

SPARC

1995
newsletter n° 5
July

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

Editorial

A major event since the last Newsletter has been the "International Conference on Ozone in the Lower Stratosphere" which took place at Halkidiki, Greece, in May 1995. The first steps towards organising such a wide meeting, with a goal of merging together all the recent results from the European and US Ozone campaigns as well as the UARS results, were taken during the SPARC SSG meeting at Cambridge in September 1993. SPARC SSG members John Pyle, and Susan Solomon with the help of Jack Kaye, began the process of organi-

sing the meeting, together with gracious local host Christos Zerefos and an extensive scientific steering group. The meeting was co-sponsored by SPARC, and we are therefore happy to offer you in this issue of the SPARC Newsletter an extensive summary of the different sessions of that meeting. Due to the high scientific quality of this report, and with the agreement of the organising Committee and of the European Commission, also sponsors of the meeting, we decided to present it in considerable detail in this enlarged Newsletter, and have postponed for a later

issue of the Newsletter the updating of the SPARC national contributions.

Next year a major event for SPARC will be the First SPARC General Assembly to be held in Melbourne, Australia on December 2-6, 1996. It will be the opportunity to present the results of the first 4 years of SPARC. We hope that a large part of the community will attend and contribute. The first circular and the letter of intention to participate are included in this issue.

● Marie-Lise Chanin
SPARC Co-Chair

Report from the JSC

The Joint Steering Committee (JSC) of the World Climate Research Programme (WCRP) met in Pasadena, California, during the period March 13-17, 1995. There have been great changes in the JSC in that it now has a new chairman in Dr. Lawrence Gates and a new Executive Director in Professor Hartmut Grassl. Marvin Geller

attended this meeting, making a presentation about the activities of the SPARC programme. He informed the JSC about the scope of its activities, its interactions with other Global Change programmes, and the relevance of SPARC activities to anthropogenic influences on global change. One item that was discussed extensively was the

adequacy of international climate monitoring activities, both in relation to SPARC and in general.

Another was the impact of changes in the free-data policy that has been in existence for the atmosphere.

● Marvin Geller
SPARC Co-Chair

Contents

Editorial.....	1
Report on SPARC JSC.....	1
Report from SPARC Initiatives.....	2
SPARC Scientific Steering Group	2
SPARC Session in IUGG.....	5
Future SPARC Meetings.....	5
Report from Halkidiki.....	6
Declaration of Interest SPARC 96	13
New Stratospheric Aircraft Programmes.....	20
Access to SPARC Relevant Data.....	21
First Circular SPARC 96	23
To Our Readers	24



Edited
by SPARC Office

Service d'Aéronomie,
CNRS, BP 3 - 91371
Verrières-le-Buisson, France
Tel : (33) 1 64 47 43 15
Fax : (33) 1 69 20 29 99
e-mail : sparc.office
@ aerov. jussieu.fr

ISSN 1245-4680

Published by Météo-France
Service Central
de la Communication
et de la Commercialisation

Report from SPARC Initiatives

SPARC Ozone Trend Panel

N. Harris - Chair, J. Kaye - Vice-Chair

A short meeting of the SPARC Panel on Ozone Trends was held in Halkidiki on May 16, 1995 to discuss what the aims of the group should be and how they might best be achieved. The panel is aiming to complete any report/work by about the end of 1997 so that the work is available for consideration in the next WMO/UNEP ozone assessment. The main aims (in order of emphasis) are :

1. to assess the evolving understanding of the situation regarding the ozone trends in the lower stratosphere, and to encourage and/or instigate any actions to achieve that aim ;

2. to look at the likely quality of the various ozone measurements that will be made in the coming years and to help develop a validation and inter-comparison programme ;

3. to keep an eye on any developments in total ozone data quality or trends, in particular in the tropics, and the implications of TOMS v7 data and trends. The early analyses of the TOMS v7 data do not indicate any major surprises.

A second meeting was held during the IUGG meeting in Boulder. The main focus will be on the trends in the lower stratosphere for which the only direct long-term measurements are by ozonesondes and SAGE. A working meeting should be held in the summer of 1996 to assess the quality of the two data sets both through critical evaluation of the measurement techniques and through inter-

comparisons (with a variety of instruments), and to discuss what are the best approaches for the statistical analyses of these somewhat sparse records. A second focus will be the development of a framework for the validation and intercomparison of the future measurements of ozone. J. Kaye will produce an outline and plan of action (in consultation with G. Megie and R. Hudson - see below) to be presented to the SPARC SSG meeting in October 1995.

WMO and IOC have set up a working group currently comprising R. Hudson (chair), R. Bojkov and G. Megie to deal with similar, though not identical, issues. N. Harris and R. Hudson have discussed how to avoid unnecessary duplication, and there is a clear understanding that the two groups will work together. Close contact will be maintained in the coming months.

Gravity Wave Processes and Parameterization

K. Hamilton, R. Vincent - Co-Chairs

The SPARC Gravity Wave (GW) committee should have its first full meeting at IUGG in Boulder in July 1995. In recent months, the members have been in contact by e-mail on two issues : the organisation of a GW workshop planned for April 1996 and lobbying on behalf of SPARC for the archiving of high resolution operational radiosonde data. K. Hamilton was in contact with officials of the U.S. National Weather Service (NWS) on this later issue. The NWS agreed to begin saving high resolution data at

six seconds intervals (about 30 m effective vertical resolution) from 91 of the 93 radiosonde stations it operates in the continental U.S., Alaska, Hawaii, Puerto Rico and U.S. trust territories in the Pacific. The accumulation of these data started on 1 April 1995 and they will eventually be made available to researchers through the National Climatic Data Center in Asheville.

Stratosphere-Troposphere Exchange (STE)

T. Shepherd- Chair

A special SPARC "meeting-of-experts" workshop on STE was held during 13-15 June 1995 in Pointe-du-Lac, Québec, Canada (convener : T. G. Shepherd). It was sponsored jointly by the Atmospheric Environment Service of Canada and by the WCRP. The subject of STE is crucial to many areas of atmospheric science, and lies at the heart of present concerns about the impact of aircraft emissions on the ozone layer. At present, considerable research funds are invested in the USA and Europe in measurement campaigns and in the development of research aircraft, with a primary motivation being this very question of the impact of aircraft emissions on the atmosphere. So the SPARC SSG decided at its last meeting (September 1994) to bring together a cross-section of experts from various scientific communities concerned with STE, in order to try to coordinate different national research and to work towards a comprehensive measurement and modelling strategy.

2

Composition of the SPARC OFFICE

Director :
M.-L. CHANIN

Project scientist :
Yu. P. KOSHELOV

Assistant :
M.-C. TORRE
Service d'Aéronomie,
CNRS, BP 3, 91371
Verrières-le-Buisson, France

SPARC Scientific Steering Group

Co-Chairs

M.-L. Chanin (F)

M. Geller (USA)

Members

D. Ehhalt (G)

K. Hamilton (USA)

I. Isaksen (N)

V. Khatatov (R)

T. Matsuno (J)

J. Pyle (UK)

T. Shepherd (C)

S. Solomon (USA)

H. Tanaka (J)

R. Turco (USA)

Ex-Officio members

IGBP/JGOFS : J. Priddle (UK)

IGBP/GCTE : M. Caldwell (USA)

SCOSTEP WG & : P. Simon (B)

SCOSTEP WG 5 : K. Labitzke (G)

WMO/GAW : R. Bojkov (C)

SCOPE : E. De Fabo (USA)

COSPAR : J. Gille (USA)

ICTP : S. Radicella (A)

A total of 37 scientists from 8 countries participated, involved in theory; global and mesoscale modelling; airborne-ground-based and satellite measurements; stratospheric chemistry; diagnostics, and assessment studies (also some representation was from the funding agencies). The workshop began with overview presentations on the theoretical and modelling background, in order to sharpen the scientific questions; there followed presentations on recent measurement campaigns, to show what is presently possible, as well as on future campaigns and measurement technologies, to point the way forward.

The workshop took as its starting point the progress reported at the highly successful SPARC NATO ARW on STE held in Cambridge in 1993 (see a review paper on STE by J. R. Holton et al., to appear soon in *Reviews of Geophysics*) which marked the beginning of a turning point in the subject. Previous research on STE had focused almost exclusively on the behaviour of the tropopause itself, and on the mesoscale phenomenology of strong mixing events such as mid-latitude tropopause folds and deep tropical convection. At Cambridge, it was explicitly recognized that STE is but one aspect of a global picture of mixing and transport of chemical species, and one which for many purposes is constrained significantly by the dynamics of the entire stratosphere. In this respect it is clear that rather than focusing on STE *per se*, it makes more sense to consider the broader question of transport and mixing in what is now referred to as the "lowermost stratosphere" (the stratospheric region whose isentropic surfaces are connected to the troposphere - or, in the language of B. J. Hoskins, the stratospheric part of the atmospheric "middleworld").

The SPARC workshop now consolidated this development and pushed it still further. Following the clear recommendation from the Cambridge workshop (see report by P. H. Haynes in SPARC Newsletter No 2) that we need to consider well-conceived global measurement campaigns of appropriately chosen chemical tracers in order to constrain conceptual and numerical models, the SPARC workshop included the presentation of results from the recent ASHOC/MAESA and STRAT campaigns. These results clearly demonstrated the potential for chemical measurements to provide quantitative information on critical questions such as the extent of mixing across the subtropical

potential-vorticity "barrier", as a function of altitude; and the most likely route for air to get from the troposphere into the lowermost stratosphere. To many participants, these new results offered a kind of insight familiar to oceanographers in their ability to identify water masses by their T-S relations. It seems that we may now be in a position to achieve a similar kind of Lagrangian view of the chemical circulation of the stratosphere - which is an exciting prospect. The transition layer between the troposphere and stratosphere in the tropics (roughly 360-380 K) was also highlighted as being a crucial determinant of the character of the air (especially its water vapour concentration) that gets drawn up into the Brewer-Dobson circulation. It was noted that many critical questions, including those mentioned above, are hampered by the lack of reliable wind measurements in the tropical stratosphere; for the time being, the only way to estimate mixing rates appears to be by inferring them from chemical concentrations.

A more complete report on the workshop is expected for the next SPARC Newsletter.

Stratospheric Temperature Trends Assessment (STTA)

V. Ramaswamy - Chair

The STTA group met at the University of Reading on March 9-10, 1995 to discuss the current research status of stratospheric temperature trends as inferred from observational records and model simulations and to start coordinated research consistent with the outline presented in the SPARC Newsletter No 4. General points noted by the group included: the lack of systematic stratospheric temperature trends assessments since the WMO report of 1988; the importance on analysing and intercomparing different datasets; and the need to understand the links between observed temperature changes and chemical, radiative and dynamical processes. A need for contacts with other relevant groups, both within and outside of SPARC, was also emphasised.

The first part of the meeting included presentations of recent and ongoing research based on stratospheric data observed from radiosonde, rocketsonde, satellite infrared and microwave instruments, and lidar.

Temperature datasets resulting from a 3D-model analysis were also reported. Discussions focused on problems associated with the measuring devices, the quality of and consistency among the datasets, and the reliability of trend determinations. The influence of the radiatively active species upon the stratosphere and the surface-troposphere radiative energy budgets, as diagnosed using theory and model calculations, was presented. A GCM simulation of the impact of stratospheric ozone loss on the thermal structure of the stratosphere and its effect relative to that due to increases in the well-mixed trace gases was discussed. The role of dynamical variability in the stratosphere was demonstrated using a model, and its possible effect on trend inferences was highlighted. The impact of satellite-retrieved stratospheric temperatures upon the biases of a 3D assimilation model was also noted.

The second part of the meeting dealt with developing research strategies for the near future. To begin with, it was decided to examine in detail the time series of as many stratospheric temperature observational datasets as possible, focusing on zonal monthly means. The agreements/disagreements between the patterns from different datasets will be investigated. In parallel, model simulations of stratospheric temperature changes due to changes in concentration of greenhouse gases, ozone, water vapour, volcanic aerosol loadings will be studied. The role of dynamical variability will be assessed from both observations and models. Contributions from any groups outside of SPARC will be appreciated.

The STTA group will have an informal review meeting during the IUGG Assembly in Boulder. A formal meeting to discuss the progress and to plan further research pursuits is tentatively scheduled for early 1996.

UV Monitoring at the Earth's Surface: the WMO Initiative

P. Simon - Chair

After the WMO Meeting of Experts held at Les Diablerets (Switzerland) in July 1994, it was decided that WMO will take the leadership to establish a global UV monitoring network. For that purpose, a Scientific Steering Committee on UV Monitoring (UV SSC) has been appointed according to the mechanism defined during the meeting and based upon the structure

presented in figure 1. The membership of the UV-SSC is given below.

The terms of reference for this UV SSC adopted during its first meeting held in Boulder in May, 1-3, 1995 are the following :

Following the recommendations by the WMO/EC XLVI and the WMO Meeting of Experts on UV-B Measurements, Data Quality and Standardisation of UV Indices, Les Diablerets, July 1994, the EC Panel of Experts/CAS Working Group on Environmental Pollution and Atmospheric Chemistry has at its meeting in March 1995 in Garmisch-Partenkirchen recommended the establishment of a WMO ad hoc SSC on UV monitoring, with the following terms of reference :

- to act as a focal point for the UV measurements and monitoring programmes,

- to coordinate UV instrument calibration,

- to promote instrument intercomparison,

- to promote comparison, use and integration of measurements and models,

- to develop, in cooperation with the WMO World Ozone and UV Data Centre, requirements for UV data, and organise the data archiving and data distribution system,

- to implement, in cooperation with Quality Assurance/Scientific Activity Centres, a QA/QC programme,

- to advise, in ad hoc, the EC Panel on UV-related research, as deemed necessary,

- to promote understanding and development of the specifications of user requirements for UV data,

- to promote communication within the diverse UV community.

The meeting was mainly devoted to reviewing the plans of each working group (WG) to fulfil their tasks. The priorities for implementing the WG action plans were also defined.

It was decided that the first priority should be the definition of the guidelines for uncertainty estimates at a site, quality assurance (QA) and quality control (QC) of UV irradiance measurements at the Earth's surface. These tasks require strong coordination with the activities of both the Instrumentation and Data Archiving WGs. The UV SSC also approved the implementation of continental/regional archiving centres mainly to support the associated QA/QC activities and data evaluation.

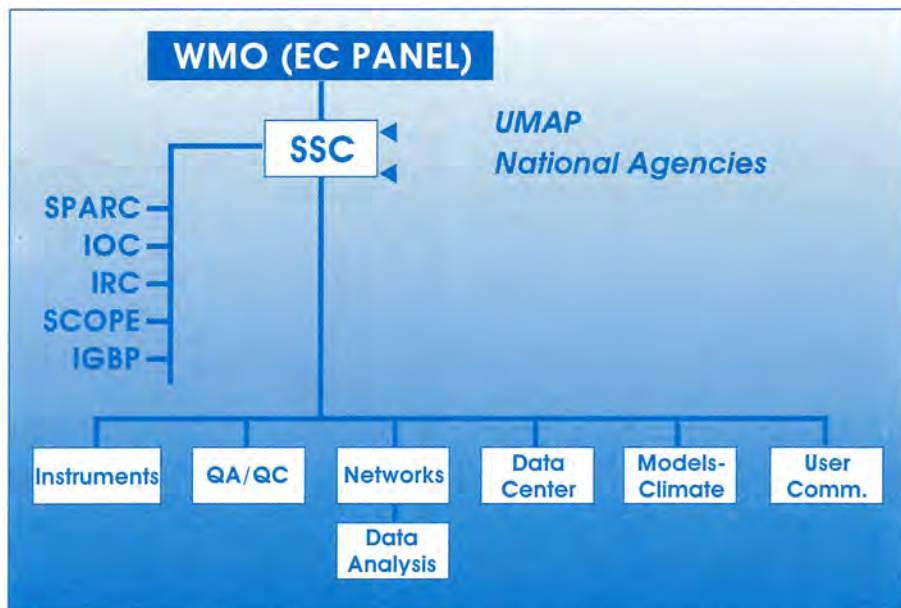


Figure 1 - Organization of Scientific Steering Committee

The WMO/World UV Radiation Data Centre (WUDC) is in operation since approximately one year. It is located in Downsview (Canada) and led by Dr. David Wardle.

