

Report of the 10th Session of the SPARC Scientific Steering Group

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Participants of the SSG in Kyoto

First row (from left to right):
N. Kawamoto, N. Mc Farlane,
V. Ramaswamy, S. Yoden,
A. O'Neill, M.-L. Chanin, M. Geller,
A.R. Ravishankara, D. Karoly,
K. Kodera

Second row (from left to right):
T. Ogawa, G. Amanatidis, S. Liu,
P. Simon, S. Pawson, M. Suzuki,
M. Kurylo, K. Hamilton, I. Stajner,
C. Granier, A. Akimoto, Ph. deCola,
J. Inatani, Y. Koshelkov

Third row (from left to right):
V. Yushkov, V. Ryabinin, E.-A.
Herland, F. Vial, P. Canziani,
W. Randel, M. Baldwin,
T. Shepherd, C. Michaut, D. Kley,
T. Peter, T. Wehr

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Introduction

The tenth session of the SPARC Scientific Steering Group (SSG) was held in the Kansai Seminar House, in Kyoto, Japan, at the kind invitation of Prof. S. Yoden of the University of Kyoto and a member of the SPARC SSG.

The meeting started with a moment of silence in memory of Dr. Petra Udelhofen, who tragically died. She was key in starting and operating the SPARC Data Centre at Stony Brook.

In their opening address the SSG co-chairs, M. Geller and A. O'Neill, briefly listed top priority issues of SPARC

research. The co-chairs recalled that the SSG session was preceded by a very interesting "International Symposium on Stratospheric Variations and Climate", which was organised by S. Miyahara with the help of S. Yoden in the Kyushu University, Fukuoka, Japan, on 12-15 November 2002. On behalf of all SSG members who attended the



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symposium, the co-chairs expressed their gratitude to **S. Miyahara** and **S. Yoden** and other organisers of the symposium for a remarkable meeting, which set the high tone for the SSG session.

Another very positive news was that, by decision of the WMO Executive Council, the STTA group of SPARC led by **V. Ramaswamy** was recently awarded the annual WMO Norbert Gerbier-MUMM International Award for 2003 for the paper entitled "Stratospheric temperature trends: observations and model simulations" published in *Rev. Geophys.*, 19, 2001. The official award ceremony will take place during the next session of the WMO Executive Council.

The co-chairs expressed their satisfaction that almost all SSG members were able to attend the session. They welcomed warmly **V. Ryabinin** who is a new member of the Joint Planning Staff (JPS) for the WCRP, and our liaison with the JPS, since **R. Newson** departed for retirement. They also welcomed **Shaw Liu**, a co-chair of IGAC, to the meeting. Particularly gratifying was the fact that agencies were well represented at the meeting. Having wished the participants a successful and fruitful outcome, the co-chairs gave the floor to **S. Yoden** who welcomed the guests to Kyoto and provided logistical information.

The introductory part of the meeting was concluded with a brief overview of the WCRP activities, which was given by **V. Ryabinin**. He first presented the current composition of the JPS and the distribution of tasks and stated that, for the first time in several years, experts within the JPS working on a full-time basis occupied all professional posts.

V. Ryabinin continued with a description of the Earth System Science Partnership (ESSP) activities and corresponding joint projects, the area, in which WCRP collaborated with the International Geosphere Biosphere Programme (IGBP), DIVERSITAS, and International Human Dimension Programme (IHDP). He described the three joint ESSP projects, namely on water, global carbon, and food systems and indicated that another project on health was expected to follow.

The attention of the SSG session was then drawn to following important developments in the WCRP projects. After the assessment of its first phase, the GEWEX (WCRP Global Energy and Water Cycle Experiment) project entered its second phase, which will be

focussed on integration of data into diagnosis of variability and predictability of global and energy water cycle. WOCE (World Ocean Circulation Experiment) was about to finish producing the first globally coherent snapshot of the global ocean circulation. CLIVAR (Climate Variability and Predictability) project continued studies of seasonal and inter-annual climate phenomena, decadal modes, anthropogenic climate change and paleo-climate. ACSYS (Arctic Climate System Study) was finishing with a major wrap-up conference planned for 2003. CliC (Climate and Cryosphere) was in the development stage. Other developments in the WCRP included preparatory work of setting up a co-ordinating mechanism for activities in the area of air-sea fluxes, formulation of WCRP requirements in satellite observations, and an initiative on data management. Considerable attention was being paid to a new WCRP "banner", which envisioned an extension of WCRP studies of predictability. Finally, **V. Ryabinin** presented some additional information on activities, which were formally outside WCRP but were related to it. This included the Global Climate Observing System (GCOS) activities, such as continuing development of Global Terrestrial Networks, finalisation of the second GCOS adequacy report, preparation of the Science and Implementation plan for the Atmospheric Observation Panel for Climate (AOPC).

Modelling Stratospheric effects on climate

Intercomparison of stratospheric models

S. Pawson and **K. Kodera** gave a progress report on GRIPS ("GCM Reality Intercomparison Project for SPARC").

The first GRIPS results were published in 2000 (BAMS and JGR) and the recent results are now submitted to JAS (Horinouchi *et al.*, 2002). The highlights of 2002 included several events. At a workshop in Tsukuba, Japan, the participants agreed on a further distribution of tasks within GRIPS. There were 12 participants in the project at the time of the presentation. A project web site was established at: http://userpages.umbc.edu/~pawson/html_flies/grips.htm.

Among the tasks of level 1, which aim to answer the question "How well we simulate the present-day climate sys-

tem?", studies of sudden stratosphere warming events, atmospheric tides and travelling waves, computation of spatial wave number spectra were considered close to completion. The work was pursued on preparation of model documentation, generation of basic climatological data, troposphere-stratosphere connection and exchange, polar vortices, and Southern Hemisphere variability.

The level 2 tasks are aimed at development of parameterisations and studying model sensitivity to them. Simulation experiments on imposed mesospheric forcing were successfully completed. Progress was reported in experiments on the evaluation of gravity wave drag schemes. Evaluation of corresponding radiation schemes and retrieval of gravity wave drag data in diagnostic mode need attention.

The level 3 tasks are supposed to study mechanisms by which various forcing factors control the atmospheric circulation and how they are represented in models. The experiments on intercomparison of model response to the Mount Pinatubo eruption conditions and on response to ozone trends were proceeding satisfactorily. At the same time assessment of ozone related sensitivity faces uncertainties in perturbation levels and even the base state. Therefore one of the GRIPS Level 3 tasks should be to lead the efforts to resolve existing uncertainties in time for the next WMO-UNEP and IPCC assessment.

The SSG noted that the year 2003 was seen as the right time for completion of GRIPS level 1 and level 2 tasks. The following GRIPS workshop was expected to take place in March in the Washington DC area. The SSG felt that it was important to support further studies of GRIPS level 3 tasks, which would require forcing simulation by complex models and would focus on climate – atmospheric chemistry interactions. It was also mentioned that the experience of model intercomparisons in the WCRP was very significant, particularly under the auspices of the CAS-WCRP Working Group on Numerical Experimentation (WGNE) and the Working Group on Coupled Modelling (WGCM). Relationships of SPARC and GRIPS with these groups need to be strengthened.

K. Kodera's presentation on level 2 tasks completed the presentation. He presented some results of experimentation related to the temperature and ozone concentration response to solar forcing. A paper on those initial results has been submitted to *Meteorology and Geophysics* (Matthes *et al.*, 2002).

Disparities between model responses were very significant. The effort was aimed at finding regular patterns of the response and suggesting the dominant mechanisms for it. The experimentation highlighted a need for better observational data to compare temperature and ozone variations and additional evaluation of two mechanisms likely to be important in linking ozone and temperature changes to chemical interactions in the lower stratosphere and dynamical response in the tropical and subtropical stratopause.

The participants agreed that SPARC and specifically GRIPS should co-ordinate future efforts in forthcoming ozone and related climate change assessments, mostly concerning water vapour, column ozone, aerosol and solar cycle effects.

Stratospheric reference climatology

In the subsequent presentation **W. Randel** summarised results of a compilation of middle atmosphere climatological data sets. This study was ready to be published as a SPARC technical report "SPARC Intercomparison of Middle Atmosphere Climatologies" in December 2002. The SPARC reference Climatology Group was able to combine 12 different data sets. The inclusion of rocketsonde and lidar data into the data intercomparisons allowed the extension of the climatology of temperature and winds up to the middle mesosphere. Despite the significant difficulties due to the scarcity of rocketsonde and lidar sites, the non-simultaneity of the data sets, discontinued character of the rocket series, the work was successfully completed. The group was able to include ERA40 from ECMWF into the data intercomparison.

W. Randel presented results showing typical vertical profile of parameters associated with quasi-biennial and semi-annual oscillations, variations of temperatures in polar regions and over the equator zone, and comparisons of results with rocketsonde data.

The SSG was very pleased to hear about the completion of this important task and applauded **W. Randel** for his leadership in this important project. The reference climatological data will facilitate further studies under GRIPS and will benefit other SPARC activities.

SPARC data assimilation

Based on the initial efforts of the SPARC SSG co-chair **A. O'Neill**, a SPARC ini-

tiative in data assimilation started to develop. **I. Stajner** reported on the progress. The state of the art was discussed at the first SPARC data assimilation workshop that took place in Catonsville, Maryland, USA, on 10-12 June 2002. NASA/Goddard Space Flight Centre Data Assimilation Office and the University of Maryland Baltimore County hosted the workshop. The participants from 16 research groups gave presentations on stratospheric data assimilation techniques, data intercomparisons, constituent satellite data, reconstruction of potential vorticity, assimilation of ozone and chemical composition data. The results of the workshop were published in the SPARC Newsletter No. 19 in July 2002.

As a result of the above efforts the SPARC Data Assimilation Working Group was formed. Its meetings are anticipated on a yearly-basis. The group's plans are:

- to collect information on availability, quality, formats, reading software and documentation for stratospheric meteorological data sets that can be used in the intercomparisons;
- to perform process-focussed quality assessments of stratospheric meteorological data;
- to collect, validate, and intercompare chemical assimilated data,
- to collect information on CTM and GCM assimilation systems that are available for intercomparison and coupling.

The group has prepared a progress report on the first of the above tasks and has established a mailing list (sparcda@dao.gsfc.nasa.gov) and a web site at:

http://polar.gsfc.nasa.gov/sci_research/cooperative_ventures/sparc.

The session was pleased to learn the progress in the SPARC data assimilation activities and emphasised that data assimilation was seen by the group as the most efficient technique to obtain global quality controlled, internally consistent data sets of the dynamic and chemical state of the stratosphere.

Long-term changes in the stratosphere

Stratospheric temperature trends

V. Ramaswamy presented the update of the stratosphere temperature trends for the periods 1979-2000 and compared them with the previous 1979-

1994 SPARC studies. A significant and relatively clearly seen temperature trend was reported for the summer 50 hPa series at 70°N. Recently the new focus has been on observed seasonal trends (winter/spring versus summer) and on understanding the causes of global-mean trends, in particular, the role of trace gases changes (ozone, greenhouse gases, and water vapour) in generating the trend. The results demonstrated that model simulations had a tendency to underestimate observed stratospheric cooling. Winter anomalies showed some variability of unknown origin and it would be interesting to trace their connections, if possible, to events such as El Niños. **V. Ramaswamy** also presented some preliminary projections of 50 hPa temperature variations up to the year 2020. The results indicated the relative signs and amplitudes of the variations under the different forcing mechanisms. Another area of intensive research was focussed on transient experiments aimed at explanation of observed annual variability. The simulations included effects of aerosol variations, chlorine and bromine concentration variations, and solar radiance.

The SSG noted that the Temperature Trend Assessment report had been delayed in order to include the seasonal variations, but will be completed soon under the NOAA-SPARC auspices. A meeting of the Stratosphere Temperature Trends Assessment team was considered useful in 2003 or 2004. However future thrusts in the stratospheric indicators activities area will be on the agenda of the Angell Symposium, which will be an opportunity for the community to meet. Another venue for presenting these results would be the Gordon Conference "Solar Radiation and Climate" in July 2003.

SPARC/SCOSTEP assessment of upper atmosphere temperature trends

V. Ramaswamy, **M.-L. Chanin** and **M. Geller** commented on the output of the Heraeus Seminar on trends in the upper atmosphere which took place in Kühlungsborn, Germany, in May 2002 (see report in SPARC Newsletter No 19). This seminar co-sponsored by SPARC and SCOSTEP showed the difficulty encountered in the determination of trends in these upper layers due to the lack of long series of data and indicated that further work is needed.

However the updated trend detection in the upper mesosphere using all the rocket data should be available soon.

Ozone trends and WMO/UNEP report

N. Harris, unable to attend, had sent a report on the activities of the group during the year. W. Randel presented the item.

Most of the effort of the ozone trend community went into the Ozone WMO-UNEP Assessment 2002. An important milestone in this work was a SPARC/IOC (International Ozone Commission) workshop on Understanding of Ozone trends was held at the University of Maryland on 7-9 March 2001. A summary of the workshop was published in the SPARC Newsletter (N. Harris and R. Hudson, SPARC Newsletter N° 17, 2001). The main aims of the workshop were to identify the major current issues concerning ozone trends, to improve quantification of the contributions and uncertainties of the chemical and dynamic mechanisms to observed ozone trends, particularly at mid-latitudes and to identify how to assess the consistency of these proposed contributions. The main emphasis was on the dynamical influence on the ozone trends.

Chapter 4 of the WMO-UNEP assessment "Global Ozone: Past and Future" was led by W. Randel and M. Chipperfield and 2 SSG SPARC members were co-authors: T. Shepherd and T. Peter. Both commented on the contents of the chapter as well as on the state of other chapters. Consideration of the ozone changes suggested that a cooler stratosphere would act so as to prolong ozone recovery. Nevertheless, ozone is likely to recover in the next 50-100 years.

To move forward on the issue of Arctic ozone, a workshop on Arctic Ozone Loss was organised at the Alfred Wegener Institute in Potsdam, Germany, from 4-6 March 2002. The relevance of this workshop to the Assessment is related to the fact that the two chemical, ozone-depletion processes about which there is most confidence are the high-altitude and polar-ozone losses, together with the subsequent impact on mid latitudes. About seventy scientists attended the workshop (see report by M. Rex *et al.*, SPARC Newsletter N° 19, 2002).

SPARC Aerosol Assessment

Aerosol in the upper troposphere/lower stratosphere (UT/LS) can have a significant impact on climate through

radiative effects and on stratospheric chemistry, particularly on ozone. Accounting for aerosol effects properly is a key component of modelling climate/chemistry effects properly. The SPARC Assessment of Stratospheric Aerosol Properties (ASAP) is being led by L. Thomason and T. Peter. Its status was presented at the SSG by T. Peter. The focus of this initiative is to develop the scientific understanding of UT/LS aerosol and critically consider available aerosol measurements.

The assessment was initiated with a workshop in Paris, France, on November 4-6, 2001. Five project areas were identified namely: aerosol processes, precursor gases, aerosol record, trend analysis, and modelling. The assessment is underway. T. Peter presented the state of the five chapters.

An intermediate result of the work would be a 20-year long, gap-free higher spatial, temporal and spectral resolution data set. It will be available at the SPARC Data Centre.

The work was hampered by the sparseness of stratospheric profile measurements of OCS and SO₂. The authors had little confidence in source gas distributions. An open question was the quality of model transport. Nevertheless, the study was progressing at a good pace and the report draft should be sent out for review in August 2003 and the report would be ready for publication in January 2004.

Indices for Antarctic ozone depletion

This agenda item was presented by D. Karoly and M. Proffitt. At the SPARC SSG meeting in November 2001, there was discussion on the need to assess the different indicators used to describe the interannual variability of the size, intensity and duration of the Antarctic ozone hole. The aim was to develop small set of agreed indices that could be used to describe the ozone hole variability and its expected future recovery. There was a similar discussion during the preparation of the current WMO/UNEP ozone assessment report. At the SPARC SSG meeting of 2001, D. Karoly agreed to co-ordinate a small working group that would undertake this project.

M. Proffitt of the WMO has prepared a list of possible indicators. This list is not comprehensive, but gives an idea of some different indices that are being used at present. It would be desirable to intercompare groups of the indica-

tors with other indices and to decide on a smaller set of agreed indices of key aspects of the ozone hole such as size (area), intensity (mass deficit, minimum column ozone, etc.) and duration (date of break-up). A short paper in a refereed journal will be produced. The exceptional case of the winter Antarctic 2002 should be included in this article.

The agreed participants include D. Karoly (Australia), M. Proffitt (WMO), G. Bodecker (New Zealand), V. Fioletov (Canada), P. Newman (USA), W. Randel (USA), and O. Uchino (Japan). The draft manuscript including comparisons of groups of indices and recommended set of key indices should be ready for June 2003.

Stratospheric processes

Gravity Wave processes and their parameterisation

K. Hamilton reported on the SPARC Gravity Wave (GW) initiative. It had two main goals: to produce a global climatology of the GW field in the middle atmosphere using high-resolution radiosonde observations, and to improve the parameterisation of GW processes in climate models.

The meridional and seasonal dependence of the potential energy associated with GW in the lower stratosphere was determined using high-resolution data. Participants from 13 countries are involved. The results will be published in a joint article and the data set will be available through the SPARC Data Centre.

A workshop on Darwin Experiment organised by K. Hamilton was to be held in Honolulu, Hawaii, on 3-5 December 2002. The analysis of DAWEX data will likely span 2002-2003. They expect most papers resulting from DAWEX (including an overview paper) to be submitted by the end of 2003. Then the GW initiative should continue to be involved in planning for a much larger field experiment (ETCE) to study effects of Hector convection in 2005 or later.

Future efforts will focus on reviewing existing data and encouraging appropriate new observational and modelling projects to characterise the spectrum of GW momentum fluxes, including its geographical and seasonal dependence and its short-term intermittence. The aim will be to distil the available observational data and limited-area model

results to provide as much guidance as possible for the formulation of source specifications and saturation mechanisms for parameterisation schemes. The GW initiative will concentrate on this aspect for the next 2 years, while leaving the main focus of GW parameterisation to GRIPS.

The SSG confirmed its agreement with **K. Hamilton** plans and proposals, but suggested a sunset for this activity in 2 years from now. In particular, the session agreed that there was a need to hold a fairly large (about 70 participants) Chapman Conference in 2003, which would initiate a general discussion of GW parameterisation issues.

In relationship with the detection of high resolution GW, **F. Vial** was invited to present the status of the VORCORE ("vortex core") Experiment. The experiment will allow the study of the stratospheric Antarctic polar vortex core at the end of winter, when it is well isolated, up to its final breakdown. Together with VOREGGE this experiment represents a part of the STRATEOLE experiment. STRATEOLE goal is a study of the dynamics of the stratospheric Antarctic polar vortex, the transport of minor constituents and its interaction with ozone chemistry in late winter and spring. The main element of the STRATEOLE observing system is a set of small superpressurised balloons (SPB) (few hundred cubic meters) drifting for long duration flights (months) at two different constant density levels (about 50 and 70 hPa). Balloons are equipped with lightweight (10-20 kg) instrumented gondolas.

In the course of VORCORE, 20 SPB will be launched by CNES from McMurdo (166.37°E, 77.51°S) during September - December 2004. The balloons will fly for about two-three months at two different constant density levels of about 50 hPa (13 balloons) and 70 hPa (7 balloons). The data will lead to a better understanding of the vortex core dynamics. It will make it possible to obtain estimates of 2-D turbulence (dispersion rates), evaluate intensity of subsidence inside the vortex core, derive infrared radiation budget and study vertical fluxes of energy, detect sources of Antarctic GW, which was observed in the vortex. It is hoped that the Envisat observations will complement the data set.

The SSG expressed great interest in the prospects of this experiment. A thought was also expressed that a similar (in scope) experiment in the equatorial zone would be very valuable in a 5-year time frame.

Dynamic coupling of the stratosphere and troposphere

M. Baldwin presented recent results on the coupling between the stratosphere and the troposphere. The Northern Annular Mode (NAM) patterns are the leading empirical orthogonal functions (EOF) of low-frequency geopotential height variability. This mode patterns exhibited marked similarity over the whole height range from Earth's surface to more than 50 kilometres. **M. Baldwin** showed evidence of the apparent downward propagation of anomalies from the stratosphere to the troposphere, implying that knowledge of the state of the Arctic Oscillation AO in the stratosphere could increase predictive skill for the troposphere.

The analysis of the composites of weak and strong vortex regimes revealed that surface pressure anomalies after stratospheric events look like the AO signatures. Examination of AO persistence in winter and summer showed that winter signatures of the AO were more persistent. Similar behaviour was characteristic for NAM in the stratosphere and could be traced in the tropospheric NAM. This apparent influence of the stratosphere on the troposphere could be a factor in increasing the predictive skill of atmospheric GCM. For example, the UK Meteorological Office (UKMO) Unified Model gained additional skill at forecast ranges from 5 to 30 days by taking into account stratospheric layers (Norton, 2002). These results indicated a possibility of using AO indices and indices of annual modes for long-range atmospheric predictions of NAM (10-40 days during wintertime). The lowermost stratosphere happened to be the best predictor of the future (surface) AO. It was also mentioned that observations above 10 hPa would be useful to know the precursor.

The tropospheric Southern Annual Mode (SAM) was found to be most persistent during November-December, when the stratospheric polar vortex broke down, not during midwinter.

Numerical studies of trends of AO in the stratosphere in response to greenhouse gas increase remain contradictory. Some models (e.g., Shindell *et al.*, 1999) predict that increasing greenhouse gases will result in a stronger, colder stratospheric polar vortex—and a large positive AO trend. Other models (e.g., Gray, Manzini) pre-

dict that increased tropospheric wave driving will result in a warmer, weaker vortex—and only a small positive AO trend. These contradictions should be addressed through such SPARC initiatives as GRIPS.

In conclusion, **M. Baldwin** posed a series of questions which will be the focus of attention at a workshop "The Role of the Stratosphere in Tropospheric Climate", which is being organised in Whistler, British Columbia, Canada, on 29 April to 2 May, 2003. More than 60 scientists and students are expected to participate. Funding was requested from SPARC, NASA, ESA, NSF, NOAA, NASDA, and RPI, to cover travel and meeting costs.

M. Geller pointed out that the SPARC/WGNE project on stratospheric predictability should have to be extended to include tropospheric predictability. The SSG agreed that the focus on the role of stratosphere in tropospheric deterministic forecast would be the desired focus of the SPARC/WGNE initiative. At the same time, the role of stratosphere in statistical dynamic climate prediction on a variety of time scales was also considered a relevant theme. The group recommended that these thoughts were discussed at the workshop in Whistler and supported the idea of organising such a workshop.

Upper Troposphere / Lower Stratosphere processes (UT/LS)

T. Shepherd started his presentation of this agenda item by stating that it was the lowermost stratosphere (i.e. heights below 20 km) where the ozone variability occurred. The decreases of ozone content are observed mostly in late spring/summer and accompany the ozone build up in winter/early spring. Dynamical variability was certainly playing a role in this pattern, which was confirmed by the fact that ozone variations were associated with AO changes and variations in the tropopause height (H_{trop}). He emphasised that the causality of these relationships was unclear, as the H_{trop} may be only a proxy for something else. The anti-correlation of H_{trop} changes and ozone changes up to 20 km is not understood, and furthermore the long-term ozone changes below 20 km is not yet very well known. This indicates a need to focus studies on the mechanisms governing relations between ozone, dynamics and radiation in the lowermost stratosphere.

Participants in the subsequent discussion agreed with **T. Shepherd's** thoughts and stressed that to understand processes in the UT/LS an integrated approach was needed because chemical, radiative and dynamical processes there were strongly coupled. Cloud microphysics in the UT/LS also plays an important role.

Chemistry/climate interactions. SPARC-IGAC initiative

A.R. Ravishankara introduced this agenda item by reviewing most important climate forcing agents: greenhouse gases, ozone, and aerosols. Through the review of existing issues, **A.R. Ravishankara** substantiated a need for a joint program between SPARC and the International Global Atmospheric Chemistry (IGAC) Project of the IGBP. This joint activity was felt as a natural progression of previous activities, which were conducted by practically the same pool of scientists based on nearly the same pool of resources.

Previous discussions (including a meeting at ETH, Zurich, hosted by **T. Peter** in July 2002) indicated the major topics and most significant research interests for this joint activity. They are both described in the report of the Zurich meeting in the SPARC Newsletter N° 19, 2002.

The IGAC community was given an opportunity to look at these issues and topics and decide on their interests at the IGAC symposium in Crete in September 2002, where **A.R. Ravishankara** and **A. O'Neill** were requested to make a presentation (see report in this issue).

To proceed further in the concrete planning, a joint workshop is being organised by **A.R. Ravishankara** and **A. O'Neill** of SPARC and by **Shaw Liu** and **U. Platt** of IGAC. The workshop will take place in Giens, France, on 2-6 April 2003. **C. Granier** and the SPARC Office will act as the local host. SPARC will co-sponsor the workshop jointly with IGAC.

Shaw Liu was given the floor. He briefly reviewed the IGAC meeting in Crete on 18-25 September 2002. He reported that the idea of having a joint initiative created enthusiasm and about 100 participants attended the evening SPARC/IGAC meeting. More than 20 proposals were put forward as potential joint research topics.

He also presented the new structure of IGAC (IGAC-II). It will be organised around a set of scientific questions.

The limited lifetime tasks will focus on specific scientific question relevant to IGAC and IGBP, will include a timetable of research activities with a completion date, develop a quality assurance and data plans, which will include public access to data, provide a brief annual summary to the IGAC SSC, and have a peer-reviewed manuscript as a final product. IGAC nominated **K. Law**, **D. Parrish** and **Shaw Liu** as liaison points for SPARC. Much was expected from the joint SPARC/IGAC workshop on chemistry and climate in Giens.

As a result of the subsequent discussions the following issues of potentially highest interest for SPARC were agreed:

- The role of convection (both deep and warm) in controlling UT/LS water vapour abundance and redistribution of chemical constituents (with IGAC).
- Tropical tropopause layer and climate/chemistry interactions.
- A need to achieve greater confidence in projecting future polar ozone.
- The role of UT/LS aerosol and clouds in chemistry, climate, and their interactions (with IGAC).
- A need for relevant laboratory studies (with IGAC).
- Stratosphere/troposphere exchange (with IGAC).

Interaction with other programmes and activities

IGAC

The interactions with IGAC have been described just above. **Shaw Liu**, representing IGAC, expressed enthusiasm of the project on climate/chemistry interactions with regard the collaboration with SPARC. Other areas of constant interest for IGAC are air pollution and air quality.

SCOSTEP

Besides the joint activity on upper atmospheric trend mentioned above, a need of co-operation with SCOSTEP was again emphasised, particularly with its CAWSES project. SCOSTEP has initiated a project entitled CAWSES (Climate and Weather of the Sun-Earth System), which is expected to run from 2004 to 2008 or so. The project will deal with mechanisms governing solar influences on climate, foster a scientific approach to understanding the short term ("Space Weather") and long term ("Space Climate") variability of the integrated solar-terrestrial environment.

Specifically attention will be paid to mechanisms, through which the solar variability influences the atmosphere.

CAWSES is expected to provide a forum to bring together the international solar-terrestrial science community to help define future programs. It will contribute solar-terrestrial information to the Global Change community. It also plans to review the quality of solar-terrestrial databases and derived information and improve metadata for solar-terrestrial products so that they meet scientific community needs.

The presentation of CAWSES created interest among the SSG session participants. It was felt that co-operation between SPARC and CAWSES would be very desirable. SPARC should inform CAWSES and SCOSTEP about what it is doing. It was also felt that there was no shortage of links between SCOSTEP and SPARC because one of the present co-chairs of the SPARC SSG, **M. Geller**, was at the same time the President of SCOSTEP.

WMO Global Atmospheric Watch (GAW)

M. Proffitt of the WMO presented the current state of the related activities of the WMO/GAW. The system is based on a number of so-called "Dobson Centres" ensuring continuing maintenance and calibration of ozone measurement instruments (calibration has to be performed every 3-4 years). Such centres existed in Europe (Germany, Czech Republic), South America (Argentina), Africa (South Africa), Asia (Japan), Southwest Pacific (Australia). The World Calibration Centre is located in the USA. The World Training Centre is located in Czech Republic. The GAW ozone network was based on 119 Dobson stations. The GAW also maintained a list of regularly reporting ozonesonde stations. More than 50 stations are operational. Important information was being gathered from several satellites systems, one of the most valuable sources being Total Ozone Mass Spectrometer. The system operationally monitors the global ozone. The WMO uses every opportunity to expand the system and maintain its performance (see for more information SPARC Newsletter N° 18, p 24-27).

