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STRATOSPHERIC PROCESSES AND THEIR ROLE IN CLIMATE (SPARC)

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STRATOSPHERIC PROCESSES AND THEIR ROLE IN CLIMATE (SPARC)

(Submitted by the Co-chairs of the SPARC Scientific Steering Group)

This report summarizes the main recent developments within the SPARC Project and the WCRP/IGBP Cross-cutting Activity in Atmospheric Chemistry and Climate, including items and recommendations emerging from the seventeenth session of the SPARC Scientific Steering Group (SSG) held at the University of Kyoto, Japan, 26-30 October 2009. This session of the SPARC SSG was held in conjunction with the IGAC Scientific Steering Committee meeting.

Project objectives and approach

The SPARC Project facilitates research and highlights the importance of stratospheric and upper tropospheric processes in the climate system by:

(1) Being responsive to the need for scientific input to international scientific assessments for the benefit of WCRP, WMO/UNEP Ozone Assessment, IPCC, and space agencies.
(2) Identifying manageable projects where co-ordination at an international level can make a difference.
(3) Having clear deliverables for each project, such as scientific reviews which summarise the state of knowledge, facilitate and stimulate new directions for research.
(4) Anticipating, facilitating and stimulating new directions for research to address emerging issues.

The goals of the SPARC programme are encapsulated within three main themes: (1) detection, attribution, and prediction of stratospheric changes, (2) chemistry – climate interactions, and (3) stratosphere – troposphere dynamical coupling. In addition to activities within these themes, the SPARC programme includes a number of cross-cutting activities with specific foci. Responsibility for leading the WCRP/IGBP joint activity on Atmospheric Chemistry and Climate (AC&C) is shared between SPARC and the IGBP International Global Atmospheric Chemistry (IGAC) Project.

Upcoming SPARC reports

(a) *The SPARC CCMVal Report on the Evaluation of Chemistry-Climate Models*. Chemistry-climate models (CCMs) are key tools for the detection, attribution and prediction of the response of stratospheric ozone to ozone depleting substances and other factors (climate change, solar variability, volcanic eruptions, natural variability). It is therefore necessary to assess the confidence that can be placed in CCMs. The CCMVal report responds to this need by providing a comprehensive, timely assessment of the ability of CCMs to represent the stratospheric ozone layer, stratospheric climate and climate variability, and the coupled ozone-climate response to natural and anthropogenic forcings. The assessment will be based on the diagnostic metrics developed within the SPARC CCMVal activity, and will provide useful and timely information for the 2010 WMO/UNEP Ozone Assessment as well as for the IPCC AR5. The SPARC CCMVal Report is nearly finalized.

(b) *The Second SPARC Assessment of Upper Tropospheric and Stratospheric Water Vapour (WAVAS-2)*. This report will update the SPARC water vapour assessment of 2000. It will summarize new results over the past decade from various field experiments, laboratories and models. It will assess the value and the accuracy of recent measurements and give new recommendations and guidelines for future research on UTS water vapour. Author and Planning meetings were held in 2009. Chapter meetings will be held in spring and summer of 2010 with a final review meeting to be held near the end of 2010. The expected publication date for the report is mid 2011.

The 17th Session of the SPARC Scientific Steering Group (SSG)

The 17th Session of the SPARC Scientific Steering Group (SSG) was held concurrently with the IGAC Scientific Steering Committee (SSC) meeting during the period 26-30 October, 2009 at the University of Kyoto. These meetings were immediately preceded by a local workshop, jointly sponsored by the Japanese SPARC and IGAC communities. This workshop was well attended and featured invited and contributed talks from the Japanese and international SPARC and IGAC communities as well as an excellent poster session.

In a one-day joint session the SPARC SSG and IGAC SSC reviewed progress on activities of common interest and explored areas where closer interaction and collaboration is desirable. In the general discussion it was evident that both SPARC and IGAC and their parent organisations (WCRP and IGBP) have recognised the need to embrace new perspectives and objectives. A key principle for success in programmatic developments is that organisational forms and structures must serve the functional requirements that evolve from the combined demands of the science and societal needs. These are continuously evolving and pose ongoing challenges for program development. A more detailed report on the SPARC SSG meeting and associated and emerging interactions with IGAC is included in SPARC Newsletter No. 34 available on-line at http://www.atmosp.physics.utoronto.ca/SPARC/index.html.