The priority for the Data Archiving WG will be to review and expand the input instructions for UV data, with update of format (if necessary) and the definition of the required ancillary data. This will be done in close connection with the QA/QC guideline definition.

The Instrumentation WG will define the tasks for UV-instruments and the definition of specifications for each class of UV instruments. The common calibration methods will be assessed and the ancillary instruments will be defined with their specifications. This later task will be carried out in connection with the Modelling WG. Finally, it will provide instrumental requirements for the QA/QC guideline definition.

The Network WG will finalise the WMO/NOAA inventory on UV sites and networks which is currently in preparation. When completed, this inventory will be installed at the WUDC.

The priorities for the Modelling WG are the radiative transfer model inter-comparisons, the model-measurement intercomparison and the requirements and availability of atmospheric input (ancillary) data.

The Users WG will start with preparing a model working database and of data specifications for human health effects. The outcomes will be circulated in other user communities for comments and recommendations.

The Data Analysis WG will initiate the survey of existing UV irradiance

datasets for global analysis, the harmonisation methods and the definition of an ideal dataset. It will contribute to the definition of the necessary ancillary measurements.

It was decided to hold the second meeting of UV SSC in the first week of October 1995 in conjunction with the NATO ASI on Solar UV Radiation Modelling, Measurements and Effects organised by Prof. C. Zerefos dealing mainly with the most urgent issues, namely the QA/QC guideline definition in relation to the input instructions for data archiving and the instrument specification requirements. In addition, progress made by the other WGs will be also reported.

The third meeting is scheduled for March 1996.

Membership of the WMO SSC on UV Monitoring :

Prof. Paul C. SIMON (*Chairman*), Inst. d'Aéronomie Spatiale de Belgique, 3 Avenue Circulaire, B-1180 Brussels, Belgium. Tel : +32 2 375 1579. Fax : +32 2 374 8423. e-mail : pauls@oma.be

Dr. Betsy WEATHERHEAD (*Networks*), NOAA/ERL/R/E/ARX1, Boulder, USA. Tel : +1 303 497 6653. Fax : +1 303 497 6546. e-mail : betsy@srbb.eri.gov

Dr. Petteri TAALAS (*Data Analysis*), Finnish Meteor. Inst., Helsinki, Finland. Tel : +1 358 0 1929 253. Fax : +1 358 0 1929 537. e-mail : petteri.taalas@fmi.fi

Dr. Gunther SECKMEYER (*Instruments*), Fraunhofer Inst. für Atmosphärische Umweltforschung, Garmisch-Partenkirchen, Germany, Tel : +49 8821 183181, Fax : +49 8821 73573, e-mail : sech@ifu.fh6.de

Dr. Ann WEBB (QA/QC), Univ. Reading, Reading, UK. Tel : +44 1 734 875 123. Fax : +44 1 734 352 604. e-mail : swwsweban@reading.ac.uk

Dr. Sasha MADRONICH (Modeling), NCAR, Boulder, USA. Tel : +1 303 497 1430. Fax : +1 303 497 1400. e-mail : sasha@acd.ucar.edu

Dr. David WARDLE (Data Centres), Atmos. Env. Serv., Downsview,

Canada. Tel : +1 416 739 4632. Fax : +1 416 739 4281.

Dr. Anne KRICKER (User Communities), NSW Cancer Council, Kings Cross, Australia. Tel : +61 2 334 1891. Fax : +61 2 368 0843. e-mail : annek@pub.health.su.oz.au

Prof. Christos S. ZEREFOS (EC/CAS), Aristotle Univ. Thessaloniki, Greece. Tel : +30 31 998 041, Fax :

+30 31 283 752. e-mail : zerefos@olymp.ccf.auth.gr

Dr. Antti KULMALA (WMO), Geneva, Switzerland. Tel : +41 22 7308 587. Fax : +41 22 7400 984. e-mail : kulmala@ties.itu.ch

SPARC Workshop during the IUGG Assembly,

Boulder, July 1995

At the Boulder IUGG meeting, special sessions were held on "Stratospheric Processes And their Role in Climate". M. Geller gave a brief presentation explaining what SPARC is and what projects were underway. There were five invited papers on SPARC explaining existing SPARC projects and giving their status. S. Pawson and K. Koder gave a paper titled "The GRIPS Project : Aims and Status". V. Ramaswamy gave a paper titled "Stratospheric Temperature Trends Assessment : A SPARC Project". K. Hamilton's presentation was titled "Gravity Wave Processes and Their Parameterization". J. Gille reported on

"Development of a Water Vapour Climatology for the Lower Stratosphere-Upper Troposphere," and T. Shepherd gave a paper titled "Stratosphere-Troposphere Exchange". There were also contributed oral papers relating to GCM experiments on the dynamical impacts of the Antarctic Ozone Hole; the impact of the Montreal protocol on the radiative forcing of climate; derivation of a gravity wave climatology; long-term trends in stratospheric water vapour; the SAGE II water vapour data set; and stratosphere-troposphere mass exchange in mid-latitudes. There were also 13 poster papers presented, covering a variety of topics

such as derivation of a gravity wave climatology; GCM modelling; and lidar measurements of polar stratospheric clouds.

About 150 people attended the sessions, and in the ensuing discussion expressed great interest in SPARC but suggested that more activity be implemented in the areas of stratospheric influences on the radiative forcing of climate, and in the impact of large volcanic eruptions on the stratosphere-tropospheric system.

● M. Geller

5

Future SPARC and Related meetings

Future SPARC meetings :

5-15 September 1995 : NATO ASI on "The Stratosphere and its role in the climate system" Director : G. Brasseur (NCAR, PO Box 3000, Boulder 80307, Co, USA), Québec, Canada.

April 1996 : NATO ARW "Gravity Wave Climatology and Parameterization", Convener : Kevin Hamilton (GFDL, PO Box 308, Princeton, NJ 08542, USA), Santa Fe, NM, USA.

December 1996 : First SPARC General Assembly, Melbourne, Australia. Conveners : M. Geller and D. Karoly.

July 1997 : IAMAS General Assembly, SPARC Session, Uppsala, Sweden.

SPARC related meetings :

19-20 July 1996 : COSPAR : Symposium AI-I : "Middle Atmosphere-Satellite Observations, Interpretation and Validation, Models and Processes and their Role in Global Change". Convener : J. J. Barnett (Oxford University, Clarendon Lab., Oxford OX1 3 PU, UK).

19-24 August 1996 : IRC Symposium on "Current Problems in Atmospheric Radiation", Fairbanks, AL, USA. Convener : K. Stamnes (Geophysical Institute, University of Alaska, 99775-0800 Fairbanks, AL, USA)

12-21 September 1996 : International Ozone Commission, Rome, Italy. Conveners : G. Fiocco (Physics Department University, La Sapienza, Rome, I-00185, Italy) and G. Mégie (CNRS/SA, Université Paris VI, B. 102, 4 Place Jussieu, 75252 Paris Cedex 05, France).

international conference on Ozone in the Lower Stratosphere,

Halkidiki, Greece, May 15-20 1995

Introduction

Christos Zerefos, Local Organizer

The Conference brought together a large number of mostly U.S. and European scientists working in the field of ozone and UV-B research. This international scientific gathering was designed by the Organizing Committee so as to stimulate discussion and the conference featured a small number of invited lectures and about 220 original poster presentations. The meeting was attended by about 300 scientists from 40 countries and was under the Aegis of the President of the Hellenic Republic, Konstantinos Stefanopoulos. The sponsors included the European Commission, the World Meteorological Organization (WMO), the Ministry of the Environment of Greece, the National Aeronautics and Space Administration (NASA), NOAA, the International Ozone Commission, SPARC, and the Laboratory of Atmospheric Physics of the Aristotle University of Thessaloniki.

The conference was held in the same place where eleven years ago the Antarctic ozone depletion was reported and a decade after its first theoretical explanation which was followed by a surge of research and other international activities. Indeed the last decade marks a period of immense international efforts to understand better the physical and chemical processes which control the ozone layer and the evolution of measures to protect it. The meeting concentrated mostly on the lower stratosphere, where most of the depletion is observed and where an acceleration of the ozone decline is reported for the 1990's through 1995. Several of the results presented at the Conference were based on data obtained during the recent large international campaigns and experiments and they were grouped to cover eight topics, discussed in corresponding eight sessions. In the following the rapporteur's reports are presented for each one of the sessions, which, however, they do not pretend to represent a consensus position but rather a summary of each rapporteur's own impression of each session. A special issue of JGR will be published containing the peer reviewed, full size papers of the work presented at the Conference by several groups.

Session 1 - Ozone Changes

*G. Mégie, Chair;
J. Gleason, Rapporteur*

Changes in Total Column Ozone

Neil Harris (University of Cambridge-UK) opened the session with a review of the 1994 World Meteorological Organization (WMO) Scientific Assessment of Ozone Depletion chapter, «Observed Changes in Ozone and Source Gases». He began by updating the Conference on the progress since the last WMO Assessment in 1992. He summarized as follows:

- The previous total ozone trend estimates were based on the Nimbus-7 TOMS data record. The ozone trends through the period of the last assessment (1978-91) have not been revised and are still valid.

- The ozone record in the 1992-93 post-Pinatubo time period showed an anomalous loss of an additional 1-2% of total column ozone.

- For the 1994 Assessment, a new combined Nimbus-7 Solar Backscatter Ultraviolet (SBUV)/NOAA-11 SBUV2 data set was created to form a new consistent 1978-94 satellite data record. This data set change was required by the failure of the Nimbus-7 Total Ozone Mapping Spectrometer (TOMS) in May 1993 and some problems with the TOMS instrument near the end of the Nimbus TOMS data record. The trends derived from the SBUV/SBUV2 data set are similar to the trends derived from the TOMS data.

- The trends from the ground-based Dobson network are in good agreement with the satellite trends.

- The trends in total column ozone from a number of two-dimensional assessment models are in qualitative agreement with the satellite and ground-based total ozone trends. The 2D models are able to reproduce the latitude-dependent shape of the measured trends, but some quantitative discrepancies, up to a factor of four, remain.

- The most significant new development with the latest data sets is the small barely statistically significant trends in total column ozone in the tropics. This small tropical negative trend has been observed in both the satellite and ground-based total column ozone data.

Rumen Bojkov (WMO-Switzerland) presented his ozone trend analysis using the measurements from the Dobson network. He has gone back to reevaluate the measurements from each of the individual Dobson stations. The Dobson network has a longer temporal record than the satellite data. He presented his long-term regional analysis showing that, for the period 1960-80, there was no trend in total column ozone measured by the Dobson network. The ozone decreases have been measured since 1980; the largest changes are observed in the Antarctic winter/spring with significant changes being observed in the northern mid-latitude springtime.

Antarctic Ozone Hole Summary

The October monthly mean total ozone measured at the Antarctic Dobson stations continues to decrease. Ozone sondes launched from the South Pole in 1993 measured profiles with less than 100 DU, with essentially no measurable ozone between 14 and 19 km. The poster from the British Antarctic Survey [OZ.34], presented by Anna Jones, showed that the annual springtime ozone reductions at Halley Bay are now continuing into the late summer months. Since 1990, the lowest four January and the three lowest February monthly mean total ozone values have been recorded.

TOMS Version 7 Results

The first results from the recent reprocessing of the Nimbus 7 TOMS data, version 7 (V7), were presented by Rich McPeters (NASA Goddard Space Flight Center). The new algorithm has incorporated several small changes which improve both the absolute calibration and the time-dependent calibration. These changes will improve the retrieval accuracy over a wider range of geophysical conditions (clouds, dust, high solar zenith angles, and seaglint).

Comparisons of the TOMS V6 with an ensemble of 30 Northern Hemisphere Dobson stations showed several artifacts, whose causes were identified and fixed in the V7 data. The source of the absolute bias (~4% in V6) with respect to the Dobson network was identified as a small error in the wavelength calibration of the TOMS instrument. The corrected wavelengths used in V7 removed this absolute bias. The time-dependent drift with respect to these stations has been removed with an improved diffuser plate calibration and the seasonal

differences were removed with a correction for photomultiplier non-linearity.

Another important change was the use of the International Satellite Cloud Climatology Project (ISCCP) climatological cloud heights. The V6 TOMS data used latitude-dependent, zonal-mean cloud heights. The new climatology discriminates between marine and continental cloud heights, removing artifacts associated with the ocean-land boundary.

The long-term ozone trends measured using the V7 data are quite similar to the trends determined from the V6 data. The springtime northern mid-latitude trends are smaller in the V7 data, -2 to -6% per decade (V6) instead of -4 to -8% per decade (V7).

Changes in the Ozone Profile

The trends in the ozone profile have also been updated from the 1992 Assessment. One of the discrepancies identified in the last Assessment was the difference in the ozone trend in the mid-upper stratosphere as determined by the Stratospheric Aerosol Gas Experiment (SAGE I/II) data set and the trend determined from the SBUV or Umkehr data sets. The SAGE I/II showed significantly smaller trends in the region. The discovery of a small error in the attitude of SAGE I has led to a reanalysis of the SAGE I data and the ozone profile trends have been recalculated. With this adjustment the SAGE I/II, SBUV/SBUV2, and Umkehr data sets now are all in good agreement above 25 km, measuring ozone decreases of about 6-8% per decade at 40 km in the northern mid-latitudes. A discrepancy between SAGE I/II and SBUV/SBUV2 in the tropics remains.

The corrections to the SAGE I data set were described in a poster from the SAGE Team [OZ.64], presented by Joe Zawodny (NASA Langley Research Center). A small error in the wavelength calibration of the SAGE I instrument meant that incorrect cross sections were used to determine the altitude from Rayleigh scattering. Another poster presented by Derek Cunnold (Georgia Institute of Technology) [OZ.14] showed additional independent evidence for a SAGE I reference height error. Cunnold also presented evidence for a small aerosol optical depth dependence of the SAGE ozone data. When the reference height error and some aerosol optical depth corrections are made to the ozone data set, the trends derived from the column-integrated SAGE I/II data set are in good agreement with those derived from the TOMS total ozone data set.

SAGE I/II data set ozone profile trends below 20 km are still inconsistent with the trends determined from the ozonesonde data set, with the trends

from SAGE I/II being much more negative than the ozonesonde trends.

The importance of analyzing the ozonesonde data relative to tropopause height was presented by Bojkov and Fioletov [OZ.6] and De Muer and De Backer [OZ.17]. The Bojkov and Fioletov analysis, from three North American and three European sites, showed converting the vertical coordinate from altitude to relative distance to the tropopause reduced the variance in the ozonesonde data by accounting for the seasonal dependence of the tropopause height. Reducing the ozone variance in the region near the tropopause is critical in determining the ozone trends in this radiatively critical region. De Muer and De Backer showed their ozonesonde data relative to the tropopause height from Uccle. Their analysis showed the seasonally-dependent positive ozone trend in the upper troposphere clearly separated from the seasonally-dependent negative trend in the lower stratosphere.

