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SPARC

STRATOSPHERIC PROCESSES AND THEIR ROLE IN CLIMATE

A Project of the World Climate Research Programme

News and Views from the SPARC Co-Chairs

It has been a very good year for SPARC. Having served SPARC superbly for more than a decade in Paris (France), our International Project Office (IPO) has relocated smoothly to Toronto (Canada). Our 3rd General Assembly, held in Victoria (Canada), was a great success. Our science programme is developing strongly, thanks to the efforts of an enthusiastic SPARC community. And our role as a key project in the World Climate Research Programme (WCRP) is being enhanced by strengthening links with other international projects, both within the WCRP and within the International Geosphere Biosphere Programme (IGBP).

The new SPARC IPO was set up at the University of Toronto in April 2004, staffed by **Norman McFarlane** (Director), **Diane Pendlebury**, (Project Scientist) and **Victoria De Luca** (Project Manager). The relocation from Paris to Toronto went smoothly thanks to their efforts, and to the unstinting help of **Marie-Lise Chanin** and **Catherine Michaut** at the Paris office. Catherine willingly made extended visits to Canada to help get the new office under way, helping, for instance, to produce this newsletter. There cannot be many people in the SPARC community who have not had occasion to be grateful to Marie-Lise or Catherine at some time or another. On your behalf, we warmly thank them for their commitment to SPARC and for their professionalism in running the SPARC IPO in Paris. We are also grateful to CNES (Centre National d'Etudes Spatiales, CNRS (Centre National de la Recherche Scientifique), and Meteo France for their support of the SPARC office in Paris. Luckily for SPARC – and especially for us, the far less well-organised co-chairs – Norm, Diane and Victoria have taken over without a hitch.

We gratefully acknowledge the financial support for the new IPO given by several Canadian sponsors: the Meteorological Service of Canada (MSC), the Canadian Foundation for Climate and Atmospheric Science (CFCAS), the Canadian Space Agency (CSA), the Climate Change Action Fund (CCAF) and the University of Toronto.

In August 2004, SPARC's 3rd General Assembly was held in beautiful surroundings (and balmy summer weather) in Victoria (BC), Canada. The science programme was structured around overview talks to outline the key scientific issues for each session, contributed talks, poster sessions, overarching talks we called SPARC lectures, and a special talk by **Prof. F. S. Rowland**. The poster sessions were given ample time, and (with the slight encouragement of a cash bar) were seen to be highlights of the General Assembly, as the organisers intended. Some of the key developments highlighted were that: (1) chemistry-climate models have finally reached a level of maturity for attribution and prediction of long-term changes in the stratosphere; (2) process studies in the upper troposphere/lower stratosphere (UT/LS) demand an interdisciplinary approach, involving models and measurements; (3) high-resolution (cloud-resolving) modelling will play an important role in understanding the UT/LS; (4) connections between different timescales are important for dynamical variability on seasonal and climate

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timescales; and (5) there is an emerging understanding of the nature of long-term changes (beyond trends) involving temperature, water vapour, ozone, methane and other chemical species. You can read more about the scientific highlights of the General Assembly in this newsletter (p. 3). We thank the local organizers and the Scientific Organizing Committee for their excellent work. (Please see the names in the report on the General Assembly.)

The scientific programme of the General Assembly was organised around the new structure of SPARC (**Figure 1**). There are three main themes: chemistry-climate interactions; detection, attribution and prediction of stratospheric change; and stratosphere-troposphere dynamical coupling. The first of these, chemistry-climate interactions, is being pursued as a joint activity with the International Global Atmospheric Chemistry Project (IGAC) of the IGBP. The themes are integrators of activities in SPARC. A critical role in SPARC is played by the working groups, which focus on specific activities that support the main science themes. (See the back page of this newsletter for further details). The working groups are where much of the hard work gets done. As SPARC's priorities evolve, the working groups reconstitute themselves accordingly.

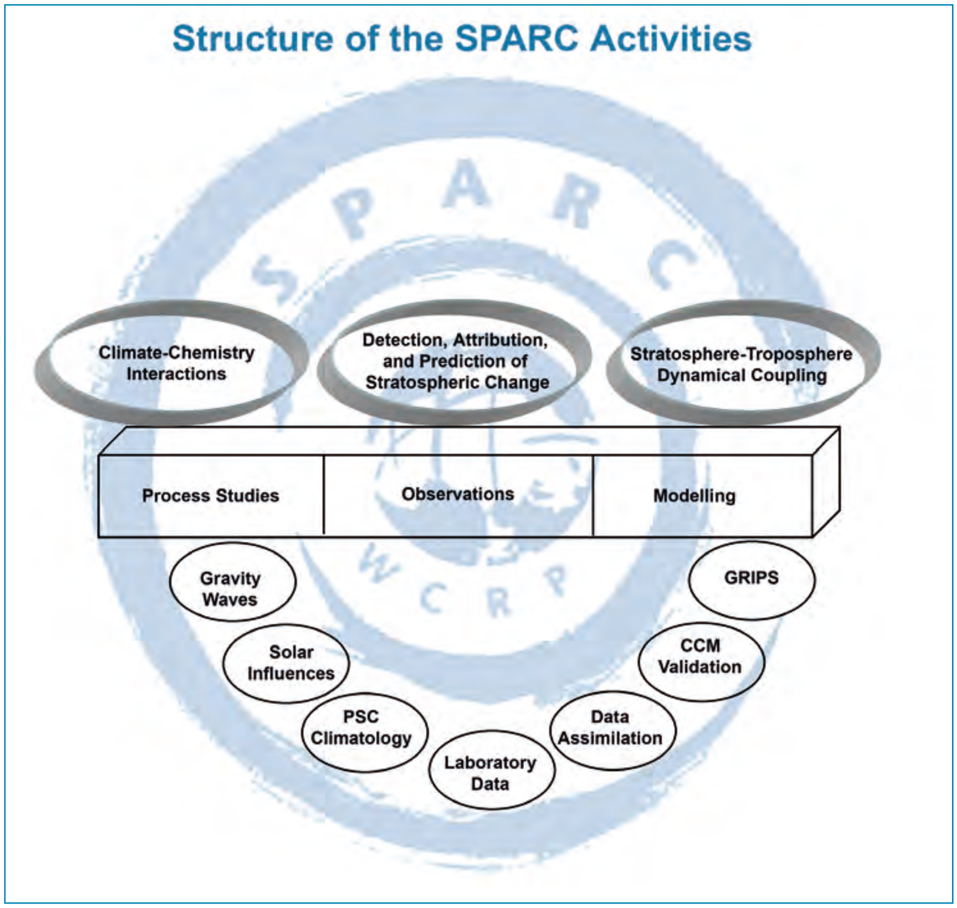

Figure 1. The structure of recently adopted SPARC activities is shown in the figure. The activities of SPARC, a project of WCRP, are aligned into thematic areas shown as shaded ovals. The basic information for SPARC research and activities are in the form of observation, process studies, and modelling, which are integral to all the three themes; they are shown as boxes supporting the themes and connecting to the specific tasks that are shown as ovals below. The specific tasks are the heart of SPARC and it is through these tasks that SPARC activities are carried out and the SPARC community is involved. This is meant to be a "living"figure in which, for example, new ovals will be added for additional SPARC activities when they are established.

The GCM Reality Intercomparison Project for SPARC (GRIPS), for example, has played a leading role internationally in identifying strengths and weaknesses of climate models that have a representation of the stratosphere. The last formal meeting of GRIPS will be held in Hawaii, March 21-25, 2005. Many modelling issues remain problematic, however (*e.g.* the representation of gravity waves). Effort will now be focused on these issues in the context of the three SPARC themes, such as chemistry-climate model evaluation. We thank **Steve Pawson**, GRIPS leader, and his colleagues for running GRIPS so successfully, and for their long-standing commitment.

We should like to mention one new working group, in particular, which is currently being formed – the working group on solar variability. **Kuni Kodera** is leading this activity for SPARC, in close collaboration with the CAWSES (Climate and Weather of the Sun-Earth System) project of SCOSTEP. Understanding the impact of solar variability on the stratosphere, and on the rest of the climate system remains, a very high priority for SPARC. Such an understanding is essential scientific underpinning for our theme on detection, attribution and prediction of stratospheric change, and we very much welcome the developing collaboration with CAWSES.

Collaborations "closer to home" within WCRP are essential, if our knowledge of the stratosphere is to be brought to bear on wider issues of change in the physical climate system. WCRP's strategy for the next ten years has, as its central integrating theme, the Coordinated Observation and Prediction of the Earth System (COPES). The aim is to facilitate prediction of Earth system variability and change for use in an increasing range of applications of direct value to society. SPARC will be fully involved in this initiative. We have been tasked with leading WCRP efforts on chemistry-climate interactions, in collaboration with WCRP's Working Group on Coupled Modelling (WGCM) and with IGBP's IGAC project. Amongst other contributions to COPES, SPARC will be represented on the Task Force for Seasonal Prediction, on the Modelling Panel, and in the Working Group on Observations and Assimilation (WGOA) of the Climate System. CLIVAR, a major project in WCRP, is large and multi-faceted. Although the interests of SPARC and CLIVAR overlap, previous links between the two projects have not been as strong as they should have been. There are now so many scientific points of contact between CLIVAR and SPARC that forging stronger links leading to joint activities is a priority.

During the next few years, our efforts will be directed at contributing effectively to future scientific assessments – the next WMO/UNEP Ozone Assessment

(2006) and IPCC report (2007) – as well as participating fully in the planning and execution of scientific campaigns for the International Polar Year, 2007-2008. If you are reading this as a newcomer to SPARC, and would like to get more involved with an extremely enthusiastic, committed scientific community, please contact us. We'd be delighted to hear from you. We also welcome comments and suggestions from the veterans of SPARC who have made this project such a success.

We thank the participation of the SSG in fleshing out the themes, tasks, etc. and the continued involvements in the workings of SPARC. The next SSG meeting will be held in Oxford, England in September of 2005. The venue for the next General Assembly will be decided at the meeting or soon after.

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Report on the SPARC 3rd General Assembly

Victoria (BC), Canada 1-6 August 2004

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Overall Structure

SPARC General Assemblies provide a venue for the exchange of scientific information related to SPARC research activities. They also provide a good venue for people to interact, one-on-one and in small groups, to discuss individual issues of mutual interest. They are held only in plenary format, *i.e.* with no parallel sessions, with a moderate number of oral contributions and an emphasis on poster sessions. As such, they are integrative in nature and complement the highly focused workshops that are the main venues for discussing some of the pressing questions addressed by SPARC. The General Assemblies also complement the mainstream large meetings, such as the American and European Geophysical Union meetings. The plenary approach and the format of the meeting allow a synthesis of information as well as discussions of the details of the science. Lastly, the General Assemblies ensure that all the activities that are integral parts of SPARC have a "home" for scientific exchanges and discussions.

Even though a very large number of research topics and areas form the "bricks and mortar" of SPARC science, they all contribute to one, or more, of the overarching three themes of SPARC: (1) Stratospheric Chemistry and Climate, (2) Stratosphere-Troposphere Dynamical Coupling, and (3) Detection, Attribution, and Prediction of Stratospheric Changes. This is the new architecture of SPARC and this Assembly, the first since the adoption of this architecture, strived to represent the science along these themes. To take into account the importance of current research focusing on the extratropical and tropical tropopause regions, the SPARC 2004 General Assembly mapped the three SPARC themes as follows: *Day 1*: Chemistry-climate coupling; *Day 2*: Extratropical Upper Troposphere/Lower Stratosphere (UT/LS); *Day 3*: Stratosphere-troposphere dynamical coupling; *Day 4*: Tropical Tropopause Layer (TTL); *Day 5*: Detection, attribution, and prediction.

The three SPARC Lectures, each one hour long, were the venue for the "grand scale" synthesis. For each of the five themes, the theme leader gave a synthesis and review of the specific theme of the session. Invited Lecturers also strived to synthesize and review information, and to offer a concise description of the state of the science. Specific research issues were addressed in contributed oral presentations and poster sessions. The half-day session on tools and techniques provided some of the "building blocks" of the science, which are essential for all the themes. They included laboratory studies, microphysics, gravity waves, and data assimilation.

The Assembly began with a SPECIAL talk by **F.S. Rowland** on "Environmental Science in the Global Arena: Stratospheric ozone to megacities to climate". This presentation put the work of SPARC in a global perspective and showed why this work is important for the good of humanity.

The poster sessions formed the backbone of the Assembly. They were the main venue for disseminating the detailed science. To ensure success of the poster sessions, and hence of the assembly, the posters were each up for two days, viewed for four 2-hour long sessions, and made more attractive by the location, availability of ample space and lighting, and food and drinks to lubricate the science. The availability of the posters for two days in the vicinity of the auditorium allowed people to look at posters even during times that were not dedicated to posters. All together there were 375 presentations at the Assembly, and roughly 340 participants from 30 countries.

Building Blocks

Laboratory studies of gas phase and heterogeneous chemical reactions, microphysical processes, and photochemical processes are crucial for understanding and modelling atmospheric chemistry. The invited talk by **J. Abbatt** highlighted the key role of laboratory experiments in deciphering chemical and cloud processes in the upper troposphere. The invited talk by **B. Kärcher** highlighted the understanding of detailed microphysical processes and the representation of these processes in models. Clearly, there has been significant progress in these areas over the years as shown by a few papers on gas phase and heterogeneous processes, as well as better calculations of the global warming potential of HFC-134a. However, new and interesting atmospheric observations such as the formation of large nitric-acid containing particles in the polar winter/spring lower stratosphere have elicited more studies in the laboratory, formulation of detailed mechanisms for their formation, and analyses of atmospheric data. Incorporation of this information into 3D chemistry models was demonstrated. The coating of atmospheric ice and other aerosols was shown to affect the reactivity and properties of the particles. Information needed to check microphysical models was shown to be available via balloon borne measurements. One laboratory study highlighting the properties of cubic ice was presented and this information will be very useful in interpreting laboratory and field data. **D. Weisenstein** hypothesized that tropospheric SO_2 from industrial sources, such as emissions from China, could have led to more aerosol formation in the tropical upper troposphere, which in turn could have led to a larger number of smaller ice particles lofted into the stratosphere. Such a temporal change in SO_2 emission was suggested to be a possible reason for the increase in water vapour in the LS over the past decade. The question of how uncertainties in input of sulphur at the tropical tropopause influence the stratospheric aerosol budget is part of the SPARC Assessment of Stratospheric Aerosol Properties, which is soon to be released.

Gravity waves (GW) play an important role in stratospheric climate, principally through GW drag which contributes to the driving of the diabatic circulation. The "cold pole problem", which is characteristic of stratospheric climate models, is attributed to missing GW drag, and the treatment of this problem through GW drag parameterization represents one of the most significant uncertainties in modelling polar ozone chemistry. **J. Alexander** reviewed the subject of GWs, and emphasized the lack of consensus among the experts concerning key aspects of GW drag parameterization. While one might hope that measurements could be brought to bear to resolve these disagreements, the interpretation of GW measurements is extremely challenging because of the mismatch between what is observed and what is needed for models (**Figure 1 p. I**); thus it takes great care to ensure that one is comparing apples with apples. However, **J. Scinocca** showed that detailed differences between GW drag parameterizations may not be so important if certain bulk properties (*e.g.* the source spectrum) are constrained to be the same. This helps to narrow the uncertainty associated with GW parameterization. On the measurement side, the availability of high-quality, high-resolution global temperature measurements from GPS occultations is an exciting development for GW studies, and several papers presented results using this data.

Data assimilation is the process by which measurements are optimally combined with models to produce the best available estimate of the state of the global atmosphere at any given time. Originally developed to determine initial conditions for weather forecasts, assimilated data sets are increasingly used for diagnostic analyses and process studies. Dynamical analyses in the stratosphere have been available from several operational weather centres for many years, and have played an important role in understanding polar ozone processes, for example. These centres are currently raising their model lids above the stratopause, and there is also a wealth of stratospheric chemical data now available from satellites. **R. Rood** reviewed the history of these developments, as well as current hopes and challenges. He specifically noted several fundamental challenges relating to bias and noise, especially as seen in chemical transport calculations which are invariably too diffusive (**Figure 2 p. I**). **S. Polavarapu** developed this issue of bias and noise, both for constituents and for dynamical fields, noting how both bias and noise become particularly severe in the upper stratosphere. Because this region also coincides with the top of the observation domain (typically the stratopause), special kinds of tensions arise between model and observations. **D. Fonteyn** highlighted the remarkable development of stratospheric chemical data assimilation in recent years, especially as applied to Envisat data, illustrated with several applications to calibration/validation and science studies.

Chemistry-Climate Coupling

The chemistry-climate coupling session consisted of a session overview talk by **C. Granier**, a SPARC Lecture, three invited talks, 7 contributed talks and 74 posters. A wide range of issues were discussed in the talks and posters, dealing with lower stratospheric ozone, tropospheric ozone, aerosols and polar stratospheric clouds (PSCs), water vapour, and the impact of climate change in the stratosphere and the troposphere. Results from observation systems, either from laboratory, ground-based or satellite-borne platforms, as well as results from chemistry-transport models and chemistry-climate models, were discussed.

The SPARC Lecture by **G. Brasseur** painted the "big picture" of the role of chemistry in the evolution of the climate system and the biosphere. Ozone plays a central role in this respect, as it filters UV radiation, warms the atmosphere, and controls the lifetime of pollutants. The first invited talk, given by **J. Pyle**, showed that the stratosphere-troposphere system is a highly coupled system, through a discussion of the response of tropospheric ozone to climate change, to changes in stratospheric ozone, and to anthropogenic emissions. In his invited presentation, **R. Garcia** compared results of simulations performed with a coupled chemistry-climate model with observations of ozone variability, and temperature and water vapour trends from 1980 to 2001. The third invited presentation, given by

W. Collins described the importance of including chemistry in global circulation models (GCMs). The talk focused on the increase of water vapour resulting from climate change and its impact on temperature, the relationship between climate and surface emissions of chemical compounds, and the impact of climate change on dynamical processes.

The contributed talk given by **J. Zawodny** discussed the 1984-2004 record of NO_2 data from SAGE, which displays a strong hemispheric asymmetry in the long-term changes in NO_2, with a positive trend in the Southern Hemisphere (SH) and a decrease in the Northern Hemisphere (NH), the largest changes being in the LS. Another analysis of satellite data was given by **M. Weber**, who discussed the links between planetary wave driving and trace gas transport and chemistry using observations from TOMS and GOME. A quantification of the relation between winter-spring loss of Arctic ozone and changes in stratospheric climate was discussed by **M. Rex**, who gave an estimation of the additional ozone loss resulting from possible stratospheric cooling linked with climate change.

J. Austin discussed the analysis of coupled chemistry-climate model (CCM) simulations, looking at a set of diagnostics: temperature, PSCs, age of air, correlations between tracers, or area of the ozone hole. **V. Eyring** discussed how a process-oriented validation of CCMs could complement traditional validation and increase confidence in the results of the models.

Within the SPARC community, transient simulations can now be performed for long periods of time, and analysis of both surface and satellite observations and model results for various periods of time (from a few years to about 45 years) were presented in both oral talks and posters. Several discussions regarding assimilation exercises and their evaluation were displayed in the posters, using observations from diverse past and current satellite data sets. The first uses of the ERA-40 reanalysis data set were reported, and preliminary results on simulations for this period were analyzed. Ozone calculations have also been included in a few global forecast models, which have been shown to reproduce reasonably well ozone fields up to at least 4-5 days ahead. For example, analyses of long-record observations were presented from surface stations such as the Dobson network, or from satellite observations, for which long records are becoming more and more available.

Simulations for future conditions were also discussed for different sets of scenarios. The impact of climate change on ozone levels and corresponding UV levels were shown for different conditions and scenarios. Solar-terrestrial interactions were also presented in several posters; the impact of the 11-year solar cycle on stratospheric and mesospheric ozone and global circulation was simulated with CCMs.

In summary, the presentations in the session showed that since the previous SPARC General Assembly in 2000, there have been large advances in both the availability and analysis of global observations in the stratosphere, troposphere and mesosphere, and in the development of CCMs, which are starting to be widely used. Several discussions focused on the best strategies for the validation of these models.

Extratropical UT/LS

J. Burrows opened the oral session with an overview of some of the current research issues in the extratropical UT/LS. Experiments using measurements and models are currently aimed at providing a much better understanding of cross-tropopause transport and the dynamics on both sides of the tropopause. **D. Fahey** gave the opening invited lecture for the session. He discussed the use of *in situ* measurements to probe the UT/LS, providing a perspective on the use of tracer correlations, and describing recent progress in this field. The latter focused on some recent aircraft measurements in the UT/LS region. Comparison of the correlations of HCl and CO with O_3 in the UT/LS demonstrates the need for an improved interpretative framework for STE. The community is well prepared to conduct the next generation of UT/LS experiments, which are now urgently required. In an invited lecture, **H. Wernli** described the key issues of Stratosphere Troposphere Exchange (STE) in the extratropics. The processes involved in STE and their timescales were discussed, with evidence for STE on many scales. Potential Vorticity (PV) streamers and cutoffs are currently considered to be more significant for STE than tropopause folds. However many processes are poorly understood — for example the importance of latent heat, radiative processes, turbulence, and deep convection, to name a few.

The morning session was completed with three contributed talks. **L. Pan** described modelling of the UT/LS. In particular, the potential to quantify the influence of mixing and transport near the subtropical jet has been investigated in a case study (**Figure 3 p. I**). The initial results show that the large-scale wind fields appear to be responsible for the observed tracer behaviour. **J.-P. Cammas** discussed recent results and analyses from the European MOZAIC project. This project, which began back in 1992, has equipped in-service aircraft with instruments for measuring ozone and water vapour. Recently, the measurement suite has been extended to include of CO and NO_y. The long haul aircraft used in MOZAIC provide some unique measurements in the UT, and vertical profiles at a series of airports around the world. **C. Schiller** introduced the SPURT (Trace gas transport in the tropopause region) study, which made measurements of water vapour and a variety of tracer substances in the tropopause region at midlatitudes. A variety of campaigns took place from 2001 to 2003.

