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STRATOSPHERIC PROCESSES AND THEIR ROLE IN CLIMATE
A Project of the World Climate Research Programme

Report on the Fourth SPARC SSG Session

Adelaide, Australia, December 9-12, 1996

As the SPARC SSG just followed the SPARC First General Assembly (see report in this issue), the session started by reviewing new scientific results and conclusions from the assembly that would need to be taken into account in the future development of SPARC. The SSG also reviewed progress in the various SPARC initiatives, in relationship with the issues raised above and to adjust the direction of these initiatives where appropriate, and/or to initiate new ones if needed. Another important task undertaken during this session was to refine the formulation of the SPARC implementation plan. An overview of each of the current SPARC Initiatives follows.

Intercomparison of Troposphere-Stratosphere General Circulation Models (GRIPS)

Progress of GRIPS in 1996 and plans for 1997 and beyond were presented by S. Pawson and K. Kodera.

- The EuroGRIPS Project of the European Commission, a four-way partnership involving FUB, CNRM, UGAMP and UKMO, has started.

- The Victoria Workshop (cf. SPARC Newsletter # 7) was an excellent opportunity to better define the project, formulate plans for the next year or so, and form working groups.

- The contacts with AMIP were developed : G. Boer and P. Gleckler attended the Victoria meeting and gave an excellent presentation about AMIP and much useful advice. Both speakers stressed the likely problems as well as the benefits of model intercomparisons. S. Pawson visited PCMDI in November/December 1995 and gained a much more realistic impression of what was required for a successful project.

- Within SPARC there is excellent contact with the reference climatology group (W. Randel) and an intensifying relationship between GRIPS and the gravity wave initiative (K. Hamilton, R. Vincent); many of the GRIPS modellers were represented at the Santa Fe meeting.



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- The GRIPS Web site is finally operating ; this will be updated in the near future to include all relevant reports and links to many members and related topics.

- Many models have already submitted their data to the FUB. A limiting factor has been the time available to process it and the storage space available. The second of these should be solved by now.

Future plans for GRIPS :

- Completion of the « Phase 1 » topics « documentation », basic

should be performed, and the data collected and evaluated during 1997.

- Increase in the data exchange since the initial problems have been overcome; data from all groups can be read from Berlin, even though caution is needed due to storage restrictions. Assistance has been offered from PCMDI which may become essential eventually if data sets start becoming too large.

- Links with AMIP-II : GRIPS has assumed that it is a complementary project to AMIP and would support

Stratospheric Reference Climatology

One of the key questions to be addressed by GRIPS is how well comprehensive GCM's simulate the current climate and its variability. To answer this question requires a comprehensive documentation on stratospheric climate. To this end, the SPARC Stratospheric Reference Climatology (SRC) Group was established to provide an updated climatology of the middle atmosphere based on observations. Activity in this area is lead by a small group chaired by Dr. W. Randel (NCAR, USA). In the absence of W. Randel, a report on progress was presented by M. Geller.

Workshop at Port Jefferson

The first workshop of the SRC group, convened by W. Randel and M. Geller, took place in Port Jefferson in September 1996 and a short report is given in this issue. Prior climatologies were reviewed as well as the need for an updated data base. Details of the various data sets considered for inclusion in the climatology were discussed and firm plans for future work set.

Phase 1

The first phase of the SRC work involves compiling a set of global meteorological statistics derived from operational analyses, together with data sets describing tropical wind variability, mesospheric structure, and a climatology of selected trace gases, as summarised below :

- The stratospheric meteorological data to be used due to their global coverage are : the National Centers for Environmental Prediction (NCEP) operational stratospheric analyses (formerly called National Meteorological Center (NMC) data), the NASA Goddard Earth Observing System, Data Assimilation System (GEOS DAS) troposphere-stratosphere assimilation, and the United Kingdom Meteorological Office (UKMO) stratospheric assimilation products.



Participants of the 4th SSG Meeting in Adelaide. From right to left, and from front to back, 1st row : S. Solomon, V. Ramaswamy, K. Hamilton, K. Labitzke, S. Pawson, C. Phillips; 2nd row : M. Geller, M.-L. Chanin, D. Ehhalt, A. Ravishankara, J. Miller, 3rd row : R. Vincent, M. Manton, H. Tanaka, Imamura, V. Kattharov, K. Koder, J. Gille, 4th row : N. Harris, Y. Koshelkov, J. Kaye, D. Offerman, R. Newson, F. Hasebe, T. Shepherd. Courtesy of Univ. of Adelaide.

climatology and progress towards results in most other tasks during 1996/1997.

- As well as the climatology, both stratospheric assimilation groups (UKMO, NASA/GSFC) are calculating the standard GRIPS diagnostics from their data sets.

- Organisation of a second workshop in Berlin in March 1997.

- Model integrations to test the response to mesospheric drag

and welcome a « stratospheric subproject » within AMIP-II, as has been coordinated by C. Mechoso in AMIP-I.

- EuroGRIPS-II : whereas the first EuroGRIPS application drew on the GRIPS proposals, EuroGRIPS-II is setting more of the precedent for GRIPS. Planned start is April 1998, subject to reviewers and EU-politics. It will include a component with coupled climate-chemistry/transport models.

- Tropical winds in the above global data sets will be analysed in order to characterise the quasi-biennial oscillation (QBO).

- Mesospheric data are needed for comparison with models extending into the mesosphere. The Reference Climatology will include the COSPAR International Reference Atmosphere CIRA-86 and the empirical model of Hedin et al. (1993). A novel data set to include will be the stratospheric and mesospheric wind measurements from the High Resolution Doppler Imager (HRDI) instrument on the Upper Atmosphere Research Satellite (UARS). A coordination of this effort is anticipated with current revisions of the CIRA climatology.

- Trace constituent data sets of interest in stratospheric modelling need to be included, i.e. : the monthly mean climatologies of ozone, water vapour and methane, mostly from the UARS data.

Comparison of climatologies will be performed systematically to highlight uncertainties in the data sets, mostly for more highly derived quantities.

Phase 2

Research topics of interest include obtaining better climatologies of tropical winds and updating our knowledge of the QBO, and improving data sets in the mesosphere (combining historical rocketsonde, lidar, and satellite data sets). Phase 2 may include more highly derived quantities to match future initiatives of GRIPS, to study troposphere-stratosphere statistical connections, diagnostics of sudden warmings and space-time spectra of transient atmospheric waves.

SPARC Data Center

The presentation of this project was the first opportunity during the SSG meeting to discuss the issue of the SPARC data base, common to several projects. The need for establishing a « SPARC Data Center » to aid in handling and disseminating the stratospheric climatological data

was identified. Support for such a data center and a host institution will be sought.

Gravity wave processes and their parameterisation

K. Hamilton and R. Vincent reported on the SPARC Gravity Wave Initiative (GWI). Two principal activities have taken place since last year :

The archiving of high-resolution radio-sonde data

This initiative encouraged by the success of the Australian experience has gained in volume since the US National Weather Service (NWS) has accepted to archive the radiosondes in the continental US, Alaska, Hawaii and US territories in the tropical Pacific. These data are available to researchers through the US National Climate Data Center. In early 1997, it is expected that the NWS archive will include 7 Caribbean stations as well. Several other national meteorological services have also started the high resolution archiving routinely (France, UK), others such as Canada, New Zealand, Germany, Argentina, Japan and Italy, are joining the initiative but for some stations only and limited time periods. The connecting issue is the organisation of a data center to centralise this data (see above). The analysis of these data is being planned with a common approach, involving scientists from 11 countries under the leadership of R. Vincent.

The Santa Fe Workshop

The International NATO Workshop organised under the leadership of the GWI has been reviewed in SPARC Newsletter # 7 and a proceedings volume will be published in early 1997 by Springer-Verlag. A number of very exciting results were presented. It now appears that the one-dimensional (vertical) spectrum of typical variability in the upper stratosphere and mesosphere can be characterised quite well from observations, particularly as radar

measurements are being increasingly supplemented by lidar measurements of various types. Work on detailed numerical modelling of the generation and propagation of gravity waves is also progressing quite rapidly. A driving consideration is to incorporate better gravity wave parameterisation in models. However to characterise the performances of various schemes, it was decided that a set of standard « test bed » atmospheric profiles will be developed, so the different modelling groups can usefully compare their gravity wave parameterisation implementations in an efficient « offline » approach. This step seems necessary before approaching the more ambitious project of comparing results of global model integrations using different gravity wave drag schemes. All further work will be carried out in close connection with GRIPS.

A plan for a future Gravity Wave Field Experiment developed by C. Gardner to examine middle atmospheric gravity waves in relationship with their sources, and modelled after the ALOHA-93 campaign at Hawaii, was presented. There was overall concern that the scientific issues to be addressed and hypotheses to be tested were not clearly enough described to lead to a definite conclusion. The question was raised whether such a large scale field experiment was necessary or whether the priority should be given to a more specific campaign to study for example convection sources. One site offered for such a campaign, Darwin in Australia, was recognised to be an ideal location for such a regional experiment. The use of data obtained from ER-2 flights was also discussed and considered as very important for such studies.

Stratosphere-troposphere exchange (STE)

After the SPARC workshop on STE, which took place at La Pointe-du-Lac, Québec, 13-15 June 1995, (cf Shepherd's review in SPARC Newsletter # 6), an unresolved issue remained ; that was

« to develop combined measurement and modelling strategies to progress in gaining the necessary understanding of these processes that are needed for better assessments ». This difficult task has not been dealt with during the past year and the discussion recognised that the evolution of the concept of STE should be viewed in the broader context of transport and mixing of mass and chemical species. As pointed out by T. Shepherd at the SPARC General Assembly, (cf the Assembly Report session 5 in this issue) even though there are many promising new approaches, the community is not ready for a « grand measurement strategy » which could lead to a major step forward. The field is changing extremely rapidly and a detailed strategy will stand a high risk of being obsolete before it happened. Measurements are being carried out anyway but improved coordination between the different programmes would be beneficial to avoid the serious limitations associated with particular measurement platforms or strategies (e.g. intrinsic biases and under-sampling inherent in fixed-location measurements ; the inability of the ER-2 aircraft to cruise low enough to intersect the midlatitude tropopause; the lack of chemical tracer measurements in traditional meteorological studies of STE). His suggestion was that SPARC should provide strong « steering » to avoid scientists losing their efforts on what does not work and provide focus on key scientific questions.

The subject of STE is very important in many areas of SPARC and in atmospheric science in general, particularly as they relate to climate. A few examples are : the impact of aircraft emissions on the ozone layer, the vertical distribution of greenhouse gases in the UT/LS, and midlatitude ozone depletion. In this context a document on Chemical-Radiative-Dynamical Coupling in the UT/LS will be written in co-operation with the UT/LS Chemistry study Group.

Upper tropospheric and lower stratospheric Ozone, Aerosols and climate (UT/LS)

The question of upper tropospheric/lower stratospheric (UT/LS) chemistry is of the utmost importance since changes in trace species, in particular ozone and water vapour at this altitude are crucial in determining the overall climatic effects of stratospheric changes and in assessing the potential impact of aircraft emissions.

The main activity in this initiative in the last year was the organisation in October 1996 of the Strasbourg Workshop on heterogeneous chemistry. A. Ravishankara reported on the highlights of this workshop. It was noted that the treatment of reactions in/on stratospheric sulphuric acid aerosols is « mature » and the information to include them well in models is available, but the knowledge of reactions on solids (PSCs, SAT, ...) is not as developed and its parametrisation in models is very approximate. The question was raised whether it is necessary to unravel all the details of those reactions. It was considered that it may not be for ozone holes issues, but it is required for reactions at high latitudes and the edges of the vortex. The role of temperature as a key parameter which controls the heterogeneous chemistry was highlighted ; it conditions the appearance of PSCs, ternary solutions and it controls the relative humidity. The predictive ability is very much dependent on large unknowns in the « microphysics ». The state of UT heterogeneous chemistry appeared to be in a worse shape : the nature of the substrate is unclear, and even the potential importance of heterogeneous processes in this region is not known. A short report of this workshop is given in this issue, and a complete report will be published in 1997 as a SPARC/WCRP Report.

In the light of these conclusions, the need for an enlarged programme on this topic was recognised. It will be carried out as a joint SPARC/IGAC initiative. The programme should take into account the following issues :

- the need to include laboratory chemists in the programme,
- the necessity of data evaluation for heterogeneous and gas-phase chemistry, (through the organisation of a joint workshop as a first step),
- the definition of a measurement program for UT chemistry

The need to include a modelling component was stressed. A letter was addressed to the IGAC Chairman with this proposal.

Stratospheric Water Vapour Climatology

In complement to the above discussions, J. Gille who chairs the SPARC Stratospheric Water Vapor group indicated his intention to focus the effort on the atmosphere up to 20km (UT/LS). It is intended to assess the available instrumentation, review the present data base, explore future plans, and suggest a monitoring programme that could lead to a climatology of UT/LS water vapour.

The two first tasks have been considered by the group in the last year. The measurement strategy comprises three components : determination of the UT/LS global water vapour distribution and temporal variations in the tropopause region, understanding of the processes that maintain the distribution and developing a capability to model and predict its future evolution with a hierarchy of models both interpretative and predictive.

More precisely the determination of the present global LS/UT water vapour distribution, which is also a priority of GvAp within GEWEX, should take into account the following data sources :

- Observation from satellites, limb absorption or limb emission, to show global, spatial and temporal variation : currently data from SAGE II, HALOE, MLS, ILAS are available, and later data from SAGE III, MIPAS, HIRDLS, MLS and other future instruments can be used.

- In-situ measurements from balloons and aircraft, with accurate high spatial and temporal resolution, using frost point, Lyman α , tunable diode laser instruments.

- Ground and aircraft based remote observations, with continuous spatial and temporal data based mostly on Raman lidar and DIAL.

- The strategy will use satellite observations to observe spatial and temporal variations, intercompare satellite observations to reduce systematic effects, and anchor observations as firmly as possible to coincident in-situ and ground-based observations.

The understanding of the mechanisms that maintain the water vapour distribution requires both tropical and mid-latitude observations. The tropics are the region of highest priority, but studies in this region are compromised by the small number of stations. Extra sites are needed in the convectively active western Pacific, the subsidence region in the eastern Pacific, the monsoon-controlled Indian ocean, South America and Africa. A proposed installation of three new sites (Galapagos, Ecuador and Christmas Island) by Japan, which has received a high support from the SSG, may contribute to an improvement in this area, if implemented.

Several measurement campaigns are being planned in the coming years at different latitudes and will contribute to water vapour climatology. The establishment of such a climatology will require extended efforts, both in logistical and financial supports and it will be obviously more productive to conduct these studies in concert with GEWEX and maybe IGAC.

Assessment of stratospheric temperature trends

Dr. V. Ramaswamy reviewed progress in this SPARC initiative whose aim is to investigate stratospheric temperature trends using and inter-comparing all sources of data.

Progress so far includes :

- The preparation of the data base of zonal and monthly-mean time series of radiosondes, lidar, MSU and SSU satellites and analyses products from CPC/NOAA, UKMO/SSU Analysis, NCEP/Reanalysis and NASA/GEOS1.

- The trend determination for the periods 1979-1994 and 1966-1994 in annual and seasonal means.

- The intercomparison of the trends obtained from the different data sets and the comparison of the model results with observed trends.

The results confirm the cooling of the lower stratosphere especially in mid-to-high latitudes and its significance particularly in mid-latitudes and during the Antarctic winter/spring. Model simulations confirm that ozone loss plays a dominant role in this cooling and thus affects strongly the vertical profile of the atmospheric temperature change due to anthropogenic emissions. In the middle and upper stratosphere, modelled greenhouse gas cooling (including ozone) is qualitatively consistent with observations, however GCM simulations suggest a warming above the lower stratospheric ozone loss region.

A complete review of these results was presented by M. Gelman at the General Assembly and a summary can be found in the General Assembly Report session 3 in this issue. The complete report of the results obtained during this first phase should be available in mid 1997 and will be published as a SPARC/WCRP Report. It will be available for the next WMO-UNEP Scientific Ozone Assessment.

Phase 2

During Phase 2, the analysis of trends including detailed comparisons of rocketsonde and lidar with

satellite data, and analysis of the causes of differences observed between the different datasets will be pursued. Time series and trends will also be studied at individual geographic locations. Numerous modelling experiments are also planned to estimate changes in stratospheric temperature which may come from spatial and temporal inhomogeneities in the radiative species as water vapour, clouds, ozone around the tropopause.

Understanding ozone trends

The primary objective of this group is to improve understanding of trends in the vertical distribution of ozone, the second to help ensure that the data sets collected by the instruments measuring ozone are consistent. The work involved is being undertaken jointly with the International Ozone Commission and the WMO Global Atmosphere Watch.

The first objective takes as a starting point the results of the last WMO-UNEP Scientific Assessment, in which the trend in total ozone were well characterised. However there is still uncertainty about the trends below 20km, with SAGE giving considerably larger trends than the ozonesondes. A joint SPARC/IOC/GAW workshop was held at the Observatory of Haute Provence from July 8-11, 1996 to review the state of knowledge and to document and understand better the questions involved (see Newsletter # 7). It was attended by 28 scientists who agreed to undertake a number of studies in 1997 and to prepare a report for the end of 1997.

The report will be structured in the following way :

- Chapter 1 : Instruments and algorithms. Co-chairs C. Rodgers, D. Hoffman.

- Chapter 2 : Intercomparison of the different datasets. Data quality. Co-Chairs : J. Russell, H. Smit.

- Chapter 3 : Trend in the ozone vertical profile. Co-Chairs : W. Randel, R. Stolarski and D. De Muer.

- Chapter 4 : Lessons learned from this study. Provisional responsibility : N. Harris, R. Hudson.

A further meeting of the group is scheduled for September 1997 in Cambridge to review the work and finalise the report which should be published as a SPARC/IOC/WMO Report and will come in time to contribute to the next WMO-UNEP Scientific Ozone Assessment.

Phase 2 of this work, very likely to be carried out in 1998, will include the study of instrument consistency, the attribution of trends and the study of sources of variability (solar, volcanic). The need for more measurements in the tropics was again stressed and the SPARC interest for the ITOY initiative of IGAC was confirmed. The Japanese proposal to set up new sites in the tropics, and which was strongly supported by the SPARC SSG, may contribute in this area.

UV Monitoring

J. M. Miller presented the activities of the WMO/GAW Programme on UV-B and commented the status of the different reports prepared by the 9 members of the UV Committee on the issues relevant to UV monitoring and modelling. Some of those are already available on the Web : <http://www.srrb.noaa.gov/UV/>.

New Initiative : The role of the QBO in the coupling between the stratosphere and the troposphere

At the SPARC General Assembly, it was clear that a large amount of work was evolving around the QBO issue and its role in the coupling between the stratosphere and the troposphere. This is a major issue for SPARC, but could also be of interest for CLIVAR which is focusing specifi-

cally on different modes of climate variability.

Recognising what is already known on the signature of the QBO on ozone, temperature, winds, tides, occurrence of hurricanes, changes in SST..., it appears that identifying the connection between the QBO and climate may be a key issue for SPARC. The issues to be considered include :

- what drives the QBO ?
- how do models simulate it ?
- what role is the QBO playing in climate coupling ?

The SSG is setting up a study group on this topic, and will organise a workshop leading to review the issue. This will help to decide if such a topic should become a new SPARC project. Professor Hirota will lead this activity, with Dr M. Baldwin as co-chair.

Preparation of the SPARC implementation plan

A first outline of the Implementation Plan was proposed at the 1995 SSG and a number of initial draft contributions have been prepared. After the intensive discussions at this meeting on the issue of STE and the unifying theme of UT/LS, new emphases and a new time table have been established with the goal of having a completed document at the end of 1997.