Post-Pinatubo anomalies in the ozone profile

David Hofmann (NOAA Climate Monitoring and Diagnostics Laboratory) presented an analysis of ozonesonde data taken in several regions of the globe. The North American ozonesonde stations measured 10% deviation from their 1979-90 mean values during the winter/spring of 1992-93, with a recovery in the winter of 1993-94. The anomalies over Boulder, Colorado were accompanied by increases in the aerosol content, measured by the Fritz Peak lidar. He showed that the changes in the ozone profile over Mauna Loa, Hawaii, are strongly correlated with the shift in the quasi-biennial oscillation (QBO) winds but that the ozone minima after the QBO phase shift are getting significantly lower with time. He showed interesting morphological changes in the ozone profile over Boulder associated with the presence of Pinatubo aerosols; the ozone has increased above the ozone peak and decreased below the peak. He proposed a chemical mechanism involving heterogeneous reactions of sulfate aerosols. It was not clear that the atmospheric temperatures were cold enough to drive the chemical depletion required to explain the observed ozone profile changes.

Ozone losses during the Northern Hemisphere Winter

The latter part of Neil Harris's talk concerned seasonal ozone losses in the Northern Hemisphere. He was seeking to answer the question «Has chemical ozone depletion occurred in the last two years?» He summarized a number of recent studies which used satellite data (Upper Atmosphere Research

Satellite (UARS) Microwave Limb Sounder (MLS) ClO and ozone), aircraft data (in situ ozone and N₂O correlations from the ER-2 and lidar ozone/aerosol analysis done on the DC-8), and ozonesonde data. These studies, which analyze completely independent data sets, show that chemical ozone loss occurs at the 475 K potential temperature surface at the rate of about 0.5% per day. Some of these studies also showed similar losses at the 400 K and 500 K surfaces. Markus Rex (Alfred Wegner Institute for Polar and Marine Research-Germany) then followed with his presentation of the Lagrangian analysis of ozonesonde data from the European Arctic Stratospheric Ozone Experiment (EASOE) (winter 1991-92) and MATCH, during the Second European Stratospheric Arctic and Mid-latitude Experiment (SESAME, winter 1994-95) campaigns. The EASOE results were recently reported in *Nature* (volume 375, page 131, 11 May 1995). During these campaigns, diabatic air parcel trajectory calculations were initialized at each ozonesonde launch. When an air parcel trajectory approached an ozonesonde site, an additional ozonesonde was launched. Analysis of this coupled sonde data showed an ozone depletion rate of about -0.25% per sunlight hour. There was considerable discussion from the audience on how to convert this into the more traditional ozone depletion units of % per day. The ozone depletions were highly correlated, with the trajectories passing through regions that were cold enough to form polar stratospheric clouds (PSCs). Analyses of the 1994/95 winter showed ozone depletion after a PSC event, ozone recovery, a second PSC event, ozone depletion, and then recovery. The poster by von der Gathen et al. (Alfred Wegner Institute for Polar and Marine Research-Germany) [OZ.23] displayed the Ny-Alesund/Spitzbergen ozonesonde data from the winters of 1991-92 and 1994-95. These ozone profiles showed large notches or cut-outs in the ozone profiles in the region of the ozone peak. These perturbed Northern Hemisphere winter ozone profiles look very similar to Antarctic ozone hole ozone profiles. The Lagrangian analysis combined with the appearance of the ozone profiles themselves are strong evidence of chemical ozone depletion occurring during the Northern Hemisphere winters.

Session 2 - NO_x

S. Solomon, Chair;

A. Weaver, Rapporteur

Although ozone destruction in the lower stratosphere is primarily due to the HO_x and ClO_x catalytic cycles, reactive nitrogen chemistry has a key

role and strongly affects these other cycles. With the NO_y species we have the most complete and longest-term set of measurements, the basic chemistry is fairly well understood, and the heterogeneous chemistry is relatively simple. Yet, as we continue to collect atmospheric data, particularly for the less well-known species like N_2O_5 , ClONO_2 , and HNO_3 , new questions appear. Many of these questions are connected with the perturbed conditions of polar winter or volcanic aerosol loading, and much of the session focused around these effects.

Jean-Pierre Pommereau (CNRS-France) discussed the uncertainties in the sources and budget of NO_y . Questions include the sources of N_2O (which is the source of 90% of NO_y), the changing rate of increase of atmospheric N_2O (from 0.23% per year in 1950-84 to 0.36% per year in 1984-93), and the conversion efficiency of N_2O to NO_y . Other sources of NO_x in the lower stratosphere are lightning and aircraft emissions. The magnitude of the lightning source recently has been estimated at 2 MT/yr, the previous estimate was 10-20 MT/yr. The magnitude of the aircraft source is much better known, but the lifetime of NO_x from this source is not.

Under unperturbed conditions (i.e., other than polar winter or high sulfate aerosol loading), a wide variety of NO_y species measurements have been made. The posters included many contributions from ground-based NO_2 measurements, which are becoming more widespread and continue to be improved. Groups with newer instruments are focusing on seasonal cycles at particular locations and modeling them. Instrument intercomparisons like that at Camborne, UK in 1994 have enabled some groups to make significant improvements in data quality, and allow for meaningful comparisons of data from different sites and instruments. More of these instruments are now capable of measuring less abundant species like NO_3 , OCIO , and BrO . For example, J. B. Renard et al. (CNRS-France) presented new NO_3 data from balloon-borne measurements at Aire sur l'Adour.

The NO_y instrument, as well as other instruments on the NASA ER-2 high-altitude aircraft, have produced an extensive data set from the 1993-94 missions (i.e., the Stratospheric Photochemistry, Aerosols and Dynamics Expedition (SPADE) and the Airborne Southern Hemisphere Ozone Experiment/Measurements for Assessing the Effects of Stratospheric Aircraft (ASHOE/MAESA)) in the Northern and Southern Hemispheres. The data provide a detailed picture of NO_y at about 20 km, over

a range of latitudes and seasons. For example, Ru-Shan Gao (NOAA Aeronomy Lab) presented results of a quantitative study of NO_y partitioning from March through October 1994 at 40°N-70°S which showed that, although NO_y is about 90% HNO_3 at all seasons, there are significant shifts between ClONO_2 and NO_x in the remaining 10%. Other studies of NO_y partitioning are expanding rapidly as new data become available from instruments flown on the German aircraft and balloon-borne Michelson Interferometric Passive Atmosphere Sounder (MIPAS) instruments, which will be capable of measuring each species of the NO_y family.

The ER-2 data also provide information about dynamics. David Fahey (NOAA Aeronomy Lab) presented studies of the $\text{NO}_y/\text{N}_2\text{O}$ correlation, where N_2O is used as a tracer of transport. These data provide constraints on the extent of mixing and other transport processes. For example, the 1994 latitudinal surveys show evidence for significant exchange of mid-latitude and tropical air in the lower stratosphere. Comparisons to two-dimensional model results [Solomon and Garcia] show significant differences in the tropics, where the observed $\text{NO}_y/\text{N}_2\text{O}$ is much lower than modeled. There is also a lot of structure in the measurements that is not reproduced by the model.

The significant perturbations to NO_y partitioning during polar winter continue to be studied, with some very interesting results. The very fortuitous timing of the 1994-95 Second European Stratospheric Arctic and Mid-Latitude Experiment (SESAME) campaign, during an extremely cold Arctic winter with a very long-lived and stable vortex, gives us a great deal of detailed and important data. The capabilities for measuring N_2O_5 and ClONO_2 have improved significantly in the last few years, and these data will define much better the role of heterogeneous chemistry under such perturbed conditions. The poster presentations included work showing very large HNO_3 reductions and ClONO_2 increases during 1994-95 [C. Blom et al., MIPAS instrument, NO_2]. Hermann Oelhaf (KFK/IMK-Germany) presented results of the first N_2O_5 profiles in the Arctic vortex (in 1990 and 1992), showing that N_2O_5 is somewhat lower than expected between 20 and 30 km, although it is in reasonably good agreement with the TOMCAT model when heterogeneous chemistry is included.

Robert De Zafra (State University of New York at Stony Brook) presented HNO_3 data from the South Pole from 1993-94, showing a sudden sharp decrease at the end of May, coincident with the onset of PSC temperatures.

The spring HNO_3 recovery is slow. At higher altitudes (35-45 km), HNO_3 increased significantly at the end of June, and then returned to low levels at the end of August. This observation generated a lot of discussion, including the possible role of aerosols and descent from the mesosphere, neither of which is completely suitable as an explanation. Randy Kawa (NASA Goddard Space Flight Center) noted that the Cryogenic Limb Array Etalon Spectrometer (CLAES) N_2O_5 data show similar behavior. He suggested that ionic reactions might be important. Ralf Toumi (Imperial College-UK) suggested $\text{HO}_2 + \text{NO}_3$ as a possible source.

Further questions about HNO_3 are raised by data like that presented by John Remedios (Oxford University-UK), using the CLAES, Microwave Limb Sounder (MLS), and Improved Stratospheric and Mesospheric Sounder (ISAMS) instruments being flown on board the Upper Atmosphere Research Satellite (UARS). The behavior of HNO_3 in the vortex is not well understood; for example, high levels at higher altitudes and during stratospheric warmings.

Measurements during polar winter offer stringent tests of our understanding of the effects of heterogeneous chemistry. Other information about these effects is available from data following the eruption of Mt. Pinatubo. ER-2 aircraft measurements [D. Fahey] and ground-based NO_2 column measurements like those from Lauder, New Zealand [J. G. Keys] show that heterogeneous chemistry must be included in modeling NO_2 and NO_y under conditions of high sulfate aerosol. Particular modeling questions include the effects of aerosol composition; David Fahey and Michael Hoepfner (KFK/IMK-Germany) both presented evidence of the importance of supercooled ternary solution (STS) particles rather than nitric acid trihydrate (NAT). Fahey also discussed the use of $[\text{NO}_x]/\text{surface area}$ rather than simply $[\text{NO}_x]$ as a parameter for evaluating the effects of aircraft emissions on ozone.

The wide spatial and temporal coverage of the ground-based NO_2 measurements has made possible several studies on the effects of Mt. Pinatubo aerosols. These show NO_2 column decreases in 1991-92 that coincide with transport of the aerosol cloud and recovery in subsequent years (e.g., the 1990-93 shipboard SAOZ latitudinal surveys by Pommereau et al.). The altitude dependence of the extent of saturation has been studied [Pommereau et al.] and shows a transition between measurements below 15 km, where $\text{N}_2\text{O}_5 + \text{H}_2\text{O}$ is always satura-

ted, to above 21 km, where it is not. In the intermediate altitude range, the degree of saturation depends on aerosol loading. Ralf Toumi noted that the box models used to simulate these results often underestimate NO₂ under conditions where heterogeneous chemistry is important.

Session 3 - HO_x

R. Bevilacqua, Chair;

R. Toumi, Rapporteur (with great help from Kathy Wolfe)

The HO_x session provided some new exciting data presentation for source gases and radicals. The Upper Atmosphere Research Satellite (UARS) has provided new insight into the distribution of hydrogen source gases in the middle atmosphere. Jim Russell (NASA Langley Research Center) presented Halogen Occultation Experiment (HALOE) observations of CH₄ and H₂O. The observations confirmed earlier notions of a reactive H₂O yield from CH₄ oxidation in the range of 1.5-2.0. A new HALOE finding was the observation of continuous H₂O cross-tropopause transport which maintains the tropopause values over a year or longer and is transported up to 30 km. This transport appears relatively unaffected by horizontal mixing from subtropical regions. The tropical H₂O ascent data also provided a plausible explanation for the elevated hygropause. Another intriguing feature is an observed hemispheric H₂O asymmetry thought partly to be a consequence of Antarctic dehydration.

Several outstanding issues remain unresolved. Recent aircraft data obtained during the Stratospheric Photochemistry, Aerosols and Dynamics Experiment (SPADE) indicate a higher lower stratospheric H₂O yield than the satellites and models suggest. Paul Wennberg (Harvard) pointed out that seasonality may need to be considered. The quantification of the polar dehydration and stratosphere-troposphere exchange remains elusive.

Paul Wennberg presented seminal results from the SPADE and the Airborne Southern Hemisphere Ozone Experiment/Measurements for Assessing the Effects of Stratospheric Aircraft (ASHOE/MAESA) aircraft campaigns. OH diurnal variation is tightly constrained by the solar zenith angle. The HO_x production and loss rates are balanced as expected from steady-state considerations. A sudden rise of OH in the early morning remains unexplained fully, but it is thought that larger O(1D) yields and heterogeneous BrONO₂ hydrolysis followed by HOBr photolysis may provide a plausible solution. The HO₂/OH ratio as determined by the measurement follows

model predictions closely to the extent that the uncertainty of rate constants can be tested. Current rate constant recommendations appear correct.

The simultaneous determination of a host of other radicals involved in the rate-determining steps allowed for the first time a direct comparison of the relative importance of the various ozone loss cycles. Catalytic destruction by HO_x in the lower mid-latitudes accounts for over half of the total photochemical loss rate. At high latitudes halogen catalytic cycles become important. NO_x plays a less direct role in ozone loss but is important in modulating HO₂ and ClO. Within the uncertainties of the measurements, the fast photochemistry of the HO₂/OH ratio and HO_x budget appear well-understood in this part of the atmosphere.

Cornelius Schiller (KFA Jülich - Germany) showed balloon-borne in situ measurements of total hydrogen (CH₄, H₂, H₂O) of 7.2 and 6.9 ppm at mid-latitudes and in the Arctic, respectively. The derived H₂O yield was not significantly different from 2 and a stratospheric entry level H₂O of 3.6 ppmv was derived. These findings are in broad agreement with the satellite observations.

Lesley Gray (Rutherford Appleton Laboratory-UK) demonstrated the power of combining 10-day trajectories with HALOE observations to identify the origin of air masses. These trajectories were labeled with potential vorticity and H₂O. She concluded that, during Southern Hemisphere winter, there are regions in the mid-latitudes and in the subtropics that have dehydrated polar origins. In the future, it should be possible to use this technique to quantify this exchange between mid- and polar latitudes.

There was also a poster presentation by Robert Conway (Naval Research Laboratory) [HO.1] showing preliminary results of the first global OH measurements as part of the Middle Atmosphere High-Resolution Spectrograph Investigation (MAHRSI). The retrieval covered 35-90 km and 43°S-63°N. Qualitative agreement with model predictions was found at low solar zenith angles, but some problems appear at higher solar zenith angles. A further mission is planned in 1997.

Many issues were raised during the discussion. Of particular interest was the observation of an H₂O increase over the last decade in the lower stratosphere (Dave Hofmann/NOAA Climate Monitoring and Diagnostics Laboratory). It was agreed that CH₄ oxidation could not fully account for the trend and that the origins of the trend must lie in the exchange of troposphere to stratosphere. Susan Solomon (NOAA Aeronomy Laboratory) noted that tropical tropopau-

se temperatures have not changed noticeably, leaving the possibility of increased storm activity as an increased source of H₂O. The increased frequency of El Nino events in the 1990s was also commented on as a plausible cause (Darin Toohey/University of California at Irvine).

It was noted by many that at least two major issues remain unquantified. First, exchange of dehydrated air between polar and extra-polar regions has been demonstrated but remains poorly quantified. Secondly, the rate of loss cycles has been determined by observations, yet the quantitative connection to observed ozone trends remains elusive. Nevertheless, it is clear that some real breakthroughs have been achieved, particularly in the fast HO_x photochemistry, and one was left with the impression that understanding the variability in space and time of the source gases poses the bigger challenge. Unfortunately, the number of presentations (poster and oral) was not in proportion to the outstanding importance of the hydrogen-containing compounds. Further exciting work remains to be done.

