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

Report on the Seventh Meeting of the SPARC Scientific Steering Group

Paris, France, 2-5 November 1999

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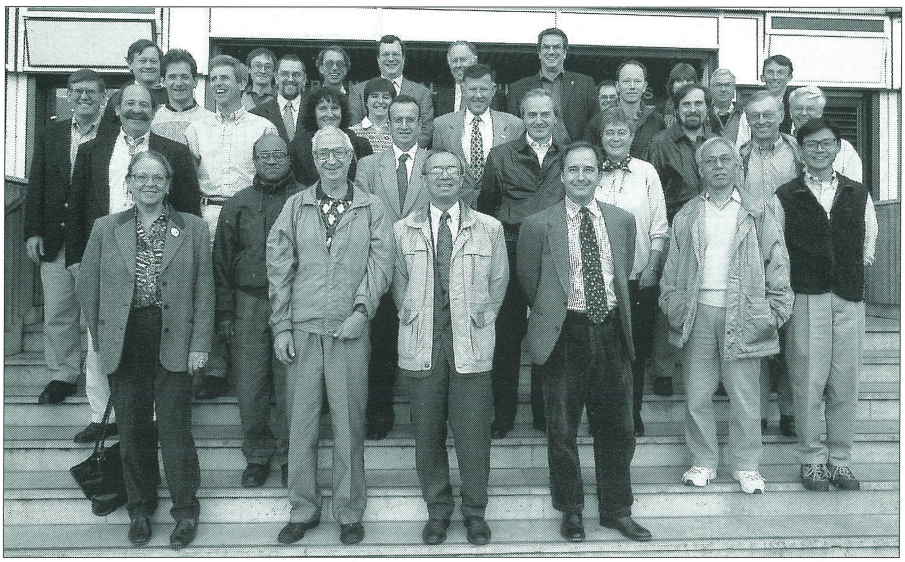
This year the SPARC Scientific Steering Group (SSG) met in Paris, at the headquarters of the French Space Agency (Centre National des Etudes Spatiales, CNES). After a busy and successful initial seven years, this meeting marks the beginning of a critical review, by the SSG and study group leaders, of the scientific objectives and scope of the project. The agenda of the three and a half day meeting was therefore a very full one.



Participants, from left to right:
1st row: M.-L. Chanin, V. Ramaswamy, Y. Koshelkov, V. Khattatov, P. DeCola, K. Kodera, S. Yoden. 2nd row: M. Geller, W. Randel, C. Granier, G. Amanatidis, A. O'Neill, K. Labitzke, J. Gille. 3rd row: J. Russell, T. Peter, T. Wehr, C. Phillips, R. Newson, M. Baldwin, K. Hamilton, R. Vincent. 4th row: N. Harris, F. Dulac, D. Karoly, P. Canziani, M. Proffitt, U. Schmidt, G. McFadyen, P. Udelhofen, S. Penkett, P. Haynes

M. Geller opened the meeting by thanking F. Dulac (CNES Middle Atmosphere Programme) for his help in the organisation of the meeting and for providing excellent facilities at CNES. He also thanked the numerous funding agency representatives for attending the meeting (European Commission, CNRS, CNES, NASA, European Space Agency (ESA), and the Department of the Environment, Transport and the Regions (UK)). Their contributions to the meeting were very useful and the interactions with them were fruitful.

M.-L. Chanin, M. Geller and R. Newson reviewed the main events of concern to SPARC since the last SSG meeting in October 1998, in particular the meeting of the WCRP Joint Scientific Committee (JSC) that took place in March 1999 (see *Newsletter 13*) and the opening of the SPARC Data Centre (more information at end of this report).

Contents

The SSG was pleased to learn that the European Commission has recently agreed to fund two projects related to SPARC, EuroSPICE (European project on Stratospheric Processes and their Impact on Climate and the Environment) and SOLICE (Solar Influence on Climate and Environment). The EuroSPICE project (co-ordinated by J. Austin) will study the impact of stratospheric ozone trends on past (1980-2000) and future (2000-2020) climate, updating observations and intercomparing models. The SOLICE project (co-ordinated by J. Haigh) will attempt to determine the mechanisms by which changes in solar forcing can impact climate, intercompare the results of various models, and extend and improve existing data analyses.