In discussing the role and form of the plan, it was noted that an implementation plan should spell out clearly the basic scientific requirements and what nations have to do to meet these. It should identify what is already being done nationally or regionally and what specific EXTRA observational programmes or activities (or developments/extensions of existing activities) are needed.

If contacted by the writers of the different sections inquiring about your national programmes, please be cooperative, since this document's purpose is to help the futu-

re development of the overall SPARC programme, as well as individual nation's contributions.

Other issues

Cooperation with other international programmes :

IGAC. The major issues of cooperation between the two programmes are, firstly, the joint initiative in the organisation of the IGAC/SPARC/GAW Conference on « Global Measurement Systems for Atmospheric Composition » to be held in Toronto in May 1997 (cf announcement in Newsletter # 7). Another important joint activity is « Laboratory kinetics /spectroscopy » related to gas-phase and heterogeneous chemistry. This issue would become part of the enlarged UT/LS joint initiative described above.

A major concern for IGAC is to implement the ITOY (International Tropospheric Ozone Year) proposed originally by P. Crutzen ; one of its main objectives is to increase the number of ozonesonde stations in the tropical and southern Hemisphere troposphere to detect ozone trends around the tropopause. J. M. Miller, convener of the GLO-NET Project to which ITOY belongs, presented the situation of ITOY and announced a document highlighting the scientific objectives of ITOY for 1997. This topic is strongly related to the SPARC Ozone Trends Initiative and close collaboration between SPARC and IGAC is in everybody's interest.

GAW. The attendance and the active participation of J. M. Miller, Chief, Environment Division, WMO Atmospheric Research and Environment Programme, in this SSG session was extremely important in developing the cooperation between SPARC and GAW in areas of mutual interest as UV and ozone monitoring, and the SSG confirmed its equal interest in working closely with GAW on these issues.

National activities

NASA. J. Kaye presented the recent NASA activities of interest

to SPARC. In the Strategic Research Plan of NASA, the Atmospheric Ozone Research is of greatest relevance to SPARC. It includes Laboratory Science, Ground-based, Balloon-based, Aircraft-based and Space-based Measurements, Modelling and Data Analysis. The future emphasis is placed on the following topics: chemistry-climate coupling, constituent assimilation, atmospheric chemistry-aerosol interface, atmosphere-land and atmosphere-ocean interface, air quality and applications. Several field missions are planned with the instrumented DC-8 : PEM/TROPICS in tropical Pacific, SUCCESS in central US (mainly focused on the radiative effect of exhaust/particles), and OMS Balloons will be launched in support of STRAT at several locations.

The satellite programme includes the launch of a third TOMS on Meteor 3M in 2000, following the launches of EP-TOMS and ADEOS TOMS both in 1996. Active discussions are under way with CNES for a third SAGE III to fly on SPOT, and with the Canadian space agency for a total solar irradiance instrument to go on Canadian SciSat. J. Kaye described also the new EOS chemistry-climate focus and the establishment of new teams on issues of interest for SPARC. (For more information about future space projects and their complementary aspect in the international scale see the article by J. Kaye on « Space-based observations of atmospheric chemistry » in this issue.)

NASA/GSFC has made a commitment to provide for the continuation of laboratory calibration facilities (UV, visible, near IR) for both NASA and non-NASA spacecraft. NASA also has plans to assist/support non-US atmospheric chemistry instruments, including ozone-measuring instruments from Chile (OLME), Israel (TECHNSAT) and Europe (GOME and SCHIAMACHY).

NASA has strong interest in promoting major Uncrewed Aerial Vehicles (UAV) activity, and the

development of instruments and platforms to fly on Theseus and Perseus B aircraft. It is considering launching an A.O. for UAV Science missions with possibilities of UAVs carrying a 300kg payload, with up to a 24 hour duration, altitudes of 40-65 kft, and flying around the year 1999. The SPARC community should benefit from these opportunities.

Japanese Proposals

Two presentations of Japanese projects were made during the SSG :

- F. Hasebe, from the Department of Environmental Sciences of Ibaraki University, presented a proposal made to NASDA concerning a measurement programme for tropical ozone and water vapour soundings. The SSG recognised the importance of this proposal as a complement to the need for ADEOS-TOMS validation.

- Dr Imamura from NIES presented a proposal of H. Nakane to the Japanese Environment Agency entitled « Ozone depletion mechanisms and modelling from satellite, balloon and ground-based data ». It is planned to include observations by FTIR, lidar, radiometers, spectrometers and in situ sensors to be used in an international context at different sites. The SSG encouraged the analysis, modelling and laboratory studies proposed in this project.

German CRISTA-CRISTINE Projects

D. Offerman, from the University of Wuppertal, Germany, presented the first results of the CRISTA experiment which flew on the space shuttle in November 1994 and which are the subject of a special article in this issue. He then described future plans to fly CRISTINE, an instrument with similar capabilities, on the International Space Station, and asked for a recommendation of the SSG on this new proposal. The SPARC SSG agreed that this would be an important contribution to SPARC objectives

Activities of the SPARC Office

The year 1996 has clearly been a busy year for the SPARC Office due partly to the preparation of the SPARC General Assembly, (even though most of the organisational burden was handled at the SPARC-96 Office). Together with all the other continuing activities, these included updating and enlarging the SPARC directory (currently 2150 names) following a partial merging of the SPARC and IGAC mailing lists.

The activity of the Office in handling the organisation of study group meetings, the research of financial support and the writing of reports has been increasing as expected, and the preparation of the Implementation Plan will be a major load in 1997. The staff needs to be complemented, and an invitation is made for foreign scientists to join the Office. Ideally, they would be able to pursue their research part-time and their stay would be supported by their own funding agency, although they may also solicit partial support from the French Research Agency CNRS. Propositions should be sent to the SPARC Office as soon as possible.

The SPARC home page is updated regularly by C. Phillips. It was proposed during the SSG to use the Web site as a platform for educational documents on SPARC and SPARC related science.

First general Assembly of the WCRP-SPARC project « Stratospheric Processes and their Role in Climate »

Melbourne, 2-6 December 1996

The First SPARC Assembly, sponsored by numerous Australian and International Sponsors, was opened on 2 December 1996 by Prof. M. Geller, Chairman of the Assembly Scientific Programme Committee. The participants were welcomed by Dr. J. Zillman, the WMO President and Director of the Australian Bureau of Meteorology, and by Prof. D. Karoly, Chairman of the Local Organising Committee for the Assembly. Dr. Marie-Lise Chanin presented the scientific goals of SPARC and its main activities.

More than 220 people attended the Assembly (plus about 10 local people who came for a day or two), and 21 countries were represented. Of a total of 211 papers presented, 75 were oral and the remaining 136 were poster presentations. An abstract volume has been prepared by the LOC and issued before the assembly. In 1997, the extended (4-page) abstracts of the assembly will be published as a WRCR report.

Below follows the summary of the main results as prepared by the SPARC co-chairs and SPARC Study Group chairmen and edited by the SPARC Office.

Session 1. Troposphere- stratosphere general circulation models

Rapporteur : S. Pawson

Many of the presentations at the meeting included results from comprehensive numerical models of the troposphere and middle atmosphere. These were supplemented by a range of studies using simpler numerical models. The various models included some or all of the dynamical, radiative, and chemical processes in the atmosphere.

Several of the studies examined the success with which the comprehensive models currently simulate the climatic structure of the atmosphere. Although the dominant features of the circulation are captured, there are important systematic errors in the strength and location of, say, the polar night jet in the winter stratosphere. In this sense, the use of some parameterisation of small-scale gravity wave drag was shown to be an essential feature, although the models can react quite strongly to changes in some of

the « unknown » parameters. Topics such as the seasonal evolution of the atmosphere were addressed : some models display a reasonably accurate progression through the year. The use of these models as an integral part of data assimilation systems was also a theme.

The dynamics of the tropical middle atmosphere were discussed in several presentations. These studies concentrated on the propagation of tropical waves in the middle atmosphere, as well as the sensitivity of the wave spectra to some numerical aspects (resolution) of the models. Mechanisms of wave excitation in the stratosphere were discussed, as were the propagation of waves from tropospheric sources. These tropical waves are, of course, a potential forcing mechanism for the dominant vacillations of the tropical stratosphere : the semi-annual and quasi-biennial oscillations (QBO). This latter feature, which dominates the low-frequency dynamics of the tropical lower stratosphere, has until recently proved elusive in GCMs, so it is of considerable interest that some simulations can produce analogues of the observed QBO : these point the way towards its simulation in more models, which will facilitate studies of its potential climatic impact.

As precursors to fully coupled chemistry-dynamics studies, some presentations examined the effects of imposed ozone perturbations, which disturb the radiative balance, on the circulation of models.

Chemical transport models (CTMs), which use observed or modelled winds to advect trace gases and the corresponding temperatures in the chemistry calculations were the basis of several presentations. These studies examined the



Dr. J. Zillman, the WMO President and Director of the Australian Bureau of Meteorology, during his welcome speech at the SPARC 96 General Assembly. Courtesy of CRC for Southern Hemisphere Meteorology.

transport of long-lived tracers, the contributions of dynamics and chemistry to certain situations.

Further studies examined the coupled chemistry-circulation problem. The seasonal evolution of various chemically active trace gases with and without heterogeneous chemical processes was discussed. Several studies examined the 3D structure of such coupled models, showing successes and problems with the ozone distribution, as well as examining the distributions and importance of other trace gases.

All in all, the modelling studies gave a representative overview of current research interests and showed how comprehensive 3D models have evolved over the past years. Many of the models were used in later presentations in the meeting, to examine trends and variability in the atmosphere.

Session 2. Stratospheric climatology studies

Rapporteur : W. Randel

Stratospheric climatology studies focused on analyses of global data sets to study aspects of stratospheric dynamics and trace constituent behaviour in the middle atmosphere. Long time records of stratospheric circulation statistics from the National Centres for Environmental Prediction (NCEP), the United Kingdom Meteorological Office (UKMO) and the NASA Goddard Earth Observing System/Data Assimilation System (GEOS/DAS) were analysed by a number of groups. These data sets form the basis for the SPARC Reference Climatology program, which will compile statistics and also make systematic comparisons between the analyses to highlight uncertainties. Aspects of stratospheric variability based on analyses of these data sets were presented by a number of researchers, including troposphere-stratosphere coupling, stratospheric variations associated with the quasi-biennial oscillation

(QBO) and the 11-year solar cycle, and « natural » internal stratospheric variability. Among the more novel results was the use of « elliptical diagnostics » to study behaviour of the stratospheric polar vortices (presented by D. Waugh of Monash Univ. in Melbourne) ; these diagnostics describe the position of the vortex centre, its orientation and elongation in a set of compact statistics that are complimentary to the usual zonal Fourier wave decomposition. Other climatological data sets used for studies of long-term variability included tropical winds from Singapore (to study the QBO), NCEP re-analyses, and direct measurements of stratospheric winds from the High Resolution Doppler Imager (HRDI) instrument on the Upper Atmosphere Research Satellite (UARS) (figs. 1 and 2). The analyses of temperature and geopotential heights and total ozone variations with a period close to that of the solar cycle were presented by K. Labitzke and H. van Loon (fig. 3) ; the results for ozone are based on only a 15-year series of TOMS observations and may thus be not representative of a longer period.

Along with the dynamical climatology studies, results based on analyses of stratospheric trace constituents provided novel insight into stratospheric transport issues. Seasonal and interannual variations in ozone and water vapour were discussed in a number of presentations. Novel results from the Halogen Occultation Experiment (HALOE) on UARS were presented by K. Rosenlof of NOAA, addressing the asymmetry in lower stratospheric water vapor between the NH and SH, and aspects of transport between the tropics and middle latitude. A new climatology of stratospheric aerosol parameters (including surface area and volume density) derived from several satellite data sets was presented by L. Thomason of NASA Langley ; this promises to be a valuable resource for the research community. The combination of climatological constituent

data sets with stratospheric circulation diagnostics promises to refine our understanding of stratospheric transport behaviour, and provide concise tools for model validation.

Session 3. Trends in temperature, ozone and water vapour

Temperature

Rapporteur : V. Ramaswamy

Presentations were made concerning the impact of changes in radiative constituents, which included both modelling and observational studies. Progress was reported on the intercomparison of trends in the lower stratospheric temperature over the last decade as inferred from a variety of datasets. It is found that the midlatitude Northern Hemisphere lower stratosphere has undergone a statistically significant cooling. Problems were noted concerning the inhomogeneity in the radiosonde records due to changes in instrumentation and methods of observation, and radiation-related errors that can occur in the temperature sensors, all of which affect the quantitative trends analyses.

Temperature trends inferred from aerological stations located in the Arctic suggest an amplification of the lower stratospheric cooling in recent years in late winter ; however, the trends in this season are not statistically significant. From modelling studies, the loss of ozone in the global lower stratosphere is estimated to be largely responsible for the cooling trends in this altitude region over the past one-and-a-half decades. Fig. 4 compares the satellite-based and GFDL-modelled trends. Additionally, model simulations show that there also occurs a slight cooling of the upper troposphere.

Rocketsonde data based on launches by the United States since 1969 have been systematically analysed and a cooling of the upper stratosphere is evidenced.

Russian rocketsonde data have also been analysed and a negative trend is seen in most of the stratosphere and particularly in the mesosphere. The prospective launch of the SAGE III instrument offers a hope for continuous measurements of the vertical temperature profile and thus of trends in the future. Diagnostic analyses of observations reveal a more substantial cooling of the Antarctic lower stratosphere in southern spring and summer over the past 15 years than before 1980. A simulation of the impacts of the Antarctic springtime ozone depletion has been carried out which reveals the occurrence of a strong cooling accompanied by a delay of the springtime warming, consistent with observations. Another diagnostic study indicates that there may be a dynamical contribution to the cooling in the wintertime Northern Hemisphere polar stratosphere (European and Siberian sectors) in recent years, which could be conducive for the formation of PSCs and thus holds potential implications for ozone depletion.

In contrast to the traditional Fixed Dynamical Heating method and its results, a new method employing observed stratospheric ozone and temperature changes finds the resulting change in the irradiance at the tropopause to be substantially less. Modelled dynamical adjustments in the stratosphere in response to ozone losses are seen to be non-negligible.

In another paper, concurrent ozone and temperature measurements are analysed and it is inferred that both vertical displacement and radiative adjustment to changes in trace gas concentrations need to be considered in order to explain observed ozone and temperature variations. The impacts on stratospheric temperatures and surface-troposphere forcing due to uncertainties in the vertical profile of ozone were presented; the influence of ozone

losses relative to other trace gases on temperature trends in the middle/upper stratosphere was also discussed. A series of GCM experiments related to increases in trace gases (e.g., doubling of CO_2) reveal that the stratospheric circulation and the tropospheric climate changes are strongly linked.

Ozone

Rapporteur : Neil Harris

The trends in ozone were fully assessed in the last WMO-UNEP Scientific Assessment of Ozone Depletion (WMO, 1995). There have been no major changes in our knowledge of the trends since that time, although a number of studies have been made which have either added to our picture or changed certain features. The information

given in WMO (1995) is briefly summarised, before the new findings discussed at the SPARC General Assembly are presented.

The changes in total ozone were found to be relatively well characterised. At mid-latitudes in the northern hemisphere the trends from 1979 to 1994 found in the combined SBUV/SBUV-2 record are significantly negative in all seasons and are larger in winter/spring (up to 7 %/decade) than in summer/autumn (about 3 %/decade). In the tropics there seems to have been no statistically significant change in total ozone. Trends in the southern mid-latitudes are significantly negative in all seasons (3-6 %/decade) and there is a smaller seasonal variation than in the north. From 1979 to 1991, the agreement between the trends derived from the SBUV, TOMS and the ground-based Dobson network records is better than 2 %/decade.

WMO (1995) also reported that the bulk of the loss in total ozone at mid-latitudes has taken place at altitudes between 15 and 25 km. The available long term records are sparse with nearly all of those longer than 10 years in the northern mid-latitudes. In this region there is good agreement between the ozonesonde and SAGE trends above 20 km. However there has been considerable debate about the magnitude of the trends below 20 km with SAGE giving considerably larger trends than the ozonesondes (-20 ± 8 vs 7 ± 3 %/decade). SAGE also reports large trends (-25 to -30 %/decade) in the very low stratosphere in the tropics, although it should be noted that there is very little ozone at these altitudes so that the effect on the total column is small.

Re-analysis of the TOMS measurements has produced a continuous record of total ozone from 1979-1994 by producing version 7 level data from the

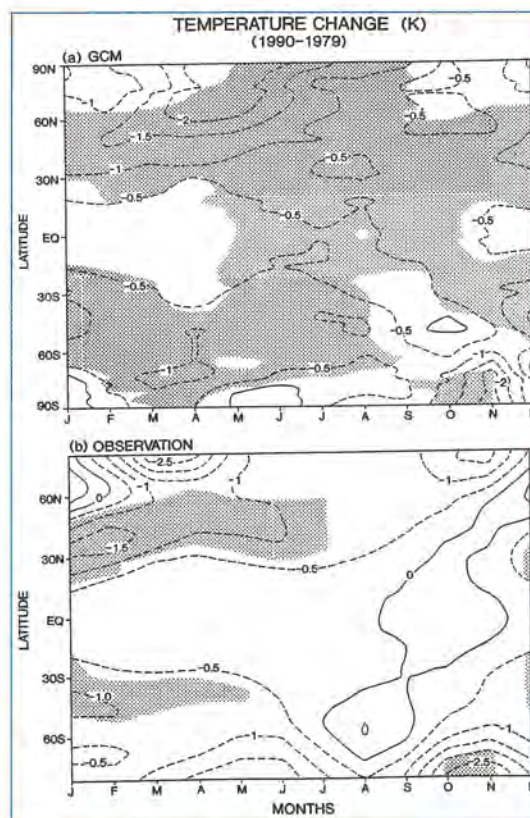


Figure 4. (Ramaswamy et al., *Nature*, Vol. 382, pp. 616-618, 1996, fig. 2). Zonal, monthly-mean pattern of the lower stratosphere change over the past decade (1979-1990)

a - As simulated by the GCM due to the observed ozone depletion (Stolarski et al, *GRL*, 1991; McCormick et al. *GRL*, 1992) for the altitude region of the model where ozone concentration changes occur.

b - as inferred from satellite observations for a layer comprising the lower stratosphere. Shaded areas denote the statistical significance at the 95 % level.

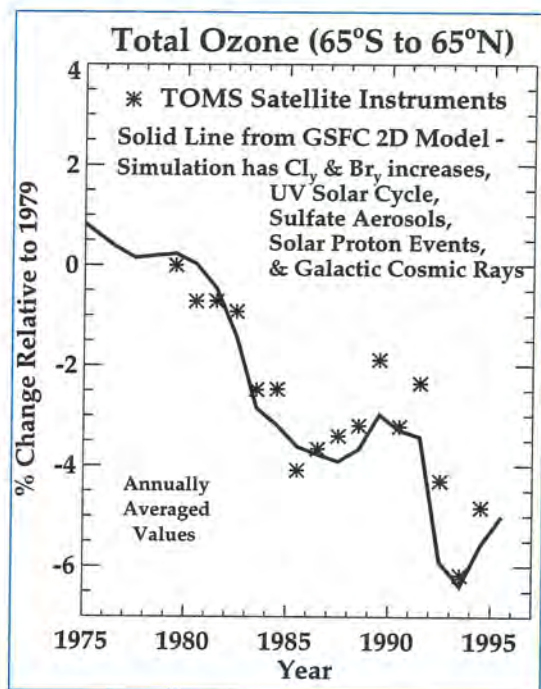


Figure 5. Percentage total ozone changes between 1975 and 1995 for annually averaged values integrated between 65°S and 65°N for TOMS version 7 (stars) and a GSFC 2-D model simulation (solid line). (adapted from fig. 15 of Jackman et al., *Past, present, and future modelled ozone trends with comparisons to observed trends*, JGR, 101, 28753-28767, [1996], copyright AGU).

instruments on the Nimbus 7 and Meteor 3 satellites. The losses calculated from this record are about 1 % per decade smaller than those found in the SBUV record, and so some of the smaller losses which were previously statistically significant by a small amount are found in TOMS v.7 to be just insignificant. This effect is most obvious in summer in northern mid-latitudes and in the tropics where the TOMS v.7 trend is found to be about -1% per decade and not statistically significant. The TOMS v.7 data has not been widely available for long and further close examination will be of great interest.