Session 4 - Halogens

D. McKenna, Chair;

M. Santee, Rapporteur

Summary of Key Issues

Much work has been done to reduce the uncertainties in the rate constants and absorption cross sections necessary to quantify ozone loss due to halogen species, but further improvements in our knowledge of these and other critical parameters controlling inorganic halogen partitioning are needed. We especially need to improve our understanding of stratospheric bromine abundances and chemistry. Closure of the stratospheric chlorine budget, and the fraction of the total available chlorine in HCl, remain outstanding issues. The degree of mixing of mid-latitude air into the tropics required to explain source gas observations in the lower stratosphere (as characterized by the «global diffuser» or «tropical pipe» transport models) remains unresolved.

Summary of Oral Talks

There were five oral talks presented in the halogens session; the first three concerned source gases and longer-lived reservoirs and the last two focused on shorter-lived radicals.

Rudi Zander (University of Liege-Belgium) [HA.26] spoke on the budgets of chlorine and fluorine in the stratosphere. Starting in the 1950s, the tropospheric concentrations of the three most important organic chlorine and fluorine

source gases (i.e., CFC-11 and -12 and HCFC-22) increased steadily until the effects of the Montreal Protocol, which regulated these species, began to be noticeable. After peaking in 1989, the rates of increase of CFC-11 and -12 (though not of HCFC-22) are now declining. Balloon, satellite, and ground-based measurements all show a substantial (about 3.5-4% per year) increasing trend in HCl concentrations. There is some offset between Halogen Occultation Experiment (HALOE) and Atmospheric Trace Molecule Spectroscopy Experiment (ATMOS) HCl profiles above 10 mbar, with HALOE values lower by about 15%. Mid-latitude intercomparisons between the Cryogenic Limb Array Etalon Spectrometer (CLAES) and ATMOS ClONO₂ show that the profiles usually agree to within 0.2 ppbv (about 20%); the agreement between CLAES and the Michelson Interferometric Passive Atmosphere Sounder (MIPAS-B) and Mark IV ClONO₂ is also generally satisfactory; and CLAES ClONO₂ total column amounts are within 12% of those from both Lauder, New Zealand, and ISSJ. The amount of available chlorine, Cl_y, in the stratosphere is increasing. The inventory of Cl_y can be obtained either indirectly, by exploiting the compact correlations between the mixing ratios of the long-lived source gases, or directly, by summing up various species measured by ATMOS. Results from the two approaches show good agreement. The stratospheric budgets of total Cl and F are consistent with the source inventories at the ground, to within the experimental uncertainties. Continued monitoring of key source, sink, and reservoir species, including substitute gases, is necessary.

Jim Elkins (NOAA Climate Monitoring and Diagnostics Laboratory) [HA.5] described the Airborne Chromatograph for Atmospheric Trace Species (ACATS IV), a new instrument developed for the Airborne Southern Hemisphere Ozone Experiment/Measurements for Assessing the Effects of Stratospheric Aircraft (ASHOE/MAESA) mission which measures a total of 11 species comprising 80% of the organic chlorine and 20% of the organic bromine budget. Tight linear correlations between the mixing ratios of CFC-11 (whose lifetime is well known) and other tracers measured by ACATS allow their lifetimes to be constrained. ACATS provides the first lower stratospheric in situ measurements of SF₆, which is an excellent tracer of atmospheric dynamics, having a lifetime of about 3200 years and a global growth rate of 8.7% per year. The growth rate of SF₆ can be used to estimate the mean age of the air parcels in a particular region with a precision of a few months. ASHOE/MAESA data indicate that the largest SF₆ values up to

the 50 mbar level are found in the equatorial regions, where the age is typically less than one year. Measurements of halon-1211 and SF₆ are used to investigate the «global diffuser» versus the «tropical pipe» transport models. In order to obtain agreement between the halon-1211 data and the results from a photochemical model, a «leaky» tropical pipe model must be invoked, with about 35% mid-latitude air mixed into the tropics.

Andreas Engel (KFA Jülich - Germany) [HA.6] presented the results of two balloon flights from Kiruna (68°N) using KFA Jülich whole air samplers measuring N₂O, CH₄, CF₂Cl₂, and other long-lived tracers and the Jet Propulsion Laboratory (JPL) Submillimeterwave Limb Sounder (SLS) spectrometer measuring N₂O, HNO₃, ClO, HCl, and ozone. For the first flight on 1 February 1994, Kiruna was inside the vortex at the 550 K and 700 K levels, and comparison of the in situ N₂O measurement with a reference profile indicated strong subsidence. For the second flight on 9 February 1994, Kiruna was outside the vortex at both levels and both instruments recorded an N₂O vertical distribution very similar to that of the mid-latitude reference. The correlation between CF₂Cl₂ and total organic chlorine was used to estimate the available chlorine, Cl_y. Inside the vortex, higher values of Cl_y and HCl were found at a given height on 1 February, due to the effects of diabatic descent; ClO values were also higher, but the ClO enhancement was larger than expected from subsidence. Back trajectories indicated that in the 10 days prior to the flight, 675 K temperatures were above (but close to) the polar stratospheric cloud (PSC) formation threshold. Box trajectory model calculations showed a strong anticorrelation between ClO and ClONO₂, little change in HCl, and highest ClO values in air parcels situated the farthest south. These results imply that the ClO enhancement may have arisen from ClONO₂ photolysis, although some chlorine activation may have occurred. About 50-60% of Cl_y was found to be in HCl at 20 km, increasing to about 70% at 25 km.

Darin Toohey (University of California at Irvine) [HA.22] discussed the partitioning of inorganic chlorine and bromine in the lower stratosphere. A variety of measurements indicate that HCl comprises 55-65% of Cl_y at mid-latitudes in this region. Models underpredict HCl at high altitude and overpredict HCl at low altitude. Daytime partitioning of active chlorine involves cycling between ClO, Cl, and Cl₂O₂. Photolysis is inhibited during darkness and the ClO becomes proportional to temperature, as the dimer is in equilibrium with the ClO. Measurement/model comparisons using various Cl₂O₂ cross sections imply a lower photolysis

rate than the JPL-94 recommendation, with better agreement attained using the recent cross sections of Huder and DeMore. ER-2 data indicate that in highly perturbed regions, ClO accounts for less than half of the total chlorine, with the rest residing in Cl₂O₂, so that it is the dominant reservoir. Following the eruption of Mt. Pinatubo, the ClO increase (of perhaps a factor of two) in response to the enhanced aerosol surface area was smaller than predicted but was consistent with the changes in NO_x. Abundances of inorganic bromine are small and less is known about its partitioning. Measurements of HBr in the stratosphere are less important since there are no major pathways to create HBr quickly. Models tend to overpredict the amount of BrO relative to Br₂ during the day. Data from the ASHOE/MAESA mission indicate that BrO constitutes about half of Br_y, with most of the remaining Br_y in HOBr and BrONO₂. Results from a balloon flight over Kiruna during the Second European Stratospheric Arctic and Mid-Latitude Experiment (SESAME) indicate about 16 pptv of BrO at 20 km.

Lucien Froidevaux (JPL) [HA.11] summarized Upper Atmosphere Research Satellite (UARS) Microwave Limb Sounder (MLS) observations of ClO, HNO₃, and ozone in the extra-vortical lower stratosphere. Averaging MLS ClO over approximately month-long intervals in the upper stratosphere (2 hPa) and performing a simple linear regression reveals a 6-8% per year increase over the period 1991-95, the first indication of such a trend in reactive chlorine. In the lower stratosphere (22 hPa), ClO abundances are significantly larger than expected from gas-phase chemistry alone, and some decrease is evident from the linear regression (implying a larger net post-Pinatubo decrease masked by the expected long-term increase from chlorine loading). A seasonal cycle in ClO is observed at both levels. In MLS HNO₃ data, a decreasing trend generally is observed between 1991 and 1995, superimposed on the seasonal variations. The decline in HNO₃, which is strongest at low latitudes, is also seen in ground-based data and is consistent with the enhanced concentrations observed following the eruption of Mt. Pinatubo. Northern mid-latitude column ozone values during the 1994-95 winter are close to the lowest values observed in the past four winters; dynamical variations must play a significant role in this interannual variability, since Mt. Pinatubo-related ozone decreases should have diminished in 1994/95.

Summary of General Discussion

There were several questions related to the stratospheric chlorine budget. It was noted that the 3-4% per year increa-

sing trend in stratospheric HCl concentrations (from HALOE, etc.) is consistent with the tropospheric organic chlorine trends. The issue of the consistency of the chlorine budget was raised, i.e., can any other species that are not currently being detected be ruled out? ATMOS data indicate that, within the uncertainties, there is not much room for additional species (e.g., as suggested by S. Sander). However, more refined laboratory spectroscopic measurements are necessary before this can be completely discounted.

Much debate was provoked by Jim Elkins assertion of a «leaky» tropical pipe. The validity of assuming horizontal mixing from mid-latitudes, rather than descent from above, to explain equatorial data was challenged. The point was made that a vertical process is less likely because crossing an isentropic surface is difficult, whereas the large stationary monsoon anticyclone causes considerable exchange between the tropics and mid-latitudes in the lower stratosphere. It was argued that a fair amount of mixing (e.g., the 35% suggested by Elkins) into the tropics is not too surprising in the lower stratosphere, but that there should not be substantial mixing throughout the pipe. This was countered by Ken Minschwaner (New Mexico Institute of Mining and Technology) in reference to his poster [KE.19], which showed box model results suggesting very rapid mixing (with a time scale of 6 months or less) at 400 K falling off to a mixing time of about 1 year at 550 K. The mixing fraction of mid-latitude air in the tropics was shown to be about 30-35% at 400 K and about 60% at 550 K; Minschwaner did not present mixing fraction results above that level.

There was some concern expressed about the approximately 1 ppbv of Cly «missing» or unaccounted for in data acquired by Chris Webster (JPL) during the Second Airborne Arctic Stratospheric Expedition (AASE-II). The low HCl values measured by Webster still remain unresolved, but recent ASHOE/MAESA results show an HCl/Cly ratio in better agreement with model calculations. Webster has postulated a strong particle surface area dependence to the HCl/Cly partitioning, so the ratio should increase with time as the sulfate aerosol loading from the eruption of Mt. Pinatubo decays. (It was pointed out later that this issue may be addressed by the upcoming Stratospheric Tracers of Atmospheric Transport (STRAT) flights in October). It was also noted that some of the discrepancy may have been related to the total chlorine estimated from the N₂O relationship, or that the HCl may in fact have been higher than the Webster measurements suggest, and

that ClONO₂ should not be excluded since the ER-2 does not measure it.

There was a significant amount of discussion related to the HCl/ClONO₂ ratio, both before and after chlorine activation. Column measurements show that ClONO₂ first disappears when vortex temperatures drop, leaving an excess in the HCl column before the appearance of PSCs. However, C. Webster's measurements indicate an HCl/ClONO₂ ratio of 60% inside the vortex before PSC processing. The sequence of activation events, the temperatures at which activation commences, and the manner in which 100% activation is achieved were questioned. The complete removal of HCl may not be accomplished in a single event, but may require multiple «hits». That is, PSCs evaporate during warm periods, releasing HNO₃ which then photolyzes, leading to the reformation of ClONO₂; when PSCs reappear, more HCl is converted to reactive chlorine via the heterogeneous reaction with ClONO₂. Reaction with HOCl, which builds up in PSC-free periods via ClO + HO₂, also processes any remaining HCl into active chlorine. However, it was mentioned that HOCl chemistry is not fast enough until there is a significant amount of sunlight, at which time ClONO₂ formation proceeds rapidly unless substantial denitrification has occurred.

Summary of Poster Presentations

Twenty talks were presented in poster form at this meeting. A number of the posters dealt with polar processing, chlorine activation, and ozone loss. Marvin Geller (State University of New York at Stony Brook) [HA.12] examined the progression of chlorine activation using UARS observations (MLS ClO, CLAES ClONO₂ and aerosol, and HALOE HCl) and a chemical transport model. Decreases in ClONO₂ and HCl were seen where processing was predicted and ClO enhancements were seen in the sunlit regions. Processed air filled the vortex in the Northern Hemisphere about two weeks after steady processing began; in the Southern Hemisphere it took about three weeks. Yukio Makino (Meteorological Research Institute-Japan) [HA.14] presented ground-based, high-resolution Fourier Transform Infrared (FTIR) spectrometer measurements of HCl and HF from the Arctic Stratospheric Ozone (AStrO) observatory near Eureka which showed that the column density ratio HCl/HF in the Arctic springtime is about half that in the fall at Eureka or over Japan (northern mid-latitudes). This result implies that HCl in the Arctic stratosphere is converted to other chlorine species, e.g., ClO_x. Rolf Müller (Max-Planck Institute-Germany) [HA.15] reported that HALOE observations in the Arctic lower stratos-

pheric vortex during the winter/spring of the last four years indicate an almost complete conversion of HCl to more reactive forms. Using CH₄ as a chemically conserved tracer, significant ozone loss was shown to have occurred in the Arctic vortex during all winters. In 1992-93, chemical ozone depletion was severe, with local reductions in the ozone mixing ratio of over 50% and a column ozone loss of more than 100 DU; preliminary results for 1994-95 show similarly severe ozone loss. Michelle Santee (JPL) [HA.18] combined UARS MLS observations of ClO and HNO₃ and CLAES observations of aerosol extinction and ClONO₂ with trajectory calculations to investigate the correlation between observed ClO enhancement and PSC activity. Tracking individual air parcels showed that almost all ClO points downstream of PSCs were either enhanced or were located in the region of polar night, and that most of the parcels coincident with high ClO points had at some time along the trajectory traversed regions of high aerosol extinction. Xu Xie Tie (National Center for Atmospheric Research) [HA.21] simulated the changes in stratospheric ozone in response to enhanced aerosol surface area following volcanic eruptions using a two-dimensional chemical/dynamical/microphysical model. For chlorine loads typical of the pre-1980 period, column ozone should increase after an eruption due to the decrease in NO₂ abundance through heterogeneous processes; for chlorine loads representative of current conditions, high-latitude column ozone decreases due to a large increase in ClO. In the future (after 2015), the ozone response is expected to become positive again if CFC production is sufficiently reduced.

Several posters utilized a variety of measurements to place constraints on photochemical parameters controlling the partitioning of inorganic chlorine and bromine in the lower stratosphere. Linnea Avallone (University of California at Irvine) [HA.1] reported that photolysis rates of Cl₂O₂ as a function of solar zenith angle calculated from AASE-II in situ ClO observations were bracketed by those from a photochemical model assuming the Cl₂O₂ absorption cross sections of Huder and DeMore and DeMore and Tschuikow-Roux; they did not agree with model results based on the cross sections of Cox and Hayman or Burkholder et al. Calculations of the BrO + ClO → BrCl + O₂ rate constant based on ClO and BrO measurements indicate that the branching ratio of the BrCl channel could be as large as 35% of the total reaction, a larger fraction than expected due to the quenching of a BrCl-bound excited state. D. Shindell (State University of New York at Stony Brook) [HA.20] com-

pared measurements obtained in hourly intervals from a ground-based mm-wave spectrometer at McMurdo Station to a photochemical model and found that cycling between ClO and its dimer accounts for nearly all diurnal variation in ClO at 20 km under polar spring conditions. The measured and modeled diurnal cycles and vertical profiles were also used to reduce the uncertainty in the equilibrium constant between ClO dimer formation and thermal dissociation by about 60% at 190 K and to reduce the uncertainty of the dimer formation rate by about 40% at 190 K from the JPL 94 recommended values, leading to reduced uncertainty in the calculation of ozone loss rates. D. Fish (Cambridge University-UK) [HA.9] used zenith-sky measurements of the diurnal variation of BrO in winter above Cambridge (52°N) and Aberdeen (57°N), along with a photochemical model, to investigate bromine partitioning in the stratosphere. The stratospheric abundance of Br₂ above 24 km was found to be 21 pptv, and sunrise BrO abundances agreed best with results from a model that included the heterogeneous conversion of BrONO₂ to HOBr on sulfate aerosol and used the HOBr cross sections of Rattigan et al.