The afternoon session began with the SPARC Lecture by **M. Schoeberl**, who described the satellite view of extratropical STE and the UT/LS. The extratropical UT/LS is a mix of tropospheric and stratospheric air, and the tropopause is not well defined for trace gases (**Figure 4**). The concept of the age of air in the stratosphere and its applications to investigate the LS were thoroughly discussed. Examples of useful satellite data from instrumentation on NASA-UARS and ESA-ENVISAT were given. The final part of the lecture addressed the potential of the instrumentation aboard AURA to investigate the UT/LS. After this exciting review and overview of different satellite observations and their applications, **H. Kanzawa** gave an invited lecture about results from the ILAS (Improved Limb Atmospheric Sounder)-I and ILAS-II instruments, which provided infrared (IR) solar occultation measurements of the atmosphere from November 1996 to June 1997 and from April to October 2003. This instrument provided measurements of key stratospheric species in the stratosphere at high latitudes.

The last session of the day was devoted to contributed talks on current research topics. **D. Knopf** described the experimental measurement and theoretical investigation of the nucleation of NAT and NAD. It appears that current laboratory data are insufficient to explain the Arctic denitrification. **L. Poole** described the first analyses of PSCs using the extended capability of the SAGE-III instrument, which is a solar occultation instrument operating in the UV-visible and near IR spectral regions. Two distinct types of PSCs and some large NAT particles were identified. **J. Logan** addressed our current understanding of the interannual variability of the vertical distribution of ozone in the UT/LS. Overall the interannual variability is poorly understood in the 80-125 hPa region. Finally, attribution of ozone recovery requires a detailed understanding of the dynamical factors influencing ozone in the LS. **G. Mullendore** described advances in modelling cross-tropopause transport in midlatitude convection, one of the three mechanisms by which tropospheric air is transported into the stratosphere.

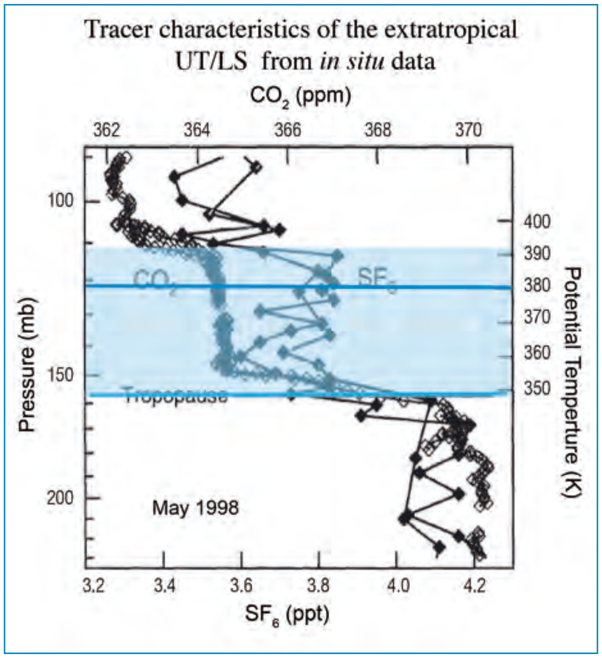

Figure 4. LACE balloon profiles at 34°N for May 1998. SF_6 and CO_2 are increasing in time so older air has lower amounts. Air above the 390 K isentrope shows distinctly older air (low values of SF_6 and CO_2), air below the 350 K isentrope shows distinctly younger, tropospheric air (high values), and air in between these two isentropes shows a mixture of tropospheric and stratospheric air. The tropopause and region near 380 K appear as transition layers in trace gases. [Ray et al., J. Geophys. Res., 104, 26565-26580, 1999].

The poster session addressed a wide range of topics including laboratory studies and analyses of data from a variety of platforms: ground based observations, aircraft and balloon campaigns and satellite observations. In total 83 posters were presented, demonstrating the continuing and growing scientific interest in this region.

Overall, it can be concluded that much progress has been made in our understanding of the extratropical UT/LS. Currently, one large focus of research activity addresses the dynamics of the UT/LS region using chemical compounds as tracers. It is however worth reconsidering whether the elementary homogeneous and multiphase physicochemical processes, which determine the behaviour of this key region, are adequately understood. Our current knowledge of the physical and chemical processes determining the behaviour of the tropopause region remains of fundamental scientific interest and a very significant limitation in the accuracy of current predictions of the impact of climate change on the stratosphere.

Stratosphere-Troposphere Dynamical Coupling

Coupling between the troposphere and stratosphere through radiative, chemical and dynamical effects is one of the central themes of SPARC. Recent observational and modelling work has re-emphasised the central role of dynamical coupling. **P. Haynes**, as session convenor, summarized the recent developments in this field and emphasized some of the remaining uncertainties.

The strong intrinsic variability of the troposphere-stratosphere system is an essential component of any consideration of dynamical coupling. **S. Yoden** emphasized that this strong variability requires a probabilistic interpretation of the response of the troposphere-stratosphere system to external change, either change imposed in a model as part of a scientific investigation, such as an imposed Quasi-Biennial Oscillation (QBO), or change imposed on the real atmosphere, such as input of volcanic aerosol or increase in source gases. He stressed the usefulness of a hierarchy of models in studying such change and described how modern computing resources (which tend to be allocated to increasingly sophisticated coupled chemistry-climate modelling, for example) could allow very long time integrations of relatively simple, but usefully realistic, atmospheric models and hence reliable computation of probability density functions and reliable assessment of the significance of apparent changes (**Figure 5 pII**).

Stratospheric sudden warmings have for the last 50 years been regarded as a remarkable example of dynamical variability and a stringent test of dynamical understanding. The sudden warming in the SH stratosphere in September 2002 emphasized some of the limitations of our current understanding. **T. Hirooka** described an investigation of this sudden warming using the Japan Meteorological Agency forecast model, examining the differences between forecasts initialized on different days, and argued that deceleration of the flow in the LS by the action of synoptic-scale eddies may have been important in allowing the subsequent upward propagation of planetary waves associated with the warming.

M. Baldwin summarized the observed characteristics of the annular modes of variability. It has been argued that these are evidence of dynamical coupling between troposphere and stratosphere. In particular, he emphasized the strong observational evidence that circulation anomalies in the mid-stratosphere are precursors to (but not necessarily the cause of) circulation anomalies in the troposphere and speculated that the stratosphere acts as an integrator of high frequency forcing from below, producing long-lived circulation anomalies that feed back to affect the troposphere. He also discussed the interesting possibilities that this picture might offer for medium-range weather forecasting and also for understanding aspects of future climate change (**Figure 6 p. II**). **B. Christiansen** developed this theme further by describing the use of stratospheric information in statistical forecasts of tropospheric circulation. He demonstrated that including lower stratospheric winds, in particular, in statistical forecasts, was an effective way of improving skill out to 30 days or more.

W. Robinson reviewed the dynamical mechanisms by which changes in the stratospheric circulation might significantly affect the troposphere. He emphasized the observational evidence that synoptic eddies played a very significant role in any tropospheric annular mode response but noted also strong observational and modelling evidence for the active role of longer planetary waves. **L. Polvani** emphasized that the anomalous stratospheric events were strongly associated with previous upward wave flux from the troposphere, but went on to present evidence (modelling work with **R. Scott** presented in a poster) that the stratosphere itself played an active role in determining this upward flux. **J. Perlwitz** argued that the dynamical link from stratosphere to troposphere may sometimes be *via* the zonal mean circulation and sometimes *via* downward propagation (reflection) of planetary waves.

Whilst the evidence for dynamical coupling between stratosphere and troposphere has renewed interest in the possibility of a significant modulation of the tropospheric circulation by the equatorial QBO, **K. Hamilton** demonstrated the difficulty of unambiguously demonstrating such modulation in limited-duration (20 years or so) GCM simulations. There is also significant interest in the role for dynamical coupling in determining tropospheric response to stratospheric injections of volcanic aerosol. **G. Stenchikov** described relevant GCM simulations and noted modelled aerosol injections appeared to cause both direct dynamical changes within the stratosphere, and indirect changes due to surface cooling in the troposphere and resulting changes in planetary waves.

Other oral presentations and many poster presentations gave different angles on many of the important dynamical and dynamical coupling issues mentioned above.

Tropical Tropopause Layer

Although the importance of the tropical tropopause as the principal source region of air entering the stratosphere was pointed out by Alan Brewer in 1949, this region is still largely "terra incognita" due to its inaccessibility. It was recognized only recently that most of the tropical deep convection does not reach the cold point tropopause but ceases a few kilometres lower, sandwiching the TTL, *i.e.* a relatively undisturbed body of air, subject to prolonged chemical processing of air parcels which may slowly ascend into the stratosphere (**Figure 7**). These background issues were reviewed by **T. Peter** in the session overview.

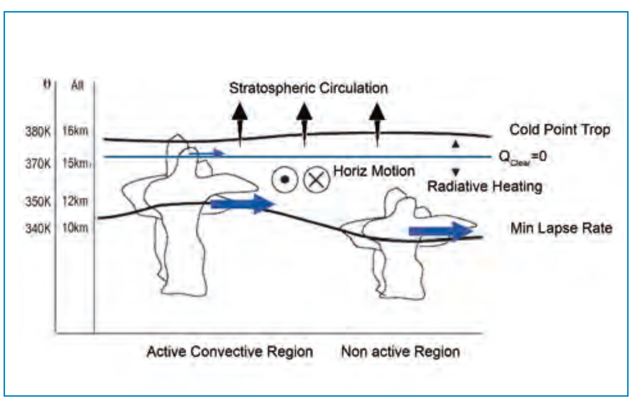

Figure 7. Schematic figure of the Tropical Tropopause Layer (TTL). The altitude of the Cold Point Tropopause (upper black line), Minimum Lapse Rate (lower black line), and Q_{Clear}=0 (blue line) are shown. The horizontal motion is indicated as vectors in and out of the page (it also occurs along the zonal dimension). Thin black arrows represent radiative heating, large black arrows are the stratospheric (Brewer-Dobson) circulation, and blue horizontal arrows are the detrainment from convection. [Gettelman and Forster, J. Met. Soc. Japan, 80 (48), 911-924, 2002].

The TTL session was kicked off by **P. Wennberg**, by asking whether deep convection could transport short-lived halogen species into the TTL. He provided lines of evidence suggesting that WMO estimates for stratospheric bromine could be low by 25%, and that calculated ozone trends are highly sensitive to assumptions about the existence of short-lived bromine compounds. **I. Folkins** generalized this aspect by pointing to the long convective replacement times making the TTL suited for chemical processing of air with significant probability of undergoing Troposphere-to-Stratosphere Transport (TST). The efficiency of these processes is determined by the average convective detrainment profile, which is not well known. Predictions of how the detrainment profile will respond to changes in sea surface temperature or in the Brewer Dobson circulation are presently uncertain. Most pronounced might be the effects of such changes on H_2O through implications for cold point temperatures.

A. Gettelman summarized the present paradigms of how air enters the stratosphere, and how this specifically differs from water entering the stratosphere: convection up to the cold point tropopause *vs.* slow radiative lifting, and moistening/dehydration mainly as convective phenomenon *vs.* the formation of cirrus, respectively. With particular view on the large scale, **A. O'Neill** highlighted various dehydration scenarios: does the tape-recorder signal originate from freeze-drying in the western Pacific ("Fountain" Hypothesis) associated with strong localized convection, or from slow, widespread up-glide associated with diabatic heating at the tropopause? Both speakers emphasised the importance of the southeast Asian monsoon, which according to model studies contributes at least 25 % of the moist signal in the tape recorder.

A. Dessler presented the first satellite-borne aerosol lidar data from IceSAT/GLAS, revealing extremely high TTL clouds. Climatologies from space-borne lidars will in future become very useful to constrain the dehydration problem. Another important aspect of the tropical water budget is high H_2O supersaturation with respect to ice outside and inside cirrus clouds. This issue was presented by **J. Smith**, showing frequent observations of clear air supersaturations, evidence for very high ice nucleation threshold (< 200 K) and for persistent in-cloud supersaturations as high as 20-30%. The in-cloud supersaturations remain a fully unexpected and not understood phenomenon: they challenge the conventional belief that any water vapour in excess of ice saturation should be depleted by crystal growth given sufficient time. **E. Jensen** presented detailed simulations of supersaturations in thin cirrus near the tropopause. Consequences are enhanced ice number densities, decreased crystal sizes, extended cloud lifetimes, increased aerial coverage of thin cirrus in the tropics, and most significantly an increase by 0.5-1 ppmv in H_2O entering the stratosphere across the tropopause cold trap. This would imply that lower tropopause temperatures are required to explain the observed stratospheric water vapour mixing ratios than previously assumed.

Global models and detailed cloud models, such as those presented by **A. O'Neill** and **E. Jensen**, leave a gap in the description of mesoscale processes.

T. Birner presented a 100km x 100km cloud-resolving model which allows this gap to be bridged. The model suggests that the final stage of dehydration is achieved by convectively generated buoyancy waves.

Isotopic composition measurements of water can help to identify dehydration processes leading to fractionation. Similarly, other compounds revealing strong enrichments of the heavy isotopes during photolysis or reaction with $O(^1D)$ could help to constrain the residence time of air in the TTL. For the free stratosphere such techniques were illustrated by **J. Kaiser** for the case of N_2O.

D. Hartmann's SPARC Lecture gave an opportunity for synopsis of fundamental aspects governing the TTL on all spatial scales, and with particular emphasis on changes of the TTL in a future, warmed world. The lecture provided arguments in support of an accelerated Brewer-Dobson circulation in a warmer world. But will this cool the tropopause? And how will convective overshoot change? While substantial progress has been made toward a quantitative understanding, many questions concerning the future TTL remain open.

In total there were 75 posters in the TTL session. These posters offered a very broad spectrum of TTL-related issues, from cubic ice in the laboratory, *via* vertical wind measurements in the TTL, to the response of global climate to El Niño.

Detection, Attribution, and Prediction

The Detection, Attribution and Prediction theme of SPARC encompasses the overall understanding of past and future stratospheric changes, and acts as an integrator of the process-oriented activities of SPARC. Accordingly, this theme occupied the last day of the General Assembly, and provided a summary for the week's activities. Themes discussed included updated observations and interpretations of past stratospheric changes, interactions with the troposphere, and predictions of future stratospheric evolution. These issues were introduced in the session overview by **W. Randel**.

There is substantial current interest in understanding changes in stratospheric water vapour, and its coupling to tropical tropopause temperature changes. **K. Rosenlof** gave an overview of observational results from different data sets, and highlighted measurement uncertainties in the LS that influence estimates of long-term changes. **L. Thomason** discussed long-term variations in stratospheric aerosols as measured by SAGE satellite observations. Current aerosol levels are at historic low values, allowing for observations of seasonal circulation effects on aerosols. The SAGE data do not show evidence for long-term trends in background aerosol amounts.

Understanding the influence of natural and forced changes on the stratospheric circulation is a key to attribution studies. **U. Langematz** presented an overview of dynamical influences on past stratospheric changes, comparing observations and simulations from several chemistry-climate models. A key result is that derived dynamical responses to imposed ozone or greenhouse gas changes vary considerably between models. **M.-L. Chanin** gave an updated view of solar cycle variability (from observations and models), and showed significant spatial structure during winter, pointing to the importance of planetary waves in the solar response. Dynamical changes in stratospheric ozone and temperatures were discussed in a number of presentations. New statistical analyses by **L. Hood** quantified dynamical influences on midlatitude ozone variability and change: the effects of planetary wave forcing of the stratosphere, plus synoptic-scale potential vorticity variations in the UT, account for over 50% of the interannual variance in NH midlatitude ozone during 1979-2002.

Direct coupling of stratospheric changes with tropospheric climate is an exciting activity within several SPARC themes, and current work aims to demonstrate and quantify these effects. **B. Santer** discussed using changes in the global tropopause as an indicator of climate variability and change, showing consistent results (increased tropopause altitude) from analyses of the ERA40 data set and climate model simulations (**Figure 8 p. III**). **N. Gillett** demonstrated the influence of Antarctic ozone depletion on tropospheric and surface climate using CGM simulations; the model results furthermore show that tropospheric eddy dynamical feedbacks are a key factor for this coupling.

Studies of model-predicted future stratospheric change were presented by several groups, based on chemistry-climate models. A key uncertainty in such models regards changes in tropospheric planetary wave forcing of the stratosphere under changing climate conditions. While past model results have shown conflicting results, a new intercomparison of model results by **N. Butchart** shows that most current models predict future increase in planetary waves, and corresponding increases in the stratospheric Brewer-Dobson circulation. This is an important result that must be considered in understanding stratosphere-troposphere coupling in future climates.

There were a total of 84 posters in the final session, which provided more details on these issues.

Overall, the body of work presented at SPARC 2004 highlights the significant strides taken by the community as a whole for understanding and quantifying the effects of stratospheric changes. These strides have been fueled by the detailed understanding of stratospheric processes, and in integrating that understanding for interpreting past and predicting future changes.

Acknowledgements

The scientific organizing committee was greatly assisted in the execution of these ideas by the Local Organizing Committee. The success of any scientific meeting depends on the local arrangements, and this assembly was no exception. The arrangements worked seamlessly and facilitated excellent scientific interaction. The travel support and the support of the meeting by various organizations is gratefully acknowledged.

Local Organizing Committee:

N. McFarlane (Chair); **M. Berkley**; **J. Fyfe**; **J. Scinocca**; **D. Tubman**; **K. von Salzen**; **V. Arora** (webmaster).

In addition, the efforts of the following people were instrumental to the smooth running of the General Assembly:

A. Chautard (WCRP), **V. De Luca** (SPARC IPO), **L. Droppleman** (NOAA), **C. Michaut** (SPARC/CNRS).

Report on the 12th Session of the SPARC Scientific Steering Group

Victoria (BC), Canada 9-12 August 2004

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Participants of the SSG Meeting in Victoria. From left to right
1st row: V. De Luca, S. Doherty, D. Conway, K. Carslaw, T. Peter, U. Schmidt, A. R. Ravishankara, C. Granier, J. Kerr, T. Shepherd, T. McElroy, N. McFarlane, R. Michaud, J.R. Drummond
2nd row: R. Menard, M. Baldwin, D. Pendlebury, K. Kodera, D. Hartmann
3rd row: M.A. Geller, S. Polavarapu, S. Pawson, T. Wehr, V. Ryabinin, S. Yoden, W. Randel, V. Ramaswamy, V. Eyring, M. Kurylo, P. Canziani, L. Thomason, D. Carson, C. Michaut, A. O'Neill, K. Hamilton, J. Burrows, M.-L. Chanin, V. Yushkov

Introduction

The 12th session of the SPARC Scientific Steering Group (SSG) was held at Dunsmuir Lodge near Victoria (BC), Canada, at the invitation of **N. McFarlane**, the Director of the SPARC International Project Office (IPO).

Opening the meeting, **A. Ravishankara**, co-chair of the SPARC SSG, emphasized that one of the most important tasks for SPARC and the SSG session was to flesh out the scientific content of the three major project themes and define ways for their implementation. Examples of issues of high importance for SPARC are microphysics modelling, Tropical Tropopause Layer (TTL) chemistry, upper troposphere/lower stratosphere (UT/LS) interaction, the generation of stratospheric indicators of climate change, solar activity, and, increasingly, laboratory experiments. GRIPS is drawing to a close as a key successful SPARC activity, and optimal organization of future intercomparison of models is a topic of high value. In addition to fundamental research, SPARC will continue its practice of conducting focused assessments, and specialists will actively contribute to the ongoing work of the IPCC Fourth Assessment Report. SPARC must be prepared for the new WMO ozone assessment that will start soon, and must start collecting ideas for future IPCC assessments. SPARC must also decide how to maintain and foster closer connections with projects within and outside WCRP, such as CLIVAR and GEWEX, IGAC (IGBP), and groups like WGNE, and how to effectively contribute to new WCRP initiatives such as COPES.

WCRP Comments

D. Carson presented the new overarching framework for the World Climate Research Programme (WCRP), entitled "Coordinated Observation and Prediction of the Earth System" (COPES). He reviewed the development of the WCRP since its formation in 1980 under the sponsorship of the World Meteorological Organization (WMO) and the International Council for Science (ICSU) with additional support from the Intergovernmental Oceanographic Commission (IOC) of UNESCO starting from 1993. In the nearly 25 years of its existence, the main goals of WCRP have been to determine the predictability of climate and the effects of human activities on climate.

There are now a number of new challenges facing the WCRP:
- The problem of seamless prediction over time periods ranging from weeks to decades and longer,
- Prediction of the broader climate/Earth system,
- Demonstrating the use to society of WCRP-enabled science and predictions,
- Efficient use of new opportunities such as new and increasing data streams, growth of computer capacities, and complexity and breadth of models and data assimilation schemes,
- Interaction with other Earth System Science Partnership (ESSP) programmes (DIVERSITAS, IGBP, and IHDP apart from WCRP).

The main goal of COPES is to facilitate prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society, and to predict the entire climate system.

Initial suggestions for COPES activities include determining the predictability potential of current systems, with focus on seasonal time scales, further developing and testing ensemble forecasting methods, determining the scientific basis for, best approaches to and current skill of projections of regional climate change, developing well-tested chemistry-climate models (CCMs), and addressing projections at the decadal time scale. Formulation of specific tasks should be made in close consultation with the wider WCRP community.

The Joint Scientific Committee (JSC) of WCRP will oversee COPES. The WCRP Modelling Panel will coordinate modelling initiatives across WCRP, focus on climate system prediction, and oversee data management in modelling activities. The Working Group on Observations and Assimilation (WGOA) will coordinate synthesis of global observations, information and data management across WCRP and facilitate interactions with other agencies, and observing systems.

New challenges for the ESSP include developing operational tools capable of monitoring and simulating the Earth System including the atmosphere, ocean, land, and cryosphere with physical, chemical and biological processes, and introducing the human dimension. This will require collaboration of the ESSP partners and the establishment of a framework for the integration, into which existing and planned research can contribute. This process should be driven by the science of global change.

The SSG exchanged views on how SPARC could contribute to COPES. The obvious roles are providing guidance on how to prescribe atmospheric composition and to initialize the stratosphere in a range of applications, and proposing/implementing diagnostic studies and numerical experiments. Concerns on limited WCRP resources were raised and a need for close coordination between WCRP COPES and IGBP GAIM were expressed. It was also noted that the future activities would strongly depend on developments within the WMO and the Global Earth Observation System of Systems (GEOSS).

Review of the main Events since the last SSG

The 3rd SPARC General Assembly (SPARC GA) was held in Victoria on 1-6 August 2004, in the week prior to the SSG meeting. The main theme of the SPARC GA was chemistry and climate. A discussion on the lessons learned and consequences for SPARC was led jointly by **T. Shepherd** and **A. Ravishankara**, co-chairs of the Scientific Committee for the SPARC GA, and **N. McFarlane**, chair of the Local Organizing Committee. The general agreement was that the SPARC GA was very successful. The SPARC GA web site would remain online until late in 2004 to allow access to the GA presentations.