The correction made in the SAGE algorithm for the presence of stratospheric aerosol changes has been known to induce an uncertainty into the ozone measurement at low altitudes. Any change in aerosol loading could induce an artificial trend. The influence of changes in size distribution of aerosols on the SAGE measurements was examined (Steele et al.).

They concluded that any change in size distribution over the SAGE observational period could lead to artefacts in ozone trends below about 20 km.

The BUV instrument on Nimbus-4 was operational from 1970-77. The number of measurements decreased through this period. During the first two years, near-global coverage was achieved. These data have been re-examined by Stolarski et al. and compared to the available ground-based measurements and are found to be consistent to within about 5 %, although it should be noted that the BUV measurements were calibrated using the World Standard Dobson Instrument. It is hoped that the BUV data can be re-analysed to version 7 standard using the experience gained from TOMS and SBUV.

The evolution of ozone levels as atmospheric chlorine amounts fall and the possibility of early detection of a recovery was discussed by Hofmann et al. The ozonesonde data collected at the South Pole from 1967-71 and since 1985 indicate that ozone loss at altitudes above 20 km have accelerated in recent years and so could be reasonably expected to show early signs of recovery. The globally averaged (65°S-65°N) total ozone from TOMS has been compared by Jackman et al. (see JGR, 1996) with the output from the Goddard 2-D model (fig. 5). According to this model, most of the ozone changes (4 %) are driven by halocarbon increases, UV radiation variations (1.2 % difference in ozone between solar maximum and minimum) and changes in sulphate aerosol (ozone decrease -2.8 % in 1992 due to Pinatubo).

The effect of aerosol on model calculated ozone trends has been investigated in more detail by Solomon et al. They conclude, among other things, that the effect

of the solar cycle on total ozone could be much less than currently thought as the eleven year solar cycle could have acted as a proxy variable for volcanic aerosol loading over the last 20 years. More study of the time evolution of ozone changes as a function of season, altitude and latitude before cause and effect can be quantitatively ascribed. The effects of global warming on the stratosphere are not well enough understood to do this at the current time.

Water vapour

Rapporteur : John Gille

There was no session devoted specifically to Upper Troposphere/Lower Stratosphere (UT/LS) water vapour, although a number of papers bearing on this subject were presented in sessions on trends and climatology, and in the posters. These are reviewed here; because of the overlap, some of the papers will be mentioned in other sections as well.

A number of advances in knowledge of the UT/LS were reported, and plans for further activities were presented. K. Rosenlof reported analyses of satellite data showing that the effects of Antarctic dehydration extend to about 50° S at the 46 hPa level. They also displayed significant longitudinal variations, explaining differences in earlier aircraft observations. She also showed that mixing from the dehydrated region above the tropical tropopause is more effective toward the northern hemisphere than the southern hemisphere. For this and other reasons, the southern hemisphere lower stratosphere is slightly drier than the northern hemisphere. P. Mote and T. Dunkerton extended Mote's earlier analysis of the tropical tape recorder, deriving an estimate of the upward velocity in the tropics. They found a minimum near 50 hPa, in agreement with Rosenlof's results. D. Jackson presented maps of UT/LS water vapour derived from HALOE data. These showed large longitudinal variations, with higher water vapor concentrations in regions

characterised by more active convection. In a related paper, G. Reid showed that short term variations of tropical tropopause height and temperature are quite large, especially during the northern summer. The vapour pressure associated with these temperatures correspond to water vapour mixing ratios that are larger than observed. The observed values can be understood if air only enters the stratosphere when the tropopause is highest and coldest, i.e. when vertical motions are largest. Tropical water vapour content also varies strongly in response to the QBO, according to results based on SAGE and HALOE data presented by E.W. Chiou.

In middle latitudes D. McKenna outlined the result of an aircraft study of a major tropopause fold event off the coast of France. In this case, because water vapour mixing ratios were altered by phase changes and sedimentation, he concluded that the negative correlation between ozone and water vapor may not be true after the exchange, and that air going through the fold could carry significant amounts of water vapour into the lower stratosphere.

J. Gille reviewed the global distribution of water vapour and presented the preliminary outline of plans for the SPARC UT/LS water vapour initiative. The activities are envisaged to fall under three major headings: determination of the present distribution of water vapour, understanding the mechanism that maintains that distribution, and developing a capability to model the distribution and predict its future evolution. While much progress can be made to determine the present distribution from satellite data, these need to be validated and have their absolute values confirmed through comparison with in situ measurements. In-situ measurements and ground-based remote sensing are likely to play a major role in understanding the smaller-scale mechanisms.

Session 4. Gravity wave processes and their parameterisation

**Rapporteurs : K. Hamilton
and R. Vincent**

The session included a total of 22 presentations and posters. The use of single-station radiosonde horizontal wind and temperature measurements to determine dominant gravity wave characteristics was dealt with in five of these papers. R. Vincent reviewed the efforts of the SPARC Gravity Wave Initiative to gather and analyse high-resolution radiosonde data on a global basis. G. Roff et al. and F. Guest et al. discussed radiosonde data from the TOGA-COARE experiment in the tropics and at Macquarie Island (54°S), respectively. K. Sato and T. Dunkerton described their research on determining the momentum flux associated with equatorial modes using near-equatorial radiosonde data, while S. Ogino et al. presented an analysis of radiosonde data from two research cruises that spanned a large meridional range in both the Northern and Southern Hemispheres.

Seven of the papers dealt with the inclusion of practical gravity wave drag parameterisations within global, three-dimensional models. K. Hamilton reviewed the status of such parameterisations in light of the recent SPARC workshop on this topic (Santa Fe, USA, April 1996, see SPARC Newsletter #7). B. Lawrence described some experiments with a mechanistic 3D model of the middle atmosphere incorporating a parameterisation of non-stationary gravity waves. Papers by E. Manzini and by N. McFarlane and C. McLandress described aspects of simulations obtained with general circulation models that included parameterisations of non-stationary wave drag. Three papers (Y. Chang et al., Y.-J. Kim et al., W. Min et al.) discussed the effects of inclusion of topographic drag parameterisations in GCMs. An overall theme emerging from all of these papers is the complicated

nature of the interaction between the parameterised drag and other aspects of the model formulation.

Four papers dealt with simplified models of gravity wave generation and propagation. J. Alexander and J. Holton described simulations of the gravity wave field generated by a tropical squall line in a nonlinear, time-dependent, 2D mesoscale model. I. Mikkelsen and J. Thayer showed 3D simulations of topographic waves over Greenland which were compared with actual incoherent scatter radar measurements. S. Eckermann and J. Bacmeister described the application of ray tracing models to predict the gravity wave response to flow over Iceland. They were able to apply this to explain aircraft observations considerably downstream from the wave source. J. Alexander showed that a ray-tracing model with a simple saturation condition imposed could explain many of the observed geographical variations in upper stratospheric wave variance, even when a globally-uniform source is assumed.

There were also interesting papers describing the application of sophisticated statistical analysis techniques to isolate gravity wave properties in observations (X. Zhu et al., T. Shimomai et al., F. Chané-Ming and F. Molinaro) and model simulation (M. Charron and G. Brunet). Also discussed were simple models of the effect of adiabatic gravity wave displacements on observed ozone profiles (D. Gibson-Wilde et al.) and visualisation of gravity waves in laboratory experiments (S. Sakai et al.).

Session 5. Stratosphere- troposphere transport and mixing

Rapporteur : T. Shepherd

It is now widely accepted that the subject of stratosphere-troposphere exchange (STE) is best viewed within the broader context of transport and mixing and this

viewpoint was reflected in the title of the session. Results presented in the session fell, for the most part, within one of the six following areas.

Brewer-Dobson circulation

The Brewer-Dobson circulation describes the equator-to-pole Lagrangian circulation in the stratosphere, and results from a combination of the residual circulation and (mainly quasi-isentropic) mixing. There have been many recent attempts to quantify the residual circulation through radiative calculations, though as T. Shepherd noted this calculation is subject to considerable uncertainties. In any case the effect of mixing is very far from negligible, and so there is much current interest in quantitatively characterising the Brewer-Dobson circulation through the « age » of stratospheric air (relative to when it passed through the tropical tropopause). This can be done using chemical tracers - either real or idealised - with simple time dependence, e.g. linear or seasonally varying (T. Hall, D. Rind, J. Bacmeister (presented by S. Eckermann)). Hall emphasised, however, that while « age » corresponds to periodic-signal phase lags (like in the tropical « Tape recorder » when the tracer motion is essentially advective, when there is significant mixing the two quantities can be very different. Thus one must be careful in interpreting time dependencies in tracer signals in regions such as the lower stratosphere - where there is strong mixing. In general one must consider an « age spectrum ». More effort is needed now to quantitatively interpret tracer information and relate it to mixing and transport properties.

Tropical tropopause

The tropical tropopause remains a region of great interest. Efforts continue to further refine the « tape recorder » model by including the effects of the QBO (P. Mote). Certainly the annual cycle in height and temperature of

the tropical tropopause seems driven from above, as it is not well correlated with the middle troposphere (G. Reid). On the other hand, it seems quite clear that the monthly mean tropical tropopause temperatures are nowhere near cold enough to account for the low water vapour values (G. Reid). Reid suggested that this discrepancy could be resolved if air entered the stratosphere via intermittent injections in cold turrets, so that the tropopause temperature would be particularly cold when the air passed through.

Of course large-scale longitudinal asymmetries are also significant. D. Jackson et al. presented the global distribution of upper troposphere/lower stratospheric water vapour based on the HALOE observations (version 17) (figure 6). The map for Dec., Jan., Feb. shows that the moistest air is located over Indonesia, Africa, and South America, all regions of strong convective activity, and this suggests that the air here is being moistened by the tops of convective cloud systems. The Sept., Oct., Nov. plot shows these regions of moist air less clearly (by the way, this plot shows dehydration at southern high latitudes due to the cold temperatures there).

More complete measurements of the tropical tropopause region, especially of the water vapour distribution, are clearly needed to resolve this issue of what controls the water vapour values in the lower tropical stratosphere.

Extratropical downwelling

The Brewer-Dobson circulation ends in extratropical downwelling. T. Shepherd discussed the recent work of Appenzeller et al. (1996) which demonstrated a lag between the mass flux into and out of the Northern Hemisphere lowermost stratosphere, a result of its « seasonal breathing ». This lag explains the seasonal cycle of STE inferred from tracers ; insofar as this is distinct from the seasonal cycle of tropopause folds, this reinforces the global view of STE.

There remains an enormous discrepancy between the total mass flux across the tropopause and local estimates based on Wei's (1987) diagnostic (P. Siegmund, A. Ebel) ; clearly this must be clarified. Finally, a significant reason - especially within SPARC - for being interested in STE in the extratropics concerns the downward transport of ozone, and this is becoming the object of global budget analyses (A. Gettelman).

Tropical/extratropical mixing

A major focus of recent studies has been mixing/exchange across the subtropical lower stratosphere « quasi-barrier » (manifested in a jump in tracer correlations). T. Shepherd reviewed the many recent papers that use dilution of chemical correlations with altitude to infer that, by 22 km, nearly half the air ascending in the « tropical pipe » is of extratropical origin. Presumably such significant entrainment should show up in the age spectrum. It is not clear whether further refinements of these calculations are possible, or sensible. This issue continues to be hampered by the lack of reliable wind data in the tropics, and by the apparent inability of all models to simulate a realistic subtropical transport barrier, i.e. to maintain a tracer edge (D. Cunnold).

Mixing and filamentation in the lowermost stratosphere

It is now clearly established, through a number of recent studies, that laminae seen in vertical profiles of ozone and other tracers, previously attributed to gravity waves, are in fact the result of filamentation of the vortex edge (M. Schoeberl, B. Legras, S. Reid). It was emphasised by T. Shepherd that this is in accord with the current picture of tracer motion being dominated by large-scale quasi-horizontal (2D) advection. The phenomenology of large eddies acting on sharp tracer gradients (the essence of the STE problem) is opposite to that assumed by

classical diffusion (K-theory), and the fact that homogenisation occurs first on large-rather than small-scales is again opposite to diffusive behaviour.

T. Shepherd argued that large-scale filamentation of the vortex edge led to sharp « cliff-like » features in horizontal tracer profiles, and was thereby responsible for the k-2 horizontal wavenumber spectra seen in certain chemical tracers down to scales of 1 km

or so (and previously attributed to gravity waves). M. Schoeberl made a similar point in conjunction with interpretation of recent data from the TOTE/VOTE campaign. Although large-scale advection is evidently dominant, there is nevertheless some evidence of small-scale gravity wave related activity in tracer structure (A. Langford). Note that gravity waves do seem to dominate the dynamical (as opposed to tracer) fields at these scales.

Mesoscale case studies of STE

There were a number of fairly traditional case studies of STE in tropopause folds (R. Rood, A. Ebel, D. McKenna, C. Schiller, E. Schuepbach). Rood showed a particularly clean case of rapid diabatic ascent of air from the boundary layer into the stratosphere, though it was notable that the ascent was capped in the very lowest layers of the stratosphere. This confirms the view that tropopause folds cannot

ECHAM3/CHEM (on-line) Aircraft - Control

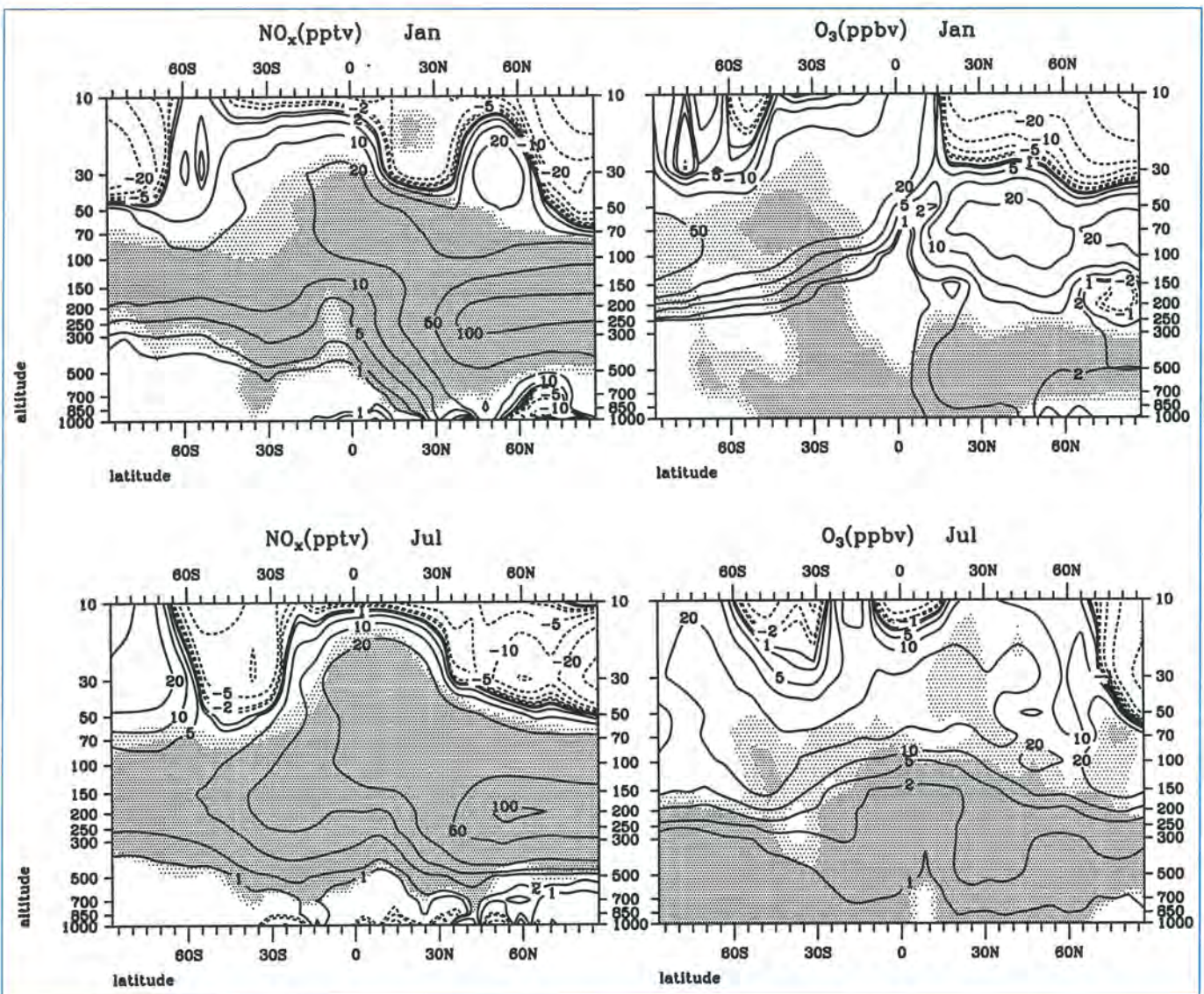


Figure 7. (from M. Dameris et al. « Impact of Aircraft Emissions on Atmospheric Chemistry », Inst. f. Physik d. Atmosphäre, Report n° 6 ; Contributions on the topic of impact of aircraft emissions upon the atmosphere, edit. by U. Schumann, fig. 2). Differences in NO_x (left column, in pptv) and O_3 (right column, in ppbv) volume mixing ratio between a perturbed on-line integration with aircraft emissions and an on-line control integration without aircraft emissions for January (top) and July (bottom), using the GCM ECHAM3 coupled with a comprehensive chemistry module CHEM. Positive values indicate increase due to air traffic. Light (heavy) shaded areas denote regions of significance on the 95 % (99 %) level.

get air very deep into the stratosphere; they are strongly asymmetric in this respect. D. McKenna showed evidence of a fold having both tropospheric and stratospheric chemical characteristics, suggesting that simple distinctions between stratosphere and troposphere are inadequate. The issue remains of how to fit these illuminating case studies into a broader quantitative framework.

Session 6. Chemistry- climate interaction

Rapporteur : A.R. Ravishankara

The session on the UT/LS chemistry was rather small. However, it has to be combined with papers and posters from other sessions to form an image of the current research in this area. Almost all the presentations in this session dealt with the abundance of ozone and its changes in the UT/LS. A few papers also dealt with other atmospheric constituents, their variations and their optical/radiative properties.

Most emphasis of the session was on the lower stratospheric ozone depletion. From the talks and discussions of the Trends Group, it was clear that there is a downward change in the column ozone abundance from 1970s to 1990s. Even though this depletion is small, ~5 % in integrated ozone abundance between 60° N and 60° S, compared to the polar ozone depletion, the signature for the loss is unquestionable. The vertical distribution of the ozone shows a depletion in the lower stratosphere. Theoretical studies presented at the meeting could account for the observed yearly trends in the column ozone loss when satellite-measured sulphate aerosol loading were incorporated in models along with the most up-to-date chemistry. In addition, the findings clearly suggested that volcanic eruptions have modulated the ozone loss rates. It was also clear that these modulations could have been previously attributed to solar cycles. One of the major highlights of the meeting was the ability of current models (mostly

2D) to near-quantitatively account for the observed decadal trend in the stratospheric column ozone abundance. All these analyses show that the increasing anthropogenic chlorine is responsible for the observed stratospheric ozone loss. This is particularly important because it strongly links the stratospheric ozone depletion on the global scale with anthropogenic chlorine, as in the case of the Antarctic ozone hole.

