be described. These corrections include (1) the cosine errors associated with the full sky diffuser, (2) the temperature dependence of the response of the instruments and (3) the temporal variation in the instrument response due to optical changes in the characteristics of the instruments. The effects of these corrections on the UV irradiance for some Brewers are quite significant. While for many sites the total corrections amount to less than 10%, for certain sites they are much larger, in some cases amounting to more than 25%. Corrections for the cosine error depend on the solar zenith angle and range between 3 and 20% depending on the site. The temperature dependence of the response leads to corrections of up to 5-10% at the extreme ends of the operating temperatures. Changes in the temporal variation of the response between annual calibrations due to degradation of the optics and alignment errors require corrections of up to 15% at some sites. Application of these corrections bring the errors of the absolute irradiance values to ±5%. Corrected irradiances for some of the sites extending over a number of years will be compared with clear sky models. Intercomparisons of the DUV measurements from some of these sites to DUV values calculated from simultaneous satellite measurements at the locations of these sites will be made in order to validate the estimates from the satellite data.

P/4.18

Comparison of measurements of surface UVR and TOMS satellite data over Australia: health implications

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Ultraviolet radiation (UVR) has a profound impact on erythema, skin cancer, and plant damage. Over the tropical parts of Australia, incidences of skin cancer rank amongst the highest in the world. The maximum UVR at solar noon, often expressed as UV Index (UVI), is useful as an indicator of the maximum potential UVR hazard. However, daily or yearly total exposures are better measures of the overall levels of the ambient UVR, because they take into account the cloud cover variability. For example, measurements at solar noon on two consecutive days in March in Melbourne resulted in similar noon dose rates of 0.23 and 0.21 W/m^2 (or 9.1 and 8.5 UVI's), but the daily total dosage was reduced by 47% from 4880 to 2160 J/m^2 due to cloudiness.

The Australian Radiation and Nuclear Safety Agency (ARPANSA) has run a network of broadband UV instruments since the middle of the 1980's. The network initially employed International Light (IL) actinic detectors. Since 1992/1993 Solar Light 501 UVBiometers have been in use in all major capitals taking measurements routinely every 10 mins. From these measurements we will derive the ambient UVR for the major capital cities in Australia. The interannual variability will be discussed in terms of ozone and cloud variations. We then compare our results to the TOMS UVR exposures. Comparisons between the TOMS and the IL detectors have shown biases between 6-18% and standard deviations of 14-38%. Agreement between the Solar Light UV501 Biometers and TOMS UVR is assessed and the results presented.

P/4.19

Modeling of UV radiation over Cairo Part 1: statistical method

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During the recent years there has been considerable concern regarding the modelled and measured UV changes at the surface as a result of stratospheric ozone depletion, there has been less attention on the influence of tropospheric changes on surface UV.

Different results over the past few decades suggest a significant uncertainty in UV trends which mainly originates from the accuracy of the UV instruments and the short period for which the data is available. So, we will tend to make different multiregression models to try estimated the values of UV in relation with different parameters. In addition, the large spatial and temporal variability of changes in tropospheric composition make the situation more ambiguous. Until now, there is no definite conclusion has been obtained with regard to UV trends. While some long-term studies show negative UV trends, short-term result suggest an increase in ultr-violet radiation.

P/4.20

Calibration of filter radiometers against spectroradiometers: error assessment.

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Multichannel instruments as the GUV (Biospherical Instruments Inc., BSI) available in Chile (Punta Arenas, Valdivia y Santiago), Argentina (Ushuaia, Buenos Aires, Puerto Madryn y Jujuy) and elsewhere must be calibrated at least once a year. As recommended by manufacturers, the easiest and least expensive procedure is a comparison with spectroradiometers which is to be preferred to lamp calibrations. However, the error implicit in such comparisons is not reported in the calibration forms. Spectroradiometers of type SUV (BSI) exist at Valdivia and Ushuaia so that simultaneous operation of both types of instruments at these two sites makes possible such assessment as frequently as desired. Input for calibration is net voltage, ΔV, measured with the GUV and absolute irradiances, E, from the reference instrument. Two types of calibration constants are considered for each channel:

$$C = \frac{\Delta V}{E^*} \qquad k = \frac{\Delta V}{\sum R' E}$$

C is normally included by manufacturers, E* being irradiance at a nominal central wavelength, while k requires a knowledge of relative filter responsivity R' and the sum covers the spectral interval where R' is not zero.