Review of progress in SPARC activities

GCM-reality intercomparaison for SPARC (GRIPS)

K. Kodera and T. Shepherd reported on recent progress of the GRIPS initiative. This intercomparison project has grown both in the number of research groups involved and the number of assigned tasks. The 1999 GRIPS meeting is described in detail in Newsletter 13, and only a brief summary of progress and issues is given here.

The first phase of the GRIPS initiative, a simple intercomparison of models, is nearing completion. A summary of the results and their scientific implications will appear in the Bulletin of the American Meteorological Society in March 2000. The second phase of GRIPS, already underway, involves validating the models and carrying out controlled experiments to test the parameterisation schemes. The phase 2 tasks include: intercomparisons of radiation schemes (led by U. Langematz), intercomparisons of model responses to mesospheric drag (led by S. Beagley), and tests of gravity wave parameterisations (led by C. McLandress).

During the third phase of GRIPS, the group plans to clarify understanding of the factors that determined the atmospheric state from 1979 to 1999. The three main issues that will be addressed will be natural variability, lower boundary forcing (i.e. the impact of interannual differences in sea surface temperatures and sea ice) and variations in radiative forcing. The sensitivity of the model climates to interannual variations in radiative forcing will be studied by carrying out a series of perturbation experiments, imposing interannual changes in solar forcing, ozone and volcanic aerosol. The solar forcing experiments will be co-ordinated by K. Kodera. He presented the plans for this task in detail, as it is one of the scientific issues the WCRP JSC has asked SPARC to study.

A proposal for a fourth phase of GRIPS was described. The fourth phase would involve imposing climate change scenarios in the model runs and comparing the ensemble of transient runs, the aim being to show the impacts of middle atmospheric change on climate.

Stratospheric Reference Climatology

W. Randel presented the reference climatologies and stratospheric circulation statistics that this initiative has produced for the validation of stratospheric models.

The climatologies (monthly) have been created using UARS measurements of:
- temperature
- zonal winds (UKMO/HRDI)
- constituents (N_2O, CH_4, H_2O, O_3, NO_2, HNO_3, ...)

The stratospheric circulation statistics (monthly, daily) have been calculated using:
- NMC stratospheric analyses
- NCEP reanalyses
- UKMO stratospheric assimilation
- Free University of Berlin analyses
- GSFC assimilation

Other data sets that have been made available include the Singapore QBO winds and tropopause statistics.

This year the main activity of the group has been making the data available for use at the SPARC Data Centre. The climatology group plans to hold a meeting in 2000 and to produce a technical report describing the available data sets, comparing the stratospheric circulation statistics and quantifying uncertainties and interannual variability.

Stratospheric Aspects of Climate Forcing

This initiative has been led by D. Karoly to facilitate the modelling of stratospheric aspects of time-varying climate forcing. Data has been compiled on interannual changes from 1880 (if possible) to present of ozone, volcanic aerosol and solar irradiance. The data sets are now available at the SPARC data centre. The concluding report of this initiative is on page 15 of this issue.

Penetration of UV radiation in the lower stratosphere and troposphere

P. Simon and S. Penkett reviewed the scientific issues related to the penetration of UV radiation in the lower stratosphere and troposphere. They reminded the SSG that decreases in stratospheric ozone impact the chemical composition of the troposphere, including the concentration of the OH radical that regulates the lifetime of greenhouse gases such as CH_4, HCFCs and HFCs. Long-term atmospheric observations of methane already show this effect, (see article by C. Granier in Newsletter 13).

They pointed out that there is currently a need for measurements of global photodissociation rate constants (Js) (climatology as a function of altitude and variations) and of actinic flux (to calculate the Js) and to improve model calculations of Js.