There was very little discussion of the polar ozone depletion observed during the past two decades. However, it was suggested at the meeting that one of the indicators for the recovery of the Antarctic ozone hole may be found in the changes in the vertical profiles measured in the polar regions. This insightful and interesting suggestion needs to be followed up.

Many of the papers dealt with the fundamental processes involved in the chemistry and physics of the UT/LS. This included free radical reaction kinetics, heterogeneous reactions, photochemical properties, and spectroscopic constants. It was suggested that formation of water clusters could change the transmission of the infrared radiation through clouds. Measurements of rate constants of certain free radical reactions down to 190 K were shown to deviate from those extrapolated from higher temperatures. The quantum yields for dissociation of atmospheric molecules were shown to vary with wavelength, temperature, and pressure. The heterogeneous reaction rates were suggested to vary with composition of the substrate, relative humidity, and temperature. Thus, the need for determinations of the basic parameters under conditions prevalent in the UT/LS was highlighted.

The heterogeneous hydrolysis of bromine nitrate on liquid stratospheric sulphuric acid aerosol was shown to be an important HOx source and a pathway for the conversion of NOx to NOy at high latitudes. Some field observations pertaining to the stratosphere were presented. This included observation of particles as well as gas-phase species.

Application of these laboratory and field observations to modelling studies aimed at explaining the field observations in the lower stratosphere were also discussed. Perturbations to lower stratospheric ozone due to various emissions, including those from aircraft, were presented (fig. 7 as an example).

The general impression was that there have been many recent successes in this field. A good example of the success is the explanation of the decadal ozone trend is one example. The lower stratospheric chemistry is maturing rapidly and has a large number of scientists working on it. Many of the practitioners of this field, however, were missing at the assembly. They need to be attracted into future SPARC activities.

Discussions of the upper tropospheric chemistry was very limited. The major questions for research in this area are : What determines the abundance of ozone in the UT ? How is this abundance affected by natural and anthropogenic emissions ? The area of UT chemistry has attracted significant current interest because of the possible environmental impact of subsonic aircraft. The transport of ozone from the stratosphere to UT was discussed in another session. It is clear that the estimated flux of ozone from the stratosphere to the UT is very uncertain. The in-situ photochemical production is also uncertain because of major uncertainties in the abundance of NOx in the UT. Further, the detailed chemistry in this region is not fully elucidated ; it is, indeed, far from complete. For example, the impact of recently observed high levels of acetone on the chemistry of this region is unclear. The role of heterogeneous chemistry in this region is very poorly understood. The lack of understanding about the heterogeneous reactions arises because of a lack of information about the composition of the particles as well as the reactivities of species on many substrates at warmer temperatures. The deficiency in the overall chemistry arises because of a lack of focused and

coordinated field programs which can provide information on the composition of this region of the atmosphere. Thus, the UT chemistry is a field that is in its infancy and can be greatly aided by many SPARC activities.

Session 7. UV radiation and its impacts

Rapporteur : M.-L. Chanin

In this session, the papers presented could be classified into 4 categories: UV effects on human health, UV radiative transfer models, UV-Index calculation and forecast, and UV-B measurements (with the largest quantity of papers).

The introductory paper by B. Armstrong reviewed the potential effects of UV on human health, mostly the harmful ones: i.e. the effects on immunity, eye damage and skin cancer. The dose-response relationship was discussed as well as the question of accumulation versus occasional exposure, which could both lead to dangerous effects strongly dependent on the pattern of exposure. At least one fact seems to be well established: it is that recreational sun exposure is more dangerous than laborious one. Australia being the place with the largest incidence of melanoma in the world, numerous causal studies were attempted and we heard the results of a recent large study of trends in melanoma incidence which was conducted in a quite thorough manner, taking into account the seasonal and annual ozone trends, the geographical trends of UV radiation (UV-B, UV-A, MEDs) as well as the demography and its variation with time versus latitude and longitude and the characteristics of the population.

The sensitivity of UV-B calculations on atmospheric variables was the subject of several papers; it concerns clouds, aerosols, pollution, solar zenith angle, surface albedo and ozone concentration and vertical profile. Models taking into account those parameters were presented and as an example the STAR model (System for Transfer of Atmospheric Radiation, by A. Rug-

gaber) shows consistency with measurement within 10% under cloudless skies. The role of scattered clouds as an amplifier of UV radiation was stressed by R. L. McKenzie, and the mechanism of amplification does not seem to be understood and could be an issue that the SPARC scientific community should address. Most of the papers dealing with those radiative transfer calculations aimed towards a predictability in UV-B doses, based mostly on the ozone situation and the cloud forecasts. For example the Bureau of Meteorology in Brisbane issues a daily UV forecast map for all Australia, converted into an index which indicates the potential maximum UV-B intensity for the next day assuming cloud-free skies. The German Weather Service 48h-forecast was also presented. UV irradiance measurements have been the topics of the largest number of papers and they were introduced by an extensive review of the subject by R. L. McKenzie. The general goal of such UV monitoring programme was clearly stressed with 3 aims: understanding the causes of variability in UV radiation, relate UV variation at different sites in the world, and determining UV trends. Very interesting results of observations carried out from Lauder N.Z. (45° S, 170° E, 370m), Mauna Loa Observatory, Hawaii (19°5 N, 155°6 W, 3400m) and other Northern Hemisphere sites show that relatively high UV is observed in the South Hemisphere compared to the Northern Hemisphere due to the combined effects of less ozone, closer Earth-Sun separation in the summer and less tropospheric pollution. The difference can be as high as 15% but the peak UV can reach values obtained at the equator. The site of Mauna Loa Observatory due to its high altitude shows enhanced sensitivity to ozone change and seasonal effects. Results from other Southern Hemisphere sites as La Paz, Bolivia (16.3° S), Ushuaia, Argentina, (54.5° S) and Syowa Station in Antarctica confirm the enhanced level of UV in the Southern Hemisphere.

The difficulties of trend detection and data quality insurance proce-

dures were also discussed by R. L. McKenzie and the advantages of high resolution spectral distribution was demonstrated: a drift of 0.1nm could carry an error in the estimate of erythral UV of 2%. Procedures to maintain the wavelengths shifts within 0.02nm based on the Fraunhofer lines spectral positions were suggested.

Session 8. Other aspects of stratospheric processes

Rapporteur : M. Geller

The section dealt with topics that were not covered by the previous seven sessions corresponding to the existing SPARC projects.

Some of the important points were that in-situ measurements were still to play a very important role even when satellites were making measurements of similar quantities. The in-situ observations have greater precision, in many instances, and they give more local time coverage at a given point in space than satellites, allowing one to infer, e. g., photolysis cross-sections and sunrise-sunset behaviour in a way that is not possible with satellites.

Another paper showed how TV imaging and lidar observations can be used to validate satellite images of contrails. The subject is of how aircraft contrails may be affecting climate by altering the earth's albedo directly and by altering the optical properties of existing clouds. Another paper showed the results of a 3-D isentropic dynamical-chemical modelling of the structure of the Brewer-Dobson circulation. This model reproduced the mean latitude-longitude TOMS O₃ structures. The trend in total ozone was found to be highly correlated with the trend in the vertical component of the Eliassen-Palm flux. However, two earlier papers had shown that their 2-D models reproduced observed O₃ trends well, not accounting for interannual variations in dynamics. Thus, it

Figure 1

(courtesy of D. Ortland, University of Michigan). HRDI monthly and zonally averaged zonal winds at the equator. Westerlies are indicated with shades of yellow to brown and Easterlies are green to blue. Contour intervals are 10 m/sec.

The wind pattern in the altitude region from 15 to 30 km is dominated by the QBO. A semiannual oscillation (SAO) predominates from 35 to 95 km, with an abrupt 180° phase shift from the stratopause to the mesopause. These patterns in the evolution of the equatorial winds are interrelated. The westerly and easterly phases seem to originate from the corresponding phase of the SAO at 40 km. SAO Westerlies descend as low as 35 km when the QBO is in its easterly phase. The SAO at the mesopause also has a pattern that follows the QBO. An easterly phase first descends below 70 km (September 1993 and 1995), followed by a relatively weak westerly phase, which is in turn followed by abnormally strong Easterlies at 90 km overlying strong Westerlies at 70 km.

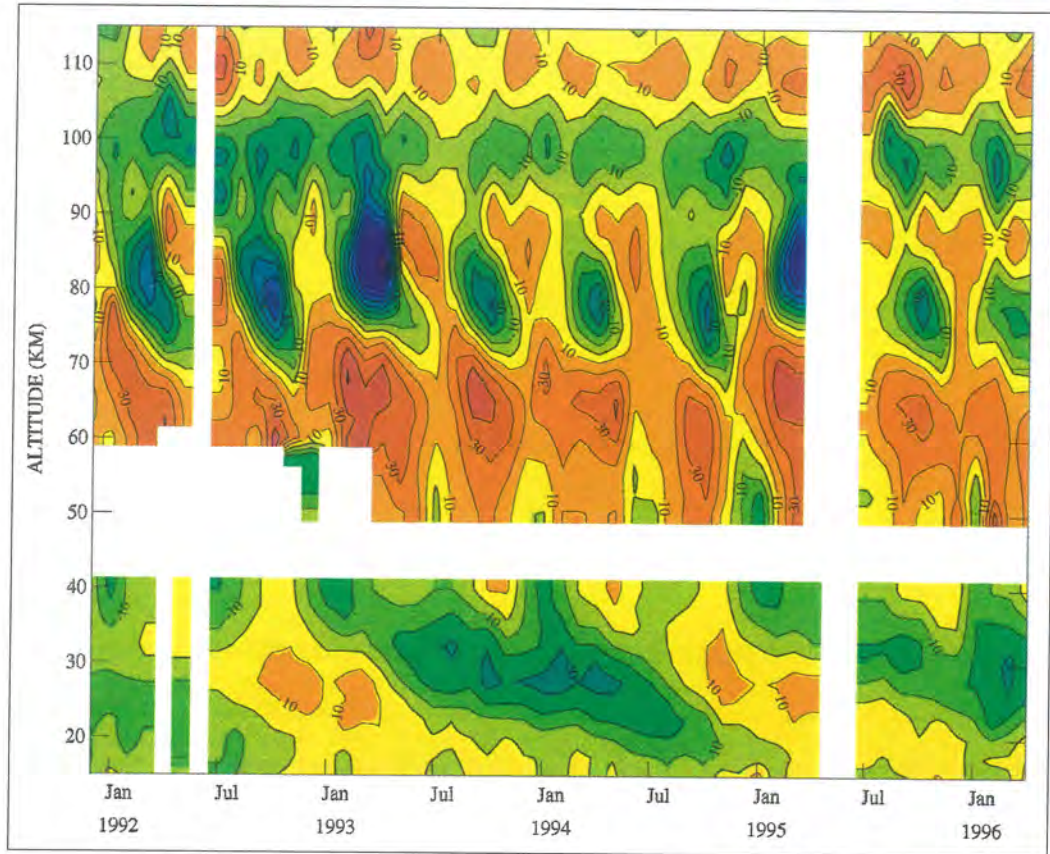
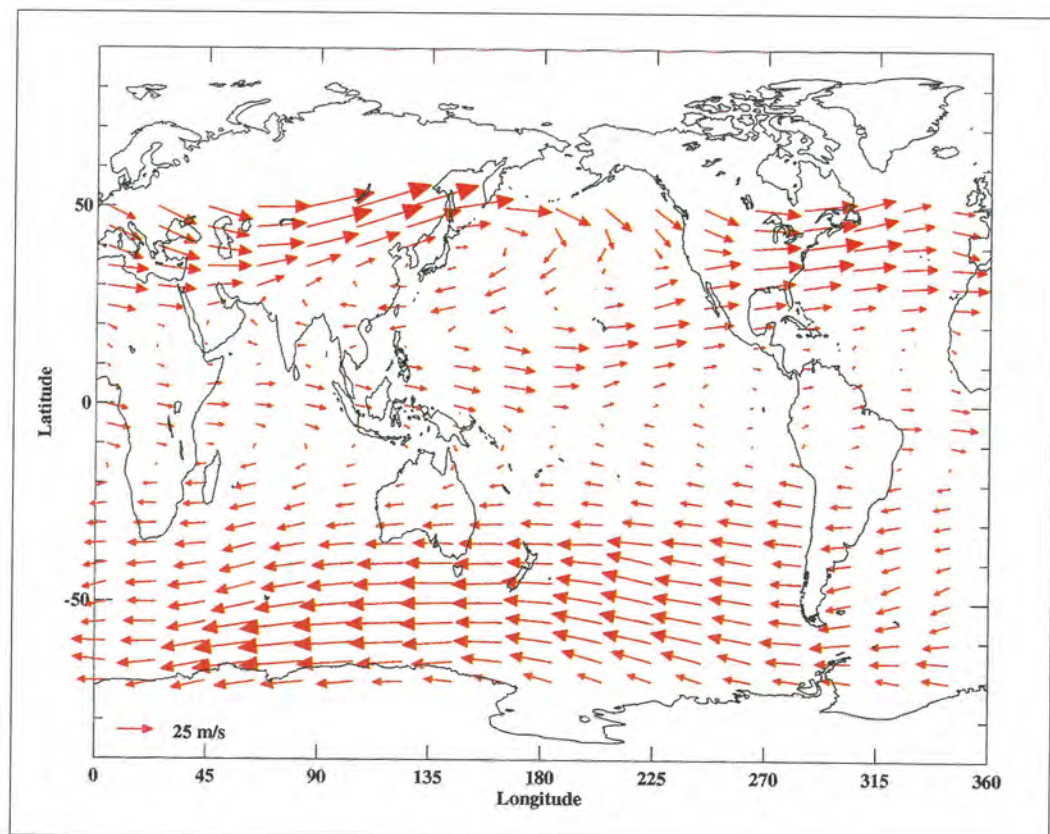


Figure 2

(courtesy of D. Ortland, University of Michigan). Wind field at 35 km measured by HRDI, averaged over the period from 16 November 1994 to 30 November 1994. A strong stationary wave is propagating through Westerlies in the northern hemisphere at a time when Westerlies are also present at this altitude in the tropics (see figure 1), allowing the wave to penetrate into the southern hemisphere.



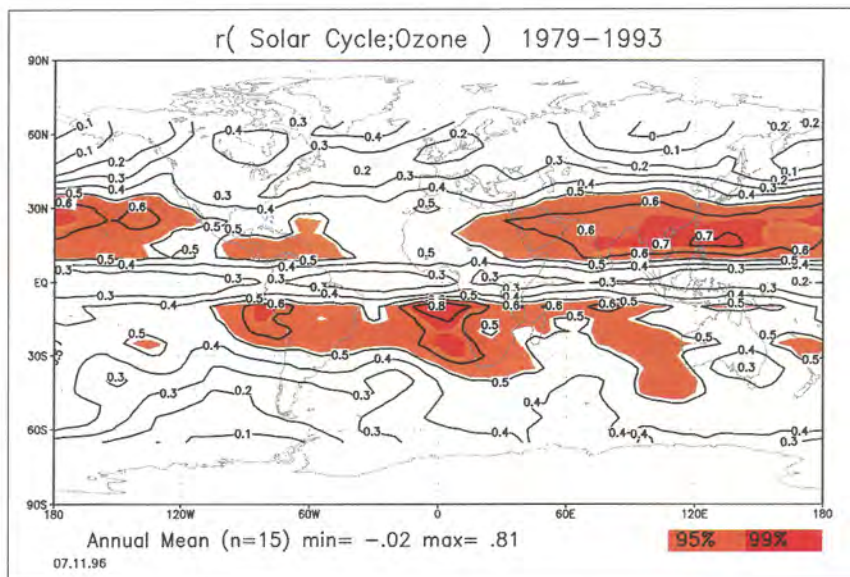


Figure 3

(from K. Labitzke and H. van Loon, *JATP*, 99(1), pp. 9-19, 1997, fig. 2). Correlation between the annual mean total ozone and the 10.7 cm solar flux. Areas with 95% and 99% significance level are shown in red.

Stratosphere-troposphere transport and mixing

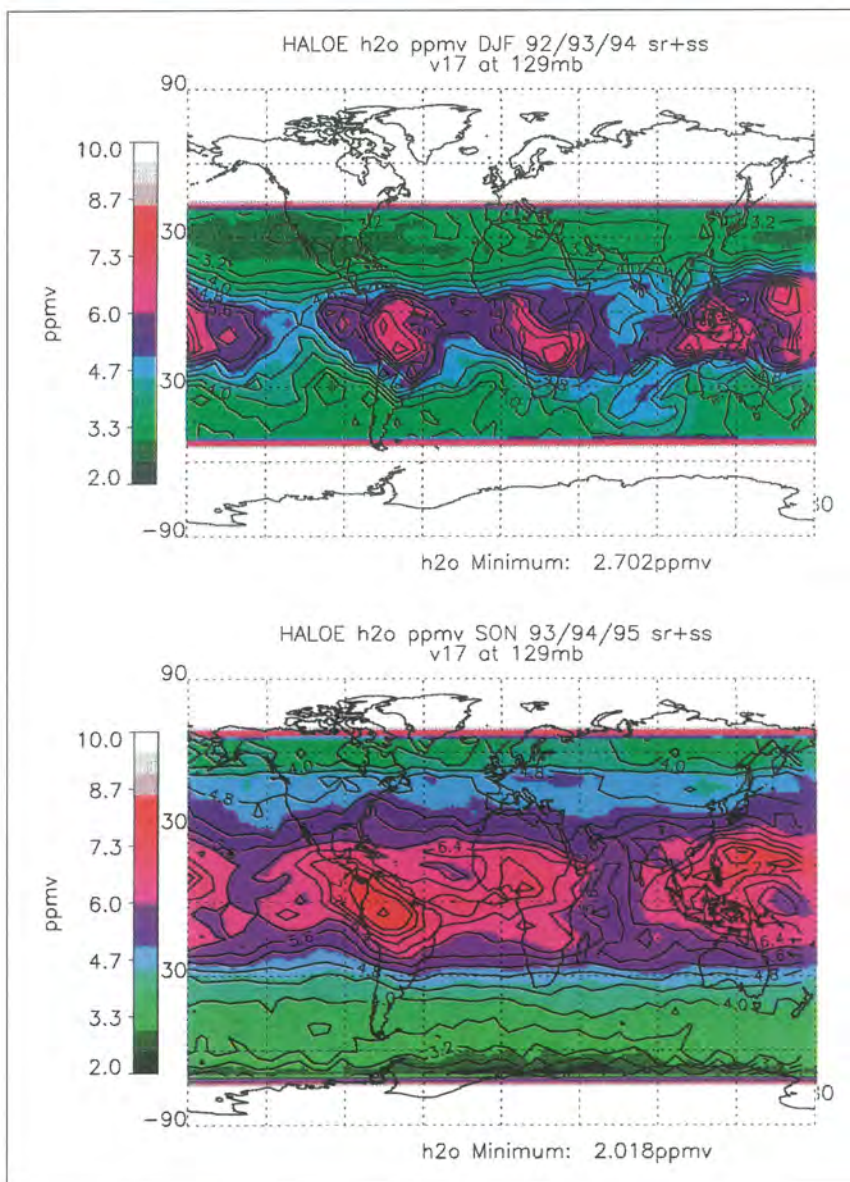


Figure 6

Mean HALOE-based water vapour distribution (ppmv), (sunrise + sunset) V17 at 129 mb :

- Top - December, January, February 1992-1993-1994,
- Bottom - September, October, November 1993-1994-1995.