The results here reported were obtained through a series of comparisons performed in Valdivia during the high-sun season 1999-2000 for each of the four channels of the GUV radiometer (centered at 305, 320 340 and 380 nm). Values for the calibration constants can be determined by simple linear regression of irradiance collected during the full daylight period, including high solar zenith angles (about 60 values). For k, mean standard errors for the channels during ten clear days expressed in per cent are as follows: 0.2, 0.4, 0.4 and 0.5% for the 305, 320, 340 and 380 nm, respectively. Analyses of 20 days with variable cloudiness indicate an increase of these errors in a factor around three. For C, similar figures are found. Errors introduced by improper leveling and orientation of the instrument are given special consideration together with some suggestions to minimize their impact on the calibration procedure. Additional errors due to interdaily variations are presented for days with clear skies and scattered cloudiness.

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P/4.21

Empirical model for the investigation of the intradiurnal variations UV-B radiation

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Presented are empirical models for the investigation of intradiurnal variations of the global UV-B irradiance reaching the Earth's surface.

The mathematics model uses empirical relation between solar zenith angle (Za) and value of the global UV-B irradiance (Duv). Duv = exp{A[cos(Za)]^(1/C)+B}, where A, B, C is linearization parameters, A characterises the inclination angle, B is a line shift, C is a constant. This model usually presents itself the function of the graphic representation which give a change of UV-B radiation as a number of parallel lines. The preliminary calculations of the measurements were obtained by spectrophotometer Brewer Mark II #044 in Obninsk (Russia, 55.12 N, 35.6 E) show that most of experimental data obtained at the clear sky or direct sun expositions plotted in co-ordinates ln(Duv) vs. [cos(Za)^(1/C)] form straight lines. The best fits were obtained for C=2.5.3, moreover to a great changing limits UV-B irradiance on two and more power. It was found by the measurements that linearization parameters A and B for measurements made at morning (A1 and B1) and afternoon (A2 and B2) can be changed at different parts of the day in different ways. The division begins at local noon. They can be either similar to A1=A2 and B1=B2 or differ in one or two parameters A1<>A2 and B1<>B2, A1=A2 and B1<>B2, A1<>A2 and B1=B2.

The statistical analysis of the sums of the parameters A+B, (that is ln(Duv) for Za=0) depends on ozone layer thickness with the correlation coefficient being about -0.8.

The obtained results may be useful for inter- and extrapolation, for filtering and smoothing of experimental data, for procedures for the short-term UV index forecasting. A few early morning measurements at solar elevation about 80-85 degrees can predict all daily values of DUV with very good accuracy, it means for the clear sky conditions.

The usage of this model gives the possibility of determining the influence of total ozone content, aerosol, haze and cloudiness in changing UV-B irradiance reaching the ground.

P/4.22

Solar UV risk in Argentina. First tests of the ISUVN index

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In this work we present the ISUV-ISUVn, a one day UV index forecast for Argentina, that is prepared and distributed daily by the Argentine National Weather Service. It is a generalisation and extension to all the country of a previous version of this index developed by Piacentini (1995), that was applied during several years for predicting the solar risk at the central region of Argentina and Uruguay. The new prediction model is based on experiences from long term measurements of erythemal irradiance at several sites in Argentina and includes actual measured ozone values and meteorological cloud forecast. The difference between forecast and actual case, determined through the measured erythemal irradiances, is analysed for different geographical locations. The particular situation of Argentina in the Southern Cone of South America, with very large latitude extent and altitude variations and consequently very different climates an UVB solar irradiances, shows the importance of the UV index. The presence of the ozone hole over Southern Patagonia in the spring season is also of significance for the appropriate protection of the population against an over-exposure to solar UVB radiation.