Network for the Detection of Stratospheric Change (NDSC)

M. Kurylo provided the update of the NDSC, which had been in operation for more than 10 years. A symposium

was held in Arcachon, France in September of 2001 to mark this anniversary (see report in SPARC Newsletter N° 19, p 30). The NDSC working groups are involved in the following activities: lidar measurements, microwave techniques, sounding, Dobson/Brewer instruments, theory and analysis, UV and visible remote sensing techniques, spectral UV techniques and Fourier Transform IR spectrometry. New developments were related to the inclusion of water vapour and air temperature in data sets. The network considers SPARC as a major customer.

COSPAR (Committee on Space Research)

J. Gille submitted a report on the SPARC Session of the 34th COSPAR Scientific Assembly (the 2nd World Space Congress) to the SSG session. The Symposium "Climate change processes in the stratosphere and at the tropopause" was sponsored by SPARC and NASA. The meeting was very successful and well attended. Initial results from the Envisat sensors, from SAGE III and a preview of AURA sensors were presented. A review was conducted of long-term changes in the stratosphere. Vertical transports of atmospheric constituents and trace gas transports at the tropopause were discussed as well.

IGOS (Integrated Global Observing Strategy) / IGACO (Integrated Global Atmospheric Chemistry Observations)

M.-L. Chanin informed the meeting of the situation with the IGACO Project, a new component of IGOS. This theme builds on the CEOS ozone Project which delivered a WMO/CEOS report on the strategy for integrating satellite and ground-based observations for ozone (see report in SPARC Newsletter N° 16, p 22-25), but extends its scope to atmospheric composition measurements of all climate relevant species. The project is in its phase of definition and **M.-L. Chanin** who was member of the IGACO team and attended the first two meetings asked to be replaced. It was decided that **T. Peter** and **C. Granier** will represent SPARC in this project starting in 2003.

Other projects of WCRP

In the subsequent discussion the remark was made that SPARC needed not only extended co-operation with projects and programmes outside

WCRP. Closer ties are needed with CLIVAR on the issues of predictability, GEWEX on studies of water vapour, hydrological cycle, and radiation, and ACSYS and CliC on utilisation of results of reanalysis in polar regions. It was recommended that SPARC findings should be presented to the WCRP WGSIP (Working Group on Seasonal and Interannual Prediction). Interaction with WGNE on data assimilation was considered essential.

European Space Agency (ESA)

E.-A. Herland gave a detailed overview of the ESA Earth observation programmes. He started the review with the Living Planet Programme Earth Explorer core missions (GOCE; Gravity field and steady-state ocean circulation and ADM-Aeolus: Atmospheric Dynamics) and opportunity missions (Cryosat and SMOS: Soil Moisture and Ocean Salinity); and then presented operational and planned missions of the Earth Watch Programme (GMES: Global Monitoring for Environment and Security, first and second generations of Meteosat, MetOp: polar orbiting operational meteorological satellite, ERS 1 and 2: Earth Remote Sensing satellites of 1991 and 1995, and Envisat). Some of the missions were operated or developed jointly with other agencies, e.g. NASDA. Envisat successful operation is of major relevance to SPARC (see first Envisat results by **T. Wehr et al.**, in SPARC Newsletter N° 19).

With current ESA plans SPARC can count on having in the future cloud, aerosol and radiation measurements leading to heat flux estimates at the top of atmosphere with an accuracy of the order of 10 W/m². ESA considers WCRP one of the major customers also affecting future operational requirements. Recognising the role of the WCRP and SPARC in particular, ESA was trying to provide funding for a post-doctoral position in the SPARC office.

The review created deep interest among the participants. The offer of a postdoctoral fellowship was accepted by the SPARC SSG with great enthusiasm.

European Commission

G. Amanatidis presented to the session an impressive review of corresponding research supported by the European Commission, particularly under the 6th Framework Programme

(FP6), which is expected to cover 2002-2006. The research funding was subdivided into three "pillars" covering sustainable energy systems, sustainable surface transport, and global change and ecosystems. A call for applications for the Integrated Projects or Network of Excellence was expected on 17 December 2002, with closure data of 8 April 2003. Information on FP6 is located at: <http://europa.eu.int/comm/research/nfp.html>. The EU research web site can be found at: <http://www.cordis.lu/en/home.html>. Current European stratospheric research related to SPARC is extensive. The funding going into the stratosphere is significant with 31 projects in the 5th Framework Programme, 23 of them being directly linked to stratospheric issues. They were closely associated with major national programmes and related satellite observations. Five research clusters are covering UV radiation, aviation impact in the UT/LS, global atmospheric measurements, ozone/climate interactions, stratospheric ozone loss. A sound basis for planning is created by past assessments of European Research in the stratosphere (1997, 2001), major field experiments such as (EASOE, SESAME, THESEO) and regular European Symposia on stratospheric ozone.

In conclusion, **G. Amanatidis** presented a programme "Validation of International Satellites and study of Ozone Loss" (VINTERSOL), which is described in more detail in this issue. A major report on Ozone-Climate interaction is being prepared in Europe under the editorship of **I. Isaksen**. Several meetings are expected in 2003.

The presentation of **G. Amanatidis** created considerable interest. A need of commitments for long-term observations was expressed in the subsequent discussion.

National Aeronautics and Space Administration (NASA)

Ph. Decola presented relevant activities of NASA. His presentation started with a brief review of the Stratospheric Aerosol and Gas Experiment (SAGE III) onboard Meteor-3M satellite. The launch of Aura is expected at the beginning of 2004. The mission will measure ozone, aerosols, and several key atmospheric constituents. The objective is a study of the chemistry and dynamics of UT/LS in the height

range of 0-30 km. CloudSAT will carry radar to provide data on clouds. The launch is expected at the end of April 2004. Other missions and activities of interest for SPARC included: ozone mapping and profiler suite (OMPS), Integrated Atmospheric Chemistry Mission (2003-2010), tropical Composition and Climate Coupling Mission, CALIPSO (aerosol and cloud properties), and several others.

National Space Development Agency of Japan (NASDA)

This item was presented by **M. Suzuki**. The Earth Observation Research Centre (EORC) of NASDA was preparing for launch of the Advanced Earth Observing Satellite (ADEOS-II). Among other sensors it carries ILAS (Improved Atmospheric Limb Spectrometer), which monitors high altitude atmospheric ozone and several species related to ozone depletion.

Other sensors/missions of interest included GCOM-A1/ODUS (Ozone Dynamics Ultraviolet Spectrometer), Jem/SMILES (Superconducting Submillimetre-wave Limb-Emission Sounder). These missions are expected to take place in 2007-2008. The EORC also was conducting a Global Atmospheric Chemistry Experiment.

A reorganisation of several agencies involved in space research in Japan was expected.

Other areas of collaboration

V. Yushkov presented plans of an UT/LS water vapour validation project initiated by the Central Aerological Observatory (CAO) of Russia. The description of the proposed campaigns is given in this issue of the Newsletter.

Co-ordination of international stratospheric field campaigns

Determining the wind fields in the equatorial stratosphere on a global basis is a challenging problem due to the scarcity of *in situ* observations and the limited value of satellite-derived temperature in constraining the wind field at low latitudes. Current stratospheric meteorological analyses display much more significant deficiencies in the equatorial region than elsewhere on the globe. Recent developments in the technology of long-lived constant level balloons and new satellite instruments to be deployed in the next few years will allow for more complete observations of the stratospheric wind field. By the end of this

decade there will be a need for extensive validation field campaigns with a focus on low-latitude stratospheric wind. The SPARC SSG sees a need for international co-ordination of such campaigns that should include conventional radiosonde observations and remote sensing observations, and also co-ordination of field campaigns with on-going data assimilation efforts. It is the intention of the SPARC SSG to initiate planning for international co-ordination of such campaigns.

Future SPARC activities and directions

A. O'Neill led this discussion. He felt that, first of all, SPARC must be outward looking. The group agreed that a new structure for SPARC was indeed required and that the three first "pillars", i.e. stratospheric indicators, processes, modelling should be modified to represent better the new goals.

After a long and active discussion, the session established three basic research themes, which contained fundamental questions each of them being of interest to the "outside" world. The themes and questions are as follows:

1. Stratospheric chemistry and climate:

- How will stratospheric ozone and other constituents evolve?
- How will changes in stratospheric composition affect climate?
- What are the links between changes in stratospheric ozone, UV radiation and tropospheric chemistry?

2. Stratosphere-troposphere coupling

- What is the role of dynamical and radiative coupling from the stratosphere in extended range tropospheric weather forecasting?
- What is the role of the dynamical and radiative coupling in determining long-term trends in tropospheric climate?
- By what mechanisms does the troposphere and stratosphere act as a coupled system?

3. Detection and attribution of past stratospheric changes

- What are the past changes and variations in the stratosphere?
- How well we can explain past changes in terms of natural and anthropogenic effects?

A need for an update of the SPARC brochure and of the SPARC Web site in the light of these discussions will be needed in a near future

The SPARC Office

The SPARC office continued its regular activities in 2002 (compiling and editing SPARC Newsletters, updating the SPARC mailing list, maintaining contacts with the SPARC community of scientists, organising various SPARC meetings, maintaining the SPARC website, preparation of SPARC reports for publication).

The session applauded the director and the office staff, **C. Michaut** and **Y. Koshelkov** for their excellent inter-session support. Continuation of the office operation in France after the retirement of the director, **M.-L. Chanin**, depended on the availability of funding, which has been provided by CNES and CNRS. Developments on this issue should be monitored closely.

The SPARC Data Centre

M. Geller presented the work of the centre. After the tragic death of its chief scientist, **P. Udelhofen** on 17 May 2002 who had been in charge of the centre operations for about 3 years, **X. Zhou** continued support to the centre since August 2002. NASA supports the SPARC Data Centre. New updates of the centre holdings included quantum yields and some USA high-resolution radiosounding data (<http://www.sparc.sunysb.edu>). The centre administrator was compiling a new user list and an update of the operating system of the centre computer was taking place. A link to the WCRP Initiative on Data (WIND) was mentioned as a possible new development for the centre.

Next SSG Meeting

U. Schmidt who was unfortunately unable to attend the 10th SSG session in Kyoto kindly extended an invitation for the next session. This invitation was accepted with appreciation. The 11th session of the SPARC SSG will take place in Frankfurt on 22-25 September 2003.

SPARC General Assembly in 2004

N. McFarlane described facilities available for the SPARC General Assembly to be held in Victoria (BC), Canada, in 2004. His talk included estimates of financial resources needed to hold the session as well as expected contributions by sponsors. Due to a date conflict with the next COSPAR Assembly (18-25 July, Paris,

France), **N. McFarlane** was asked to negotiate alternative dates for the Assembly. It was then planned to hold the assembly on 1-6 August 2004 with subsequent SSG meeting on 8-11 August 2004. The programme committee will be run by **T. Shepherd** and **A.R. Ravishankara**.

SPARC SSG composition

Having concluded the presentations, the SSG members discussed the future composition of the group. Since the term of service for **M. Geller** expired, he stepped down from the group and from the position of the SSG co-chair. The group unanimously elected **A.R. Ravishankara** as a co-chair. The group deeply thanked **M. Geller** for his long, devoted and very productive service for SPARC in various capacities including the one of SSG co-chair. **D. Karoly**, another member of the SSG is stepping down. He was warmly thanked for his contribution during his mandate. Proposals of 2 new members will be submitted at the next JSC.

Related Japanese Research Programmes

On the last day of the SSG session, several leading Japanese scientists gave a review of national research activities in areas close to SPARC. **S. Yoden** opened the series of talks and introduced the audience into the organisation of stratospheric research in Japan. A special issue of the *Journal of the Meteorological Society of Japan* (Vol. 80, N° 4B, September 2002) was devoted to most recent findings in the areas of stratosphere/troposphere coupling.

S. Fukao reported on an Equatorial Atmosphere Radar, which was

installed in West Sumatra of the Republic of Indonesia in March 2001. The data cover the height range of 2-20 km and include wind speeds. The results are instrumental for studying coupling processes in the equatorial atmosphere and provide continuous record of the tropopause record.

T. Tsuda demonstrated the concept of observing the humidity in the lower troposphere, temperature in the stratosphere, electron density in the ionosphere using the occulted GPS radio signals. The system is intended for the Equatorial Atmosphere Research Satellite, which is planned for launch by Brazil, Canada, Japan and USA in 2006. The technique produce high resolution data at low latitudes, which are useful for studying dynamical coupling processes in the equatorial region.

The talk by **J. Inatani** was on superconducting submillimetre-wave limb emission sounder (ISS-JEM-SMILES). It is based on a research project "Space Superconductivity" conducted by NASDA in 1998-1995. The system permits monitoring of the following species: ozone, ozone-isotopes, HCl, ClO, HO₂, H₂O₂, HOCl, BrO, HNO₃, CH₃CN, SO₂. The latitude coverage is approximately 38°S-65°N. Daily mapping is possible. The results are characterised by high sensitivity to thermal emissions of atmospheric constituents. The system is capable of measuring key species responsible for atmospheric ozone depletion. An early experiment was required to test the technique.

Two presentations by **H. Akimoto** and **T. Matsuno** of the Frontier Research System for Global Change were devoted to an impressive global

change modelling facility, which was created around the Earth Simulator, the most powerful scientific computer in the world. The architecture of the Earth Simulator was described. Unprecedented performance of the supercomputer enabled scientists at the Earth Simulator Centre to run a GCM with the highest resolution. Several areas of the modelling system development were presented. Some of the results shown in these two presentations can be accessed at: www.es.jamstec.go.jp/esc/eng/index.html (in English).

The status and results of SOWER (Soundings of Ozone and Water in the Equatorial/Pacific Mission) were given by **M. Shiotani**.

K. Sato concluded the presentation session with a talk on the Program of the Antarctic Syowa Mesosphere - Stratosphere - Troposphere / Incoherent Scatter Radar (PANSY). Such a VHF monostatic Doppler radar would contribute to studies of relevance to SPARC Science.

The SPARC SSG strongly supported the idea of the establishment of such a radar at the Japanese Antarctic Station, Syowa, and welcomed the provision of data from the radar to the international scientific community.

9

Message of Marvin Geller to the SPARC Community

I have had the very great pleasure of serving as the co-chair of the SPARC SSG since SPARC's inception in 1992. It was truly a great pleasure to partner with my founding SPARC SSG co-chair, **Marie-Lise Chanin** for whom I have the greatest respect as both a scientist and a marvelous human being.

It was also a great pleasure to interact with the remarkably talented group of scientists who were responsible for

SPARC's great success during its first decade. I want to thank you all for making SPARC, Marie-Lise, and me look so good. I've greatly enjoyed my interactions with the WCRP during this time. Here, I must particularly mention **Roger Newson**, to whom SPARC owes so much. I want to wish the best of luck to **Alan O'Neill** and his co-chair, who has yet to be named by the WCRP in their activities. I'm sure they will enjoy the experience

just as much as I have. I will no longer be SPARC co-chair, but I still plan to be active in supporting SPARC through its Data Centre and hopefully through my scientific contributions.

I have great confidence that SPARC will be at least as successful in its second decade as it was in its first.

● Marvin Geller

The SPARC Intercomparison of Middle Atmosphere Climatologies

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SPARC has from its outset been concerned with "Stratospheric Indicators of Climate Change," "Stratospheric Processes," and "Troposphere/Stratosphere Modelling." The SPARC project GRIPS (GCM Reality Intercomparison Project) has focused on comparing troposphere/stratosphere general circulation models (GCMs) with one another, both in terms of their technical formulations and in their results. Of course, another aspect of GRIPS is to examine how well model results compare to observations. Direct model/data comparisons are not so straightforward, however. For instance, the stratosphere displays a great deal of interannual variability, so that model-data comparisons necessarily include statistics of both means and variances over comparable time periods. Additionally, stratospheric data are obtained from complicated inversions of satellite-derived radiance measurements, from direct but sparse balloon or rocket measurements, from time continuous but geographically sparse ground-based remote sensing instruments, and finally from analysis of stratospheric measurements either by statistical techniques or from data assimilation methods. The climatologies derived by these different methods do not agree in all respects. Finally, the entire concept of stratospheric trends means that stratospheric climatology is itself time varying.

The SPARC Reference Climatology Group was established to update and evaluate existing middle atmosphere climatologies for use in GRIPS, and in other SPARC activities. Rather than create a single new "super climatology," it was decided that a valuable contribution would be to (1) compile existing climatologies and make them easily available to the research community, and (2) carefully compare and evaluate the existing climatologies. The SPARC Data Center was estab-

lished (in part) as a response to item (1), and an extensive Technical Report of intercomparisons (SPARC Report No 3, 2002) was compiled in response to item (2). SPARC (2002) includes detailed intercomparisons of a few basic and derived quantities, such as temperatures, zonal winds, and eddy flux statistics. Special attention is focused on tropical winds and temperatures, where large differences exist among separate analyses. SPARC (2002) also includes comparisons between the global climatologies and historical rocketsonde temperature and wind measurements, and also with more recent lidar temperature data. These comparisons highlight differences and uncertainties in contemporary middle atmosphere data sets, and allow biases in particular analyses to be isolated. This article presents a brief summary and some examples of the intercomparisons in SPARC (2002); for further details the reader is referred to the full report.

Background

Current GCM simulations routinely extend into the middle atmosphere (50 km or higher), and require observational data sets for validation (e.g., Pawson *et al.*, 2000). A number of middle atmosphere climatologies have been developed in the research community over the years, based on a variety of data sources and analysis techniques. The earliest comprehensive climatologies for the middle atmosphere were the 1964 and 1972 COSPAR reference atmospheres (CIRA), which were based largely on interpolation of single station balloon and rocket data. An updated version of CIRA in 1986 included early satellite observations of the stratosphere and mesosphere and has served as a community standard since that time. Around 1979, daily meteorological analyses with significant stratospheric

coverage that included operational satellite temperature soundings began, and more recently sophisticated model-based data assimilation schemes began to produce stratospheric analyses. These analyses (supplemented in the 1990's by extensive retrospective reanalyses) have served as the basis for some more recent middle atmosphere climatologies. Also, satellite observations from the Upper Atmosphere Research Satellite (UARS - launched in 1991 and continuing to operate in 2002) have provided additional climatological data sets for the middle atmosphere. An example of climatological zonal wind data (extending through the mesosphere) derived from UARS measurements is shown in Figure 1.

Data Sets

Details of the various stratospheric analyses included in the intercomparisons are described at length in SPARC (2002). Table 1 (p. 15) provides a summary and definition of acronyms used throughout this article. The simplest stratospheric analyses provide global or hemispheric fields based on hand-drawn analyses (FUB) or objective analysis gridding techniques (CPC and UKTOVS). More sophisticated analyses can be derived by the use of numerical forecast models to predict first-guess fields, and incorporate observations by optimal data assimilation (UKMO, NCEP, ERA15 and ERA40 data). Most of the analyses discussed below are based on very similar radiosonde and satellite data, and so the differences revealed in our comparisons highlight the sensitivity of the final statistics to details of the data usage and analysis techniques.

The data intercomparisons here are based on a monthly climatology derived for the time period January 1992-December 1997, which gives direct overlap of the UKMO, CPC,

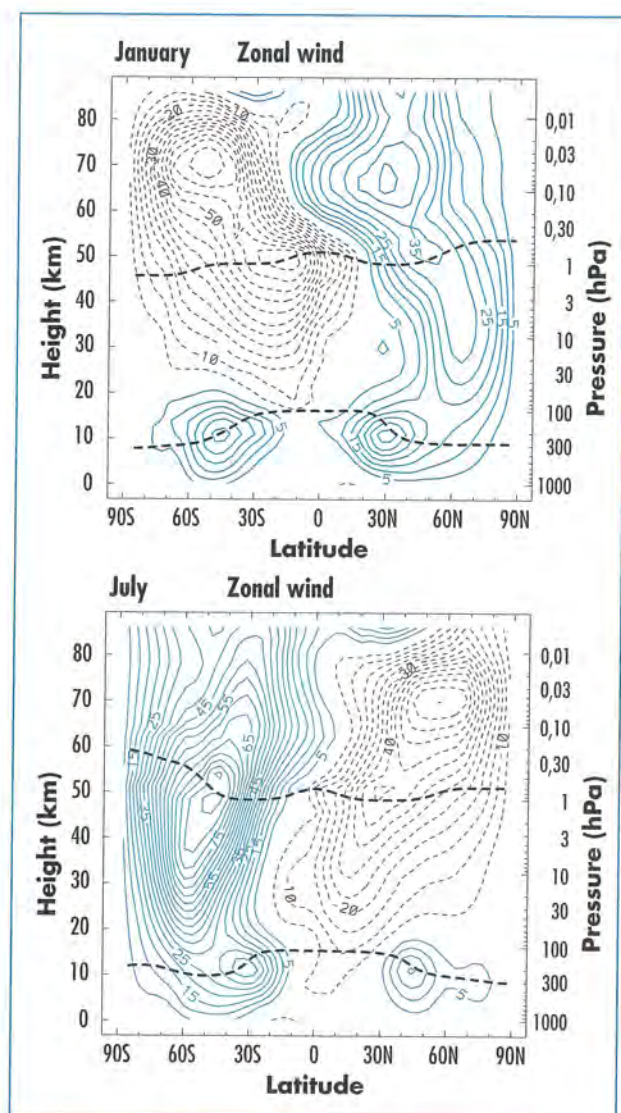


Figure 1. Climatological zonal mean zonal winds for January (top) and July (bottom), derived from the URAP data set (contour interval 5 m/s, with zero contours omitted). The heavy dashed lines denote the tropopause (taken from NCEP reanalyses) and stratopause (defined by the local temperature maximum near 50 km).

NCEP and ERA40 reanalysis, and FUB fields. The UKTOVS record is slightly shorter (to April 1997). The ERA15 reanalysis has a much shorter record during this 1992-1997 period (January 1992-December 1993). We include comparisons for these data by calculating differences only over this 1992-1993 record, rather than the full 6 years 1992-1997. We also include comparisons with the CIRA86 climatology, although it should be kept in mind that these data are derived from a very different time period (covering the 1960's-1970's).

Two independent data sets are also included in the SPARC (2002) comparisons, namely historical rocketsonde wind and temperature measurements, and lidar temperature data. Measurements from meteorological rockets provide *in situ* wind and temperature data covering ~ 25-85 km. Rocketsonde observations span the 1960's - 1990's, but the majority of data occur during the 1970's - 1980's. The climatologies here are based on simple monthly averages, derived by binning all of the available observations during 1970-1989. Lidars provide measure-

ments of the vertical temperature profile over ~ 30-75 km based on the Rayleigh lidar technique (Hauchecorne and Chanin, 1980; Keckhut *et al.*, 1993). For the climatological analyses here, we obtained a number of lidar temperature time series (for stations with relatively long records) from the Network for the Detection of Stratospheric Change (NDSC) web site: <http://www.ndsc.ws/>. The individual profiles are binned into monthly samples, using all the lidar observations over 1990-1999.

Results: Temperature

Comparisons of zonal mean temperature climatologies in the lower stratosphere show relatively large differences among analyses over (1) polar regions in winter and spring, and (2) near the tropical tropopause. As an example of the polar differences, Figure 2 compares the seasonal cycle of 50 hPa zonal mean temperature in the Arctic (80°N) from each data set, including a plot showing their respective differences from UKMO analyses (to quantify the relatively small difference values). The CIRA86 data exhibit warm biases by up to ~ 5 K in the Arctic (and ~ 10 K in the Antarctic; not shown here), maximizing during winter-spring in each hemisphere. A large portion of these differences probably reflect true cooling in the polar lower stratosphere between the 1960's and 1990's (e.g., Randel and Wu, 1999; Ramaswamy, 2001). Aside from CIRA86, the other climatologies agree to approximately ± 1 K in the Arctic (and ± 2 K in the Antarctic). Most analyses are colder than UKMO during Arctic winter in Figure 2, suggesting a small warm UKMO bias.

Figure 2. Left panel shows the seasonal variation of 50 hPa zonal mean temperature at 80°N, and the right panels show the corresponding differences from UKMO analyses (i.e., CIRA86-UKMO, etc.).

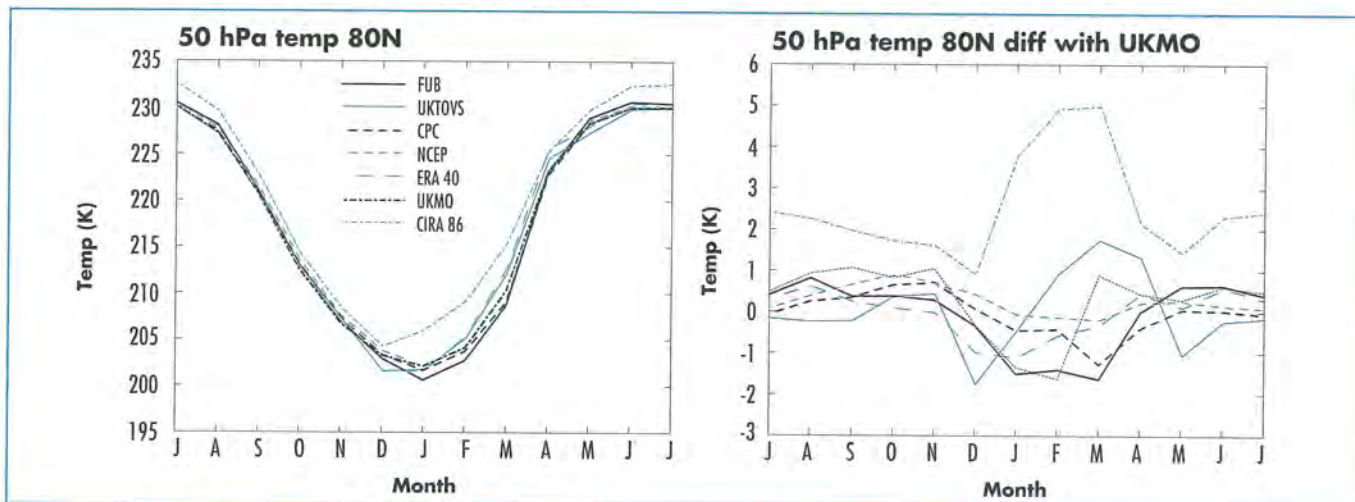


Figure 3. Comparison of the seasonal variation in equatorial zonal mean temperature from available analyses at 100 hPa. The circles show a climatology derived from radiosonde measurements at eight near-equatorial stations (over 5°N-5°S), and the error bars denote plus/minus two sigma uncertainties of the corresponding monthly means.

The seasonal variations of equatorial temperature at 100 hPa derived from each climatological data set are shown in Figure 3. Included in these figures are estimates of monthly temperatures derived for the same 1992-1997 time period from radiosonde measurements at a group of eight near-equatorial stations (within 5° of the equator). The amplitude of the seasonal cycle in temperature is reasonably well captured in most analyses at 100 hPa, but there are clear biases among the data sets. In particular, the ERA15, ERA40 and FUB data are the coldest and agree best with radiosondes (except for FUB during January-March), whereas UKMO, CPC, NCEP and CIRA86 data each have a consistent warm bias of ~ 2-3 K (and UKTOVS is almost 10 K too warm, and not shown in Figure 3).