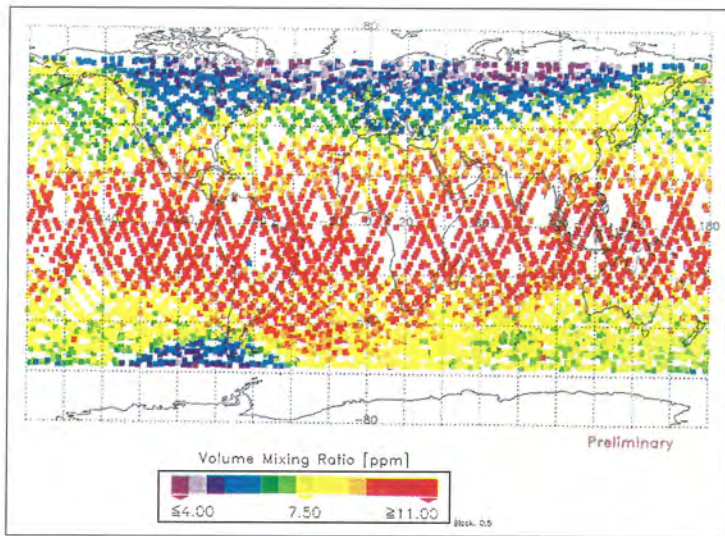


Figure 8
Ozone mixing ratios measured on Nov. 6, 1994 at 30 km altitude.

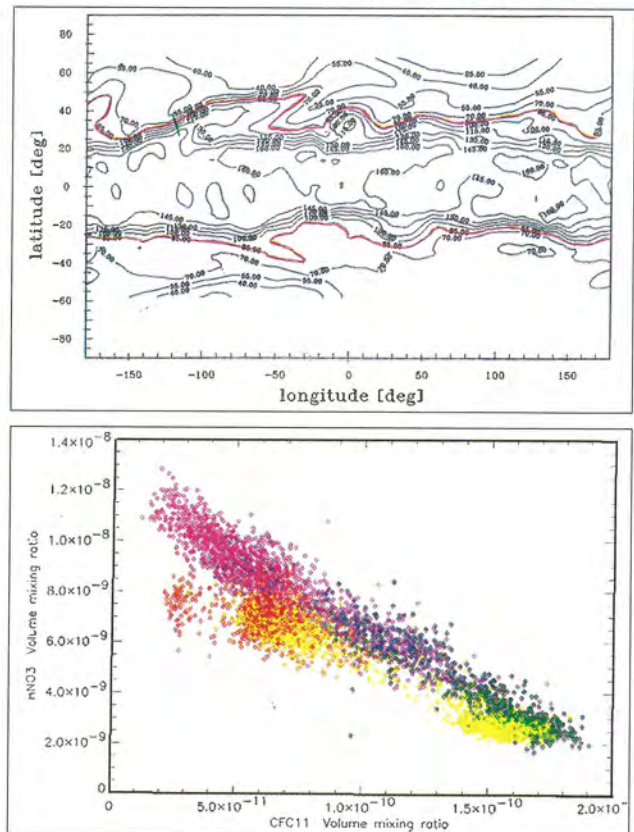


Figure 9
Global distribution of CFC11 on November 6, 1994 at 24 km altitude. Isoline labels are in ppt.

Figure 10
Scatter plot for mixing ratios of HNO_3 versus CFC11 (November 6, 1994, 24 km altitude). Colour code is as follows: 70-50° N pink; 50-30° N blue; 30-10° N green; 10° N-10° S yellow; 10-30° S light green; 30-50° S orange; 50-70° S red.

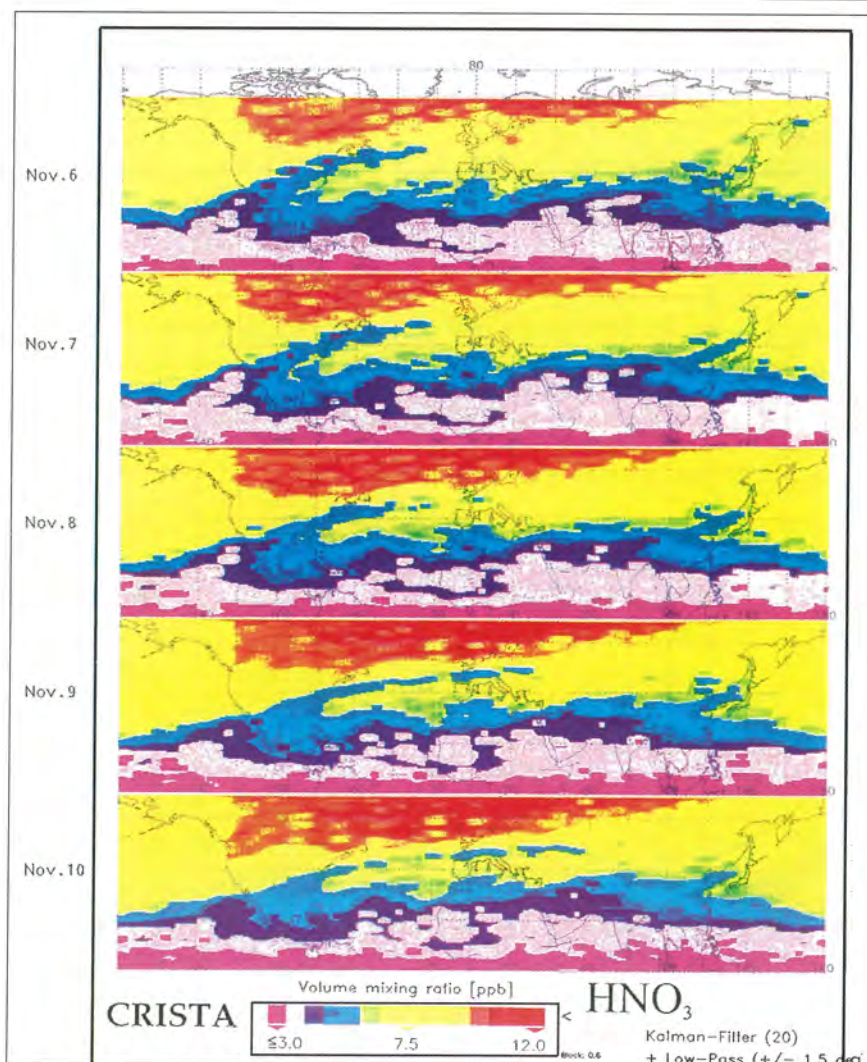


Figure 11
Time development of northern hemisphere HNO_3 distribution from November 6 to 10, 1994 at 27 km altitude.

MAHRSI first results

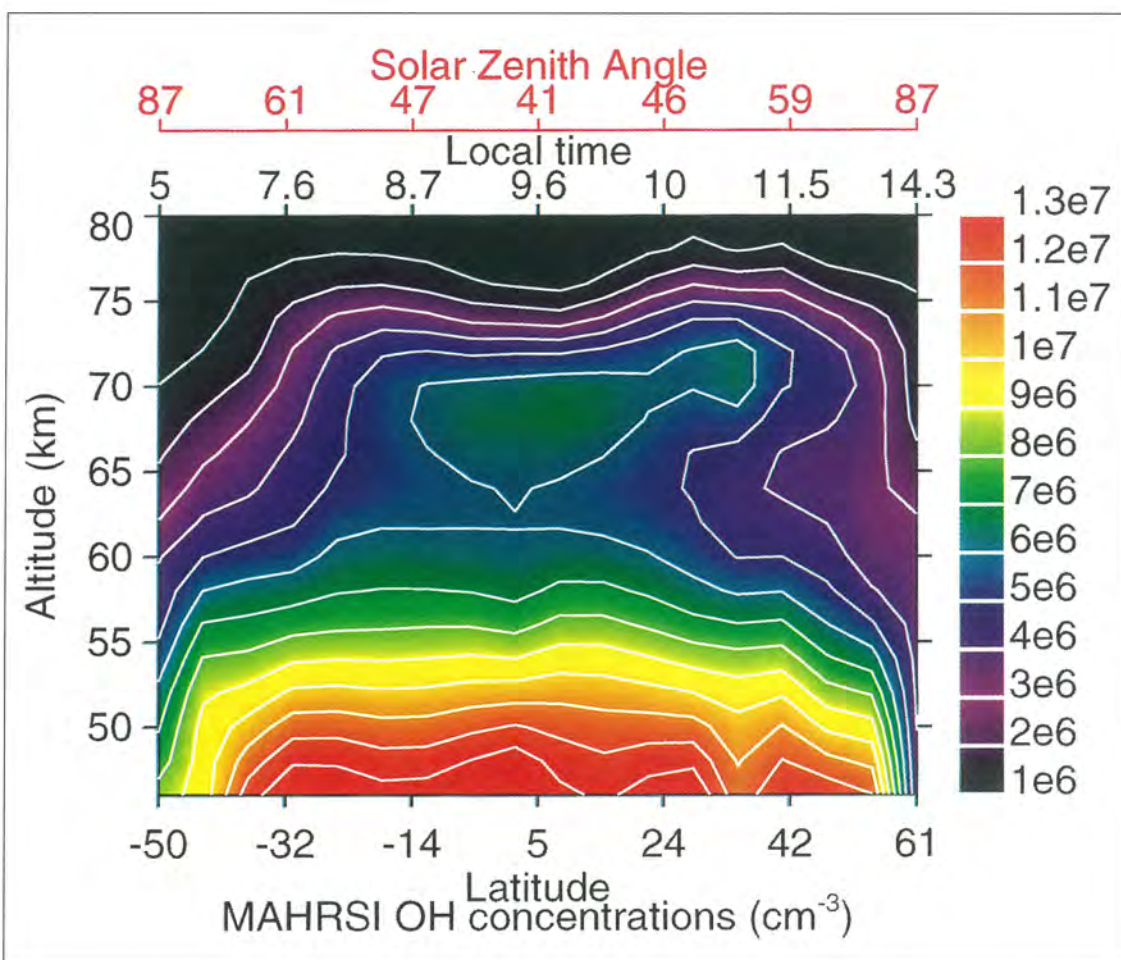
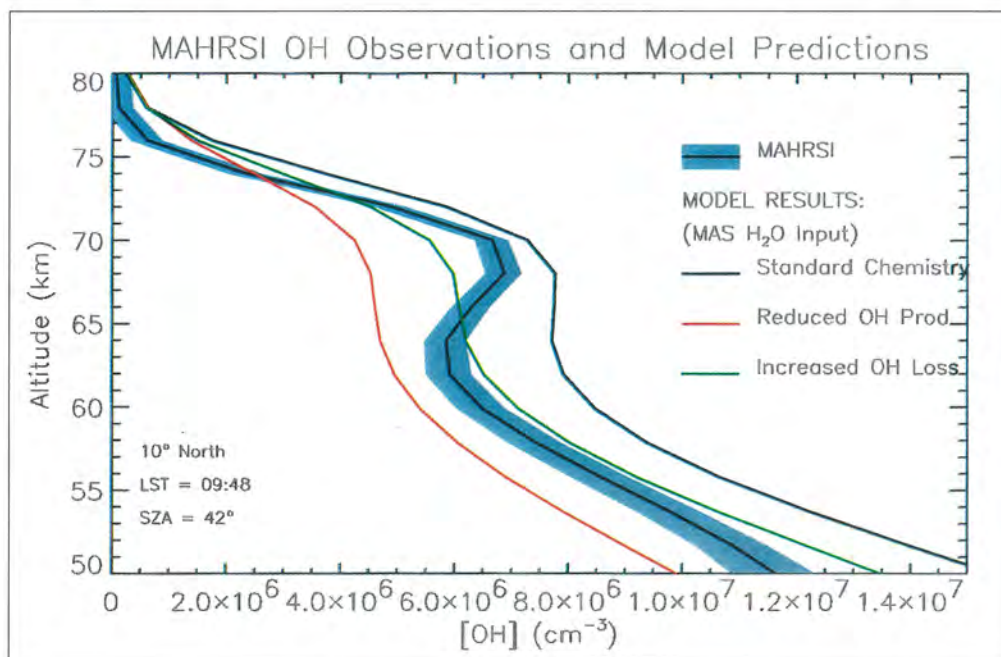


Figure 12
OH abundances observed on November 5, 1994 during a single orbit. Latitude of the observed tangent height is shown on the abscissa while the solar zenith angle and local solar time are shown above the figure. Random errors are typically 5-10%. The diurnal variation of OH illustrated by this image is discussed in the text.

Figure 13

Comparison of retrieved MAHRSI OH number densities for one limb scan (~10N latitude) with photochemical model results at the appropriate local time and latitude. The shaded area shows the MAHRSI OH random measurement error propagated through the retrieval.



propagated through the retrieval. The black line shows model results for standard (JPL94) recommended HOx chemical kinetics. The green line is a model incorporating a 30% increase (1 sigma laboratory uncertainty) in the rate coefficient for $\text{OH} + \text{HO}_2 \rightarrow \text{H}_2\text{O} + \text{O}_2$. The blue line is the model result with a 70% decrease in the rate coefficient for $\text{O} + \text{HO}_2 \rightarrow \text{HO} + \text{O}_2$. Standard JPL94 HOx overpredicts OH at all altitudes and none of the models adequately reproduce the observed vertical density distribution or its.

appears that there are conflicting results on the role of dynamics in producing observed O_3 trends.

Other papers dealt with the role of SST variations in producing the time variability of the length of the QBO cycle. Again, an earlier paper suggested that the variation of the periods of individual QBO cycles was probably due to variations in the tropical upwelling vertical velocity. The respective roles of these two processes remain to be determined. Some interesting results from the CRISTA instrument showed filamentary constituent structures that agreed quite well with trajectory calculations.

Yet other papers dealt with calculations of vertical velocities in the Antarctic derived from the UKMO analyses as well as those derived from HIS temperature measurements (the HIS-derived values were larger). In another paper, temperatures and aerosol concentrations were derived from lidar observations at Reunion Island. Another interesting paper used models and observations to study O_3 feedback effects on the QBO in stratospheric winds, and

another one tried to understand what processes lead to the highest and coldest tropopause over NE India in the June-July period.

Some topics concerned interannual variations of stratospheric dynamics and O_3 behaviour; the excitation of planetary transient waves; dynamically-induced changes in the Antarctic O_3 hole; and an update of the previously noted relationships between stratospheric temperatures, the QBO, and the Sun. Other presentations dealt with the predictability of stratospheric flow; Kelvin waves in the stratosphere as seen by the HRDI instrument; the role of meridional and vertical motions in giving rise to O_3 structures; and the diurnal variations in stratospheric CIO as determined by balloon observations. Methods were presented how to determine PSCs from AVHRR measurements. New theoretical calculations of the factors that give rise to stratospheric sudden warmings were shown. GCM calculations of the Pinatubo effect on climate were presented and compared to observations. The predictive skill of the

Australian BoM's Global Assimilation and Prediction scheme was demonstrated, and some potential vorticity diagnoses were shown illustrating the relationships between the stratospheric vortex and tropospheric circulation. Polarisation observations of the Pinatubo aerosol layer were shown, as was a diagnosis of the 1989 sudden stratospheric warming in terms of atmospheric angular momentum, and a new formulation for 2D middle atmospheric models was presented.

There were a couple of themes that emerged from this and previous sessions. One is that it is still unclear how much of the interannual variability in the ozone record is due to variabilities in dynamics. Another theme seen throughout the entire meeting is the effects of the stratospheric QBO in many different contexts.

The conference proceedings containing the 4-page extended abstracts will be published as a WCRP report. It will be available in limited quantity by applying to the SPARC Office.

International Workshop on Modelling Heterogeneous Chemistry of the Lower Stratosphere/Upper Troposphere

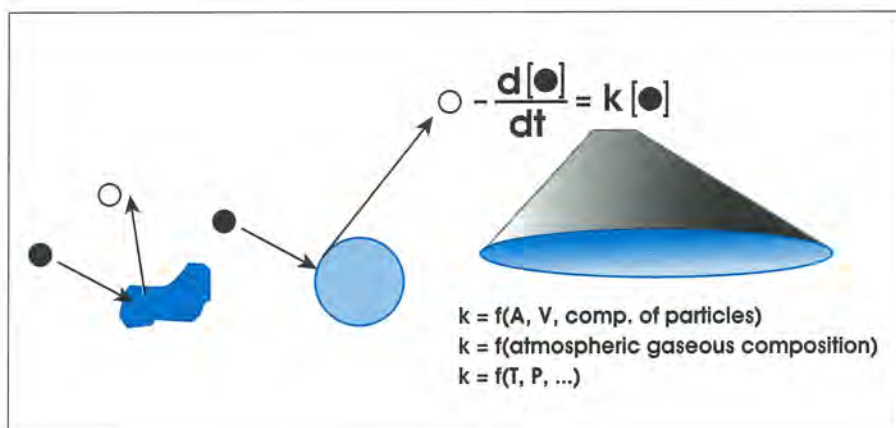
Strasbourg, France, October 21-23, 1996

It is now recognised that heterogeneous reactions play critical roles in the atmosphere. Unfortunately, however, these reactions are still not represented in atmospheric models in a completely realistic manner. Information needed to comprehensively include such processes is either lacking or not being communicated between scientists involved in various disciplines of atmospheric chemistry. To hasten the communication of information between the scientists in all the major disciplines: labo-

ratory measurements, microphysics, field measurements, and modelling, and to take stock of where we are in realistically including heterogeneous processes in modelling activities, a workshop was organised in Strasbourg, France, under the auspices of SPARC of WCRP. Other sponsors of this workshop included NASA, NOAA, Météo-France and the University of Strasbourg. This workshop also provided some of the information needed for the development of an

implementation plan for the UT/LS initiative of SPARC.

This workshop covered heterogeneous chemistry of the LS/UT where such reactions play critical roles. The topics discussed were: (1) Abundance of stratospheric aerosols and PSCs, (2) Microphysics of stratospheric aerosols and PSCs, (3) Heterogeneous chemistry in/on stratospheric aerosols and PSCs, (4) Heterogeneous chemistry of the UT, and (5) Particle formation, predictability, and their properties.



Each of the sessions contained 2 to 3 short talks. The majority of the time was spent on discussion, and the meetings took up ten hours a day ! The chairs directed the discussions (which were often lively and heated, but always polite!) and together with the rapporteurs came up with a summary. The last day was spent on « synthesising » the information.

Session Chairs and Rapporteurs were : Drs. J. Abbatt, R. Bevilacqua, S. Bormann, C. Brogniez, S. Clegg, T. Cox, K. Drdla, G. Fiocco, C. Granier, L. Jaegle, A. Laaksonen, C. Nielsen, J. Penner, J. Rodriguez, M. Tolbert, and J. Wilson.

Speakers at the workshop were: Drs. F. Arnold, K. Carslaw, M. Chipperfield, D. Considine, C. David, F. Dentener, J. Dye, P. Hammill, R. Mackenzie, K. Mauersberger, B. Portmann, R. Salawitch, U. Schurath, L. Thomason, B. Toon, D. Worsnop, and R. Zellner.

On the final day: Drs. I. Isaksen, J. Kaye, P. Mirabel, T. Peter, M. Prather, L. Poole, A. R. Ravishankara, and S. Solomon took part in an organised discussion.

The local organisation was excellent and was handled by Prof. P. Mirabel and his colleagues: Dr. C. George, Mr. F. Schweitzer, and

Mr. L. Magias as well as by Ms. K. Wolfe (NASA). The workshop ran extremely smoothly, and the ambiance was extraordinary ; the visit to the winery was special. The attendance of many participants was made possible by generous travel support by WCRP-SPARC and by NASA.

The organising committee consisted of : Dr. A. R. Ravishankara (NOAA), Prof. I. Isaksen (Univ. of Oslo), Prof. P. Mirabel (Univ. of Strasbourg), Dr. J. Kaye (NASA), Dr. L. Poole (NASA/Langley), and Dr. T. Peter (MPI-Mainz).