Andreas Engel presented two posters concerning the measurement of long-lived trace gases using whole air samplers. The first [HA.7] involved observations in the 550-700 K range from balloon flights at Aire sur l'Adour (44°N) in March 1993, on a day when the elongated polar vortex reached southern Europe, and on a second day a week later. Mixing ratios from the later flight were similar to those of a mid-latitude reference profile, while those from the earlier flight showed a relative downward shift of as much as 5 km. However, the ensuing enhancement in Cl_y was no more than 300 pptv because at these altitudes most of the chlorine has already been released from the source gases even under normal mid-latitude conditions. The second poster [HA.8] discussed trends in the mixing ratios of chlorine source gases since 1983. A decrease in the growth rate of CFC-11 and CFC-12 was observed in the lower stratosphere since 1993, whereas a strong increase in CFC-113 was observed, with no reduction in its growth rate. Calculations indicate available chlorine Cl_y increased by about 1 ppbv on the 200-ppbv N₂O mixing ratio surface (42 hPa at mid-latitudes) between 1983 and 1993. John Daniel (CIRES, University of Colorado) [HA.3] estimated the age of stratospheric air from measurements of CFC-115 and CO₂ made by the whole air sampler during AASE-II. The ages deduced from the measurements both inside (about six years) and outside (about four years) the polar vortex are significantly older than those calculated from a two-dimensional dynamical/radiative/chemical model,

suggesting that the model has too much mixing across the tropopause. This causes the model to underestimate Cl_y and Br_y in the lower stratosphere outside the vortex and overestimate Cl_y and Br_y inside the vortex.

The majority of the posters presented preliminary results from relatively new or upgraded instruments and/or techniques. M. Burton (Cambridge University-UK) [HA.2] described a high-resolution FTIR spectrometer at the Rutherford Appleton Laboratory (51.3°N) used to measure the absorption of HCl, ClONO₂, HNO₃, HF, N₂O, and ozone using the sun as a source as part of the SESAME-III campaign. Vortex edge events appear to have been observed, and preliminary comparisons with a three-dimensional photochemical model show good agreement in column HCl trends. F. Danis (Cambridge University-UK) [HA.4] introduced a new lightweight instrument designed to fly piggyback on other balloon-borne payloads to measure CFC-11 and CFC-12. B. Franke (University of Bremen-Germany) [HA.10] described the newly improved Airborne Submillimeter SIS Radiometer (ASUR) for measuring ClO, HCl, N₂O and ozone. The ClO and HCl profiles measured during SESAME I (February 1994) outside the polar vortex were typical of undisturbed chemistry; analysis of the profiles measured during SESAME III (February/March 1995) is in progress. Manuel Gil (Laboratorio de Estudios de la Atmosfera-Spain) [HA.13] reported OCIO total column measurements carried out at Keflavik (64°N) during SESAME III. Stratospheric OCIO was found to be enhanced when potential vorticity was highest and temperature was lowest (i.e., the station was inside the vortex), and the maximum OCIO slant column occurred when NO₂ was a minimum. Retrieved OCIO amounts in December and February did not show enhancement with solar zenith angle during twilight, indicating a tropospheric origin, possibly related to volcanic emissions close to the observatory. R. Peter (University of Bern-Switzerland) [HA.16] demonstrated a microwave spectrometer located at Bern (47°N) that obtains ozone profiles with high temporal resolution in the range 15-75 km. During SESAME in late January 1995, a sharp decrease in ozone at all altitudes was observed following the passage of the polar vortex over mid-latitudes; below 25 km the low ozone recovered, but in the 30-40 km region ozone remained depleted days after the vortex passage. Philippe Ricaud (CNRS-France) [HA.17] described a ground-based microwave radiometer for monitoring mid-latitude ClO on a regular temporal basis installed at the Plateau de Bure in the French Alps (45°N, 2550 m). When an analysis of day-night spectra was performed to eliminate instrumental

artifacts, a diurnal pattern in ClO emerged that agreed well with photochemical model results from 20 to 40 km. G. Schwaab (University of Bremen-Germany) [HA.19] reported on millimeter-wave observations of ozone and ClO from the Radiometer for Atmospheric Measurements (RAM), which was operated on a campaign basis since 1992 and began continuous operation at Ny-Ålesund/Spitzbergen in December 1994. The derived ozone profiles show a large, dynamically-induced variability in mixing ratio; an unexpected feature was a strong ozone minimum between 30 and 40 km observed in March 1995. Darin Toohey [HA.23] presented results from a new lightweight balloon-borne instrument measuring ClO and BrO in the Arctic stratosphere which was successfully flown from Kiruna (68°N) in February 1995 during SESAME. A peak ClO mixing ratio of 1260 ppt was observed at 490 K (43 hPa) (current three-dimensional models predict only 400 ppt for that date and location), where an anticorrelation between ozone and ClO was seen. A preliminary peak mixing ratio for BrO of 15 ppt was found in the 70-40 hPa region. M. Van Roozendaal (Belgian Institute for Space Aeronomy-Belgium) [HA.25] demonstrated the feasibility of ground-based (Harestua, 60°N) UV-visible spectroscopy for measuring column amounts of stratospheric OCIO, NO₂, and ozone during SESAME. The largest abundances of OCIO were observed at low temperatures and high potential vorticity values, inside the polar vortex, and good general agreement was obtained in comparison with other ozone measurements.

Session 5 - Key Issues

J. Pyle, Chair; F. Lefevre, Rapporteur

The key issues in transport in the low stratosphere were addressed by Alan O'Neill (University of Reading-UK), who considered three different aspects of this topic in his talk: 1) the transport into the polar vortex from above, and in particular at what rate does the air flow vertically through the vortex; 2) the transport from the polar vortex to mid-latitudes; and 3) the transport in and out of the tropics.

Evidence of transport into the polar vortex from above was given by a cross section of CH₄ observations performed from the Halogen Occultation Experiment (HALOE) instrument on board Upper Atmosphere Research Satellite (UARS). These data show a strong descent of mesospheric CH₄ (characterized by low mixing ratios) into the polar vortex down to the low stratosphere. A striking feature of these observations is the quasi-vertical CH₄ isopleths

1st SPARC General Assembly Melbourne, Australia 2-6 December 1996



The World Climate Research Programme on **Stratospheric Processes And Their Role in Climate (SPARC)** will hold its first general assembly in Melbourne, Australia, during the period December 2-6, 1996. It will be hosted by the Australian Cooperative Research Centre for Southern Hemisphere Meteorology (CRC SHM) and be co-sponsored by SCOSTEP, IAMAS, IAGA, NASA and NOAA. Additional cosponsorships will follow.

SPARC is an international programme with the goal of facilitating research into the relationships between stratospheric processes and their role in climate (both tropospheric and stratospheric). It is recognised that there is much national and international activity in stratospheric research, so SPARC seeks to facilitate research into areas that need additional activity and/or can benefit from more international communication among separate national programmes. Some of the ongoing SPARC activities concern the following topics :

- Intercomparison of troposphere-stratosphere general circulation models
- Compilation of a stratospheric climatology for comparison to models
- Assessment of trends in temperature, ozone, and water vapour and of the necessary observational capability in these areas
- Gravity wave processes and their parameterization
- Stratosphere-troposphere exchange
- Chemistry of the lower stratosphere and upper troposphere
- UV radiation and its impacts

The 1st SPARC Assembly will be organised around these themes and will include invited, contributed and poster papers.

Scientific Organising Committee :

M. Geller (Chair), R. Atkinson, M.-L. Chanin, J. Pyle, S. Solomon, R. Vincent.

Local Organising Committee : D. Karoly (Chair)

Some Key Dates : Contact Address :

1st Circular : July 4, 1995
2nd Circular and Call for Papers : January 1, 1996
Final date to submit abstract : May 1, 1996
Notification of acceptance of abstract : July 15, 1996
Deadline for early registration : October 1, 1996
Conference : December 2-6, 1996

SPARC 96
CRC for SH Meteorology
Monash University, Bldg. 70
Clayton VIC 3168
AUSTRALIA
sparc96@vortex.shm.monash.edu.au

1st SPARC General Assembly Melbourne, Australia 2-6 December 1996

DECLARATION OF INTEREST

Please send me the second circular for the SPARC General Assembly

NAME :

AFFILIATION :

ADDRESS :

TEL :

FAX :

E-MAIL :

I intend to participate to the SPARC General Assembly : **Yes/Probably/No**
(delete as appropriate)

I intend to submit an abstract for a contribution on the following topics :

- | | |
|---|---------------|
| 1 • Intercomparison of troposphere-stratosphere general circulation models | Yes/No |
| 2 • Compilation of a stratospheric climatology for comparison to models | Yes/No |
| 3 • Assessment trends in temperature, ozone, and water vapour and of the
necessary observational capability in these areas | Yes/No |
| 4 • Gravity wave processes and their parameterization | Yes/No |
| 5 • Stratosphere-troposphere exchange | Yes/No |
| 6 • Chemistry of the lower stratosphere and upper troposphere | Yes/No |
| 7 • UV radiation and its impacts | Yes/No |
| 8 • General SPARC Science | Yes/No |

Approximate title of your paper(s) :

Oral presentation (O) or Poster presentation (P) :

Your response should be sent or preferentially e-mailed to :

SPARC 96
CRC for SH Meteorology
Building 70
Monash University
Wellington Road
Clayton VIC 3168
AUSTRALIA
e-mail : sparc96@vortex.shm.monash.edu.au

observed at the vortex edge, giving evidence that the air flowing down from the mesosphere remains unmixed with mid-latitude air for a considerable period of time, and that the polar vortex is providing containment. In the Northern Hemisphere, Microwave Limb Sounder (MLS) observations of water vapor also show a strong descent inside the polar vortex, converting the usual vertical stratification of H_2O into a horizontal stratification as the air flows down the axis of the vortex. O'Neill emphasized our relatively good understanding of the picture of descent into the polar vortices, driven by cooling rates of the order of -0.25 to -0.5 K per day in the lower stratosphere which are inferred from satellite observations and long-lived tracers measurements, and which are in good agreement with model calculations. These values lead to a descent rate of about 1.5 to 2 km per month, which is considerably slower than the «flowing processor» hypothesis originally envisaged.

The transport from the vortex to mid-latitudes was addressed through a series of examples revealing the profound effect played by the underlying troposphere on the circulation of the lower stratosphere. For instance, a sequence taken in late January 1992 shows the impact of a strong blocking ridge pushing into the vortex, while a «tongue» of polar air is stretched to mid-latitudes and eventually separated from the vortex. Strong cyclogenesis in the troposphere is also an important cause of mixing, as observed in February 1995 when vortical air was peeled off from the vortex and transported to mid-latitudes in a completely separated mini-vortex structure. Such disturbed cases clearly show that if the vortex is not the flowing processor in the sense originally envisaged, it is certainly not a complete «containment vessel» either. The real point of issue is therefore to quantify the cross-vortex transport. In their recent study, Norton and Chipperfield have attempted to quantify the amount of air processed by polar stratospheric clouds (PSCs) and transported to mid-latitudes expressed as percentage of mass poleward of $55^\circ N$ equivalent latitude. A considerable interannual variability appears from this work, a result of the difference in the intensity of the dynamical disturbances of the vortex from year to year. A large variability with height is also found by the authors: for the 1992-93 Arctic winter for instance, transport of PSC-activated air into mid-latitudes was found to be equivalent to only 7% of the vortex at 550 K, while a value of 23% was computed at 400 K where low temperatures beneath the vortex allowed considerable PSC activation at levels where equatorward transport is more rapid than at higher altitudes.

The issue of transport in and out of the tropics was illustrated by the Airborne Southern Hemisphere Ozone Experiment/Measurements for Assessing the Effects of Stratospheric Aircraft (ASHOE/MAESA) and MLS data, which suggest the picture of a coherent and only partially mixed inner tropical region across the equator, although the amount of mixing is likely to be altitude dependent. At ER-2 altitudes, halon-1211 data indicate mixing values of about 35% over the course of the year between tropical and mid-latitude air.

In his conclusion, O'Neill highlighted the significant advances in our understanding of transport and mixing in the lower stratosphere:

- N_2O trends, radiative calculations, satellite data, and models are now giving consistent results in terms of cooling rates and time scale for descent in the polar vortex. The average value of -0.25 K per day estimated in the lower stratosphere indicated that the polar vortex is not a flowing processor as originally envisaged.

- We have strong evidence of the direct influence of tropospheric synoptic events such as blocking ridges or cyclogenesis on the transport processes in the lower stratosphere. This explains the considerable interannual variation observed in the amount of PSC-processed air present at mid-latitudes. However, even for very perturbed winters, less than half of the activated air appears to be transported to mid-latitudes, which confirms that the polar vortex is not a flowing processor to the extent originally hypothesized.

- Satellite and aircraft data show an inner tropical region where the air is only partially mixed, and outer tropics characterized by strong gradients of long-lived tracers. Episodic planetary and synoptic-scale events play a very important role in the transport by modulating the slow, radiatively driven circulation, although quantifying this effect particularly as a function of height remains an outstanding issue.

In his introduction to the key issues in the chemistry of the lower stratosphere, Rod Jones (University of Cambridge-UK) underlined the fact that if we now have a fundamental understanding (or «zeroth order» picture) of the ozone loss, the essential need to model and predict the ozone trends quantitatively remains. This challenge obliges us to go into the details of each step of the ozone loss mechanism, and to pay particular attention to areas where uncertainties might be critical for a quantitative understanding.

Looking at the seasonal time scale temperature variations in the polar vortices, the first outstanding question is

how does the transition from sulfuric ternary solution (STS) to nitric acid trihydrate (NAT) take place? This problem is still poorly understood and we first have to consider the «critical area» in terms of chlorine activation when temperatures are between the NAT and STS formation points. This critical area is of particular importance in the Northern Hemisphere, where temperatures may remain below the NAT threshold and above the threshold for rapid STS growth threshold during a large fraction of the winter.

Another issue is our actual knowledge of stratospheric temperatures used in model calculations. The comparison between analyzed temperatures and sonde measurements shows that we can expect excursions of about 2.5 K around the synoptic-scale temperature, which may have a considerable impact on the chemistry and particle growth. Interestingly, despite these uncertainties, chlorine activation appears reasonably well reproduced in model simulations, which suggests that activation might occur above the point where STS freezes (if it does!).

The issue of chlorine deactivation shows that models are generally less successful and that their results depend critically on the details of their formulation; for instance, the isobaric version of the TOMCAT three-dimensional model tends to overestimate the $ClONO_2$ column amount compared to ground-based measurements, while the isentropic version (SLIMCAT) does not show a recovery as large as in the observations.

In conclusion, it appears that although our basic interpretation of the polar ozone loss is not in doubt, we still have difficulties simulating the losses accurately. This is particularly the case in the Arctic, where large uncertainties emerge from the more «marginal» conditions in terms of seasonal temperature variations. Outstanding issues are chlorine activation when temperatures are in the critical band between the NAT and STS formation, as well as the rate of chlorine recovery which still is poorly reproduced by photochemical models.