Figure 4 compares the vertical profile of zonal mean temperature at 30°N in January among all the analyses (up to 80 km), also including results from the

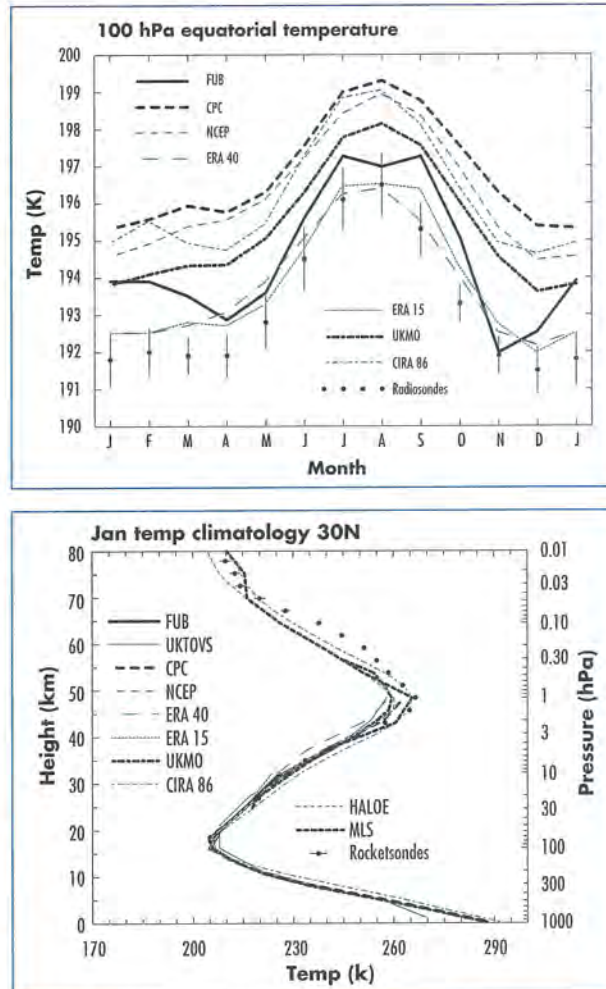


Figure 4. Comparison of January average zonal mean temperature profiles at 30°N. Circles show rocketsonde statistics.

rocketsonde climatology. While the overall profile is similar among the different data sets, there are relatively large differences near the stratopause (near 50 km). The stratopause level can present special problems in analyses, because the temperature maximum it is not captured

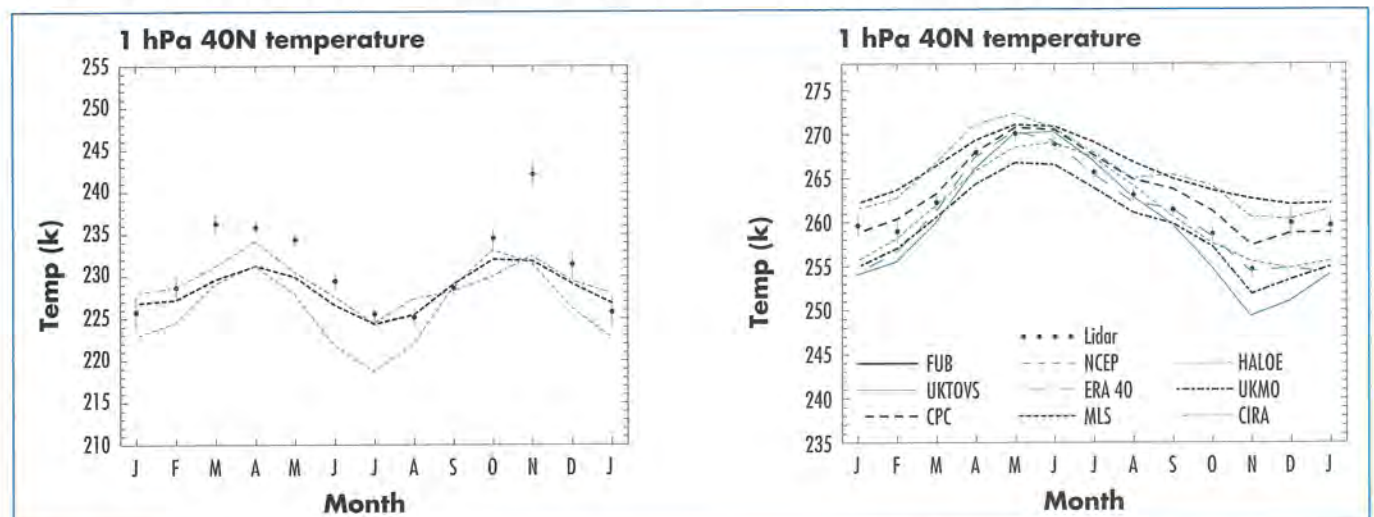
uncertainties in the various analyses near the midlatitude stratopause.

The semi-annual oscillation (SAO) dominates the seasonal variation in equatorial temperatures above the lower stratosphere, and it is useful to

accurately in the satellite thick layer radiance measurements, plus it is near the top of the UKMO forecast/assimilation model. The rocketsondes show good overall agreement in the stratosphere, and in locating the altitude of the stratopause. The rocketsonde temperatures in the mesosphere (~ 50-70 km) are warmer than the HALOE and MLS (and CIRA86) climatologies, and this is a typical feature that is at least partly due to the differing respective time periods.

Lidar temperature measurements from the 1990's are contemporaneous with the global analyses, and offer the most direct comparisons. Figure 5 shows a seasonal comparison of analysed zonal mean temperatures at 40°N for the 1 and 0.1 hPa levels, including results from the lidar climatology (lidar measurements from Table Mountain, OHP, Hohenpeissenberg and Toronto). The lidars fall in the mid-range of analyses at 1 hPa, and exhibit reasonably good agreement at 0.1 hPa (with a strong semi-annual variation). Note that because of the substantial variability evident in the lidars at 1 hPa (even during summer), they do not provide strong guidance in assessing

Figure 5. Comparison of the seasonal variation of lidar temperatures near 40°N with zonal mean analyses, showing results at 1 and 0.1 hPa. Circles denote the lidar means, and error bars the plus/minus two standard error of the monthly means



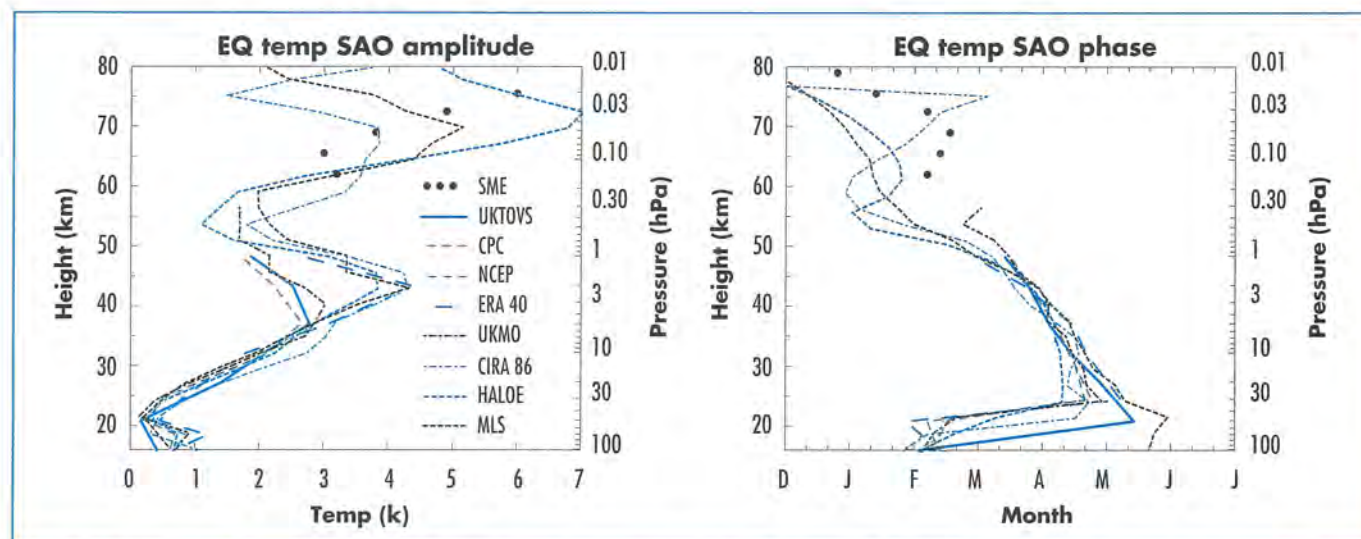
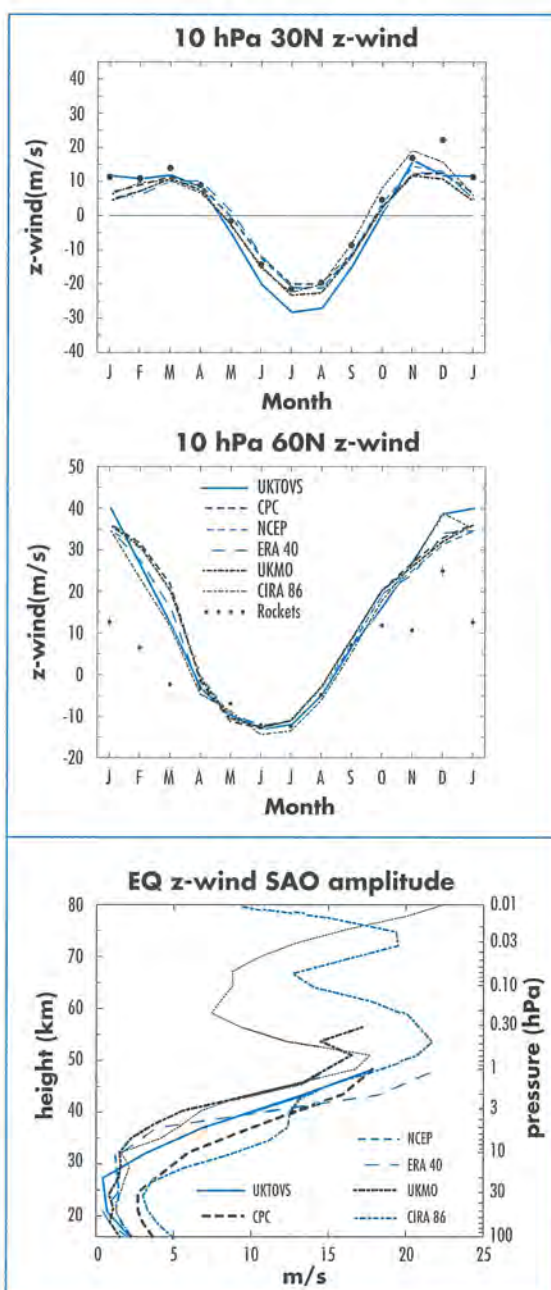


Figure 6. Comparison of the amplitude of the semi-annual oscillation (SAO) in equatorial temperature derived from each data set. The dots show the mesospheric results derived from SME satellite data, taken from Garcia and Clancy (1990).

quantify the SAO amplitude and phase structures derived from the different data sets. The vertical structure of the temperature SAO amplitude is shown in Figure 6, including results from each data set. As well-known from previous analyses (e.g., Hirota, 1980), the temperature SAO has a double peaked structure in altitude, with maxima below the stratopause (~45 km) and mesopause (~70 km), and these maxima are approximately out of phase. The maximum near 45 km has an amplitude of ~4 K in MLS, HALOE, CIRA86 and ERA40 data sets, and substantially weaker amplitude in CPC, UKMO and UKTOVS data. For the maximum near 70 km the CIRA86, MLS and HALOE show a range of amplitudes of ~4-7 K. For further comparison of the upper level peak, the dots in Figure 6 show results derived from Solar Mesosphere Explorer (SME) temperature data for 1982-1986 (taken from Garcia and Clancy, 1990). These SME results show similar amplitude and phases as the other data sets, but don't exhibit an absolute peak near 70 km.

Zonal Winds

Seasonal climatologies of zonal mean zonal winds from the different data sets are compared in Figure 7, showing results at 10 hPa, for latitudes 30°N and 60°N. These comparisons also include results derived from rocketsondes, which provide



direct measurements of zonal winds, and are unique for comparing to winds derived from analyses (given the caveat of differing time periods). The different analysis data sets are in reasonable agreement in Figure 7, and zonal winds agree well over most of the stratosphere outside of the tropics. The rocketsonde data show excellent agreement with analyses at 30°N, while at 60°N there are some systematic differences with rocketsondes during local winter (November-March), with weaker rocketsonde measurements. Given the good agreement with rocketsondes at 30°N (and at other locations), the observed differences at 60°N could be an effect of real (decadal-scale) time changes (with a stronger Arctic polar vortex during the 1990's).

The SAO is a primary component of variability in tropical zonal winds above the lower stratosphere, and Figure 8 compares the vertical amplitude structure of the zonal wind SAO among the different data sets. The zonal wind SAO shows an amplitude maximum near the

▲ Figure 7. Comparison of the seasonal variation of 10 hPa zonal mean zonal winds from different analyses at 30°N (top) and 60°N (bottom), together with results derived from rocketsondes.

◀ Figure 8. Vertical profiles of the zonal wind semi-annual oscillation (SAO) amplitude at the equator derived from each available data set.

stratopause (~ 50 km), with reasonable agreement between various data sets. A second amplitude maximum near the mesopause (~ 80 km) is suggested in URAP and CIRA86 winds, but there are large differences in detail between the two data sets above 50 km.

Figure 9 shows interannual anomalies in equatorial zonal wind at 30 hPa during 1985-1999 derived from the various analyses. The quasi-biennial oscillation (QBO) dominates variability in these time series, and included in Figure 9 are anomalies derived from Singapore radiosonde data, which are a standard reference for the QBO (e.g., Naujokat, 1986). The QBO signal is evident in each analysis, but the amplitude varies strongly between different data (and with altitude). In general the assimilated data sets (UKMO, NCEP, ERA15 and ERA40) have the largest amplitudes, and most closely approach the Singapore data, whereas the balance winds derived from CPC and UKTOVS are much too weak. The strength of the zonal wind QBO in the different data sets is quantified in Figure 10, where the equivalent QBO amplitude at the equator (defined, following Dunkerton and Delisi, 1985, as $\sqrt{2}$ times the rms deviation of deseasonalised anomalies during 1992-1997) is plotted as a function of height. For comparison, Figure 10 also includes the 30 hPa QBO amplitude derived from Singapore radiosonde measurements over pressure levels 70-10 hPa. Overall the ERA40 data exhibit the largest QBO amplitude (in best agreement with the Singapore data), with the ERA15, UKMO and NCEP reanalyses somewhat weaker,

Figure 10. Vertical structure of the equivalent QBO amplitude in zonal wind at the equator, defined as $\sqrt{2}$ times the rms anomaly values during 1992-1997. For comparison, the 30 hPa result of Dunkerton and Delisi (1985) is included (dark dot), together with estimates from Singapore radiosondes (plus signs).

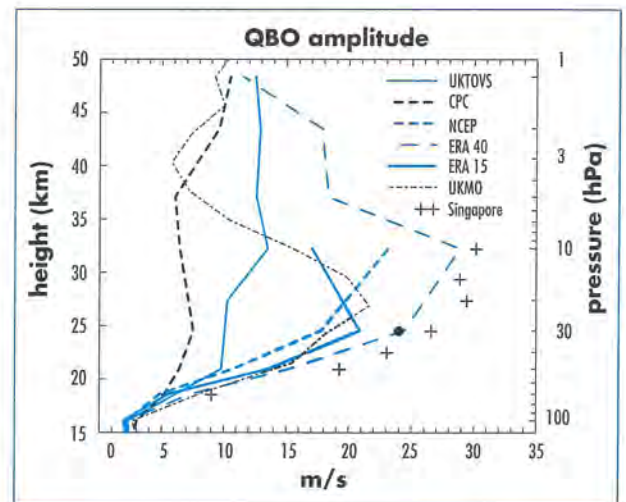
and CPC and UKTOVS (derived from balance winds) as severe underestimates.

Above 10 hPa there is a factor of two difference between the ERA40 and UKMO results, and here the UKMO data are almost certainly too weak.

Outstanding uncertainties

This study has focused on comparing climatological data sets for the middle atmosphere that are currently used in the research community. Overall the climatologies developed from analyses (and lidar measurements) for the 1990's agree well in most aspects, although each global data set can exhibit 'outlier' behaviour for certain statistics. SPARC (2002) includes a list of the largest apparent biases in each climatological data set, as derived from the intercomparisons.

Comparisons of the recent climatologies with the historical data sets (CIRA86 and rocketsondes) show reasonable overall agreement, but the effect of decadal-scale cooling



throughout the middle atmosphere is evident, particularly in the polar lower stratosphere (Figure 2) and in the upper stratosphere and mesosphere (e.g., Figure 4). Decadal changes may also influence zonal mean winds at high latitudes (Figure 7).

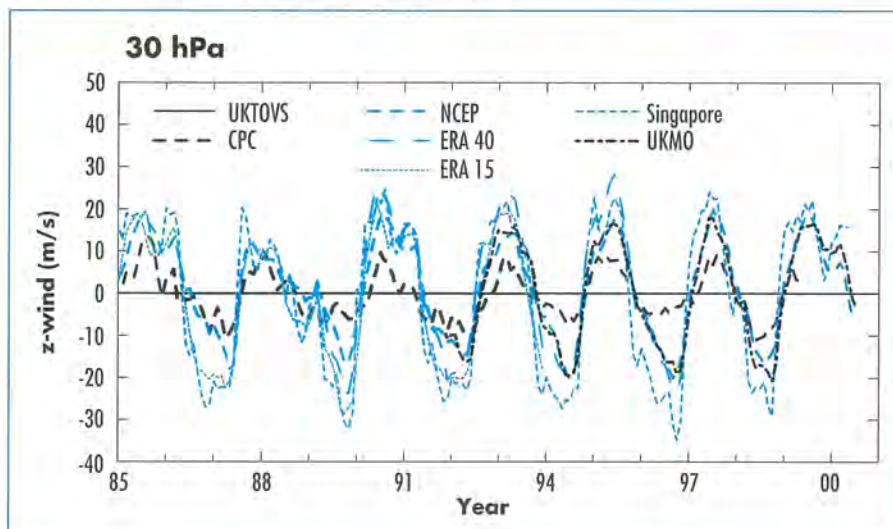
The direct intercomparisons also allow us to highlight aspects of middle atmosphere climatologies that are relatively uncertain. These are identified for statistics that show large variability among each of the different data sets, suggesting a fundamental level of uncertainty or high sensitivity to the details of data analysis. These include:

- 1 - The tropical tropopause region is biased warm (compared to radiosonde data) in many analyses. Relatively smaller biases are found in the ERA15, ERA40 and FUB analyses, which are more strongly tied to radiosonde measurements. The warm biases in this region of sharp temperature gradients probably result from a combination of low vertical resolution in the analyses, plus the less than optimal use by most analyses of thick-layer satellite temperature measurements.

- 2 - The temperature and 'sharpness' of the global stratopause shows considerable variability among different data sets. This is probably due to the relatively low vertical resolution of operational satellite measurements, and also the fact that the stratopause is near the upper boundary for several analyses (UKMO, CPC, UKTOVS).

- 3 - Temperature variability in the tropics (associated with the QBO) is underestimated in all analyses (except FUB), compared to radiosonde measurements. The underestimates are particularly large for analyses that rely primarily on low resolution TOVS satellite data (CPC and UKTOVS). The

Figure 9. Time series of interannual anomalies in equatorial zonal mean winds from various analyses and from Singapore (1°N) radiosonde measurements. Anomalies are calculated with respect to the 1992-1997 average.



temperature SAO near the stratopause is also underestimated in the CPC, UKMO and UKTOVS data sets.

4 - QBO variations in zonal wind are underestimated to some degree in most analyses, as compared to Singapore radiosonde data. The best results are derived from assimilated data sets (ERA40, ERA15, UKMO and NCEP, in that order) and only ERA40 has realistic zonal wind amplitudes above 30 hPa. The use of balance winds in the tropics (derived from geopotential data alone) is problematic for the QBO.

Acknowledgments

These climatological comparisons have resulted from work of the SPARC Reference Climatology Group, which has been ongoing since 1994. A majority of the work has centred on obtaining and archiving the numerous data sets in the SPARC Data Center. This activity was primarily organised by **Dr. Petra Udelhofen**, who unfortunately died during the final stages of preparation of the SPARC (2002) report. Petra was a valued friend and colleague of everyone involved with this project, and we dedicate it to her memory.

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Data Source	Acronym	Reference	Type of Analysis	Time Period Available
Met Office Stratospheric Analyses	UKMO	Swinbank and O'Neill, 1994	Assimilation	Nov. 1991-present
Met Office TOVS Analyses	UKTOVS	Bailey <i>et al.</i> , 1993	Objective analysis	Jan. 1979-Apr 1997
NCEP Climate Prediction Center	CPC	Gelman <i>et al.</i> , 1986	Objective analysis (above 100 hPa)	Oct. 1978-present
NCEP reanalysis	NCEP	Kalnay <i>et al.</i> , 1996	Assimilation	1948-present
ERA15 reanalysis	ERA15	Gibson <i>et al.</i> , 1997	Assimilation	1979-1993
ERA40 reanalysis	ERA40		Assimilation	1957-2001
Berlin Stratospheric Analyses	FUB	Labitzke and Naujokat, 1983	Hand analysis (NH only)	1964-2001
CIRA86 climatology	CIRA86	Fleming <i>et al.</i> , 1990	Various	Various (1960's-1970's)
HALOE temperatures	HALOE	Russell <i>et al.</i> , 1993	Harmonic analysis of seasonal cycle	1992-2001
MLS temperatures	MLS	Wu <i>et al.</i> , 2002	Harmonic analysis of seasonal cycle	Jan. 1992-Dec.1994
UARS Reference Atmosphere Program zonal winds	URAP	Swinbank and Ortland, 2002	UKMO and HRDI data	Jan. 1992-Dec.1998

Table 1. Middle Atmosphere Data Sets included in the SPARC Intercomparisons

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A presentation to the IGAC Community on the "Joint SPARC-IGAC Climate-Chemistry Initiative"

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An evening session was organised to present the joint SPARC-IGAC Climate-Chemistry initiative to the IGAC community during the recent 7th Scientific Conference of IGAC (and the 10th conference of IAMAS's CACGP). This symposium was called "Atmospheric chemistry within the Earth System: From Regional Pollution to Global Climate Change" held in Crete, Greece, during September 18-25, 2002. The special session was organised with the generous help and support of M. Kanakidou, the chair of the local organizing committee of the Symposium.

Nearly 100 people attended this session. The aim was to present to the community the need for bringing scientists working in this area together under the joint umbrella of SPARC and IGAC and to receive the response of the community to this joint effort. A.R. Ravishankara (SPARC SSG member and the SPARC lead for this initiative) and S. Liu (co-chair elect of IGAC and the IGAC lead for this initiative) organised this session.

The session started with a short presentation of the science behind the climate-chemistry interactions and the need for a joint venture (see Figure) by A.R. Ravishankara. He listed the following topics of possible mutual interest to IGAC and SPARC. This list was produced by the 14 participants of a small

Discussion Session organised in Zurich earlier in 2002 and hosted by T. Peter (see previous SPARC Newsletter N°19).

1 - The role of aerosols in chemistry, climate, and their interactions. The processing of aerosol in the atmosphere and their impact on chemistry and climate. Understanding and representing micro-physical processes in numerical models.

2 - The role of convection (both deep and warm) in controlling the water vapour abundance and redistribution of chemical constituents.

3 - The role of tropical tropopause layer (TTL) in climate-chemistry interactions.

4 - The extent and role of stratosphere-troposphere exchange (STE) in controlling the abundances of ozone and other species in the UT and LS. Specifically, an accurate quantification of the STE contribution to tropospheric and upper-tropospheric ozone budget (which is likely to be a function of time and location).

5 - The state of radiative transfer codes in calculating heating rates and photolysis rates.

6 - The use of tracers and their variabilities in observations and in models to identify and diagnose roles and contributions of processes. An assessment of the role of inter-annual variability in the circulation patterns affecting the distribution of chemical constituents in the stratosphere and troposphere.

7 - The role of lightning in the production and distribution of nitrogen oxides.

8 - Determination of the fundamental parameters in kinetics, heterogeneous chemistry (specifically aerosols and ice in UT), photolytic processes, spectroscopy, and optical properties via laboratory studies. This is an on going as joint activity between SPARC and IGAC.

9 - Satellite observations of trace species and meteorological parameters in the troposphere and lower stratosphere, assimilation of satellite observations, evaluation of models by using satellite data.

This presentation was followed by seven short invited presentations on topics noted next to their names:

1 - J. Fishman
GTOP

2 - J. Burrows
Satellites and what they can do

3 - P. Crutzen
Black Carbon and other topics

4 - U. Platt
Nitrogen oxides

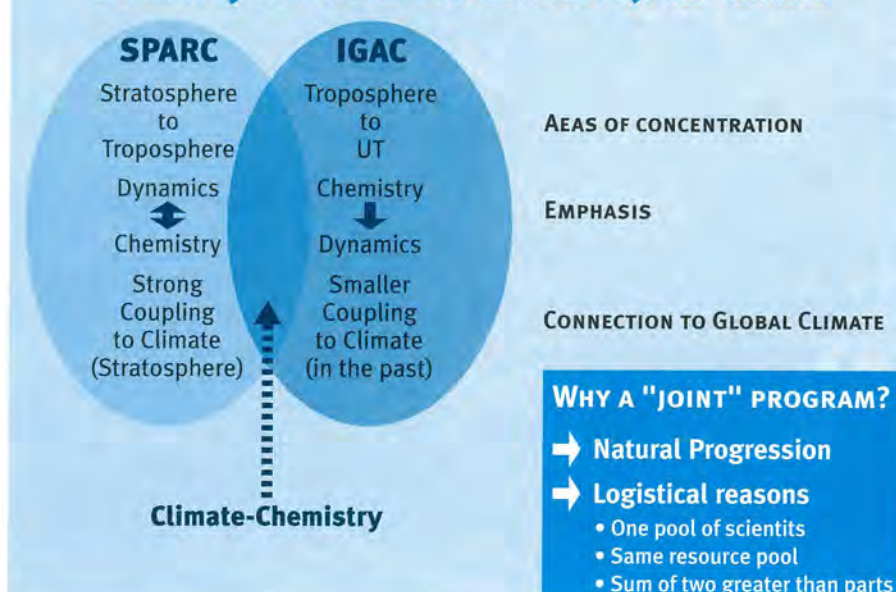
5 - J. Lelieveld
Ozone & Other topics

6 - L. Barrie
Ice and surfaces

7 - S. Liu
A few concluding thoughts

There was some interesting discussion of the science by the participants. It was clear that there was a great deal of enthusiasm for this joint initiative and it was summed up by P. Crutzen's comment: "It is about time!" It was also clear that not all the research topics of interest to SPARC would also be high priority for IGAC and vice-versa. Based on the discussion, it was clear that a joint workshop was needed to further explore the contents of the joint initiative. This workshop will be held in the south of France on April 2-6, 2003, just prior to the joint EGS-AGU meeting. It is anticipated that a white paper on the highest priority research in the area of climate-chemistry interactions will emerge from this workshop and the following discussions.

Chemistry-Climate Initiative: A New Joint Venture



Status of the SPARC Radiosonde Initiative

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The SPARC radiosonde initiative was established to exploit the unique resource of high-resolution radiosonde observations made by weather agencies. These observations, made regularly once or twice per day, provide one of the few ways of characterising the gravity wave field up to heights in the lower to middle stratosphere (up to ~30 km). The results complement measurements made with ground-based radars and lidars and emerging techniques using spaceborne instrumentation, such as the GPS/MET observations (e.g. Tsuda *et al.*, 2000). The goal is to produce a climatology of GW parameters in the lower stratosphere in order to help constrain GW parameterization schemes used in numerical climate models (Hamilton and Vincent, 1995).

The basic analysis of the observations is based on the original work of Allen and Vincent (1995), who analysed temperature-only measurements made in the Australian sector of the Southern Hemisphere. Using wind, as well as temperature observations, the analysis techniques were extended to include directions of wave propagation (e.g. Vincent *et al.*, 1997).

Scientists from over a dozen countries are involved in the analysis of the radiosonde data for this initiative. Figure 1 shows the distribution of sounding sites currently used in the project. While radiosondes are routinely launched over a wide part of the globe, it is unfortunate that more national meteorological services do not archive their observations at high resolution, despite strong encouragement from SPARC. It is apparent that large gaps exist in the network, especially in central Asia and large parts of the Southern Hemisphere. Observations taken with more specialised networks, such as the SOWER campaigns (Shiotani *et al.*, 2000)

and the SHADOZ ozone sondes (Thompson *et al.*, 2002; see also Thompson *et al.* in this Newsletter), have been especially helpful in filling in gaps in tropical regions. Despite the gaps, there are regions, such as the USA, where large numbers of sites may make possible the identification of wave sources, such as jet streams, fronts etc., and quantify their relative importance.

A workshop held in Abingdon, Oxford, in July 1999 considered a number of issues associated with the analysis and interpretation of data. One of the first decisions concerned the height coverage of the analysis. Allen and Vincent (1995) analysed data in 7 km height ranges, covering 2-9 km in the troposphere and 17-24 km in the stratosphere. However, it was decided for the global stratospheric analysis to use a 7 km height range just above the tropopause. The shaded region in Figure 2 shows the height coverage used and is based on a climatology of the tropopause described in Hoinka (1998). At the poles the height range is 12-19 km, corresponding to a mean pressure of ~100 hPa, while in the tropics the height coverage is from 18-25 km (~40 hPa).