A summary of the workshop findings will be published in the next issue of the SPARC Newsletter and the workshop report will be prepared by the organisers and will be distributed to all the participants (others interested in receiving copies should contact the SPARC Office).

● A. R. Ravishankara

Report of the first SPARC Reference Climatology Workshop

Port Jefferson, New York, September 9-10, 1996.
Conveners : W. Randel and M. Geller.

Introduction

GRIPS provides a framework for analysing and comparing troposphere-stratosphere GCM simulations. One of the key questions to be addressed by GRIPS is how well comprehensive GCM's simulate the current climate and its variability. To answer this question requires a comprehensive documentation of the stratospheric climate. To that end, the SPARC Reference Climatology group was established

to provide an updated climatology of the middle atmosphere based on observations.

The first Reference Climatology workshop took place in Port Jefferson. It allowed scientists with expertise in various stratospheric data bases to discuss compilation of this climatology, and establish plans for future action. In addition, several atmospheric modelling groups were also represented, to help determine which

aspects of observations will be most useful for model validation.

The objectives of the meeting were :

- To review prior climatologies and the need for an updated data base,
- To discuss details of the various data sets considered for inclusion in the climatology,
- To set firm plans for future work.

Summary of Scientific Discussions

M. Geller started with an overview of prior climatologies of the stratosphere, including data bases and diagnostic quantities of interest. There followed a series of talks on various global stratospheric data bases: 1) The National Centers for Environmental Prediction (NCEP) operational stratospheric analyses (formerly called National Meteorological Center (NMC) data), by M. Geller; 2) The NASA Goddard Earth Observing System, Data Assimilation System (GEOS DAS) troposphere-stratosphere assimilation, by L. Coy; 3) The United Kingdom Meteorological Office (UKMO) stratospheric assimilation products, by R. Swinbank. These three data sets will form the basis for the stratospheric meteorological climatology, based primarily on their global coverage.

S. Pawson next presented details of the Berlin meteorological analyses, which have an independent analysis system and unique long record which make them valuable for comparing to the more recent global analyses. He also led a discussion on aspects of tropical wind measurements for characterizing the QBO. Characteristics of stratospheric and mesospheric wind measurements from the High Resolution Doppler Imager (HRDI) instrument on UARS were presented by D. Ortland. These data provide both direct tropical wind measurements, and mesospheric altitude data.

K. Hamilton and S. Pawson next discussed the SPARC Climatology from the perspective of atmospheric modelling groups. This inclu-

ded choosing diagnostic quantities to be included in the climatology, and the need for firm documentation of a few basic quantities (in addition to inclusion of more derived fields). It was decided that Phase 1 of the Reference Climatology archive should include fields that mimic the list of meteorological variables chosen for the GRIPS initiative. A list of these quantities is included below. W. Randel led a discussion on inclusion of trace gas climatologies in the SPARC data base, and it was decided to inclu-

ducts. It was concluded that such comparisons will be an important part of documenting the SPARC Climatology data base.

Short and long-term goals

Final discussions centered on setting plans for future action. Stratospheric statistics for the NCEP, GEOS DAS, and UKMO data bases will be included in Phase 1, along with tropical winds and selected trace constituents. Comparisons of these data sets and documentation of the climatologies will be reported in a WCRP Technical Report, and summarised in the refereed literature.

The exact character of the data archive is undecided at present. M. Geller proposed establishing a «

SPARC Data Center » to aide in handling and disseminating the climatological data. Such a proposal is under consideration.

Longer-term plans (Phase 2) may involve research on tropical wind data bases, and inclusion of various mesospheric data sets in the climatology. Also, there may be a need for more highly derived quantities to match future initiatives of GRIPS, such as troposphere-stratosphere statistical connections and space-time spectra of transient atmospheric waves

Meteorological parameters to be included in Phase 1

Field	Symbol	Sampling
Zonal wind, temperature	U,T	Monthly zonal means*
Geopotential, temperature	Z,T	Monthly means on pressure levels* (500, 100, 50, 10, 5 and 1 mb levels)
Eddy heat flux Eddy momentum flux	$u'v'$ $v'T'$	Monthly zonal means*
Residual mean circulation	v^*, w^*	Monthly zonal means*
Eliassen-Palm flux divergence	DF	Monthly zonal means*
Trace gasses	O ₃ , H ₂ O, CH ₄	Monthly zonal means*
Warming diagnostics	U (10 mb, 60° N/S) T (10 mb, N/S poles)	Daily

*Interannual variability of these quantities also included

de a few selected species (ozone, water vapour and methane) derived from UARS measurements.

The next day started with discussions of comparisons between the various data sets. Such comparisons are important in establishing uncertainties and areas in need of improvement in the various data sets. M. Geller compared upper tropospheric data assimilations with and without inclusion of aircraft wind measurements, showing how the added information made important differences in data void regions. W. Randel showed comparisons between stratospheric circulation statistics derived from NCEP and UKMO analyses, highlighting differences in zonal winds, temperatures and eddy flux quantities. These differences exhibit strong seasonality over several years of comparisons, pointing to biases in the analysis or assimilation pro-

Impact of aircraft emissions upon the atmosphere

Paris, October 15-18, 1996.

Rapporteur : N. Louisnard

Following the yearly NASA US meeting in Virginia Beach (1990 to 1995) and the first European meeting in Köln in April 1994, it was agreed by NASA and by the European partners to hold the 1996 international meeting in Paris. This colloquium was focused on the impact of subsonic and supersonic aircraft upon the atmosphere. It has been sponsored by the European Union DG 12 and by the French Office National d'Etudes et de Recherches Aérospatiales (ONERA) under the auspices of the Association of European Research Establishment in Aeronautics (AEREA). The colloquium was chaired by J. Carpentier, Manager of the Comité Avion Ozone (the French National Committee in charge of assessing the potential impact of aviation upon the atmosphere). The objective was to bring together scientists from different countries, exchanging information related to the on-going and finished programs, to the results of recent campaign measurements and of various theoretical approaches, and finally evaluating the uncertainties and the need for future programs. The colloquium was organised into 7 sessions corresponding to the following topics :

- Present Status and Perspective.
- Aircraft Emission and Traffic.
- Physics and Chemistry in the Aircraft Wake.
- Corridor Effects and Stratosphere-Troposphere Exchange.
- Natural and Anthropogenic Emissions.
- Chemical Impact of Aviation at Global Scale.
- Radiative Impact of Aviation.

A total of 230 attendees participated in the meeting with 68 talks

and 60 posters. Among the different output of the meeting, the following should be emphasised:

- Atmospheric observations and new recent measurement campaigns -POLINAT, MOZAIC, SUCCESS, STREAM...- have brought important results. Such campaigns are still fundamental for orienting the theoretical work.

- The uncertainties about the emissions from aircraft and the actual traffic are now decreasing but the evaluation of the future traffic is somehow hazardous and should be considered with more critical aspect.

- The study of processes for the formation of contrails, aerosol nucleation and concentration occupied a large part of the discussions. These studies have not reached a final status. International collaborations are still needed to clarify these processes.

- Tracer measurement at global scale greatly helped the understanding of the dynamical stratosphere-troposphere exchange. More work has to be done especially on small scale.

- An indirect chemical impact of the stratospheric ozone decrease lies in the increasing rate of PSC formation. The role of aviation on this topic is not clear yet.

- 3D global models are not yet able to correctly evaluate the radiative and chemical impact of aviation but large improvements are expected within the next few years.

The colloquium was closed by a panel discussions chaired by J. Carpentier and including D. Fahey (NOAA), R. Friedl (NASA), A. Ravishankara (NOAA), D. Lister (DRA), M.-L. Chanin (SA/CNRS), G. Brasseur (SA/CNRS) and A. Tuck (NOAA).

The following conclusions from the whole discussions can be summarised this way. Right now there is no proof of a significant impact of the aircraft traffic at cruise altitude upon the atmosphere, either in the lower stratosphere or in the upper troposphere. However, considering the expected growth of the traffic leading to an increase of the emissions mainly of carbon dioxide and of water vapour (even accounting for an improvement of the technology), the decision makers have to take into account the mean lifetime of an aircraft (25 years). If the potential impact of aircraft nitrogen oxides on ozone seems now to be weakened, the potential impact of aircraft on the greenhouse effect has to be investigated further. Future programs should concentrate on :

- the effect of the particle emission, mainly the sulphuric aerosol formation,
- the effect of water vapour and of contrails, mainly under critical temperature conditions and in high latitude range,
- the evaluation of the local and global stratosphere-troposphere exchange,
- the production of NO_x by lightning within high altitude clouds.

Proceedings of the colloquium are being prepared by ONERA and will be distributed at the very beginning of 1997.

● Nicole Louisnard

A Short Summary of the IRC-96 Symposium

Fairbanks, Alaska, 19-24 August 1996.
Convener - K. Stamnes, Geophysical Institute,
University of Alaska

The International Radiation Commission has conducted its symposium on « Current Problems in Atmospheric Radiation ». About 400 presentations were made during 10 sessions :

- 1 - Radiation in Polar Regions (conveners : S. Warren, E. Raschke) about 25 reports.
- 2 - Radiative Properties of Clouds (including Radiative Transfer) (E.M. Feigelson, Kuo-Nan Lio) - about 75 reports.
- 3 - Radiation Codes for Models (J.H. Joseph, G. L. Stephens) - about 30 reports.

4 - Results of Field Measurements (C.R.M. Platt, R ; G. Ellingson) - about 45 reports.

5 - Remote Sensing and Radiative Transfer (M. Lynch, T. Takashima) - about 100 reports).

6 - Radiation Climatology (R.S. Kandel, J. Schmetz) - about 40 reports.

7 - Fundamental Problems in Radiative Transfer (J. Lenoble, P. Varanasi) - about 25 reports.

8 - V Radiation Measurements and Modelling (S. Madronich, P.C. Simon) - about 50 reports.

9 - Spectroscopy (S.A. Clough, N.A. Scott) - about 10 reports.

10 - Solar and Terrestrial Radiation Research in Developing Countries and Newly Independent States (G. Ohring, Da-Ren Lu) - about 20 reports.

A list of reports is available in the SPARC Office.

A proceedings volume will be prepared with 4-page papers.

● Knut Stamnes

Summary of Space-Based Observations of Atmospheric Chemistry

21

The study of the chemical and aerosol composition of the stratosphere has been one of the great accomplishments of space-based measurements of the Earth. The history of success in this area goes back more than 25 years to the launch of the Backscatter Ultraviolet (BUV) instrument aboard the US National Aeronautics and Space Administration's (NASA's) Nimbus 4 satellite, and has been continued from the late 1970s, largely through instruments aboard the NASA Nimbus 7 satellite, the Earth Radiation Budget Satellite (ERBS), the Upper Atmosphere Research Satellite (UARS) and a series of meteorological satellites operated by the US National Oceanic and Atmospheric Administration (NOAA). Other missions, including the Solar Mesosphere Explorer (SME), the Atmospheric Explorer Mission (AEM), and space shuttle flights carrying the Shuttle Backscatter Ultraviolet (SSBUV) instrument and/or the Atmospheric

Laboratory for Applications and Science (ATLAS) payload and its component instruments. The legacy of this series of missions has been extensive knowledge on the distributions of trace constituents, particles, and temperatures in the Earth's stratosphere and, in some cases, the upper troposphere, mesosphere, and lower thermosphere, as well as of quantities which directly affect the stratosphere, such as solar ultraviolet irradiance.

This article includes a review of progress made by measurements to date, a fairly detailed description of recently-launched instruments (1993 and later) and platforms making atmospheric chemistry measurements, and a summary of planned measurements (known to the author) for the next few years. A listing of internet home pages associated with most of the instruments and projects mentioned in this article is included as an appendix.

Although this article focuses on space-based measurements, it should be noted that such measurements form only a part of an integrated observing strategy for atmospheric chemistry. Ground-, balloon-, and aircraft-based measurements are all needed to provide answers to the broad range of questions associated with atmospheric chemistry and transport.

Summary of Progress

Total Ozone

Although the broad features of the distribution of total column ozone were fairly well understood on the basis of the long record of ground-based measurements, the Total Ozone Mapping Spectrometer (TOMS) instruments revolutionized its study by providing near-global, high horizontal resolution (50 km x 50 km) daily coverage over an extended time period

(Nimbus 7 TOMS 1978-1993, Meteor-3 TOMS 1991-1994 and now the recently-launched Earth Probe and Advanced Environmental Observation Satellite TOMS instruments; see section on Recently launched instruments and programs). The high horizontal resolution of the TOMS data facilitate its use in studies of atmospheric dynamics. The nearly global coverage of TOMS helped demonstrate that the Antarctic ozone depletion observed by the British Antarctic Survey from its ground-based measurements was indeed a continental-scale phenomenon, and also showed the seasonal evolution of the depletion. The well-characterized stability of the TOMS instruments has allowed the use of their data in long-term trend studies, providing a complement to parallel studies carried out with the ground-based network. The TOMS trends show evidence for statistically significant ozone depletion over most of the stratosphere at latitudes above 30 degrees, and much higher depletion rates at latitudes above 45 degrees.

The Tiros-N Operational Vertical Sounder (TOVS) series of instruments aboard NOAA's operational meteorological satellites, provide information on total ozone through the 9.7 micron channel of their High Resolution Infrared Sounder (HIRS) components. The TOVS measurements are best characterized as lower stratospheric ozone measurements, as they are insensitive to mid- and upper-stratospheric ozone. They have been shown to provide a total ozone data set which is useful for some climatological applications, however. Unlike TOMS, TOVS provides some information on ozone distributions in polar night, which is of interest because of the formation of the ozone hole.

Ozone Vertical Profile

Two sets of instrument have provided the bulk of our knowledge of the vertical profile of ozone in the stratosphere over long time periods. The Solar Backscatter Ultraviolet (SBUV) series of instru-

ments, including the SBUV on Nimbus 7 and the SBUV/2 instruments aboard the NOAA-9, NOAA-11, and NOAA-14 spacecraft, have provided low vertical resolution information on the ozone profile in the middle and upper stratosphere, as well as total column ozone amounts. The BUV technique employed by SBUV and SBUV/2 allows for sub-satellite (nadir-pointing) measurement over the sunlit Earth. Calibration information was provided by comparisons with the eight flights of the SSBUV instrument.

The Stratospheric Aerosol and Gas Experiment (SAGE) instruments have provided much higher vertical resolution information on the stratospheric ozone profile for the periods 1979-1981 (SAGE I, aboard the AEM-2 satellite) and 1984-present (SAGE II aboard ERBS). The nature of the SAGE instrument, which makes use of the solar occultation technique and thus obtains only approximately 30 profiles per day in two narrow latitude bands, limits its spatial coverage. The « self calibrating » nature of the measurement provides high accuracy and stability. The SAGE data record has been instrumental in demonstrating that most of the reduction seen in the ozone column has occurred in the lower most part of the stratosphere. The occultation technique is very sensitive to aerosol loading, and the impact of high aerosol loading such as that which occurred in the period immediately following the Mt. Pinatubo eruption (June, 1991) on ozone measurements must be very accurately understood. SAGE II ozone profiles can penetrate into the troposphere in cloud-free regions; at mid-latitudes nearly half the profiles get into the middle troposphere.

Four ozone-measuring instruments are aboard UARS; two, the Halogen Occultation Experiment (HALOE), an infrared occultation instrument, and the Microwave Limb Sounder (MLS), a microwave emission instrument, have been

taking data nearly the entire time period (> 5 years) since UARS was launched. Since HALOE uses the occultation technique, its spatial coverage is very similar to that of SAGE. As a limb emission instrument, MLS covers the full latitude range from either 30° S to 80° N or 30° N to 80° S depending on the orientation of the UARS spacecraft, which is changed by a yaw maneuver approximately every 36 days. Two infrared emission instruments - the Cryogenic Limb Array Etalon Spectrometer (CLAES) and the Improved Stratosphere and Mesosphere Sounder (ISAMS), obtained data for approximately 20 and 7 months, respectively. The spatial coverage of these instruments paralleled that for MLS described above.

More limited ozone profile data sets have been obtained by several space-based instruments which operated for shorter periods. The Russian Ozone and Aerosol Fine Structure (OZAFS) experiments obtained a few ozone profiles during its operation aboard the Soviet Salyut 7 orbiting station in 1985. The Canadian Sunphotometer Earth Atmosphere Measurement (SPEAM) made measurements as part of a Canadian payload aboard two Space Shuttle flights - STS-41G in October, 1984 and STS-52 in October, 1992. The US Cryogenic Infrared Radiance Instrument for Shuttle (CIRRIS) instrument, designed mainly for airglow studies, flew aboard the Space Shuttle in April-May, 1991 (STS-39) and has been shown to have information on the distribution of ozone and other trace constituents. Some information on ozone and aerosol profiles in the stratosphere was also obtained with the Aerosol Limb Absorption (ALA) instrument which flew on the Japanese « Ohzora » satellite, launched in Feb. 1984. ALA was a two channel sun-photometer (600, 1000 nm), which used the solar occultation technique. Another occultation instrument, the Limb-Atmospheric Infrared Spectrometer (LAS) also flew aboard Ohzora.

Aerosols and Polar Stratospheric Clouds

The largest body of information on the distribution of stratospheric aerosols and polar stratospheric clouds (PSCs) has come from instruments using the occultation technique - the SAGE instruments described above and the Stratospheric Aerosol Monitor (SAM II) instrument aboard Nimbus 7. The latter, a single-channel instrument, measured the distribution of particles in the stratosphere, making measurements only at high latitudes (a characteristic of occultation instruments in polar sun-synchronous orbits) from 1978 to 1995 (with some data loss in later years as the orbit of the spacecraft drifted). The SAGE instruments, which are in inclined orbits, provide data over a very broad range of latitudes, and provide some information on aerosol properties because of their measurement at multiple wavelengths. As noted above, the occultation technique is hampered by the high aerosol loading in the atmosphere which follows very large volcanic eruptions; after the Mt. Pinatubo eruption, atmospheric extinctions became too large in some regions to be quantitatively determined by SAGE. There was no SAGE instrument operating at the time of the El Chichon eruption (1982), although significant information on that eruption was obtained from SME. The three infrared instruments aboard UARS (HALOE, CLAES, ISAMS) have also provided extensive information on the stratospheric aerosol distribution, including wavelength-dependence that can be used to provide information on particle composition.

The SAGE II instrument has been shown to provide some information on the distribution of aerosols in the upper troposphere after separation of cloud and aerosol extinction. Such measurements, with their high vertical resolution and limited horizontal coverage, are unique. The reprocessed TOMS data have recently been shown to have information on UV-absorbing aerosols. Daily global maps of this information have

been produced for the entire period of TOMS operation. Although these measurements provide no direct information on the aerosol vertical profile, they complement other space-based methods for determining tropospheric aerosol loading.

Stratospheric Trace Constituents

The first space-based measurements of the trace distributions of stratospheric trace constituents (besides ozone) came from the Limb Infrared Monitor of the Stratosphere (LIMS) and Stratosphere and Mesosphere Sounder (SAMS) instruments aboard Nimbus 7. The LIMS instrument measured distributions of H_2O , NO_2 , and HNO_3 (in addition to O_3 and temperature) for a period of 7 months (10/89-5/79), while SAMS measured distributions of N_2O and CH_4 in the middle and upper stratosphere and lower mesosphere for approximately three years. Both data sets had significant impacts on our understanding of chemical and dynamical properties of the stratosphere, especially on the interplay between the two processes. Measurements of NO_2 were made by other instruments (SME, SAGE I, SAGE II), as well as of H_2O (SAGE II).