At mid-latitudes, evidence of reactions on sulfate aerosols has been established. Recent results now confirm that HO_x and halogen reactions are the dominant processes in ozone photochemical loss, and that NO_x serves to moderate the halogen reactive/reservoir ratio. Highlights of these advances in our understanding of mid-latitude ozone loss were obtained during the Stratospheric Photochemistry, Aerosols and Dynamics Expedition (SPADE) aircraft mission, which gave the striking confirmation of both the effectiveness of heterogeneous chemistry on aerosols and a very fast photochemistry. In particular, SPADE results give a strong indi-

cation of a rapid BrONO_2 hydrolysis which explains the peak of HO_x observed at sunrise also discussed by Salawitch and which is in good agreement with laboratory measurements.

Implications of bromine heterogeneous chemistry are larger HO_x and ClO_x amounts, as well as more denoxification, leading to greater in situ destruction.

Vortex processing and its effect on mid-latitudes are also potentially large contributors to ozone depletion. It is important to note that even at low altitudes, temperatures in the Antarctic drop well below the threshold for PSC formation, and large ozone losses are observed below the vortex boundary where significant isentropic outflow to mid-latitudes takes place. The interaction between transport and heterogeneous chemistry is also a source of considerable uncertainty for the evaluation of ozone loss at mid-latitudes if one considers the tail of the reaction probability of $\text{HCl} + \text{ClONO}_2$ at temperatures above the NAT formation point (195 K). Jones illustrated this point by showing the large difference between the amount of PSC-activated air present at mid-latitudes when going from 195 K to 199 K for which a totally different seasonality emerges in the Northern Hemisphere, with an area exposed to heterogeneous chemistry comparable to the Southern Hemisphere.

Jones concluded his talk by underlining the major issues that remain unresolved at mid-latitudes, such as the HCl/ClO_y ratio that models do not reproduce properly, or HOBr for which no measurements are available to confirm the hypothesis of the bromine nitrate hydrolysis. Although the agreement between SPADE data and model simulations looks impressive, it was also recalled that these results were obtained with a model constrained by tracer fields, which restricts our ability to compute ozone losses. Our confidence in the calculation of $\Delta\text{O}_3/\Delta t$ is also altered by the large uncertainties in the efficiency of the STS chemistry and in the transport issues from the polar vortex to mid-latitudes.

Three shorter presentations were given during the second part of the session. Ross Salawitch (Jet Propulsion Laboratory) gave a talk about the photochemical regulation of ozone and the constraints from recent aircraft, balloon, and satellite observations.

From the results of the ASHOE/MAESA campaign, Ross Salawitch showed that photochemical models provide a very accurate description of the observed NO , NO_2 , ClO , HCl , and BrO along the ER-2 flight track. This is somewhat surprising, given the uncertainties. However, models tend to underestimate

OH and HO_2 by 10-25%, which is a important issue at these altitudes where HO_x reactions dominate the removal of ozone.

Opposite tendencies are observed above ER-2 altitudes, where models give a good description of OH , HO_2 , and NO_2 but do not simulate the chlorine partitioning very well; a consistent bias is to overestimate ClO , HOCl , and ClONO_2 and underestimate HCl . A possible explanation may be the production of HCl by the reaction $\text{ClO} + \text{OH}$, although this is still a very open issue. The fact that less chlorine radicals are present at high altitudes than previously thought is extremely important, since the odd oxygen production rates now balances the loss rates, i.e., a «missing source» is no longer necessary to explain the O_x concentrations at 30-40 km altitude.

Salawitch then addressed the issue of denitrification through MLS observations of nitric acid in the Antarctic, which seems to be more indicative of a ternary solution than NAT or nitric acid dihydrate (NAD) in terms of temperature threshold before HNO_3 removal. However, it is difficult to reconcile quantitatively the picture of STS with the observed differences in HNO_3 amounts between June 1992 and June 1994, emphasizing the need for more research to understand exactly how denitrification takes place, and how it varies from year to year as a function of the cooling rate history and the aerosol load.

The outstanding questions emerging from the comparison of recent observational data with model simulations were summarized. These issues include the excess of HO_x near 20 km, the low ClO_x at about 30 km, the exact altitude where the loss of ozone by HO_x balances the loss by NO_x , and the response of HO_x , NO_x , and ClO_x to volcanically perturbed aerosols.

Stephen Reid (Norwegian Institute for Air Research-Norway) then gave an observational overview of ozone filaments in the winter and spring lower stratosphere. Using the 25-year record of ozonesonde data in the World Meteorological Organization (WMO) archive, Reid showed that ozone laminae appear soon after the polar vortex is established in November, and increase progressively in abundance throughout the winter extra-tropical lower stratosphere. The abundance of laminae present in ozone profiles reaches a maximum in spring and is linked to the polar vortex breakdown.

By using model trajectories to compute the location of ozone laminae several days prior to observation, it was also demonstrated that ozone-enhanced laminae seemed to be ejected from the edge of the vortex, while ozone-depleted laminae tended to come from low latitudes.

From the large number of coordinated soundings performed for the MATCH experiment, it was possible to infer an horizontal extent of at least 500 km for a typical ozone lamina event, and a lifetime of about one week before irreversible mixing, indicating one possible mechanism for mid-latitude ozone loss in spring.

Adrian Lee (University of Cambridge-UK) gave the last talk of the session. His presentation related to case studies of the influence of polar processes on mid-latitudes using SESAME, ASHOE/MAESA, and UARS data.

Using a tracer initialized like N_2O and the SLIMCAT chemistry transport model, Lee demonstrated the existence of a filament of polar air present in lidar data during SESAME, which appears to coincide with a «tongue» of low N_2O values in the isentropic model.

In a similar experiment a good coincidence was found between an area of low N_2O values extracted from the vortex in the SLIMCAT simulation and a region of high ClO observed by MLS in the Pacific, giving evidence of the strong chemical identity of the filaments of PSC-processed air transported to mid-latitudes and their importance for the ozone loss.

Two other simulations performed during the period of the ASHOE/MAESA campaign in the Southern Hemisphere nicely demonstrated the degree of maturity achieved by current state-of-the-art chemistry transport models, which can reproduce with excellent agreement the fine structures of ClO observed from the ER-2 inside filaments of air extracted from the vortex edge. To quantify the importance of these events in terms of mid-latitude ozone loss is clearly the outstanding challenge for this modeling work.

Session 6 - Aerosols

*D. Hofmann, Chair;
R. Ferretti, Rapporteur*

Discussions during the international conference on ozone in the lower stratosphere brought up interesting questions on the role played by aerosols in the formation of polar stratospheric clouds (PSCs). The general discussion and recent development of aerosol studies presented at the conference are summarized in what follows.

Presently there is a large amount of data related to aerosols and PSCs: lidar data, radio soundings, satellite data sets, backscatter sondes, and ER-2 flights in both the Arctic and Antarctica. The data allow a continuous improvement in our understanding of the nature of aerosols; temperature behavior, phase, radius,

surface area, and refractive index are fundamental and critical parameters in determining the composition of PSCs. In spite of the availability of such information, several questions still arise due to the uncertainties in observation and laboratory experiments on aerosol freezing. Lidar observations associated with temperature profiles from radio soundings reveal many PSC formation events at temperatures lower (by 2-3 K) or, in some cases, at temperatures above those required to form nitric acid trihydrate (TNAT). Computed refractive indices, using lidar and particle counter data, show good agreement with those of $\text{HNO}_3/\text{H}_2\text{O}$ suggesting the existence of a sulfuric ternary solution ($\text{H}_2\text{SO}_4/\text{HNO}_3/\text{H}_2\text{O}$ or STS). The nucleation of STS is considered one of the probable mechanisms for PSC formation.

Long-term trends (from the early 1970s to the early 1990s) in stratospheric sulfate aerosol loading, presented by Lamont Poole (NASA Langley Research Center, USA) in his talk, show good agreement between in-situ measurements at Laramie and ground-based lidar observation at Hampton, Virginia (USA) and Garmisch-Partenkirchen (Germany). The background aerosol mixing ratio show an increase of the larger particles and a constant value for the smaller ones. Therefore, the apparent increase in the aerosol background implies a change in the particle size distribution. An in-situ unimodal log-normal size distribution is consistent with theoretical assumptions (Wilson, Brock et al); additional measurements, taken eight months after Pinatubo eruption, revealed that accumulation mode diameter peak has moved up toward larger radii because pre-existing particles have taken on water vapour. It takes another one year to recover to the previous values with a bimodal distribution.

A comparison between sulfate aerosol surface computed using in-situ sampling (balloon and ER-2) and from contemporaneous zonally averaged satellite extinction measurements (SAGE II) revealed reasonably good agreement: satellite data overestimate the surface by 20-30%, but the shape is the same.

Satellite data of boreal spring (April-May-June) 1-micron aerosol extinction data from SAGE I in 1979 and SAGE II in 1988-1991 allow a comparison between background and volcanic-perturbed states showing that a volcanic signature was present in the stratosphere in the late 1980s (from the 1982 El Chichon and 1985 Nevada del Ruiz eruptions). Data near latitude

40°N show a 40-50% increase from 1979 to 1989, which is consistent with the observations from Laramie, Hampton, and Garmisch-Partenkirchen. However, there were larger increases between this time periods elsewhere around the globe, suggesting that a «background» or non-volcanic state had not been reached by the late 1980s. Since about 1987, SAGE II has frequently recorded higher levels of aerosol extinction in the lower stratosphere of the Southern Hemisphere than in the Northern Hemisphere. There is no explanation to date for this phenomenon, but it has been seen all seasons and in both phases of the QBO. SAGE II multi-wavelength extinction data from 1984 to 1995 were analyzed to derive statistical representations of global aerosol surface area which could be used in photochemical models. The 10-percentile distribution was suggested as a reasonable model for the background aerosol state, while the median distribution provides a more reasonable model for a volcanic active period.

The physics and chemistry of stratospheric aerosol and PSCs were discussed by Thomas Peter (Max-Planck Institut für Chemie, Germany). Observations of both PSC Ia and PSC Ib were shown with high depolarization occurring at an early stage and later diminishing as backscattering increases. Therefore there is evidence for both liquid and solid PSCs. Box model (Carslaw, 1994) computations with and without liquid volcanic aerosol were performed; the results of the liquid volcanic aerosol case show good agreement with the data. A review of the historical development of PSC research was also made. PSCs in Antarctica are better comprehended since the temperature trend is usually monotonic, reaching extremely low values below freezing point in the winter. The meteorological variability in the Arctic region produces a more irregular temperature trend, allowing successive melting and freezing of the particles. Several experiments on the freezing of ternary solution using different amount of HNO_3 and H_2SO_4 were presented. Four hypotheses on the stratospheric particle freezing may be inferred:

- the binary $\text{H}_2\text{SO}_4/\text{H}_2\text{O}$ solution droplets freeze out sulfuric acid tetrahydrate (SAT), then nitric acid trihydrate (NAT) nucleates sublimatively on SAT;
- the binary droplets remain liquid and take up HNO_3 at $T < 193$ K, then NAT or NAD or some other metastable hydrate freeze out from these ternary solutions;
- even the ternary droplets remain liquid as long as temperatures do not fall

below the frost point, at which water ice precipitates from the solution;

- below 193 K the ternary liquid transforms into an amorphous state which freezes upon warming.

All these hypotheses have conceptual difficulties. Lee waves may play a crucial role in explaining PSC observations associated with temperatures higher than TNAT. The aerosols may freeze at the passage of the wave and remain frozen for a certain time, even if the temperature is returned to a value higher than the freezing threshold. An important tool for understanding PSC formation at temperatures higher than TNAT is the back-trajectory analysis. The aerosols may freeze in a cold area and be transported to a warmer region, remaining frozen and allowing for PSC formation.

Laboratory studies of PSC nucleation on sulfuric acid aerosol were discussed by Margaret A. Tolbert (CIRES, USA); measurements of the size, composition and phase of the aerosols as a function of time at low temperature were presented. Experiments on $\text{H}_2\text{SO}_4/\text{H}_2\text{O}$ with uptake of HNO_3 and H_2O to ternary solutions, and ternary solutions with similar uptake to binary solutions ($\text{HNO}_3/\text{H}_2\text{O}$) show that homogeneous freezing is not observed for several hours at stratospheric temperatures, but heterogeneous freezing is observed on a solid surface or using silica spheres. An experiment performed with micrometer-diameter binary 1:1 and 1:3 $\text{HNO}_3/\text{H}_2\text{O}$ aerosols do not crystallize via homogeneous nucleation in several hours. In contrast, 1:2 $\text{HNO}_3/\text{H}_2\text{O}$ aerosols crystallize readily to nitric acid dihydrate within minutes at stratospheric temperatures, but supercooled 1:2 unlikely form in the atmosphere. These results suggest that a degree of caution is necessary before deriving a definitive assessment on the freezing process in PSC formation.

Observations well outside the polar vortex (45°N) presented by Stephan Borrmann (University of Mainz, Germany) show a linear correlation between aerosols and ozone suggesting aerosols as inert tracers. This is observed approximately three months after the volcanic eruption, lasting for six months and implying a development of the microphysical process within the first three months after the eruption. Sedimentation processes, the short lifetime of the ozone, and the dynamical processes of the lower stratosphere may play a crucial role in the breakup of the linear correlation. A microphysical model shows similar results, with nucleation processes occurring shortly after the volcanic eruption and coagulation leading to a

near log-normal size distribution within a few days. Condensation processes appear to be slower and allow for a gradual increase of the mean particle size.

In-situ observations of polar stratospheric clouds in the Southern hemisphere during ASHOE/MAESA and comparison with previous observations were presented by Jim Dye (NCAR, USA). During the ASHOE/MAESA campaigns 2 PSCs were observed out of the vortex; the onset temperature was 193 K, about 3 K below NAT existence temperature. The particle volume increased as the temperature decreased outside the PSCs and it was strongly anticorrelated with temperature below 195 K. Pueschel and Goodman impactors show type II particles up to 30 μ m were also present. A comparison of ER-2 data from the Antarctic and Arctic, plotting aerosol-condensed mass volume as a function of temperature, shows a similar behavior; indeed strong anticorrelation between the volume and the temperature is found for both regions. Model computations performed using the ternary solution fit the observations in the Arctic but are not satisfactory when applied to those from the Antarctic. Many questions remain about type I PSC formation, in particular information on denitrification and activation are needed.

Lidar observations during the last five years in Antarctica were presented by Christine David (CNRS, France) showing differences between the pre- and post-volcanic period in the PSC climatology, especially for factors related to temperature threshold formation. In the pre-volcanic period, there is no occurrence of PSCs at temperatures higher than 200 K. However, in the post-volcanic period, the threshold temperature for PSC observation does not appear to be well-defined: the temperature related to PSC observation is mostly greater than TNAT and the altitude of PSCs is lower than in the pre-volcanic period. Furthermore, an analysis of the depolarization coefficient with respect to backscattering suggests that most PSCs are of type Ib, supporting the hypothesis of a liquid ternary solution mechanism.

In conclusion, there are still open questions about the PSC formation process. The main discussion concerned aerosol freezing; ice is not observed to form on sulfate aerosols, raising the question of whether the aerosols really freeze going below the frost point or if soot is necessary for freezing and if this is realistic for the stratosphere. The rapid cooling produced by lee waves may partly answer this question. Furthermore, the problem of

the natural tropical reservoir and the privileged path toward the Southern Hemisphere, (i.e., how this can be explained or if this is only related to volcanic eruptions) is still an open problem.

Session 7 - Laboratory Chemistry

T. Cox, Chair;

A. Mellouki, Rapporteur

«Helios is making ozone, and HO_x, NO_x, ClO_x, and BrO_x «horses» are trying to pull it away». During his talk, A.R. Ravishankara (NOAA Aeronomy Laboratory) presented the knowns and unknowns of chemical processes that affect the abundance of ozone in the lower stratosphere. They include homogeneous gas-phase free radical reactions, heterogeneous reactions on sulfate aerosols and PSCs, and photochemical processes.

