Annual Report

SPARC 2015

SPARC
Stratosphere-troposphere
Processes And their Role in Climate

WCRP World Climate Research Programme

WMO

UNESCO

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ICSU
International Council for Science

SPARC
Annual Report
2015

prepared by:
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Overview from the Co-Chairs

The year 2015 marked the release of a new SPARC Implementation Plan, replacing our previous 2009 plan. This document was more than a year in the making, and it included input from not only the SPARC SSG, but also activity leaders and participants, and many others in the community. The themes and activities outlined in the new plan reflect SPARC's evolution to include atmospheric processes more generally, rather than our past focus on stratospheric processes. We've termed this a "whole atmosphere" approach, with new themes of Atmospheric Dynamics and Predictability, Chemistry and Climate, and Long-Term Records for Climate Understanding. We invite you to read the new plan available at the SPARC webpage:
www.sparc-climate.org/publications/implementation-plans

While this plan was developed for a five-year horizon, we consider it a living document, and input from the community is of course valued at anytime.

In 2015, SPARC co-sponsored several cross-cutting workshops that involved the full breadth of WCRP scientific expertise and close engagement with the WCRP Grand Challenges, including: Storm Tracks (Grindelwald in August), Tropical Composition and Transport (Boulder in July), Width of the Tropical Belt (Santa Fe in July), Chemical and Physical Processes in the Climate System (Boulder in November). In addition, SPARC scientists contributed to the definition of several CMIP6 MIPs. 2015 also marked the formation of several new SPARC activities, which you can read about in the pages that follow. You can also read about several of our existing activities that have either accomplished their final goals in 2015 or are finishing reports early in 2016. The SSG encourages all the SPARC activities to formulate clear short-term deliverables, and either close their chapters in this way or/and renew their goals and leadership every few years in order to remain fresh and relevant.

Participants of the 23rd SPARC Scientific Steering Group meeting held at NCAR, Boulder, Colorado, USA, in November 2016.

We also note here a change in leadership, with the end of 2015 marking the end of Joan's term as SPARC SSG Co-Chair, while January 2016 marks the beginning of Judith Perlwitz's new term as Co-Chair with Neil. Thanks to everyone in the SPARC community and other WCRP colleagues for your time, energy, and enthusiasm that continue to make SPARC the vibrant project that it is.

A Word from the Project Office

Once again 2015 was a very busy and productive year at the SPARC Office. We helped organise and fund almost 20 workshops and meetings, arranging travel, providing website support, and more. The very first workshop of the year was one dedicated to Capacity Development and was instrumental in bringing together shared knowledge on the topic, which was then used to develop the first SPARC Capacity Development Strategy, which the SPARC Office helped to produce. This strategy has been developed in parallel to the new SPARC Implementation Plan, which will serve to guide the focus of SPARC research in the coming years and to which the SPARC Office also contributed.

The SPARC Office has seen a small change in staff, with Fiona taking over from Johannes as office director in February. Johannes continues in the SPARC Office informally as project scientist. Petra (Office Manager) and Carolin (Communications Officer) also remain to support the SPARC community through their work at the SPARC Office. Early in the year, funding was secured for the continuation of the SPARC Office at the ETH Zurich until the end of 2017, and a new contract between all sponsors has been signed.

We continued efforts to ensure smooth communication within the SPARC community and beyond, through our website, eNews bulletins, the biannual SPARC newsletter, as well as by representing SPARC at various national and international meetings. A lot of this has been made easier through the development of an extensive community database, which we hope to expand further in future. The SPARC Office has also contributed to SPARC science activities, with Fiona being involved in the Ozone Profile Trends – Phase-II (SI2N) activity, Atmospheric Composition and the Asian Monsoon (ACAM), and Chemistry-Climate Model Initiative (CCMI). Johannes also recently completed work on a book chapter about the history of ozone measurements in Switzerland and the vital contribution they have made to international ozone research.

The SPARC Office would warmly like to acknowledge the support of ETH Zurich, FOEN, the Federal Office of Meteorology and Climatology (MeteoSwiss), the Swiss National Science Foundation (SNF), and WCRP, as well as the excellent collaboration and support of the WCRP Joint Planning Staff in Geneva.

The SPARC Office Team

Workshops and Meetings held in 2015

10 – 11 January
SPARC Capacity Development Workshop
Granada, Spain

12 – 13 January
Regional Workshop on the Role of the Stratosphere in Climate Variability and Prediction
Granada, Spain

13 – 16 January
22nd SPARC Scientific Steering Group Meeting
Granada, Spain

16 – 18 March
QBO Modelling and Reanalyses Workshop
Victoria, British Columbia, Canada

9 – 10 April
Temperature Trends Workshop
Victoria, British Columbia, Canada

27 April- 1 May
SSiRC Scientific Steering Group Meeting
Bern, Switzerland

8 – 12 June
2nd ACAM Workshop and 1st ACAM Training School
Bangkok, Thailand

20 – 23 July
Composition and Transport in the Tropical Troposphere and Lower Stratosphere Meeting
Boulder, Colorado, USA

26 – 31 July
AGU Chapman Conference - The Width of the Tropics: Climate Variations and their Impacts
Sante Fe, New Mexico, USA

24 – 28 August
SPARC Workshop on Storm Tracks
Grindelwald, Switzerland

15 – 17 September
8th Atmospheric Limb Workshop
Gothenburg, Sweden

28 September – 2 October
ISSI Meeting on PSCs
Bern, Switzerland

5 – 6 October
Workshop on "Solving the Mystery of Carbon Tetrachloride"
Zurich, Switzerland

7 – 9 October
Joint AEROCOM-CCMI Workshop
Frascati, Italy

12 – 16 October
SPARC S-RIP and DA Workshops 2015
Paris, France

4 – 6 November
SOLARIS-HEPPA Working Group Meeting
Boulder, Colorado, USA

9 – 10 November
SPARC Regional Workshop on Chemical and Physical Processes in the Climate System
Boulder, Colorado, USA

10 – 13 November
23rd SPARC Scientific Steering Group Meeting
Boulder, Colorado, USA

8 – 11 December
WAVAS-II Meeting
Boulder, Colorado, USA

SPARC Activity Report Summaries

Atmospheric Composition and the Asian Monsoon (ACAM)

Activity Leaders: Laura Pan and James Crawford

Achievements for 2015

The 2nd ACAM workshop took place from 8-10 June in Bangkok, Thailand, with participation from approximately 170 scientists from 22 countries. The workshop was an important milestone for ACAM both in its scientific scope and community formation. Scientifically, the workshop brought together diverse expertise ranging from emissions, air quality measurements and modelling to aerosol-cloud interaction, as well as dynamics and transport by the monsoon. From a community building perspective, the workshop provided the first opportunity for the four ACAM working groups to have in-person discussions for their activities.

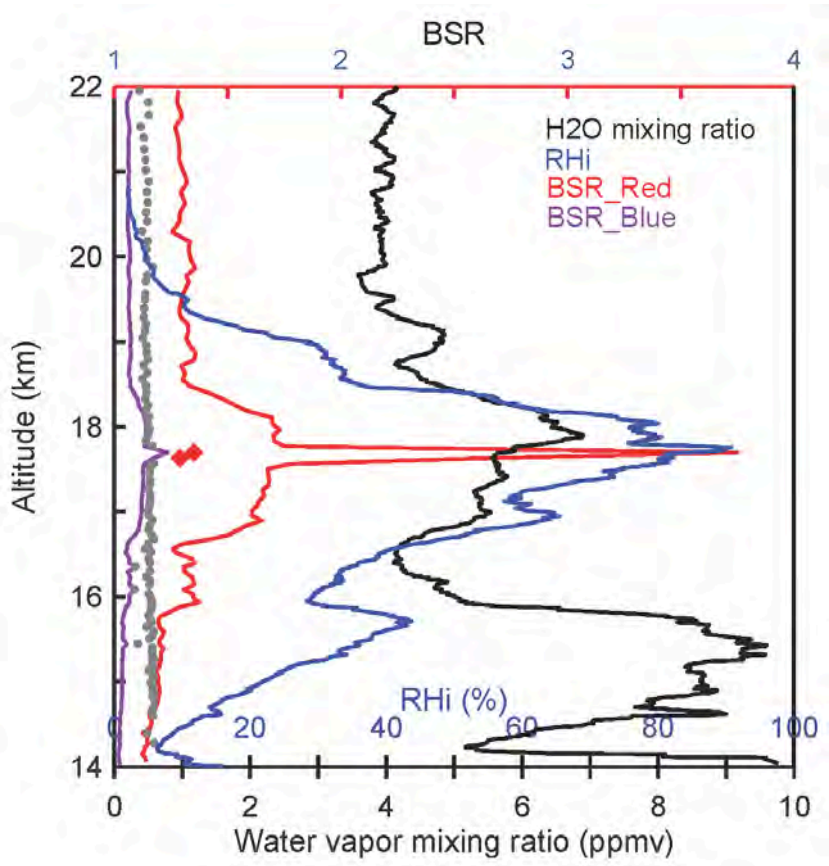

Figure 1: New balloon-borne observations of water vapour, relative humidity, aerosols, and cirrus cloud particles over the Tibetan plateau during the Asian Summer Monsoon season. This example sounding was made on 19 August 2014 (unpublished data presented by Jianchun Bian at the 2nd ACAM workshop). The UTLS profiles of water vapour mixing ratio (black curve) and relative humidity (blue) indicate multiple layers between altitudes of 14-20km. In particular, the layer between 16-19km contains a broad aerosol layer and a narrow cirrus cloud layer at 17.7km where the relative humidity is near 100%, both indicated by the backscatter ratio (BSR) of 940nm (red) from COBALD. The identification is from the colour index of 940nm over 455nm (grey dots and red diamonds represent aerosol and cirrus, respectively; colour index values near 5 indicate aerosol particles and values above 10 are associated with cirrus particles).

The 1st ACAM training school for Asian regional students and early career researchers was organised in conjunction with the Bangkok workshop. The theme of the training school was "Satellite and Model Data use for Aerosols and Air Quality" and was organized by the ACAM Training working group. 33 students from 12 Asian countries participated in the training school, with nine volunteer lecturers.