P/4.23

UV-index forecasts and observations in Korea

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This system mainly consists of UV-B radiative transfer model, total ozone prediction model, and weather forecast model. The operational procedures of this forecast system is that collecting input data, calculating forecast day's total ozone and meteorological variables, running UV-B radiative transfer model based on the NCAR TUV (Tropospheric Ultraviolet and Visible) radiation model to get surface UV-B intensity in cloud free condition, weighting cloud factor to estimate UV-index, and publishing it through internet home page of Korea Meteorological Administration(KMA).

The UV-index forecast system has been routinely operating two times(06 and 18 LST) a day for 25 cities all over Korean Peninsula (33° 39°N, 124°131°E) since June 1998.

To verify the UV-index forecast system, the forecasted UV were compared to observed data by Brewer Spectrophotometer or UV-Biometer in cases of several stations over Korea for summer season(June, July, and August) in 1998. In the cases of clear sky, differences between forecasts and observations are about 10%, UV-index forecasts in cloud free condition are well agreed with observations. For the cloudy sky, however, the results showed less than 50% agreement between forecasts and observations. It might be caused mainly by failure of cloud prediction by the numerical weather prediction model.

P/4.24

Simultaneous UV-B radiation and ozone measurements at Punta Arenas, Chile, during appearances of the ozone hole

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Solar UV-B radiation and total ozone were measured simultaneously at Punta Arenas, Chile (53.0°S; 70.9°W), and are described for occasions of the appearance of the ozone hole. UV-B radiation at 305, 320, 340 and 380 nm is measured by a GUV spectroradiometer model 511 and ozone with a Brewer spectrophotometer (#068). The GUV was installed in April, 1993, and the Brewer spectrophotometer in March, 1992.

The data analysed was obtained between 1993 and 1998. Peak radiation intensities were obtained at each channel, measured between 10: 00 AM and 03: 00 PM (local time) and the mean daily values of ozone from the Brewer.

These ground-based observations show the typical seasonal variation of the UV-B radiation. During local spring, peaks in UV-B radiation are observed, caused by the passage of the ozone hole over Punta Arenas. The radiation ratios between 305 and 340 nm were calculated to compare with the total ozone.

The data show that the ozone decline (increase) is always accompanied by an increase (decline) in the ratio 305/340. This work also presents diurnal variations of the 305nm radiation for several selected days with different levels of total ozone.

According to these observations, for example, on October 17, 1994 total ozone observed was 145.8 DU (this is the minimum ozone value recorded at Punta Arenas ever), and a comparison with ozone value of October 08, 1994, which was 336.1 DU, shows an increase of the UV-B Radiation at 305 nm by 155.8 %.

P/4.25

UV measurements at high altitude locations

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Most of UV monitoring stations are located at sea level or at moderate altitude (0 to 2000 m asl. Consequently, there is little data reported at high altitude locations (3000 to 5000 m asl) as well as at tropical latitudes.

In this work we show:

a) Four-year erithemical UVB (290-325) trend at a high altitude location obtained by a Brewer spectrophotometer operating at La Paz, Bolivia (16.5ºS, 68.1ºW, 3420 m asl). As expected we find very high values for the irradiance, just mitigated by the inverted seasonal trend of the climate i.e. sunny winters and cloudy summers.

b) A preliminary study of UVB variation with the altitude has been carried out at two locations: La Paz (3420 m asl) and Mount Chacaltaya (5200 m asl). Both sites are just 30 km far away, so similar atmospheric conditions may be assumed. Two YES UVB radiometers (280-320 nm) operated during some months at both locations, however only data from clear days has been used for comparison. We find that the UVB irradiance grows with altitude 2.5% every 300m, less than the 4% every 300 m, reported for moderated heights, due to the decreasing density of the atmosphere with altitude.

c) A media campaign on the UVB Index was carried out in La Paz in order to prevent risks for human health due to the high values of the irradiance, especially in the "dangerous" season (September to March). This is an example in which scientific research should not be divorced from social reality.