The HO_x cycle is the largest contributor to odd oxygen loss in the lower stratosphere. Ball et al. [Ball et al., GRL 1994; Ball and Hancock, GRL 1995] have shown that the quantum yield of O₂(¹D) from ozone photolysis could be higher than the quantum yield for O(¹D) recommended by the most recent NASA/JPL evaluation. If the O₂(¹D) yield reflects that of O(¹D), the OH production rate could be higher than previously calculated. Measurements of O(¹D) quantum yields are needed to quantify stratospheric NO_x and HO_x production. Heterogeneous chemistry can also have a role in OH production (e.g., hydrolysis of BrONO₂ → HOBr → OH + Br) [Hanson and Ravishankara, JGR 1995]. One major uncertainty in the HO_x cycle is that the rate coefficient for the reaction of HO₂ with ozone, together with the mechanism of this reaction, are poorly defined at the temperatures of the lower stratosphere.

NO_x is the «glue» that holds the cycles together. Much of the NO_x/NO_y chemistry was talked about in the context of other catalytic cycles and chemical processes. Of all the reactions of NO_x catalytic ozone destruction cycles, the O + NO₂ → NO + O₂ reaction is poorly understood.

A few general comments about halogens were made. A great deal of work has shown that fluorine and C_xF_yO_z radicals are not efficient ozone destroyers. One of the major questions about ClO_x and BrO_x is the partitioning between active and unreactive forms (it is therefore highly influenced by heterogeneous reactions). Some radical-radical reactions that can lead to reservoir species are somewhat uncertain (i.e., such reactions are hard to study). Halogens

are chromophores. Long wavelength absorption can be important; these cross sections can be small and it is then a challenge to measure them. Among the outstanding problems in ClO_x are:

- The products of the HO₂ + ClO reaction (HCl + O₃ and HOCl + O₂) at stratospheric temperatures. The new results presented by Finkbeiner et al. [LA.21] seem to show that the branching ratio for the HCl-forming channel could reach 5% at 210 K at lower stratospheric pressures. Similarly, the products of the reaction OH + ClO are still uncertain.

- More work is required for identifying and quantifying the products of the HOCl photolysis.

- There is a discrepancy between different groups on the pressure dependence of the quantum yields for the dissociation of ClONO₂ and the formation of products in the atmospheric photolysis of ClONO₂.

Bromine is by far the most potent ozone destroyer on a per atom basis of the three most abundant halogen species, fluorine, chlorine, and bromine. The possibility of conversion of bromine radicals to the reservoir HBr via reactions such as BrO + HO₂, is a major uncertainty in the atmospheric kinetics of bromine. It is now clear that the major products of the HO₂ + BrO reaction are HOBr and O₂, since the yield of HBr from this reaction has been shown to be very low at the stratospheric temperatures [Mellouki et al., JGR 1994; Larichev et al., LA.10]. The first experimental value for the rate coefficient for the reaction of BrO with OH at 298K has been reported to be (7±3) × 10⁻¹¹ cm³ molecule⁻¹ s⁻¹ [Bogan and Stief, private communication]. This value is higher than that estimated by the recent JPL/NASA evaluation. The products of this reaction are still uncertain. The gas-phase UV-visible absorption spectrum of HOBr has been reported very recently by Orlando and Burkholder [J. Phys. Chem. 1994]. Rattigan et al. [LA.15] presented a new measurement of this spectrum, which shows that the cross-sections are two and a half times larger in the 310-430 nm region than those of Orlando and Burkholder. This implies that the photolysis rate of HOBr could be 2.5 times faster than the ozone loss in the lower stratosphere due to the fact that this cycle is a little larger, and that HOBr is a less efficient reservoir. The very recent spectrum measured by Schindler et al., and shown during the discussion by Gilles Poulet (CNRS-France), lies between the results of Orlando and Burkholder and of Rattigan et al. in the 320-400 nm region. More lab work is needed on the HOBr spectrum to clarify these discrepancies. More work is also needed

ded on identifying the photo products of BrONO_2 and HOBr in the UV-visible region.

«The fifth horse which is trying to pull away ozone is IO_x ». If the labile tropospheric CH_3I ($\text{C}_x\text{H}_y\text{I}_z$) gets to the stratosphere and if the kinetics and photochemistry are fast, all iodine would be in its active form even at the lower altitudes [Solomon et al., JGR 1994].

Ozone depletion could occur by coupling between IO_x , ClO_x and BrO_x cycles. The coupling of this iodine with ClO_x and BrO_x could play a role in sudden episodic ozone removal in the Arctic springtime troposphere. Three posters were presented on iodine chemistry [LA.3, LA.11, and LA.16]. The reactions $\text{IO} + \text{ClO}$, $\text{IO} + \text{BrO}$, and $\text{IO} + \text{HO}_2$ are the key reactions for ozone depletion in the lower stratosphere due to iodine. Rate coefficients for the first two reactions were reported for the first time during the meeting. Quantification of the products of these reactions at stratospheric temperatures are required. A revised IO spectrum was reported for the first time [LA.11].

Heterogeneous reactions of BrONO_2 may enhance OH concentration in the lower stratosphere, suppress the NO_x to NO_y ratio, and activate more chlorine [Hanson and Ravishankara, JGR 1995]. Each of these changes enhances active chlorine. Also, for the first time, bromine has been suggested to activate chlorine, thus adding to its role of ozone destruction in the lower stratosphere. Therefore, the heterogeneous processing of BrONO_2 (and HOBr) will enhance the role of bromine in catalyzing ozone destruction in the stratosphere. Inclusion of the heterogeneous chemistry appears to be essential for understanding the partitioning of some trace constituents by bromine in the stratosphere. A complete appraisal of the effects of bromine reactions would be benefited by further studies of the reactions of BrONO_2 with HCl and HOBr with HCl on/in sulfuric acid aerosols as a function of temperature and composition as well as more realistic treatment using a well-established stratospheric model.

Lastly, the question «Does it matter whether Type I PSCs are liquids or solids» was addressed by A. R. Ravishankara. Using the framework by Hanson et al. [JGR 1994] and the most recent HCl solubility data, it was shown that chlorine processing in liquid droplets would be faster than on solid Type I PSCs when the temperatures are within a few K of the frost point. Further, because liquid PSCs are present even if Type I PSCs do not

nucleate, the ternary solutions are processing chlorine all the time when the temperatures are close to or less than the Type I PSC thresholds.

Interesting papers were presented on the heterogeneous chemistry involved in the ozone partitioning in the lower stratosphere [LA.6, LA.7, LA.12, LA.18, and LA.19]. Among the recent important advances, data from different groups agree reasonably well on the solubility of HCl in sulfuric acid.

Session 8 - Radiative Processes

R. McKenzie, Chair;

K. Minschwaner, Rapporteur

Radiative processes in the stratosphere are of crucial importance to the terrestrial environment, not only for the regulation of solar ultraviolet (UV) reaching the Earth's surface but also for the radiation budget that determines climate on a global scale. Recent findings presented in this session dealt with a variety of issues relating to biologically-damaging UV radiation, the radiative forcing of climate, and the chemistry and composition of the stratosphere and troposphere.

There were nine poster presentations on the intensity of surface-level UV-B radiation (280-320 nm). Measurements were reported over a large range of geographic locations using a variety of instruments. Both spectrally-resolved and narrow-band filter instruments deployed in Chile and Antarctica recorded significant increases in erythemally-weighted UV-B during late austral spring, coincident with decreases in total column ozone associated with the Antarctic ozone hole [Dahlback, RA.4; McKenzie, RA.10; Taalas et al., RA.12]. Remarkably, maximum daily doses at Palmer Station are larger than maximum values observed at mid- and low-latitude sites. In New Zealand, maximum doses are up to 50% larger than at comparable latitudes in Europe. The difference is attributed to the Earth's elliptical orbit (closest approach is austral summer), the influence of a more polluted troposphere in Europe, and lower climatological values of total column ozone [McKenzie, RA.10].

Spectral measurements of UV-B at Thessaloniki (40°N) and Reykjavik (64°N) in the Northern Hemisphere suggest an increasing trend on the order of 4% per year since 1992 [Bais et al., RA.1]. Under predominantly clear sky conditions, negative correlations were observed between UV levels and coincident measurements of total ozone. Monthly mean measurements from Belsk (52°N) obtained with a combina-

tion of Robertson-Berger and UV-biometers indicate an upward trend in UV-B on the order of 2.2% per decade since 1976 [Krzyscin, RA.8]. Ancillary measurements of column ozone and visible radiation suggest that over one-half of the increase in UV-B expected from the observed change in ozone is offset by increasing opacity in the troposphere, due likely to increases in tropospheric ozone, aerosols, and possibly cloud amounts.

A common theme of the UV-B discussions was the need for longer time series and geographic coverage. Important factors governing surface level UV-B, such as clouds and tropospheric aerosols, remain poorly understood [Weihs and Webb, RA.14]. Results presented from theoretical studies show good agreement between measured and modeled UV radiances under clear sky conditions, provided that total ozone input is constrained by ancillary measurements. Finally, although significant improvements have occurred in the cross-calibration of UV instruments, further work is required to achieve absolute calibration accuracies on the order of expected decadal trends, or better than ~5%.

Five papers in this session concerned the impact of ozone changes on the climate and chemistry of the troposphere. Recent estimates of ozone radiative forcing confirm earlier results that observed decreases in stratospheric ozone act to cool the climate. This negative forcing is approximately 20% as large as the positive climate forcing due to increases in carbon dioxide, methane, nitrous oxide, and halocarbons over the past decade or so [Shine and Forster, RA.11]. Results from a general circulation model also indicate a significant dynamical effect from changes in stratospheric ozone [Christiansen, RA.3].

Granier et al. [RA.7] reported that the chemistry of the lower atmosphere is quite sensitive to changes in stratospheric ozone through modulation of the tropospheric actinic flux. The calculated impact of decreases in total ozone observed during the 1990-94 period includes higher levels of OH and lower levels of CO and ozone in the troposphere. A key point was made concerning the sensitivity of these results to background levels of NO_x and the corresponding importance of longitudinal variability in modeling global effects on tropospheric chemistry. One study [Toumi, RA.13] focused on how changes in tropospheric chemistry could influence the microphysical properties of clouds through enhanced conversion of SO_2 to H_2SO_4 , leading to higher concentrations of cloud concentration nuclei. Modelled increases in cloud albedo were

found to have a short-wave effect on climate which could be as large as the direct effect due to changes in stratospheric ozone.

Lloyd et al. [RA.9] presented results of actinic flux measurements in the lower stratosphere during the SPADE and ASHOE/MAESA aircraft campaigns. Inferred photolysis rates agree well with radiative calculations in most cases, however an important issue for the calculation of ozone photolysis is the adopted choice of O_3 overburden.

A presentation by Keith Shine (University of Reading-UK) on the interaction between lower stratospheric ozone and radiation reviewed the development of our present understanding

on all these issues. Emphasis was placed on the link between ozone changes and climate. The concept of radiative forcing as a mean of assessing potential climatic impact was discussed. Regarding the radiative forcing due to changes in stratospheric ozone, it was pointed out that the comparatively weak 14-micrometer band is nonetheless important in determining the overall long-wave effect. Precise knowledge of the altitude profile of ozone change is also a critical factor. An alternative view was presented on the height-forcing profile of ozone changes, one which emphasizes percent changes rather than equal Dobson unit changes used in previous studies. Calculations of the direct and indirect (due to destruction of ozone) climatic

effects of chlorine and bromine compounds were presented. The indirect forcing was considered as analogous to a long, small volcano, whereby ozone destruction can temporarily offset some of the positive direct forcing of halocarbon compounds. It was pointed out that decreasing trends in lower stratospheric ozone imply, at least from a radiative standpoint, a cooling effect on the lower stratosphere. Temperature changes observed over the past 25 years (about $0.4^\circ\text{C}/\text{decade}$ in the mid-latitude lower stratosphere) appear to be consistent with the amount of ozone loss at mid-latitudes.

New Stratospheric Aircraft Programmes

In-Situ and Remote-Sensing Measurements with the M-55 Geophysika Stratospheric Research Aircraft : The Airborne Polar Experiment

S. Borrmann (Inst. Phys. Atmos., J. Gutenberg Univ., Mainz, Germany),

L. Stefanutti (Inst. Ricerca sulle Onde, IROE, Firenze, Italy),

V. Khattatov (Centr. Aerolog. Observ., Dolgoprudny, Russia)

Introduction : Since the early nineties efforts have been made to transform the Russian high-altitude M-55 Geophysika into a flying laboratory suited for stratospheric research aimed at environmental issues such as ozone depletion, the assessment of the influence of commercial aircraft on the atmosphere and other topics concerned with upper tropospheric and lower stratospheric physics and chemistry. As a result of these efforts,

the Airborne Polar Experiment (APE) is presently being planned and prepared. The first field campaign with Geophysika is scheduled to take place in the 1996/1997 winter season from an airport in Northern Sweden or Finland.

The Geophysika Aircraft : The M-55 Geophysika is a one-seated dual turboprop aircraft which has been manufactured by the Russian Myasishchev Design Bureau (MDB). It carries payloads up to 1500 kg to an altitude of 21 km, supplying up to 60 kW of electrical power. The aircraft was certified by the International Aeronautical Federation in January 1994 for holding the altitude record of 21 340 m. The cruise speed at altitude is 750 km per hour and the flight duration is between 5 and 6 hours allowing for a radius of operation between 1950 and 2100 km. For its maximum take off weight of 24 tons Geophysika requires a runway length of 860 to 910 m. The cruise altitude is reached in 23 minutes. The Geophysika is operational under all weather conditions and in this respect less limited than the American NASA-operated ER-2 high altitude research aircraft. Geophysika has been presented to the public during

the second Airborne Experiment workshop in Rome (November 1993) and during the International Aviation Shows in Berlin (June 1994) and Farnborough (UK, 1994).

The Airborne Polar Experiment : The main objectives of the APE project is the study of the microphysics and chemistry of Polar Stratospheric Clouds (PSC) and stratospheric aerosols in the regions of the Norwegian Alps, the Ural Mountains and the Russian Arctic. The APE project has been approved by the European Science Foundation in November 1994. For this experiment in the winter of 1996/97 up to 45 flight hours are planned for a maximum of 8 flights. Mission support, weather forecasts and stratospheric forecast and analysis are provided by the Finnish Meteorological Institute and Norwegian Norsk Institutt For Luftforskning. Simultaneously with Geophysika, another Russian aircraft (IL-18D "Cyclone") may be used for tropospheric research and for the logistics support of the mission.