Some key developments seen in the SPARC GA are:
- CCMs have reached a high level of maturity,
- Modern process studies of UT/LS and TTL are of interdisciplinary character and involve a combination of models and measurements,
- Detailed (*e.g.* cloud-resolving) modelling is coming into the fore,
- Connections are strengthening between studies of different time scales, from seasonal to climate,
- A view of coupled long-term changes, *i.e.* beyond trends, is emerging for temperature, water vapour, ozone, methane, etc.

The discussion suggested a number of possible future SPARC actions and initiatives motivated by these developments such as coupling of microphysics and gravity waves in models, potentially in contact with the GEWEX Cloud Systems Study; use of very high resolution models for designing observing systems; a need to validate numerical weather predictions in the TTL region including data obtained by airplane campaigns; inclusion of chemistry and higher stratospheric levels in new reanalyses, etc.

The new SPARC International Project Office (SPARC IPO)

N. McFarlane, the new Director of the SPARC IPO, reported on the relocation of the office to the Dept. of Physics at the University of Toronto (Canada). Sponsorship and funding for the new IPO comes from the Meteorological Service of Canada (MSC), the Canadian Foundation for Climate and Atmospheric Science (CFCAS), the Canadian Space Agency (CSA), the Climate Change Action Fund (CCAF), and the University of Toronto (in kind). In addition, the transition between the two offices has been greatly facilitated by extended visits of **C. Michaut**, manager of the SPARC Office in Paris. Arrangements for the transition have gone well. **V. De Luca**, the new office manager, and **D. Pendlebury**, the new project scientist, were present at the SSG meeting. Deep gratitude was expressed by the SSG to the new sponsors of the IPO and also to the Centre National de la Recherche Scientifique (CNRS), the Centre National d'Etudes Spatiales (CNES) and Meteo France, for the long support given to the project while the office was located in France.

Presentations from the Canadian Climate Research Community

A half-day of the session was devoted to presentations on Canadian stratospheric research.

J. Fyfe, on behalf of **D. Whelpdale** and the MSC, welcomed SPARC to Canada and expressed their pleasure at being able to support SPARC through the establishment of the SPARC IPO at the University of Toronto. The efforts of **N. McFarlane** and **T. Shepherd** ensuring that this opportunity became a reality were recognized.

D. Conway, Executive Director of CFCAS, reported on the role of CFCAS in funding Canadian research in climate science. The vision of CFCAS is to "enhance Canada's scientific capacity by funding the generation and dissemination of knowledge in areas of national importance and policy relevance, through focused support for excellent university-based research in climate and atmospheric sciences".

Funding priorities for the 2004-2005 period will be high latitude research into the Arctic and cryosphere, extreme weather including drought, marine climate and the use of technologies in research (remote sensing and satellites). Examples of funded projects related to SPARC are: (a) Measuring the Ozone Column from Astronomical Archives, (b) Stratospheric Indicators of Climate Change, and (c) Modelling of Global Chemistry for Climate. CFCAS is also a joint partner in funding the SPARC IPO in Canada.

R. Michaud reported on key activities of the CSA. The CSA was established in 1989 with the goal of integrating Canadian space activities such as Canada's contribution to the International Space Station, the RADARSAT and the Space Science Programmes.

There are three themes in the Earth Observations branch of CSA: the environment, resource and land-use management, and security and foreign policy. The priorities in the environment, remote sensing are: (a) better understanding of the key parameters and processes of the earth-atmosphere-ocean-cryosphere and biosphere systems and their inter-relationship; (b) impact of climate change on land, marine and atmospheric environments and the variations in key factors influencing the climate; (c) support to environmental policy and decision-making at all levels.

The CSA has focused its efforts on small payloads such as the Middle Atmosphere Nitrogen Trend Assessment (MANTRA) high-altitude balloon, which measures stratospheric composition and ozone chemistry. The 3rd field campaign occured in August 2004. Other small payloads include the Gravity Wave Imaging and Mapping (GWIM), which measures gravity wave (GW) activity in the upper mesosphere and lower thermosphere with a potential flight onboard Brazil's EQUARS scientific satellite in 2007.

J. Scinocca reported on research activities of the Canadian Centre for Climate Modelling and Analysis (CCCma). The primary activity is the ongoing development and application of global coupled climate models aimed at understanding past climate change and variability, and projecting future climate change under various GHG emission scenarios. CCCma is involved in a variety of collaborative projects with universities, most of them supported (often in partnership) by a combination of agencies including MSC, CCAF, CFCAS, and the National Science and Engineering Research Council (NSERC). These include projects in Regional Climate Modelling (RCM/URANOS), Middle Atmosphere Dynamics and Chemical Processes (CMAM/GCC), Climate Variability and Prediction (CLIVAR), Clouds and Chemistry (MOC2), Carbon Cycle (GC3M), Air-Sea Interaction/Coupling (SOLAS), and Aerosols Processes (CCAF project/CAFC).

The Modelling of Global Chemistry for Climate Project (GCC) is a focus for a major part of Canadian SPARC related research activities. The two central activities of GCC, done in cooperation with MSC and CSA, are the development and use of a CCM and a chemical climate data assimilation system. In summarizing its activities, **T. Shepherd** noted that it has several unique features. Among these is a strong team of research associates, responsible to the GCC project as a whole. Another feature is participation in numerous national and international collaborative activities. These include the WMO UNEP 2002 Ozone Assessment, SPARC/SCOSTEP Mesospheric Temperature Trends Assessment, Arctic Climate Impact Assessment (ACIA), GRIPS (radiation, GW drag, circulation response to doubled CO_2, and the representation of equatorial waves), SPARC Stratospheric Data Assimilation Initiative, and SPARC CCM Process-Oriented Validation Initiative.

S. Polavarapu reported on the Canadian Middle Atmosphere Model (CMAM) data assimilation activities and the new CMAM-FDAM (Facility for Data Assimilation and Modelling). The goal of the CMAM Data Assimilation System (CMAM-DAS) is to improve the understanding of middle atmosphere dynamics by confronting a climate model with observations. A direct, rather than statistical, comparison of a climate model with measurements creates a more solid platform for the assimilation and helps to optimize design parameters for middle atmosphere observations and, as well, to produce assimilated data sets for climate studies. Comparisons of assimilated tropospheric and lower stratospheric dynamical variables with radiosondes and ECMWF analyses have produced encouraging results (Polavarapu *et al*., 2004).

J. Drummond reported on the Canadian Network for the Detection of Atmospheric Change (CANDAC), an informal organization combining technical facilities and highly skilled researchers from university and government organizations. Three great challenges that CANDAC will address are air quality, climate change and ozone depletion. A primary initial focus of CANDAC is the revitalization of measurements at the Eureka Arctic Stratospheric Ozone (ASTRO) observatory. CANDAC has held three workshops including one concept workshop funded by CFCAS in support of atmospheric networks. It has received CFI funds for the installation of observing equipment at the PEARL station.

R. Menard reported on the chemical weather prediction and assimilation capability being developed at the MSC. This integrated system will perform real time analysis and prediction and will facilitate analysis for longer-term applications. It couples the ADOM tropospheric chemistry module and the routine weather prediction Global Environmental Model (GEM). Work in progress includes implementation of the CMAM stratospheric chemistry package and development of the adjoint chemistry for 4D variational assimilation.

J.B. Kerr and **T. McElroy** discussed MSC UV measurement and modelling studies. Despite significant advances in the past 30 years, there are still gaps in knowledge of key processes such as non-homogeneous scattering and absorption by clouds and aerosols. For instance, satellites estimate up to 40% more surface UV than is measured by ground-based instruments.

The SPARC Themes

Detection, Attribution, Prediction

W. Randel's overview of this theme included discussions of:
- Key points from the Angell Workshop on Temperature Trends in the Stratosphere (Silver Springs, November 2003, co-sponsored by SPARC and reported in Newsletter No. 22);
- Using models for detection, attribution, and prediction;
- Issues regarding stratospheric temperature and water vapour trends;
- Needs for upcoming IPCC and WMO assessments.

The Angell Workshop reviewed updated observations, model simulations of stratospheric temperature changes and their interpretation, and the effects of changes in stratospheric variability and circulation. Several of the issues arising from this workshop were addressed in presentations at the SPARC GA.

The observational base includes operational, climatological, process study-related and experimental data sets. Key issues for operational data are the availability of long-term high quality temperature records in the stratosphere and mesosphere, identification of problems and quantification of uncertainties in current satellite data and reanalyses, efforts to bridge data sets across the TOVS-ATOVS satellite boundary and in future satellite datasets, inclusion of SPARC input into future reanalyses and "climate network" designs. Key points for process and experimental data sets are the inclusion of specific UT/LS measurements, multiple sources of data, and ensuring the quality of radiative forcing data sets including ozone, water vapour and aerosols.

Success of modelling requires consistency of simulations and processes, and progress in parameterization. Consistency of simulations requires intercomparison of radiation codes and intercomparison of model responses to specified forcings. Key issues for process studies and parameterization are evaluating the role of interactive chemistry in model variability, improving quantification of GW parameterization effects, identifying sensitivities and uncertainties, gaining better understanding of dynamical coupling of the troposphere and stratosphere (especially Eliassen-Palm flux coupling and annular modes), evaluation of model uncertainties in the face of interannual variability (particularly in winter polar regions), improving UT/LS physics (especially aerosol and cloud microphysics), and identifying robust indicators for model sensitivity studies. SPARC should actively cooperate with AMIP and CMIP, GCOS and GEOSS. The use of PCMDI facilities for SPARC intercomparisons, and making best practices known *via* the project website would be desirable.

It follows from both the workshop and the GA that the most important issues for the Detection, Attribution and Prediction Theme include:

- Estimating signal versus noise using ensemble runs and long control simulations, emphasizing the use of a probabilistic approach for attribution and prediction;
- Understanding sensitivity of past and future predictions to uncertainties in forcings;
- Testing consistency across different indicators (*e.g.* temperature and radiative gases);
- Developing and using fingerprint techniques based on space-time patterns of signal responses and noise;
- Understanding the differences between equilibrium runs and transient response experiments;
- Quantifying the role of tropospheric forcing of the stratosphere including the impact of using observed *versus* climatological and observed *versus* simulated SSTs;
- Developing improved diagnostics to distinguish radiative and dynamical responses.

Available data for middle and upper stratospheric temperature fields include operational satellite data (SSU/MSU/AMSU), meteorological analyses and reanalyses, lidars (several locations) and research satellites, *i.e.* HALOE. Issues related to stratospheric temperature changes are: (a) taking into account details of updated SSU data; (b) comparisons with other data (*e.g.* lidar; HALOE); (c) problems with reanalyses in the stratosphere; and (d) interpreting the observed record.

Given uncertainties in quantifying and interpreting the past record, and importance for the SPARC themes and the future WMO Ozone Assessment, it was proposed that a small working group and a workshop on updating the stratospheric temperature record be organized. The workshop will be held in early 2005.

Needs for upcoming IPCC and WMO assessments

T. Shepherd discussed the use of models for detection/attribution/prediction of climate change. A key is the ratio of signal to noise. In this connection there are several challenges. The noise is not well characterized statistically and has time scales overlapping with those of the forcing. Coupling between the signal and the noise is not negligible. There may be a need to attribute some aspects of the noise. Models likely underestimate the noise and have their own sources of errors in variability.

A number of recently published studies addresses these challenges, *e.g.*, a 1000-year model run under different topographic forcings shows that PDFs of monthly mean temperature near the pole are not Gaussian (Yoden *et al*., 2002). In Fioletov and Shepherd (2003), it is shown that springtime trends (1979–2001) explain the trends in other months of the year. This relationship holds even better for the extratropics in both hemispheres. Attribution needs to be made on a case-by-case basis, for example, for Antarctic *versus* Arctic temperature - ozone relationships (Randel and Wu, 1999).

GCM studies with imposed ozone changes cannot account for the observed trends in the Arctic and Northern Hemisphere (NH) midlatitudes over the past 20 years (Shine *et al*., 2003). But given the magnitude of the variability, it can be argued that there is no discrepancy "within the error bars" (*i.e.* the noise), indicating that the signal is perhaps mainly natural variability. That variability may be crucial in understanding other changes, *e.g.* H_2O or O_3. CCMs are the main tools for uncovering the coupled chemical-dynamical variability. The dynamical forcing is predominantly wave drag. It is associated with (mainly horizontal) mixing. The planetary wave-drag (PWD) response to climate change may be critically important, but model studies to date are inconclusive on this point (Austin *et al*., 2003).

All CCMs show development of the Antarctic ozone hole in line with observations. But the observations are near the lower edge of model simulations of the springtime minimum of total ozone over the Arctic. Natural variability is a major factor for the Arctic. A better characterization of PWD variability and its chemical consequences is needed. It must distinguish between the purely radiative response to the forcing and the PWD feedback. It should also include an understanding of tropospheric versus stratospheric effects on PWD.

The next round of assessments will need to build on, and improve on Austin *et al*. (2003). This will require improved diagnostic characterization of the simulations. But before the runs begin, it is essential that they use the same forcings and include all relevant chemical processes. **T. Shepherd** proposed that a small meeting of key players under the auspices of SPARC would be useful and offered to host such a meeting in Toronto in the near future.

The ensuing discussion raised a number of questions for future consideration, including the carrying out of AMIP-like CCM experiments under the auspices of SPARC, and adequate use of SPARC experience in the IPCC assessment process.

C. Granier presented highlights of the Quadrennial Ozone Symposium held in Kos (Greece), in June 2004, with 450 participants and 690 presentations. One of the key questions is whether ozone recovery is under way. Several talks addressed the leveling off of the chlorine content in the stratosphere. Is the downward trend in ozone slowing down in a statistically significant way? Natural variability and interference by other factors (*e.g.* QBO and solar cycle effects) have to be evaluated and removed from the ozone record. New analyses of ozone variations based on long records of high quality ground based measurements (*e.g.*, by Fioletov) reveal long-term changes in variability. Trends in surface ozone are upward in several locations, but not in all. Results from analyses of data from new satellite instruments were presented in several papers.

Several papers on CCMs addressed the coupling between climate and ozone changes. Among these are climate change impacts on stratosphere-troposphere exchange. Simulations show enhancements of both the Brewer-Dobson and Hadley circulations with increasing GHG loading.

The SSG noted that several new members have been elected to the International Ozone Commission (IOC). Various options for joint SPARC, IGAC and IOC meetings were suggested.

V. Ramaswamy summarized the CCSP (U.S. Climate Change Science Program) Synthesis Assessment Report on temperature trends in the lower atmosphere. The CCSP website (**http://www.climatescience.gov/Library/sap/sap-summary.htm**) contains a prospectus for the report. Its goals are to: (a) identify cases where uncertainties can be clarified/reduced, (b) consider context with subsequent US and international assessment reports, (c) identify aspects of uncertainty requiring more thorough review and assessment, and (d) identify strategies to reduce uncertainties.

The target date for release of the report is in September 2005.

V. Ramaswamy reported on timelines and the structure of the IPCC AR4 (2007) report and noted some key points from the IPCC Climate Sensitivity Workshop held in July 2004 (report available at the IPCC web site: **http://www.ipcc.ch**). The workshop included reports on advancements in radiation codes since the last intercomparison (presentations by Fu and Ramaswamy) and IPCC GCM radiative forcing intercomparisons (presentations by Collins and Ramaswamy). The first Lead Authors meeting has been held in Trieste in September 2004. All material referenced in the AR4 should be available by May 2005. The suggested timescale for WCRP projects to directly contribute is by the end of 2004. Some chapters may be of direct relevance to SPARC.

V. Ramaswamy then summarized some aspects of the radiative forcing intercomparison. The radiative transfer calculations used standard clear sky midlatitude profiles. Computations of absolute SW and LW fluxes and forcings from line-by-line (benchmark) and GCM radiation codes were compared for specified concentrations of well-mixed GHGs (present-day minus pre-industrial $2xCO_2$ minus $1xCO_2$), and a case when carbon dioxide and water vapour are changed simultaneously). One important result is that absorption of solar radiation by CH_4 bands (not usually included in GCMs) is comparable to that of CO_2.

Stratospheric Chemistry and Climate

A. Ravishankara gave an overview of outstanding issues, which include polar stratospheric cloud (PSC) climatology, a review of chemistry in the TTL, and microphysics modelling for the TTL. Cloud resolving models may be productive for exploring a number of TTL issues. It was noted that Chemistry and Climate is a cross-cutting theme within the WCRP. The SSG agreed that overlapping interests with the GEWEX Global Cloud Systems Study (GCSS) concerning microphysical processes should be explored.

SPARC Polar Stratospheric Cloud Assessment (SPA)

K. Carslaw presented a summary of progress in preparing for the SPA, noting first that the motivation for carrying out the assessment is the existence of significant gaps in our understanding that are relevant to stratospheric chemistry, the lack of consensus on how to describe PSCs and denitrification in global models, the limited and selective use of PSC observations, and the risk of instrument-dependent climatologies since intercomparisons are rare, as well as the lack of a large-scale consistent and evaluated data set for model testing.

Both Arctic and Antarctic PSCs will be included in the assessment and information will contain their occurrence (seasonal, spatial, interannual and long term variability and trends), assessment and development of understanding (model and theory testing and consistency with lab experiments), instrument intercomparison of primary and consistent secondary quantities (lidar, satellite and *in situ* measurements), and consistency with denitrification and dehydration mechanisms. Excluded from the assessment will be heterogeneous reaction rates and PSC effect on stratospheric chemistry. The aims of the assessment are to gather a consistent microphysical interpretation of all measurements and to generate a particle climatology and evaluate statistical occurence of PSCs. Understanding of the microphysical processes will be examined to test hypotheses and models, and to make recommendations to modellers regarding past and future changes in PSCs.

The chapter titles have been defined and the lead authors have been chosen and accepted. The lead authors have prepared chapter outlines. Co-authors have yet to be contacted. A kick-off meeting is being arranged for early 2005, and the first science meeting will be held in Summer 2005. The chapters are laid out in the following way: *Chapter 1* - PSC Processes (N. Larsen); *Chapter 2* - Detection and discrimination (B. Luo , M. Fromm); *Chapter 3* - Observations and their intercomparison (T. Deshler and L. R. Poole); *Chapter 4* - Assessment of understanding (K. Drdla, K. Carslaw); *Chapter 5* - Denitrification and dehydration (M. L. Santee and G. E. Nedoluha); *Chapter 6* - PSCs in a changing stratosphere (M. Rex and R. Bevilacqua).

Process Based Comparison of Coupled Chemistry-Climate Models

V. Eyring discussed progress on process-oriented validation of coupled CCMs. GRIPS has examined the dynamical/radiative state of stratospheric GCMs. Now that CCMs are mature enough, it seems appropriate to evaluate the chemistry and transport in these models to the same extent, using a process-oriented validation approach similar to that used for GRIPS. Measurement and process-studies communities, for example trajectory modelling, need to be involved.

A detailed summary of the CCM Validation Project appeared in SPARC Newsletter No. 23 (V. Eyring *et al*., 2004) and a BAMS paper has been submitted. In addition, the coordinators are committed to having a project publication before the next WMO-UNEP assessment.

Individual assessments of different processes are already under way; for example a comparison of radiation schemes used in climate models, microphysical model calculations for the SPARC Assessment of Stratospheric Aerosol Properties (ASAP), and the evaluation of GW drag schemes.

Progress is being made on development of software packages for complex diagnostics and further development of a table of core processes. The next CCM validation workshop will be held in October 2005.

As the CCM Validation Project has been based on the experience gained in the GRIPS project and is a natural extension of it, amalgamation and renaming of the two projects were proposed and approved by the SPARC SSG. This will take place following the final GRIPS workshop, which will be held in Hawaii in March 2005.

SPARC/IGAC Collaboration

A. Ravishankara introduced the topic, noting that this joint venture between natural partners started under the previous co-chairs of SPARC. He drew attention to the report from the Joint SPARC-IGAC Workshop on Climate-Chemistry Interactions held in Giens (France) in 2003. It can be downloaded from the SPARC web site: (**http://www.atmosp.physics.utoronto.ca/SPARC**).

S. Doherty continued the discussion. The traditional view of IGAC has been that SPARC represents research in atmospheric properties and processes for the tropopause and higher, IGAC for the free troposphere, and iLEAPS for the atmospheric boundary layer the surface. The overlap in research interests between SPARC and IGAC, the tropopause layer and UT/LS region, was explored in Giens. Topics included stratosphere-troposphere coupling, LS ozone and its changes, tropospheric ozone and other chemically active GHGs, aerosols and their role in climate, and water vapour and clouds. Overarching issues for the workshop were temporal and spatial scale mismatch (*in situ vs.* model *vs.* satellite data), and chemical kinetics and laboratory studies.

In the UT/LS region, two projects are underway. An NCAR initiative led by **L. Pan** studies the coupling of large and small scales. It started as an internal initiative inspired by NCAR HAIPER and AURA. The second is the EU Project SCOUT headed by **J. Pyle**. It has a significant component of chemical-climate modelling with a focus on the tropics.

Stratosphere/Troposphere Dynamical Coupling

M. Baldwin gave an overview of scientific issues in this theme. He started with the results of the Workshop on Stratosphere-Troposphere Dynamical Coupling held in Whistler (BC), Canada, in April 2003 (see report in the SPARC Newsletter No. 22). A second workshop on stratosphere-troposphere coupling in 2006 will focus on understanding dynamics, coupling on longer (10-100 years) time scales and chemical/dynamical coupling.

Recent work on predictability and downward propagation of the Northern Annular Mode is indicative of the potential importance of stratosphere-troposphere dynamical coupling for long-term prediction. M. Baldwin reported on the WCRP COPES Task Force on Seasonal Prediction (TFSP). The goal is to determine to what extent seasonal prediction is possible in all parts of the globe with currently available models and data. The importance of the stratosphere in seasonal prediction was unanimously recognized at the TFSP meeting held in Hawaii (USA) in November 2003. The TFSP defined "seasonal" to begin at 7-10 days in order to be consistent with the COPES seamless prediction strategy. SPARC actions could include establishing partnerships with other WCRP projects and working groups, and with operational forecasting centres to promote and facilitate the inclusion of the stratosphere in the operational analysis and prediction systems.