P/4.26

A comparison of direct and global UV-B X ozone anticorrelations

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UV-B radiation was measured at two stations in the Antarctic region. At Punta Arenas (53.2^{o}S, 70.9^{o}W), with a Brewer spectrophotometer, and at the Brazilian Antarctic Station Comandante Ferraz (62°S, 58.2°W), with a GUV radiometer. The data are analysed and correlated with total ozone. Both sites are maintained by "The National Institute for Space Research of Brazil", INPE, with the co-operation of Universidad de Magallanes in Punta Arenas. The period analysed is for October 1999, when the Antarctic Ozone Hole develops. Relative deviations between total ozone and global and direct UV-B radiation were compared. Two different conditions were used, the daily maximum of UV radiation, and UV radiation at a fixed solar zenith angle, 50° for Punta Arenas and 60° for Ferraz. At Ferraz, depletions in total ozone up to 60% were observed, with corresponding UV-B variations at 305 nm of 600%; at Punta Arenas the largest depletion was about 35 %, with UV-B variations of 200 %. At Ferraz, for the larger variation range, UV-B varies in a non-linear way with total ozone. From linear fits in the range up to 35% it was observed that direct radiation has higher correlation with ozone than global radiation. It was also observed that measurements at a fixed solar zenith angle show larger correlation than measurements at local noon, because geometrical variability is then eliminated. The use of an irradiance ratio, for example 305/320, improves the linear correlation coefficients as compared to using a single channel. Global UV-B radiation at a fixed solar zenith angle resulted in correlation coefficients, at 305 nm, of 0.59 at Punta Arenas and 0.34 at Ferraz; with irradiance ratio 305/320, the correlation coefficients were 0.89 for Punta Arenas and 0.78 for Ferraz.

P/4.27

Brewer spectrophotometer UV-B measurements for aerosol optical thickness determinations during biomass burning

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Direct sun measurements using a Brewer spectrophotometer have been made at five wavelengths in the UV-B range: 306.3, 310.1, 313.5, 316.8, and 320.1 nm. During August 1999, a field campaign was organised in Campo Grande, MT (20.4 S, 54.7 W), a Brazilian savannah region subject to seasonal biomass burning. The instrument was especially transported to the observation site, located outside of the city limits. It was determined that the SO_2 signal, which is seen at about the same wavelength than the O_3 signal, was at least 30 times weaker, and was therefore not a problem in the determination of the optical thickness. The aerosol optical thickness was then deduced in order to assess the impact of biomass burning on this important parameter of the lower atmosphere.

It was determined that the technique could resolve time variations of about 10 m duration. The optical thickness was deduced using the Langley plot technique for the direct sun UV-B measurements giving values in the range 0.5 to 2.0 at 306.3 nm.

P/4.28

Measurements of UV radiation at Thule, Greenland

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UV radiation has been measured at Thule, Greenland, using both broad band and spectral instruments. Thule is one of the primary arctic NDSC stations and well equipped with auxillary measurements to support the UV measurements (total shortwave, direct shortwave, aerosol optical depth, ozone, NO_2, lidar) as well as meteorological observations from the airport. The global CIE-weighted irradiance has been measured since 1993 using a modified version of the Solar Light model 500 instrument whereas the global spectral irradiance has been measured since 1995 using a precision spectroradiometer constructed specifically for the purpose. The presentation will focus on the measurement precision, the variability of the measured UV radiation and the inter-dependence of UV on ozone, clouds, aerosols and surface albedo, and how well the measured UV can be modelled.

P/4.29

Global spectral UV-radiometer with automatic shadow band

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A solar radiometer (GUV-511 C, Biospherical Instruments Inc., San Diego, USA) with three UV channels is operating at Trelew (43.2 S, 65.3 W), Argentina, since the spring of 1997. The instrument provides global on horizontal plane measurements all the year around with 1-minute period. At January 1, 1999, an automatic shadow band was added in order to calculate diffuse and direct radiation. The error introduced by the band is corrected with two additional measurements taken at  7.5^o respect the solar zenith. The period of the measurements was increased to 2 minutes in order to keep the same S/N ratio.