A joint SPARC-IGAC activity on UV penetration was proposed which would:
- Evaluate existing data
- Evaluate current J values and actinic flux measurements
- Discuss requirements for possible new instrumentation
- Organise radiative transfer model validation campaigns

The SSG agreed that such an activity would be very useful and could be carried out within the SPARC UT/LS processes initiative. P. Simon and S. Penkett proposed to hold a workshop on measurements and radiative transfer modelling and to work towards a better synergy of ground-based and satellite observations, together with the WMO Global Atmosphere Watch UV Scientific Steering Committee. The results of this work should also benefit the new IGBP Surface Ocean and Lower-Atmosphere Study (SOLAS), as one of the principal scientific objectives is to understand whether changes in the spectrum and intensity of solar radiation affect the production of trace gases in the surface ocean.

Stratospheric temperature trends

V. Ramaswamy reported on the activities of this working group. The original aim of this initiative was to assess observations of stratospheric temperature trends. Modelling studies also carried out by the group have helped improve our understanding of the observations. The results of the data and modelling activities have already been used in the WMO/UNEP 1999 Assessment of ozone trends and will be published in Reviews of Geophysics in 2000. A longer report is in preparation and will appear as a SPARC report. The work of the group is currently being used for the preparation of the IPCC 2001 report, in particular the chapters on radiative forcing, processes and detection-attribution.

In July 1999 the working group met in Birmingham and decided to revisit the data sets, address new scientific issues and plan new model investigations. They plan to update the data sets till the end of 1999, re-calculate trends and uncertainties, resolve discrepancies between satellite and radio-sonde trends, compare reanalyses with "raw" data sets, continue work on the rocket and sonde data and consolidate previous work by carrying out cross-checks. The data will be analysed for seasonal trends and variability and in particular the Northern Hemisphere polar winter-springtime trends will be examined closely. The sensitivity of the trend calculations to the inhomogeneities in the data (spatial and temporal) and to the time period being examined will be tested.

The group also plans new model investigations of the causes of the observed stratospheric seasonal and mean temperature trends, (e.g., the potential effect of interannual changes in water vapour concentrations) and to examine trends over regions and specific locations. To complement the linear trend experiments carried out to-date, sources of disturbances in the stratospheric climate will be examined. Transient GCM simulations will be carried out with appropriate time-varying forcings (e.g. Pinatubo volcanic aerosol) and compared to the observations. For each of these issues the comparisons with the data will be on finer spatial and temporal scales and will be more rigorous. With an increasingly longer data record, the detection-attribution arguments should be more reliable. The model uncertainties will be estimated so that the variability and trends can be compared with observational diagnostics.

The scientific objectives of the working group have become much broader than those set originally, and the group now wishes to address: the analysis of trends above the middle stratosphere in collaboration with ICMA, IAGA and SCOSTEP, as discussed during the LT-ACT conference in Pune in February 1999 (see Newsletter 13), refining the trends near the tropopause including tropopause height, the solar cycle signature in the observations and the models and stratosphere-troposphere coupling. The group plans short "mini-thrusts" focussing on climate variability and long-term change, and research on the major unresolved issues that have appeared during the past 3-4 years. They also hope to work alongside the other SPARC initiatives in a combined "integration" task studying on other stratospheric parameters (e.g. ozone, H_2O, dynamical activity and clouds). They believe that this research activity should continue to be carried out under the auspices of SPARC, as this is an ideal way of carrying out coherent international research activity.

The working group hopes to meet during the second SPARC General Assembly, then late 2001, or early 2002.

Understanding ozone trends

N. Harris reported that this working group proposes to hold a workshop in the year 2000 on the attribution of past stratospheric ozone trends and the detection of the effect of the Montreal Protocol. Such a workshop would help to identify gaps in our knowledge on the attribution of stratospheric trends, consolidate existing work and hopefully encourage more research in this area by promoting contact between the various research groups. If there is a consensus to do so, the results of the workshop could be published as a set of peer-reviewed papers or in another format. It is hoped that the results would be available for use by the community by the year 2002, and could feed into the future WMO/UNEP Ozone Assessment planned for 2002-03.

It is felt that the SPARC project is the ideal context for such a workshop as it will encourage international co-operation and would hopefully lead to work on attribution of stratospheric trends in general (including temperature), one of the issues the SPARC project hopes to address within the coming years (see section below on the future of SPARC).