The workshop also decided that the basic analysis for the SPARC project should concentrate on producing climatologies of wave kinetic (KE) and potential energy (PE) and directions of propagation. Other potentially important parameters included in this analy-

sis are parameters of the vertical wavenumber spectra, such as spectral slope, axial ratios of the perturbation wind hodographs and the mean vertical wavelength. Other potentially important, but more controversial quantities, such as momentum fluxes derived from combining the wind and temperature measurements (e.g. Vincent and Alexander, 2000), were left for individual researchers to pursue as research topics.

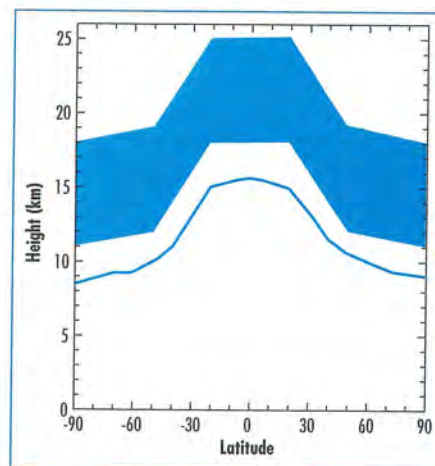
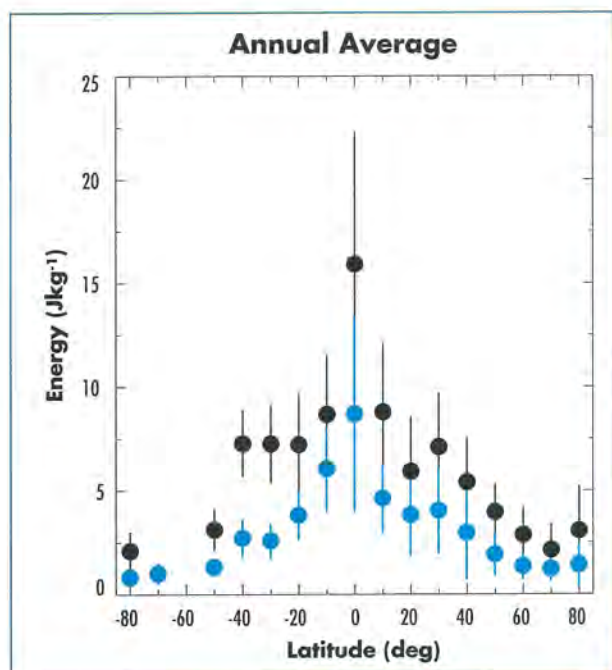


Figure 2. The solid line shows a mean tropopause based on Hoinka (1998). The shaded region indicates the 7 km height range used in the stratospheric analysis of gravity waves.

Examples of some of the products coming from this study are shown in Figures 3 and 4. Kinetic energies (KE) are about 1.5-2 times larger than potential energies (PE), consistent with



Figure 1. Location of radiosonde stations.



domination of the short vertical wavelength component of the wave field by inertia gravity waves. RMS wave amplitudes range from $\sim 6 \text{ ms}^{-1}$ at the equator to 2.5 ms^{-1} at the pole.

The steady decrease of wave energy with increasing latitude may be due to observational selection, related to the latitudinal increase in the inertial frequency and the slow vertical group velocity of inertia gravity waves (Alexander *et al.*, 2002). An apparent 'spike' in energy at the equator, which is particularly strong at the November-February period, is probably associated with short vertical wavelength Kelvin waves (Holton *et al.*, 2001).

winds. The sense of rotation of the perturbation wind hodographs shows predominantly anticyclonic rotation in both hemispheres, consistent with upward energy propagation.

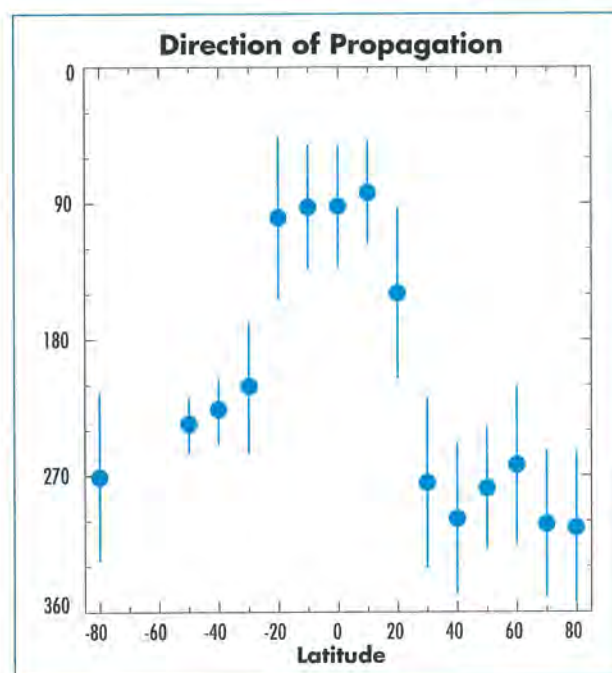
Some global general circulation models (GCMs) are now being run at sufficiently high vertical and horizontal resolution that comparisons of statistical behaviour of simulated wind and temperature fluctuations with the high-resolution radiosonde observations may be appropriate. For example, the GFDL "SKYHI" troposphere-stratosphere-mesosphere GCM has been run with 160 levels in the vertical, corresponding to a level spacing of about 300 m in the lower stratosphere (Hamilton *et al.*, 1999).

Figure 3. Annual average values of gravity wave kinetic (black) and potential energy (blue) in the stratosphere in 10-degree latitude bands.

Horizontal directions of propagation show a systematic shift as a function of latitude. In tropical regions waves tend to propagate eastward, while at latitudes greater than $\sim 25^\circ$ the waves propagate westward, with a poleward component (northwestward in the Northern Hemisphere and southwestward in the Southern Hemisphere). In general, the waves are observed to propagate against the prevailing

Wave characteristics derived from the radiosonde data set are now being compared with wind and temperature fluctuations sampled over the same geographical network in the high-resolution SKYHI simulation. Preliminary results suggest that the explicitly resolved waves in the lower stratosphere of the GCM are similar in many respects to those seen in the radiosonde observations.

Figure 4. Annual mean values of the propagation direction of waves observed in the stratosphere.



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The Darwin Area Wave Experiment (DAWEX)

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Introduction

The study of high-frequency gravity wave (GW) motions in the middle atmosphere (MA) has been a leading area of research in both meteorology and aeronomy. This interest has arisen since GW motions often dominate the variance observed in the upper mesospheric and thermospheric wind field, and since the vertical transport of mean flow momentum by GW is thought to play a key role in maintaining global-scale circulation throughout the MA. A key issue for modelling stratospheric climate and chemistry is parameterizing the unresolved GW effects on the resolved flow. A major difficulty in formulating credible GW parameterizations is the lack of empirical data on the details of the wave spectrum in the MA and its relation to sources such as moist convection, flow over topography and jet stream instabilities.

Discussions in the community beginning with the December 1996 SPARC SSG meeting in Adelaide raised the idea of a field experiment in the Darwin, Australia area to study the GW excited by deep convection in the pre-monsoon period. Particular interest was expressed in studying the so-called "Hector" convection that appears regularly in the afternoon over the Tiwi Islands located north of Darwin. In the Austral winter, convection over Northern Australia is rather limited. However, in the late pre-monsoon, typically from November to mid-December, intense convection over the Tiwi Islands, known locally as "Hector", develops virtually every afternoon. It is generally initiated by interaction of convectively driven cold pools and sea breeze fronts and builds to a bundle of intense thunderstorms over the western portion of the Islands, reaching the tropopause in mid-afternoon. The Hector thunderstorms represent some of the most intense and penetrative convection observed anywhere, with updrafts as strong as 40 m/s and cloud tops sometimes above 20 km (e.g. Keenan *et al.*, 2000).

The SPARC GW Initiative co-chairs formalized the DAWEX proposal in 2000 (Hamilton and Vincent, 2000), and the field campaign took place du-

ring October-December 2001. Preliminary results of the experiment were recently reviewed at a workshop in Honolulu (USA) from December 3-5, 2002.

The scope of the experiment

DAWEX involved contributions from scientists from at least ten different institutions in Australia, Japan and the USA. The field campaign was organised around three intensive observing periods (IOPs): October 13-18, November 15-20 and December 11-16, but many instruments were deployed before and after the IOPs.

The convection over the Tiwi Islands and elsewhere in the Darwin area was observed in detail by the Australian Bureau of Meteorology Research Centre C-band polarized Doppler (CPOL) radar located near Darwin, while the occurrence of convection over a larger area was monitored by weather radar and geostationary satellite IR imagery.

Wave responses in the vicinity of the mesopause were observed by a total of five airglow imagers deployed during the experiment. **Figure 1** shows the estimated useful fields-of-view near 90 km altitude for each of the imagers.

Figure 1. Locations of some observational sites in the DAWEX field campaign. The triangle shows Pirlangimpi on the Tiwi Islands. The five closed contours show the estimated useful fields-of-view near 90 km for the airglow imagers at Wyndham (15.3S, 128.1E), Darwin (12.3S, 130.5E), Katherine (14.3S, 132.2E), Alice Springs (23.5S, 133.5E) and Adelaide (34.5S, 138.3E).



A boundary-layer radar that profiled the three components of the wind up to about 7 km height was installed at Pirlangimpi on the Tiwi Islands. At Katherine, about 400 km south and east of the Tiwi Islands, a medium-frequency radar was installed to measure horizontal winds near the mesopause.

Three-hourly balloon soundings of the wind and temperature were made during each of the IOPs at Pirlangimpi, Darwin (130 km south) and Katherine. The soundings were made with larger balloons than used routinely; in practice over 75% of the IOP soundings reached 25 km and over 65% reached 30 km.

Some preliminary results

The character of the convection differed among the three IOPs as the prevailing circulation changed from pre-monsoonal to monsoonal. The October IOP had three days with modest Hectors and two with only disorganised convection. In the November IOP there were three consecutive days (15,16 and 17) with very strong Hectors as well as more extensive areas of convection. In the December IOP a more monsoonal pattern with widespread convection over the mainland prevailed. **Figure 2** (p. 1) shows a CPOL radar section through the intense Hector.

The airglow imagers yielded a rich trove of data indicating the horizontal wavelengths and horizontal phase velocities of waves propagating through the field of view of each imager. One overall tendency observed at all the imagers is dominant southward propagation. This suggests that the dominant source for waves in this season is convective activity in Northern Australia or the Maritime Continent. More detailed analysis of the behaviour of waves at each station and its relation to the weather each day is now being performed.

The radiosonde observations revealed some systematic wavelike variations at both short time scales and longer time scales. One prominent component near the tropopause in the October and December IOPs is a large-scale wave (coherent at Darwin and Katherine) with period near 84 hours (**figure 3**). Overall there is tendency for small vertical scale variations to be strong near the tropopause and also above 25 km, but to be suppressed in the 20-25 km

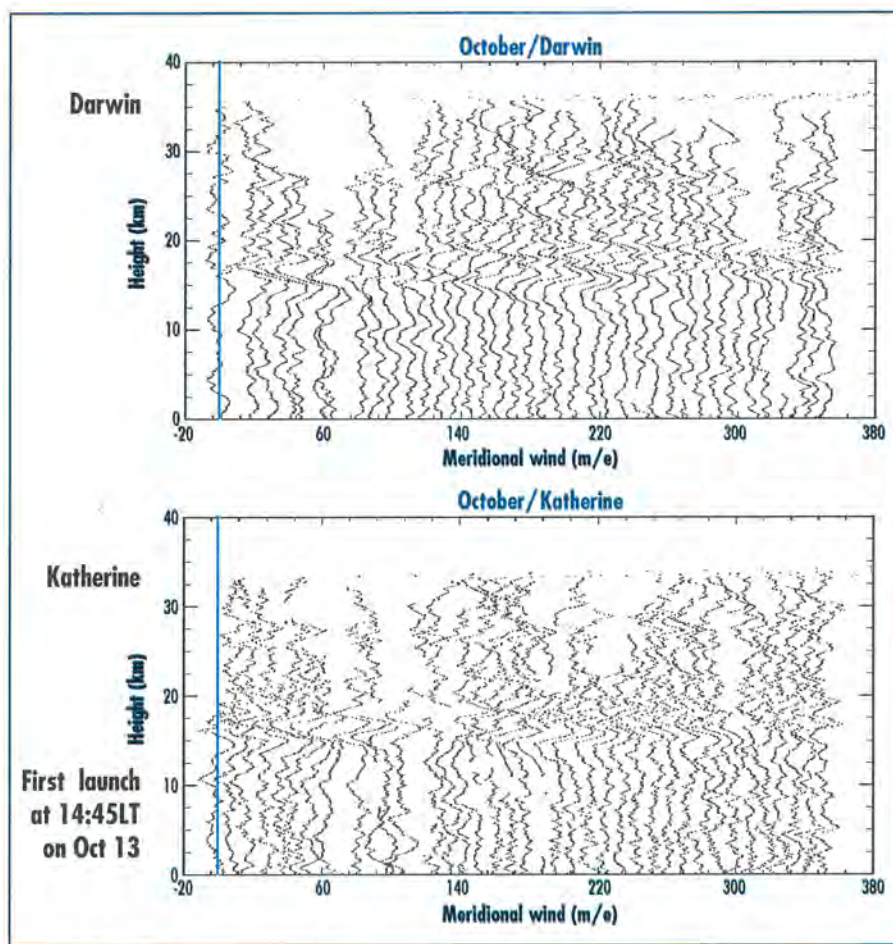


Figure 3. Profiles of meridional wind measured at roughly three-hourly intervals at Darwin and Katherine during the October 2001 DAWEX IOP. Successive profiles are displaced rightward on the plot. [Courtesy Toshitaka Tsuda].

height range. All these findings are unexpected and await satisfactory explanations.

Lessons for future campaigns

There was considerable enthusiasm at the Honolulu workshop for another field campaign focussed on GW generation by convection in Northern Australia. A new experiment would benefit greatly by extending the observational capabilities available for DAWEX. Valuable additions would be provided by Rayleigh lidars to obtain information of wave fluctuations in the 30-70 km height range, and also by deployment of airglow imagers on aircraft to allow a broader geographical coverage. An experiment that could extend over a long period of time would also be useful, as it would allow sampling of days with a wide variety of weather situations. It was noted, in particular, that the Austral spring season of 2002 featured at least one day with a strong Hector storm that was rather isolated from any other

significant convection, a situation that did not occur so clearly during DAWEX.

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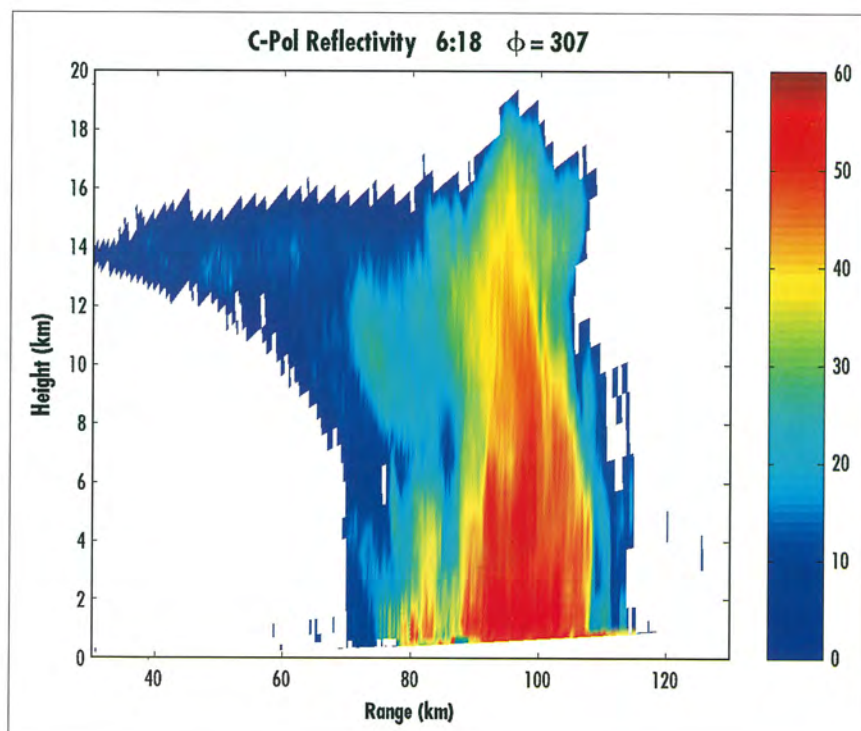
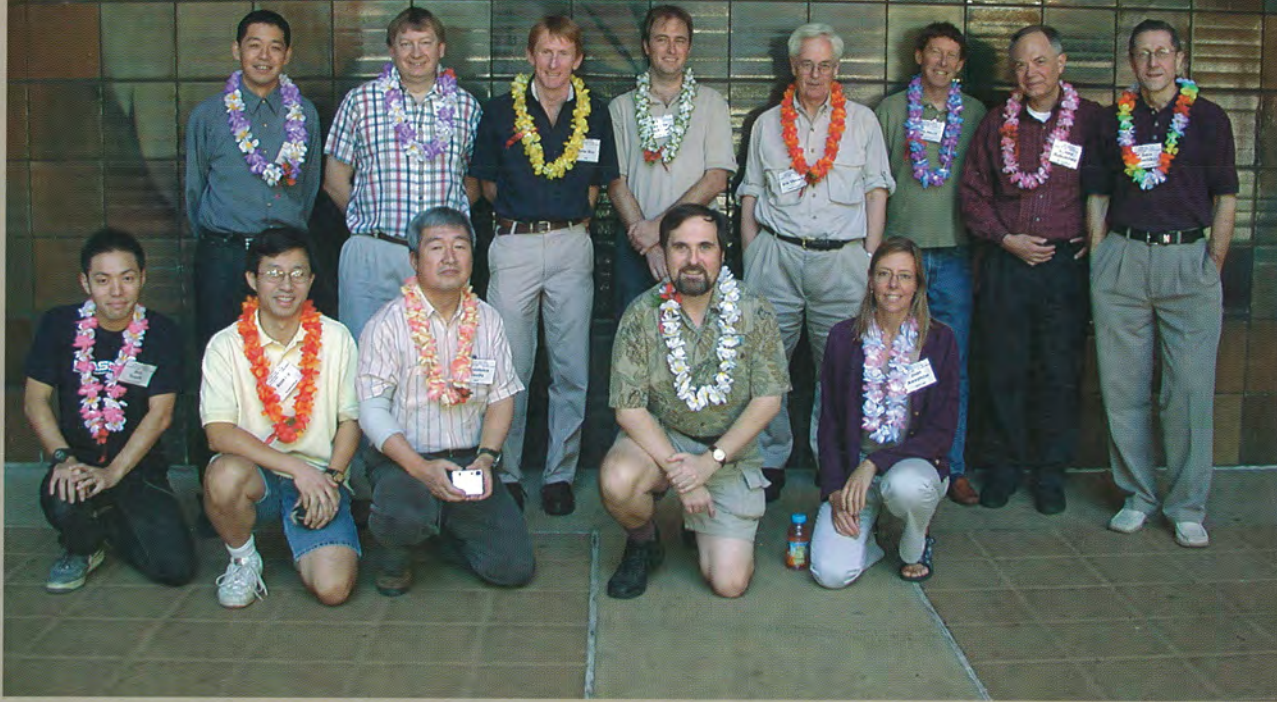
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The Darwin Area Wave Experiment (DAWEX)

Participants in the Workshop on Analysis of DAWEX Results, Honolulu, Dec. 3-5, 2002

1st row: S. Suzuki, A. Liu, T. Tsuda, K. Hamilton, J. Alexander

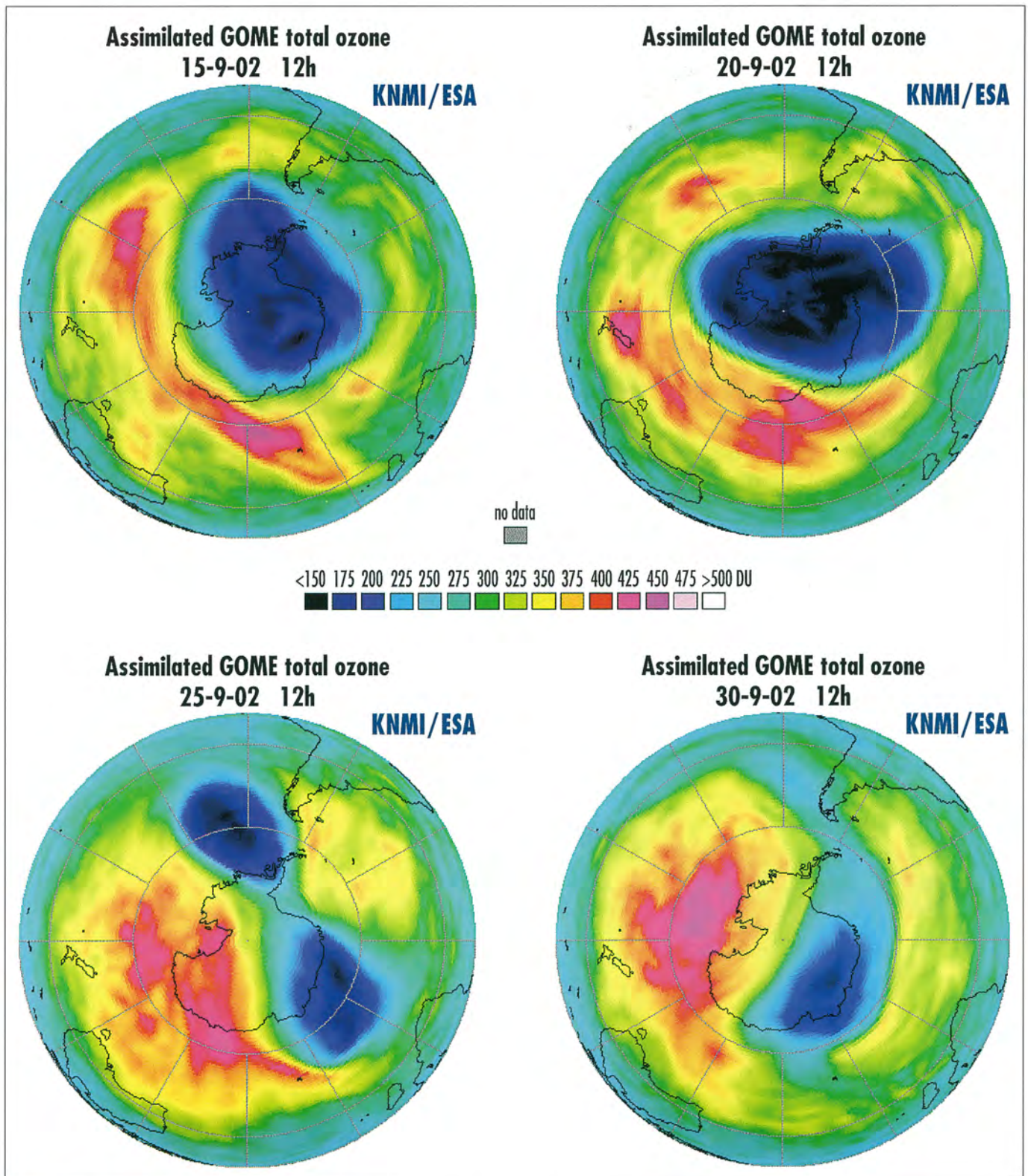
2nd row: K. Shiokawa, M. Taylor, P. May, A. McKinnon, B. Vincent, J. Hecht, R. Walterscheid, G. Stenchikov



◀ **Figure 2**

Radar reflectivity measured in a vertical scan from the CPOL radar looking approximately northward from near Darwin at 15:48 local time on November 15, 2001. This shows a well-developed Hector storm with radar echoes up to near 20 km. Courtesy Peter May.

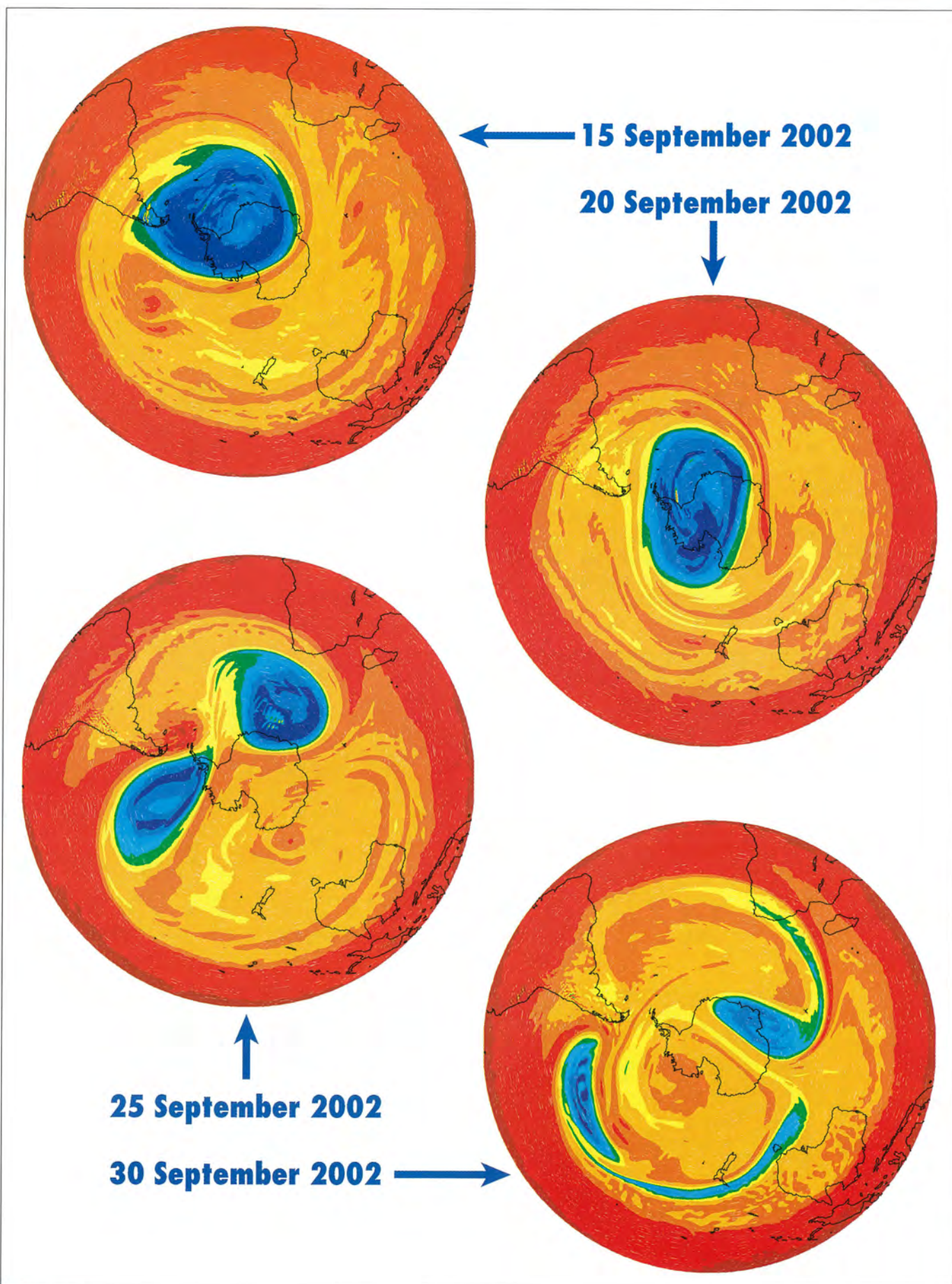
Major Stratospheric Warming in the Southern Hemisphere in 2002: Dynamical Aspects of the Ozone Hole Split



▲ Figure 1

Time evolution of the total ozone field assimilated at KNMI: September 15, 20, 25, and 30 in 2002.