UV direct radiation can be used to calculate the total content of ozone in the atmosphere by using differential absorption procedures. The ratio between the signals for the 305 nm and 320 nm channels were used. For calibration, a modified Langley plot (total ozone given by NASA times air mass vs. natural logarithm of signals ratio) was used; calibration constants were obtained with 10 measurements from different ozone and air mass conditions.

This work discuss the results obtained for total ozone for clear days since January, 1999 to the end of March, 2000. Till October, 99 the comparison with results from TOMS shows no significant deviation (standard deviation less than 3 %) but after that the difference increased to reach around 10 % at the end of the reported period. On March 2000, it was run an inter-comparison with the instrument and a reference GUV. Results show that the instrument's calibration constants must be modified by one amount that depends on the channel. When spectral values were corrected the new total ozone value wereed in very good accordance with data given by NASA.

P/4.30

Total ozone measurements in Mar del Plata, Argentina

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The middle-latitude Atlantic seaside results of big importance for summer tourism in Argentina. Instead of that there are no terrestrial measurements of ozone in that region. For those reasons it was decided to install one ozone meter in that region.

Since the Spring of 1998 total ozone measurements are performed in Mar del Plata, Argentina (38.00 S, 57.56 W) by using a Microtops II (Solar Light Inc.). The instrument is a low-cost solar photometer with three ultraviolet channel, centered at 305 nm, 312 nm and 320 nm, with a bandwidth FWHM of 1.4 nm. Two extra infrared channels (940 nm, 1020 nm, with 10 nm FWHM) are designed to measure precipitable water and aerosol optical depth. Total ozone values are calculated by using the three channels measurements and a proprietary software that corrects for aerosol scattering. Alternatively total ozone values can be obtained by using the irradiances for any pair of wavelengths. Measurements were performed with direct solar light as close to noon as possible.

Results are compared with TOMS values given by NASA as overpass measurements for this position. During a first period till March 1999, results show a systematic bias of near 9 %, but after a change in the quartz window of the instrument, the bias was solved and the standard deviation for the difference was reduced from 6.0 % to 1.9 %. Quality of measurements do not show a significant dependence with sky conditions. Values obtained by using pair of UV-wavelengths are also discussed; they seem less precise but more independent of air mass values present during measurements.

The quality of the optical components included in the Microtops II, the power of the microprocessor used and the easy operation of the instrument permit to advance that it will bring measurements of total ozone in conditions unthinkably for conventional instruments.

P/4.31

An investigation of high and low frequency ozone and UV variations

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Total ozone data collected at the two Italian Brewer stations of Rome and Ispra, are analysed by means of an appropriate filtering technique. The long-term variation and the synoptic scale fluctuations are singled out. The former data are interpreted in connection with trends observed for other meteorological parameters both at the earth surface and in upper air, stratosphere included. Moreover, possible scenarios of ozone and UVB for the next decade are discussed under various assumptions, with the aid of a radiation transfer model. The relationship between synoptic scale ozone fluctuations and stratospheric meteorological variables, is analysed by means of an advanced statistical technique to investigate for possible non linear links.

P/4.32

Ultraviolet radiation studies in Cordoba, Argentina

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Ultraviolet-B radiation (UV-B, 280-315) is monitored in Córdoba, Argentina (31°24' S, 64°11' W, 400 meters above sea level) using the Yankee Environmental Systems (YES) pyranometer, model UVB-1. Measurements of solar broad band UV-B irradiances were conduced between November 1998 and December 1999. These are, to our knowledge, the first measurements obtained in Córdoba with a high quality pyranometer. The site selected for the measurements represents semi-urban conditions and is along the most frequent wind direction (NE-SW). For clear sky days, the measurements are in good agreement with results of a radiative transfer model. However, this study shows substantial reduction of UV-B radiation on days with high levels of air pollution. The maximum UV irradiance measured was 2.61 W m^{-2}. In this work we investigate the seasonal variation of UV-B radiation to assess its response to air pollution, physical variables, and meteorological factors.