M. Baldwin also discussed the role of the stratosphere in climate change. Most models predict a stronger Brewer-Dobson circulation in a warmer climate with increased GHGs. Recent simulations (*e.g.* by J. Kettleborough), also suggest a weaker polar vortex consistent with enhanced planetary wave driving. Future changes will depend on both chemical and dynamical stratosphere-troposphere coupling.

The theme of the stratosphere-troposphere dynamical coupling was continued by **S. Yoden**. The familiar idea that the troposphere affects the stratosphere through upward propagation of waves (large-scale Rossby and also gravity waves) goes back to the simple theory of Charney and Drazin. It is supported by numerical experiments with so called "mechanistic" and troposphere-stratosphere general circulation models (GCMs) and as well by observations of summer-winter and interhemispheric differences.

Sudden stratospheric warmings, a major perturbation of wintertime stratospheric circulation, were a research focus for dynamics in 1970s and 1980s. Occurrence of the SH warming and "vortex split" in September 2002 has reinvigorated interest to this topic. Despite ongoing efforts, we still cannot point to circulation anomalies in the troposphere and identify them as the "cause" of a dynamical perturbation in the stratosphere. The one-way view of troposphere affecting stratosphere no longer makes sense. Extratropical dynamics is non-local in both the horizontal and the vertical. Changes in the LS inevitably affect the UT and *vice versa*. There is evidence from numerical modelling studies, *e.g.* Boville (1984), and Kodera *et al.* (1990), that changes in the middle and upper stratosphere affect the troposphere and that communication is dynamical.

Stratosphere-troposphere dynamical coupling is primarily through the mechanism of planetary wave drag (as noted in the presentation of **T. Shepherd**). It is currently a major research activity, aided by a hierarchy of models. Attention was drawn to several of the presentations in the SPARC GA that dealt with various aspects of this topic (talks by P. Haynes, S. Yoden, M. Baldwin, B. Christiansen, T. Hirooka, W. Robinson, L. Polvani, K. Hamilton, J. Perlwitz, M. Geller, and G.L. Stenchikov). Three paradigms have emerged, supported by results of observational and modelling studies: (a) the troposphere affects the stratosphere (seasonal cycle in stratospheric circulation, interhemispheric differences etc.); (b) the stratosphere affects the troposphere (tropospheric signal of QBO, solar cycle, volcanic aerosol, dynamical response to ozone depletion); and (c) there is two-way coupling (aspects of low frequency variability in NH winter, SH spring, response to changes in long-lived GHGs).

D. Hartmann introduced the ENSO and stratosphere theme. Recent work indicates that warm ENSO events are associated with a warm Arctic polar stratosphere and more stratospheric warming events in winter, while colder ENSO events are associated with a cold polar stratosphere and an enhanced vortex. Earlier work has also shown a relationship between stratospheric variability and ENSO. Simulations with the NCAR WACCM model support observations and show that warming events are significantly more likely during ENSO years (Taguchi and Hartmann, 2004). When El Niño and warming events occur together, they produce cumulative effects over North America. In summary, evidence has been accumulating to show that ENSO events have a strong influence on the NH stratosphere.

Cross-Cutting and Supporting Projects

Assessment of Stratospheric Aerosol Properties (ASAP)

L. Thomason reported that the final texts of the ASAP report chapters were to be reviewed in September 2004. Technical editing had also been arranged and it was expected that the report would be ready for publication by the end of 2004. The assessment will consist of 6 chapters: *Chapter 1* - Aerosol processes (an overview); *Chapter 2* - Aerosol precursors; *Chapter 3* - Instruments; *Chapter 4* - Data assessment; *Chapter 5* - Trends; *Chapter 6* - Modelling.

The report will outline several key findings as follows: most observations do not comprise a complete measurement set. Some parameters are derived indirectly from the base measurement, and during periods of very low aerosol loading significant differences exist between data sets for key parameters, *e.g* for surface area density and extinction. It is found that only the period from 1999 onwards can be confidently identified as free of volcanic aerosols. There is also a significant dearth of SO_2 measurements. Sedimentation plays an important role in the vertical redistribution of aerosol throughout the stratosphere. Understanding of aerosols in terms of coherence of measurements and modelling in the LS during periods of low loading is poor, although there is reasonable agreement during post-volcanic periods.

Data Assimilation

S. Polavarapu discussed data assimilation of stratosphere and climate models, noting that it could provide many benefits to SPARC and WCRP. An immediate result would be the inclusion of mesospheric data in the SPARC Data Centre. There is a wealth of current mesospheric satellite data available from SCIAMACHY, TIMED, OSIRIS, GOMOS, MIPAS, SABRE, and SCISAT. A similar proposal has been made within the CAWSES programme of SCOSTEP.

Links to other WCRP activities can be made through the WGOA within the COPES framework. GEWEX has proposed a new climate system reanalysis including chemistry, which may benefit from data assimilation. The COST 723 action group also includes a data assimilation task, and the WGNE is ideal as a liaison. Possible activities for data assimilation within SPARC are process oriented validation, the use of analyses to assess gravity wave drag parametrizations in GCMs and CCMS, and water vapour analysis.

An annual workshop on data assimilation with the focus on the middle atmosphere and climate was proposed. This is desirable since other data assimilation workshops usually focus predominantly on operational forecasting issues, with the stratosphere as a side topic. The workshop would also bring together non-data assimilation people from the SPARC community with complementary expertise on dynamics, chemistry, and transport. It would be possible to assess our knowledge of stratospheric winds and quality of their analyses, and focus on both climatologies and winds for process studies and transport calculations.

The SPARC Gravity Wave Initiative

K. Hamilton reported on the SPARC Equatorial Circulation Experiment (ECE). This initiative was inspired by the VORCORE experiment proposed by **F. Vial** at the 10th SPARC SSG meeting in Kyoto in 2002. The VORCORE involves launching an ensemble of super-pressurized balloons (SPB) that would fly for several months at 50 hPa to 70 hPa levels in the vicinity of the Antarctic polar vortex. It received strong support from the SPARC SSG with a suggestion that a similar campaign would be valuable in the tropics. The SPARC ECE will be a tropical campaign. A working group has been formed, co-chaired by K. Hamilton and F. Vial. VORCORE will take place in 2005 as planned. ECE is planned for 2006 near Darwin, and a workshop may be held at the end of the project. Continued SPARC interest is important for its success.

K. Hamilton also reviewed the Gravity Wave Initiative, which is nearing its completion. A radiosonde climatology paper is in preparation. The DAWEX campaign took place in late 2001, and a workshop was held in Honolulu in 2002. It was reported in SPARC Newsletter No. 20 and a series of papers are part of a forthcoming JGR Special Issue.

SPARC was a cosponsor of the Chapman Conference, held in Waikoloa, Hawaii, in January 2004. This was a very successful conference with 64 participants from 11 countries (see report in SPARC Newsletter No. 23).

K. Hamilton proposed an additional, smaller workshop on convectively forced gravity waves, to be held in 2006, which will focus on some key remaining theoretical questions of relevance to GW parameterization, analysis of results from, or planning for the 2006 field experiment.

In discussion of the Gravity Wave Initiative, **M. Geller** suggested that the high-resolution radiosonde data used for the climatology could be made available for general use through the SPARC Data Centre.

LAUTLOS Field Campaign for Hygrosonde Comparisons

V. Yushkov presented some results from the measurement campaign of the UT/LS Water Vapour Validation Project (LAUTLOS-WAVVAP). This project is aimed at improving the knowledge of the role of water vapour in the atmosphere-biosphere system. The focal point of this project is the improvement of water vapour observation in the UT/LS. The LAPBIAT campaign was hosted at the Arctic Research Centre of the Finnish Meteorological Institute, and the participants included the Central Aerological Observatory (CAO) (Dolgoprudny, Russia), the University of Colorado (Boulder, USA), the Meteolabor AG (Wetzikon, Switzerland), the University of Bern (Switzerland), the Alfred Wegener Institute (Potsdam, Germany), the German Weather Service (DWD) (Lindenberg, Germany), Vaisala (Helsinki) and FMI-ARC (Sodankylä, Finland).

Instruments involved in the campaign were the Lyman-alpha optical hygrometer FLASH-B (CAO, Russia), NOASS-CMDL frostpoint hygrometer (University of Colorado), Snow White chilled mirror hygrometer (Meteolabor, Switzerland), FN method hygrometer (Lindenberg Observatory, Germany), Vaisala RS-92, and Microwave 22 GHz MIAWARA (IAP, Switzerland). The campaign consisted of 13 night-time flights on balloons with 6 onboard instruments (FLASH-B, NOAA frostpoint, Snow White, FN, Vaisala RS-92 and an ozonesonde), and 1 day and 1 night-time launch on rubber balloons with 5 instruments on board (Snow White, FN, Vaisala RS-80, RS-90 and RS-92). Simultaneous measurements of stratospheric water vapour content were made by FLASH-B and NOAA hygrometers.

Coordination with Other Agencies/Programmes

European COST 723 Action

V. Ryabinin reported activities of the Data Exploitation and Modelling for the UT/LS Action group (COST 723) working under the auspices of the European Cooperation in the Field of Scientific and Technical Research (COST).

Working Group 1 of COST 723 covers data and measurement techniques. Their mandate is to gather data and to make it available to the Action, critically assess the weak links in measurement capabilities, and help identify new techniques and platforms to reduce those weaknesses. The focus is on humidity in the UT/LS region. The inconsistency of humidity data sets is a most prominent issue on the global scale. It requires simultaneous temperature data for conversion of absolute/relative humidity.

Working Group 2 focuses on assimilated ozone and humidity datasets. The task is to identify the most relevant datasets of atmospheric constituents and other key parameters for the UT/LS, develop and publish assimilation algorithms, ensure quality control of observations and models, analyze the benefits of combining nadir and limb sounder information and preliminary studies towards an assimilation of instrument radiances from research satellites.

Working Group 3 is focusing on the state of the UT/LS and understanding the relevant processes. Its tasks are to assess the UT/LS climatology and trends, study dynamical processes in the UT/LS, and quantify the anthropogenic effects on the UT/LS. Specific areas of study include ozone assessment and variability, vertical diffusivity in the UT/LS, cirrus clouds and supersaturation.

COST Action 723 will host a Summer School at the Cargese Institute of Scientific Studies, Corsica, France, from 26 September to 8 October 2005. Topics will include UT/LS measurement techniques, data assimilation, and modelling studies of the UT/LS. The school will be limited to 15 lecturers and 50-60 participants.

Participation of SPARC in the International Polar Year 2007-2008 and International Geophysical Year

M. Baldwin and **C. Granier** addressed the issue of SPARC participation in the International Polar Year (IPY) and the International Geophysical Year (IGY) programmes. The 125th, 75th, and 50th anniversaries of the first two IPYs and IGY will occur in 2007-2008. These milestones represent an opportunity to foster new polar science research. ICSU and WMO will establish an IPO for IPY. The IPO will support the anticipated ICSU-WMO IPY joint committee tasked with the oversight and guidance of the IPY planning and implementation.

SPARC participation is important; a well identified focus is needed. Possible research areas include polar ozone, the polar vortex, polar stratospheric and mesospheric clouds, chemistry-climate interactions, tropospheric bromine in polar regions, tropospheric precursors, and arctic haze.

ESA/Earth Explorer Missions for Implementation

T. Wehr reported on current ESA operational missions. These are ERS-2, ENVISAT, PROBA, and the operational meteorological satellite Meteosat Second Generation.

ERS-2 carries the GOME instrument. It is performing well, but a failure of the tape recorders reduces coverage. An increased number of ground stations somewhat compensate for this gap in data. ENVISAT carries GOMOS, MIPAS and SCIAMACHY. An ENVISAT validation workshop was held in May 2004 (Frascati, Italy) and an ENVISAT symposium will be held 6-10 September 2004 in Salzburg, (Austria). PROBA is a microsatellite with a high-resolution imaging spectrometer (CHRIS), a high-resolution camera (HRC), a wide-angle camera (WAC), a Space Radiation Environment Monitor (SREM), and a debris in-orbit evaluator (DEBIE). It has been operational since 2001.

The Meteosat Second Generation in cooperation with EUMETSAT continues the Meteosat programme with enhanced performance and adds elements of climate observing capability. It consists of a series of at least three geostationary weather satellites. MSG-1 was launched September 2002, and was re-named Meteosat-8. The instruments are SEVIRI (imaging radiometer), GERB (Earth radiation budget), and S&R (search and rescue transponder).

There are several future ESA missions. Details are available at the ESA web site (**http://www.esa.int/export/esaEO/index.html**). Either EARTHCARE or SPECTRA will be selected this autumn for implementation. The EARTHCARE payload will include a backscatter lidar, a cloud profiling radar (a Japanese contribution), a multi-spectral imager, and a broad-band radiometer. EARTHCARE will quantify aerosol-cloud-radiation interactions for improvement of climate and numerical weather prediction models. SPECTRA will quantify surface processes, ecosystem changes, and terrestrial vegetation. It is a hyperspectral multi-directional imager.

The EGPM (microwave radiometer and precipitation radar) mission will be pursued with the Earth Watch programme, focused on pre-operational and prototype operational missions.

A new call for future missions within the Earth Explorer Programme will be posted toward the end of 2004. This call will be coordinated with the NASA ESSP call.

T. Wehr also briefly summarized ongoing preparatory activities in the area of climate and atmospheric chemistry, stratospheric dynamics and ozone transport, and data assimilation.

Planned future missions of interest to SPARC are:
- ***ADM-Aeolus****:* wind retrievals from Doppler shift of UV-lidar (355 nm) light back-scattered by aerosols and molecules along the line-of-sight. Launch is expected in 2007. Additional products are: cloud profiles, cover, heights; multi-layer clouds including cloud extinction and optical thickness, tropospheric aerosol extinction, optical thickness and stratification; wind variability and clear air turbulence.
- ***Metop:*** a sequence of three polar-orbiting meteorological satellites with the first launch in 2005. Operations are expected to continue for 14 years. Meteorological payload includes two IASI and ESA-developed instruments; GRAS for GPS radio occultation, measuring atmospheric refractivity for temperature and humidity profile retrievals; and GOME-2, an improved version of ERS-2 GOME (maximum swath width of 1920 km instead of 960 km), improved polarization measurements, optics and calibration.
- ***Meteosat 3rd Generation (MTG):*** to be launched around 2015. Preparatory activities are ongoing. Industrial pre-Phase A is currently in preparation. Considered instrumentation is com-

prised of imagers and sounders, including an infrared sounder (4.0 15 mm; IASI & GIFTS heritage) and UV-Visual sounder (GOME/SCIAMACHY heritage) for frequent observations of mainly O_3, CO, NO_2, SO_2, H_2CO (total tropospheric column). Atmospheric chemistry is part of the current mission requirements baseline.

The website for presenting future ESA programmes is located at **http://www.eumetsat.de**.

In discussion, **J. Burrows** noted that SPARC support for the atmospheric chemistry component of MTG would be beneficial.

NASA

M. Kurylo, in place of **P. De Cola**, gave a brief description of the restructuring of NASA and presented a comprehensive report on EOS AURA, which was successfully launched into a polar orbit on July 15, 2004, and flies approximately 15 minutes behind Aqua. It includes four instruments:

- ***HIRDLS***: a UK and USA IR limb sounder,
- ***MLS***: an US microwave limb sounder,
- ***OMI***: a Netherlands/Finland visible and UV nadir hyperspectral imager,
- ***TES***: an US IR limb and nadir high-resolution spectrometer.

All four instruments view the same location within 14 minutes.

The mission is described in the paper by Schoeberl *et al*., 2004. Its science objectives are: tracking ozone layer recovery, recording the impact of atmospheric constituents on climate, making global measurements of air quality (ozone, nitrogen dioxide, aerosols), determining pollution sources from mapping tropospheric trace gases, and observing influences on the global oxidizing capacity of the atmosphere. It is expected to have a six-year lifetime. These objectives address the following science questions: Is the ozone layer changing as predicted and are international protocols working? What are the roles of upper tropospheric water vapour, aerosols, and ozone on climate forcing? What are the sources and distribution of tropospheric pollutants and their impact on environmental health? How does the transport of gases between the stratosphere and troposphere influence ozone, climate change, and air quality?

The discussion supported a suggestion by **M. Geller** that SPARC should send NASA a letter of congratulation on the successful launch of the AURA mission.

CSA Activities of Relevance to SPARC

R. Michaud presented a summary of the CSA initiatives. MANTRA is a series of high-altitude balloon missions (1998, 2000, 2002 and 2004) to study stratospheric composition at midlatitudes. The project is an international collaboration with the participation of the University of Denver (USA) and Service d'Aéronomie du CNRS (France). A number of instruments are involved, including several Fourier Transform Spectrometers (University of Denver, MSC/University of Toronto, University of Waterloo), emission radiometers (MSC/University of Toronto), Sun photospectrometers, MAESTRO-B (MSC/University of Toronto), and the SAOZ instrument (CNRS).

OSIRIS on Odin (2001) is composed of a UV/visible spectrograph that continues to provide vertical profiles of ozone and other minor atmospheric species, such as NO_2, OClO and BrO, in the stratosphere, and an IR imager whose observations will be used to obtain distributions of ozone in the upper stratosphere and lower mesosphere. There have been requests from many different research groups for OSIRIS data. A new effort to enhance the returns from OSIRIS through collaboration with the SCIAMACHY Team in Bremen has been initiated, and the partner agencies (Sweden, France, Finland and Canada) have agreed to extend the mission until April 2005.

The Atmospheric Chemistry Experiment (ACE) with SCISAT provides simultaneous measurements of trace gases, clouds, and aerosols using the solar occultation technique. The goal is to gain a better understanding of the chemical processes that control the distribution of ozone in Earth's atmosphere, especially at high latitudes. It was launched successfully on 12 August 2003. The first Arctic Validation campaign was carried out at Eureka in February-March 2004, and SCISAT has been making routine sunset and sunrise occultation measurements since April 2004.

An upcoming satellite instrument for CSA is the Stratospheric Wind Interferometer For Transport studies (SWIFT), which is a Canadian instrument designed to make global stratospheric wind measurements both in daytime and night-time conditions at heights between 15 and 55 km and provide simultaneous co-located ozone profiles. There is also potential for obtaining operational stratospheric wind measurements for medium range forecasts. SWIFT has been endorsed and Phase A studies have been performed by ESA and JAXA. Unfortunately, JAXA has re-scoped the GOSAT satellite and disembarked SWIFT (December 2003). Currently, CSA is performing preliminary studies for flying SWIFT on a small Canadian satellite, and both CSA and ESA are investigating alternative flight opportunities for SWIFT. Potential secondary payloads are being considered.

SPARC support for SWIFT is considered to be important. It was suggested that letters of support from the co-chairs directed to both the CSA and ESA would be helpful at this stage. After discussion this action was approved by the SSG.

Network for Detection of Stratospheric Change

M. Kurylo, in a brief report, confirmed to the SSG the commitment of NDSC to continue its operations. The current priorities are supporting the networks that have problems, extending the system into the tropics working jointly with SHADOZ, replace some of the instruments which are already 20 years old, and to keep the validation going.

COSPAR News from the Recent General Assembly

The 35th COSPAR (Committee on Space Research) symposium was held in Paris from 20-25 July, 2004, and was attended by approximately 3000 participants. **M.-L. Chanin** was the Programme Chair. Relevant to SPARC are Commission A dealing with the Atmosphere, and Commission C on the Upper Atmosphere and Planetary Atmospheres.

J. Burrows was chair of the organizing committee for the COSPAR 2004 Session "Atmospheric Remote Sensing: Earth's Surface, Troposphere, Stratosphere and Mesosphere." It ran for 5.5 days with 220 contributions and approximately 110 speakers. A summary of the session can be found in this issue of the SPARC Newsletter. The 36th COSPAR Symposium will be held in Beijing in 2006.

M.-L. Chanin noted a number of general issues dealt within COSPAR that are also of interest to SPARC. It is important for SPARC to encourage ESA and national agencies to continue calibration and validation activities for ENVISAT instruments, and to continue the improvement of the ground segment, data re-processing and distribution. It is also necessary to stress a need for continuity and development of atmospheric observation.

A number of points regarding interactions with the COSPAR community were brought forward in discussion. One suggestion (**M. Geller**) is to encourage SPARC scientists to contribute to the improvement of the COSPAR reference atmosphere (CIRA).

SCOSTEP and Interactions with SPARC/GRIPS

M. Geller reported on SCOSTEP CAWSES activity. The mission of SCOSTEP is to implement research programmes in solar-terrestrial physics that benefit from international participation and involve at least two ICSU bodies. Under SCOSTEP, the Climate And Weather of the Sun-Earth System (CAWSES) has been developed to run between 2004 and 2008. The CAWSES Office has been established at Boston University, with **D. Pallamraju** as the scientific coordinator. The first newsletter was published in March 2004 and the first CAWSES campaign organized in March-April 2004 in conjunction with the CPEA Campaign.

There was a special all-day CAWSES meeting at Observatoire de Paris on 17 July 2004 and a CAWSES presentation at the ILWS Session in the COSPAR GA.

There are four main themes of CAWSES: *Theme 1* "Solar Influence on Climate" [co-chairs: M. Lockwood (UK) and L. Gray (UK)], has two working groups: "Assessment of Evidence for Solar Influence on Climate" and "Investigation of Mechanisms for Solar Influence on Climate". *Theme 2:* "Space Weather: Science and Applications" [co-chairs: J. Kozyra (USA) and K. Shibata (Japan)]. *Theme 3*: "Atmospheric Coupling Processes" [co-chairs: F.-J. Luebken (Germany) and J. Alexander (USA)], has working groups on "Dynamical Coupling and its Role in the Energy and Momentum Budget of the Middle Atmosphere", "Coupling *via* Photochemical Effects on Particles and Minor Constituents in the Upper Atmosphere", "Coupling by Electrodynamics including Ionospheric Magnetospheric Processes", and "Long-Term Trends in Coupling Processes". *Theme 4*: "Space Climatology" [co-chairs: C. Froehlich (Switzerland) and J. Sojka (USA)] with working groups "Solar Irradiance Variability", "Heliosphere Near Earth", "Radiation Belt Climatology", and "Long-Term trends in Ionospheric and Upper-Atmospheric Variability".

In addition to the themes, CAWSES runs a capacity building and education programme, co-chaired by M. Geller, **S. T. Wu** and **J. Allen**. This programme provides training courses and helps with computational and data resources for scientists from developing nations. It will also establish partnerships between developing and industrialized nations. An ICSU Grant Application has been made for such activities.