http://www.knmi.nl/gome_fd/index.html

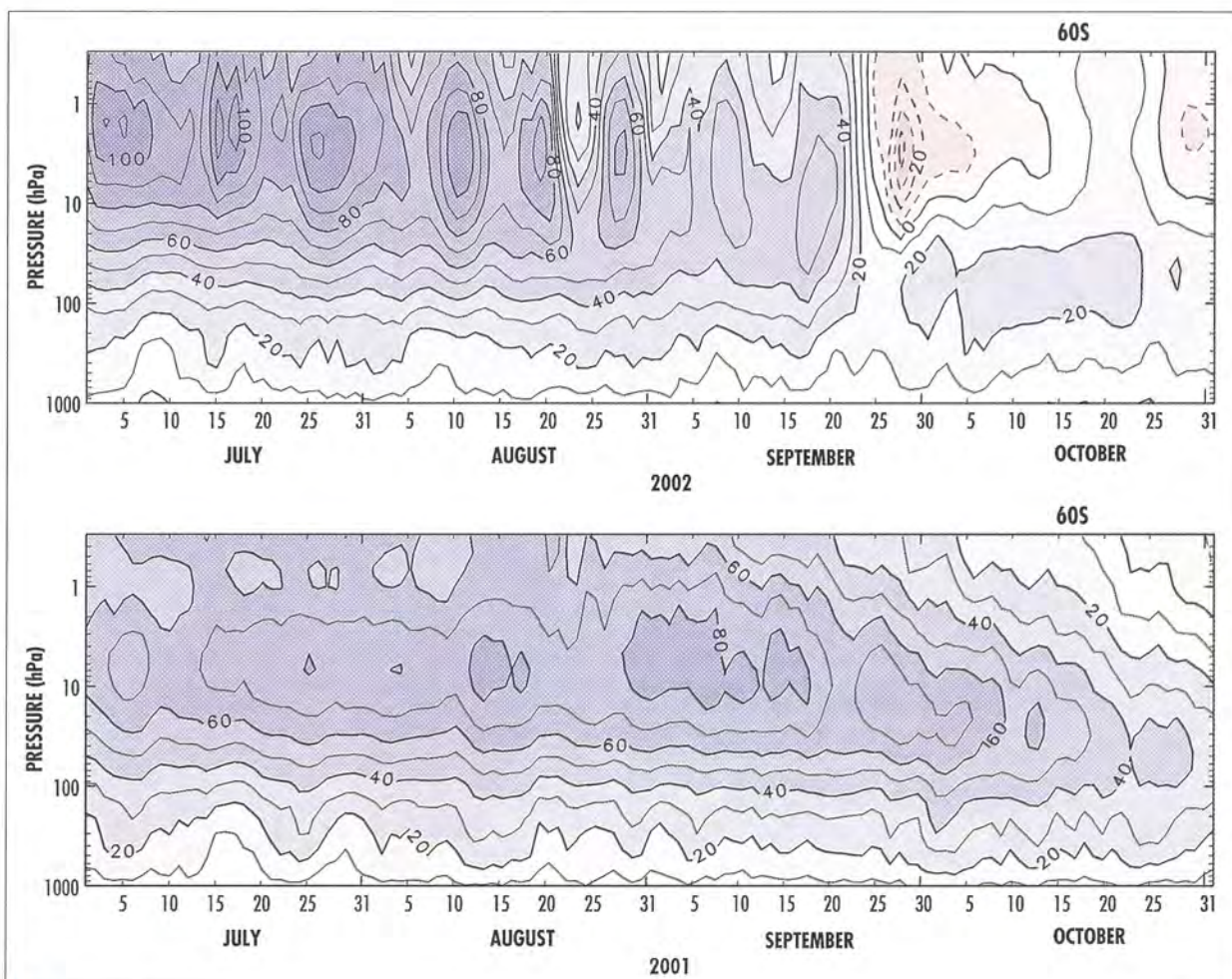
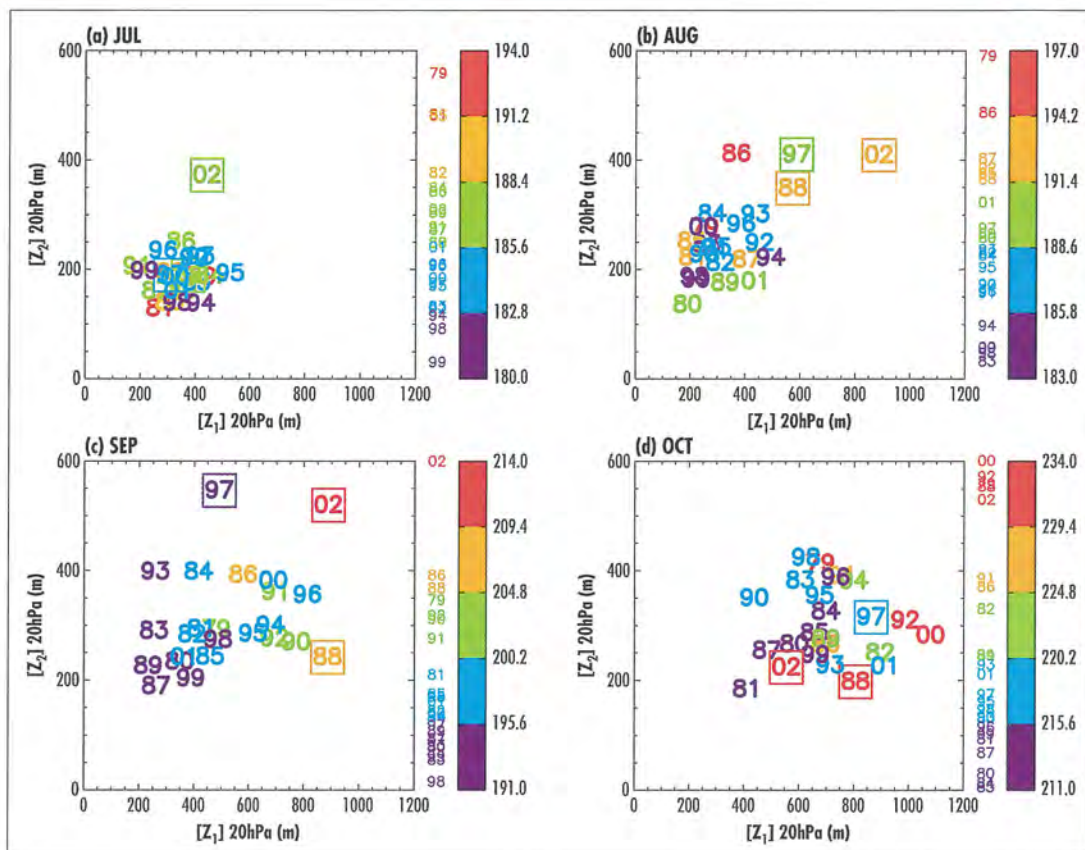


▲ Figure 2

Potential vorticity on the 850K isentropic surface (near 10 hPa) for the Southern Hemisphere on the dates shown during September 2002. The fields are derived from high-resolution (T511) meteorological analyses provided by the European Centre for Medium Range Weather Forecasts. On each chart, the Greenwich Meridian is at the top. Values of potential vorticity associated with the stratospheric polar vortex are indicated with the colour blue.

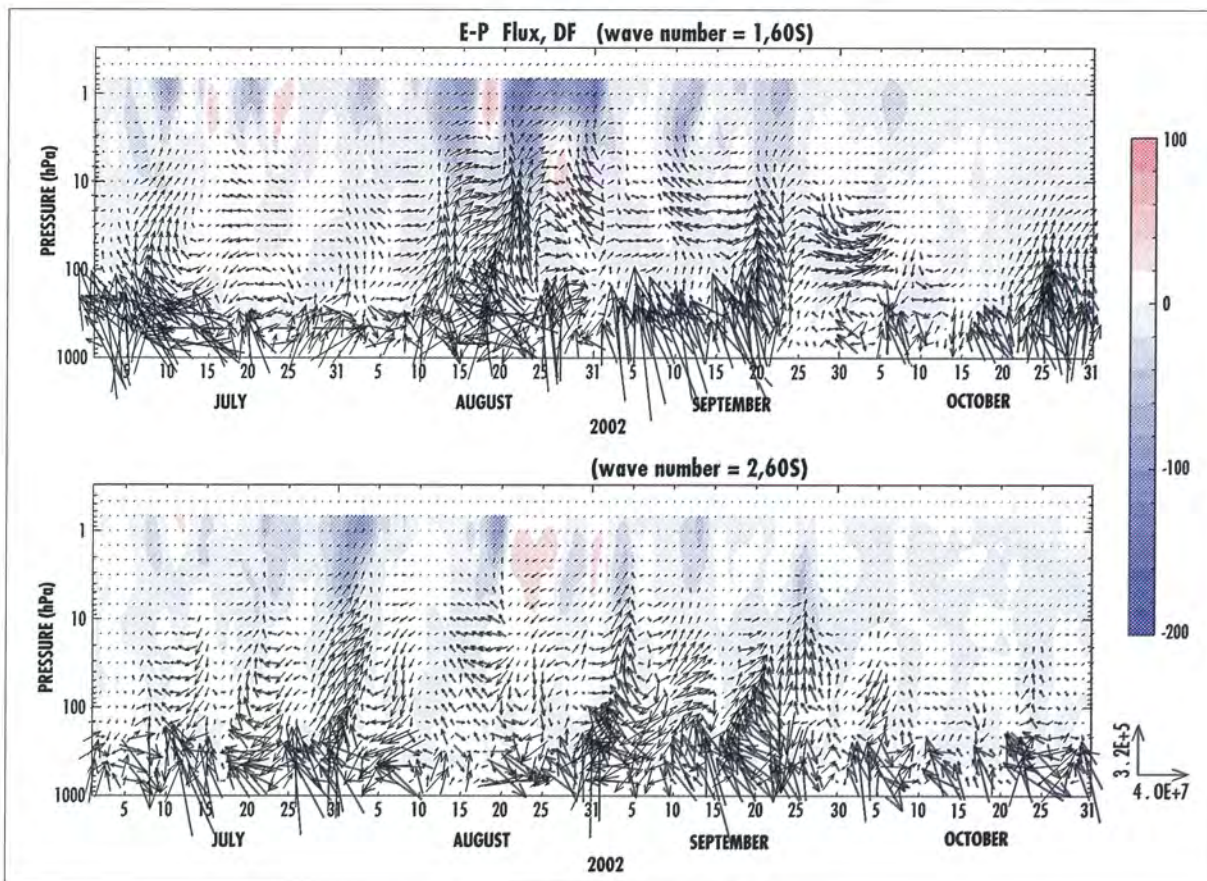
► **Figure 4**

24-year records of the monthly mean of daily geopotential-height amplitudes of zonal wavenumber 1 [Z_1] and 2 [Z_2] averaged over the latitudes between 60°S and 70°S, at the 20 hPa level. Monthly mean temperature at the pole is also shown with colour indicated on the right side of each panel.

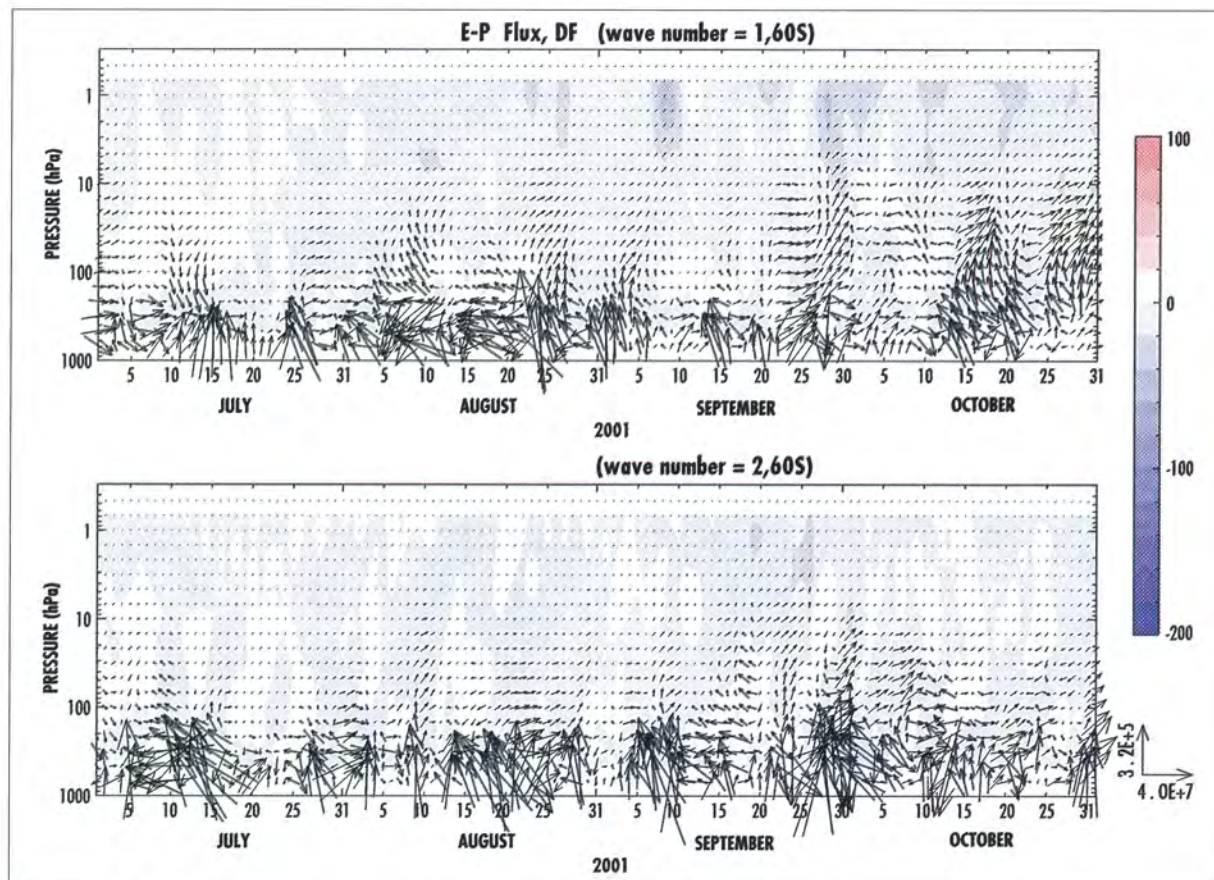


▲ **Figure 5**

Time-height sections of the zonal mean zonal wind at 60°S for the period from July to October in 2002 (upper panel) and 2001 (lower panel). Units are ms⁻¹ and the contour interval is 10 ms⁻¹. Blue shading denotes the westerlies while red denotes the easterlies.



(a)



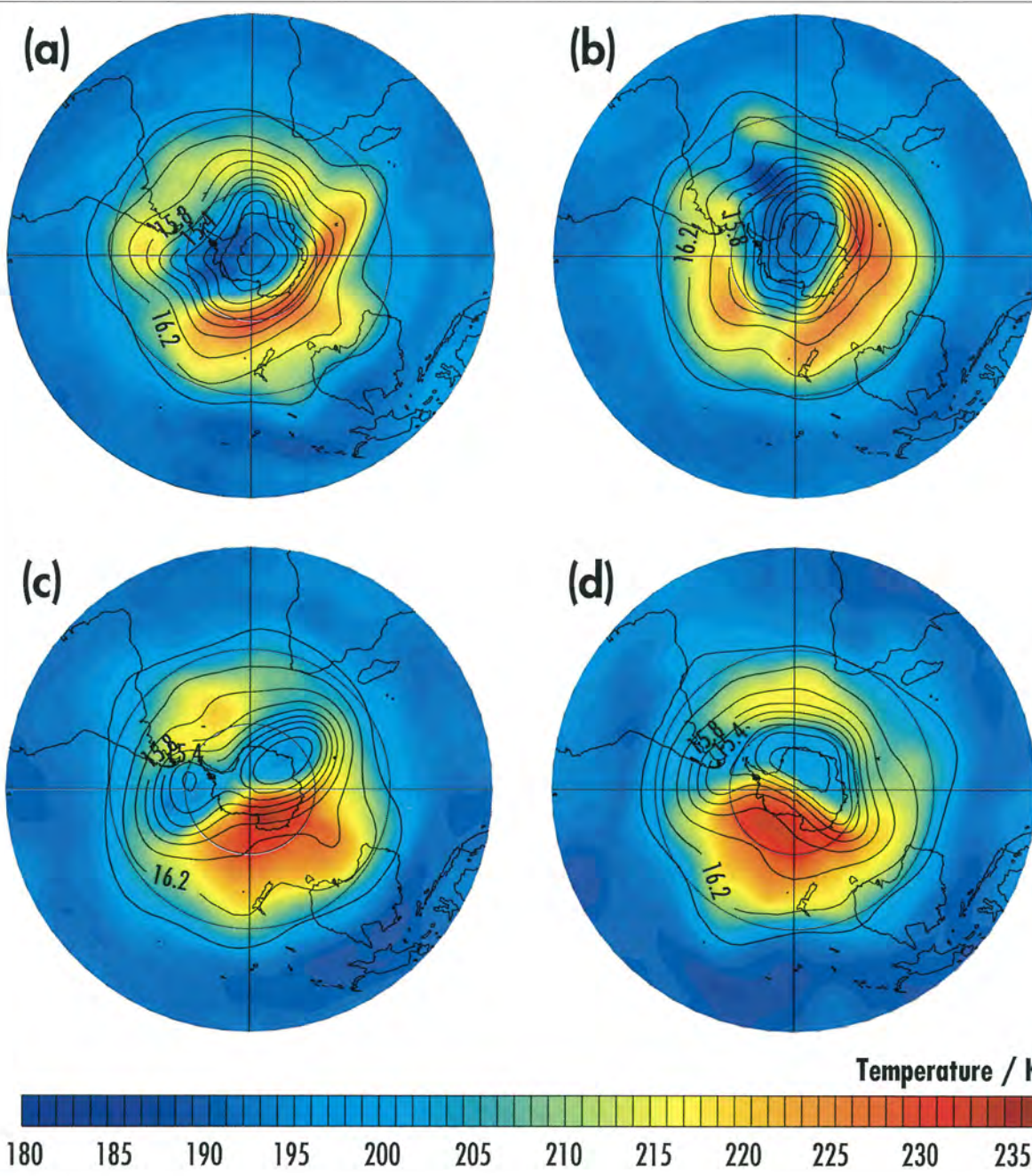
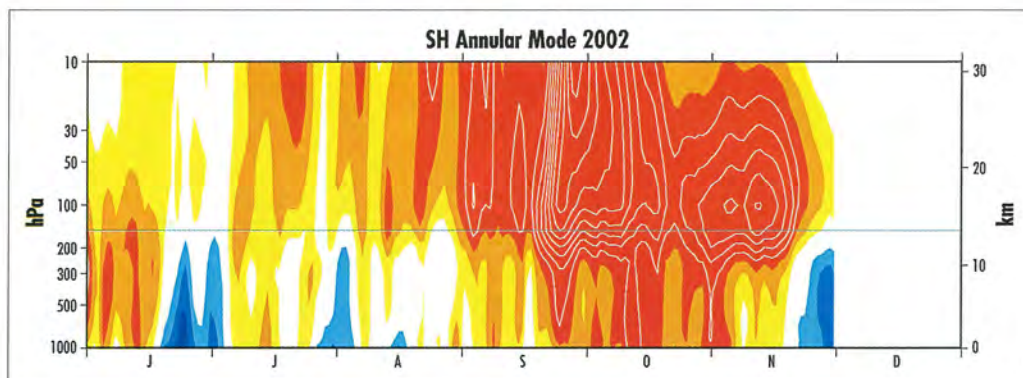
(b)

▲ Figure 6

Time-height sections of the Eliassen-Palm (E-P) flux (vectors) at 60°S and the wave driving (shading) due to its divergence for the period from July to October in (a) 2002 and (b) 2001. Each upper panel shows the contribution of zonal wavenumber 1 and lower shows that of zonal wavenumber 2. The arrow scale denotes vertical and horizontal components of the E-P flux vector (kg s^{-2}) and the right direction corresponds to the poleward. Blue shading denotes zonal wind deceleration while red denotes acceleration; see the tone bar where the units are $\text{ms}^{-1}\text{day}^{-1}$.

► **Figure 7**

Time-height development of the SAM during 2002. The daily SAM index for each level is obtained by projecting daily geopotential anomalies onto the SAM patterns. Blue corresponds to positive values (strong, cold vortex), while red corresponds to negative values (warm, weak vortex). The values at each level are normalised by the standard deviation of the September-November index during 1979-2001. The contour interval is 0.5σ , with values between -0.5σ and 0.5σ unshaded. The thin horizontal line is at 150 hPa.

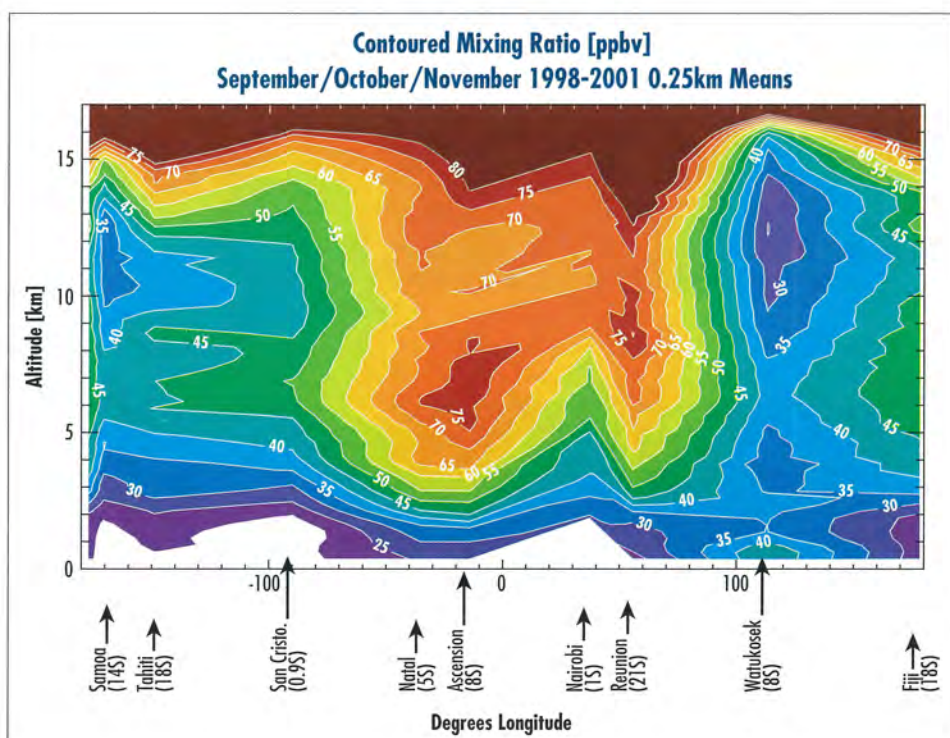
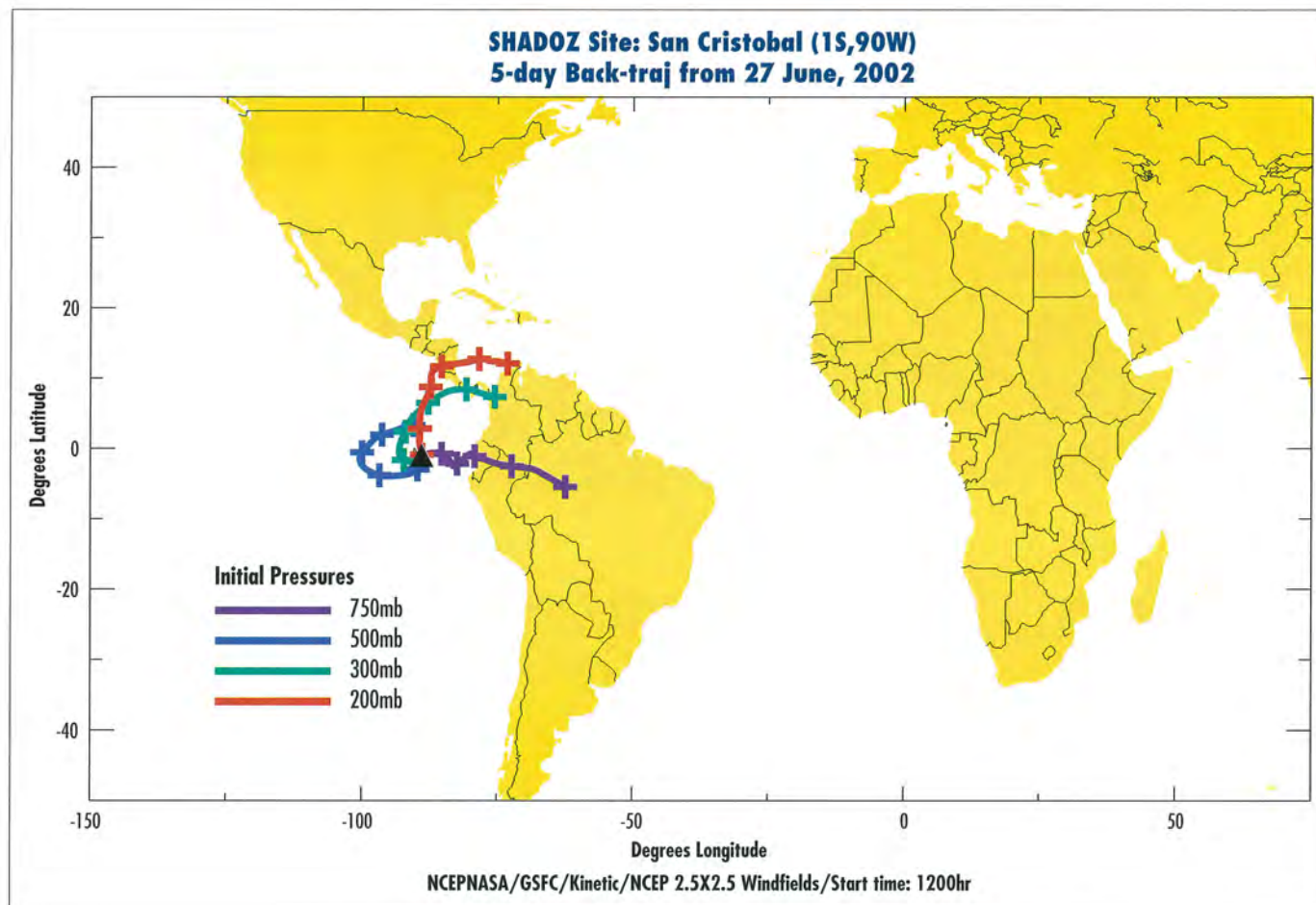


▲ **Figure 8**

Fields of geopotential height (contours at intervals of 0.2 km) and temperature (colours given by the scale at the bottom of the figure) at 100 hPa for the Southern Hemisphere (a) 15, (b) 20, (c) 25 and (d) 30 September 2002. The fields are derived from meteorological analyses provide by the U.K. Met Office. On each chart, the Greenwich Meridian is at the top.