P/4.33

Twenty-five year record of spectral UVB in the mid-atlantic region, USA

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The Smithsonian Institution (SI) has been monitoring global solar UV-B since the mid 1970s at a number of sites in Maryland. The scanning multifilter spectral radiometers used for these measurements were designed, tested and built by the SI. Two similar types of radiometers have been used; the first type, which was used from the mid 1970s, used 8 optical interference filters of 5nm nominal half power bandwidths with filter center wavelengths nominally centered at 290nm to 325 nm in 5nm steps. The second type of SI multifilter radiometer, which came into use in the mid 1990s, uses 18 optical interference filters of 2nm half power bandwidths nominally centered at 290nm to 324nm in 2nm steps. A primary purpose of the monitoring network is to assess the biological impact of solar UV in both ecological and human contexts by application of appropriate weighting functions to the spectral data. A standard function is the McKinlay-Diffey (CIE) weights for erythemal irradiance, which is the biological weighting function used to calculate the UV-index forecast. Daily solar-noon centered erythemal irradiance was calculated at filter center wavelengths and averaged on monthly and yearly bases. The record shows a slight positive trend of increasing average erythemal exposure in April, June and September, though the increase is small compared to interannual variation. There is good agreement between the two instruments in estimates of erythemal irradiance for the period when both were operating and with NWS forecasts of the UV index over the last five years.

P/4.34

Comparison of USDA UV- MFRSRUV irradiance measurements with TOMS retrievals under various aerosol and cloud conditions abstract

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An array of widely spaced ground-based radiometers gives frequent, accurate point measurements of UV irradiances but lack the broad spatial coverage necessary for UV climatologies and the precision of single-platform satellite retrievals from NASA TOMS. Comparison of irradiances from these two methods can increase the accuracy of the satellite UV retrievals, especially in the presence of absorbing aerosols and broken clouds. Irradiances under a wide variety of sky conditions from the 7 channel UV Multi-filter Rotating Shadowband Radiometer (UV-MFRSR) are compared with UV retrievals from TOMS as well as those using a radiative transfer model (DISORT). The UV-MFRSR makes direct-beam measurement, which allow aerosol optical depth determination, in-situ-Langley calibration, and direct to diffuse ratios. The USDA UVB Monitoring Program operates 27 sites in the US and 2 in Canada with next day download of total, direct, and diffuse irradiances at 300, 305, 311, 317, 325, 332, and 368 nm on http://uvb.nrel.colostate.edu/. TOMS global retrievals of column ozone, UV, and aerosol index may be found on http://jwocky.gsfc.nasa.gov/.

Comparisons with clear-sky data show excellent agreement between ground-based measurements and satellite estimates when aerosol effects are taken into account. Comparisons during cloudy conditions require time averaging to overcome the differences between point and wide-area observations.

P/4.35

Ozone profiles and its influence on solar UVB irradiance incident over Buenos Aires, Argentina

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The stratospheric ozone profile was determined for the first time over Buenos Aires, Argentina at CEILAP (CITEFA-CONICET) using a differential absorption lidar system. It is composed of two lasers, the excimer one emitting at the ozone absorbing wavelength of 308 nm and the reference Nd: YAG one at 355 nm. The backscattered photons are received in a 50cm aperture Newtonian telescope and analysed in the detection-acquisition subsystem. When satellite (SAGE II) results are available for the region and measurement period, they are compared with the DIAL ones. The same comparison is made with respect to the TOMS (Goddard Space Flight Center-NASA) profiles. The stratospheric lidar ozone profiles are included in the Madronich and DISORT computational codes for solving the radiative transfer equation. UV spectral irradiances are obtained in this way and also with the (smooth) US standard profile at 45º N, normalised to the actual ozone total column. Their relative differences increase with decreasing wavelengths. Also the influence of the ozone profile extend to a larger wavelengths domain at greater zenith angles.

P/4.36

Enhanced ultraviolet-B radiation in natural ecosystems as an added perturbation due to ozone depletion.