SPARC thematic activities

Chemistry – climate Interactions

(Contributions to Assessments, New Initiatives, Cross-cutting SPARC/IGAC Activities)

(a) CCMVal

A major focus of the SPARC CCMVal Activity is supporting the WMO/UNEP Ozone Assessments (2006, 2010) and the IPCC Assessment Reports (AR4, AR5) through coordinated CCM simulations for the recent past and present and projections for the remainder of the 21st century, accompanied by a diagnostic evaluation. Output from CCMVal-1 simulations has been collected in the central CCMVal database at the British Atmospheric Data Centre (BADC). Evaluation diagnostics have been obtained from various observational datasets. Currently around 60 CCMVal Collaborators are working with CCMVal output, and numerous CCMVal-1 papers have been published. Multi-model evaluations have revealed important differences among models and have demonstrated the advantage of a multi-model evaluation strategy, but the results of CCMVal-1 were somewhat unsatisfying from an assessment perspective. This led to an effort to develop quantitative performance metrics. The CCMVal metrics development has come at an opportune time to mesh with other similar efforts within the WCRP and the IPCC. CCMVal-2 is now well underway with eighteen models participating. Most simulations extended throughout the 21st century to allow systematic multi-model ozone projections and an analysis of the causes of these projected changes throughout the 21st century. As noted above a major undertaking of CCMVal in the past year has been production of the forthcoming SPARC CCMVal Report on Evaluation of CCMs.

(b) Ozone Data Base for CMIP5

The WCRP JSC/CLIVAR Working Group on Coupled Modelling (WGCM) facilitates intercomparison and evaluation of coupled ocean/atmosphere/land models (CGCMs) for climate studies and coordinates modelling support for the IPCC assessments. SPARC interactions with WGCM have increased in recent years. SPARC SSG member Veronika Eyring is also a member of WGCM and this facilitates a liaison between AC&C, SPARC and WGCM activities. A recent outcome of this interaction is the inclusion of the AC&C / SPARC Ozone Databases in the forcing data sets for CMIP5. The Ozone Databases have been constructed to provide a merged tropospheric / stratospheric ozone time series from 1850 to 2100 for use in CMIP5 simulations

without interactive chemistry. The future database (2010-2099) utilizes a multi-model CCMVal-2 mean for the stratosphere combined with tropospheric ozone projected using the Community Atmosphere Model (CAM) version 3.5.

(c) SPARC Data Initiative

The SSG endorsed development of an initiative to address a number of outstanding issues highlighted by the CCMVal activity in regard to the availability and use of chemical observational data sets. While a variety of such data sets are available, it is not necessarily known which data set is most reliable for a particular application. Conflicting results may be obtained when comparing models to different data sets. In the context of CCMVal, scores for a specific diagnostic are dependent on the data set used, making comparisons less meaningful and increasing uncertainties in assessments. Similar difficulties were manifest in regard to comparing and evaluating middle atmosphere model climatologies in the context of the GRIPS project and led to the production of the SPARC Intercomparison of Middle Atmosphere Climatologies (SPARC Report No. 3). There is a need for a similar assessment of the available data sets for chemical trace gases. The proposed report and associated climatologies will offer guidance for the use of chemical trace gas observations from space based instruments. It will involve the following steps: (a) establishing a data portal for chemical observations in collaboration with the space agencies and assessing the state of data availability; (b) compiling climatologies of chemical trace gases (e.g. zonal means, variability, seasonal evolution, annual means) in collaboration with the instrument PIs; (c) creating a detailed inter-comparison of these climatologies, summarising useful information and highlighting differences between the data sets. The initial action will be to hold a workshop in early 2010 to assemble the author team, define the report structure, and address issues involved in coordination of the data initiative. The target completion date for the report is May 2012.

(d) Atmospheric Chemistry and Climate (AC&C) Cross-cutting activities

Being a joint initiative between the WCRP and IGBP with IGAC and SPARC having joint responsibility for it, AC&C is jointly chaired by representatives of the SPARC and IGAC research communities. A. Ravishankara, founding Co-Chair, has stepped down and Martyn Chipperfield has replaced him as the SPARC Co-Chair. Phil Rasch remains as the Co-Chair for IGAC. Phase I of AC&C involves a number of modelling activities: (1) 20-year hindcast; (2) determination of what controls the vertical distribution of species in the upper troposphere; (3) cloud-chemistry interactions; and (4) sensitivities and uncertainties of future scenarios. The Phase I modelling activities interface with CCMVal in a number of ways. For example for 'whole atmosphere' model hindcasts, the chemistry needs to build on recent CCMVal REF-B1 simulations (1960-2005). Full chemistry specifications need to include stratospheric forcings and boundary conditions.