Before and during the workshop, the four ACAM working groups hosted discussions to facilitate collaborations in terms of sharing of Monsoon regional data, coordinating campaign activities, interactions with the modelling community (including CCMI and AeroCom), and planning of future training schools.

In particular, the discussion of the Field Campaigns working group helped to connect a number of field studies funded by different countries/organizations, including the airborne 'Oxidation Mechanism Observations' (OMO) (DLR/Germany), the balloon measurement campaign of the Asian Tropopause Aerosol Layer (BATAL) (NASA Langley/USA and NARL/India), the Sounding Water vapour, Ozone, and Particle (SWOP) (IAP/China) and possible collaborations with the upcoming StratoClim campaign.

Plans for the Coming Year

A small workshop on the UTLS response to the Asian Monsoon is being organised from 6-9 March 2016 in Boulder, Colorado, USA. The goal of the workshop is to bring together the scientists already engaged in the research of dynamics, chemistry, and microphysics in the Asian Monsoon UTLS. Discussions will revolve around the current state of the science and outstanding issues for upcoming observational studies. A possible review paper or report is in discussion.

The ACAM community will continue to facilitate field study collaborations, especially for the 2016 StratoClim campaign time period.

ACAM plans to have its 3rd workshop in 2017. In 2016, the community building effort will continue through various conferences, for example, through an ACAM-themed special session at the EGU (April 2016) and at the AOGS (October 2016).

The ACAM activity formation committee (AFC) will continue to develop a working model for ACAM leadership. The current AFC, which has served the purpose of leading the workshop planning and working group activities, will likely transition into a scientific steering group in the coming year.

Activity website: http://www2.acom.ucar.edu/acam

IGAC/SPARC Chemistry-Climate Model Initiative (CCMI)

Activity Leaders: Jean-François Lamarque and Michaela Hegglin

Achievements for 2015

Over the past year, the IGAC/SPARC Chemistry-Climate Model Initiative (CCMI) has reached major milestones of its time plan:

In collaboration with AeroCom, CCMI developed a proposal for the Aerosols and Chemistry Model Intercomparison Project (AerChemMIP), which was officially approved as a MIP by the CMIP panel in August 2015. AerChemMIP will contribute to CMIP6 by (1) diagnosing forcings and feedbacks involving near-term climate forcers (*e.g.*, tropospheric aerosols, tropospheric ozone precursors, and methane) and chemically reactive well-mixed greenhouse gases (*e.g.*, N_2O, methane, and halocarbons), including the impacts from changes in stratospheric ozone; (2) documenting and understanding the past and potential future evolution of the chemical composition of the atmosphere; and (3) estimating the global-to-regional climate responses to these changes. AerChemMIP has specified simulations and a set of diagnostics that will help meet these goals.

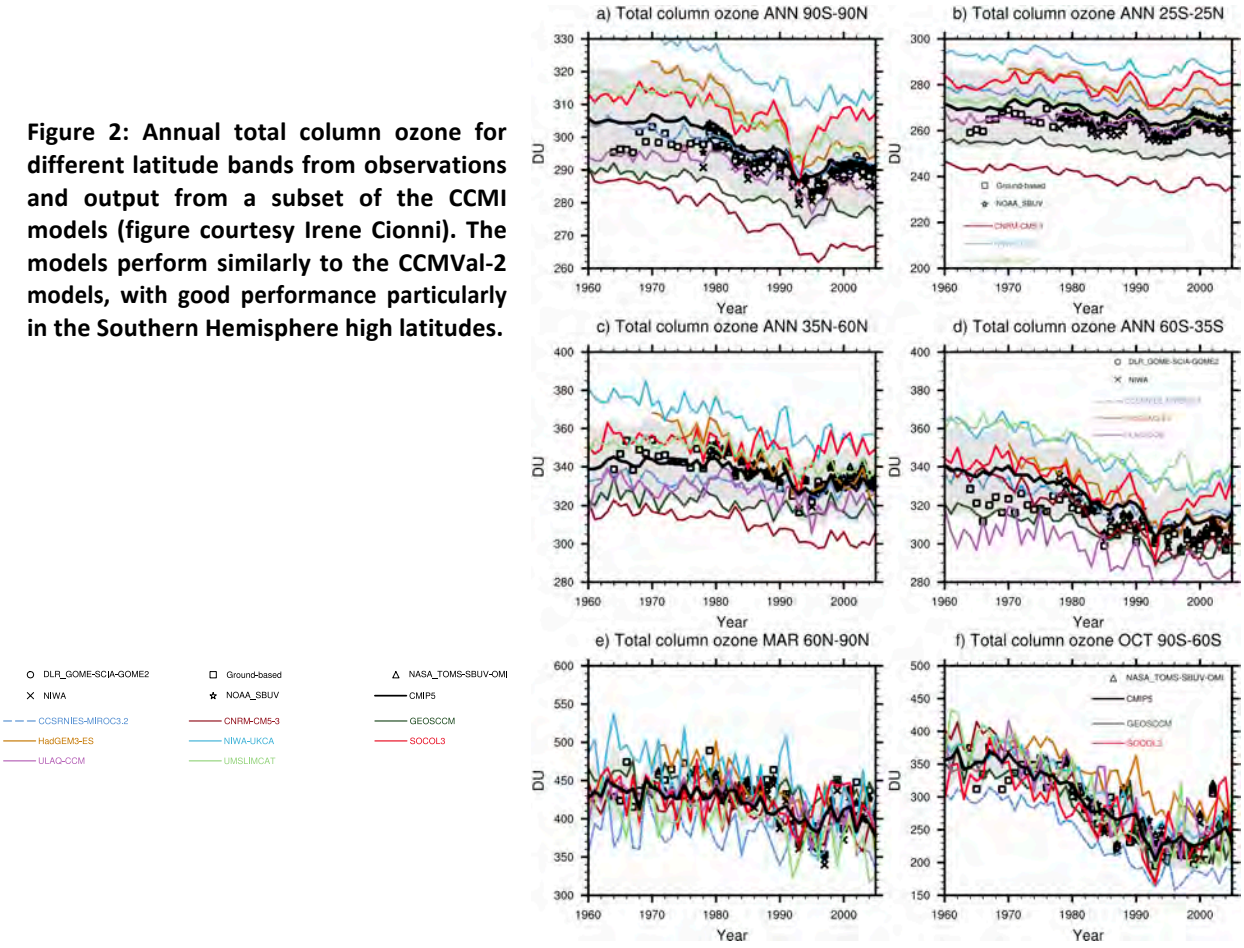

Figure 2: Annual total column ozone for different latitude bands from observations and output from a subset of the CCMI models (figure courtesy Irene Cionni). The models perform similarly to the CCMVal-2 models, with good performance particularly in the Southern Hemisphere high latitudes.

CCMI contributed to the coordination and formulation of a proposed new WCRP Grand Challenge on Biogeochemical Forcings and Feedbacks, with a meeting held on 21 September at the University of Reading, UK. A white paper on the new WCRP GC is in preparation.

The CCMI modellers contributed very significantly to this year's achievements, working on finishing the CCMI phase-1 model simulations and uploading more than 50TB of output to the BADC CCMI data archive (http://badc.nerc.ac.uk/home/index.html). CCMI researchers have now begun using these data to evaluate model performance, relating these issues to simulated radiative, physical, and chemical processes, and thereby providing feedback in terms of model development.

The 2015 CCMI Science Workshop was held from 7-9 October 2015 in Frascati, Italy. The first day of the workshop was joint with AeroCom, with around 200 participants. This part of the workshop introduced AerChemMIP to the wider science community, and included a discussion of planned emission and forcing databases. The second and third days of the CCMI meeting were hosted by the Italian National Research Council's Institute of Atmospheric Sciences and Climate (CNR-ISAC), with over 130 participants. This part of the workshop was dedicated to highlighting and fostering links between CCMI and other international activities (WMO/UNEP Ozone Assessment, TOAR, and ACAM), updating the CCMI community on recent model developments and the status of the CCMI-1 simulations, as well as presenting and discussing new science results with relevance to chemistry-climate coupling and process-oriented model evaluation of the CCMI-1 simulations. The workshop was preceded by a Scientific Steering Committee (SSC) meeting on the evening of 6 October 2015. Reports for this workshop can be found both in the SPARC newsletter (www.sparc-climate.org/f6_Publications/SPARCnewsletter_Jan2016_Web.pdf) and the IGAC news (www.igacproject.org/NewsletterArchives/Issue_55_AugSep_2015.pdf).

CCMI has established three focus groups on (1) tropospheric OH and ozone budgets, (2) specified dynamics simulations, and (3) ocean-atmosphere coupling in CCMI models.

Plans for the Coming Year

Over the course of 2016 more CCMI phase-1 simulations will be contributed to the BADC and ESGF archives by the different CCMI modelling groups.

Scientific evaluations of the CCMI phase-1 simulations are currently ongoing and are expected to peak in summer 2016 with publications of results in a joint special issue between the online journals ACP/ESSD/AMT/GMD (see www.atmos-chem-phys.net/special_issue812.html).

CCMI will write an overview paper on phase-1 of CCMI, which will also appear in the joint special issue.

Over the coming year, CCMI will define its new science plan for CCMI phase-2. This will include the definition of CCMI phase-2 model simulations, which will support efforts within AerChemMIP, thereby strengthening CCMI links to the AeroCom community.

CCMI will not hold a workshop in 2016, but will instead have a strong presence at the 2016 IGAC meeting in Breckenridge.

Activity Website: www.met.reading.ac.uk/ccmi

Data Assimilation Working Group

Activity Leader: Quentin Errera

Achievements for 2015

The goal of the SPARC Data Assimilation Working Group (DAWG) is to sustain a forum around the SPARC themes for data assimilators, providers, users, and modellers. This year, a workshop was held at the Pierre and Marie Curie University (Paris, France) together with S-RIP. The first two days of the week were dedicated to a S-RIP progress meeting, while days 4 and 5 were dedicated to DAWG activities. Day 3 was a joint workshop between S-RIP and DAWG.