SHADOZ

(Southern Hemisphere Additional Ozonesondes): A New Source of Ozone and Temperature Data from a Tropical Network



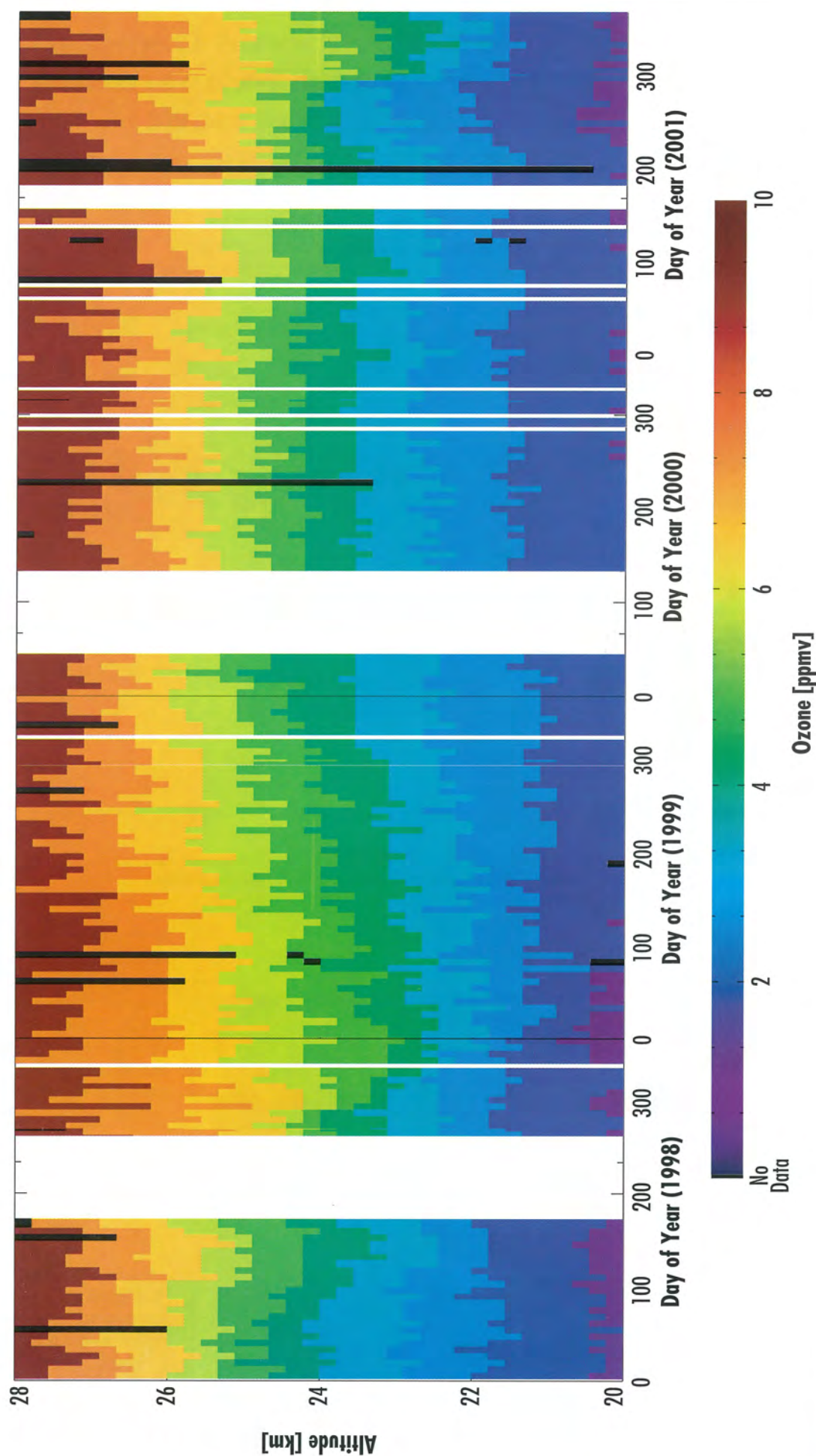
▲ **Figure 3**

An example from the SHADOZ website of 5-day backtrajectories at fixed pressure levels as shown in key. Every 24 hours is marked by a cross. The illustration corresponds to the launch with profiles shown in Figure 2 (p. 29).

◀ **Figure 7**

Contoured ozone mixing ratios in ppbv averaged for September through November (SON) 1998-2001. Details in Thompson *et al.* (2002b). Station locations by longitude with their respective latitudes and sonde sample numbers are marked below.

Nairobi 1998-2001 Data - 0.25km Bins



▲ **Figure 9**

Time-vs-altitude stratospheric ozone mixing ratio (in ppmv) based on 0.25 km averages for Nairobi during 1998-2001. Shifts in ozone mixing ratio between 24 and 28 km level correlate well with the QBO cycle. See Logan *et al.* (2002) for details.

Report on the International Symposium on "Stratospheric Variations and Climate"

Fukuoka, Japan, November 12 -15, 2002

Saburo Miyahara, Kyushu Univ., Fukuoka, Japan

Toshihiko Hirooka, Kyushu Univ., Fukuoka, Japan

Masato Shiotani, RASC, Kyoto Univ., Uji, Japan

Masaaki Takahashi, CCSR, Univ. of Tokyo, Tokyo, Japan

Shigeo Yoden, Kyoto Univ., Kyoto, Japan (yoden@kugi.kyoto-u.ac.jp)



Group photography on November 13, 2002 during the International Symposium on "Stratospheric Variations and Climate"

Introduction

Middle atmosphere sciences have rapidly progressed in the last several decades, owing to the development of observational methods, computer facilities, and theories of middle atmosphere dynamics. On the other hand, investigations of global stratospheric climate-change, such as ozone depletion in the polar regions and cooling of the stratosphere, have drawn growing social attention.

Recognising the importance of stratospheric processes for the climate system, the WCRP set up a research project SPARC. Working in closer cooperation with this international project, we have been carrying out a four-year project from 1999 to 2002 "Variations of Dynamical Processes and Ozone in the Stratosphere and Their Role in Climate" under the Grant-in-Aid for Scientific Research on Priority Areas of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan.

This symposium had been planned to discuss important issues related to stratospheric variations and climate under the attendance of international researchers. It was sponsored jointly by MEXT and Faculty of Science, Kyushu

University. It consisted of three sessions and two special sessions:

- (1) Variability of the Troposphere-Stratosphere (T-S) Coupled System
 - (2) Upper Troposphere/Lower Stratosphere (UT/LS) and Tropical Tropopause Layer (TTL)
 - (3) Chemistry-Climate Interaction
- (S1) Special Talks on the 10th anniversary of SPARC
(S2) Antarctic Stratospheric Sudden Warming (SSW) in September 2002

A total of 96 scientists participated, from 10 countries. The symposium included 21 invited papers and more than 50 contributed papers and posters. Session S1 had been planned in commemoration of the 10th anniversary of SPARC, while session S2 was hastily arranged to discuss the major Antarctic Stratospheric Sudden Warming (SSW) occurred in September 2002. Following is a brief report of each session.

Variability of the T-S Coupled System

Various aspects of variability of the T-S coupled system were discussed. In particular, a number of papers dealt with the Arctic Oscillation (AO) and/or the North Atlantic Oscillation (NAO).

K. Hamilton reported GCM experiments on effects of polar vortex perturbations on the tropospheric winter circulation by the use of the GFDL SKYHI model. **Y. Kuroda** discussed observational results on dynamical coupling of the Polar-night Jet Oscillation (PJO) and AO during the Northern Hemisphere (NH) winter. **D. Karoly** showed the observational evidence of trends in the Southern Hemisphere (SH) annular mode. **Y. Orsolini** presented signatures seen in the stratospheric ozone distribution that originated from interannual changes of tropospheric dynamical fields. **K. Iwao** discussed dynamical contribution to ozone mini holes frequently observed over Europe during winter.

K. Kodera discussed the influence of the stratosphere on the troposphere in connection with AO and NAO on the basis of a GCM experiment. **T. Dunkerton** discussed the stratospheric vacillation due to the annular mode variability based on model experiments. **K. Harada** reported on the dynamical linkage of the troposphere and stratosphere in terms of leading mode coupling. **A. Ruzmaikin** showed the observational evidence of the solar variability influence on the

T-S coupling. **S. Zhou** presented observational evidence of dynamical links of AO and the Madden-Julian Oscillation (MJO).

A. O'Neill discussed the dynamical coupling of the troposphere and stratosphere from a viewpoint of weather forecast improvement. **T. Iwasaki** presented a new formulation to diagnose the wave-mean flow interaction and discussed the energy cycle. **N. Kawamoto** showed time variations of the descent rate in the Antarctic vortex based on the ILAS observations. **Y. Tomikawa** presented observational results of short-period disturbances trapped at the edge of the stratospheric polar vortex. **Y. Hio** discussed observational results of quasi-periodic variations in the SH stratosphere.

W. Robinson investigated a mechanism for downward influence of the stratosphere on the troposphere by the use of an idealised model. **H. Nakamura** discussed the linkage of the troposphere and stratosphere due to the propagation of stationary Rossby wave trains. **Y. Naito** presented the results of a parameter-sweep experiment concerning the effects of the QBO on SSWs. **H. Mukougawa** spoke on the predictability on recent SSWs on the basis of one-month forecast data of the JMA numerical weather prediction model.

M. Baldwin used an empirical statistical model and discussed extended-range forecasts of the dominant pattern of surface weather variability. **M. Taguchi** reported on the tropopause valve effect on the troposphere and stratosphere seen in a simplified GCM. **K. Yamazaki** discussed a possible mechanism of the ozone minimum over the subtropical north-western Pacific during winter. **M. Inatsu** discussed atmospheric response to zonal variations in mid-latitude SST by the use of a simplified GCM. **J. Ryoo** presented observational features of SSWs based on a composite analysis.

UT/LS and Tropical Tropopause Layer (TTL)

J. Holton opened the session as one of the key invited speakers. He introduced a new concept referred as the TTL which has been highlighted in recent years in view of the troposphere-stratosphere exchange and stratospheric dehydration. He emphasized horizontal transport in this layer and performed a simple mechanistic

model experiment with an annual variation of the tropopause. Also he mentioned a possible impact of the QBO on water vapour distributions.

M. Shiotani presented results from the SOWER/Pacific campaigns including unique water vapour profiles in the tropics and some comparisons between several hygrometers. **M. Niwano** found out using the HALOE water vapour and methane data that the inferred ascent rates in the equatorial lower stratosphere show clear seasonal variation with modification by the QBO. **H. Takashima** utilised the SHADOZ ozonesonde data to investigate ozone variations in the TTL.

S. Pawson addressed issues related to the modelling and assimilation of water vapour in the UT/LS. He also emphasized the importance of appropriate representing physical processes in models. **T. Peter** focused on ultra-thin tropical tropopause clouds with a vertical thickness of only 100-300 m and stressed their importance for dehydration from the view point of microphysical processes. **N. Eguchi** showed results from the UARS/MLS upper troposphere water vapour data, focusing on the tropical intraseasonal oscillations.

P. Haynes demonstrated trajectory-based analyses to understand the tropopause region. In the extratropics the distribution of transport timescales from the boundary layer shows an objective contrast between the troposphere and stratosphere. In the tropics, he suggested that the microphysical efficiency of the drying process may be important. **H. Hatsushika** showed using trajectory analyses that the anticyclonic circulation acts like a spiral staircase crossing the tropical tropopause. **J. Suzuki** analysed Kelvin wave activity around the tropical tropopause and found its maxima in the Eastern Hemisphere during the solstitial seasons. The first results from the Equatorial Atmosphere Radar (EAR) (Bukit Kototabang, Indonesia) were presented by **M. Fujiwara** concerning Kelvin wave breaking events and by **M. Yamamoto** about possible Kelvin-Helmholtz instability.

K. Sato showed results from radiosonde observations through a ship cruise in the Central Pacific. One highlight is a clear evidence of meridional propagation of an inertia-gravity wave generated at ITCZ. **S. Dhaka** used Indian MST radar to investigate convective updraft by gravity waves

(GW) during tropical convective events. **Y. Kawatani** investigated enhancement of GW activity in the Atlantic Ocean using AGCM simulation. **H. Chun** used a mechanistic model to discuss the generation mechanism of convectively forced internal GW. **T. Horinouchi** also discussed convectively generated GW in a numerical experiment including the troposphere, stratosphere and mesosphere.

Chemistry-Climate Interaction

J. Austin reviewed difficulties of simulation in chemistry-climate models (CCM) of the stratosphere, and also reviewed assessments of the future ozone hole. The 11-year solar cycle, volcanic aerosol, halogen release, temperature coupling are important to chemistry-climate problem. There is model temperature bias that should be improved to predict PSC area. Ensemble experiments are rather essential, because dynamics is important (e.g., the 2002-year ozone hole).

T. Nagashima discussed the results of ozone hole experiment in the CCSR/NIES CCM. He also discussed less water vapour problem in the model. The model used a nudging method to relax to observed water vapour content. If there is no nudging, short duration of PSC makes insufficient ozone hole. **M. Takigawa** presented SO_x chemistry in the CCSR/NIES CCM and an application to the Pinatubo eruption event. In this event, ozone decrease was well simulated.

Y. Kondo discussed denitrification mechanism. They analysed the removal of HNO_3 and the difference between 20 km (decrease) and 15 km (increase). To estimate HNO_3 decrease, the ILAS data were used. A box model was also used to check their results. NAT/NAD nucleation is important in the denitrification.

T. Wehr presented ESA atmospheric missions. GOME is still operational. MIPAS, GOMOS, SCIAMACHY, SWIFT projects were discussed. **T. Dunkerton** proposed a new project of South Asia monsoon and transport experiment.

M. Schoeberl discussed suitability of assimilated meteorological fields for chemical transport. They estimated age spectrum for UKMO DAS winds fields diabatic trajectory, UKMO kinematic trajectory, FVDAS data set, and

GCM. **H. Akiyoshi** discussed nudging Chemical Transport Model for study of ozone change and comparison to ILAS observational data. The model simulates ozone change showed by ILAS in 1997 summer time. NO_x chemistry for ozone destruction was also discussed.

A. Ravishankara reviewed the chemistry of ozone and aerosols. He emphasized the need for process understanding to quantify the formation and removal processes of aerosols. **V. Ramaswamy** discussed temperature changes in the stratosphere and related changes in chemical species.

S1. Special Talks on the 10th Anniversary of SPARC

Two talks were given by **M.-L. Chanin** and **M. Geller**, who had been co-chairs of SPARC Scientific Steering Group from the beginning, i.e., March 1992. **M.-L. Chanin** recollected the efforts to establish the SPARC project in WCRP since late 1980's. It was the first project "to introduce Chemistry into the fortress of Physics" in WCRP. She also summarised its development phase under three themes: (1) stratospheric processes and their relation to climate, (2) stratospheric indicators of climate change, and (3) modelling stratospheric effects on climate. Her article on the history of the beginning of SPARC will appear in the next SPARC Newsletter.

M. Geller talked on his association with SPARC under the title of "How SPARC has influenced my research". He gave three examples: (1) finding of

the cooling trend of the tropical cold point tropopause temperatures in contrast to the increasing trend of the stratospheric water vapour, (2) analysis of GW activity over the USA with high vertical resolution radiosonde soundings, and (3) modelling total ozone evolution in the past two decades with a CCM. He closed by saying that "if one chooses to spend part of one's precious time and effort to participate in international programs, such as SPARC, my experience is that you get back not only what you put in but even more in terms of scientific ideas, scientific interactions, and especially long-lasting friendships".

S2. Antarctic Stratospheric Sudden Warming in September 2002

A special discussion session on the Antarctic SSW events, which occurred in September 2002, was held. **S. Yoden** showed animations of the daily total ozone fields assimilated at KNMI (http://www.knmi.nl/gome_fd/) and potential vorticity fields at a mid-stratospheric level to characterise the split of the polar vortex. Diagnosis of planetary waves for the past 24 years showed that this is an unprecedented event in September, but similar and weaker events were observed in November in the past. A simple vortex-dynamics model in 2-D can describe the vortex split and re-merger, but an extreme condition for the split suggests the importance of stationary wave of zonal wavenumber one.

T. Hirooka described the vertical linkage of the events on the basis of the Met Office stratospheric assimilated data and compared it with another year, 2001 when the usual seasonal march was observed. In 2002, the polar night jet fluctuated rather regularly with a typical time scale of about 10 days throughout the winter. The regular fluctuation of the polar night jet was associated with periodic strengthening of the planetary wave activities of zonal wavenumber 1 and 2, as illustrated by time-height sections of the Eliassen-Palm flux and its divergence. Seasonal march of the polar vortex and planetary wave activity were quite different in 2001 and 2002.

A. O'Neill diagnosed the SSW events with high-resolution PV maps from the Met Office. He also pointed out the occurrence of blocking phenomenon in the upper troposphere and discussed the vertical linkage between the stratosphere and the troposphere. **M. Baldwin** also discussed the vertical linkage based on the Southern Annular Mode (SAM). He pointed out that the warming event was not only unprecedented in the SH, but the SAM values exceeded those seen in the NH. An event of this magnitude, intensity, and duration has never been observed in either hemisphere.

More details about this event are reported in this issue of the Newsletter (**Baldwin et al.**).

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Announcement

The MUMM International Award 2003 for a SPARC /STTA paper

At its 54th session, the Executive Council of the WMO conferred the Norbert Gerbier-MUMM International Award for 2003 to the authors of the paper entitled "Stratospheric temperature trends: observations and model simulations" published in *Review of Geophysics*, 19, 1, in February 2001.

This paper was co-signed by V. Ramaswamy, M.-L. Chanin, J. Angell, J. Barnett, D. Gaffen, M. Gelman, P. Keckhut, Y. Koshelkov, K. Labitzke, J.J.R. Lin, A. O'Neill, J. Nash, W. Randel, R. Rood, K. Shine, M. Shiotani and R. Swinbank.

It is felt by the SPARC SSG as a major honour and a recognition of the very successful activity carried out under the banner of SPARC by the Stratospheric Temperature Trends Assessments Initiative (STTA) under the leadership of V. Ramaswamy.

Major Stratospheric Warming in the Southern Hemisphere in 2002: Dynamical Aspects of the Ozone Hole Split

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Toshihiko Hirooka, Kyushu University, Fukuoka, Japan (hirook@geo.kyushu-u.ac.jp)
Alan O'Neill, University of Reading, Reading, UK (alan@met.reading.ac.uk)
Shigeo Yoden, Kyoto University, Kyoto, Japan (yoden@kugi.kyoto-u.ac.jp)
 and collaborators*

Collaborators*: A.J. Charlton (Univ. of Reading), Y. Hio (Kyoto Univ.), W.A. Lahoz (Univ. of Reading), and A. Mori (Kyushu Univ.).

Introduction

In late September 2002 the Southern Hemisphere stratosphere underwent its first recorded major stratospheric warming, splitting the vortex and tearing the normally quiescent Antarctic ozone hole into two parts. The occurrence of this "unprecedented event" (WMO, 2002), in which the stratosphere suddenly warmed, is in contrast to the trend for the last ~20 years toward a stronger, colder, longer-lasting Antarctic vortex. Why did a major warming occur in the Southern Hemisphere? Was its occurrence somehow related to ozone or climate trends, or was it simply a highly unusual event? What are the implications for future ozone and climate trends?

Several weeks after the event, in November 12–15, the "International Symposium on Stratospheric Variations and Climate" was held at Kyushu University, Fukuoka, Japan (Miyahara *et al.*, 2003, this issue). Following the suggestion by J.R. Holton, we had a special discussion session on the sudden warming and split of the Antarctic ozone hole. Preliminary results on several dynamical aspects were presented by the authors, followed by an intensive discussion session.

Figure 1 (p. II) shows time evolutions of the total ozone field assimilated at KNMI (the Royal Netherlands Meteorological Institute). Animations on the special events, which are also available at their WEB site (http://www.knmi.nl/gome_fd/index.html), clearly show that the elongated ozone hole rotated eastward in mid September, and shifted off

the pole just before the event. The highly elongated ozone hole split into two parts, with the smaller part equatorward of the northwest side of the Antarctic Peninsula disappearing by the end of September.

Time evolution of the polar vortex

The dramatic split and subsequent breakdown of the polar vortex, as well as the accompanying mixing of high- and low-latitude stratospheric air are clearly shown by the sequence of high-resolution fields of Ertel's potential vorticity

(PV) of **Figure 2** (p. III). On 15 September, the vortex is characterised by high (modulus) values of PV (indicated in blue), with a sharp gradient of PV in the associated strong westerly jet stream. Outside the vortex at mid latitudes, gradients of PV are small as a result of the mixing of PV by transient, large-scale anticyclones in the stratosphere, which track eastwards around the polar vortex. Such a flow regime is characteristic of the stratosphere in the Southern Hemisphere at this time of year, and is often accompanied by an elongated polar vortex (Méchoso *et al.*, 1988).

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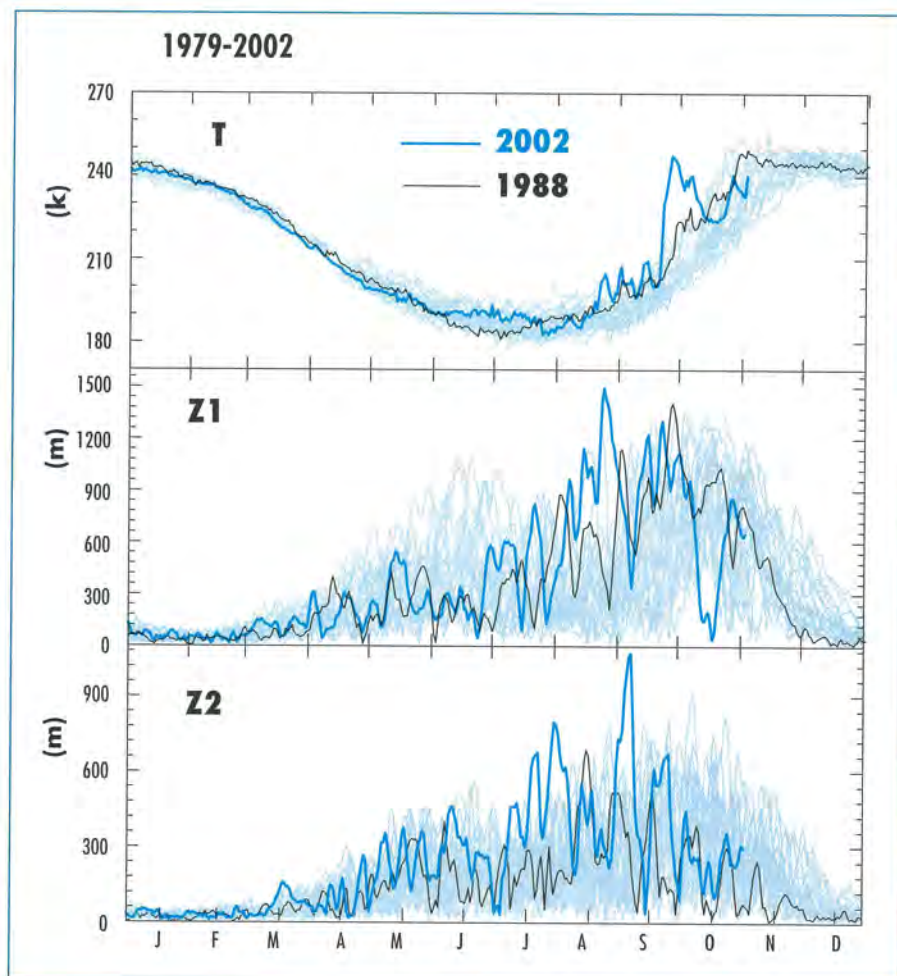


Figure 3. 24-years records of the daily evolution of the polar vortex (NCEP/NCAR reanalysis from 1979 to 2002): temperature at the South Pole (T), geopotential-height amplitudes of zonal wavenumber 1 (Z1) and 2 (Z2) averaged over the latitudes between 60°S and 70°S, at the 20 hPa level.

Figure 2 shows such an elongated polar vortex on 20 September, a few days prior to the split. It seems plausible to regard the elongated vortex as being in a preconditioned state to split (e.g. by tropospheric effects or dynamical instability). The subsequent split leads, on 25 September, to two distinct centres of high (modulus) PV connected by a long thin streamer of air from the edge of the polar vortex. A large anticyclone, centred between Antarctica and Australia, and a weaker anticyclone over the South Atlantic, is evidenced by weak gradients of PV in these regions. Once the vortex has split, the individual vortices are rapidly weakened by the shearing out of PV around the anticyclones, as indicated on 30 September.

Evolution of the SH polar vortex during the past 24 years

Figure 3 (p. 24) shows the daily evolution of two quantities which characterise the polar vortex from 1979 to 2002: temperature at the South Pole (top) and geopotential height amplitudes of zonal wavenumber 1 (middle) and 2 (bottom) in high latitudes, at the 20 hPa level. The polar temperature in late September 2002 was extremely high (blue line), indicating this is an unprecedented event at least in the past 24 years. Three minor warming events are also observed in late August and early to mid September, which are comparable to that in 1988 (black line). These warming events are associated with amplification of planetary waves. The daily amplitude of wavenumber 1 is very large in August 2002, while that of wavenumber 2 is large in July and early September. We note that the largest amplitudes of wave 1 and wave 2 ever observed occurred during the winter of 2002.

Year-to-year variations of the monthly mean of the daily amplitudes of zonal wavenumber 1 and 2 are shown in **Figure 4** (p. IV) for July (a), August (b), September (c), and October (d), together with the monthly temperature at the pole in colour. The monthly mean values for both wavenumbers are large in July, August and September 2002, although either amplitude in some years is comparable to that in 2002 (e.g., $[Z_1]$ in 1988 and $[Z_2]$ in 1997 in September). The planetary waves in the polar region are quite active through the winter 2002.

Vertical linkage of the events

Here we describe the vertical linkage of the events on the basis of the U.K. Met Office stratospheric assimilated data and compare it with a typical year (2001) when the usual seasonal march was observed. **Figure 5** (p. IV) shows time-height sections of the zonal mean zonal wind at 60°S for the period from July to October in 2002 (top) and 2001 (bottom). In 2002, we can see a regularly oscillatory change of the polar night jet with a typical time scale of about 10 days throughout the winter season prior to the sudden warming. Eventually, the sudden warming occurred on 26 September, with winds reversing to easterly at 10 hPa, 60°S and a reversal of the temperature gradient between 60°S and the pole, meeting the WMO criteria for a major stratospheric warming.

Figure 6 (p. V) illustrates time-height sections of the Eliassen-Palm flux at 60°S and the wave driving due to its divergence of zonal wavenumbers 1 and 2 for the period from July to October in 2002 and 2001. From these panels, it can be seen that planetary wave activities of both wavenumber 1 and 2 are very strong throughout the period in 2002 while those are relatively weak in 2001. These periodic strengthening seen in 2002 corresponds to the regular oscillation of the polar night jet. In particular, the difference between the two years is fairly large in the upper stratosphere due to the frequent occurrence of vertical propagation of planetary waves, which results in the strong deceleration of the westerlies. However, the deceleration giving rise to the sudden warming is rather inconspicuous, whereas the strong deceleration can be seen in the second half of August. As shown in **Figure 5**, such strong deceleration corresponds to the sequential occurrence of minor warmings; after that the strong polar vortex could not be fully re-established. Hence, it appears that the vortex was fairly vulnerable to planetary-wave activity, i.e., preconditioned. The conditions necessary for the major warming were in fact the results of several minor warming events during mid-to-late winter.

Southern Annular Mode

The warming event was remarkable not just for its intensity, but for its duration, penetration to the lowermost stratosphere, and coupling to the surface.

The time-height development of the event can be seen through changes in the Southern Annular Mode (SAM) (**Figure 7** p. VI). The SAM patterns are a measure of the strength of the polar vortex at each pressure level, and are defined as the leading empirical orthogonal function of slowly varying (in this case 90-day low-pass filtered) geopotential anomalies. At each level a positive SAM (blue) corresponds to a strong vortex, with negative geopotential anomalies over the polar cap and positive geopotential anomalies over midlatitudes (Thompson and Wallace, 2000).

In **Figure 7** the stratospheric vortex was weaker than normal throughout the winter, with 10-hPa values continuously negative until the end of November. The major warming was preceded by nearly three months of an anomalously weak stratospheric vortex, becoming much weaker during September (the average stratospheric SAM value in September before the onset of the warming is $\sim -2\sigma$).

The troposphere was not unusual before September, but during September the tropospheric SAM also became negative, and remained continuously negative during September, October, and most of November. This is consistent with behaviour seen in the Northern Hemisphere in which the tropospheric NAM tends to be biased toward the NAM in the lowermost stratosphere near 150 hPa (Baldwin and Dunkerton, 2001). The long time scale of the tropospheric SAM is also consistent with the long-lived stratospheric anomaly. What is not obvious in **Figure 7** is a clear downward propagation of stratospheric anomalies, as seen in Baldwin and Dunkerton (2001). In terms of the SAM, the warming appears to have occurred first in the lowermost stratosphere, rather than propagating downward. However, the most negative SAM values, exceeding -6σ , occurred at 10 hPa, coincident with the warming.

The warming event was not only unprecedented in the Southern Hemisphere, but the SAM values exceeded those seen in the Northern Hemisphere. An event of this magnitude, intensity, and duration has never been observed in either hemisphere.

Upper troposphere and lower stratosphere

Figure 8 (p. VI) shows a sequence of fields of geopotential height and temperature at 100 hPa near the base of the stratosphere during the time of the split.

The circulation is dominated by a strong westerly vortex (a), with a zonally asymmetric temperature structure. The strongest temperature anomaly is located between Antarctica and Australia, overlying the stronger of the two anticyclones involved in splitting the stratospheric polar vortex. The westerly vortex at 100 hPa evolves into two distinct cyclonic centres (c) in unison with the split in the stratospheric polar vortex, recombining into one centre (d) as the stratospheric polar vortex breaks down. Modelling studies will be needed to determine whether this evolution of the vortex in the upper troposphere and lower stratosphere near 100 hPa can be regarded as having "forced" the split of the stratospheric polar vortex.