Detection, Attribution and Prediction
(Seasonal and decadal prediction)

Links between the SPARC and CLIVAR modelling activities have been noted above in the context of interactions between CCMVal and WGCM. Another area of emerging links is the seasonal and decadal prediction activities of the CLIVAR Working Group on Seasonal to Interannual Prediction (WGSIP). A presentation on WGSIP activities was given by Adam Scaife at the SPARC SSG meeting. This presentation and ensuing discussion identified a number of entry points for collaboration in joint modelling and analysis activities relating to seasonal and decadal prediction. Steps are being taken to encourage and facilitate interactions with WGSIP on these topics. The WGSIP Climate-system Historical Forecast Project (CHFP) will benefit from SPARC participation. A stratospheric extension of the CHFP is now being undertaken by WGSIP. This will involve hindcasts parallel to the WGSIP-CHFP with extended models using the same initial ocean data. SPARC contributions to key diagnostic projects utilizing model output is one of the foci for joint activities.

Stratosphere – troposphere dynamical coupling

(Developments within the SPARC DynVar Activity)

The recognition that key elements of interannual to decadal variability are strongly influenced by stratospheric processes has come about largely through research activities on stratosphere-troposphere coupling within the SPARC community. Currently the SPARC DynVar Activity provides foci for research on this theme. A substantial amount of the applied and theoretical research that was proposed for DynVar has been done by different groups in the past two years. Paul Kushner has stepped down as coordinator for the DynVar activity. E. Manzini has taken over this responsibility and has undertaken a restructuring of the DynVar activity to facilitate future efforts. An optimal way for DynVar to pursue its goals is to exploit the data sets that will be produced for assessment purposes, such as the high-top CMIP5 runs, and the stratospheric seasonal prediction hindcasts produced as part of WGSIP's Stratosphere Historical Forecast Project (SHFP) with high-top models. This will mesh with the aforementioned SPARC-CLIVAR connections focused on the role of the stratosphere in weather and climate predictability. A DynVar workshop is being planned for late 2010, likely in Boulder, CO, USA.

Cross-Cutting Activities, Initiatives and Issues

The Polar Initiative

The role of the polar regions in climate was raised by SPARC at the 2008 meeting of the WCRP JSC as an important cross-cutting issue for the WCRP in the near future. The JSC endorsed an effort aimed at using IPY results and other available knowledge and capacity to undertake an assessment of polar predictability at various time scales. Follow-on discussions between SPARC, JPS, and other WCRP projects have suggested an overall focus on the interaction of polar regions with lower latitudes, processes that affect the poles, and interactions between various components of the climate system in the polar regions. The initiative will take advantage of opportunities such as the revolution in ocean in situ observations and their assimilation, IPY data, and the possibility of an International Polar Decade (IPD). A scoping workshop is planned to exchange thoughts and information between various WCRP communities on polar prediction. T. Shepherd has agreed to serve as chair of the Scientific Organizing Committee. The target date for the workshop is late 2010. A Polar Initiative web site is being developed. It will be linked to the SPARC web site and maintained by the SPARC Office.

Gravity-wave Initiative

A major outcome of the 2008 workshop that was held to reactivate the SPARC Gravity-Wave Initiative (see the report in SPARC Newsletter No. 31) has been the preparation of a review paper*: "A Review of Recent Developments on Gravity Wave Effects in Climate Models and the Global Distribution of Gravity Wave Momentum Flux"*, which has been submitted to the Quarterly Journal of the Royal Meteorological Society. A number of key issues remain to be explored further and understood better. This has motivated additional new activities for the coming two years. *The Gravity Wave Project - An International Team for Merging Space-Based Observational Constraints for Gravity Wave Parameterizations in Climate Models* has been funded by the International Space Science Institute (ISSI). The goal of the project is to create a self-consistent data set of atmospheric gravity wave momentum fluxes and propagation properties suitable for climate and weather forecasting applications. The SPARC SSG has endorsed this project. Complementary to this new activity a Chapman Conference proposal has been submitted to the American Geophysical Union for a conference entitled *"Atmospheric Gravity Waves and their Effects on the General Circulation and Climate"*. There have been recent advances on this topic and the community is growing. The meeting would provide a chance for this community to come together to assess the recent results and forge the interdisciplinary collaborations that are needed to address the current issues.

Geo-engineering

Because of the potential inadequacy of global CO2 emission reductions, the need to look to geo-engineering to mitigate the surface warming due to increasing atmospheric CO2 has become a topic of serious discussion in the broader scientific community. This has motivated the forthcoming comprehensive Royal Society report on geo-engineering. The question of what role SPARC should play in the debate on geo-engineering (specifically in response to the Crutzen proposal) was first raised at the 2007 SSG meeting in Bremen and discussed further at the 2008 meeting of the WCRP JSC. However the role of the WCRP, and SPARC in particular, in the debate has remained largely unresolved. In the meantime, recent modelling results are relevant to the Crutzen proposal to introduce and maintain an artificial stratospheric aerosol layer as a means of offsetting the surface warming associated with increasing CO2. The aerosol size distribution is important in determining any such effect and related impacts. The validity of the particle size assumptions in the Crutzen proposal and some other initial modelling studies have been questioned in more recent studies that account for microphysical processes in the evolution of the aerosol size distribution. Formation of larger particles than after volcanic eruptions may accompany continuous SO2 emissions in the stratosphere. Potential repercussions include a warmer tropopause, moister stratosphere, changed dynamics, and more ozone loss. As government interest in geo-engineering is growing rapidly, it is vital for organisations such as SPARC to facilitate research that clarifies the benefits, dangers, unintended consequences, feasibility, and other scientific aspects of the issues, so that policy-makers can make well-informed decisions.