Several interesting results were presented at the workshop, in particular results from MERRA2, the latest reanalysis produced by NASA. Figure 3 compares the potential vorticity from MERRA and MERRA2 above the North Pole and shows how the new cubed sphere grid of MERRA2 provides a much improved better representation of the PV field in the Polar Regions.

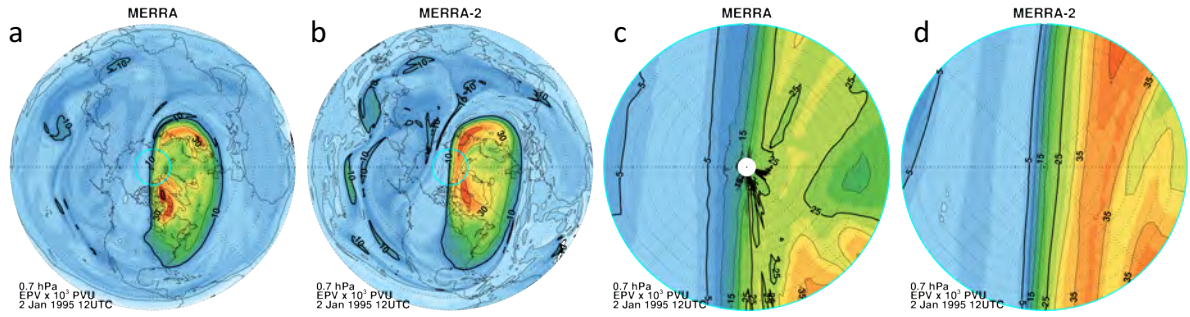

Figure 3: Potential vorticity over the Northern Hemisphere (a) and (b) for the MERRA (a and c) and MERRA-2 (b and d) reanalyses. (c) and (d) show zooms for latitudes >80°N).

DAWG also sent a white paper to the NASA decadal survey on Earth Observations with recommendations regarding future satellite limb sounding observations. DAWG advocates future missions for monitoring middle atmospheric ozone and related trace gases with global coverage on a daily basis, including day and night time observations and with a vertical resolution of 1-2km in the lower stratosphere and 2-4km in the upper troposphere and mesosphere.

Plans for the Coming Year

DAWG will again organise a joint workshop with S-RIP. This workshop will take place at the Inn in Laurel Point, Victoria, BC, Canada, from 17-19 October 2016. Themes are not decided yet but will likely be: (1) the possible looking 'gap' in satellite limb observations, (2) model representation of the upper stratosphere and mesosphere, and (3) latest results from S-RIP.

Activity Website: www.sparc-climate.org/activities/data-assimilation

Dynamical Variability (DynVar)

Activity Leaders: Elisa Manzini and Edwin Gerber

Achievements for 2015

Over the past years DynVar has initiated a debate within the modelling and analysis communities interested in atmospheric dynamics on how best to participate in the next phase of CMIP, CMIP6. The result of these discussions lead to the request that additional diagnostics be output from the core CMIP6 experiments and a few specific additional MIPs, rather than proposing a new set of experiments on atmospheric dynamics. Over the past year DynVar finalized the scientific motivation and associated data request constituting the diagnostic DynVarMIP, which was submitted to CMIP6. DynVarMIP proposes a set of diagnostics to enable a mechanistic approach to confront model biases and understand the underlying causes behind circulation changes. DynVarMIP primarily addresses key CMIP6 science questions on the origin and consequences of systematic models biases in the context of atmospheric dynamics.

After a few rounds of reviews, DynVarMIP was endorsed by CMIP6 in the middle of 2015. This endorsement means that the additional model output requested by DynVarMIP will be archived on the Earth System Federation Grid (ESFG). In addition, 12 modelling centres have planned to provide the DynVarMIP variables. The latest version of DynVarMIP is at: www.sparcdynvar.org/storage/DynVarMIP.pdf.

Figure 4: Helsinki, location of the upcoming DynVar workshop being held from 6-10 June 2016.

Plans for the Coming Year

We are planning to write a manuscript on DynVarMIP (motivation and data request description, rather than results) to contribute to the CMIP6-endorsed special issue in Geoscientific Model Development.

A major activity in the next year will be the DynVar workshop being held in Helsinki, Finland, and kindly hosted by Alexey Karpechko, at the Finnish Meteorological Institute. The objective of the workshop is to reinforce connections between the modelling centres involved in DynVarMIP and the wider research community interested in atmospheric dynamics, so as to make effective use of the DynVarMIP data request. Through this workshop and other activities we invite the community to analyse the CMIP6 experiments and encourage synthesis papers. As workshop deliverable, we aim at drafting a plan for such key papers.

Activity Website: www.sparcdynvar.org

Gravity Waves

Activity Leaders: Joan Alexander and Kaoru Sato

Achievements for 2015

Several papers arising from our focused study group on "Gravity Wave Sources and Forces" co-sponsored by SPARC and the International Space Science Institute (ISSI) have appeared or are in press. Scheffler and Pulido (2015) examined the role of non-orographic gravity waves in the timing of Southern Hemisphere stratosphere final warming. Sato and Nomoto (2015) examined the dynamics of planetary-wave generation from instability caused by gravity wave drag. Plougonven *et al*. (2015) revealed an important role for moist physics in gravity wave emission from jets and fronts, and de la Cámara and Lott (2015) developed a new stochastic parameterization method appropriate for waves emitted by jets and fronts.

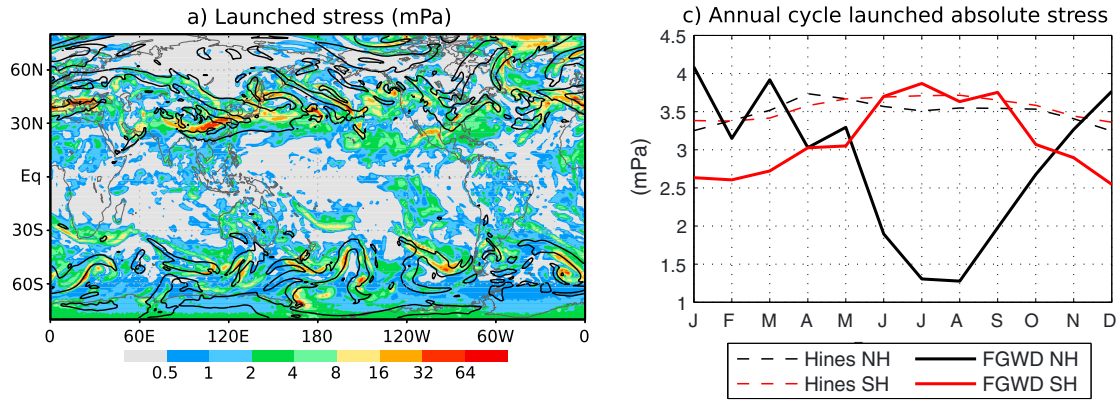

Figure 5: Stochastic gravity wave parameterizations can simulate realistic spatial and temporal intermittency in large amplitude gravity wave events and realistic stratospheric drag for improved climate simulations. The left panel (a) shows 600hPa temperature gradients (contours) from ERA-interim on 1 January 2010. Colours show parameterized frontal-launched gravity wave stress with the new stochastic parameterization. The right panel (c) shows the annual variations in midlatitude gravity wave stress (solid lines) and stress using a more traditional uniform source parameterization (dashed lines). Figure from de la Camara and Lott, 2015.

In other news, the activity leaders contributed to the diagnostic request list developed for the HighResMIP proposal to CMIP6 led by WGNE this year. The planned HighResMIP simulations, run at 0.25^{o} resolutions, will resolve a wide range of gravity waves and wave interactions with the larger-scale flow. A set of relatively simple zonal-mean diagnostic fields can be computed and saved at monthly-mean time intervals that will permit analysis of the representations of these waves and their effects on the general circulation. These diagnostic fields can be utilized in future momentum budget studies with participating models. Previous studies have indicated that the representation of gravity waves and their larger-scale flow interactions in models are quite sensitive to not only horizontal resolution but also vertical resolution, and also sensitive to model dissipation, both explicit diffusion and implicit dissipation associated with the numerical scheme. Studies utilizing these HiResMIP data may improve future simulations, in particular leading to reductions of common wind biases appearing in current climate simulations.

Plans for the Coming Year

The SPARC Gravity Wave activity has a history of leading focused workshops on the general topic of gravity wave effects on climate. The first of these was in 1996, with subsequent workshops every five years. We are busy planning for our next focused workshop, which is being held from 16-20 May 2016 at Pennsylvania State University. This next meeting, titled "Atmospheric Gravity Waves: Sources and Effects on Weather and Climate", will highlight the many recent developments in this growing field including results from high-resolution global modelling studies, new measurements and analysis methods, and the variety of effects on weather and climate processes. The meeting website is http://adapt.psu.edu/2016SPARCGWSymposium. The activity is also planning a session for the upcoming International Symposium on the Whole Atmosphere (ISWA) to be held in Tokyo, Japan, from 14-16 September 2016, with a focus on vertical and inter-hemispheric coupling of the middle atmosphere through interaction of gravity waves with large-scale waves and circulation.

Activity leaders are also working on a review paper summarizing how gravity waves affect climate. This new work puts the process of gravity wave-driving of the general circulation in the broader context of the many recent results that have detailed stratospheric circulation effects on climate.

Activity Website: www.sparc-climate.org/activities/gravity-waves

Trace Gas Climatologies (SPARC Data Initiative)

Activity Leaders: Michaela Hegglin and Susann Tegtmeier

Achievements for 2015

The SPARC Data Initiative is nearly ready for print, with all chapters including the Executive Summary and Introduction having been finalized. Much of the report is typeset and proofread, with the exception of some of the latter sections.

Access to the SPARC Data Initiative ozone data sets, which have been made available through the SPARC Data centre since the end of 2013, has been requested by 15 international scientists since the beginning of 2015. The SPARC Data Initiative CFC-11, CFC-12, HF, and SF_6 data sets have also recently been transferred to the SPARC Data Centre. Additionally, the four data sets have been made available through PANGAEA (doi:10.1594/PANGAEA.849223).