There are several national and regional CAWSES programmes under way or planned. The programmes for India, Germany, and Japan held an inaugural workshop in June 2004. The 11th SCOSTEP Quadrennial STP Symposium "Sun Space Physics and Climate" will be held on 5-12 March 2006 in Brazil.

Solar Impact Intercomparison

K. Kodera discussed the status of the GRIPS Solar Impact Intercomparison. A summary paper has been published (Kodera *et al.*, 2003). A session entitled "Solar Influence on Climate Through Mesospheric-Stratospheric Chemical-Dynamical Processes", co-organized by K. Kodera, U. Langematz and A. Smith, will be held at the fall AGU meeting (San Francisco, USA, 13-17 December 2004). The SSG discussed the future and evolution of the Solar Impact Intercomparison. It was agreed that it should continue to be supported by SPARC. With eventual merger of GRIPS and the CCM Intercomparson activities, it could become part of a possible future joint CAWSES-SPARC collaboration.

SPARC Data Centre

M. Geller reported on the current status of the SPARC Data Centre. One more year of funding is available, but it is possible to extend the funding for another round. A new project scientist is being recruited. Previous scientists were supported jointly by SPARC Data Centre funding and M. Geller's research funds. However, it may be useful to employ a full-time person who could work on projects specifically for the Data Centre.

There was unanimous support for M. Geller to continue as the Director of the SPARC Data Centre. A group of members within the SSG have been tasked with drafting a letter from SPARC that will convey the continuing need for the centre. A mirror site in Japan was being considered. The group felt that more pressure would be put on the centre when large amounts of chemical data come onboard.

Next SSG Meeting

A. O'Neill offered to host the next meeting of the SSG. This invitation was accepted with appreciation. The next meeting of the SSG will be held in Oxford (UK) on 26-29 September 2005.

Closure of Session

The co-chairs closed the Session in the afternoon of Thursday, 12 August 2004. The attendees unanimously thanked **N. McFarlane** for organizing the session and arranging for excellent conditions for its work.

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Polar Stratospheric Ozone Changes, SPARC, and the International Polar Year

As a part of the grand experiment of the International Geophysical Year (IGY) in 1957, ozone was measured in Antarctica using Dobson spectrometers. The aim was to measure the abundances and variations of ozone, which was thought to be a passive stratospheric tracer in this region, to understand the dynamics of the Antarctic stratosphere. What emerged in 1985 with the publication of Farman *et al.* (Nature, 315, p 207, 1985) was the clearest picture of an enormous annual depletion of ozone in the austral spring over Antarctica – the infamous Antarctic Ozone Hole. In less than 5 years, it was proven that the ozone hole was caused by human emitted fluorochlorocarbons (CFCs) and since then the ozone hole has been a "poster child" for showing how humans can cause global scale changes. The discovery of the ozone hole, its association with the CFCs, and its continued larger and larger depletions were the key factors that led to the Montreal Protocol and its amendments to ban CFCs, and the first truly international treaty to preserve the environment. Thus the Antarctic Ozone Hole became inarguably one of the most recognized environmental issues of the 20th century, recognized by people everywhere in the world. The Arctic ozone changes, though lesser in magnitude than the Antarctic ozone hole, are by no means of lesser importance.

The science of the polar ozone losses – the atmospheric dynamics, chemistry, and radiation understanding – was and, continues to be a major theme of Stratospheric Processes and their Role in Climate (SPARC), a WCRP project. The SPARC community was instrumental in understanding the polar ozone depletions, and the many advances that have been made regarding the stratosphere to date. We in the SPARC community are confident that this progress will continue.

In light of such an internationally visible, scientifically important, and societally relevant event of the 20th century in the polar region, it would be inappropriate not to include stratospheric ozone issues as an important theme in the International Polar Year (IPY). Not only will it clearly provide a context for IPY but also show how international activities such as IGY and IPY provide scientifically and societally important information. It also provides a wonderful opportunity to describe the brief, but eventful, history of the stratosphere and benefits, foreseen and unforeseen, of activities such as the IPY. We strongly urge the National and International communities involved in IPY to include the polar stratosphere in the schedule.

SPARC Co-Chairs

Report on the 2nd International Limb Workshop

Stockholm, Sweden, October 11-14, 2004

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Introduction

During recent years, satellite instruments measuring scattered and emitted radiation from the Earth's limb have become more and more central for studies of the middle atmosphere. The 2nd International Limb Workshop brought together 46 scientists from various satellite communities to discuss limb instruments, retrievals and results. The workshop was hosted by the Dept. of Meteorology at Stockholm University (Sweden) under the auspices of SPARC and IGAC. Financial support was available from the International Meteorological Institute in Stockholm. For the detailed workshop programme and the list of participants see **http://www.misu.su.se/limb2004.html**.

While the 1st International Limb Workshop (Bremen, Germany, 2003) focused on UV/Vis limb scattering, the scope of the 2nd Workshop was broadened to include limb measurements of infrared and microwave emissions. This opened new perspectives for future collaborations on atmospheric results. Nevertheless, the main focus of the workshop continued to be on the important first steps of data analysis: instrumental issues, retrieval algorithms and data validation.

The following satellite instruments were represented at the workshop: OSIRIS and SMR (on Odin), SCIAMACHY, MIPAS and GOMOS (on ENVISAT), SABER (on TIMED), ILAS-II (on ADEOS-II), SAGE III (on Meteor-3M), ACE (on SciSat), as well as SOLSE and LORE (on the Space Shuttle). In addition, exciting outlooks were given towards new limb missions ranging from the ultraviolet to the microwave part of the spectrum.

Limb Techniques in the UV, Visible and Near-Infrared

Similar to the 1st Limb Workshop, the majority of presentations concerned techniques and results related to the limb detection of scattered sunlight in the ultraviolet and visible. Efforts have focused in particular on the co-analysis of various species and their interaction in stratospheric chemistry. The set of stratospheric species retrieved from SCIAMACHY, OSIRIS, GOMOS, SAGE-III and ILAS-II is comprised of O_3, NO_2, N_2O, OClO, BrO and aerosols. Presentations on these observations were given by **C. S. Haley**, **A. Rozanov**, **C. Sioris**, **S. M. Brohede**, **A. Seppälä**,

D. F. Rault, **E. Kyrölä**, and **F. Khosrawi**. The solar proton event of October/November 2003, presented by **A. Seppälä** and **G. J. Rohen**, was of particular interest for satellite-borne limb observations. Enhanced NO_2 chemistry led to long-lasting effects on ozone depletion in the upper stratosphere.

D. F. Rault and E. Kyrölä presented limb scatter results from instruments that were designed primarily for occultation measurements, such as SAGE-III and GOMOS. Instrumental issues like out-of-field scatter are particular challenges for the latter. Their analysis can provide important input for the general understanding and development of new limb techniques. Stratospheric limb measurements were also presented from SOLSE and LORE onboard STS107 by **D.E. Flittner** and **R. Loughman**. These experiments serve as important steps towards the next generation of U.S. instrumentation for ozone-related studies.

From the OSIRIS data, exciting perspectives were presented by **E. J. Llewellyn** to retrieve mesospheric OH and possibly water vapour from the OH (A-X) solar fluorescence at 308 nm. First highlights were also presented by **J. Sloan** and **G. Witt** from the ACE instrument onboard the Canadian SciSat platform.

Limb scatter techniques have become increasingly important tools for the detection and characterization of middle atmospheric aerosol layers. Near infrared measurements along the limb path provide the necessary sensitivity and signal-to-background ratio to detect cirrus and subvisual cirrus clouds, and polar stratospheric clouds in the tropopause region and the lower stratosphere. Presentations regarding these issues were given by **A. Bourassa**, **J. Sloan**, and **C. von Savigny**.

Progress was also reported on mesospheric clouds in a noctilucent cloud (NLC) climatology and particle characterization by **B. Karlsson**, C. von Savigny, and **S. Petelina**. Comprehensive NLC data sets are now available from OSIRIS and SCIAMACHY, but a number of challenges need to be overcome in the study of these thin inhomogeneous cloud layers.

Infrared and Microwave Limb Techniques

Techniques based on infrared and sub-mm emissions were a new feature of the 2nd Limb Workshop. Presentations about these limb techniques readily showed the synergies with data retrieved from limb scattered UV/Vis/IR radiation. A major purpose of the workshop was to provide a forum to prepare future co-analysis of these data sets.

On the infrared side, comprehensive non-LTE (local thermo-equilibrium) data sets are available from TIMED/SABER, presented by **M. Mlynczak** and **C. Mertens**, and ENVISAT/MIPAS presented by **B. Funke**. These missions provide comprehensive information on the energy budget, chemistry, and exchange processes in the mesosphere and lower thermosphere. C. von Savigny presented the retrieval of mesospheric temperatures from the OH (3-1) Meinel band, demonstrating the ability of SCIAMACHY to perform limb analysis of infrared emissions.

Unique limb measurements of trace gases related to chemistry and transport processes were also reported from the Odin/SMR sub-mm instrument by **J. Urban**, **N. Lautié**, and **E. Dupuy**. Species presented include ClO, N_2O, HNO_3, O_3 and H_2O in the stratosphere, as well as H_2O and CO in the mesosphere. The large potential of sub-mm techniques has also been suggested for future missions such as STEAM/SWIFT (**D. Murtagh**, and **P. Eriksson**) and, JEM/SMILES (**Y. Kasai**).

Model Studies

Presentations about numerical tools were an important complement to instrument and data contributions. **W. Lahoz**, **S. Hassinen**, and **J. Rösevall** presented methods for chemical data assimilation, which have in recent years provided new tools for the analysis of limb data in the stratosphere. Presentations on tools for radiative transfer modelling and limb retrievals were given by **J. Kaiser**, **J. I. van Gent**, **H. Walter**, **A. Doicu**, and **P. Eriksson**, and included both new theoretical concepts and operational codes.

Data Comparison and Technical Collaboration

Data comparison projects are ongoing for a number of stratospheric species involving several of the satellite instruments represented at the workshop. In order to facilitate data comparisons in the future, it has been suggested that a number of case studies with co-located measurements be defined. Further details about these efforts will be made available on the Odin/OSIRIS website (**http://osirus.usask.ca**). Evidently, co-location is a very limiting requirement when it comes to the comparison of more than two satellites. In a long-term perspective, chemical data assimilation will need to provide a more solid basis for the joint analysis of individual satellite data sets.

When it comes to mesospheric limb data, comparisons between various satellite missions are still at a more basic stage. There is a large potential for co-analysis concerning the chemistry and transport of tracers H_2O, O_3, and CO primarily from the IR and microwave limb instruments. A prime candidate for joint mesospheric analysis efforts in the UV/Vis is the climatology and properties of noctilucent clouds.

As instrumental issues and retrieval techniques are of central importance for this workshop series, a number of areas of collaboration have been defined. In order to further improve collaborations, it was agreed that a data base of technical notes be created. The following topics have been defined as issues of particular interest: pointing accuracy and altitude reconstruction, baffle effects and their quantification (out-of-field effects), quantification of albedo and multiple scattering (in-field effects), inhomogeneity along the line-of-sight (terminator problem etc.), and topographic techniques.

We invite everybody to share experience on these issues by submitting technical notes to a common data base. The data base will be hosted by the Odin/OSIRIS website (**http://osirus.usask.ca**). Please contact **N. Lloyd** (nick.lloyd@usask.ca) with any contributions or suggestions.

Conclusions

During recent years, satellite instruments scanning the Earth's limb have provided a quickly growing data base on middle atmospheric chemistry and dynamics. Efficient networks exist for the analysis of stratospheric data, and similar developments are under way for the mesosphere. In the years to come, we can also expect a downward extension of limb techniques, contributing to important scientific issues in the Upper Troposphere and Lower Stratosphere. In this region, rapid progress in new microwave limb techniques will play a particular role.

The 2nd International Limb Workshop extended its focus towards data comparisons over a spectral range from the UV to the microwave. Nevertheless, the major objective continued to be to provide a forum for the detailed exchange of ideas on measurement issues and limb retrieval techniques. The refinement of retrieval algorithms and validation efforts are in many cases still ongoing. Both of these developments benefit greatly from collaboration between individual missions. This was clearly confirmed by the fruitful exchange of ideas during the workshop.

The instrumental and retrieval issues, and the focus on final data products, make the limb workshop series a valuable complement to large-scale conferences. The 3rd International Limb Workshop be held in Montreal, Canada, in the spring of 2006. **E. J. Llewellyn** from the University of Saskatchewan, Saskatoon (Canada) volunteered to organise this next meeting.

Report of the 2nd International SOWER Meeting

San Cristóbal, Galápagos, Ecuador, 10-15 July 2004

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M. Shiotani, M. Fujiwara, T.J. Dunkerton, I. Folkins, P. Fortuin, A. Gettelman, N.O. Hashiguchi, S. Iwasaki, Y. Kasai, N. Nishi, M. Niwano, S. Oltmans, L. Poveda, W, Randel, K. Rosenlof, Y. Tsushima, H. Vömel, and K. Yamazaki

Introduction

The Soundings of Ozone and Water in the Equatorial Region (SOWER) was initiated in the late 1990's (Hasebe *et al.*, 1998) for the purpose of improving our understanding of the distribution and variabilities of ozone and water vapour in the tropics. A series of ozone and water vapour sonde launches has been conducted, together with conventional radiosonde observations at several tropical stations such as San Cristóbal, Galápagos (eastern Pacific), Christmas Island, Kiribati (central Pacific), and Watukosek, Indonesia (western Pacific). These data constitute a unique dataset for the monitoring of water vapour in the tropical stratosphere and provide key information pertaining to transport processes between the troposphere and the stratosphere.

The identification of the tropical tropopause region has changed drastically since the introduction of the Tropical Tropopause Layer (TTL), leading to several new hypotheses on the dehydration of the stratosphere. Existing satellite data enables the study of long-term trends in water vapour, and with the launch of EOS/AURA in July 2004, high quality constituent data are becoming available. A large observational campaign in the equatorial region has been proposed by the United States to support the satellite programme, and the SOWER Team is also preparing an intensive campaign in the western tropical Pacific in the coming northern winter. In view of these programmes, we believe it is quite timely to have a focused scientific discussion on the dehydration process in the TTL, following the first of such meetings in October 1997 (SOWER, 1998).

The scientific sessions were divided into the following subjects: (i) Development of observational techniques; (ii) Observational descriptions of UT/LS water vapour; (iii) Atmospheric processes influencing stratospheric water vapour; (iv) The role of UT/LS water vapour in climate; (v) Hypotheses on the dehydration mechanism in the TTL; (vi) Observations of dehydration processes; and (vii) Modelling of stratospheric water vapour and dehydration processes.

In addition to the scientific discussions, ozone and water vapour sonde launches were demonstrated during the meeting for those not familiar with radiosonde procedures. Other highlights of the meeting were the presentation of NASA awards to **M. Agama**, **J. Cornejo** and **F. Paredes** in recognition of their contribution to the Southern Hemisphere Additional Ozonesondes (SHADOZ) programme, and a special talk on the meteorological observation network in Ecuador was given by **L. Poveda**. A special presentation in memory of **James R. Holton** was given by **A. Gettelman** and **K. Rosenlof**. For details of the meeting see **http://sower.ees.hokudai.ac.jp/**.

Development of Observational Technique

H. Vömel reviewed the accuracy and performance requirements for frost point hygrometers, noting the limitations of measurements of stratospheric and upper tropospheric water vapour. In cooperation with CIRES at the University of Colorado (CU), a new Cryogenic Frostpoint Hygrometer (CFH) was developed. It is based on the NOAA frostpoint hygrometer, but overcomes its limitations and at the same time reduces power consumption and weight, translating to a corresponding saving in weight and balloon size. Therefore, it is easier to use and to obtain high quality data.

CU-CFH sondes are regularly launched at San Cristóbal (Ecuador), Hilo, HI (USA), and Boulder, CO (USA). CFH sondes were also used during the LAPBIAT Upper Troposphere Lower Stratosphere (LAUTLOS) experiment in Sondankylä, (Finland), and during the SOWER Bandung (Indoniesia) campaign. This instrument was used as the reference sonde during the AIRS Water Vapour Experiment (AWEX) at the ARM/CART site near Lamont, OK (USA) to evaluate the performance of the radiosonde sensors, as well as the Snow White Hygrometer. Comparisons show very good agreement between these sensors.

M. Fujiwara reviewed the performance of the Meteolabor Snow White Hygrometer, which is a low-cost, chilled-mirror hygrometer for radiosonde applications provided by Meteolabor AG, a Swiss company. SOWER began testing this sensor for possible tropical tropopause water vapour measurements in 2000, and has since collaborated with Meteolabor to improve it. Snow White was found to be an appropriate reference sensor for radiosonde humidity sensors in the troposphere (Fujiwara *et al.*, 2003a, Wang *et al.*, 2003); however, the limited cooling strength of the device provides a lower detection limit of 6 to 8% relative humidity (Vömel *et al.*, 2003). The optimization and sensitivity of the controller circuit may also need to be improved for measurements above the tropopause.

Observational Descriptions of UT/LS Water Vapour

S. J. Oltmans and **H. Vömel** presented a re-evaluation of the long-term water vapour record at Boulder. This 25-year record has shown an increase in water vapour from the tropopause up to an altitude of ~28 km; however, a recent comparison between the Boulder profiles obtained with a balloon-borne hygrometer and HALOE has shown discrepancies since 1997 (Randel *et a*l., 2004).

Removal of contaminated profiles, and a small correction to the instrument calibration after 1990, produced a time series that is in better agreement with the HALOE record after 1997 (see **Figure 1**). The increase over the 25-year period in the 18-22 km layer is 0.75 ± 0.2 %/year, with lesser increases in this layer since 2000, making the change since 1991 small in both the balloon record and the

HALOE measurements.

A. Gettelman, on behalf of **W. Randel**, presented changes in stratospheric water observed in HALOE data which shows an interannual tape recorder of anomalies that propagate vertically and latitudinally in the stratosphere. Since 2001, stratospheric water vapour has been persistently low (by ~0.5 ppv; **Figure 2**). These low values spread from the tropics, and are also seen in POAM data which is correlated with HALOE observations. The changes in HALOE H_2O are also correlated with tropopause temperature anomalies throughout the record. The most recent values of water vapour (to April 2004) are still low, as are tropopause temperatures. These temperature anomalies are centred in a narrow layer just above the tropical tropopause.

Tropical ozonesondes also show low ozone from 16-18 km after 2001, with the largest changes centred around, or just below the tropical tropopause. Ozonesonde anomalies are similar to satellite (SAGE II) ozone anomalies over this period, and SAGE II ozone data show that the anomalies are centred in the tropics.

Temperature and ozone changes are consistent with an increase in tropical upwelling (the Brewer-Dobson circulation), however there is not conclusive evidence of increases in extratropical planetary wave forcing. Other mechanisms which can explain the recent changes include persistent changes in tropical convection or ozone decreases leading to cooling.

K. Rosenlof examined the observed drop in water vapour at the end of 2000 seen in both the CMDL and HALOE records at midlatitudes. This drop is also seen in the HALOE and SAGE II data sets in the tropics, and, albeit delayed by a few months, in the POAM satellite Northern Hemisphere (NH) water vapour data at high latitudes. The timing of this drop corresponds to a significant drop in NCEP tropopause temperatures, and a drop in the cold point temperature as measured by operational radiosondes, indicating a possible change in vertical stability in the upper tropical troposphere.

The reasons for the dramatic drop in temperatures are not known, but it is likely that enhanced uplift near the tropopause is responsible. If this continues, it will likely result in a decrease in stratospheric water at upper levels over the next few years, especially since a corresponding increase in surface methane is not occurring at this time.

A. Gettelman gave a historical overview of satellite observations of water vapour in the TTL, starting with LIMS in the stratosphere, and HALOE and MLS in the TTL (Kley *et. al*., 2000). Satellites such as HALOE and SAGE have helped reveal that there are significant instances of subvisible cirrus clouds in the tropics (Wang *et al*., 1996), which may account for a significant amount of dehydration in the TTL. In addition, the ATMOS instrument on the space shuttle measures water vapour and water vapour isotopes from space.

New instrumentation promises a more detailed picture of TTL water vapour from space. Many of these sensors are on a series of NASA satellites called the "A-Train", which will observe the same location on the Earth at the same time. Aura contains both HIRDLS and MLS limb sounding instruments measuring TTL water vapour. On the Aqua satellite, tropospheric water vapour (up to 200 hPa) is measured by the Atmospheric InfraRed Sounding (AIRS) suite, and TTL cloud properties are determined by the Moderate-Resolution Imaging Spectrometer (MODIS) radiometer with high spatial and moderate spectral resolution. The future challenges will be to integrate the data from these various instruments, together with cloud data and data from other instruments, to estimate long term variability in the TTL.

H. Vömel presented results from water vapour and ozone soundings taken at San Cristóbal and other tropical sites. These results have revealed a wide variety of processes that control the water vapour content in the TTL. Convective processes can dry air rising within cumulonimbus clouds to well below the mean stratospheric water vapour mixing ratio. The outflow of these convective events has been observed both in the Western Pacific region as well as over San Cristóbal. This process is highly seasonal for any given geographic location. At San Cristóbal this process also shows a clear dependency on the El Niño phase. Non-convective drying through cirrus clouds, which form at a cold tropopause, has been observed frequently at San Cristóbal during the austral winter and spring months.

During the Austral summer and early fall, when the tropical tropopause is typically much warmer, little dehydration has been observed over San Cristóbal. In one case, some indication of dehydration in the upward phase of a Kelvin wave event was observed, which may constitute an important dehydration mechanism during the warm season. The geographic pattern of the tropopause temperatures also reflects the importance of these regions for dehydration. At Juazeiro do Norte (Brazil) for example, no dehydration was observed during the season of cold tropopause temperatures, since in this region, the mean tropopause temperature is generally too warm to contribute to the dehydration in the TTL.

The tropopause temperatures over San Cristóbal showed a clear cooling in 2000, and cold temperatures continue in 2004. Therefore, it is to be expected that the geographic region of the eastern Pacific continues to play a role in dehydration, even though it is generally located outside the region of coldest tropopause temperatures.