SPARC Office Activities and Funding Status

During the past year the SPARC-IPY activity has wrapped up. The SPARC Office operational activities in the last year have included publication of newsletters (Nos.33 and 34), providing local organizational assistance and coordinating travel funding for SPARC workshops and the SPARC SSG meeting, and ongoing interaction and cooperation with the SPARC SSG and activity leaders, the WCRP JPS, and other WCRP projects and working groups on a range of issues and actions.

The mandate of the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) has recently been extended for one year, until the end of 2011, but there is no indication that there will be a further extension. Therefore its operation is expected to wrap up in early 2012. The largest portion of the cash support for the SPARC IPO is provided by CFCAS. This is matched by cash and in-kind contributions from the Canadian Space Agency, Environment Canada, and the University of Toronto. An application to CFCAS for extension of support for the SPARC IPO through December 31, 2011 has been approved. However there are currently no prospective Canadian funding sources to replace the CFCAS support beyond the end of its mandate. In the absence of this support it will not be possible to maintain the SPARC IPO in its current location after 2011. Alternative locations and sources of support are being considered. All scenarios for the longer-term operation of the SPARC IPO envisage a minimum funding commitment of three to five years duration beyond 2011. The anticipated evolution of the WCRP programmatic structure in this time period is likely to be a factor in obtaining support for continued operation of the SPARC IPO. The likely evolution of SPARC into a new project with a broader mandate in the next five years may help to attract longer-term commitments to support of the SPARC IPO.

The Future of SPARC: Long-term Structure, Functions, Themes

The evolution of the SPARC Project over the past decade has laid a solid foundation for fulfilling a significant role in the WCRP future structure and functions as discussed at the 2009 JSC meeting under the agenda item on the long-term evolution of the WCRP. Although SPARC historical focus has been on stratospheric processes, through its emphasis on comprehensive “whole-atmosphere” modelling, complemented by process oriented diagnostic analysis, theoretical and laboratory studies, SPARC has contributed significantly to the current understanding of the close dynamical and physical/chemical coupling between the stratosphere and troposphere. Recognition that these

interactions occur on a wide range of spatial and temporal scales has motivated DynVar activity to devote more attention to seasonal and decadal -scale prediction. This will eventually also include shorter time scale effects, for example the role of the stratosphere in short to medium range prediction. Future activities may include initiatives to improve understanding of the coupling between stratosphere and troposphere in such prominent tropospheric circulation systems as the monsoons. SPARC has maintained strong interactions with both the observational community, particularly with space agencies, and the major modelling and analysis centres.

The space agencies (NASA, ESA, JAXA, CSA) routinely send representatives to SPARC SSG meetings and support SPARC activities and infrastructure (SPARC Data Center, supported by NASA; SPARC Office partial support by the CSA). Interactions with SPARC are valued by the space agencies as ways of ensuring strong science input and underpinning for their programmes and missions. The archive of global analyses that was compiled through the SPARC-IPY activity is an example of a result that came about through direct and ongoing interactions between the SPARC Data Assimilation Working Group and the major operational prediction and analysis centres. These direct interactions are complementary to broader WCRP/WMO interactions in the context of the observational (WOAP) and modelling panels and working groups (WGCM, WGNE). SPARC continues to encourage stronger ties with the modelling working groups and WOAP through membership and participation. However, direct interactions with the space agencies and major modelling and analysis centres have been fundamental to the success of SPARC activities over the past decade and it is therefore vital to maintain and strengthen them. Interactions with IGAC through the AC&C activity are being broadened to include research activities that have emerged from SPARC initiatives on the role of a range of stratospheric and tropospheric processes (for example deep moist convection and long-range transport) in the structure (physical and chemical) and evolution of the upper troposphere and lower stratosphere regions.

The major input that SPARC provides to the WMO/UNEP Ozone Assessment through the CCMVal Activity and support to the IPCC Assessments through both CCMVal and DynVar Activities are examples of ongoing applications emerging from SPARC initiatives. SPARC attempts to encourage outreach and capacity building through the efforts of its SSG (which currently includes members from South Africa, India, Japan, New Zealand, North America and Europe) and activity leaders as well as by facilitating participation in SPARC workshops and conferences (the SPARC General Assembly in 2008 included participants from Africa, Asia, Latin America as well as North America and Europe).