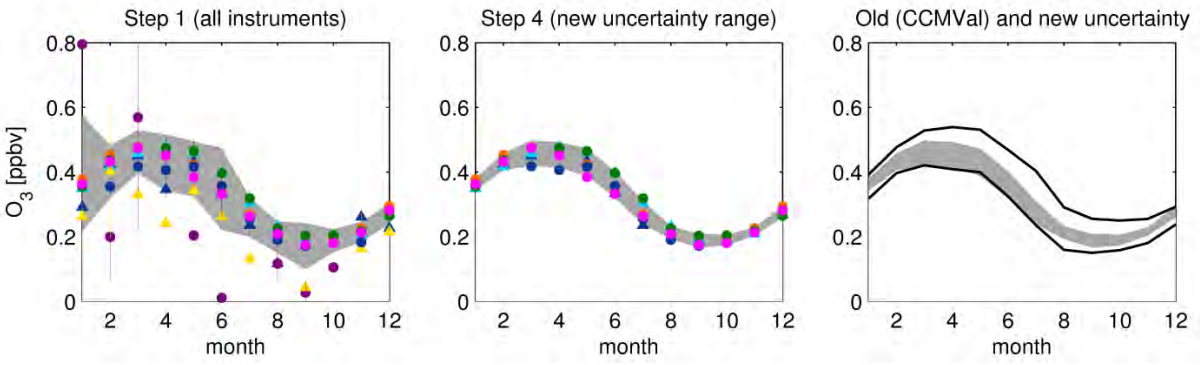

Figure 6: Implications for model-measurement intercomparison - Steps 1 and 4 of deriving the ozone seasonal cycle diagnostic for 40°N-60°N at 200hPa are shown. In step 1 all available data sets are included, while in step 4 outliers and data points strongly impacted by sampling have been removed. The uncertainty range (grey shading) is given for each month by the standard deviation over all selected data sets. In the right-most panel the old uncertainty range given in the CCMVal report (black lines) and the new uncertainty range (grey shading) are compared.

A manuscript on the evaluations of the SPARC Data Initiative CFC-11, CFC-12, HF, and SF_6 climatologies has been published in ESSDD, the scientific discussion forum of ESSD. (Tegtmeier, S., Hegglin, M. I., Anderson, J., Funke, B., Gille, J., Jones, A., Smith, L., von Clarmann, T., and Walker, K. A.: The SPARC Data Initiative: comparisons of CFC-11, CFC-12, HF and SF6 climatologies from international satellite limb sounders, Earth Syst. Sci. Data Discuss., 8, 759-808, doi:10.5194/essdd-8-759-2015, 2015.)

Plans for the Coming Year

After typesetting the remaining sections, the SPARC Data Initiative report will be published. All SPARC Data Initiative trace gas and aerosol data sets will be made available through the SPARC Data centre.

In addition, we intend to submit the following manuscripts:

- Hegglin, M. I. and the SPARC Data Initiative Team, SPARC Data Initiative: Comparison of trace gas and aerosol climatologies from international satellite limb sounders, in preparation.
- Tegtmeier., S. and the SPARC Data Initiative Team, SPARC Data Initiative: Implications for model-measurement intercomparison, in preparation.
- Hegglin, M. I. and the SPARC Data Initiative Team, SPARC Data Initiative: Comparison aerosol climatologies from international satellite limb sounders, in preparation.

Activity Website: www.sparc-climate.org/activities/trace-gas-climatologies

Ozone Profile Phase II (SI2N Initiative)

Activity Leaders: Neil Harris, Johannes Staehelin, and Richard Stolarski

Achievements for 2015

The key results of the SI2N activity have been presented in a special issue jointly organized between Atmospheric Chemistry and Physics (ACP), Atmospheric Measurement Techniques (AMT), and Earth System Science Data (ESSD): Changes in the vertical distribution of ozone – the SI2N report (Editor(s): P. K. Bhartia, N. Harris, M. Van Roozendael, M. Weber, R. Eckman, D. Loyola, J. Urban, C. von Savigny, M. Dameris, and S. Godin-Beekmann). The special issue presently includes over 55 published papers covering a wide variety of studies dealing with important aspects such as data quality and trend analyses of ground-based ozone profile measurements (in relation to NDACC and GAW) and different satellite data sets. Seven merged long-term satellite series (with different lengths) were produced and used as a basis for a quasi-global ozone profile trend analysis.

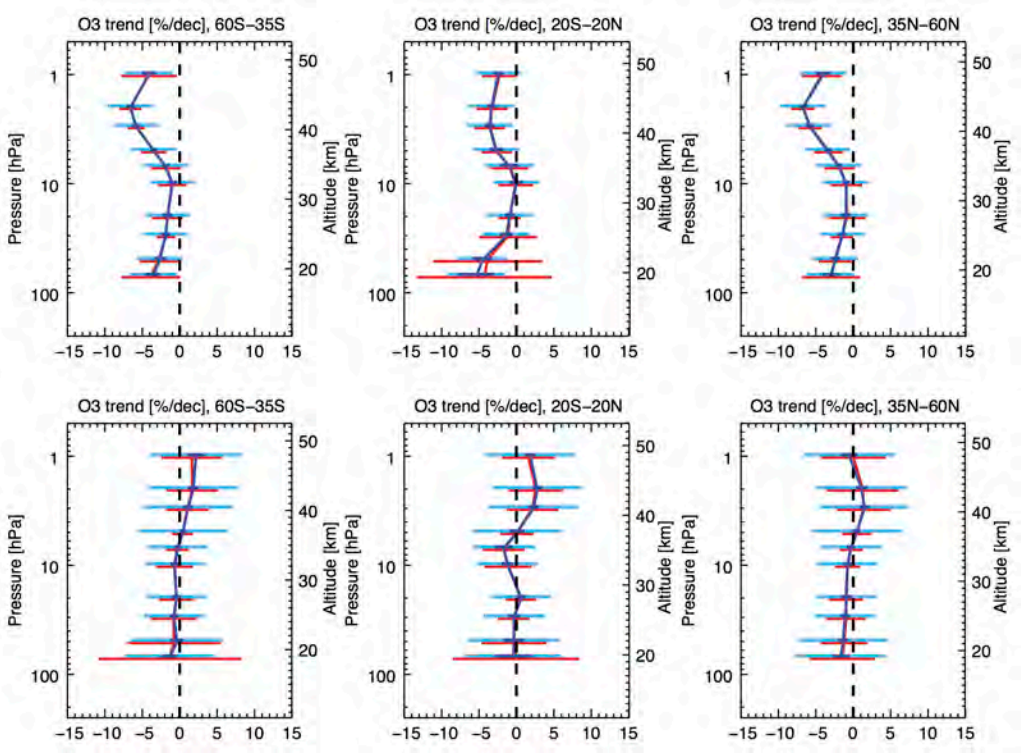

Figure 7: Combined ozone profile trends for the periods before 1998 (top row) and after 1998 (bottom row). Pre-1998 trends are calculated from the trends for 1979-1997 for two SBUV records and GOZCARDS together with 1984-1997 trends for SAGE-OSIRIS, SAGE-GOMOS, and SWOOSH. The post-1998 trends are calculated from all six satellite data sets. Error bars show the 95% confidence level calculated in three ways: thick blue lines show the central estimates and their associated most likely range for the ozone trends found by propagating the individual trend errors assuming data sets are independent. Light blue lines, based on the same analyses, additionally include a term for the possible drift of the overall observing system of 1.5% for the early trends (top row), and 2% or 3% for the later trends in the middle or lower and upper stratosphere, respectively (Hubert *et al.*, 2015). The thick red lines show the possible range for the ozone trends calculated assuming the data sets are not completely independent.

Three overview papers that summarize the main results of SI2N are being published. One of these papers, describing all relevant measurement systems, was published in AMT in May 2014. A second paper presenting an analysis of the trends with a particular emphasis on estimating the trend uncertainties was published in ACP in September 2015. The third, which will summarise the data quality of the ozone records, is being prepared. Its production has been overtaken by a paper describing a thorough comparison of the satellite measurements using the ground-based measurements, which is currently in the discussion phase of AMT.

SI2N has been formally terminated as a SPARC activity. Aspects of it will be incorporated into the work on long-term records developed under the new SPARC Implementation Plan.

Activity Website: www.sparc-climate.org/activities/previous-activities

Stratospheric Network for Assessing Predictability (SNAP)

Activity Leaders: Andrew Charlton-Perez and Gregory Roff

Achievements for 2015

Over the past year SNAP has reached several milestones:

- Published a peer-reviewed paper in Environmental Research Letters beginning the process of looking at monthly forecasts (Enhanced long-range forecast skill in boreal winter following stratospheric strong vortex conditions – http://dx.doi.org/10.1088/1748-9326/10/10/104007).
- A peer-reviewed paper analysing the SNAP experimental has also been published in the Monthly Weather Review (Examining the predictability of the Stratospheric Sudden Warming of January 2013 using multiple NWP systems – http://journals.ametsoc.org/doi/abs/10.1175/MWR-D-15-0010.1).
- The project employed two undergraduates over the summer vacation to work with the SNAP data for a Southern Hemisphere Final Warming case. We hope to write a short paper on this work during 2016.
- We co-sponsored sessions at the EGU General Assembly in Vienna and the AOGS General Assembly in Singapore and held discussions on the future direction of SNAP.
- Seok-Woo Son attended the 3rd S2S steering group meeting on Jeju Island in the Republic of Korea and gave a presentation about SNAP and its future plans.
- We have held three steering group meetings via telecon.