K. Rosenlof presented results from the January 2004 Pre-AVE WB57-F Aircraft Experiment based in San Jose

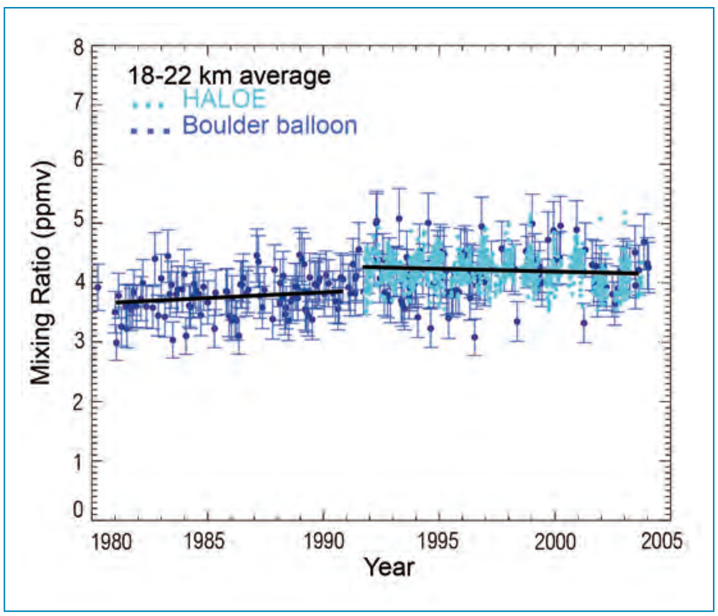

Figure 1. Time series of the water vapour mixing ratio in the 18-22 km layer over Boulder, Colorado (USA) from the balloon profile measurements and HALOE satellite observations.

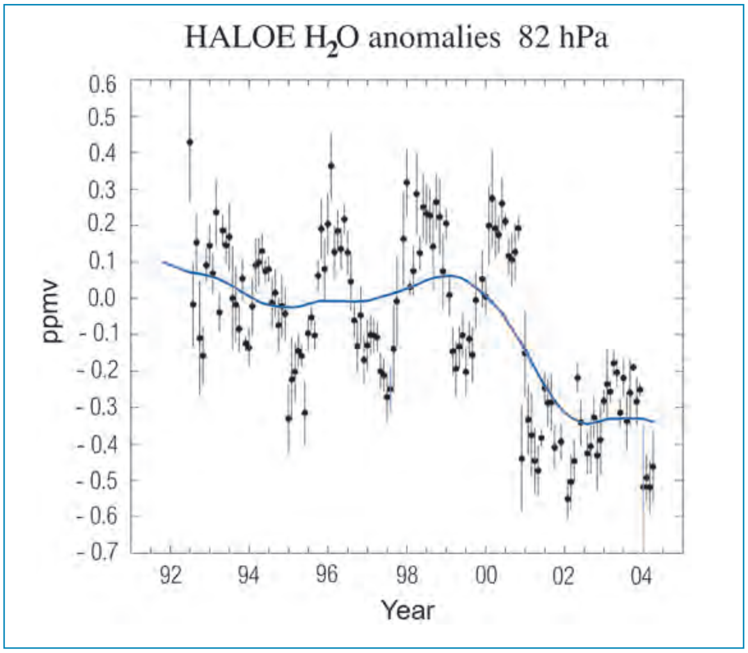

Figure 2. Time series of near-global (60°N-60°S) anomalies in lower stratospheric (82 hPa) water vapour derived from HALOE satellite measurements. The data have been de-seasonalized; the circles show monthly mean values, and the error bars denote the monthly standard deviation. The solid line is a Gaussian-weighted running mean (using a Gaussian half-width of 12 months). [This is an update from Randel et al., 2001].

(Costa Rica). These flights were part of a test mission to ready an instrument suite and demonstrate capabilities for validation of the Aura satellite, launched in July 2004. One of these flights was designed to be a comparison with the CMDL frost point balloon launched from San Cristóbal. Significant differences are seen between the aircraft and balloon measurements, with the aircraft measurements approximately 1 ppmv higher at the altitude of the water vapour minimum. The net result of the large differences between the aircraft and balloon measurements translates into large differences in estimated saturations with respect to ice. In particular, the aircraft data show large supersaturations with respect to ice that are not evident in the frost point data. Statistics on numbers of points showing high supersaturations with respect to ice differ between the CMDL and aircraft data sets, with the aircraft data showing a higher frequency of supersaturation with respect to ice than the frost point balloon.

The differences noted in the comparison are consistent with those reported in the SPARC water vapour assessment (Kley *et al*., 2000). These differences are of concern, because uncertainties in the water vapour measurements as based on comparisons between techniques/platforms are large enough to preclude making conclusions as to what processes control the stratospheric entry value of water vapour. The reasons for the differences noted are not yet known. Determining why large differences exist between these WB-57F aircraft instruments and the balloon frost point instrument at low water vapour values is a significant problem that requires close examination. Before using either set of data for satellite validation, these differences should be understood.

T. J. Dunkerton presented evidence for a "trimodal" distribution of extreme values of ozone and water vapour concentration in NH summer, using HALOE data from 1991-2004. Low values of ozone and water vapour concentration are found near the equator in the western tropical Pacific (as in NH winter), but over the major monsoon regions of North America and South Asia there exist high concentrations of water vapour, presumably due to moistening by deep convection, while ozone is low over Asia but high over North America. Evidently the Asian monsoon circulation is stronger and somewhat deeper than the monsoon circulation over North America, causing air within the Tibetan anticyclone to be relatively isolated and depleted in ozone, due to transport of ozone-poor air from the troposphere.

Since September 1999, weekly ozone- and radiosondes have been launched at Paramaribo station (Suriname) (5.8°N, 55.2°W), on the northern coast of South America. Since October 2002, more accurate water vapour balloon observations have been made with the Snow White hygrometer, installed at a receiving station through a collaboration between KNMI, Kyoto University and Hokkaido University (Japan). **P. Fortuin**, **G. Verver**, **P. Dolmans**, **M. Fujiwara** and **H. Kelder** presented an analysis of the water vapour observations from 16 of these launches over the period October 2002-June 2003 (11 launches) and March-April 2004 (5 launches).

Observations suggest a steady ascent of moisture-rich air through the TTL above Surinam, although additional evidence is needed since the humicaps observations at these high altitudes are unreliable. The coinciding recurrence of inertial instability in the UT during the South American Monsoon is also analyzed, as well as the possible role this might play in the redistribution of water vapour. This is done on the basis of a case study with ECMWF analyses and shows a stacked vertical cellular flow (Fortuin *et al*. 2003) confirming the theory of symmetrical inertial instability.

N.O. Hashiguchi presented an investigation of seasonal and interannual variations of the cold point tropopause (CPT) temperature, based on operational rawinsonde data over Indonesia and the surrounding region (90°-140°E, 15°N-15°S) from 1992 to 1999. The cold point temperature has an annual variation with a maximum/minimum in northern summer/winter, which is the same as that observed at other tropical stations, and the peak-to-peak difference is about 6 K at all the stations. In latitudinal distribution, the cold point temperature is the warmest over the equator and decreases with respect to latitude for both JJA and DJF. This is because the analysis region is located in the upper tropospheric warm anomaly region, on the west side of the Matsuno-Gill response, and the latitudinal structure in the section is opposite to a zonal mean structure presented by Seidel *et al*. (2001). The CPT temperature is also the warmest over 100°E and decreases to the east with respect to longitude.

During the non-ENSO period from July 1992 to April 1997, the CPT temperature was decreasing over the entire analysis region without changing the longitudinal inclination. In this period, activation of convective clouds in OLR and strengthening of the upper tropospheric wind of local Hadley circulations were also seen. It seems that these tropospheric changes lead to cold CPT temperatures through adiabatic cooling in this period.

Atmospheric Processes Influencing Stratospheric Water Vapour

N. Eguchi and **M. Shiotani** presented results from MLS and CLAES data, which suggest a direct effect of convective activity on wet anomalies up to a height of 146 hPa, but an indirect effect by the dynamical response to the convective heating at 100 hPa. Dynamical structures around the tropopause level are characterized by equatorial temperature anomalies (Kelvin wave response) and by subtropical anticyclonic gyres (Rossby wave response). Between the two gyres, the easterly wind blowing through the equatorial cold region may cause dehydration, along with the formation of cirrus clouds. As the northern gyre intensifies, tropical dry air is transported to the subtropical Pacific and eventually to the equatorial Pacific. It is suggested that the temperature and flow variations due to the coupled Kelvin-Rossby wave structure play an important role in dehydrating air in the tropical and subtropical tropopause region.

M. Fujiwara presented a case study of an Upper Tropospheric Inversion (UTI) and jet in the tropics. Ship-board radiosonde measurements revealed a persistent temperature inversion layer at 12-13 km over the tropical eastern Pacific, which was located at the top of a very wet layer originating from the ITCZ to the north (Fujiwara *et al*., 2003b). Radiative transfer calculations suggested that this UTI was produced and maintained by strong longwave cooling in the wet layer.

A strong easterly jet stream was also observed at 12-13 km, and was in thermal wind balance with the meridional temperature gradients produced by the cloud by radiative processes in the ITCZ and the wet outflow. The jet in turn acted to spread inversions further downstream through the transport of radiatively active water vapour. This feedback mechanism may explain the omnipresence of temperature inversions and layering structures in trace gases in the tropical troposphere. Examination of high-resolution radiosonde data at other sites in the tropics indicates that similar UTIs often appear around 12-15 km. The UTI around 12-15 km may thus be characterized as one of the "climatological" inversions in the tropical troposphere, forming the lower boundary of the TTL.

N. Nishi, **M. Yamamoto**, **A. Hamada**, **J. Hashiguchi** and **S. Fukao** presented the vertical wind distribution in and around upper tropospheric cirriform clouds, obtained by using the VHF radar Equatorial Atmospheric Radar (EAR) wind data at Sumatra Island (Indonesia) (0°N, 100°E), and GOES IR data in November 2003. It was found that the most dominant variability in the middle and upper troposphere is a high frequency oscillation with vertically standing phase structure, with a period slightly longer than the Brunt Väisällä frequency. The amplitude is sometimes more than 30 cm/s. However, in some cases during late November, strong upward motion was detected not only in the lower half of the domain, but up to 15 km for clusters with the same cloud top as early November. Large scale conditions such as wind shear, stability and humidity may effectively control the vertical wind distribution in the tropical cirriform clouds in large scale cloud clusters.

Y. Kasai, **J. Urban**, **M. Lautie**, **D. Murtagh**, **P. Ricaud**, and the Odin/SMR group presented results of the water vapour isotopes observed by the Sub-Millimetre Radiometer (SMR) onboard the Odin satellite, which is a satellite funded jointly by Sweden, Canada, Finland and France, and was launched in February 2001. In aeronomy mode, the SMR dedicates various target bands to observations of trace constituents relevant to stratospheric/mesospheric chemistry and dynamics, such as O_3, ClO, N_2O, HNO_3, H_2O, CO, as well as isotopes of H_2O and O_3.

The global distribution of water vapour isotopes and its seasonal variation were obtained for the first time by Odin/SMR measurements. The δD value of water vapour in the stratosphere agrees with the past measurements and a model (Ridal and Siskind, 2002). It increases with altitude from the TTL to the stratosphere. The methane contribution to the increase of δD was discussed and the δD value overhead of the TTL was estimated.

Role of UT/LS Water Vapour in Climate

A dominant component of climate sensitivity is the size of the water vapour feedback; the change in water vapour concentrations in response to increased greenhouse gases, and the associated radiative impact. However, understanding the water vapour feedback in the tropical troposphere is limited by our understanding of what processes drive changes in tropical water vapour concentrations. Sources and sinks of water vapour are complex; the tropical troposphere is moistened by detrainment of near saturated air and by evaporation from falling precipitation. Water vapour concentrations are reduced, locally, mainly by downward advection of drier air from higher levels. A further complication is that the budgets of mass and water vapour are strongly coupled in the tropics, since most upward motion arises from condensation, while downward motion arises from radiative and evaporative cooling.

Coupling of the mass and water vapour budgets can be used to put constraints on the sources and sinks of water vapour. For example, in the mid-troposphere (5-10 km), it can be shown that the major source of water vapour is evaporation of falling ice. This evaporation also drives a downward descent that must be offset by vertical motions occurring within clouds and by clear sky subsidence. **I. Folkins** showed that, in a tropical mean model, the enforcement of vertical mass flux balance gives rise to a constraint on the tropical mean relative humidity profile in this height interval which is well obeyed in the current atmosphere.

Y. Tsushima presented changes in UT/LS water vapour and clouds modelled by the CCSR/NIES GCM 5.7b under global warming scenarios, with different climate sensitivities and different treatment of the temperature dependency of the phase of cloud and fall speed of melted cloud ice. The temperature changes in 2 x CO_2 experiments ranged from 4.0 K in the low sensitivity model to 6.4 K in the high sensitivity model. In the control climate, both versions showed much higher concentrations of water vapour and clouds in the upper troposphere than expected from observations. In the low sensitivity model, the fraction of high thin cloud is larger and high thick cloud is smaller than in the high sensitivity model.

The equilibrium states of the control run and the 2 x CO_2 run show decreases in the upper tropospheric water vapour in both models, leading to a significant decrease in high cloud, although this change is much more significant in the high sensitivity model. The role of high clouds in the radiation budget of the earth-atmosphere system depends on optical depth; high thin cloud acts to warm the atmosphere, while high thick cloud cools. Thus, the decrease in high clouds can reduce both the warming and cooling effect to the system. In these particular experiments, the reduction of cooling seems to dominate and strengthen the magnitude of the warming, with a more significant response in the high sensitivity model. For further discussion, evaluation of the distribution of cloud and water vapour in the upper troposphere in the current climate, using the observational data, is necessary.

Hypotheses on the Dehydration Mechanism in TTL

A. Gettelman and **C. Webster** highlighted some recent work using water vapour isotopes to understand dehydration in the TTL. The process of fractionation of heavier isotopes of water (HDO), due to their lower vapour pressures and preferential partitioning into condensed phases, is temperature dependent. Lifting a parcel from the surface and removing the condensed phase water (a so-called Rayleigh curve) results in a loss of up to 95% of HDO relative to the surface abundance, however observations indicate the stratosphere is only about 65% depleted in HDO. Recent observations indicate significant variability in the TTL below the tropopause, with values in total water (including ice) of no depletion (0%) to 95% depletion (Webster and Heymsfield, 2003).

An analytical microphysical model was described which calculates water vapour and condensate along a trajectory, accounting for condensation, evaporation and sedimentation of ice, and fractionation of water isotopes. The model is able to reproduce observations of HDO in the TTL, with a similar range of variability. Depletion due to individual convective events, and *in situ* cirrus formation are well captured. Isotopic observations and the model are consistent with (1) convective transport and mixing up to the level of main convective outflow, (2) mixing of air with ice detrained from convection (the evaporation of convective anvils) and (3) slow ascent under supersaturated conditions into the stratosphere, with the final dehydration occurring in cirrus clouds. Climatological experiments with the same model and ensembles of back trajectories indicate that more depletion is expected around regions of deep convection, such as the Western Pacific.

Observations of Dehydration Processes

Vertical profiles of ozone and water vapour obtained by radiosondes at stations in the tropical Pacific have shed light on the role of vertically propagating atmospheric waves in the dehydration processes taking place in the TTL (Hasebe *et al*., 2001, Fujiwara *et al*., 2001). On the other hand, the idea emphasizing the role of horizontal advection as a key process in determining the water vapour concentration in the stratosphere (Holton and Gettelman, 2001) is becoming widely accepted (Randel *et al*., 2001, Hatsushika and Yamazaki, 2003, Eguchi and Shiotani, 2004).

To enable us to identify the mechanism determining the long-term trend of stratospheric water vapour, it is necessary to quantify the contribution of each process. The Lagrangian description from the modification of the air quality is made possible by the introduction of the "match" method. This method has proven effective in describing the ozone loss in the polar vortex (Rex *et al*., 1998), and many questions can be answered by applying it to the dehydration in the TTL.

F. Hasebe and the SOWER Team presented calculations of air trajectories in the TTL in northern winter, which show dependence on the phase of the El Niño as shown in **Figure 3 (p IV)**, which illustrates those of possible "match" pairs being caught by existing stations for the cases of December 1998 (non-El Niño) and 1997 (El Niño). The first trial of water vapour "match" is being planned for the northern winters of 2004-2005 and 2005-2006, with the aid of these analyses. Preliminary analysis of data taken during the December 2003 campaign at Bandung and Tarawa (Kiribati) indicates some dependence of water vapour concentration of the air parcels on their temperature history during horizontal advection.

M. Niwano presented a study examining the global occurrence of cirrus clouds and dehydration in the TTL in terms of short term variation, based on upper tropospheric data from HALOE and Singapore rawinsondes.

HALOE data for the period of January 1993 exhibits the global occurrence of tenuous cloud (TC) and its sedimentation, which is synchronized with downward- and eastward-propagating cold anomalies of the equatorial Kelvin wave coupled to the Madden-Julian Oscillation (MJO) convection. To the east of the MJO, TCs occur up to the 100 hPa level through adiabatic cooling due to large scale upward motion of the MJO-coupled Kelvin wave. To the west of the MJO, TCs are spread by downward and westward motions of the MJO-coupled Kelvin wave, and disappear due to sedimentation and evaporation. Apart from the MJO convection, a layered TC appears over Singapore with a thickness of ~2 km and a fall speed of about 10μm, which can be accounted for by sedimentation of cloud particles with a radius of 10 μm. On a global scale, the occurrence, transport, and sedimentation of TCs are controlled by the MJO-coupled equatorial Kelvin wave, which is inseparable from spreading from anvil and large-scale upwelling.

S. Iwasaki presented observations of subvisual cirrus clouds (SVC) using a 1064 nm lidar, a 95 GHz cloud radar and radiosondes launched every 3 hours, at 2°N, 138°E for a period of one month (Iwasaki *et al*., 2004). The observed sedimentation rate of SVCs was 3 cm/s, the same as the theoretical terminal velocity of ice crystals, and the average effective radius was estimated to be 10 μm. The result shows that sedimentation is important for dissipation of SVC. Moreover, the SVCs did not appear to correspond to negative temperature anomalies as expected, but rather they dissipated corresponding to positive temperature anomalies, $\Delta T>1.5°C$, suggesting that the relative humidity is important to their formation as discussed by Jensen *et al*. (2001).

Modelling of Stratospheric Water Vapour and Dehydration Processes

H. Hatsushika and **K. Yamazaki** presented a modelling study of the stratospheric drain over Indonesia and dehydration within the TTL using air parcel trajectories to diagnose results from an atmospheric general circulation model (AGCM). The AGCM has strong upward motions in the lower part of the TTL over the maritime continent and the western tropical Pacific, corresponding to the stratospheric fountain region, and downward motions in the upper part of the TTL over Indonesia, representing the stratospheric drain. In the TTL, strong easterlies prevail, and the cold ascent region tilts eastward. Upward motion over areas of deep convection is suppressed by longwave cooling.

Tropospheric air parcels are advected upward to the bottom of the TTL mainly from the stratospheric fountain region. A pair of anticyclonic circulations in the tropical western Pacific entrains air parcels, which then pass through the equatorial cold region during the slow ascent in the TTL. This slow spirally ascending motion brings about low humidity in the stratosphere, despite the local downward motion over Indonesia. In addition, transient disturbances, particularly low-frequency disturbances such as Kelvin waves and the MJO (Mote *et al*., 2000), produce intermittent upward motions over the fountain region, resulting in effective dehydration of the air. The spiral ascent and transient mechanisms are key factors in the dehydration process in the TTL.

It is also found that air in the tropical lower stratosphere is more dehydrated in La Niña years, than in El Niño years.

Acknowledgements

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The Lower Arctic Stratosphere in Winter since 1952: an Update

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Four years ago we published a table with monthly mean temperatures (°C) at 30 hPa over the North Pole ([Labitzke and Naujokat, 2000], hereafter LN). These data started with the winter 1955/56, *i.e.* 45 winters were available. One point of interest in the paper was the fact that there was a period of 7 winters without Major Warmings: Northern Hemisphere winter 1991/92 to 1997/1998. We pointed out that during low solar activity the winters in the west phase of the Quasi-Biennial Oscillation (QBO) tended to be cold and stable (Labitzke and van Loon, 2000) and this combination existed during 4 out of the 7 winters.

Here, we would like to give a follow up on the North Pole temperatures and on the characteristics of the last four Arctic winters by supplementing **Table 1** of LN. After the extremely cold winter of 1999/2000 (LN), we observed four highly disturbed winters with a total of five Major Warmings (Table 1). Two of the recent winters belong to the winters in the west phase of the QBO and high solar activity, and they are expected to be connected with Major Warmings.

Particularly interesting was the winter of 2001/2002 when two Major Warmings occurred in December and in February (Naujokat *et al*., 2000). This has been observed only once before, during the winter of 1998/99.

Compared with our earlier results (Table 1 in LN) the overall trend has not changed much during early and midwinter. The trend over the Arctic lower stratosphere is clearly negative in November and practically zero from December till February.