Concluding remarks

In order to discuss the rarity of the stratospheric sudden warming event in September in the Southern Hemisphere, we refer to a recent work by Taguchi and Yoden (2002) with a simple global circulation model. They investigated interannual variations of the troposphere-stratosphere coupled system based on 1,000 year integrations. In a run corresponding to the Southern Hemisphere, a highly skewed distribu-

tion of the polar temperature in the upper stratosphere is obtained for the months from April to September (their Figures 1 and 2). The probability distribution is far from the normal (Gaussian) distribution, and about 0.5% of the 1,000 years are extremely warm with a monthly temperature anomalies exceeding 6σ . The skewed probability distribution requires careful treatment in the statistical arguments of the rarity. The possibility of major warmings in the Southern Hemisphere is also supported by some GCM experiments – prior to September 2002 the occasional major warmings in the Southern Hemisphere were considered a model "defect."

We are not aware of any results that implicate climate or ozone trends in the occurrence of the 2002 major warming, and we find no evidence that this event should change our expectations concerning the recovery of the ozone hole over the next few decades. Rather, it appears that the event was simply unusual – perhaps a one in fifty or one hundred year event. However, despite carefully worded press releases and scientific papers, it is difficult to avoid the public perception that natural processes "filled in" the 2002 ozone hole and that the ozone hole will be less of a problem in the future.

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Announcement

Petra M. Udelhofen Memorial Fund

A reminder: Honour the memory of our former colleague Petra M. Udelhofen, by donating to the Petra M. Udelhofen Memorial Scholarship fund. The fund has been established by the Marine Sciences Center of SUNY to pay tribute to Petra's research accomplishments in atmospheric science, her support of the atmospheric sciences community through her work on the SPARC Data Center, and her being such a joyous colleague.

The goal is to establish a perpetual scholarship award with an initial endowment fund of \$10,000. Efforts will be made to expand the funding base in the future by inviting Petra's friends, colleagues and family members to honour her memory by participating in this special tribute.

The Petra M. Udelhofen Scholarship Award will be given to a student who will be entering his/her senior year of study. The first award of \$500 will be given in the Spring of 2003.

Gifts made payable to the SBF/Udelhofen Scholarship can be mailed to the Marine Sciences Research Center at: Udelhofen Fund c/o Ms. Gina Gartin MSRC SUNY/Stony Brook Stony Brook, NY 11794-5000, USA

Bank transfer can be made at:
Bank Name: The Chase Manhattan Bank
Address: Municipal/Correspondent Banking
52 Broadway 12th Floor,
New York, NY 10004-1699, USA
Contact: Valeria D. Cappucci
Phone Number: 212-701-4070
ABA# 021-000021
For Credit to: 777-952688
Stony Brook Foundation, Inc.
Reference: Your company name and Stony Brook Foundation account number and/or contact person.

Executive Summary of the 2002 Scientific Assessment of Ozone Depletion is Released

Assessment Panel Coauthors: A.-L. Ajavon, D. Albritton, G. Mégie, and B. Watson

On 23 August 2002, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) jointly released the Executive Summary of the "Scientific Assessment of Ozone Depletion: 2002." The Executive Summary is available at the following web sites of these sponsoring organizations: <http://www.wmo.ch/web/arep/ozone.html> and <http://www.unep.org/ozone/publications.shtml>.

The Executive Summary describes the main scientific points, established at a peer-review meeting on 24 – 28 June 2002. This assessment report will be one of the quadrennial reports to the Montreal Protocol on the status of the understanding of the stratospheric ozone layer. Participating in the writing and review of the 2002 report were 269 scientists worldwide. The printed report will be available in April, 2003. NOAA, NASA, and the European Commission co-sponsor the report's publication. Along with the Executive Summary and the five chapters will be "Twenty Questions and Answers About the Ozone Layer" which is written for a broad readership of decision-makers, educators, students, and the general public.

The key points from the Executive Summary of the "Scientific Assessment of Ozone Depletion: 2002" are the following:

Recent major findings and current scientific Understanding

Changes in ozone-depleting compounds

- In the troposphere (i.e., lower atmosphere), observations show that the total combined effective abundance of ozone-depleting compounds continues to decline slowly from the peak that occurred in 1992-1994. Total chlorine is declining, while bromine from industrial halons is still increasing, albeit at a slower rate than was occurring previously (and as reported in the 1998 Assessment).
- Analyses of air trapped in snow since the late 19th century have confirmed that non-industrial sources of the CFCs, halons, and major chlorocarbons were insignificant.
- The abundances of HCFCs in the

lower atmosphere continue to increase.

- Observations in the stratosphere indicate that the total chlorine abundance is at or near a peak, while bromine abundances are probably still increasing.
- Very short-lived organic chlorine-, bromine-, and iodine-containing source gases have the potential to deplete stratospheric ozone, but quantitative estimation of their potentials is more challenging than for longer-lived species like CFCs.

Changes in the ozone layer over the poles and globally

- Springtime Antarctic ozone depletion due to halogens has been large throughout the last decade.
- In some recent cold Arctic winters during the last decade, maximum total column ozone losses due to halogens have reached 30%.
- Ozone remains depleted in the mid-latitudes of both hemispheres.
- Models including observed changes in halocarbons, source gases, and aerosols (i.e., airborne fine particles) capture the observed long-term ozone changes in northern and southern mid-latitudes.
- Chemistry-climate models predict that springtime Antarctic ozone levels will be increasing by 2010 due to projected decreases of halogens in the stratosphere.
- Arctic ozone depletion is highly variable and difficult to predict, but a future Arctic polar ozone hole similar to that of the Antarctic appears unlikely.
- The global ozone layer recovery is expected to be linked mainly to decreasing chlorine and bromine loading, but other factors are likely to contribute.

Changes in ultraviolet radiation

- Changes in the duration and spatial extent of the ozone hole are more important for Antarctic surface ultraviolet (UV) radiation levels than the annual ozone minimum.
- Additional measurements continue to confirm that decreases in ozone column amounts lead to increases in UV radiation.

The ozone layer and climate change

- The understanding of the impact of ozone depletion on climate change has been strengthened.

- Other atmospheric changes influence both the ozone layer and the climate system.
- New research has begun to explore the coupling between climate change and the recovery of the ozone layer.

Implications for policy formulation

- The Montreal Protocol is working, and the ozone-layer depletion from the Protocol's controlled substances is expected to begin to ameliorate within the next decade or so.
- The ozone layer will remain particularly vulnerable during the next decade or so, even with full compliance. With the atmospheric abundances of ozone-depleting substances being near their highest, the human-influenced perturbations will be at or near their largest. Relative to the pre-ozone-hole abundances of 1980, the 1997-2001 losses in total column (i.e., overhead) ozone amounts are:
 - about 4 % at northern mid-latitudes in winter/spring;
 - about 2 % at northern mid-latitudes in summer/fall; and
 - about 6 % at southern mid-latitudes on a year-round basis.
- Calculations yield that such changes in ozone correspond to increases in surface erythemal radiation of at least 5, 2, and 7 %, respectively, if other influences such as clouds remain constant.
- Approaches to accelerating the recovery of the ozone layer are limited.
- Failure to comply with the Montreal Protocol would delay or could even prevent recovery of the ozone layer.
- Estimating the impacts of very short-lived ozone-depleting substances on depletion of the ozone layer requires new approaches, and, as requested by the Parties, this assessment has described one such scientific approach.
- The issues of ozone depletion and climate change are interconnected.

SHADOZ (Southern Hemisphere Additional Ozonesondes): A New Source of Ozone and Temperature Data from a Tropical Network

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Background and Project

Total ozone column amount, a sign of the health of stratospheric ozone, is tracked by satellite in concert with a ground-based network of upward-looking Dobson or Brewer spectrophotometers. For analysis of stratospheric and tropospheric processes and trends,

profiles from balloon-borne ozonesondes are also required. The network of stations used for the 1998 Assessment sponsored by SPARC and the International Ozone Commission (WMO, 1998; Randel *et al.*, 1999) and the on-going series of WMO/UNEP Ozone Assessments (WMO, 1999) consists of approximately 100 sites at middle and high latitudes of

the northern hemisphere (<http://www.msc-smc.ec.gc.ca/woudc/>). Ozonesonde measurements have been made regularly since the late 1970's at Natal, Brazil (Kirchhoff *et al.*, 1981) but at most other tropical locations, measurements have been associated with campaigns or with local efforts unsupported for data distribution.

Station	Location	Co-I/Affiliation	Operational Time
Ascension Is.	8S, 14W	F. J. Schmidlin NASA/WFF	1990-92; 1997-pres.
American Samoa	14S, 171W	S. J. Oltmans NOAA/CMDL	1995-present
San Cristóbal, Ecuador	1S, 90W	S.J. Oltmans NOAA/CMDL	1999-present
Fiji Is.	18S, 178E	S. J. Oltmans NOAA/CMDL	1996-present
Watukosek, Java	8S, 113E	T. Ogawa NASDA, Japan	1993-present
Nairobi, Kenya	1S, 37E	B. Hoegger, B. Calpini Météo Suisse	1996-present
Malindi, Kenya	3S, 40E	G. Laneve Univ. Rome, Italy	1999-present
Natal, Brazil	5S, 35W	V. W. J. H. Kirchhoff INPE, Brazil	1978-present
La Réunion, France	21S, 55E	F. Posny Univ. de La Réunion	1992-present
Irene, S. Africa	26S, 28E	G. J. R. Coetzee SAWS	1990-93; 1998-pres.
Tahiti Is.	18S, 149W	S. J. Oltmans NOAA/CMDL	1995-1999
Paramaribo, Surinam	5N, 55W	H. Kelder KNMI, The Netherlands	1999-present

Table 1: SHADOZ tropical and subtropical ozonesonde stations. Only data from 1998 onward is in the SHADOZ archive.

Table 2: Campaign Data

Campaign	Location	Reference	Sampling Period
Aerosols 99 Cruise	US to So. Africa	Thompson <i>et al.</i> (2000)	January-February 1999
SOWER	Christmas Is. (2N, 157W)	Hasebe <i>et al.</i> (2000)	March 1999
INDOEX	Kaashidhoo, Male Is, (5N, 74E)	Zachariasse <i>et al.</i> (2001)	February-March 1999
SAFARI-2000	Lusaka, Zambia (15S, 28E)	Thompson <i>et al.</i> (2002c)	September 2000

In 1998 NASA's Goddard Space Flight Center (GSFC), together with NOAA's Climate Monitoring and Diagnostics Laboratory (CMDL) and international sponsors established the SHADOZ (Southern Hemisphere Additional Ozonesondes) project to address the gap in tropical ozonesonde coverage (Thompson *et al.*, 2002a,b). SHADOZ augments launches at selected sites and provides a public archive of ozonesonde and radiosonde data from eleven tropical and subtropical southern hemisphere operational ground stations (see Table 1). The first SHADOZ site in the tropical northern latitudes (Paramaribo, Surinam) joined in 2000. Data are available to the community at the website maintained at NASA/Goddard (<http://croc.gsfc.nasa.gov/shadoz/>)

Current sampling at all stations is once-per-week or twice a month, usually but not always, mid-week. Balloon-borne ozonesondes are coupled with a meteorological radiosonde for data telemetry transmitting air pressure and temperature, relative humidity, and ozone to a ground receiving station. All stations are using electrochemical concentration cell (ECC) ozonesondes. Radiosonde packages vary from station to station and determine the recording frequency and raw data format. A uniform format is used in the SHADOZ archive, however.

Currently SHADOZ data from 1998-2002 are publicly available (> 1600 ozone and PTU profiles); data from four tropical campaigns also reside at the SHADOZ website. Figure 1 displays the SHADOZ stations and Figure 2 shows a typical profile image displayed at the website for every launch.



Figure 1. Map of SHADOZ stations. There are 11 stations currently operating; Tahiti ceased launches at the end of 1999.

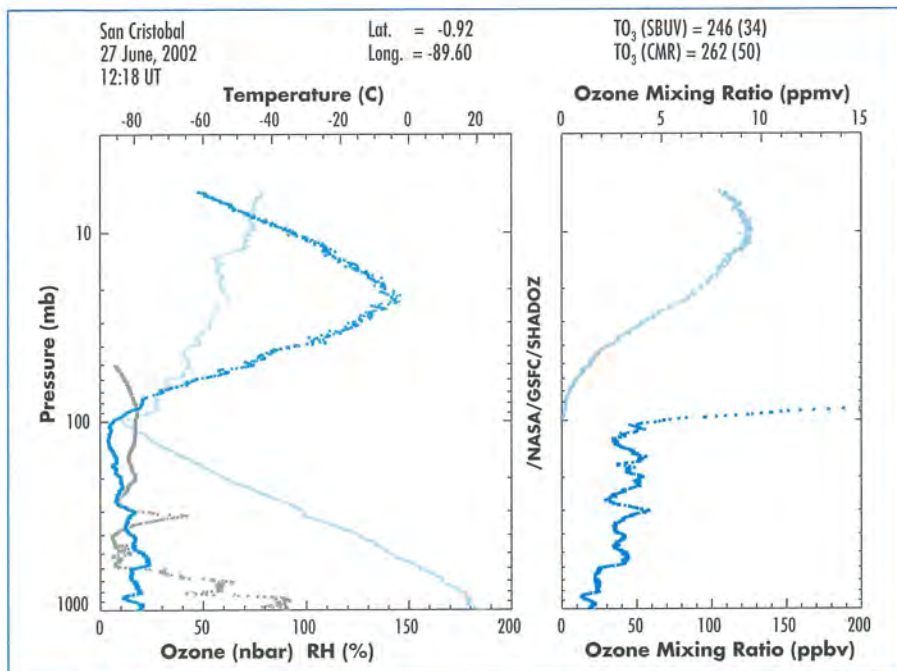


Figure 2. An example of a typical sonde profile image at the SHADOZ website: San Cristóbal in the Galapagos, 27 June 2002.

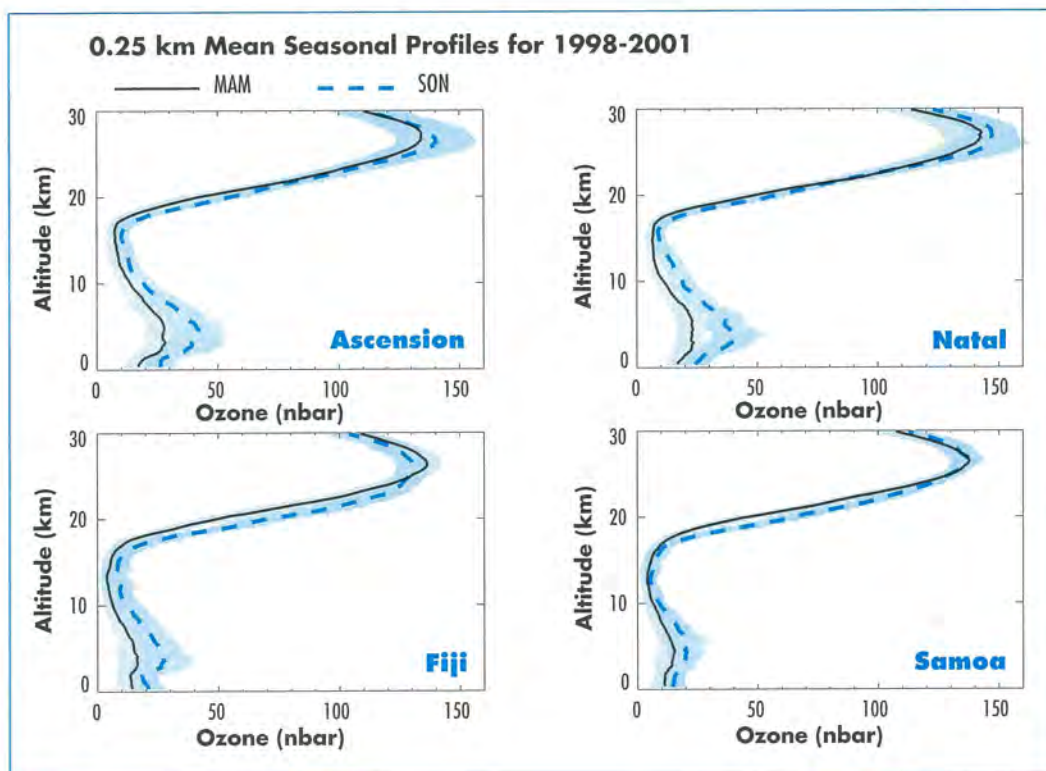


Figure 4. Seasonal profiles using 1998-2001 data for four SHADOZ stations: Ascension; Natal, Fiji, Samoa. Solid line represents March-April-May (MAM) 0.25 mean profiles. Dashed lines represent September-October-November (SON) means. Blue shading is the 1-sigma deviation around the mean.

In addition to the data archive, the SHADOZ website displays kinematic back-trajectories corresponding to the location and time of each station launch. Using 3-D wind fields and NCEP analyses, five-day back-trajectories are run at tropospheric pressure levels (750, 500, 300 and 200 hPa). Figure 3 (p. VII) shows a typical trajectory image.

Ozone Profile Climatologies from SHADOZ Data

Figure 4 shows seasonal mean ozone profiles for 4 sites. September-October-November (SON) ozone values are greater than for March-April-May (MAM) throughout the entire profile. The shading, representing the 1-sigma range of variability, shows greatest breadth in the middle stratosphere (where the sonde instrument becomes "noisy") and in the troposphere. Seasonal mean differences (between MAM and SON) for stratospheric column ozone range from 11-20 DU, depending on site (Thompson *et al.*, 2002a). Less than 5 DU of this difference is due to the tropopause being lower in SON than in MAM.

In the troposphere, week-to-week ozone variations are due to sources with greatly disparate ozone content (e.g. clean marine air vs pollution from biomass fires). This variability is most pronounced at Atlantic stations (e.g. Ascension, Figure 5), Nairobi and Réunion (not shown) in SON. Figure 5 also depicts variations at Fiji that are due to sporadic transport from biomass burning regions of Africa, Southeast Asia

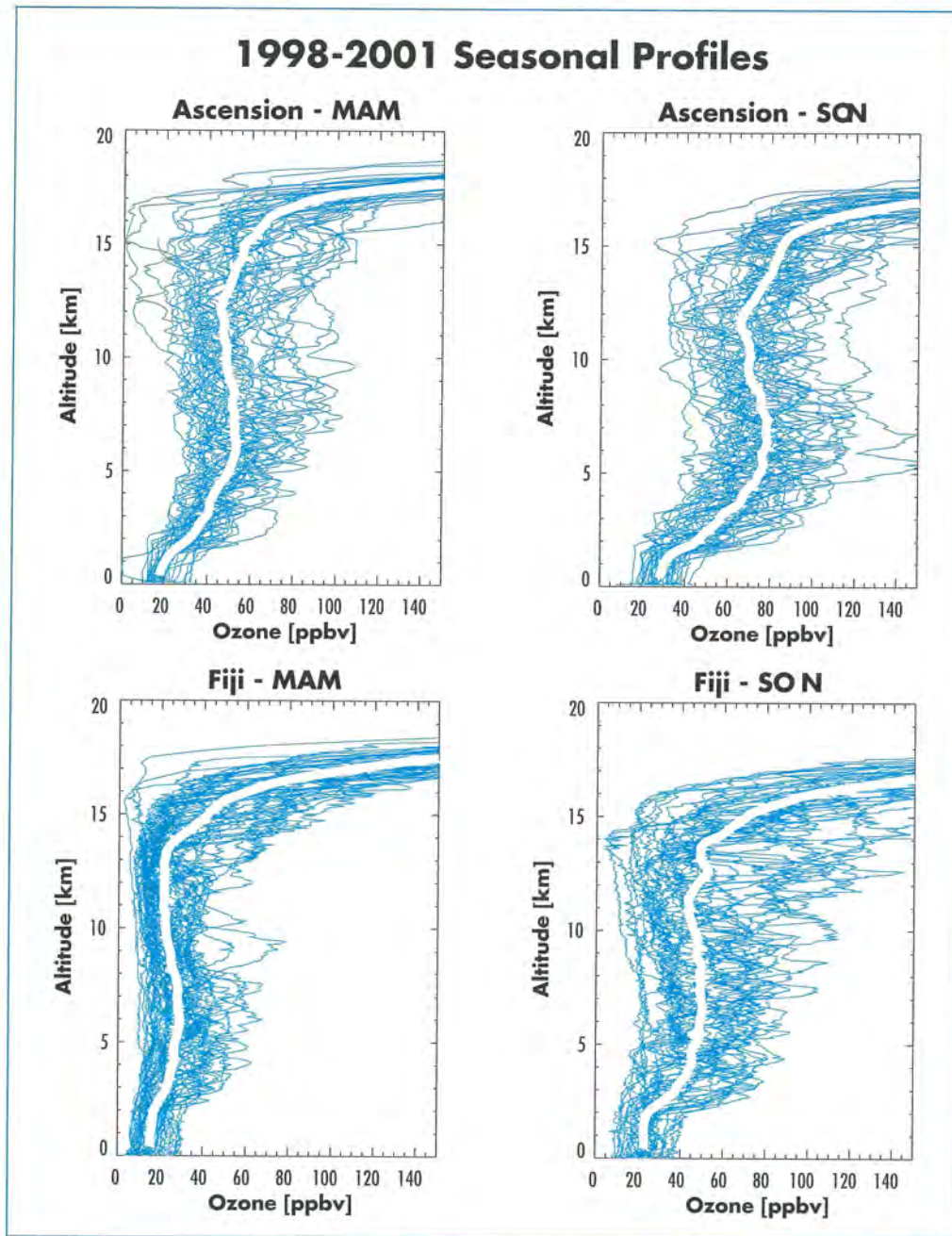
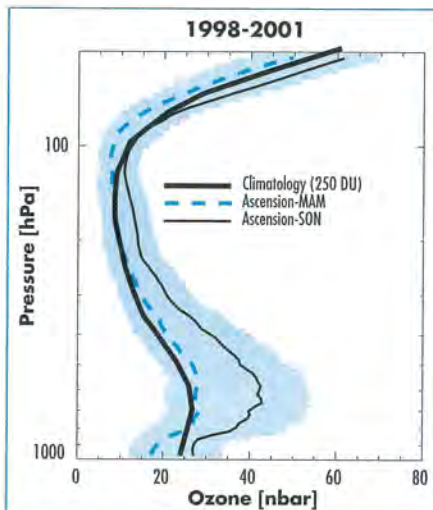


Figure 5. Multiple profiles from 1998-2001 at Ascension and Fiji for March-April-May (MAM) and September-October-November (SON) with the solid white line the mean over the four years.



and Australia. From Figure 5, it appears that averaged profiles, typically used for analysis of trends, may not be statistically robust. Temporal changes in tropospheric ozone might more accurately be evaluated by categorising profiles according to synoptic regime [Diab *et al.*, 2002; Hudson *et al.*, 2002] and analysing each category.

Figure 6. Comparison of the TOMS profile climatology (250 DU total ozone) with 1998-2001 km mean profiles for MAM (March-April-May) and SON (September-October-November) for Ascension. Blue shading indicates the 1-sigma deviation about the seasonal means. Other station comparisons appear in Thompson *et al.* (2002b)

The variability in tropospheric ozone observed in SHADOZ profiles has implications for satellite ozone retrievals. For example, a typical satellite profile, that used by the EP-TOMS (Earth Probe - Total Ozone Mapping Spectrometer) instrument for a total 250 DU ozone column, appears in Figure 6. Seasonally averaged profiles from Ascension Island are also depicted. Note that ozone in SON at Ascension differs markedly from the standard profile. Although the impact on the total ozone column retrieval is relatively small (Thompson *et al.*, 2002b), retrieval in the lower troposphere may be compromised by the discrepancy with the recent observations. SHADOZ offers a more realistic dataset for satellite algorithms.

The Tropical Zonal Wave-one

The zonal wave-one refers to relatively high total column ozone over the tropical Atlantic region compared to the column amount over the Pacific and Indian Ocean regions. The wave-one is seen in satellite data and was first described by Shiotani (1992) and further characterised by Hudson and Thompson (1998). Due to instrument imprecision in the lower stratosphere, satellite data are not adequate to determine whether the wave-one is due to a tendency for the excess ozone in the stratosphere, the troposphere or both. With the comprehensive spatial and temporal coverage of tropical ozone profile provided by SHADOZ, the structure of the wave-one can be studied for the first time.

Figure 7 (p. VII) shows that the wave-one is predominantly in the troposphere (see Thompson *et al.*, 2002b for more details) with an "excess ozone" accumulation in the Atlantic upper troposphere for SON. This is the season of the greatest magnitude of the wave-one, ~20 DU more column ozone over the Atlantic maximum than over the Pacific. It is well-known that transport and recirculation of ozone from African and South American biomass

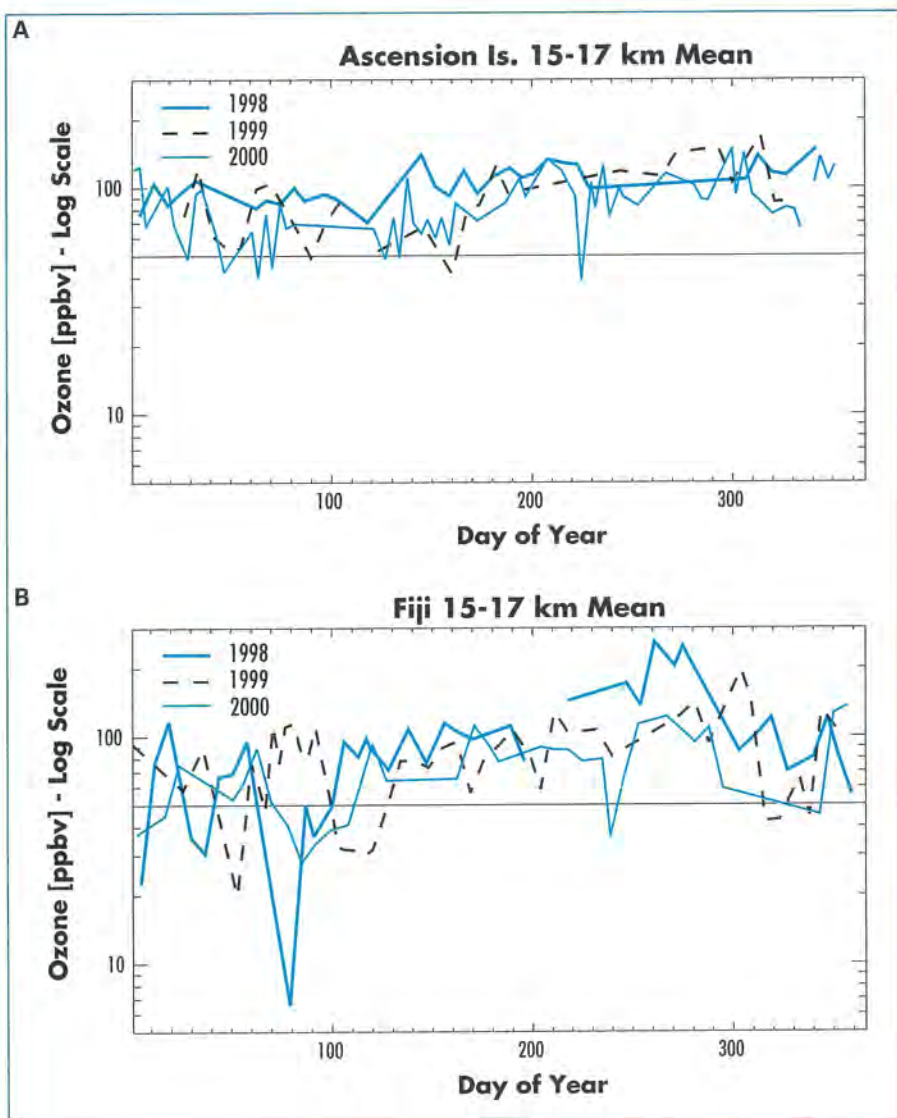


Figure 8. Ozone mixing ratio averaged within the tropopause region (15–17 km) for (A) Ascension Island; (B) Fiji. Note log scale and variations from year to year.

burning is a factor in the higher-ozone features in the middle troposphere over the Atlantic, adjacent continents, and western Indian Ocean (Fishman *et al.*, 1990; Thompson *et al.*, 1996). At all times of year upper tropospheric “excess ozone” over the Atlantic maintains a wave-one feature (Thompson *et al.*, 2002a,b).

Convection in the Tropical Tropopause Layer

The tropopause is normally between 16–18 km except for the two most southerly SHADOZ sites (Réunion, Irene). Ozone variability in the 14–17 km region has been discussed by Folkins *et al.* (2000, 2002) where the tropopause has been found to be better described as a transition zone several km thick, the so-called TTL (tropical tropopause layer) rather than as a single-level sharp feature. In the TTL

convective influence is highly variable. At Ascension Island, the week-to-week variability (Figure 8a) is relatively small (subsidence over the Atlantic dominates over convection) whereas at Fiji (Figure 8b) convection frequently brings low ozone air from the marine boundary layer into the upper troposphere.