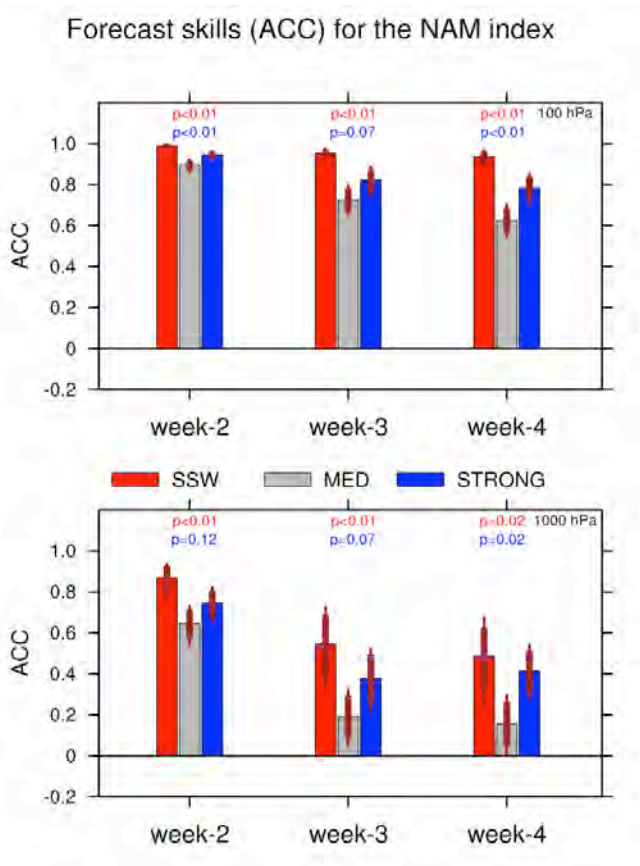

Figure 8: Weekly forecast skills (ACC) for the NAM index at 100 and 1000hPa following weak vortex (WEAK) and strong vortex (STRONG) cases. NAM is defined as the mean geopotential height anomaly averaged poleward of 60°N. The thick red bars show the forecast skill when the model is initialized on WEAK dates and the blue bars when the model is initialized on STRONG dates. The grey bars show the model skill for MED cases, when the vortex is neither very strong nor very weak. Thin error bars show the 95% confidence level calculated using bootstrap sampling. *p*-values are for the difference in skill between the MED and WEAK (STRONG) cases in red (blue) font. The skill differences in MED and WEAK or STRONG cases are significant when the thick error bars are not overlapping and the *p*-values are less than 0.05 (95% confidence level).

Plans for the Coming Year

Following discussion at conference sessions and with our steering group we have decided to revise the aims of our group in line with our achievements over the past three years and the research landscape. We propose three new over-arching scientific questions for our activity:

1) How do monthly forecasting systems predict long-lived stratospheric anomalies and their tropospheric impact?
2) Why do some prediction systems fail to capture the amplitude of stratosphere-troposphere coupling?
3) Can we develop a test set of experiments and diagnostics to assess the role of different processes in stratosphere-troposphere coupling in models?

To begin to answer these questions we propose a co-ordinated activity within the SPARC community to analyse the S2S dataset. In order to do this we have:

- Written a SPARC newsletter (January 2016) article outlining our plans and introducing the S2S dataset to the SPARC community with a call for comment on our plans.
- Included in the newsletter article is a call for project proposals, open as of January 2016, allowing members of the community to submit and share ideas on our project webpage.
- We also propose that we hold a face-to-face discussion on results from this analysis in early-2017, possibly as a break-out session at another meeting.
- Depending on the results of this analysis, produce a special collection or issue of a journal or review paper based on the results of the analysis.
- In addition, produce a real-time monitoring tool that allows members of the SPARC community to view monthly stratospheric and tropospheric forecast parameters from the models in the S2S database. This has been initiated at: http://www.met.reading.ac.uk/research/stratclim/s2s/forecast.html

Finally, Om Tripathi will be moving on from the project at the end of February 2016. We would like to thank him for his hard work in providing a great focus for this activity as it became established and wish him the very best for the future.

Activity Website: www.met.reading.ac.uk/research/stratclim/snap/index

Solar Influences (SOLARIS-HEPPA)

Activity Leaders: Bernd Funke and Katja Matthes

Achievements for 2015

The SOLARIS-HEPPA working group meeting (http://solarisheppa.geomar.de/boulder2015) was held in Boulder, Colorado, USA, from 4-6 November 2015 and focused on (1) the coordinated evaluation of the solar cycle signal in CCMI hindcast simulations and satellite observations (including the assessment of analysis tools and quantification of individual contributions to the solar signal), (2) investigation of solar signals in CMIP5 and CMIP6 model simulations, and (3) CMIP6 special issue on solar forcing.

A series of three papers investigating the solar signal in CMIP5 simulations (SolarMIP) were published focusing on:

- The stratospheric dynamical response and its influence on the surface (Mitchell *et al.*, 2015)
- The importance of the ozone solar signal and its feedback on stratospheric dynamics (Hood *et al.*, 2015)
- The role of ocean-atmosphere coupling (Misios *et al.* 2015).

A paper showing a two-year lagged response of the NAO to the solar cycle and a possible synchronization through the solar cycle in CESM-WACCM has been also published (Thiéblemont *et al.*, 2015). Several book chapters of the TOSCA textbook "Earth's Climate response to a changing Sun, Eds. T. Dudok de Witt, J. Lilensten, and K. Matthes) (undergraduate level) have contributions from the SOLARIS-HEPPA community. The book was released at the end of October 2015.

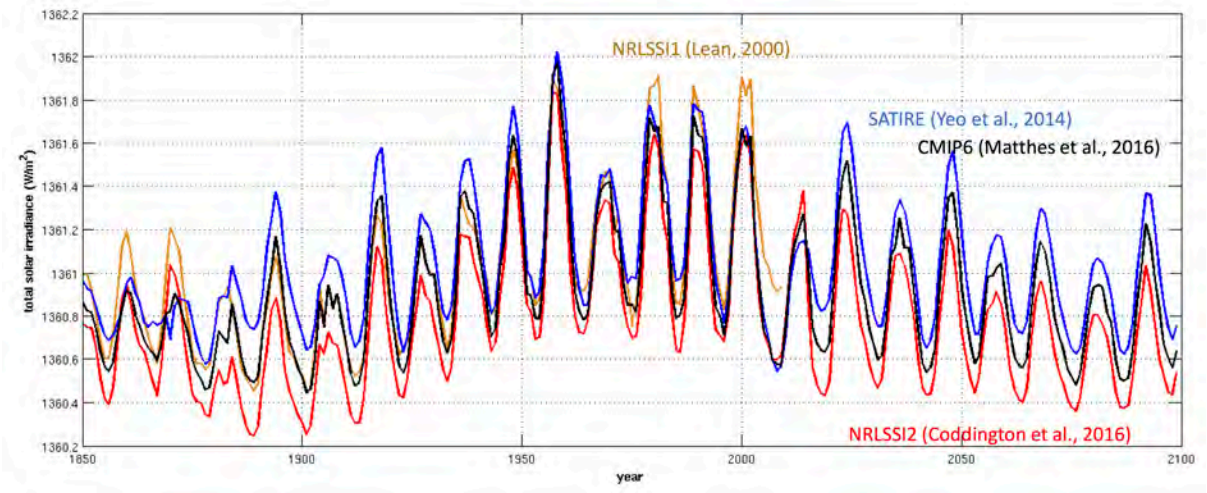

Figure 9: Time series of historic (1850-2014) and projected (2015-2100) total solar irradiance (TSI) recommended for CMIP-6 (Matthes *et al.*, in preparation). This data set has been built from a composite of the two TSI models SATIRE (Yeo *et al.*, 2014) and NRLSSI2 (Coddington *et al.*, 2016). The TSI time series for CMIP-5 (NRLSSI1; Lean *et al.*, 2000) is also shown.

The CMIP6 solar forcing time series has been produced and a description provided in the form of a contribution to the GMD CMIP6. The future solar forcing time series was constructed at an ISSI team meeting "Scenarios of Future Solar Activity for Climate Modelling" led by Thierry Dudok de Witt.

A working group on the assessment of the solar signal in stratospheric ozone has been formed and a series of publications is in preparation. The publications investigate the solar ozone signal in observations and compare them to chemistry-climate model simulations (Maycock *et al*., 2015a,b). The results will be used to better constrain the solar signal in the CMIP6 ozone climatology in collaboration with the CCMI initiative.

SolarMIP for CMIP6 has been merged with DAMIP, and the experiment to include only solar cycle forcing is now officially part of CMIP6. A questionnaire regarding the solar forcing in the pre-industrial control experiment was sent to all CMIP6 model PI's, with 13 groups answering. The result is a constant solar forcing representative for 1850 solar cycle mean conditions.

Plans for the Coming Year

SOLARIS-HEPPA plans to finalize the solar forcing article for the CMIP6 special issue and carry out coordinated analysis of solar signal in CCMI simulations (including coordination of a series of papers). A further paper comparing the solar signal in CCMVal and CMIP5 experiments is being prepared (Matthes *et al*., 2016. An investigation of pre-industrial control experiment with solar cycle variability but no long-term trend is also being planned. Seven groups who completed the above-mentioned questionnaire are willing to run an additional pre-industrial control experiment.

Finally, the 6th international HEPPA-SOLARIS Workshop will be held from 13-17 June 2016 in Helsinki, Finland (http://heppa-solaris-2016.fmi.fi).

Activity Website: http://solarisheppa.geomar.de

SPARC Reanalysis Intercomparison Project (S-RIP)

Activity Leaders: Masatomo Fujiwara, Lesley Gray, and Gloria Manney

Achievements for 2015

The S-RIP interim report, to be called the "S-RIP 2016 Report" that contains the four basic chapters has been prepared and nearly completed. The manuscripts of the four chapters will be ready for the review process in early 2016.