Water vapour in the stratosphere and upper troposphere

This working group has been very busy in 1999 preparing the SPARC Water Vapour Assessment (WAVAS). D. Kley presented the plan of the assessment (see Newsletter 13 for details) and its current status. The first draft of the assessment is currently being peer reviewed. A review meeting will be held in Paris, 17th to 20th January 2000, and it is hoped that the final version of the assessment will be ready for printing and publication on the SPARC web site by summer 2000.

Gravity wave processes and their parameterisation

The group constructing the climatology of gravity wave activity using high-resolution radio-sonde data met 15-16 July 1999 in Abingdon, UK. R. Vincent reported on the workshop. The issues discussed included: results from the initial analysis of high-resolution radio-sonde data using the common analysis package; quality control; horizontal drift; height coverage; averaging intervals; intermittency and how to quantify it; spatial variability; sources of spatial variability and interpretation of the observations aided by theory and modelling. The group has agreed to produce climatologies based on monthly-mean values of kinetic energy, potential energy, horizontal directions of propagation, spectral parameters (m*, t), axial ratios of hodographs, ratios of upward to downward propagating energy and mean vertical wavelengths. The climatology will cover a 7km interval in the lower stratosphere, the lower boundary of which will be determined by the mean height of the tropopause (using a model based on Hoinka, 1998). The analyses will be produced for as many years as possible in order to study the interannual variability of gravity wave activity.

It is planned to produce the following research products: intrinsic frequencies; horizontal wavelength; phase velocities and maybe momentum fluxes.

The initial collation of the results for hemispheric climatologies will take place early 2000 and will then be distributed to the working group for comment and update. Mid-2000, it is planned to submit for publication a series of articles describing the research efforts that have gone into the creation of this climatology.

K. Hamilton reported on the plans for the international field campaign ETCE (Effects of Tropical Convection Experiment). This approximately 6-week intensive observation period would study the intense diurnal convection that occurs over the Tiwi Islands north of Darwin, Australia. The main scientific objectives are to: characterise the 3D development of tropical deep convection in unprecedented detail; study the generation of stratospheric gravity waves by deep convection; study the effects of the convection on transport and mixing in the upper troposphere and lower stratosphere; the transformation of ozone precursors in the upper troposphere; the injection of water vapour into the stratosphere and the generation and dynamical and microphysical evolution of tropical anvil cirrus. The fourth planning meeting for this field campaign was held in October 1999 in Boulder. The target dates are now late October-early December 2002. A detailed plan of the scientific objectives and the instrumentation to be deployed during the field campaign is available at **http://www.princeton.edu/~kph/EXP2.**

Lower stratospheric/upper tropospheric processes

T. Shepherd and P. Haynes reviewed the scientific driving force for studying transport and mixing in the lower

stratosphere and upper troposphere and presented plans for a workshop on the tropopause to be held in 2001 in France. The workshop will address the following key questions: what is the tropopause, how well is it known, and why does it have its observed structure? How does the tropopause control the distribution of radiatively active species (locally and globally)? How might the tropopause be expected to change in the future?

A.R. Ravishankara and A. Cox reviewed the joint SPARC-IGAC studies of chemical processes in the UT/LS. A.R. Ravishankara presented some results from the group working on the quantum yield of the ozone photolysis reaction. They have reviewed recent laboratory measurements through extensive correspondence, exchange of data and analyses, and held a meeting in Oxford, UK, 23-24 September 1999. The group aims to publish a review paper in 2000 in which the evaluated data will be presented in a form accessible to atmospheric chemists.

A. Cox presented the progress of the group working on the analysis and evaluation of data on the atmospheric chemistry of small organic peroxy radicals (CH_3O_2, $C_2H_5O_2$, $CH_3C(O)O_2$, $CH_3C(O)O_2$). The members of this group aim to produce critically evaluated data that can be used for atmospheric modelling.

A.R. Ravishankara underlined that these types of joint SPARC-IGAC activity are crucial as they produce an international evaluation of a given process in more detail than that carried out by the data evaluation panels (e.g. De More *et al.*, 97 and Atkinson *et al.*, 92) and bring providers and data users together. The SPARC-IGAC groups will therefore continue to recommend crucial chemical issues that require evaluation efforts.