The first chemically comprehensive set of space-based measurements was made by the Atmospheric Trace Molecule Spectroscopy (ATMOS) instrument, an infrared occultation interferometer, aboard the Spacelab 3 Space Shuttle mission in April-May, 1985. Data from this mission were limited to two latitude bands - roughly 30°N and 47°S . ATMOS measured nearly all important nitrogen-containing species in the stratosphere (NO , NO_2 , N_2O_5 , HNO_3 , HNO_4 , ClONO_2 , N_2O), most important halogen-containing species (HCl , ClONO_2 , HF , CF_2O , CF_3Cl , CF_2Cl_2 , CH_3Cl , CHClF_2 , CCl_4 , CF_4), and a variety of other species (H_2O , CH_4 , CO , OCS , HCN , C_2H_2 , C_2H_6), including isotopically substituted forms of O_3 and H_2O . Subsequent

flights of the ATMOS instrument (3/92, 4/93, 11/94) have extended ATMOS coverage to the tropics and high latitudes, and been used for trend determination through comparison of the mid-1985 and late-1994 observations.

Trace chemical studies of the stratosphere (and mesosphere) have been revolutionized by UARS data. Taken together, the four UARS chemistry instruments noted earlier, measure nearly all the important reservoir species in the atmosphere, many of the important source species, and several free radicals, including the first space-based measurements of chlorine monoxide (ClO). Each of the chemistry instruments have provided a wealth of data. MLS has provided information on ClO , O_3 , HNO_3 , and H_2O . The comparison of winter-spring measurements of ClO , O_3 , and HNO_3 at high latitudes in both hemispheres over the period of UARS observations has been especially enlightening as to wintertime chemistry and the relationship between denitrification, chlorine activation, and ozone distributions. HALOE observations of HCl and HF have proved conclusively that the halogens seen in the stratosphere are of industrial origin, and its water observations have provided a great deal of information on the relationship between lower stratospheric water vapor and stratosphere/troposphere exchange. Given the length of the MLS and HALOE data sets, their use in studies of long-term trends and shorter-term phenomena such as the quasi-biennial oscillation (QBO) is becoming possible. CLAES and ISAMS data, through their excellent spatial coverage and comprehensive chemical nature, have provided significant information on both chemical and transport processes in the stratosphere, including issues such as tropical-mid-latitude transport of tracers. The combined use of data from several UARS instruments has been particularly enlightening; for example, combinations of ClO , HCl , and ClONO_2 measurements from MLS, HALOE, and CLAES, respectively, have

been used to quantitatively test our understanding of chlorine partitioning in the stratosphere.

Sulfur dioxide distributions in the stratosphere following large volcanic eruptions have been measured with several instruments, notably the TOMS instruments, but also MLS, ATMOS, and SBUV. These observations have been very useful in quantifying the volcanic input into the stratospheric sulfur budget, and, combined with observations of aerosol formation, to determine the time scale for the conversion of gas phase sulfur dioxide into sulfuric acid aerosols in the stratosphere.

Tropospheric carbon monoxide measurements have been made with the Measurement of Air Pollution from Satellites (MAPS) instrument which flew on the Space Shuttle four times (1981, 1984, and twice in 1994).

Temperature and Winds

Most of the instruments which detect stratospheric trace constituent composition measure temperature as well, so significant information on the temperature distribution of the stratosphere has become available. Most of these instruments, which use the technique of limb scattering, have good vertical resolution throughout the stratosphere, so the temperature measurements from the « chemistry instruments » have been of great use ; the co-located nature of the temperature and chemical measurements has been particularly important for studies of chemical/dynamical interactions. The High Resolution Doppler Interferometer (HRDI) instrument aboard UARS has provided direct measurements of winds in the stratosphere and mesosphere.

Solar Irradiation and Particle Input

Since stratospheric chemistry is driven by solar ultraviolet radiation and affected by high energy particles (which can produce ozone-destroying nitrogen oxides and hydrogen oxides), their fluxes

must be known. Spectrally-resolved solar irradiance measurements have been made by two instruments aboard UARS (the Solar-Stellar Intercomparison Experiment, or SOLSTICE, and the Solar Ultraviolet Spectral Irradiance Monitor, or SUSIM). The SBUV and SBUV/2 instruments have a « spectral scan » capability, which is used periodically, and long-term solar irradiance measurements can be obtained from them. Because of the degradation of these instruments in space, measurements of solar spectral irradiance by the SSBUV instrument have been particularly important in constraining the UV data set from the SBUV/2 instruments. It should be noted that a grating drive problem with the SBUV/2 instrument aboard the NOAA-14 spacecraft has led to discontinuation of its use in spectral scan mode. Particle information comes from the Particle Environment Monitor (PEM) instrument aboard UARS, as well as from other instruments designed for non-stratospheric studies.

TOMS data have recently been used to determine the long-term and daily exposure to ultraviolet radiation at the Earth's surface, including the effects of clouds. The surface UV data have been validated by comparison with ground-based spectral measurements made with Brewer spectrometers.

Recently Launched Instruments and Platforms

The above summaries do not include a number of recent space missions (launched in 1993 or thereafter), which are serving to further enhance our knowledge of the stratosphere. Unlike the earlier missions, which were dominated by US-sponsored entities, notably NASA and NOAA, a much broader and more international range of space agencies are contributing to the measurement capability. Among the more recently launched instruments/platforms are the following :

The Polar Ozone Aerosol Monitor (POAM) launched aboard the French Satellite Pour l'Observation de la Terre (SPOT-3) satellite in 1993. This instrument worked until late 1996, when the SPOT-3 satellite failed. POAM is a solar occultation instrument similar in spirit to the SAGE instruments, measuring vertical distributions of ozone, aerosols, and temperature. Information on NO₂ and H₂O is available from the measurements, although the retrievals are not yet operational. Because SPOT-3 is in a polar sun-synchronous orbit, the observations were restricted to high northern and southern latitudes. The POAM PSC measurements will help to extend the SAM II record, although the differences in orbit between Nimbus 7 and SPOT-3 make the connection between the two data sets somewhat complex, given the nature of the occultation viewing (one latitude per hemisphere per day).

The Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA) and Middle Atmosphere High Resolution Spectrographic Investigation (MAHRSI), which flew aboard the German ASTRO-SPAS satellite which was deployed from and retrieved by the Space Shuttle during a flight in November, 1994. CRISTA measures temperature and trace gas concentrations using both infrared and far-infrared wavelengths. There are multiple detectors and three telescopes for the infrared, looking at slightly different angles from the shuttle, so that small horizontal scale features can be observed in the temperature and constituent profiles. These measurements, which are still being analyzed, are unique because of this high resolution. CRISTA observations extend well into the thermosphere for some species. MAHRSI is an ultraviolet instrument designed to measure NO and OH, mainly in the mesosphere and thermosphere. The OH retrieval has recently been extended to 45 km. The CRISTA and MAHRSI instruments will fly again on the STS-85 Space Shuttle

mission in the summer of 1997. The different season from the previous mission, a different launch time, and full use of the flexibility of the ASTRO-SPAS satellite will allow for the gathering of a significant amount of data that will complement those of the first CRISTA/MAHRSI mission (cf more details in this issue).

Global Ozone Monitoring Experiment (GOME) launched aboard the European Space Agency's Earth Resources Satellite (ERS-2) in 1995. GOME measures total column ozone, ozone vertical profile, and total column of several trace constituents, including global BrO and NO₂ and OClO (in at least the polar vortex) as well as information on clouds, aerosols, and surface spectral reflectance. GOME can measure the ozone column at a higher horizontal resolution than TOMS, and thus complements the TOMS observations. GOME covers a much broader wavelength range (240-790 nm) and has excellent spectral resolution (0.2-0.4 nm). It is in a polar sun-synchronous orbit well suited for these measurements.

Two instruments aboard the PRIRODA module of the Mir Space Station. The PRIRODA module was launched in mid-1996. These instruments, known as OZON-MIR and ISTOK-1, use the occultation technique to measure concentrations of a number of trace gases and aerosols; ISTOK-1 also has a limb emission mode, although the retrieval studies done to date suggest that the errors in the emission mode will be considerably larger than in the occultation mode. Limited availability of on-board testing time have precluded the use of these instruments for atmospheric science studies to date, but it is hoped that with additional testing and subsequent observation time, they can become significant contributors to the atmospheric science data set.

The Ultraviolet Visible Imagers and Spectrographic Imager (UVISI) instrument aboard the Mid-Course Space Experiment (MSX), a US Department of Defense mission. UVISI is a very high spectral resolution imager, but it has only obtained

limited data to date because of operational constraints of the MSX spacecraft. More observing time is likely to become available in the future, and the UVISI data should be of great use in studying UV radiative transfer in the lower stratosphere and upper troposphere.

Total Ozone Mapping Spectrometer (TOMS) instruments launched aboard the US Earth Probe (EP) satellite in July, 1996, and the Japanese ADEOS spacecraft in August, 1996. These are follow-ons to the previous TOMS instruments, which should allow for improved measurements, especially at high solar zenith angles. The ADEOS TOMS is in a 800 km sun-synchronous orbit, and will obtain full daily coverage of the sunlit earth as did the previous TOMS instruments. EP TOMS is in a 500 km orbit, which provides for higher horizontal resolution (smallest pixel size is approximately 25 km x 25 km), but does not provide full daily global coverage (two days are required to produce a global map; full daily coverage is available poleward of approximately 60 degrees latitude).

Several atmospheric chemistry instruments aboard ADEOS. These include the Improved Limb Atmospheric Spectrometer (ILAS), the Interferometric Monitor for Greenhouse Gases (IMG), and the Retroreflector in Space (RIS) instrument which is used in conjunction with laser ground stations. A TOMS instrument is also aboard ADEOS. ILAS is an occultation instrument, getting vertical profile measurements at high northern and southern latitudes. It has two spectrometers, one using the infrared for trace constituent measurements, and one using visible wavelengths to derive temperature and pressure profiles. IMG is a nadir-observing Michelson-type Fourier Transform Spectrometer designed to measure several gases, including density profiles of CO₂ and H₂O, total ozone column, and mixing ratios of CH₄, N₂O, and CO in the troposphere. RIS, which is used together with laser ground stations, will support vertical profile and/or column measurements of a small number of gases. Another ins-

trument aboard ADEOS, the French POLDER instrument, measures aerosols in both the troposphere and stratosphere.

Future Measurements

In the longer term, many countries and agencies are expected to contribute to space-based measurements of the stratosphere. These may be considered as part of three types of programs - continuation of existing programs, new programs which are currently well-defined, and programs in the process of being defined.

Continuation of Existing Programs

An additional TOMS instrument is scheduled for launch in 2000 aboard a Russian Meteor-3M satellite. Several additional SBUV/2 instruments are planned for the NOAA operational meteorological satellites between now and 2007. Two follow-ons to the POAM instrument are planned; one is to fly on a 45 degree inclination orbit in the summer of 1997 (this will be called the Orbiting Ozone and Aerosol Monitor, or OOAM), while the other (POAM-3) will fly on the French SPOT-4 satellite in a polar sun-synchronous orbit in early 1998. A modified version of the ILAS instrument (ILAS-II) is scheduled to fly on the Japanese ADEOS 2 satellite.

New Programs

The Earth Observing System (EOS), the major new US program (which includes significant participation from other countries) for global measurements of the full Earth system, will have a significant component of atmospheric chemistry measurements. The most important such instruments and platforms include the following:

The Stratosphere Aerosol and Gas Experiment (SAGE III) instrument. This is an improved version of the SAGE instruments, with higher spectral resolution, greater spectral wavelength coverage, and a lunar occultation capability, which allows for results to be made over a

broader range of latitudes than are available from solar occultations (especially in sun-synchronous orbits where solar occultations are confined to high latitudes). The lunar occultation capability should enable the measurement of NO_3 and OCIO . Plans call for one SAGE instrument in an inclined orbit and another in a polar orbit. Currently planned flights are aboard a Russian Meteor-3M (polar sun-synchronous orbit) in 1998 and the International Space Station (51.5 degree inclination orbit) in approximately 2001. A third SAGE III instrument is under construction for probable use in a polar sun-synchronous orbit early next century.

Four instruments are to fly as part of the EOS CHEM platform, currently scheduled for 2002. These include the Tropospheric Emission Spectrometer (TES), the Microwave Limb Sounder (MLS), the High Resolution Dynamics Limb Sounder (HIRDLS), and the Ozone Dynamics Ultraviolet Spectrometer (ODUS) instruments. TES is a high spectral resolution instrument designed to observe both tropospheric ozone and its precursors. It will have both a nadir and a limb mode, and will also provide information on a number of constituents in the lower to middle stratosphere. MLS is a significantly enhanced version of the UARS MLS instrument, and will measure a good number of constituents in the stratosphere and upper troposphere, including OH. HIRDLS, a joint US-UK development, is an infrared emission instrument designed to measure stratospheric trace constituent and temperature distributions at high horizontal and vertical resolution, and should provide information on small-scale variability in the atmosphere for use in transport studies. ODUS is a Japanese-provided ultraviolet instrument measuring ozone and several other species; this will use techniques similar to those used by TOMS and GOME.

The Measurement of Pollution in the Troposphere (MOPITT) instrument, a Canadian-provided infrared instrument, will measure tropospheric carbon monoxide, and will fly aboard the EOS AM platform in 1998. Unlike the MAPS instrument,

MOPITT will measure the CO profile (4 levels expected to be retrieved). MOPITT will also measure total column methane.

Three instruments are to fly as part of the European Space Agency's ENVISAT mission in 1999. These include the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY), the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS), and the Global Ozone Monitoring by Occultation of Stars (GOMOS) instruments. SCIAMACHY is a multi-wavelength (240-1750 nm, 1.9-2.4 micron), multi-viewing geometry (limb/nadir) instrument designed to measure the column and profile distribution of a number of gases, including high horizontal resolution measurements of ozone. MIPAS, a high spectral resolution limb sounder operating in the wavelength range from 4.15-14.6 microns, will provide measurements of vertical profiles of more than 20 species (especially nitrogen and chlorine-containing species), as well as pressure/temperature, aerosols, and PSCs. GOMOS will use the stellar occultation technique to measure ozone profiles. Since there are very many stars to use as light sources, the stellar occultation technique has the potential to provide much more complete spatial coverage than is available from solar occultations, so measurements at nearly all latitudes are possible even though ENVISAT will be in a polar sun-synchronous orbit.

Several other instruments making atmospheric chemistry measurements should be flying in the near future. Tropospheric CO measurements should be obtained by a modified version of the MAPS instrument to be flown aboard the Russian Mir space station (MAPS on MIR) in early 1998. A successor to the MAPS instrument (microMAPS) will fly on the American Clark spacecraft in early 1998. Ozone-measuring instruments are scheduled for launch aboard Chilean and Israeli satellites. The Chilean instrument, known as OLME (Ozone Layer Monitoring Experiment) with UV cameras using both charge coupled device and ultraviolet photodiode detectors, will fly aboard Chile's

FASat Bravo in the second half of 1997. OLME is to emphasize measurements of ozone in the Antarctic and sub-Antarctic regions of Chile. An Israeli instrument (OM-2), which will use filters for the measurement of total ozone and the ozone vertical profile, will fly aboard the Israeli Techsat-1 satellite.

Ozone and other atmospheric chemistry measurements will also be made aboard the multi-national ODIN mission. ODIN, a collaborative effort of scientists from Sweden, France, Canada, and Finland, will have two instruments, a Sub-Millimeter Radiometer using microwave wavelengths to measure ozone, chlorine monoxide, water vapor, and other constituents, and an Optical Spectrograph and Infrared Imaging System using UV-visible and near infrared wavelengths for studying ozone, NO_2 , aerosols, and several other constituents. Launch of ODIN, to a sun-synchronous 600 km orbit, is scheduled for early 1998.

An ozone measuring payload is scheduled to fly aboard the Space Shuttle in the fall of 1997; this payload includes two ultraviolet instruments, the Shuttle Ozone Limb Sounding Experiment (SOLSE) and the Limb Ozone Retrieval Experiment (LORE). These are designed to help test the possibility of using ultraviolet limb scattering to measure ozone in the stratosphere and upper troposphere. LORE, which uses optical filters covers UV, visible, and infrared channels, and should be able to obtain ozone profiles as low as the 10-15 km altitude range. LORE itself is a multi-wavelength version of the Rayleigh Scattering Attitude Sensor (RSAS), a single channel (355 nm) instrument that flew with SSBUV on STS-72 in January, 1996. SOLSE, which uses only ultraviolet wavelengths, is a spectrometer using a two-dimensional detector (altitude/wavelength). Although the shuttle flights will provide only limited data, they could serve as an effective « proof of concept » for this technique, which has been used previously only for the topmost part of the stratosphere and the mesosphere.

Programs Under Definition

There is wide recognition that space-based ozone measurements should be made as part of operational measurement programs. In the US, there are plans to include both a total ozone mapper and an ozone profiling instrument for the National Polar Orbiting Environmental Satellite System (NPOESS), the converged program being created which combines the current NOAA operational meteorological satellite program and the Department of Defense's Defense Meteorological Satellite Program. The first launch of NPOESS may not occur until as late as 2010, although it could be as early as 2007. The nature of the ozone-measuring instruments is not yet defined, however. In Europe, an instrument known as OMI (Ozone Monitoring Instrument) is being considered for the METOP satellite series. Although still being defined, this instrument will build on the GOME heritage to measure both total ozone and ozone vertical profile, as well as the column amount for several trace gases, such as NO₂.

The EOS program was originally defined as a 15 year program

(three sets of identical missions at five year intervals), with continuity of measurements a key consideration. Plans call for continuation of atmospheric chemistry measurements throughout the EOS program, although current changes in the program make it likely that the scientific focus and instrument complement to be used for the atmospheric chemistry missions beyond CHEM will evolve.

Summary

The space-based measurement of ozone and related trace constituents in the stratosphere has provided a vast and diverse body of information about chemical and transport processes in the atmosphere. Much new information has become available recently, and should continue to become available in the near future given the ambitious flight programs of many nations and agencies. It will be a challenge to the atmospheric chemistry community to work to integrate the information coming from all these sensors.

This wealth of information provides important opportunities for fruitful interactions between scien-

tists associated with different programs. This may be particularly important in the area of calibration, especially for the many instruments using ultraviolet techniques to measure total column ozone as well as ozone profile. International scientific cooperation will also be useful in the areas of algorithm development and testing (where algorithm inter-comparisons are essential in the assessment of any differences between measurements from different instruments), and in post-launch validation programs. Given the expense associated with the latter (especially when balloon and/or aircraft flights are considered), the latter is an important consideration.