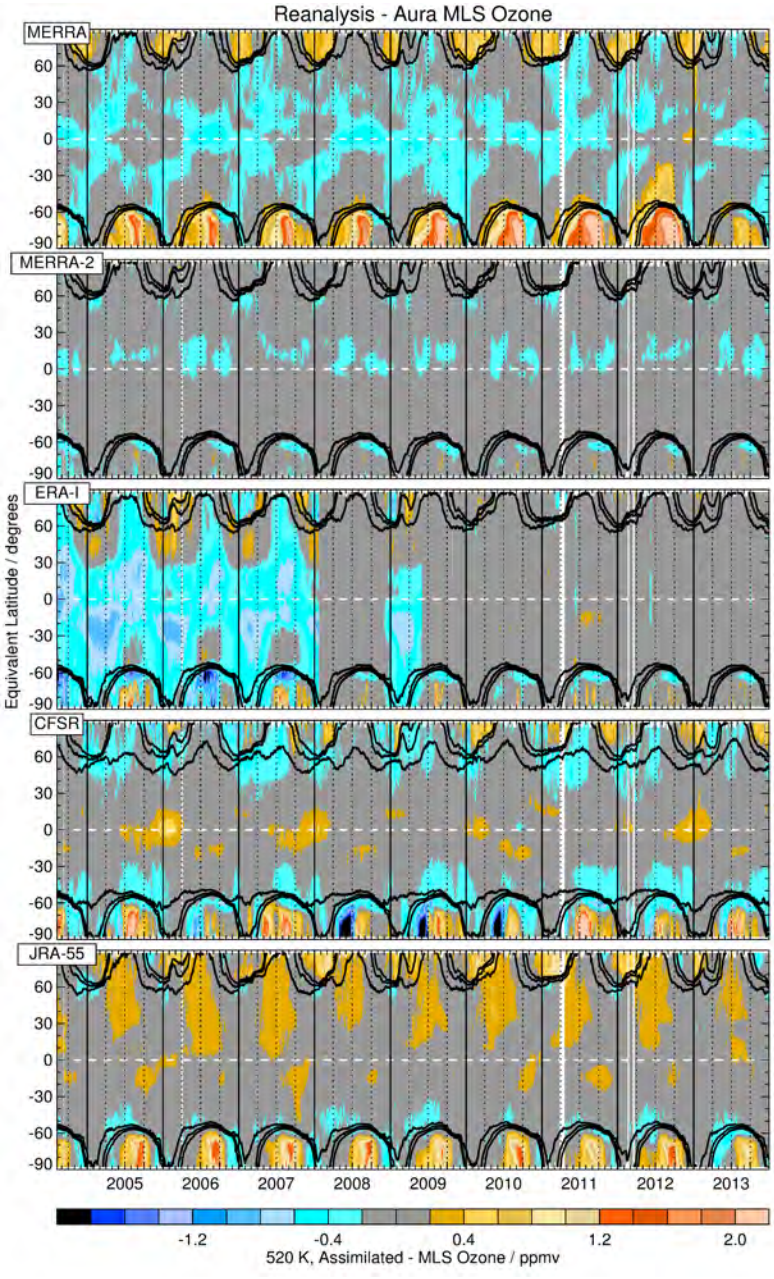

Figure 10: Comparison of equivalent-latitude/time evolution of reanalysis ozone with that from the Aura Microwave Limb Sounder (MLS) on the 520K isentropic surface (near 20km, 50hPa) in the lower stratosphere during the Aura mission (September 2004 through December 2013). Differences in volume mixing ratios in ppmv between each reanalysis and MLS (reanalysis minus MLS) are shown. Overlays are scaled potential vorticity contours indicating the stratospheric polar vortex edge region in winter, from the corresponding reanalysis. The reanalyses that assimilate MLS ozone profiles and Aura Ozone Monitoring Instrument (OMI) total column ozone, MERRA-2, and ERA-Interim starting in 2008, agree very well with MLS. The MLS profiles assimilated in these products provide information that is much better vertically-resolved than the SBUV-2 profile or column ozone products assimilated in the other reanalyses. The improvement is especially apparent in the Antarctic winter and spring, where other assimilated ozone products (*e.g.*, SBUV-2, TOMS) also do not provide measurements in darkness, and simplified parameterizations of chemistry do not adequately represent the heterogeneous loss processes. High biases in the Arctic winter in MERRA and CFSR may be partially related to inadequate representation of ozone chemistry and lack of measurements, though the predominant importance of the latter is suggested by their appearance even in years with minimal chemical ozone loss (*e.g.*, the 2005/2006, 2008/2009, and 2011/2012 Arctic winters).

The 2015 S-RIP Workshop was held at the Université Pierre et Marie, Paris, France, from 12-14 October 2015. We discussed the progress of individual chapters, suggestions for additional diagnostics, and how to address unresolved issues. The SPARC Data Assimilation Working Group (DAWG) workshop was held at the same location from 14-16 October 2015, with 14 October as a joint S-RIP/DAWG workshop. During the joint workshop, scientific presentations on reanalysis intercomparisons as well as updates from each of the reanalysis centres were given. As a result of discussions during the S-RIP workshop, a survey was taken to ensure that all S-RIP participants have access to the data products they need. Actions were also initiated to make available datasets that were not already accessible and to assist individual contributors in obtaining the numerous large datasets required for their diagnostics.

All related information and documentation has been made available on the S-RIP website: http://s-rip.ees.hokudai.ac.jp. For example, recent and past journal publications that are related to the S-RIP activity are listed at http://s-rip.ees.hokudai.ac.jp/pubs/intercomp.html.

One of the two S-RIP co-leads, David Tan of ECMWF, left the project (upon his departure from ECMWF) in July 2015. During the S-RIP 2015 Workshop, a replacement for David Tan was discussed. Two new co-leads, Lesley Gray and Gloria Manney, were then confirmed after the workshop with concurrence from S-RIP working group members and chapter co-leads. They will strengthen the scientific coordination of the project. Masatomo Fujiwara remains as a co-lead.

Plans for the Coming Year

The S-RIP interim report (the "S-RIP 2016 Report") that includes the four basic chapters will be published in 2016. The S-RIP 2016 workshop will be held in Victoria, Canada, from 19-21 October 2016, with local organizer James Anstey. Similar to the 2014 and 2015 workshops, it will be co-located with the SPARC DAWG workshop, with a one-day joint S-RIP/DAWG session.

Other S-RIP-related meetings being planned in 2016 include the DynVAR/S-RIP Chapters 5 and 6 meeting to be held in Helsinki, Finland, in June 2016 and the SPARC QBO workshop, being held in Oxford, UK, in September 2016.

Activity Website: http://s-rip.ees.hokudai.ac.jp

Stratospheric Sulfur and its Role in Climate (SSiRC)

Activity Leaders: Markus Rex, Claudia Timmreck, and Larry Thomason

Achievements for 2015

Workshop, Database and Review Paper

- A review paper that summarized the state of knowledge of SSiRC-related science to date and what has happened since the SPARC Assessment of Stratospheric Aerosol Properties (ASAP) report in 2006 was submitted to Reviews of Geophysics in late 2015.
- A SSiRC SSG meeting was organized at ISSI (Bern, Switzerland) at the end of April 2015 with the focus to structure the review paper.
- A wiki page (http://www.ssirc.info) that hosts a compilation of capacities relevant to SSiRC was updated in 2015.
- A new SSiRC task is set up to facilitate the archival and preservation of historical stratospheric aerosol measurements, because many valuable data sets are in danger of becoming inaccessible. This effort is initially focused on pre-1995 stratospheric ground-based and aircraft-based lidar data sets and is led by Juan-Carlos Antuna (SSiRC SSG member).
- A further SSiRC paper on the stratospheric sulfur burden is in process and aimed at surveying and compiling measurements of stratospheric sulfur from instruments sensitive to gas phase (OCS and SO_2) and particle phase sulfur. This effort is being led by Terry Deshler (SSiRC SSG member).
- SSiRC contributed to the SPARC capacity development side event held in the ICSHMO 2015 Conference held in Santiago, Chile, on 8 October 2015 (talk by Larry Thomason).

Supported field campaigns

- An extensive balloon campaign (BATAL-15) was carried out in summer 2015 throughout India (Gadanki, Hyderabad, Varanasi) and in Saudi Arabia (Thuwal). About 30 balloons were launched in total, with small and large OPCs, aerosol samplers, COBALD backscatter sondes, Cryogenic Frost Point Hygrometers, CO sensors, and ozone sondes.

Forcing dataset and Modelling efforts

- An update of the stratospheric aerosol database for CMIP 6 (coupled model intercomparison project – phase 6) activities is underway and will meet requirements as set up by CCMI.
- Satellite groups are working together to provide a common stratospheric aerosol forcing dataset for CMIP6 (Thomason *et al*. in preparation for GMD).
- The SSiRC model data intercomparison experiments have been extended and revised (see http://www.sparc-ssirc.org). They will be summarized in a paper, which will be submitted to GMD. Model experiments will start in 2016.
- A Model Intercomparison Project on the climatic response to volcanic forcing (VolMIP) (http://volmip.org) has been endorsed as a CMIP6 activity. VolMIP aims to understand the dominant mechanisms behind simulated post-eruption climate evolution, climate dynamics, and decadal variability. The SSiRC community is closely linked and is contributing substantially to the forcing descriptions.

Figure 11: Preparation of a heavy flight during the BATAL_15 field campaign from the balloon facility of the Tata Institute of Fundamental Research (TiFR) in Hyderabad, India, on 8 August 2015. Payloads include Wyoming University's OPC, COBALD backscatter sonde, CFH water vapour sensor, and control/transmission system from TiFR.

Plans for the Coming Year

- Continuation of SSiRC model data intercomparison experiments throughout 2016.
- Planning of a Chapman conference on stratospheric sulfur aerosol in 2017.
- Submission of a new proposal for a science team to ISSI Bern in March 2016.
- A SSiRC session on "Stratospheric aerosol, volcanic eruptions and their radiative effects" will be held during the EGU in April 2016 in Vienna.
- The second SSiRC workshop will take place in Potsdam, Germany from 25-28 April 2016.
- Several field and test campaigns will be carried out, including STratoCLIM and balloon-borne measurements to continue monitoring the UTLS during the Asian Monsoon (BATAL 2016). Campaign preparation for a rapid response after the next volcanic eruption (VolRes) is also underway.
- The Stratospheric Aerosol and Gas Experiment (SAGE III) will be installed on the International Space Station in mid-2016, providing aerosol and trace gas profile measurements.