Other scientific issues discussed during the meeting

The quasi-biennial oscillation and its role in coupling the stratosphere and troposphere

M. Baldwin reported on the activities of the ad hoc working group set up to review this scientific issue. The results of the workshop held in California in March 1998 have now been written up and are accepted for publication by Reviews of Geophysics. In 1999 a symposium on the QBO and internal gravity waves was convened by I. Hirota during the IUGG in Birmingham (see report this issue). M. Baldwin also reported on work being carried out using radio-sondes, rocket-sondes, SSU and the UARS HRDI data to estimate zonal equatorial winds in the stratosphere and mesosphere from 1963 to 1999. The SPARC SSG will continue to follow with interest research on this aspect of the dynamical coupling of the modes of variability of the stratosphere and troposphere (see below).

Stratosphere-troposphere dynamical coupling

Part of the meeting was devoted to discussion of the Arctic Oscillation/North Atlantic Oscillation (AO/NAO) and stratosphere-troposphere dynamical coupling (see article by M. Baldwin on p. 10). M. Baldwin and K. Kodera presented recent research on this theme and stimulated a more general discussion on what we really know about this issue, what the key scientific questions are and whether the scientific community is addressing them. The consensus was that the field has developed rapidly and is likely to continue to do so this coming year, promoted by a special session at the AGU on the AO, a Chapman conference on the NAO during October-November 2000 and the 2nd SPARC General Assembly in November 2000. The SSG will follow with close interest the scientific developments on the connection between stratospheric and tropospheric modes of variability, and discuss during its next meeting whether or not SPARC has a role to play in encouraging research in this area. A report on this issue will be addressed to the WCRP JSC in March 2000 and to the CLIVAR SSG in May.

Data assimilation

A. O'Neill reviewed the role of data assimilation in climate research, pointing out that this technique is ideal for the cross-evaluation of data sets and evaluating the quality of reanalyses, and provides a link between modelling groups, instrumental groups and scientific users. He reminded the SSG that assimilation is used not only in stratospheric and climate research, but also in numerical weather prediction where an expertise has developed in parallel.

A. O'Neill suggested that a SPARC initiative on data assimilation would maintain and promote international co-operation, encourage interdisciplinary exchange within the stratospheric community, and provide a link to the numerical weather prediction community. The SSG agreed that such a new SPARC initiative is indeed timely and asked A. O'Neill to chair it. The working group will hold a workshop, report on current activities to the SSG and recommend developments in those areas where it is needed. They will work in co-operation with the WCRP Working Group on Numerical Experimentation (WGNE) which monitors the advances in data assimilation and analysis methods and is the focal point in WCRP for encouraging and reviewing the reanalysis projects carried out at various centres.

Solar forcing and climate variability

The SPARC project currently reports annually to the WCRP JSC on advances in research on solar forcing, its variability as a source of variations in climate, and possible underlying mechanisms. (The evidence for past climate variability is reviewed by CLIVAR).

K. Kodera stimulated discussion on this issue by reviewing recent research on the effects of variations in solar activity. Although changes in the solar spectrum are known to impact ozone, temperature and the actinic flux in the middle atmosphere, to date there is no consensus on whether tropospheric climate is affected by these changes. The SSG noted that the data analysis planned in the European project SOLICE and the modelling activities starting up in GRIPS phase 3 and SOLICE should help elucidate this issue.

The SSG have invited SCOSTEP to work jointly with SPARC on encouraging research in solar influences on global change. They also hope that the results of the SCOSTEP International Solar Cycle Studies (ISCS) project that is studying the time-variation of solar UV and total irradiance, will be made available as input for modelling activities.

Monitoring stratospheric change

The SSG continues to follow closely the progress and strategy of measurement programmes such as the WMO Global Atmosphere Watch (GAW), the Network for the Detection of Stratospheric Change (NDSC), the WMO Global Climate Observing System (GCOS), and the Committee on Earth Observation Satellites (CEOS). When invited to do so, the SSG has supplied these programmes with recommendations for both the monitoring of the stratosphere and for process studies.

The issue of monitoring of stratospheric ozone was discussed since, if we are to follow the recovery of stratospheric ozone resulting from the actions of the Montreal Protocol and its subsequent amendments, it is essential to ensure the continuity and quality of the existing monitoring systems.