Quasi-Biennial Oscillation

Thanks to dense temporal coverage of stratospheric ozone profiles near the equator, variations due to the QBO (Quasi-biennial Oscillation) have been identified in SHADOZ data. At most stations the SHADOZ record is approaching five years, approximately two full cycles of the QBO. Near the ozone mixing ratio maximum, variations due to shifts in easterly and westerly winds are most evident. An example through the 1998–2001 ozone

record at Nairobi appears in Figure 9 (p. VIII). A paper by Logan *et al.* (2002) discusses the QBO, SHADOZ and concurrent satellite data in detail.

Interaction with WMO

Although ECC sondes are used at all SHADOZ, small station-to-station differences in technique have been detected in the total ozone column (Thompson *et al.*, 2002a). WMO's JOSIE (Jülich Ozone-sonde Intercomparison Experiment) activity has been working with the sonde community to understand these differences through a series of chamber tests (1996, 1998, 2000) and an upcoming field evaluation exercise (BESOS, June 2003). One goal for WMO is a standard procedure for ozone-sonde operations for implementation at new GAW (Global Atmospheric Watch) stations. SHADOZ Investigators participated in JOSIE-2000 through comparison of sonde instruments with a calibrated spectroscopic instrument in chamber tests conducted at the Forschungszentrum – Jülich (<http://www.fz-juelich.de/cgi-bin/icg2toicgii.cgi>)

Summary

Over 1600 ozone and PTU profiles archived between 1998 and 2002 are now at the SHADOZ website: <http://croc.gsfc.nasa.gov/shadoz/>. With unprecedented coverage of southern tropical ozone data from SHADOZ the following scientific advances have been possible: improvement of the profile climatology for satellite algorithms; elucidation of the structure of the zonal wave-one in tropospheric ozone; delineation of vertical characteristics of the ozone response to the QBO.

Acknowledgments

SHADOZ is a partnership that would not be possible without the following sponsors: NASDA (National Space Development Agency of Japan), LAPAN (Lembaga Penerbangan dan Antariksa Nasional, the National Institute of Aeronautics and Space Agency of Indonesia), INPE (Instituto Nacional de Pesquisas Espaciais of Brazil), the South African Weather Bureau, the Swiss Meteorological Agency, the Kenyan Meteorological Department, the University of the South Pacific (Suva, Fiji), the University of Réunion Island (France), the Royal Dutch Meteorological Institute. For overall

coordination and support, Goddard Space Flight Center, Wallops Flight Facility, NOAA's Climate Diagnostics and Monitoring Laboratory, NASA's ACPMAP and TOMS Programs are gratefully acknowledged. We appreciate the opportunity to participate in ozonesonde evaluations through the JOSIE outreach of WMO's Global Atmospheric Watch (GAW) Project.

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VINTERSOL - A new European Field Campaign

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VINTERSOL (Validation of International Satellites and study of Ozone Loss) is a major European field campaign studying stratospheric ozone. VINTERSOL ('Winter sun' in the Scandinavian languages) is taking place from late 2002 until mid 2004. There have been three previous European campaigns: the European Arctic Stratospheric Ozone Experiment (EASOE) in 1991/92; the Second European Stratospheric Arctic and Mid-latitude Experiment (SESAME) in 1994/95; and the Third European Stratospheric Experiment on Ozone

(THESEO) in 1998/2000. Like them, VINTERSOL relies on support from national funding agencies and from the Environment and Sustainable Development programme of EC DG Research. More information on VINTERSOL, including the full planning document, can be found at <http://www.ozone-sec.ch.cam.ac.uk/>

There are four main scientific themes within VINTERSOL:

- polar ozone loss
- ozone at mid-latitudes
- UV radiation
- tropical chemistry and dynamics

These are being addressed in the three main phases:

- intensive Arctic ozone loss studies in the 2002/03 winter/spring;
- ozone loss studies in the Antarctic winter and spring 2003
- balloon and aircraft studies in the tropics in early 2004.

In addition, a number of measurement and modelling projects are running continuously through this period yielding information on the longer time-scale processes in the stratosphere, and there is a small balloon campaign in the tropics in early 2003 in preparation for the main tropical phase.

An important dimension for VINTERSOL is the involvement of several new European satellite instruments. Measurements from the ERS-2 GOME satellite instrument (operational since 1995) and from the POAM III instrument on the SPOT IV satellite (operational since 1998) continue to be used. The ODIN satellite (launched in February 2001) and ESA's Envisat satellite (launched in March 2002) data are being validated and analysed.

The international dimension to earth observation studies is increasingly evident. There is close collaboration between VINTERSOL and field campaigns primarily associated with satellite validation. Close links, including joint flight planning and data sharing, have been forged with the NASA SAGE III Ozone Loss and Validation Experiment II (SOLVE II, see <http://cloud1.arc.nasa.gov/solveII/index.html>) based on the successful cooperation in SOLVE THESEO 2000 in the 1999/2000 winter. Cooperation has also been agreed with the Envisat validation activities (<http://envisat.esa.int>) organised by the ESA and national space agencies through the Atmospheric Chemistry and Validation Team (ACVT) and particularly its Envisat Stratospheric Aircraft and Balloon Campaigns (ESABC). All three field campaigns have extensive field activities in Kiruna, Sweden (68°N) during the 2002/03 winter. The joint initiative involves over 400 scientists from the European Union, Canada, Iceland, Japan, Norway, Poland, Russia, Switzerland and the United States. Aircraft, large and small balloons, ground-based instruments and satellites are being used to measure ozone and other atmospheric gases and particles. The combined activities thus aim to improve understanding of Arctic ozone depletion, and at upgrading satellite observation of the ozone layer. In addition, VINTERSOL significantly extends the scope and duration of the other planned satellite validation activities.

Arctic Ozone

November 2002 to March 2003

An improved understanding of polar ozone loss is one of the major aims of VINTERSOL. A great deal has been learnt in recent years, particularly during SOLVE-THESEO 2000, but there are a number of outstanding issues which restrict our ability to understand the processes leading to polar ozone loss and to predict future ozone

losses with confidence. Many of these (vortex dynamics; particle composition; denitrification; heterogeneous processes; the photochemical reactions depleting ozone; empirically determined and modelled ozone losses; and the relation between Arctic and Antarctic ozone loss) are addressed directly in VINTERSOL

The 2002/03 Arctic phase will involve several aspects:

- two European research aircraft (M55 Geophysica and DLR Falcon);
- several large balloons at Esrange;
- a Match ozonesonde campaign;
- ground-based measurements, including the NDSC UV-vis comparison;
- existing satellite instruments (GOME, POAM III and ODIN);
- a period of special study for data assimilation; and
- chemical transport modelling.

The M55 Geophysica and the DLR Falcon are based in Kiruna during January and February 2003 in the EC EUPLEX project. The Falcon with a remote-sensing payload acts as a pathfinder for the Geophysica (with primarily an *in situ* payload) directing it, for example, into synoptic and lee-wave PSCs. The Geophysica is also studying the chemical evolution in individual air parcels by measuring in them twice a few days apart. Trajectory calculations based on analysed and forecast winds from ECMWF are triggered along all flight tracks. If the air masses return to within the aircraft range, e.g. after they circled the polar vortex once, they can be probed again. The NASA DC-8 is based in Kiruna in January and early February, and is closely coordinated with the Geophysica and Falcon. In March, the Geophysica and Falcon are involved in Envisat validation with the Geophysica based in Kiruna and the Falcon covering a wide range of latitudes from the pole to the equator.

Three successful balloon flights took place in early December 2002 within the CIPA/POSTA projects. Two flights of the PSC Analysis gondola and one of the MIPAS-B instrument were made from Esrange in synoptic scale PSCs. The PSC Analysis payload carried instruments for comprehensive *in situ* measurements of chemical and physical properties of PSC particles. The MIPAS instrument flew simultaneously with the second PSC Analysis flight to study the interaction between HNO₃ gas phase abundance and PSC formation, while the DLR Falcon aircraft performed upwind and down-

wind flights to observe the larger scale properties of the PSCs. In addition to these VINTERSOL flights, there are two flights of the NASA OMS remote balloon payload within SOLVE II and 11 flights for a variety of European payloads in ESABC, four in late January and seven in March.

An Arctic Match campaign involving about 500 ozonesondes and 13 stations is organised within the QUOBI project. Air parcels in which ozone has been measured are tracked and, if these air parcels are likely to pass over another station, launch requests are issued to the stations. While the main aim is to provide accurate estimates of ozone loss rates for comparison with stratospheric models, two periods of special interest have been identified. First, with the vortex cold in November/December 2002, a Match campaign is being run to study ozone loss in cold dark conditions. Second, special attention is being paid to making good estimates of the ozone loss as this is the period where there are significant disagreements with photochemical models. The Match ozone loss studies are complemented by other approaches using ozonesonde, satellite and ground-based data.

Ground-based observations in the Northern Hemisphere are being made throughout the 2002/2003 Arctic winter, using instruments measuring stratospheric composition (UV-vis, FTIR, lidars and microwave instruments which are principally from NDSC and NDSC-related sites), total ozone in the WMO GO₃OS, and UV radiation in the European UV network. These are involved in the EU projects EDUCE, QUILT and UFTIR. In addition, the lidar at Esrange is operational for several weeks in January and February 2003. The NDSC comparison of UV-vis instruments takes place between mid-February and mid-March 2003.

Measurements from satellites such as GOME, POAM III and ODIN are used for studies of the 2002/2003 Arctic winter. With the ODIN satellite, atmospheric measurements (ClO, HNO₃, OClO and BrO) are made normally about one day in three. However arrangements have been made for additional 15 days of atmospheric observations in early 2003. Further with a few days warning, it is possible to change the observational schedule so that extended periods of observations can be made in periods of special interest.

Envisat measurements are not routinely available for scientific use until after the commissioning and validation phase. However the available data are being used in chemical data assimilation models to produce synoptic maps of several key species and in cloud detection schemes to identify PSCs and cirrus. In addition, GOME data are being assimilated to provide ozone fields. SAGE III data are also available in near real-time.

A range of models are being run in the 2002/03 winter within the MAPSCORE, QUOBI and TOPOZ III projects. SLIMCAT and REPROBUS are run throughout the winter with full 3-D chemical fields available within a few days, and other 3D CTMs will be run with longer delays. Detailed models of PSC microphysics and chemistry are used to interpret the aircraft measurements and the PSC Analysis, MIPAS and other balloons. Any widespread denitrification of the vortex is being studied with composite model approaches linking microphysical models, pseudo-Lagrangian trajectories including sedimentation, and 3D chemical transport models. Photochemical Lagrangian models are used to study detailed chemical evolution, for example the results of any aircraft Match flights and the ozone losses from the Match ozonesonde campaign.

Antarctic Ozone June to October 2003

The first ever Antarctic Match campaign will be run between June and October 2003 within the QUOBI project. It will be the most comprehensive analysis of ozone loss rates in the Antarctic ozone hole. Nine stations will be involved in the Match campaign with the participation of the Antarctic research programmes from 8 countries (Argentina, Australia, Finland, France, Germany, Japan, Spain, UK and USA). A total of nearly 600 ozonesondes will be launched between 65° and 90°S (4-5 ozonesondes per day inside the vortex). Approximately 400 additional radiosondes will be launched to improve the quality of the meteorological analyses provided by ECMWF. This will improve the quality of the ozone loss estimates derived by Match and other empirical ozone loss techniques. In addition, it will have the benefit of assisting the meteorological agencies in understanding the factors which limit the quality of their forecasts in this data-sparse part of the world.

The Match campaign will be supplemented by satellite studies, ground-based measurements and modelling. In particular, this will be the first winter at either pole where Envisat measurements are made operationally, so the chemical and particle fields will be well characterised. This means that detailed, well-constrained studies of the observed ozone loss rates can be made. The experience gained in the Antarctic should significantly improve our understanding of the processes occurring in the Arctic.

Tropical phase January to March 2004

The source of chemical species involved in stratospheric ozone depletion at global scale lies in the tropics where they are transported vertically from surface level to the tropopause by deep convection. This vertical transport can take place either gradually as part of the general atmospheric circulation or rapidly in convective storm systems. A number of issues related to the tropical UT/LS which are important for ozone and climate in the future are:

- how water vapour enters the stratosphere, given the unexplained long-term trend in water vapour in the lower stratosphere;
- how short-lived species such as the methyl halides and NO_x emitted at the surface are transported into the UT/LS;
- the influence of the tropical UTLS on global stratosphere-troposphere exchange;
- the formation, composition and impact of cirrus clouds in the tropical UTLS;
- the role of convective systems in determining the composition of the tropical UTLS;
- how well current meteorological models describe the tropical UTLS;
- an improved quantification of the NO_x production by lightning, a prerequisite to evaluate the impact of aircraft.

These issues are important in order to assess the chemical impact on the UTLS of biomass burning, changes of agricultural practices and pollution from the fast growing populations in tropical developing countries. In addition the transport of air out of the tropical UTLS into mid-latitudes is one of the critical factors which determine the composition of air in the mid-latitude lower stratosphere.

The main sub-tropical phase will involve balloons and aircraft campaigns in the HIBISCUS and TROCCINOX pro-

jects. It will take place in January and February 2004 in Sao Paulo State in Brazil. Small balloon and long duration MIR balloon flights will be launched from Bauru and the M55 Geophysica and the DLR Falcon will be deployed nearby. Ozonesondes and additional radiosondes will be launched in the region of Bauru, and there will be access to the measurements made by the lightning network and 2.6 GHz radar. In addition, coordinated measurements will be made from the ground station at La Réunion and full use will be made of in service commercial aircraft measurements within the MOZAIC and CARIBIC projects. Global fields of many chemical constituents in the UTLS will be provided by satellite instruments such as those on Envisat and ODIN. These plans can be modified in the light of the preliminary phase in February 2003. A scientific workshop will take place from 15-17 May 2003 at DLR Oberpfaffenhofen.

This article was written on behalf of the VINTERSOL core group (other members G.O. Braathen, NILU, Norway; M.P. Chipperfield, Univ. Leeds, UK; H. Kelder, KNMI, Netherlands; N. Larsen, DMI, Denmark; M. De Mazière, BIRA-IASB, Belgium; G. Mégie, CNRS, France; D. Murtagh, Chalmers Univ., Sweden; J-P. Pommereau, CNRS-SA, France; J. Remedios, Univ. Leicester, UK; H. Schlager, DLR, Germany; L. Stefanutti, CNR, Italy; F. Strohm, FZ Jülich, Germany; P. Taalas, FMI, Finland; and P. von der Gathen, AWI-Potsdam, Germany).

LAPBIAT* Upper Troposphere Lower Stratosphere Water Vapour Validation Project: LAUTLOS - WAVVAP

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The focus of this project is the improvement of water vapour measurement techniques in the Upper Troposphere and Lower Stratosphere (UT/LS). Routine measurements of water vapour with high accuracy at these altitudes are an unsolved problem up to now despite many activities in the past ten years. Water vapour is a dominant greenhouse gas in the earth's atmosphere. Recent model calculations show that observed water vapour increases in the stratosphere contribute significantly both to surface warming and stratospheric cooling. In addition to climate change, both direct chemical and indirect radiative effects of stratospheric water changes on ozone chemistry are important as well. Therefore one of the aims of the forthcoming EU COST Action 723 "The Role of the Upper Troposphere and Lower Stratosphere in Global change" is to improve balloon sounding and remote sensing techniques of water vapour measurements (see <http://www.sat.uni-bremen.de/cost/>).

Another example of the work focusing on water vapour is proposed by the GEWEX Water Vapour Project (GVaP) (see SPARC Report No. 2, December 2000 and the references therein).

The idea of LAUTLOS-WAVVAP is a comparison/validation experiment, which brings together lightweight hygrometers developed in different research groups, which could be used as research-type radiosondes in the UT/LS region. These include: Meteolabor Snow White hygrometer, NOAA frost-point hygrometer, CAO Flash Lyman alpha hygrometer, Lindenberg FN sonde (a modification of the Vaisala radiosonde) and the latest version of the regular Vaisala radiosonde with the humicap-polymer sensor. The experimental plan is based on regular launches of multi-sensor payloads at Sodankylä in January – February 2004. The aim is to study the effect of atmospheric parameters such as ambient temperature, water vapour content or relative humidity, air pressure and solar radiation on each

participating hygrometer/radiosonde records. Both night and daytime launches are planned. The campaign also aims at studying PSC occurrence and their dependence on local temperature and water vapour content. It will be hosted by the FMI Arctic Research Centre Sodankylä assisted by Vaisala Oyj and is part of the planned Finnish contribution to Cost 723 project. The campaign is partly funded from the LAPBIAT Facility, which belongs to the EU program: Access to Research Infrastructures (www.sgo.fi/lapbiat/).

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** Lapland Atmosphere-Biosphere Facility
Improving the Human Research Potential and the
Socio-Economic knowledge Base*



Report on the 34th COSPAR Scientific Assembly

Houston, TX, USA, October 10-19, 2002

COSPAR A.1.1/C.2.7 Event:

Climate change processes in the stratosphere and at the tropopause

Main Scientific Organizer:

J. Gille (gille@ucar.edu),

Sponsor: SPARC

To highlight the connection between space-based data and SPARC, **J. Gille** and **J. Remedios** organised this 1.1/2-day session aimed to discuss numerous new measurements now becoming available and analysis methods,

models showing the roles of stratospheric process in climate change, and studies of transports across the tropopause and other atmospheric barriers.

Twenty-three oral papers and six posters were presented. The attendance was very good. Tentative plans are to have another such session at the next COSPAR Assembly.

V. Ramaswamy described the evidence for the downward trend in stratospheric temperatures. He put as

the next challenge the full documentation and understanding of the inter-annual variations on continental to global spatial scales observed in the last three decades.

Some talks presented early results from Envisat. **H. Fischer** introduced the MIPAS FTIR spectrometer, preliminary profiles and cross-sections of temperature, O₃, H₂O, and 12 other gases. The operational analysis of MIPAS spectra, using microwindows, was outlined by **B. Carli**, with exam-

to solar proton events. Good agreement was found between photochemical simulations of ozone response and observations from UARS. At the same time observed NO_x production by SPE in July 2000 was weaker than in model runs (C. Jackman). A. Ondraskova *et al.* calculated the response of electron density and some ions in the D-region after strong SPE using 1-D models for neutral and ionized chemical compounds. Special focus was made to understand the response of the D-region in night conditions. The stratospheric aerosols data sets from 1953 were analysed jointly with galactic cosmic ray (GCR) data (F. Vanhellemont *et al.*). The analysis partly supported the idea that the link between GCRs and stratospheric aerosols exists, but it needs special effort to understand a physical mechanism.

So, the present growth of satellite data archive (UARS, first of all) supported by computations provide the opportunity to look at the atmosphere being influenced by cosmic factors (like strong SPE) as at a great Natural Laboratory. At the same time new questions and problems arise.

The proceedings of the Session C2.5 will be published in *Advances in Space Research*.

COSPAR D2.3/E3.3 Event:

Solar Variability and Climate Change

Main Scientific Organizer:

J. Pap (papj@marta.gsfc.nasa.gov),
Co-Chairs:

Labitzke, J. Kuhn,

Scientific Organizing Committee:

J. Beer, B. Fleck, P. Fox, E. Friis-Christensen, C. Frohlich, J. Haigh, L. Hood, K. D. Shindell, S. Solanki, W. Sprigg, W. Wagner, and S.T. Wu.

This COSPAR event, sponsored by commissions D2.3/E3.3, was also sponsored by SCOSTEP, IAMAS, NASA, NSF, and ESA.

The 2.5-day meeting was divided into three major parts: (1) solicited talks, (2) contributed talks, and (3) contributed poster papers. The meeting consisted of 5 major sessions:

- Session 1: Natural Climate Variations
- Session 2: The Sun as a Variable Star
 - 2.1. Measurements and Empirical Models of Solar Variability
 - 2.2. Mechanisms and Physical Models for Solar and Stellar Variability
- Session 3: International Research

Activities: Reports and Future Research

- Session 4: Climate Modelling
- Session 5: Particle Variations and Climate

Nineteen review papers summarised recent knowledge on solar irradiance and particle variations (both measurements and theory) and their effect on the Earth's atmosphere and climate system. In addition to these reviews, 17 contributed talks were presented and 50 poster papers were displayed. Two evening sessions were devoted to discussing the results presented in the posters, and P. Fox and P. Brekke gave a summary of posters. The papers will be published in the *Advances of Space Research* to be edited by K. Labitzke, J. Kuhn and J. Pap.

The presentations and discussions have clearly demonstrated that the Earth's climate, radiative environment and atmospheric chemistry are influenced by the varying solar energy flux. One of the most over-arching questions today is whether the Earth's atmospheric and climate system changes in a way that we can understand and predict. The important question: what is the degree to which various causal agents –both natural variability and man-made– may affect climate was widely discussed. It was pointed out by several papers that although the Sun supplies most of the energy for the Earth's atmospheric and climate system, the measured level of solar irradiance variations is generally considered to be too small to cause changes in climate above its intrinsic noise. In contrast, the correlation between observed historical solar changes and that of climate implies that there is a solar forcing which is unaccounted for, as highlighted by J. Beer, P. Damon, C. Keller, and G. North. Papers by J. Haigh, M. Salby, M. Schlesinger and U. Langematz discussed possible mechanisms for the effect of solar changes on the atmosphere and climate. Measurements of the solar energy flux, both electromagnetic and particles, were summarised by G. Rottman and D. Reames, while modelling and theoretical results were presented by P. Fox and J. Kuhn. D. Gray summarised recent results on solar-stellar connections. The role of cosmic rays in climate change was debated by E. Friis-Christensen and J. Kristiansson.

Twenty-seven of the poster papers described the effect of solar variability on the Earth's atmosphere and climate. They fall into four major categories:

(1) description of long-term climate changes and solar variability, (2) connection between solar variability and regional climate changes, (3) the response of ozone and other stratospheric constituents to solar variations, and (4) the effect of solar particle and cosmic ray variations on atmospheric constituents and climate.

Additional 22 poster papers were presented on solar variations and described various irradiance monitoring experiments, compared and some combined time series of various EUV, UV and total irradiance measurements, and ground-based observational programs some extending over several solar cycles and one calling into question the possibility of a missed sunspot cycle. Several papers were presented on various image processing techniques developed for proxy irradiance modelling describing also derived parameters for the area and contrast of sunspots, faculae and the network. Possible long-term trends in solar irradiance variations were addressed and debated as well.

Programmatic summaries on international research activities were presented by B. Schmieder (CAWSES, sponsored by SCOSTEP), J. Pap (ISCS Working Group 1 Activities), E. Friis-Christensen (S-RAMP/Climate Activities), and K. Kodera (GRIPS Solar Experiments Intercomparison Project).

The meeting was closed by T. Bogdan (NSF), pointing out the achievements on solar-terrestrial physics since the end of the 1800's and emphasising the need of coordinated research activities to better understand solar variability, its effect on Earth and its climate.

Future SPARC and SPARC-related Meetings

- 04-07 March 2003: GRIPS Workshop**, Headquarters of the American Geophysical Union, Washington DC, USA.
Chairs: S.Pawson (pawson@dao.gsfc.nasa.gov) and K. Kodera (koderam@mri-jma.go.jp)
- 17-21 March 2003: 24th Session of the Joint Scientific Committee for the World Climate Research Programme**, University of Reading, UK. (<http://www.wmo.ch/web/wcrp/jsc.htm>).
Chair: P. Lemke (plemke@awi-bremerhaven.de), Vice-Chair: B.J. Hoskins (hoskins@met.rdg.ac.uk)
- 02-06 April 2003: SPARC-IGAC Joint Meeting**, Giens, France.
Chairs: A.R. Ravishankara (ravi@al.noaa.gov), S. Liu (shawliu@earth.sinica.edu.tw), C. Granier (claire.granier@aero.jussieu.fr)
- 06-11 April 2003: EGS-AGU-EUG Joint Assembly**, Nice, France. (<http://www.copernicus.org/egsagueug/>)
- AS1: Open session on the lower, middle, and upper atmosphere. Convenor: M. Juckes (M.N.Juckes@rl.ac.uk)
 - AS6.11: Polar stratospheric clouds. Convenor: K. Carslaw (carslaw@lec.leeds.ac.uk)
 - AS6.12: Polar ozone. Convenor G. Braathen (geir@nilu.no)
 - AS8.01: Cirrus clouds near the tropopause. Convenor: B. Kärcher (bernd.kaercher@dlr.de)
 - AS8.02: Aerosols near the tropopause. Convenor C. Timmreck (timmreck@dkrz.de)
 - AS8.03: Processes controlling the chemical composition of the UT/LS. Convenor: B. Bregman (bregman@knmi.nl)
 - AS8.04: Water vapour and its isotopic composition in UT/LS. Convenor: K. Boering
 - AS9.01: Odin satellite: two years of atmospheric observations. Convenor: D. Murtagh (donal@rss.chalmers.se)
 - AS9.02: Chemical Data Assimilation. Convenor: H. Eskes (eskes@knmi.nl)
 - AS9.03: ENVISAT atmospheric chemistry instruments: the 1st year. Convenor: G. Stiller (gabriele.stiller@imk.fzk.de)
 - AS10: Network for Detection of Stratospheric Change (NSDC). Convenor G. Braathen (geir@nilu.no)
 - AS11.02: SPARC-IGAC Symposium on climate-chemistry interactions. (Co-sponsored by SPARC-IGAC)
Convenor: A. Ravishankara (ravi@al.noaa.gov)
- 29 April – 02 May 2003: The Role of the Stratosphere in Tropospheric Climate Workshop**. Whistler (BC), Canada. (<http://www.atm.amtp.cam.ac.uk/~shuckburgh/whistler/>) Organisers: M. Baldwin (mark@nwra.com), D.W.J. Thompson, W. Norton, E. Shuckburgh, N. Gillett.
- 14-16 May 2003: Workshop on Tropical Meteorology and Chemistry**, DRL, Oberpfaffenhofen, Germany.
Chairs: U. Schumann (ulrich.schumann@dlr.de) and J.P. Pommereau (pommereau@aerov.jussieu.fr)
- 04-06 June 2003: SPARC Data Assimilation Workshop**, Florence, Italy (held in conjunction with the E. U. project for Assimilation of Envisat data (ASSET) co-ordinated by W. Lahoz.)
- 30 June – 11 July 2003: IUGG General Assembly**, Japan Marine Science and Technology Center, Sapporo, Japan. (<http://www.jamstec.go.jp/jamstec-e/iugg/>).
- JSA01: Long-term trends in the mesosphere, thermosphere and ionosphere (IAGA, IAMAS)
 - JSA02: External Forcing on the middle atmosphere and ionosphere (IAGA, IAMAS)
 - JSA08: Effects of solar variability on climate change (IAGA, IAMAS)
 - JSA09: Challenges of Global Change in from below and above (IAGA, IAMAS)
 - JSM05: Solar effects in the middle atmosphere and ionosphere (IAMAS, IAGA, SCOSTEP)
 - JSM13: Data assimilation for atmospheric and oceanic processes (IAMAS, IAPSO, IAG, SPARC)
 - MI01: Variation of the solar energy output and its influence on climate (IRC, ICCI, ICACGP)
 - MI03: Chemistry -climate interaction (covers ozone interactions) (ICACGP, IOC, ICCI)
 - MC05: Middle atmosphere science (ICMA)
- 13-18 July 2003: Gordon Research Conference on "Solar Radiation and Climate"**, Colby-Sawyer College, New London (NH), USA. (<http://www.grc.org/programs/2003/solar.htm>). Chairs: V. Ramaswamy (vr@gfdl.noaa.gov), J. Kiehl (jkton@ucar.edu)
- 15-18 September 2003: 3rd IAGA Workshop "Solar Forcing of the Middle Atmosphere"**, IAP, Prague, Czechoslovakia.
Chair: J. Lastovicka (jla@ufa.cas.cz)
- 15-19 September: International Conference on Earth System Modelling**, Max Planck Institute for Meteorology, Hamburg, Germany (www.mpimet.mpg.de/mpi-conference2003)
- 22-25 September 2003: SPARC SSG Meeting**, Frankfurt, Germany.

New dates for the 3RD SPARC GENERAL ASSEMBLY 2004

01-06 August 2004

Victoria Conference Centre

Victoria, British Columbia, Canada



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