Activity Website: www.sparc-ssirc.org

Temperature Trends

Activity Leaders: William Randel, Dian Seidel, and David Thompson (new leads: Andrea Steiner and Amanda Maycock).

Achievements for 2015

The main achievements of the Temperature Trends Activity were the publication of several research/review papers, a workshop, and a transition of leadership.

Papers:
Motivated by the group's earlier analysis of temperature trends derived from Stratospheric Sounding Unit observations, and the "mystery" associated with disparities between two data products and between models and observations (Thompson *et al*., Nature, 2012), colleagues at NOAA and at the UK Met Office undertook re-examinations and revisions of their SSU data products, which resulted in two new data products and papers (Zou *et al*., 2014; Nash and Saunders, 2015).

The new SSU data sets were the basis for an analysis of stratospheric temperature changes during the satellite era, which updates and extends Thompson *et al*. (2012) and serves as a review of the current state of the science regarding stratospheric temperature climate data records (Seidel *et al*., 2016). Other studies motivated by the 2012 paper (and by discussions at the activity's September 2013 workshop in Reading) have been submitted/published during the past year, including McLandress *et al*. (2015) and Randel *et al*. (submitted).

Workshop:
The group met for a two-day workshop in April 2015, in Victoria, British Columbia, Canada, which was hosted by Nathan Gillett and the Canadian Centre for Climate Modelling and Analysis.

The three main discussion topics were updates of observational data sets, model comparisons, and the future of the SPARC Temperature Trends activity. A full meeting report appeared in the July 2015 SPARC Newsletter (Randel *et al*., 2015).

Milestones:
The two new versions of SSU data are a significant milestone. For many years, only one version, from the UK MetOffice, existed, but it was not well documented in either the peer-reviewed or grey literature. The emergence of a second dataset from NOAA several years ago provided a basis for comparison and for evaluation of uncertainties, which were shown to be large. The recent revisions of both the UK MetOffice and NOAA datasets, with a focus on analysis of structural uncertainty, are a valuable asset to the stratospheric research community. All of these advances were the result of persistent efforts on the part of the SPARC Temperature Trends Activity, whose members include leading SSU researchers.

As a very long-standing (~20 years) SPARC activity, the group took the opportunity at the Victoria workshop to reflect on its past work and to evaluate whether continuation is warranted, in light of the current state of the science and the contributing scientific community. There was overwhelming support for the activity by the attendees, but with a refined set of foci in the coming years. To

facilitate implementation of a new vision, the three co-chairs offered to step down, having served a combined 19 years as co-chairs (Bill Randel 11 years, Dave Thompson 5 years, Dian Seidel 3 years). After endorsement from the SPARC Co-Chairs and Scientific Steering Group at the SPARC SSG in November 2015, Andrea Steiner (University of Graz) and Amanda Maycock (University of Leeds) will serve as new activity co-chairs.

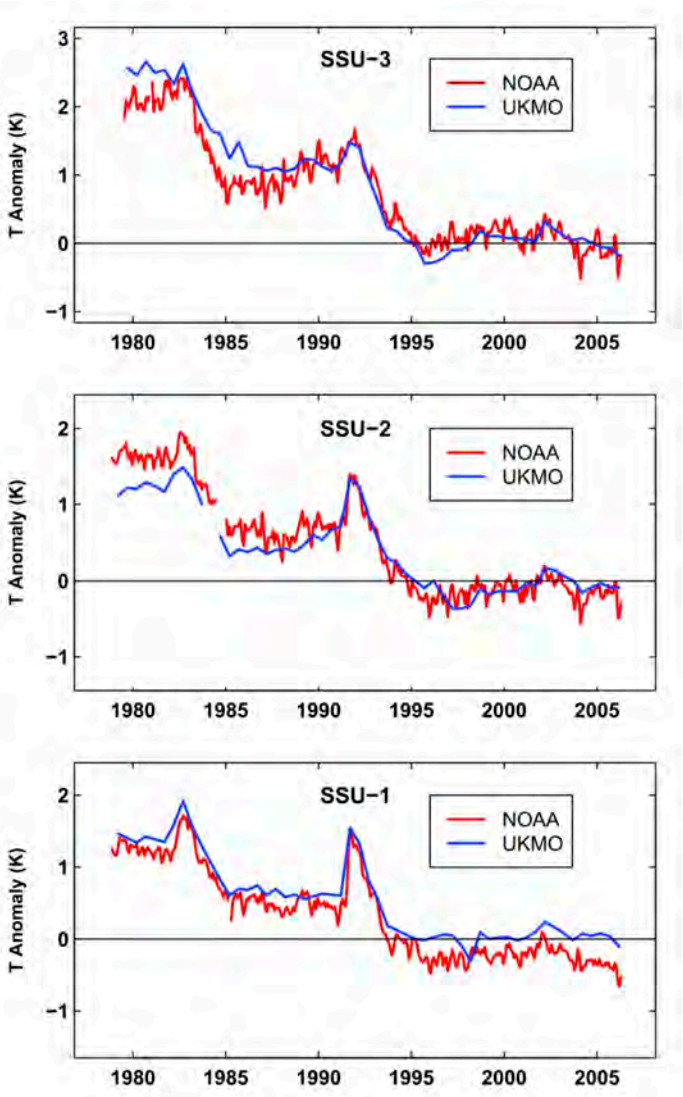

Figure 12: Near-global average (84°S–84°N) temperature anomaly time series from two climate data records derived from Stratospheric Sounding Unit observations for 1979–2005, for SSU-1, SSU-2, and SSU-3 (corresponding to various pressure ranges). NOAA and UKMO data are shown at monthly- and six-monthly resolution, respectively (From Seidel *et al.*, 2015). The two climate data records now show much greater agreement than previous versions (see Thompson *et al.*, 2012).

Plans for the Coming Year

The activity will work on a relaunch in the coming year and start coordinating papers along the new topics, as proposed in the new SPARC Implementation Plan. A dedicated workshop is planned from 25-26 April 2016 at the Wegener Centre for Climate and Global Change, University of Graz, Graz, Austria.

The proposed highlight topics are:

- Atmospheric temperature variability and trends from the troposphere to the mesosphere, and their uncertainty in climate records.
- Diagnosing the role of composition in stratospheric temperature changes.

Activity Website: www.sparc-climate.org/activities/temperature-trends

Water Vapour Phase II (WAVAS II)

Activity Leaders: Karen Rosenlof, Gabriele Stiller, and Thomas Peter

Achievements for 2015

Writing of the WAVAS-II report and papers on the quality assessment of water vapour data from satellites has started. In parallel, the assessment work has continued, *e.g.* by implementing the recommendations made at the WAVAS-II quality assessment meeting in December 2014, as well as updating data records with new versions or extending the time series until the end of 2014. A telecon was held among the key authors of the report/papers on 19 August 2015, and a second one on 29 October 2015. Kaley Walker visited KIT in August for one week to organize the writing of the satellite data set section of the report.

A meeting was held from 8-11 December 2015 at NOAA in Boulder, Colorado, USA. All key authors of the report/papers (11 people) attended. The material to be presented in the publications/report was summarized and was subject to a final critical review and discussion, and presentation styles were discussed so that they will be consistent. It was decided to present the material of the study as papers in a special issue of ACP/AMT dedicated to satellite observations of water vapour with the title: "Water vapour in the upper troposphere and middle atmosphere: a satellite data quality assessment including biases, variability, and drifts". We distributed the material over the papers and defined the contents of each paper. From the WAVAS II activity we plan to submit 11 papers with the following tentative titles:

- SPARC WAVAS-II activity: Overview, conclusions and recommendations (K. Rosenlof, G. Stiller *et al*.)
- Instrument and data characterization (K. Walker, G. Stiller *et al.*)
- Assessment of biases in stratospheric water vapor measurements by satellite sensors and frost point hygrometers (M. Kiefer, D. Hurst, H. Voemel *et al.*)
- Assessment of drifts in stratospheric water vapor measurements by satellite sensors and frost point hygrometers (D. Hurst, M. Kiefer, H. Voemel *et al*.)
- An Inter-comparison of Satellite and Ground-based Microwave Measurements of water vapour since 1996 (G. Nedoluha, M. Kiefer *et al*.)
- Satellite-satellite inter-comparisons in the stratosphere (S. Lossow *et al.*)
- Analysis of climatologies, time series, correlations and drifts (S. Lossow, F. Khosrawi *et al.*)
- Analysis of derived quantities (amplitudes of seasonal variations, QBO, ENSO, tape recorder uplift velocities *etc.*)
- Assessment of biases and drifts of upper tropospheric humidity data sets (W.G. Read *et al*.)
- HDO and delta D inter-comparisons (S. Lossow *et al.)*
- Inter-comparison of satellite measurements of H2(17)O and H2(18)O (R. Bauer, K. Walker *et al.*)

For the SPARC report it is planned to merge the papers (with some adjustment and reorganization), with each paper leading to one section of the report.

The ACP/AMT special issue has meanwhile been opened, awaiting its first contribution. It is open for contributions from the WAVAS II activity as well as any other papers on satellite observations of water vapour. Editors of the special issue are James Russell III, Karen Rosenlof, Stefan Buehler, and Gabriele Stiller. More information on the special issue is available on: www.atmos-chem-phys.net/special_issue243.html.