The SSG noted that it is crucial to continue to operate well-calibrated WMO

Global Atmosphere Watch (GAW) ground-based and sonde ozone measurements and a letter has been sent to WMO/GAW stating this support.

Faced with a potential gap in the continuity of global space-based measurements of total ozone, NASA has implemented Quik TOMS, due to be launched 15 August 2000 (http://quiktoms.gsfc.nasa.gov). The SSG has sent a letter to NASA thanking them for their responsiveness and stating that they hope that NASA will be similarly responsive in addressing the looming gap in SAGE measurements for ozone profile trend determination at mid and low latitudes.

Review of overall SPARC stragegy and status of implementation

After 7 years of activity, the SSG feels that the SPARC project has successfully completed most of the initial tasks, and now needs to assess and maybe reorganise the scientific initiatives promoted by the project. Discussion on this issue was stimulated by a review by T. Shepherd of the current role of the project and possible future priorities.

To date the initiatives of the project were highly focused and treated separately by distinct working groups. The SSG feels that although some of the scientific issues originally addressed still need a continued focused effort, the time has come to integrate the knowledge acquired and work together towards improving our general understanding of all the aspects of stratospheric variability and change, its coupling with the troposphere and its role in climate.

Stratospheric processes that still need to be addressed through concerted efforts include the gravity wave climatology, UT/LS chemistry and microphysics, the tropopause and solar forcing and climate variability. The SSG would also like to assess atmospheric observations of aerosol (together with IGAC). Specific modelling issues that should be addressed include the parameterisation of gravity waves, assimilation and the issues identified during phase 1 of GRIPS.

The integration/synthesis of our understanding of trends (O_3, temperature, dynamics, H_2O, aerosol and other constituents) and solar effects would be done through modelling studies aimed at elucidating UT/LS variability and change and its role in the climate system. This would build on the modelling work already carried out by the temperature trends initiative and GRIPS, but would also require the use of models (e.g. 2D models, Chemical Transport Models) and techniques (e.g. assimilation) which have not yet been used in the project.

It was restated that the role of the project is to continue to facilitate research on stratospheric processes and their role in climate by identifying and supporting activities that would benefit from international co-operation and encouraging interdisciplinary exchange. For example, it was felt that although the number of climate models which include the stratosphere is increasing, currently the SPARC community does not have enough contact with the tropospheric climate community and it is hoped that the new initiatives on data assimilation and UV penetration will help build bridges between them. Finally, it was noted that although the SPARC project is driven by scientific questions and not political motives, it can, and should be providing the best available evidence (on those issues addressed by the project) for international assessments such as the IPCC and WMO/UNEP assessments.

Co-operation with other programmes

The project continues to maintain strong links with other programmes both through the joint working groups and the ex-officio members of the SSG.

As mentioned above, a formal assessment of trends in upper atmospheric indicators of climate change is planned in collaboration with ICMA, IAGA and SCOSTEP. SPARC will also work with SCOSTEP on the issue of solar forcing and climate variability.

The co-operation with IGAC continues, especially through the joint working groups on UT/LS chemical processes and will be extended to the issues of the penetration of UV in the stratosphere and upper troposphere and maybe the climatology of aerosol. S. Penkett's presentation of IGAC is summarised in the insert below.

COSPAR has invited the SPARC community to submit papers to a session of its Scientific Assembly in July 2000 on the "Contribution of Remote Sensing of the Upper Troposphere and Stratosphere to Understanding Climate Change". The session is convened by J. Gille (gille@ncar.ucar.edu).

Finally, within WCRP, SPARC plans to report to the CLIVAR SSG on the AO/NAO and a possible connection between the stratosphere and troposphere.

Planning for the 2nd SPARC General Assembly

Alan O'Neill presented the scientific programme for the 2nd SPARC General Assembly to be held in Mar del Plata, Argentina, 6-10 November 2000. He pointed out that, while they were elaborating the programme, the scientific organising committee spent a lot of time thinking about the role of the project and the direction it is heading in. They hope that the organisation of the Assembly will not only help consolidate the research SPARC has undertaken to date, but will also help identify areas where new initiatives are needed. The meeting will be divided into four sessions on:
- stratospheric processes and their role in climate,
- stratospheric indicators of climate change,
- modelling and diagnosis of stratospheric effects on climate,
- UV observations and modelling.