The Payload : Advances and Deficiencies : Geophysika will be equipped with a combination of remote sensing and in-situ instruments. The Instrumentation table lists the various instruments/measured species/principal investigators. A second table summarizes the ongoing modelling activities in connection with the APE. Additional instrumentation is projected for implementation on Geophysika depending on the financing of these instruments. The current payload configuration is well-suited for the investigation of PSCs and stratospheric aerosols and various aspects of the

Modelling Activities : SUMMARY for Arctic Experiment 1996/7

Principal Investigator	Type of Modelling	Institute
Robert MacKenzie	Chemical Modelling	U Cambridge
Guido Visconti	Chemical Modelling	U l'Aquila
Geir Braathen	Dynamical Modelling	NILU
Giovanni Dalu	Stratosph. Wave Dyn.	ESF
Thomas Peter	PSC Microphysics	MPI Mainz
Vincenzo Rizi	PSC Box Model	CNR
Massimo Del Guasta	Non-spherical Particles	IROE-CNR

Instrumentation : SUMMARY for Arctic Experiment 1996/7

Country	Instrument	Measured Species	Principal Inv.
Italy/ United Kingdom	SAFIRE-A (remote sensing)	O ₃ , HO _x , ClO, HF, HCL, HOCL, HNO ₃ , HCN, CO N ₂ O ₅	B. Carli, P. Dickinson
Italy/Germany	ARIAS-MASS in-situ ARIAS-FSSP-300 in-situ	aerosol particle shape and refractive index opt. particle counter, particle size distributions	A. Adriani S. Borrmann
Italy	GASCOD (remote-sens.)	O ₃ , NO ₂ , OClO	G. Giovanelli
Italy	dual wavelength LIDAR 532 nm and 355 nm	backscatter of aerosols and PSCs	G. Fiocco
Italy/Russia	Electrochemical Ozone Sonde	in-situ Ozone	V. Galaktionov
Sweden/Italy/ Germany/USA	CVI-COPAS (*) (in-situ)	condensation particles, nanometer particles	J. Ström, S. Borrmann
Sweden/Italy/ Germany	CVI-HNO ₃ /H ₂ O (*) (in-situ)	Chemical composition, of PSC particles (H ₂ O and HNO ₃)	K. Noone P. Mazzinghi
Russia	Diode Laser LIDAR λ = 900 nm	backscatter of aerosols and PSCs	S. Pershin V. Mitev
Russia	Opt. Particle Counter	in-situ aerosols	S. Shevchenko
Italy/Russia	Chemiluminescence	in-situ Ozone	T. Georgiadis, V. Yushkov
Russia	Optical Fluorescent Hygrometer	H ₂ O (vap) low concen- trations in-situ	S. Merkulov
Russia	Frost Point Hygrometer (in-situ)	H ₂ O (vap) high conc. (Troposphere)	M. Mezrin

lower stratospheric chemistry. This is especially the case for measurements of lee-waves-induced PSCs because of the available combination of lidar and in-situ aerosol instrumentation.

However, important instruments are still missing, e. g., a fast-response detector for nitrous oxide and other long-lived dynamical tracer substances. Also instrumentation for detection of the smallest aerosol particles which serve as nuclei in polar stratospheric cloud formation is needed, as well as measurements determining the composition of PSCs particles. Two counterflow virtual impactor instruments for condensation nuclei measurements and PSC composition marked with (*) in the table are proposed but the funding is not certain yet. Additionally, it is very important to have in-situ detection of some radicals, such as ClO, BrO, or OH and HO₂. For the modelling of the chemistry, photolysis rates are required, which raises the need for radiation instrumentation. In this and various other respects the instrument configuration of the current payload could be improved.

STRATO 2C - A new stratospheric research aircraft - well under development

U. Schumann and H. Ziereis, (DLR Inst. Atmos. Phys., Wessling, Germany)

STRATO 2C is a high altitude research aircraft which is currently under development by the company GROB under the responsibility of the German Aerospace Research Establishment (DLR). The aircraft is designed for high altitudes (>20 km) and long endurance operation in the stratosphere. It will be capable to carry a scientific payload of 800 to 1000 kg for in-situ and remote sensing measurements depending on flight profile. The aircraft is built using fiber composite materials. The wingspan is 56.50 m, length and height are 23.98 m and 7.76 m, respectively.

A pressurized cabin allows two experimenters to be onboard for instruments and mission supervisions. STRATO 2C can accomodate scientific

instruments in a pressurized cabin and in unpressurized compartments in the front and rear parts of the fuselage. Several hard points under the fuselage and the wings allow the installation of payload stations with a load of up to 250 kg. Low weight instruments can also be mounted at each wing tip and the top of the tail unit.

The first successful flight took place on March 31, 1995 from Matssies, where the aircraft company GROB is located. Until autumn of this year of the order of 30 test flights are scheduled to test and further develop the flight performance of the aircraft, in particular the maximum cruise altitude. After this period the aircraft will be converted for its use as a carrier of scientific instruments. In spring of 1997 the aircraft will be handed out to the DLR, which will operate it.

The first scientific mission (CHO-RUS) with the STRATO 2C is foreseen for the winter of 1997/98. The objective of this mission is to study the chemistry of the ozone destruction in the lower stratosphere over the northern hemisphere. A number of in-situ and



Strato 2C Aircraft

In-situ Measurements for CHORUS from STRATO-2C

Parameter	Technique/Sensor	PI / (Institution)
<i>Reservoir species :</i> HCl	TDLAS	Fischer (MPI-C) Lübken (Uni Bonn)
HNO ₃ NO ₂	HAAMAS Chemiluminescence	Arnold (MPI-K) Schlager&Ziereis (DLR)
<i>Reactive species :</i> OH ClO, BrO	HAAMAS Res. fluorescence	Arnold (MPI-K) Schmidt (KFA) Zellner (Uni Essen) Toohey (Uni Irvine)
NO	Chemiluminescence	Schlager&Ziereis (DLR)
<i>Tracer species :</i> N ₂ O	TDLAS	Fischer (MPI-C) Lübken (Uni Bonn)
H ₂ O CCl ₂ F ₂ (CFC12) O ₃	Lymann-a-fluor. GC UV-Photometer	Schiller (KFA) Engel&Schmidt (KFA) Schlager (DLR)
<i>Atmospheric parameters :</i> Aerosols	MASP	Borrmann (Uni Mainz) Baumgardner (NCAR) Stingl (DLR)
CN	Opt. particle counter	Jaenicke&Dreiling (Uni mainz)
pressure temperature wind UV-flux	Rosemount Pt100, Pt500 Flow angle probe Radiometer	Busen (DLR)
		Schiller (KFA)

Remote Sensing Measurements for CHORUS from STRATO-2C

Technique/Sensor	Parameter	PI / (Institution)
DOAS (UV and VIS)	O ₃ , NO ₂ , OClO, BrO (column densities + vertical profiles)	Platt (Uni Heidelbg.) Perner (MPI-C)
MIPAS-F (FTIR)	ClONO ₂ , N ₂ O ₅ , HNO ₃ , (large scale distribution)	Fischer (KfK)

remote-sensing instruments are presently under development for this mission.

Further fields for the application of STRATO 2C include stratospheric dynamics, atmospheric impact of air traffic emissions, tropical deep convection, impact of volcanic eruptions, climatic impact of high level clouds, investigation of land and sea surface processes, and validation of satellite-based measurements.

Environmental Research Aircraft & Sensor Technology (ERAST) - A Gateway into future aeronautics

The ERAST programme being conducted in the U.S. is using a highly integrated approach to develop and flight demonstrate (1) extreme-altitude and long-endurance remotely-piloted aircraft (RPA); and (2) science payloads for environmental studies.

Programme description : The ERAST programme is a NASA initiative to develop and flight demonstrate RPA for cost effective science missions. Two science mission flight profiles have been identified as being critical to the collection, identification and monitoring of environmental data for the assessment of global change. The first is flight to extreme altitudes, defined as the region between 24 - 30 km; desired payload capacity is 200 kg with a minimum time on station of 2 hours. The second mission profile is one of extended duration; it is defined as exceeding 96 hours in continuous operation at altitudes from 15 - 23 km carrying a minimum payload of 300 kg. For each mission, the desired cost per flight hour is \$5000. Both missions require subsonic flight speeds in order to obtain chemically unaltered samples.

ERAST is also pursuing a course toward a new class of light-weight, low -power-consumption scientific sensors, the goals being to reduce weight by a factor of 5 and constrain total power consumption to 50% of current suite of instruments.

Programme Organisation : The aircraft development portion of ERAST has been organised into an industry/government partnership under a Joint Sponsored Research Agreement (a non-procurement contract between NASA and its industry partners).

ERAST consists of an Alliance Council of four U.S. companies (AeroVironment, Aurora Flight Sciences, General Atomics & Scaled Composites), the Association of Unmanned Vehicle Systems International (AUVERSI) and the NASA Project Manager. The NASA Ames, Dryden, Langley and Lewis Research Centers provide focused technology expertise to leverage industry assets.

ERAST Plans : ERAST is following a step-wise approach to meeting its objectives. The near-term focus of ERAST is the development of three - stage turbocharged propulsion technology (1996) to achieve reliable flight operations at altitudes over 24 km, continue work on the closed-cycle-powered "Perseus A" and the solar-electric "Pathfinder" (scheduled to begin flight tests this summer). Other areas of development include robust flight controls, composite structures and over-the-horizon communications. Flight tests starting late summer 1995 will demonstrate high-altitude

capabilities. These tests, while predominately at the NASA Dryden Flight Research Center, will also be conducted under industry auspices.

Environmental science payloads will be in place at every opportunity and science mission demonstrations are planned for late 1996, at Dryden, with an advanced capability RPA science mission demonstration in unrestricted airspace by the end of 1999. NASA Ames, in coordination with environmental scientists, is the focal point in the development of appropriate sensors and provides the communication link between sensor and airframe development. At present 10 peer reviewed sensor designs are under development. Ames is also lead for planning and execution of science missions. NASA is actively coordinating its research efforts with other U.S. government agencies to leverage resources for technology development, address regulatory issues and expand the scope of potential science missions.

ERAST Sensor Information :

CHEMISTRY

ClNO₃ - Anderson/Harvard University
N₂O/CH₄/H₂O - Webster/Jet Propulsion Laboratory
ClO/BrO/O₃ - Anderson/Harvard University
NO/NO_y - Wofsy/Harvard University
N₂O/CH₄ - Loewenstein/NASA Ames

AEROSOL COMPOSITION

- Aerosol Measurements
Murphy/NOAA
- Aerosol Measurements
Wilson/Denver University

TRACERS

CO₂ - Wofsy/Harvard University
CFC-11 - Elkins & Fahey/NOAA
H₂O - Anderson/Harvard University

(Information received from Karl Loutinsky, ERAST Programme manager, NASA Headquarters. (e-mail : kloutinsky@aeromail.hq.nasa.gov).)

Access to SPARC Relevant Data

TOMS Total Ozone Data

The Nimbus-7 TOMS data are available from Nov. 1, 1978 until Jan. 1992 on CD-ROM in the form of daily files of gridded column ozone (1 deg. lat. by 1.25 deg. long.) The data from Nov. 1978 through Dec. 1987 are on the first CD-ROM, and from Jan. 1988 to Jan. 1992 on the update CD-ROM. They may be obtained from Goddard DAAC : Code 902.2, GSFC/NASA, Greenbelt, MD, 20771, USA (e-mail : DAACUSO@eosdata.gsfc.nasa.gov).

Similar data from Jan. 1991 through May 6, 1993, are also available on line. The on-line data differ slightly from the CD-ROM version which has an error of about 1%. The on-line data have been corrected for this error.

Data from Meteor-3 TOMS are also available on-line in the same format from Aug. 1991 through Dec. 26, 1994.

The on-line data may be accessed through FTP :

1. 'ftp jwocky.gsfc.nasa.gov' (ip address=128.183.58.65)
2. login as 'anonymous'
3. password : your name
4. cd pub/meteor3/oz94 or pub/nimbus7
5. 'ascii' (to set type to ascii)
6. 'ls' (to get listing of directories)

The data (and images) can also be accessed through the World Wide Web

(using Mosaic or Netscape) at <http://jwocky.gsfc.nasa.gov/>

All the data are processed using the version 6 ozone algorithm. A version 7 algorithm with a more consistent calibration is under development. Inquiries should be addressed to Eric Beach (beach@itchy.gsfc.nasa.gov)

(Information obtained from S. Chandra, GSFC, NASA, chandra@chapman.gsfc.nasa.gov).

NASA Upper Atmosphere Research Satellite (UARS) Data Available on CD-ROM

The nine sensors aboard the UARS spacecraft launched by NASA in September 1991 provide the most complete data on energy inputs, winds, and chemical composition of the middle atmosphere ever gathered. The data sets yield the first simultaneous, comprehensive, global coverage of the atmospheric properties. Additional correlative data, as well as theoretical studies linked to specific sensor objectives, complement the UARS observations to provide a systematic, unified research approach.

UARS observation data for September 1991 through September 1994 have been compiled on 29 CD-ROMs.

Below is the complete UARS CD-ROM volume description (where 3AT is Time-ordered data, 3AL is Latitude-ordered data, 3TP and 3LP are Parameter data for 3AT and 3AL, respectively, 3BS is instrument degradation calibrated solar data, and 3B is gridded data from 3AL) :

- Set 1 (1 CD) : HALOE 3AT/TP, SOLSTICE 3BS, SUSIM 3BS
- Set 2 (7 CDs) : MLS 3AT/TP, CLAES 3AT, ISAMS 3AT/TP
- Set 3 (5 CDs) : MLS 3AL/LP, CLAES 3AL, ISAMS 3AL/LP
- Set 4 (1 CD) : WINDII 3AT/TP, HRDI 3AT
- Set 5 (1 CD) : WINDII 3AL/LP, HRDI 3AL
- Set 6 (8 CDs) : PEM 3AT
- Set 7 (1 CD) : Gridded 3B from CLAES, ISAMS and MLS 3AL
- Set 8 (5 CDs) : Correlative NMC and UKMO

To order UARS CD-ROMs, you must complete an order form available from the UARS Central Data Handling Facility at Internet e-mail (IP address) : uarscd@cdh6.gsfc.nasa.gov (192.67.83.9) or via mail to : UARS CDHF, NASA Goddard Space Flight Center, Bldg 23, 4th Floor, Room N406A, Mail continued p.24 Stop 64, Greenbelt MD 20271, USA .

Radiosonde Data Availability

1. NCAR archives global radiosonde (r/s) data derived from NMC decode of real-time data receipt. It also has a

number of collections of r/s data from countries around the world which augment this archive. NCAR ftp and web areas can be browsed for information about the data sets where sets ds353.4 and ds390.0 contain most of the r/s data.

NCAR charges for data based on data volume. No significant part of the archive is permanently available for online access, but reasonable volumes can be requested for fees based on data volume read and written.

NCAR has no CD-ROMs with r/s data. (information from Data Support

Section, NCAR/SCD, PO Box 3000, Boulder, CO 80307. e-mail : joseph@ncar.ucar.edu , fax : 1-303 -497-1298).

2. NCDC (Nat. Climatic Data Center) has no global r/s data on CD-ROM, only North America r/s. It has however CD-ROM Global Upper-Air Climatic Atlas (GUACA). This two-volume CD-ROM set uses 12-year (1980-1991) 2.5 degree gridded upper-air climatic summaries derived from the ECMWF model analyses. It presents upper-air statistics (for the 12-year period and individual year-months) for 15 vertical

levels in both hemispheres for dry bulb and dew point temperature, gpt height, air density, vector and scalar wind speed. The CD-ROM provides access/display software for gridpoint data, contouring capability for user-defined areas and vertical profiles. Sold as a set (\$ 240 US).

(information from Climate Service Div., NCDC, Asheville, NC 28801-5001, Fax : 1-704-271-4876).

To our readers

We appreciated your response to the first SPARC Newsletters, and we hope that you will continue to send your comments and the news from your own research relevant to SPARC. We are striving to reach every one who is interested in the SPARC programme. We would appreciate your sharing this Newsletter with your colleagues who may be interested in our programme.

We will appreciate it if those who are not on our mailing list please fill out the inside form in order to be inserted.

SPARC Office (SPARC Office, CNRS, Service d'Aéronomie, BP 3, 91371 Verrières-le-Buisson, FRANCE) with your current address and comments.

Name : MR./MRS./DR.

Institution

Address

City State

Postal Code Country

Telephone Telefax e-mail

Address correction ? yes - no (circle one)

Comments

.....

.....

.....

PS : The SPARC directory which includes 2000 names is available on special request addressed to the SPARC Office