Major Midwinter Warmings are connected with the breakdown of the polar vortex, much reduced activity of planetary waves, and weak transport of energy. This leads often in late winter to the reestablishment of a persistent cold polar vortex and to the so-called late winter cooling, which is clearly visible in the Arctic temperatures during March and April, especially in the 2003/04 winter

MONTHLY MEAN 30 hPa NORTH POLE TEMPERATURES (°C)

YEAR	RJ	Nov	Dec	Jan	QBO	Feb	Mar	Apr	FW
2000/01	95	-65CW	-70	-79C	w/e	-50*	-57	-58C	Late
2001/02	114	-73C	-71*	-59	east	-57*	-62C	-55C	Late
2002/03	80	-77C	-80C	-65*	west	-64	-57	-50	Late
2003/04	37	-75C	-72	-53*	east	-62	-71C	-63C	Late
(T) n=49		-69.8	-74.0	-71.5		-65.5	-57.8	-48.1	
sigma		3.8	61	9.0		9.8	7.8	5.7	
Trend	K/dec	-1.2	-0.1	-0.2		-0.0	-0.4	-0.7	
Conf.	%	99	13	18		3	41	80	
C		≤-70	≤-77	≤-75		≤-70	≤-60	≤-51	

Table 1. ***RJ*** *is the monthly mean of the sunspot numbers in January; in the column marked* ***QBO*** *the phase of the QBO is given (determined using the equatorial winds between 50 and 40 hPa in January-February);* ***FW*** *gives an indication of the timing of the Final Warmings which are the transitions from the winter to the summer circulation.* ***CW*** *stands for Canadian Warmings and * indicates the occurrence of a Major Mid-Winter Warming. The long-term mean and the standard deviation are based on the period 1955/56 to 2003/04. The values of the linear trend are for the full data set, n=49 years.* ***C*** *stands for a cold monthly mean (about half a standard deviation or more below the long term average; see discussion in LN). [Data: Free University Berlin (FUB) until 2000/01, ECMWF afterwards]*

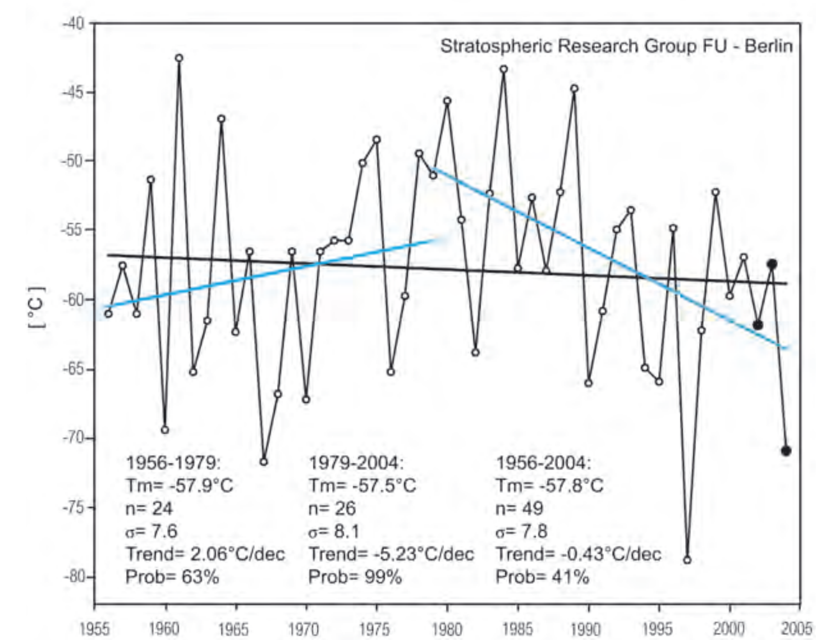

Figure 1. Time series of the monthly mean temperatures (°C) at 30 hPa over the North Pole in March, 1956 to 2004. Linear trends are given for three different periods: 1956-1979, 1979-2004 and 1956-2004 (Labitzke and van Loon, 1999, updated). Data: Free University Berlin (FUB) (open dots), ECMXF (full dots).

(Table 1). In all four winters the Final Warmings were late.

Figure 1 shows the time series of the 30 hPa North Pole temperatures (ºC) for March, an update of Figure 1 in LN. The overall trend for 49 years is weakly negative, but depending on how one divides the data, the trend can be positive, as in the first half of the data set or negative, as in the second half of the data. The change in the sign of the trend between the two different periods is, however, confirmed by the re-analyses of NCEP/NCAR and by the ECMWF-ERA-40 data (Labitzke and Kunze, submitted).

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The Earth's Protective Ozone Layer still Remains Vulnerable

Report on the Quadrennial Symposium on Atmospheric Ozone, Kos, Greece, 1-8 June 2004

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The XX Quadrennial Symposium on Atmospheric Ozone coincided with the 20th anniversary of the discovery of the springtime Antarctic ozone hole. It also marked two decades of intensified global atmospheric monitoring, and basic research in atmospheric chemistry and physics. The progress in our understanding of the impact of human activities on the chemistry and physics of the global stratosphere since the previous Quadrennial Ozone Symposium was presented among the 690 research papers at the XX Quadrennial Ozone Symposium, which was attended by 450 scientists from 60 countries. For the papers presented and the proceedings of the Symposium see **http://www.QOS2004.gr**.

Among the important topics discussed at the Symposium were recent research on possible ozone recovery, results from an expanded network of satellites and ground-based stations, ozone-climate interactions, modelling and chemistry, results from monitoring of the global composition of the troposphere from satellites, and measurements of UV-B solar radiation reaching ground level, among others.

Evidence was presented that ozone in the past few years has been a little higher than expected from earlier projections based on sensitivity of ozone to influences of aerosols, halogen compounds and the solar cycle. The data may indicate the beginning of a recovery; an issue that is complicated by a number of factors among which is the prominent role played by changes in meteorology, greenhouse gases and in the radiation balance, not excluding the observed recovery of the ozone layer from its perturbation by the volcanic eruption of Pinatubo in the early 90s. The evaluation of future ozone recovery in a changing climate and the effect of ozone on that climate has shown the importance of feedback mechanisms between water vapour content and a warmer planet.

The need for the continuation of well-calibrated instruments and measurements was discussed extensively, and emphasis was given to the use of satellite and ground-based data (*e.g.* NDSC and the Global Ozone Observing System) to evaluate models and ozone loss, and its expected recovery.

Numerous chemistry/climate models were presented at the conference. They addressed the problem of how changes in meteorology or climate interact with changes in the chemistry of ozone. One problem is how changes in meteorology over the last 25 years may have contributed to observed ozone changes and feedback mechanisms. Models can then be used to extrapolate that knowledge to what may happen in the future with the expected increase in methane, nitrous oxide, and carbon dioxide.

Significant new work that combines satellite and *in situ* observations with model calculations was presented at the Symposium, providing an insight into the budget of nitrogen oxides and a range of halogen species, which are indispensable to our understanding of the global carbon and hydrological cycles. Water vapour presents a particularly important challenge. Satellite data shown at the meeting is not consistent with trends from previous ground-based data. Understanding the feedback mechanism between water vapour content, ozone, and polar stratospheric clouds is critical to the evaluation of predictions of ozone in a future warmer global atmosphere.

Important progress was made in monitoring the tropospheric ozone budget with the development of new observational techniques from satellites, combined with models of tropospheric composition. It turns out that the key factors influencing the tropospheric ozone budget (precursors, long-range transport in the troposphere and intrusions from the stratosphere) make the determination and attribution of tropospheric ozone trends difficult.

Long-range transport of tropospheric pollution and its coupling to climate was targeted in a number of studies using climate/chemistry models. Other studies have shown the importance of long-range transport of pollutants to maintain regionally high background levels of tropospheric ozone. For example, NASA satellites and balloons reveal that seasonal episodes of high ozone over the south Atlantic begin with pollution sources originating thousands of miles away.

Future UV-B levels for 2000-2019 are predicted to decrease in all seasons but the trends are typically not statistically significant, except during spring over both hemispheres. UV-B trends are caused mainly by total ozone trends because in the future cloud, changes are predicted to be small in the coupled chemistry climate models used in these results. Nonetheless, there is a region over western Europe which is predicted to show an increase in UV-B due primarily to a decrease in cloudiness. The complexity of interference of cloud and other physical parameters in influencing UV-B levels at ground level was targeted in several papers.

The main conclusion drawn from the individual oral and poster presentations of the Symposium is that the detection of ozone recovery requires patience. We still have a long way to go to understand the complex system of interactions between ozone and a globally changing environment. The best tool we have at present is the continuation of quality observations of global coverage both from the ground and space. UV-B levels in the coming decade are predicted to decrease for all seasons except during spring over high latitudes of both hemispheres.

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Summary of the COSPAR 2004 - Session A1.1 Paris, France, 20-25 July 2004

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The system comprising the sun, the atmosphere and the earth is complex, having many non-linear feedbacks. During the past three decades the role of anthropogenic activity has become increasingly recognised as being one of the most important sources of changing emissions to the atmosphere. Understanding the behaviour of the Sun-Atmosphere-Earth system requires a detailed understanding of the physical, biological and chemical processes, which determine its nature and behaviour. Both natural phenomena and anthropogenic activity result in changing atmospheric composition, which impacts on the Earth's radiation balance and its chemistry. Knowledge of the distribution of atmospheric constituents and parameters is required to test and improve our understanding of the Sun-Atmosphere-Earth system, whose conditions are essential to the maintenance of life on earth.

Session A1.1, "Atmospheric Remote Sensing: Earth's Surface, Troposphere, Stratosphere and Mesosphere", of COSPAR 35 Scientific Assembly addressed our current ability and future potential to objectively measure atmospheric parameters of relevance to atmospheric chemistry, global climate change and numerical weather prediction. The focus of the session was remote sensing from space but in addition ground based, aircraft and balloon borne measurements also featured prominently. This is a relatively young research area and is being driven by the need to understand the changing composition of the Earth's atmosphere and its consequences for global climate change.

As part of the evolution of the needs of COSPAR, following the Houston COSPAR 34 Assembly in 2002, Committee A overhauled the structure of its sessions. In this context Session A1.1 was designed to be one continuous session running throughout COSPAR 35 on topics of relevance to the remote sensing of the atmosphere and the Earth's surface. This approach amalgamated sessions, which at previous COSPAR Scientific Assemblies had been independent from one another, and focused on different subregions of the earth-atmosphere system. The new structure enabled attendees researching the different regions of the atmosphere to obtain a holistic view of current research throughout this multi-disciplinary area. In particular, the reporting of research in the overlap areas between different regions of the atmosphere, such as the planetary boundary layer, the tropopause, the stratopause and the mesopause, which in the past have often fallen between different sessions, benefited from this new approach.

Session A1.1 was comprised of sub-sessions that were dedicated to the following topics: a) *Troposphere: Surface and Aerosol - Parts I and II*; b) *Troposphere: Cloud and Weather;* c) *Troposphere: Trace Gases,* d*) Stratosphere,* e*) Mesosphere, and* f) *Instruments and Missions.*

During the first four and half days, contributions were primarily about current space missions and the exploitation of the existing data, and the development of new techniques. The final day was focused on the development of and the planning for new missions by the agencies. In addition to the A1.1 Session itself, one of the A1.1 community (**P. J. Crutzen**) gave an invited interdisciplinary lecture on "ENVISAT: first results" and the A1.1 community participated in the relevant panel events.

Session A1.1 was comprised of approximately 220 contributions with roughly 50 %, being given as oral presentations and about 50 % in the complimentary poster session. The posters were hung for the entire week and individual posters were highlighted in the relevant sub-session. The attendees welcomed this approach to the A1.1 Poster Sessions. The attendance at each of the sessions was typically about 60 to 70 people, with over 200 COSPAR associates taking part over the week.

The session was opened with introductory remarks by **J. P. Burrows** and **P. Schluessel**. The members of the programme committee for Session A1.1, the COSPAR 35 Local Organising Committee and the Overall Programme Committee were explicitly thanked for their support. The duration and wide ranging nature of the A1.1 Session resulted in additional work for these committees, compared with that required at previous COSPAR Scientific Assemblies.

The session started with the remote sensing of the troposphere. The first sub-session was devoted to aerosol and surface. Both active and passive remote sensing techniques were described. Results from successful ground based, airborne and space based LIDAR experiments were presented and discussed *e.g.* LITE, GLAS and the forthcoming Calypso and CloudSat missions. Retrieval of aerosol parameters from the measurements of AVHRR datasets from various platforms provides a long data set of information. Aerosol retrieval from passive remote sensing over the ocean is less difficult than over land. However, significant progress has been made, with the derivation of aerosol parameters over land surface now becoming feasible from algorithms applied to the data measured by the sensors POLDER, ATSR-1, -2, AATSR, MODIS, MISR, MERIS, SeaWifs, and TOMS. The surface spectral reflectance and its applications were also discussed in this part of the meeting.

The sub-session *Troposphere: Cloud and Weather* addressed remote sensing of relevance to the hydrological cycle and weather prediction. A wide range of presentations described passive and active remote sensing by means of microwave, infrared and visible/ultraviolet spectroscopy; both absorption and scattering being the source of information about cloud parameters and water vapour distributions. Algorithms, exploiting the O_2 absorption bands in back-scattered solar radiation, and infrared emission, for the retrieval of cloud parameters were described. These offer many potential advantages for improving our understanding of clouds and improving the predictive capability of models. Measurements of water vapour in the tropopause region, which are of great significance for understanding stratosphere-troposphere exchange, were reported from aircraft measurements. There were also several contributions about the observation of cirrus and subvisible clouds.

The detection of trace gases in the troposphere has been an area of growth in the last 10 years. The sub-session *Troposphere: Trace Gases* focused on this topic. The results of retrieval studies using data from the nadir looking sensors MOPITT on NASA TERRA, GOME-1 on ERS-2 and SCIAMACHY on ENVISAT were prominent. In addition, presentations on the retrieval of limb sounding instrumentation to probe the upper troposphere presented interesting new results. Considerable progress has been made on the retrieval of trace gases of relevance to air quality such as CO_2, CO, NO_2, and formaldehyde, HCHO. The advantages of the different approaches to retrieve water vapour were also discussed. Inversion of back-scattered solar radiation has been shown to yield tropospheric water vapour columns over land.

The retrieval of tropospheric constituents remains an area of growth for the research community. The retrieval possibilities for tropospheric constituents by means of UV and visible spectroscopy with the current generation of instruments have made considerable progress, and these data have been exploited in a variety of interesting ways. Observations of solar near infrared (NIR) and short wave infrared (SWIR) spectral regions are being exploited for the first time. In this context, SCIAMACHY data is yielding the distributions of the atmospheric columns of greenhouse gases (GHGs), CO_2 and CH_4, from space. This is a first step of limited accuracy in the assessment of the sources of GHGs, which the NASA OCO instrument intends to improve upon for CO_2.

The capabilities of the sensors aboard the NASA Aura satellite, which was successfully launched the week before COSPAR, were also presented in both the tropospheric and stratospheric sub-sessions. In the stratospheric session, there was an overview of the first 25 years of the NASA TOMS measurements. This instrument along with the BUV instruments have not only provided a unique view of global ozone, and the development of the ozone hole, but also provided measurements of sulphur dioxide, SO_2 from volcanoes, and the ultraviolet absorbing aerosol. Similarly, an overview of sounding the atmosphere from balloons was a highlight of this session. Both TOMS and the balloon measurements have been two of the most productive sources of information about the stratosphere in the last 25 years.

The discussion of the results from the ENVISAT sensors MIPAS, GOMOS and SCIAMACHY and the ODIN sensors OSIRIS and the microwave limb sounder (MLS) dominated a large part of the stratospheric sub-session. The first results were shown from the Canadian SCISAT mission, which has two solar occultation instruments on it, an ACE and MAESTRO. Exciting results from the long duration mission SAGE-II and the new SAGE-III were discussed. Calibration and validation of the sensors was discussed and results presented. The measurements of stratospheric constituents during the anomalous warming of the stratospheric vortex above the Antarctic in spring of 2002 were also discussed. The ENVISAT data have provided some unique insight into this surprising stratospheric event. Interesting new results have been obtained about the development of polar stratospheric clouds, and their role in the catalytic decomposition of stratospheric ozone.

The session about the mesosphere was dominated by results from ENVISAT, ODIN, and SABER. The observations of mesospheric OH and polar mesospheric or noctilucent clouds and the determination of mesospheric temperature were highlights. The measurements of the instruments during the Solar Proton Events of October and November 2003 have provided some unique insight into the interaction between the eruptions from the sun and their impact on the mesosphere and stratosphere. The current missions observing the mesosphere and above are providing a wealth of new information about these regions within the Sun-Atmosphere-Earth System.

The final day of the meeting was dedicated to the plans of the agencies for future missions of relevance to this community. Unfortunately, the future after ENVISAT and Aura for atmospheric chemistry research from instrumentation on space-based platforms is unclear. However, the operational satellites from EUMETSAT and the NPOESS system will provide some valuable data. The further developments of the NASA OCO, which aims to extend and enhance the measurement of CO_2 from space by using the NIR and SWIR absorption bands of CO_2 was discussed. Of interest were the studies of instrumentation and the potential benefits for tropospheric research and applications of passive observations from geostationary orbit. Teams in Europe, America and Japan presented their concepts. New concepts for instrumentation from LEO were also presented. Whether from GEO or LEO, researchers have recognised the need for synergistic use of different spectral regions to probe tropospheric composition.

The session closed with thanks to all the participants, who had made this a memorable meeting. The future of the research of the Sun-Atmosphere-Earth System depends on the continued efforts of this community, which would not be possible without support from the space agencies and their governments.

In Memory of Thomas M. Donahue

Prof. Thomas M. Donahue, The Edward H. White II Distinguished University Professor Emeritus of Planetary Science at the University of Michigan, died October 16, 2004. Tom was a pioneer in advocating satellites and spacecrafts to explore and understand the atmospheres of Earth and other planets in the solar system. We are indebted to Tom for making the satellite and space shuttle measurements of atmospheric constituents possible in those early uncertain days through his tireless work and dedication. But for his efforts, the data on the Earth's atmosphere that we use in the SPARC community would have been much sparser.

Tom was deeply involved in the issue of anthropogenic destruction of stratospheric ozone in the early 1970s. His interest in stratospheric ozone changes naturally gravitated him towards Global Changes and climate. These issues still are at the heart of SPARC activities.

Tom Donahue really understood the power and need for atmospheric chemistry in solving issues, be it Earth's atmosphere or that of another planet. Even till his last days, he was thinking about the isotope enrichment in various planets and how it could be detected and used for interpreting the workings of those atmospheres.

Tom not only provided scientific knowledge to the community but also leadership. His quick mind and vast knowledge always allowed him to critically evaluate any hypotheses and know what is feasible and what is not, what is good science and what is not.

We are sure that other scientists in planetary science will have similar things to say about Tom from their perspective. We in the SPARC community are happy that Tom was interested in the Earth's atmosphere. We will miss him greatly, but are grateful for the rich legacy he left behind.

A. R. Ravishankara

Announcement

Termination of the STRATALERT Reports

Karin Labitzke, Freie Universität Berlin, Germany (labitzke@strat01.met.fu-berlin.de)

In the 1960s the stratospheric midwinter warmings were regarded as an exciting and interesting research problem. The observations taken during a warming were scarce but in great demand, and a much desired aim was to launch meteorological rockets when a warming was developing above a station. For this purpose an advisory system was necessary, such as had been established in the international geophysical community for other phenomena (GEOALERT). Charged by the World Meteorological Organization (WMO), the Stratospheric Research Group of the Freie Universität in Berlin (Germany) got together with their colleagues of the American Weather Bureau and developed a warning system, which was named STRATALERT. It was introduced in 1964 when the IQSY (International Year of the Quiet Sun) began.

The Berlin group was at first responsible for the European space, and later for the whole Northern Hemisphere. It issued a STRATALERT report every day during winter, and a GEOALERT when needed. The alerts were disseminated through the German Weather Service's international net and reached all interested parties. The STRATALERT reports were an essential source of information about what was going on in the stratosphere; information which at that time would not otherwise have been available to many scientists interested in current conditions. Because of this information it was possible to time experiments, for instance, with meteorological rockets, to take place under desired conditions, and local observations could be assimilated and interpreted on the background of a wider field. This information system has served as a basis for decisions made in many large-scale field experiments.

A review and classification of stratospheric warmings can be found in SPARC Newsletter No. 15, Labitzke and Naujokat, 2000 (**http://www.atmosp.physics.utoronto.ca/SPARC/News15/15_Labitzke.html**).

The 2003/2004 winter was the last year for STRATALERT. After 41 years we are sorry to announce that we cannot continue this timely warning system in its old format and we could not find a successor. However, those interested in the daily development of the stratospheric circulation can find analyses and different stratospheric parameters based on the ECMWF-data on the FUB web site. (http://strat-www.met.fu-berlin.de/winterdiagnostics). The general evaluation is, however, left to the user.

Additional available data links are (amongst others):

US National Centers for Environmental Prediction (CPC/NCEP):**http://www.cpc.ncep.noaa.gov/products/stratosphere/index.html**. Japan Meteorological Agency (JMA): **http://okdk.kishou.go.jp/products/clisys/STRAT/index.html**

Future SPARC and SPARC-related Meetings

2005

18-22 April: 4^{th} **WMO International Symposium on Assimilation of Observations in Meteorology and Oceanography**, Prague, Czech Republic (http://www.chmi.cz/dasympos/index.html). Co-chairs: R. Brozkova (radmila.brozkova@chmi.cz), M. Zak (michal.zak@chmi.cz,)

24-29 April: **EGU General Assemby**, Vienna, Austria (http://www.copernicus.org/EGU/ga/egu05/index.htm)
AS0: Open Session on the Lower, Middle, and Upper Atmosphere - Convener: M. Jukes
AS1.08: Clouds, Aerosols and Radiation - Convener: U. Lohmann
AS1.10: Solar UV - Convener: P. Weihs
AS3.01: Past and Future Changes in Mid-Latitude Ozone - Convener: S. Godin-Beekmann
AS3.05: Polar Ozone - Convener: G. Braathen
AS3.07: UT/LS Dynamics and Chemistry - Convener: J.P. Pommereau
AS4.01: Dynamics of the Middle Atmosphere - Convener: M. Juckes

07-13 May: **Global Chemistry for Climate (GCC) Project Summer School on "Hierarchy of Models"**, Banff, Alberta, Canada (http://www.atmosp.physics.utoronto.ca/MAM/summerschool05.html).