A description of the focus of each session is available on the conference web site (http://www.sparc2000.at.fcen.uba.ar/).

P. Canziani, chair of the local organising committee (LOC), described the local arrangements and reported on the efforts of the LOC to ensure that the meeting is successful.

M.-L. Chanin was pleased to report that the SPARC office has been able to attract many sponsors, and that some travel support for students and young scientists will be available. The requests for support should be made when submitting abstracts.

Opening of the SPARC Data Centre

An important event this year has been the opening of the SPARC Data Centre (http://www.sparc.sunysb.edu/). P. Udelhofen, the Data Centre manager, summarised the work that has been carried out so far and the products that are currently available through it. These include US high-resolution radio-sonde data and reference climatologies (NCEP reanalyses from 1978 to 1998, observed 1979-97 ozone trends, climatologies of stratospheric trace gases derived from UARS observations and a link to NCEP tropopause heights).

The SPARC Office

The SPARC Office continues to support the project by preparing the newsletter, updating the web page and organising meetings. This year the main other activities of the office have

been supporting the preparation of the WAVAS report and finding sponsors for SPARC 2000.

Plans for the next meeting of the SSG

The next SSG meeting is planned 13-16 November 99 in Buenos Aires, Argentina. P. Canziani has kindly volunteered to organise the local arrangements. In the light of the research presented during the Second SPARC General Assembly the SSG will continue to assess the project, define new objectives and discuss the renewal of its membership.

The full meaning of the acronyms and abbreviations used in this report can be found on the SPARC web site.

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IGAC for SPARC in 9 minutes

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- IGAC is concerned with processes which control the trace gas and particulate composition of the troposphere.
- The main components are studies of:
  - biogenic emissions from land and ocean and impact of human emissions
  - photochemistry leading to oxidation processes, particularly with free radicals
  - aerosol physics and chemistry
  - transport processes in the troposphere

The output from many field and laboratory studies is fed into 3D chemical transport models of tropospheric chemistry.

- A recent model intercomparison exercise carried out with support from the European IGAC Project Office (EIPO) revealed substantial differences between the models, which can only be resolved with a much larger data base on tropospheric composition requiring many more in situ experiments and hopefully new observations from satellites which will be launched in the next few years.

- Some current issues are:
  - production of natural and anthropogenic sulphate and organic aerosols over the ocean
  - global transport of emissions from biomass burning and urban/regional pollution, particularly ozone, spread of pollution
- Tropospheric chemistry is very efficient. It has controlled atmospheric composition over geological time.

When it is ineffective, it causes key problems, e.g.
- CO_2: long lifetime due to no photolysis plus no oxidation reactions
- CFC_6: not removed by tropospheric chemistry, contrast with HCs, which are and lead to ozone production in the troposphere.

- One of the prime consequences of tropospheric chemistry is the large in situ production and loss of ozone.

Stratospheric/Tropospheric exchange produces	~ 400 MT in troposphere
Gaseous deposition	~ 1000 MT/yr
Tropospheric chemistry produces	~ 4000 MT/yr
Tropospheric chemistry destroys	~ 3500 MT/yr

Distribution is poorly known because of sparseness of sonde sites, particularly in the tropics.

A new effort to use satellites is being mounted by NASA and ESA including:
- An attempt to use a geostationary satellite for tropospheric ozone.
- A major new programme entitled GTOP (Global Tropospheric Ozone Programme) with the purpose of stimulating measurements of ozone in the troposphere.

- Where is IGAC going?
  - Links with SPARC including a new group with A. R. Ravishankara in charge to consider common issues related to atmospheric chemistry.
  - IGAC is currently producing a book concerned with findings over the last decade in a process of integration and synthesis. The following 5 Chapters will be produced in the year 2000:
    - Introduction
    - Biosphere/Atmosphere Interactions
    - Photochemistry/Oxidising Capacity
    - Aerosols
    - Synthesis