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● Jack Kaye

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Appendix - List of Home Pages

ADEOS	http://www.eorc.nasda.go.jp/ADEOS/	POAM	http://www-projet.cst.cnes.fr:8060/poam/Mission.html
ATLAS	http://wwwghcc.msfc.nasa.gov/atlas.html	POLDER	http://www-projet.cst.cnes.fr:8060/polder/Mission2.html
ATMOS	http://remus.jpl.nasa.gov/	PRIRODA	http://www.ire.rssi.ru/priroda/priroda.htm
CLAES	http://pore1.space.lockheed.com/9120/CLAES/claes_homepage.html	RIS	http://www-ris.nies.go.jp/index-e.htm
CRISTA	http://www.crista.uni-wuppertal.de/	RSAS	http://ssbuv.gsfc.nasa.gov/RSAS.html
ENVISAT	http://www.dfd.dlr.de/PROJECT/ENVISAT/Index/	SAGE II	http://arbs8.larc.nasa.gov/sage2/
EOS	http://eosps0.gsfc.nasa.gov/	SAGE III	http://arbs8.larc.nasa.gov/sage3/
GOME	http://www-iup.physik.uni-bremen.de/ifepage/gome.html	SBUV/2	http://nic.fb4.noaa.gov/products/stratosphere/sbuv2to/
GOMOS	http://www.dfd.dlr.de/PROJECT/ENVISAT/Instrumente/gomos.html	SCIAMACHY	http://saturn.sron.ruu.nl/general/divisions/eos/sciamain.html
HALOE	http://http:haloedata.larc.nasa.gov/home.html	SOLSE	http://hyperion.gsfc.nasa.gov/Shuttle/solse/solse.html
HRDI	http://www.sprl.umich.edu/HRDI/hrdi_homepage.html	SOLSTICE	http://www.hao.ucar.edu/public/research/svosa/solstice/solstice_home.html
ILAS	http://www-ilas.nies.go.jp/index.html	SPEAM	http://arqmlinux.dow.on.doe.ca/aqrb/st_space.htm
IMG	http://img.ersdac.or.jp/	SSBUV	http://ssbuv.gsfc.nasa.gov/
ISTOK-1	http://www.ire.rssi.ru/priroda/Istok/Istok.htm	Techsat	http://www.technion.ac.il/pub/projects/techsat/techsat1.html
MAHRSI	http://rdpsvr.nrl.navy.mil/mahrsi/mahrsi.html	TES	http://stargate.jpl.nasa.gov/tes/
MAPS	http://stormy.larc.nasa.gov/press.html	TOMS	http://jwocky.gsfc.nasa.gov/index.html
MAS	http://rira5.nrl.navy.mil/contrib/tpauls/MAS-homepage.html	TOVS	http://nic.fb4.noaa.gov/products/stratosphere/tovsto/
MIPAS	http://www-projet.cst.cnes.fr:8060/envisat/mipas.html	UARS	http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/UARS/project.html
MLS	http://www.jpl.nasa.gov/mip/mls.html	UVISI	http://bradbury.nrl.navy.mil/msx/spacecraft.html#UVISI
MSX	http://msx.nrl.navy.mil/		
ODIN	http://irg.usask.ca/odin/		
OLME	http://www.ee.surrey.ac.uk/EE/CSER/UOSAT/fasat/mission.html		
OZON-MIR	http://www.ire.rssi.ru/priroda/Ozon/Ozon.htm		
PEM	http://pemrac.space.swri.edu:10002/spds/pem.html		

The Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA) Project : First Results

The CRISTA experiment was built to perform middle atmosphere measurements with advanced spatial resolution for the study of small scale structures in atmospheric composition and inferred dynamics. The experiment was intended to be exploratory, i.e. to find out whether and to what extent such structures are present. A short flight like the one of the Space Shuttle appeared to be suffi-

cient for such an exploration. Accordingly the instrument was adapted to the boundary conditions of the Space Shuttle.

The instrument measures the infrared (IR) emission of atmospheric trace gases. Its operation is thus independent of the time of the day. To obtain a good vertical resolution, the limb scan technique is employed. To improve

the horizontal resolution, the instrument has three telescopes instead of one. These look into three different directions (at 162°, 180°, 198° from the flight vector), and take measurements simultaneously. Each telescope is equipped with a grating spectrometer for the thermal IR (4-14 micrometers). In addition, the centre telescope has a far IR spectrometer (15-71 micrometers). To obtain good resolution along the track, a high measurement speed is needed. Therefore the IR detectors and the optics of CRISTA are cooled by cryogenic Helium (subcooled He and supercritical He in two cryostats, respectively). This allows a spectral measurement of the whole wavelength region in one second. Eighteen trace gases are measured each second (table 1). The spatial resolution depends on the altitude regime covered. In a typical measurement mode, data are obtained from 15 km to 45 km with a vertical resolution of about 2 km and with a horizontal resolution of 200 km along the track and 600 km across the track. In other modes vertical scans extend up to 180 km. Because of this altitude regime the spatial resolution is reduced.

The CRISTA instrument was mounted on the satellite structure « ASTROSPAS » which was released from the Shuttle cargo bay on the first flight day. It was operated autonomously at a distance of 50-100 km from the Shuttle. At the end of the flight the ASTROSPAS (plus CRISTA) were retrieved by the Shuttle and brought back to Earth for recalibration. The flight took place from November 3 to 14, 1994 as part of the ATLAS 3 mission of NASA (Kaye and Miller, 1996). Seven days of CRISTA data were obtained. The inclination of the Shuttle orbit was 57°. The CRISTA measurements, therefore, were restricted to the latitude region from 66° N to 57° S.

Table 1 : Trace Gases measured by CRISTA

Species	Wavelength	Altitude Regime
CO ₂	4.3 µm	15-120 km
CO	4.6 µm	*
NO	5.3 µm	100-180 km
NO ₂	6.2 µm	15-40 km
H ₂ O	6.3 µm	15-70 km
CH ₄	7.7 µm	15-70 km
N ₂ O	7.8 µm	15-40 km
CF ₄	7.8 µm	*
N ₂ O ₅	8.0 µm	20-40 km
O ₂	9.6 µm	15-95 km
CF ₂ Cl ₂	10.8 µm	15-30 km
HNO ₃	11.3 µm	15-40 km
CFCI ₃	11.8 µm	15-20 km
Aerosol	12.0 µm	15-30 km
HO ₂ NO ₂	12.5 µm	*
CCl ₄	12.6 µm	≤ 20 km
ClONO ₂	12.8 µm	20-40 km
CO ₂ , T	12.6 µm	15-70 km
CO ₂ , T, p	15.0 µm	40-150 km
N ₂ O	17.0 µm	40-45 km
H ₂ O	58.0 µm	40-80 km
HF	61.0 µm	40-65 km
O(³ P)	63.0 µm	80-180 km
HCl	69.0 µm	*

*under analysis

Gases in the lower six lines are measured by the center telescope only.

During its short mission CRISTA delivered a wealth of data from various altitudes. Here a few examples are presented for the stratosphere. In figure 8, ozone mixing ratios are shown as they were measured on November 6, 1994 at 30 km altitude (all data shown are preliminary). Each dot on this global map is part of a vertical ozone profile from 15 km to 45 km with altitude steps of 1.5 km. The three view directions of CRISTA are easily recognised as parallel traces in the map. Data points along the track are 200 km apart. The map contains more than 9000 data points. This is about a factor of eight more than present day satellite instruments can obtain. The high data density in figure 8 easily allows detection of large, medium, and small scale horizontal structures in the ozone distribution. Parts of the northern and southern polar vortices are indicated by decreased ozone mixing ratios. A streamer of ozone rich air extends from middle to high northern latitudes along the Asian Pacific coast. A weaker streamer extends from the southern US across the Atlantic to western Europe. These structures can be reproduced by dynamic modelling of the stratosphere (M. Schoeberl, private communication). They are found in a limited altitude regime and can vary substantially from day to day.

Dynamical structures are most easily seen in the maps of semi-inert tracers like CH_4 , N_2O , CFC_{11} , or CFC_{12} . Structures of importance are the transport barriers at the vortex edges or the subtropical transport barriers. An example is shown in figure 9 which gives the CFC_{11} mixing ratios at 24 km on November 6, 1994. The measured data points were slightly smoothed here, and were connected by isolines. The northern polar vortex edge at this altitude is most pronounced above the North American continent. In some places its slope is extremely steep. A gradient of more than 90 ppt (factor of 2.6 decrease) over 10 degrees of latitude can be seen near 120° W.

The subtropical barrier is not as steep, but is also clearly visible in figure 9 at $\pm 20^\circ$ to $\pm 30^\circ$ lat. It is, however, not a solid wall everywhere. It develops an extrusion in the southern US/Atlantic sector that is directed north-eastwards. This extrusion resembles the ozone streamer seen in figure 8 at this location at 30 km altitude. A second extrusion is found in the southern hemisphere east of South America, north of the southern polar vortex (30-40° S, 30-60° W). It is directed south-eastward and is not as pronounced as the northern extrusion.

To check on the consistency of these structures, a respective map for HNO_3 was calculated. Nitric acid is found to be anti-correlated to CFC_{11} , i.e. air masses rich in CFC_{11} are poor in HNO_3 . Consequently the isolines of HNO_3 look very similar to those in figure 9. The (anti-) correlation of the data is shown by the scatter plot of figure 10. The data in the lower right hand corner of the picture are at or near the equator. High latitude data are in the upper left hand corner (upper trace: northern hemisphere). Medium latitude data are in between. The anti-correlation appears to be quite close. The difference of the northern and southern traces of the picture shows that the data sets are slightly asymmetric with respect to the equator at this time of the year.

The southern US/Atlantic extrusion seen in figure 9 is observed in a similar manner in HNO_3 . It is even more pronounced at 27 km. Because the HNO_3 data were found to be quite variable with time, they were Kalman filtered. The results are shown in figure 11 (only northern hemisphere) for five subsequent days at 12:00 UT. The picture shows considerable development of that extrusion in these five days.

Since this extrusion to a large extent resembles the fainter ozone streamer in figure 8, one would have expected to find a counterpart for the much stronger East Asia/Pacific ozone streamer in the HNO_3 data as well. A counterpart

is seen in figure 11, but it is surprisingly weak in the middle of the sequence, and fairly small at its beginning and its end.

Finally it should be pointed out that in figure 11 the tropical region (equator to $\pm 20^\circ$) is not homogeneous or stationary: quite a few structures appear and disappear here on a time scale of days.

These few examples of CRISTA results show that at the time of the mission, the stratosphere was very variable within a few kilometres of altitude, a few hundred kilometres in the horizontal, and a few days in time. During a second flight (July 1997), a similar analysis will be done to determine if these results are typical.

Acknowledgement

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Reference: Kaye, J.A. and T. Miller, 1996, GRL 23, 2285-2288.

D. Offermann and M. Riese
Wuppertal Univ., e-mail
offerf@wpos2.physik.uni-wuppertal.de

The Middle High Resolution Spectrograph Investigation - MAHRSI

The flight of the CRISTA-SPAS experiment in November of 1994 provided a unique opportunity to study fundamental issues in the photochemistry and dynamics of the middle atmosphere. In addition to CRISTA (Offermann and Riese, this issue), the experiment included the MAHRSI instrument. MAHRSI's scientific objectives were to make global measurements of the vertical density distribution of the hydroxyl radical (OH) in the mesosphere and upper stratosphere and of nitric oxide (NO) in the lower thermosphere and mesosphere. MAHRSI's line of sight was aligned with that of CRISTA's central telescope so that the two instruments observed the same parcels of air concurrently.

OH is arguably the most important oxidising agent in the Earth's atmosphere. It plays a fundamental role as a natural catalyst for the chemical destruction of ozone and atomic oxygen in the stratosphere and mesosphere. Photochemical models of the mesosphere, in which ozone loss is controlled by the odd-hydrogen radicals, OH and HO₂, have continued to underestimate the abundance of O₃ by 10 to 30%. The suggestion that the problem is linked to a model overestimate of the OH radical has remained untested due to the lack of observational knowledge of the OH distribution in the mesosphere and upper stratosphere. During the ATLAS-3/SSBUV/CRISTA-SPAS space shuttle mission, MAHRSI acquired the first global measurements of OH. Combining the OH data with the CRISTA measurements of O₃, H₂O and temperature provides the first opportunity to validate the standard model odd-hydrogen (HOx) chemistry in this region (Summers et al., 1996).

The experiment

MAHRSI is an ultraviolet spectrograph experiment sensitive over the wavelength range from 190 to 320 nm. The spectral resolution at

310 nm is 0.018 nm. MAHRSI detected OH by measuring the vertical slant intensity profile of 11 bright emission features in the wavelength region between 307.8 and 310.6 nm formed by solar resonance fluorescence in the OH A²S⁺ X²P (0,0) band. The observations were made by aligning MAHRSI's 0.01 × 1.15° field of view parallel with the Earth limb and vertically scanning the line of sight while recording a complete spectrum every two km in altitude. The OH dayglow emission is blended with a bright background produced by the Rayleigh scattering of sunlight by N₂ and O₂ in the slant column (Conway et al., 1996). The instrument resolution is high specifically to resolve the OH emission from the Rayleigh scattered background. OH data were obtained between the tangent heights of 90 and 33km and between 140 and 70km for NO. The spacecraft moved about 10° down-track during each limb scan. Approximately 1700 limb scans of OH and 170 of NO were acquired during the mission. Density profiles are retrieved from the observations with a Twomey-Regularization technique constrained by the smoothness of the retrieved profiles as opposed to an a priori estimate based on a forward model. The measurements are weighted by their estimated random error. The random error is dominated by photon shot noise and is typically 5-10%. The systematic errors are estimated to be (+23, -16%).

OH results

A contour image of the density distribution of OH observed by MAHRSI during a single orbit is shown in figure 1. The image is formed from 18 sequential limb scans. The tangent point of the instrument line of sight crossed from night into day across the dawn terminator at a latitude of 57° S and travelled northward to high northern latitudes in the late afternoon local time. Since the

flight occurred in November, the minimum solar zenith angle (41°) occurred at midmorning at 5° N latitude and afternoon observations are all at large solar zenith angles. Since the production of OH is driven by photolysis in the mesosphere, its distribution exhibits a strong solar zenith angle dependence. Most of the features of Figure 12 are due to this diurnal variation. The maximum photodissociation rate of H₂O occurs near ~70km and the observations show a well defined peak in the OH density at that altitude. This peak forms more slowly than the rapid build-up at the stratopause where OH is produced by the reaction of H₂O with O(1D) which is itself a product of the photodissociation of O₃. Figure 12 is typical of the 75 orbits of OH observations. As the mission progressed, regression of the orbit increasingly confined the observation to morning hours and as a result the morning variations are measured with great clarity.

Ozone production in the middle atmosphere is due to 3-body recombination of O and O₂. Ozone loss in the stratosphere is controlled by several complex catalytic chemical cycles involving odd-chlorine (ClOx), odd-nitrogen (NOx), and odd-hydrogen (HOx) species. In the mesosphere, however, ozone loss is thought to be relatively simple and dominated by the odd-hydrogen (x=H, OH, HO₂) cycle. Odd-hydrogen is produced by the photolysis of H₂O and by its reaction with O(1D). Water vapour enters the stratosphere through the tropopause and is also chemically produced in the stratosphere by methane oxidation. As a consequence of its long chemical lifetime it is dynamically transported upward into the mesosphere. In spite of the relative complexity of lower stratospheric ozone photochemistry, recent analysis of in situ measurements of HOx, NOx, and ClOx species during the SPADE high altitude aircraft campaign, suggests that our understanding of that portion

of Ox loss governed by HOx cycles in the lower stratosphere is reasonably complete. However, most models of HOx/Ox photochemistry of the lower mesosphere (using standard recommended kinetic rate coefficients) underestimate the abundance of O₃ by 10-30%.

Analysis of MAHRSI OH observations (Summers et al., 1996) has shown that standard recommended HOx photochemistry overestimates OH by as much as ~ 40-50% in the altitude range 50-65 km. Figure 13 compares the results of a single limb scan from Figure 12 with the predictions of the NRL 1D model using the standard chemistry and for two suggested modifications of the HOx chemistry. It was also shown by Summers

et al. (1996), that the standard model overprediction could not be accounted for by uncertainties in assumed water vapour abundance nor by uncertainties in solar Lyman α flux. The MAHRSI observed OH abundance is generally consistent with earlier HO₂ and O₃ measurements of Clancy et al. (1994) who proposed a major reduction in the rate coefficient for the reaction $O + HO_3 \rightarrow OH + O_2$ in order to bring theory into acceptable agreement with their observations of these species in the lower mesosphere.

Although the OH inversions currently yield densities to 45 km, the uncertainties are large in the stratosphere due to the increased importance of errors in the spec-

tral shape of the bright Rayleigh background. Work to refine the stratospheric retrievals continues but new observations during the second flight in July, 1997 are expected to have improved precision.

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Summers, M. E. et al. GRL, 23, 2097-2100, 1996.

*R. R. Conway, M. E. Summers, Naval Research Laboratory, Washington, DC.
Fax: (202) 404-8090*

Apologies

Due to the length of the articles published in this issue of the SPARC Newsletter, the « NEWS FROM COUNTRIES » received at this date will be published in the next issue.

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2nd Annoucement of opportunity for European Groups to participate in STAARTE

Scientific Training and Access to Aircraft
for Atmospheric Research Throughout Europe
(January 1997)

The German DRL, the French INSU/CNRS, and the UK Met Office have been funded by the European Commission through the TMR (Training and Mobility of Researchers) Programme to offer, to other European teams, free access to their airborne facilities (DRL-Falcon, INUS-ARAT/Fokker 27, and Met Office-C-130).

This Second Announcement of Opportunity is being issued for the period from September 1997 to the end of 1998. The deadline is **15 May 1997**.

If you are interested in this offer, please make enquiries from one of the participating facilities :

DRL, D-82234 Wessling, Germany, tel. : +49 8153 28 2986, fax : 49 8153 28 1347

Meteorological Research Flight, Building Y 46, DRA Farnborough, Hants, GU14 6TD, UK, tel. : +44 1252 395421, fax : +44 1252 376588

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Information can also be found on the WWW, URL address : <http://www.op.dlr.de/WT-FB/staarte.html>

Future SPARC and Related Meetings

Future SPARC Meetings

3-5 March 1997 : GRIPS Workshop, Berlin, Germany. Convener: S. Pawson (FUB) (Closed meeting).

20-22 May 1997 : IGAC/SPARC/GAW Conference on "Global Measurement Systems for Atmospheric Composition", Toronto, Canada, (gomac@atmosp.physics.utoronto.ca).

August 1997 : SPARC Session, IAGA-ICMA General Assembly, Uppsala, Sweden. Convener: D. Fritts (dave@leonardo.colorado.edu).

September 1997 : SPARC/WMO/GAW Workshop on Ozone Trends, Cambridge, UK. Conveners: N. Harris, R. Hudson (Closed Meeting).

Future SPARC Related Meetings

21-25 April 1997 : EGS XXII General Assembly. Session on Heterogeneous Processes of Ozone Destruction in the Stratosphere and Troposphere, Vienna, Austria. Conveners: A. Wahner (a.wahner@kfa-juelich.de), M. Rossi (michel.rossi@dgr.epfl.ch).

4-8 August 1997 : 9th Quadriennial SCOSTEP STP Symposium, Uppsala, Sweden. Chairman: C. H. Liu (T341426@twncu865.ncu.edu.tw).

18-22 August 1997 : Second Workshop "Solar Activity Effects on the Middle Atmosphere", Prague, Czech Republic. Chairman : J. Lastovicka (jla@ufa.cas.cz.).

26-28 August 1997 : WMO/ICSU/IOC Conference on "The World Climate Research Programme: Achievements, Benefits and Challenges", Geneva, Switzerland, (jps@wcrp2.wmo.ch).

27-31 October 1997 : First WCRP International Conference on Reanalyses, Silver Spring, Maryland, USA, (gewex@cais.com).

12-19 July 1998 : COSPAR, 32nd Scientific Assembly, Nagoya, Japan :

- Symposium on "Stratospheric Ozone and Related UVB Radiation Effects. Convener: G. Horneck (gerda.horneck@dlr.de)

- Symposium on "Stratosphere and Upper Troposphere Processes and Global Change". Conveners: J. Gille (gille@ncar.ucar.edu), M.-L. Chanin (chanin@aerov.jussieu.fr).

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Edited by the SPARC Office

Service d'Aéronomie, CNRS, BP 3
91371 Verrières-le-Buisson, cedex
France

Tel: +33- 1 64 47 43 15

Fax: +33- 1 64 47 43 16

Email: sparc.office@aerov.jussieu.fr
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NASA/JPL Evaluations

The NASA/JPL evaluations "Chemical Kinetics and Photochemical Data for use in Stratospheric Modelling," Evaluation No. 12 will be available in electronic format during the March, 1997. The hard copy will be available soon after. This evaluation will be the most recent update. Scientists interested in receiving this evaluation should contact the chairman of the evaluation panel, Dr. W. B. DeMore, Jet Propulsion Laboratory, MS 183-301, Pasadena, CA 91109, tel.: 818-354-2436, fax: 18-393-4445, email: wdemore@ftuvs.jpl.nasa.gov.