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Since discovery of the "ozone hole" in Antarctica, monitoring of long- term trends and geographical variability of UV irradiance has become increasingly important. A continuing difficulty in judging these impacts is the lack of coordinated, world-wide UV monitoring networks that produce results that can be compared at the level of precision and accuracy needed to detect trends in irradiance that maybe or are likely to be occurring. We have established a network of instruments in South America based on a "nested-network" approach, where a collection of different UV networks composed of different instruments is linked by standardised protocols, inter-comparisons, and calibrations. The main objective is to bring together researchers from several countries in North and South America to combine efforts to understand the impact of zone depletion on a regional level. The network is based on ground ultraviolet radiometers (GUV) from Biospherical Instruments Inc., San Diego, California. Several UV instruments are installed and collecting data in South America and the Antarctic Peninsula. These sites include Palmer Station in Antarctica, Punta Arenas, Valdivia, and Santiago, in Chile, Ushuaia, Trelew, Bariloche, Jujuy, and Buenos Aires, in Argentina and Puerto Rico. A centralised data processing and quality control functions in Ushuaia, Argentina. Results highlighting latitudinal gradient as well as temporal and spatial variability of UVB at 305 nm will be presented. The project is being funded by the InterAmerican Institute for Global Change Research, grant CRN-026.

P/4.37

UV-B radiation over the Central Andean Region of Peru

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In this paper in progress, we use a simple empirical relationship for the noontime UV-B flux and the global irradiance established for equatorial/tropics regions in order to confirm the high levels of UV-B radiation over Huancayo (Lat. 12.05ºS and Long. 75.32ºW), the most important city over the Andean region of Peru, it has about 500 000 inhabitants.

We also consider the low ozone amount measured for this latitude by a Dobson spectrophotometer (1964-1992) and TOMS, the clouds cover and the altitude, 3313 m.a.s.l and the equatorial location of Huancayo; these conditions enhance the global radiation and the UV-B radiation to extreme levels throughout the year.

The results indicate that this zone receives almost twice the UV-B radiation of higher latitudes, for example the occurrence of the ozone hole period over Punta Arenas, Chile at October 1992. This situation can have enormous impacts over the Andean environment and its population.

P/4.38

Underwater UV spectra from measurements with multichannel profilers

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Ozone depletion is associated with UV enhancement over continents and water bodies. Although UV spectrum can be measured with ground-based spectroradiometers, its observation in the underwater environment is more difficult as attested by the few underwater spectra so far reported in the literature. Submersible spectroradiometers are very expensive and cumbersome to operate. A more common piece of equipment for underwater UV observation is the so-called filter profilers, which measure UV irradiance at a set of wavelengths with medium resolution. Typical examples are PUV profilers, which use four UV channels with 10 nm bandwidths. The importance of estimating UV underwater spectra is based on the possibility of using various action spectra and biological weighting functions to assess UV doses or biological damage received at different depths on a horizontal surface. In spite of this, to date there is no numerical model able to evaluate radiative transfer in natural waters due to complexities of hydrological optics. This problem can be avoided to a large extent by retrieving UV spectra from actual observations at a few wavelengths as do UV profilers.

A procedure to retrieve full UV spectra with one nanometer resolution from typical profiler observations is presented. This is based on a technique, which has been previously designed for ground based filter radiometers and now extended to underwater conditions. Basically, the technique rests on a smoothed spectrum retrieved from four channel measurements by constrained inversion over which fine structure of the extraterrestrial radiation is added after proper scaling. CIE dose rates and biological damage estimated from such spectra are presented for measurements performed in lakes and open-sea. Some consideration is given to the impact of adding new channels to profilers at critical wavelengths.