09-14 May: **SCOSTEP** 11^{th} **International Symposium on Equatorial Aeronomy**, Taipei, Taiwan, China (http://csrsddc.csrsr.ncu.edu.tw/isea-11.html)

23-27 May: **AGU Spring Meeting**, New Orleans, Louisianna, USA (http://www.agu.org/meetings)

23 May-03 June **Seasonal to Interannual Climate Variability: its Prediction and Impact on Society**, Gallipoli, Italy (http://www.ecmwf.int/staff/alberto_troccoli/nato_asi/index.htm

13-17 June: **Joint AMS Conference on the Middle Atmosphere and Atmospheric and Oceanic Fluid Dynamics**, Cambridge, Massachussett , USA (http://www.ametsoc.org/meet/anncall.html)
- 17^{th} Conference on Climate Variability and Change, Cambridge, Mass, USA

20-24 June: 5^{th} **International Scientific Conference on the Global Energy and Water Cycle Experiment,** Orange County, CA, USA (http://www.gewex.org/5thconf.htm). Chair: S. Sorooshian

18-29 July: 10^{th} **Scientific Assembly of IAGA**, Toulouse, France (http://www.iugg.org/IAGA/toulouse2005.htm). Chair: M. Blanc

02-11 August: 9^{th} **Scientific Assembly of IAMAS**, Beijing, China (http://www.iamas2005.com)

22-26 August: **IAG/IAPSO with IABO Joint Scientific Assembly**, Cairns, Australia (http://www.gfy.ku.dk/~iag, http://www.iugg.org/iapso)

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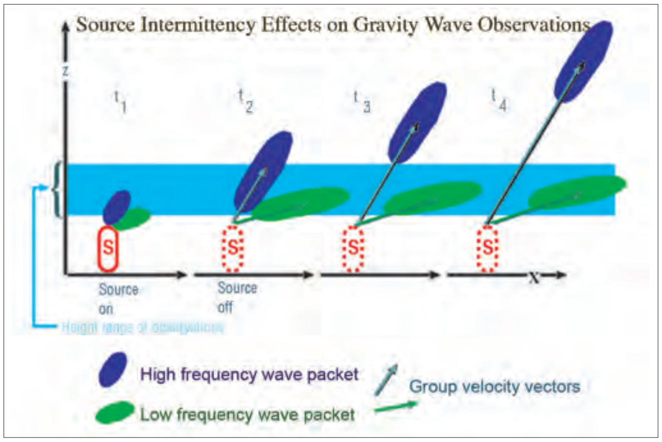
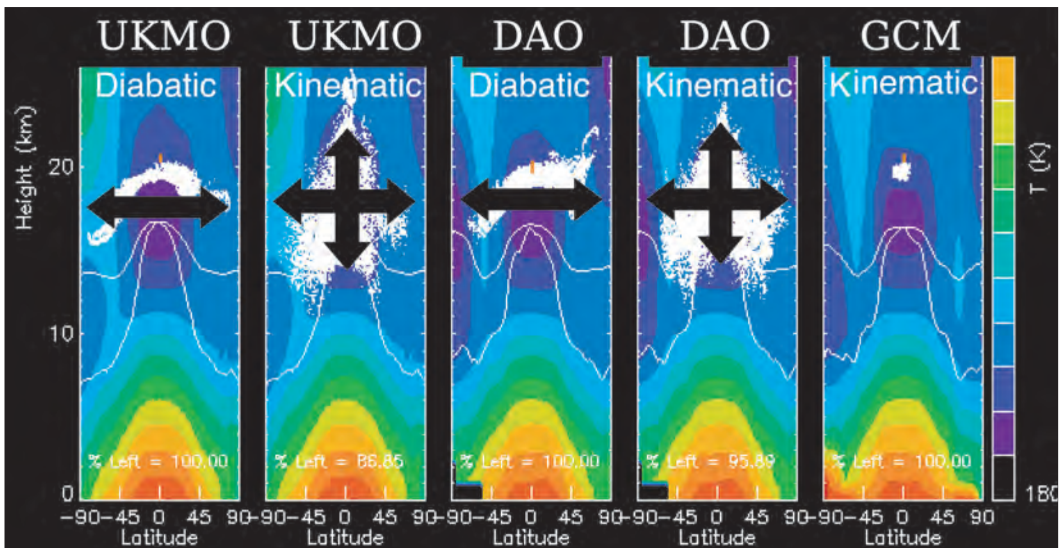
Report on the SPARC 3rd General Assembly



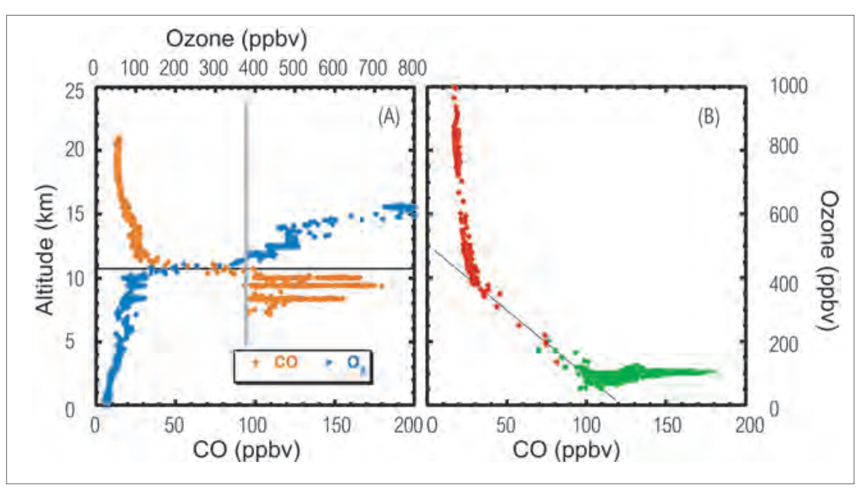
< Figure 1

Probability of observation effects: An intermittent source (e.g. time-varying heat source) will produce gravity waves (GW) of different frequencies and vertical wavelengths. The vertical group velocity of GWs is much faster for high frequency and long vertical wavelengths (represented by the royal blue packet), than for lower frequency waves with short vertical wavelengths (green packet). The result is that the low frequency waves remain in the height range of observations longer than the high frequency waves, making observation of the low frequency waves more probable. [Adapted from Alexander *et al.*, *JAS*, **59**, 1394-1404].



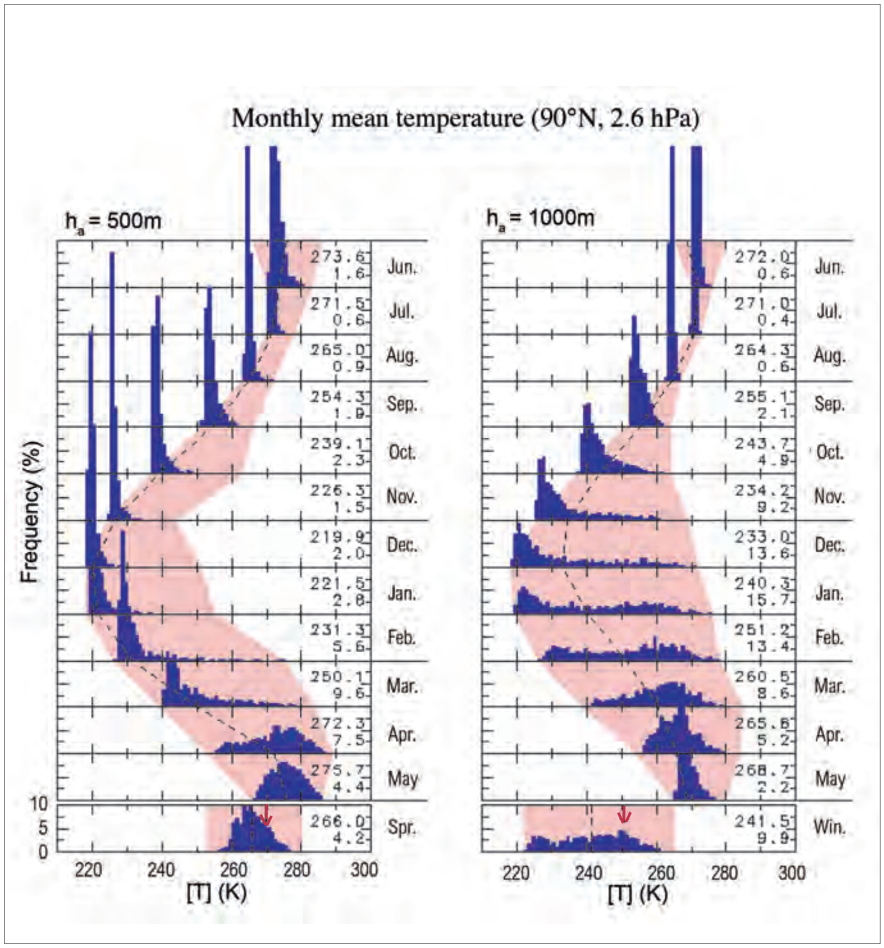
> Figure 2

The distribution of particles 50 days after the beginning of a back trajectory calculation of parcels initialized at 20 km and the equator. The lower (upper) thin white line shows the zonal mean altitude of the tropopause (380K isentrope). Zonal mean temperature is indicated by the colour contours and particles are shown as white dots. Results are from the Met. Office Data Assimilation System analysis (UKMO), the NASA Data Assimilation Office (DAO) analysis, and for a GCM. The Diabatic method, using smoothed heating rates, has reduced vertical dispersion, while the Kinematic method, using analysed vertical winds, has both considerable vertical and horizontal dispersion. The GCM shows very little dispersion, regardless of the method used (only the Kinematic method is shown), while the assimilated fields are excessively dispersive. The percent of particles remaining in the stratosphere is indicated in each figure. [Schoeberl M. R., *et al.*, *J. Geophys. Res.*, **108** (D3), 4113, doi:10.1029/2002JD002652, 2003].



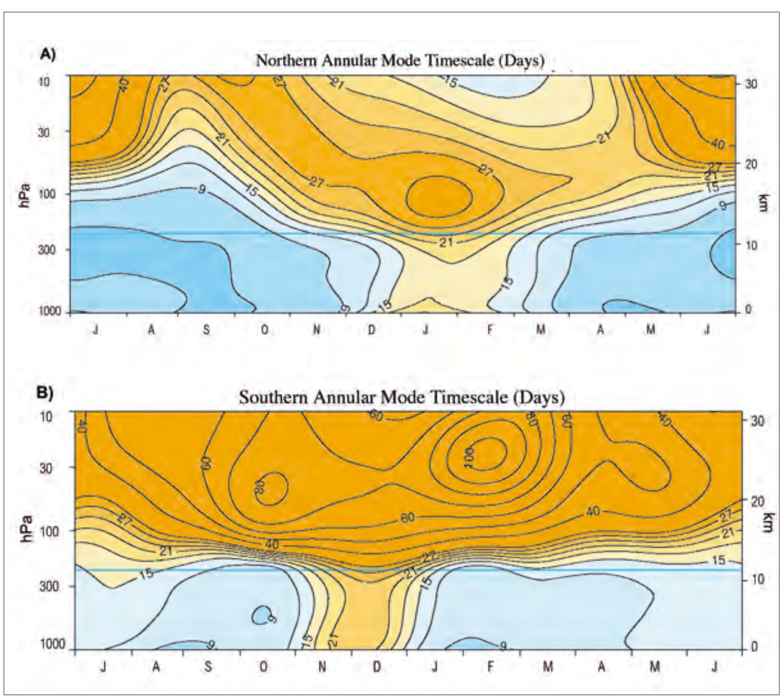
> Figure 3

Result from POLARIS 970710 showing the concentration of ozone and CO with height. The tropopause is shown in panel A by the dashed line. Air with low ozone and high CO is found in the troposphere, while air with high ozone and low CO is found in the stratosphere. Air with intermediate values is found at the tropopause. [Pan, L. *et al.*, *JGR*, in press, 2004].



> Figure 5

Frequency distributions of the monthly mean temperature at 90°N and 2.6 hPa in the two millennium integrations: h_a=500 (left) and h_a=1000 m (right). The broken line denotes the 1000-yr mean seasonal mean, and shading shows the range of variability. The two numbers for each month denote the 1000-yr mean (top) and the standard deviation (bottom). Frequency distributions for a seasonal mean are also displayed in the bottom panels: spring mean for h_a=500 m and winter mean for h_a=1000 m. The downward arrow in the seasonal mean indicates a threshold value for the 200 yr of highest temperature. [Taguchi M., and S. Yoden, *J. Atmos. Sci.*, **59** (21) 3037-3050, 2002].



< Figure 6

Timescale of the NAM as measured by the e-folding time (in days) of the autocorrelation function. Daily values are a time average of Gaussian weighting with a full-width at half maximum of 60 days. (B) Same as in (A) but for the SAM, normalized to unit standard deviation. The horizontal blue line denotes the approximate level of the tropopause. The contour interval is 3 days up to a value of 30 days, and 10 days for higher values.
[Reprinted with permission from M. P. Baldwin, D. B. Stephenson, D. W. J. Thompson, T. J. Dunkerton, A. J. Charlton, and A. O'Neill, Stratospheric memory and skill of extended-range weather forecasts, *Science*, 1 August 2003; **301**: 636-640. Copyright 2003 AAAS].

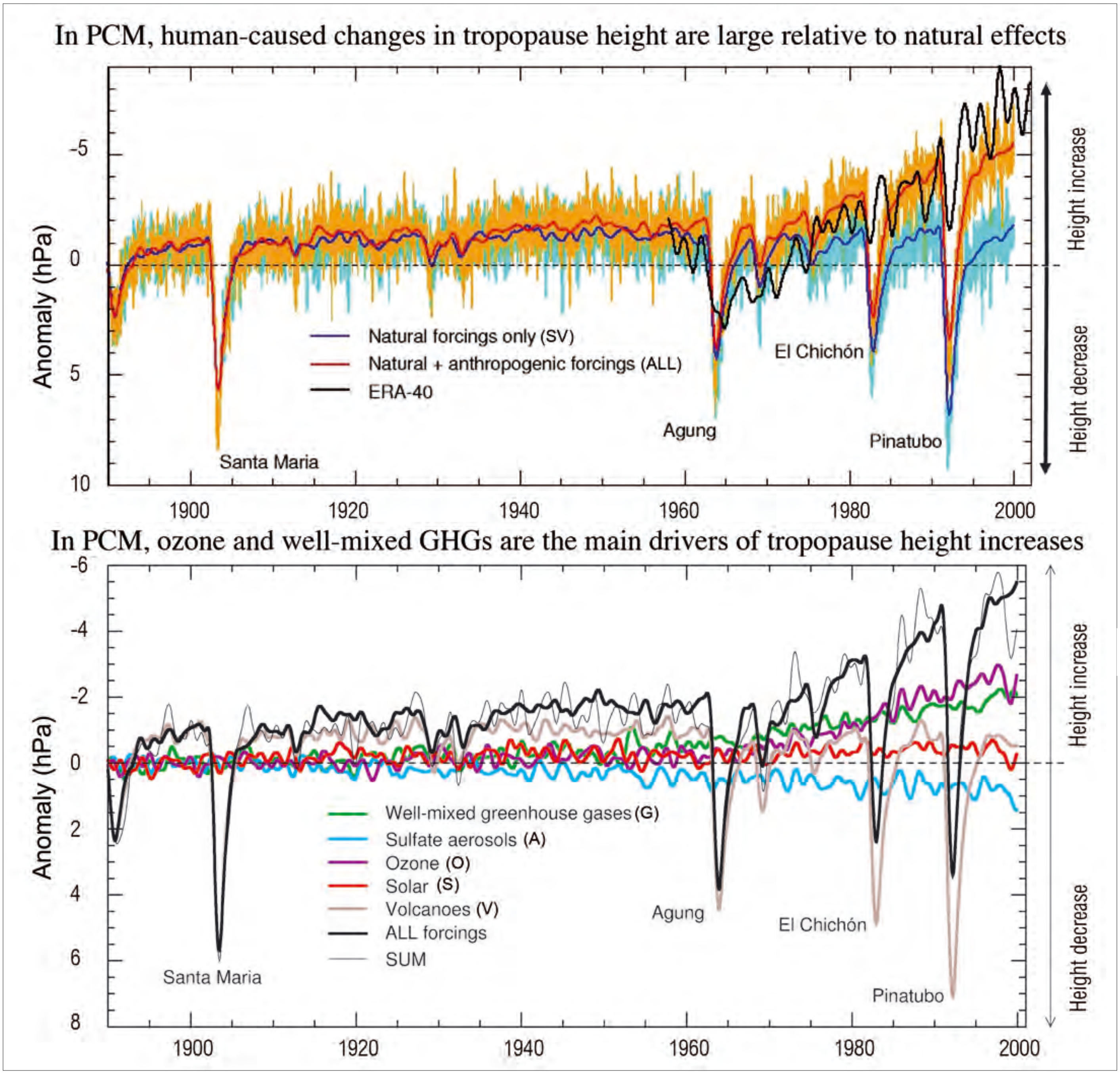
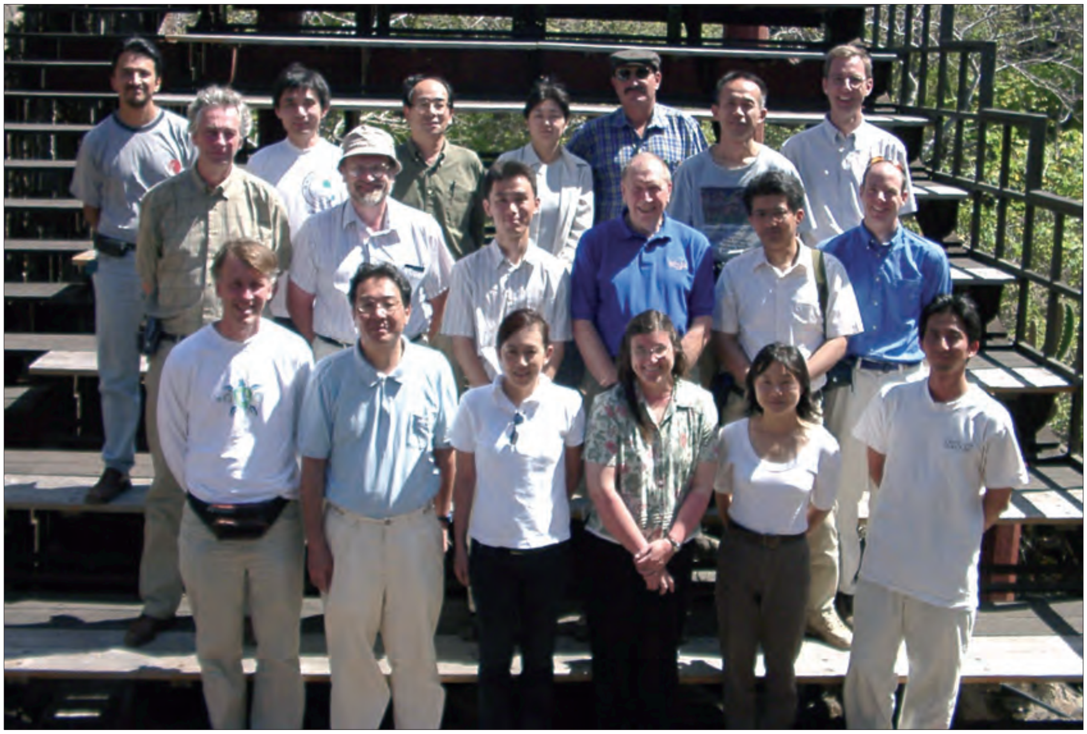


Figure 8

Time series of global mean, monthly mean anomalies in tropopause pressure. Model results are from seven different Parallel Climate Model (PCM) ensemble experiments, five using only a single forcing (G, A, O, S, or V) and two involving combined forcing changes, whether in natural forcings (SV), or in all forcings (ALL). There are four realizations of each experiment. In (B), only low-pass filtered ensemble means are shown. In (A), both the low-pass filtered ensemble mean and the (unfiltered) range between the highest and lowest values of the realizations are given. All model anomalies are defined relative to climatological monthly means computed over 1890-1909. Estimates from NCEP and ERA were filtered in the same way as model data. The SUM results are the sum of the filtered ensemble-mean responses from G, A, O, S, and V.

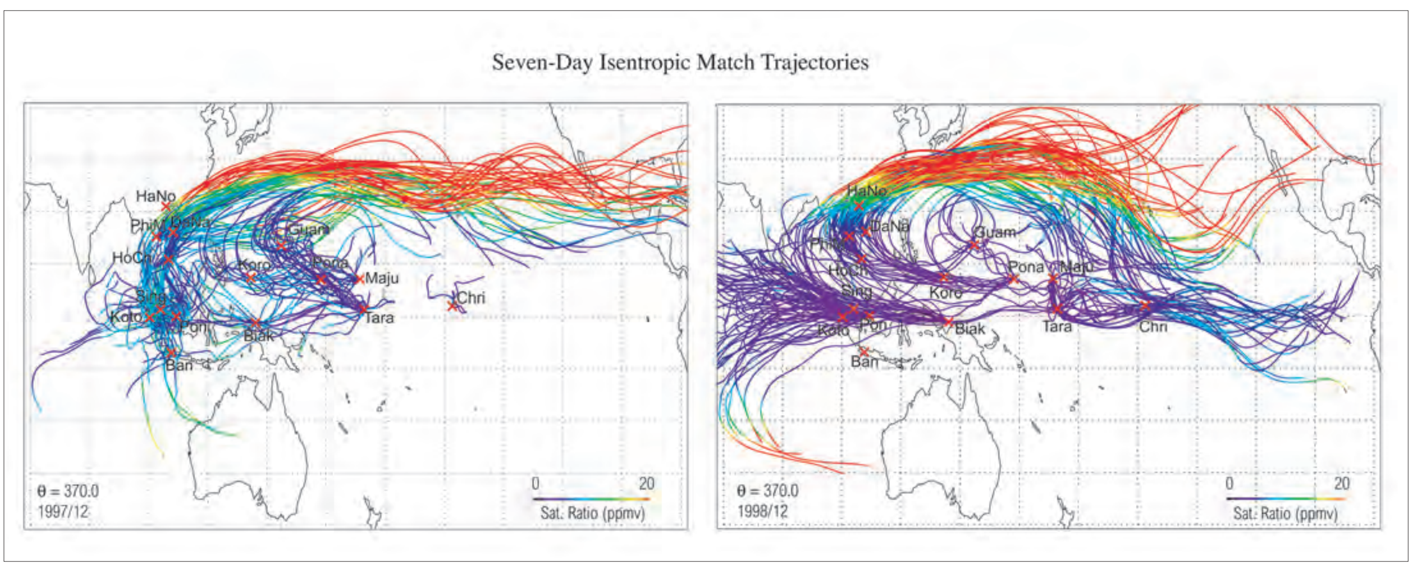
[Reprinted with permission from B. D. Santer, M. F. Wehner, T. M. L. Wigley, R. Sausen, G. A. Meehl, K. E. Taylor, C. Ammann, J. Arblaster, W. M. Washington, J. S. Boyle, and W. Brüggemann, Contributions of anthropogenic and natural forcing to recent tropopause height changes, *Science*, 25 July 2003; **301**: 479-483. Copyright 2003 AAAS].

Report on the 2nd International SOWER Meeting



^ Participants of the SOWER meeting ***(from left to right)***

First row: I. Folkins, M. Shiotani, Y. Kasai, K. Rosenlof, Y. Tsushima, S. Iwasaki.
Second row: P. Fortuin, T. Dunkerton, M. Niwano, S. Oltmans, M. Fujiwara, A. Gettelman.
Third row: L. Poveda, F. Hasebe, K. Yamazaki, N. O. Hashiguchi, C. Teran, N. Nishi, H. Vömel



^ Figure 3

370 K isentropic trajectories for December 1997 (left) and December 1998 (right) that are considered as "match" between the stations shown on the map. Calculations are based on ECMWF operational analyses and illustrations are color coded by saturation mixing ratio of the air parcel along the trajectories.