Research funded under IAI Project "Enhanced Utraviolet-B Radiation in Natural Ecosystems as an added Perturbation due to Ozone Depletion"

P/4.39

The RACRUV narrow-band ultraviolet radiation network: preliminary results

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A multichannel filter NILU-UV radiometer network (RACRUV) has been established in Antarctica in December 1999-February 2000. Three instruments were installed at the Centro Austral de Investigaciones Científicas (CADIC, Argentina) in Ushuaia (54º 48' S), and at the Argentinean Antarctic bases of Vicecomodoro Marambio (64º 14' S) and Belgrano-II (77º 52' S), respectively. The spatial configuration of the network allows us to analyze the impact of the daily changes of the polar vortex on ozone and UV radiation, since Belgrano-II station is mostly located inside the vortex, Vicecomodoro Marambio station on the edge, and Ushuaia right outside the vortex. This network has been established as a co-operation between the Instituto Nacional de Meteorología (INM, Spain) the Finnish Meteorological Institute (FMI, Finland), the CADIC and the Instituto Antártico Argentino (IAA, Argentina).

The NILU-UV measures the irradiance in five wavelengths centered at 305, 312, 320, 340 and 380 nm. The bandwidths are about 10 nm FMWF (full width at half maximum). In addition, the NILU-UV measures the biologically important photosynthetically active radiation (PAR) in the wavelength region 400 to 700 nm. The instrument is temperature stabilized and weatherproof.

The calibration coefficient determination for each channel is not a trivial task. Calibration coefficients for the NILU-UV radiometers are determined at locations with quite different atmospheric conditions (Tenerife, Helsinki, Huelva and Ushuaia), and using different reference UV spectroradiometers, in order to estimate a maximum error in this calculation. A quality control system based on 100-W lamp weekly tests is implemented in this network. Results of the instrument stability are showed. As part of the quality assurance of the network a travelling reference NILU-UV has been provided to transfer calibrations from the reference spectroradiometer to the NILU-UV radiometers of the network. The calibration schedule and results are also described.

Preliminary UV and PAR results obtained by the RACRUV network are analyzed and discussed in this presentation.

P/4.40

Halon Alternative Development Program: An Historical Perspective

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Due to their implication in the destruction of stratospheric ozone, the production of the halon agents has been halted in most countries; for example, the production of Halon 1301 in the United States was halted on January

1, 1994. As a result of the production ban on halon, intensive efforts have been undertaken in the industrial, academic and governmental sectors to develop replacements for the halon agents, and a large number of alternatives have been proposed. Great Lakes Chemical Corporation exerted significant effort in the development of an alternative to serve the fire protection industry. HFC-227ea (marketed as FM-200(r)) was developed as a zero ozone depletion potential (ODP) halon replacement.

The discussion will focus on our Halon Alternative Development Program. In particular, fire suppression agent requirements, properties and selection criteria will be discussed.

P/4.41

Towards the derivation of spectral UV actinic fluxes from irradiance measurements: an experimental campaign.

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The ADMIRA project (Actinic Flux Determination from Measurements of Irradiance), a part of the European Community's Fifth Framework Programme, aims to extend the use of spectral UV irradiance data by enabling its transformation into actinic fluxes. This will be achieved by a combination of modelling (using the libradtran radiative transfer model) and measurement campaigns. The core measurement campaign takes place in August 2000 at Nea Michianona in northern Greece. The goal of the campaign is to make simultaneous spectral measurements of actinic flux and irradiance under clear skies and then with a range of aerosol and possibly cloud conditions. The spectral measurements will be supported by a range of other radiation and atmospheric measurements, specifying the state of the atmosphere as completely as possible. In this way the model used to derive the transfer algorithms will not depend on unknown input data, and the different conditions can be used to test the sensitivity of the algorithms to a changing atmosphere. Simultaneous spectral measurements of global and direct irradiance and actinic flux will be made with a quartet of pre-compared scanning spectroradiometers over the wavelength range 285-420nm. Radiance distribution and vertical aerosol profile measurements will be timed to coincide with each scan. Ozone sondes, an ozone lidar, ground-based aerosol samplers, $J(NO_2)$ radiometer, a weather station, sky camera and broadband radiation measurements will all be used to gather supporting data. Preliminary investigations with the radiative transfer model indicate that the ratio between irradiance and actinic flux is wavelength, zenith angle and aerosol dependent, and that it is particularly important to explore periods with high solar zenith angle. The first results from the campaign will be presented and discussed.

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