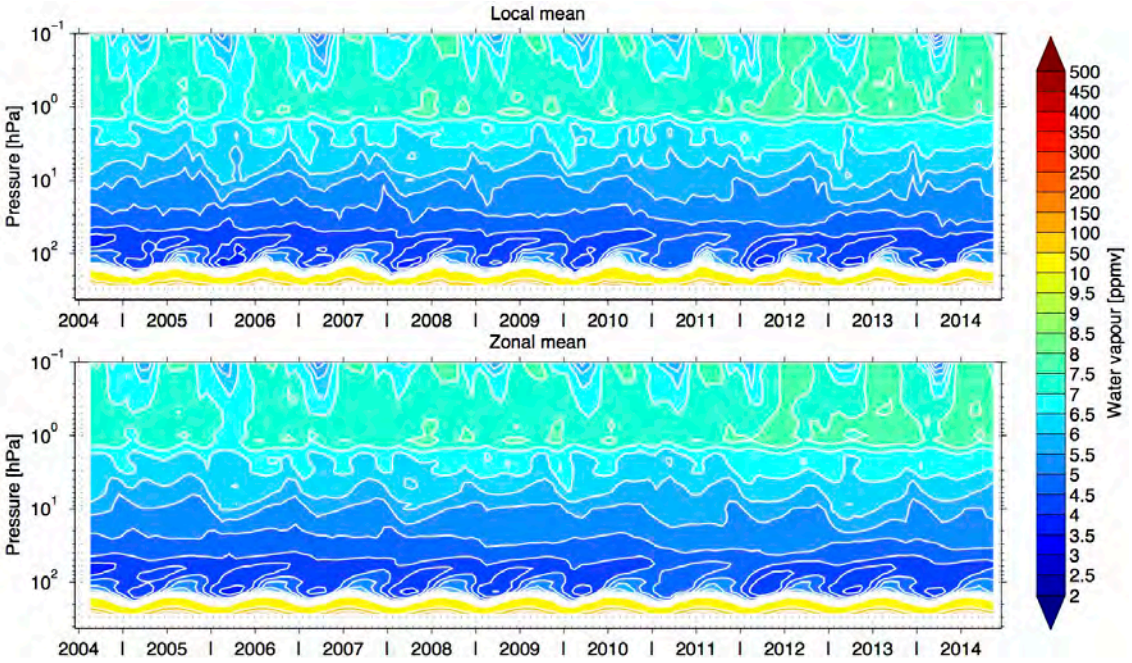

Figure 13: Top panel: Time series of MLS (v3.3/3.4) observations around Boulder (distance of 1000km around 40°N/105°W). Bottom panel: Time series of MLS (v3.3/3.4) observations, zonal mean for 30-50°N. The absolute values and patterns are similar in both time series, indicating that the location of Boulder is representative for the latitude band.

Plans for the Coming Year

We plan to continue with writing of the report and papers, with the hope of finalizing most material in 2016. For this we plan to have one more writing meeting and one report/papers review meeting - places and dates to be decided.

Activity website: http://www.sparc-climate.org/activities/water-vapour/

Emerging Activities (full activities as of November 2015)

Solving the Mystery of Carbon Tetrachloride (CCl_4 or CTC)

Activity Leaders: Paul Newman, Qing Liang, and Stefan Reimann

Achievements for 2015

The SPARC Carbon Tetrachloride (CTC) activity held a workshop from 4-6 October 2015 at EMPA in Dübendorf, Switzerland, with attendees including scientists, policy makers, and industry representatives. The workshop was mainly funded under a proposal to the Swiss Government by Stefan Reimann, while additional funding came from UNEP's Ozone Secretariat and SPARC. Funding primarily subsidized travel to the workshop.

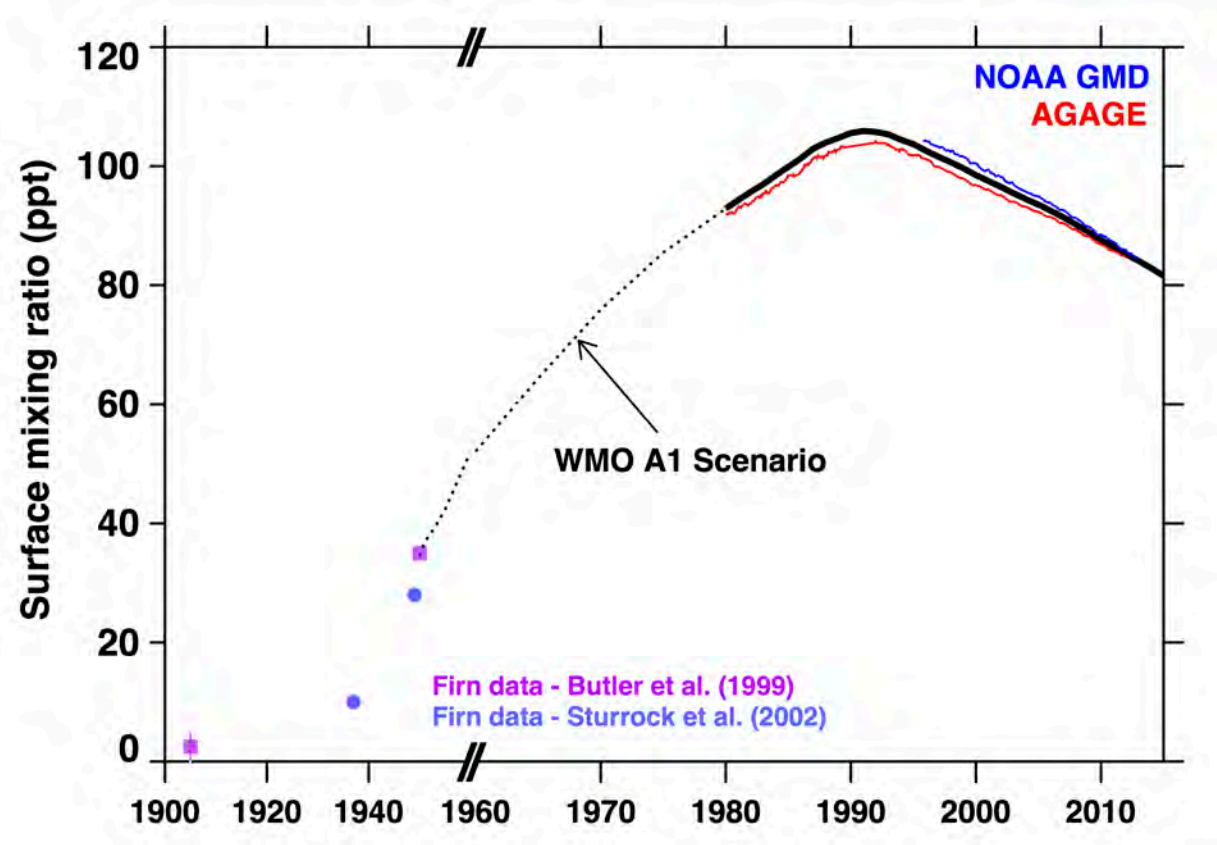

Figure 14: Timeseries of global mean surface mixing ratios of carbon tetrachloride (CCl_4) from 1900 to present. Observations derived from air bubbles trapped in snow (firn) suggest that there were very low atmospheric concentrations (<5ppt) in the early 1900s. Atmospheric concentrations of CCl_4 have increased gradually since the early 1900s due to human activities and peaked at ~105ppt around 1990. Since then, CCl_4 abundances have declined because of the Montreal Protocol controls on emissions. However, its rate of decline (~1%/year) is much slower than expected (~4%/year). This discrepancy suggests that there are either unrecognized sources of CCl_4 or a misunderstanding of CCl_4 losses.

The workshop objectives were to: (1) Document new and past research results via presentations and posters that were then summarized in rapporteur reports; (2) develop a key findings bullet list for the CTC sub-disciplines; (3) formulate research recommendations that will be forwarded to the Vienna Convention Ozone Research Managers; (4) generate a draft SPARC report that will lead to a side event on CTC findings at the Montreal Protocol meeting, and form the basis for an article that appears in the AGU EOS newsletter.

The programme and public version of the presentations can be found at:
www.sparc-climate.org/meetings/Sparc-CCl4-workshop_October2015.

Plans for the Coming Year

The activity will complete the CTC report summarizing the main findings and research recommendations from the workshop. We also plan to publish an EOS newsletter article about the report and hopefully stimulate collaborations and new peer-reviewed publications on CCl_4 in the atmosphere. Research recommendations will be presented to the Ozone Research Managers in Spring 2017.

Activity website: www.sparc-climate.org/activities/carbon-tetrachloride

Polar Stratospheric Clouds Initiative (PSC)

Activity Leaders: Michael Pitts, Thomas Peter, and Ines Tritscher

Achievements for 2015

This emerging activity submitted a successful proposal to the International Space Science Institute (ISSI) in Bern, Switzerland to support a series of meetings of the PSCi team. The first ISSI meeting was held from 28 September to 2 October 2015 and focused on synthesizing the contemporary PSC observational datasets into a state-of-the-art reference data record that can be used to test current and future global models. Twelve members of the PSCi team were in attendance. The major outcome of the meeting was the identification of new work required to quantify the sensitivity/detection limits of the CALIOP and MIPAS instruments, development of higher level products (*e.g.*, particle surface area density and volume density) that would be particularly useful to the modelling community, and examination of the long-term *in situ* data record to characterize PSC particle size distributions for different thermodynamic regimes. A timeline for the PSCi was also developed.

Figure 15: Members of the PSCi team at the first ISSI meeting held in Bern, Switzerland.

Plans for the Coming Year

In the coming year, a series of peer-reviewed journal papers will be written to document the sensitivity of the CALIOP and MIPAS PSC products, describe the retrieval of new higher order products, and characterize *in situ* PSC particle size distributions. The second ISSI meeting is tentatively planned for October 2016. At this meeting, summaries of the journal papers will be given and an outline of the comprehensive review paper on PSC science will be developed.

Activity Website: www.sparc-climate.org/activities/polar-stratospheric-clouds

Quasi-biennial Oscillation Initiative (QBOi)

Activity Leaders: James Anstey, Neal Butchart, Kevin Hamilton, and Scott Osprey

Achievements for 2015

The emerging QBOi activity held its first workshop at the Inn at Laurel Point, Victoria, British Columbia, Canada, from 16-18 March 2015. The workshop was joint with the QBO and Tropical Variability chapter of the SPARC S-RIP Report. Over 30 people attended and the workshop included a keynote talk from Alan Plumb. The workshop began by assessing the current state of QBO research, including modelling and observations. A number of key challenges and priorities were identified:

- Understanding and simulating the equatorial QBO, including potential sensitivities of the QBO simulation to model formulation.
- Understanding and reproducing impacts of the QBO, *e.g.* at high latitudes and at the surface.
- Making confident predictions about the QBO and its responses to external forcings such as future climate change.

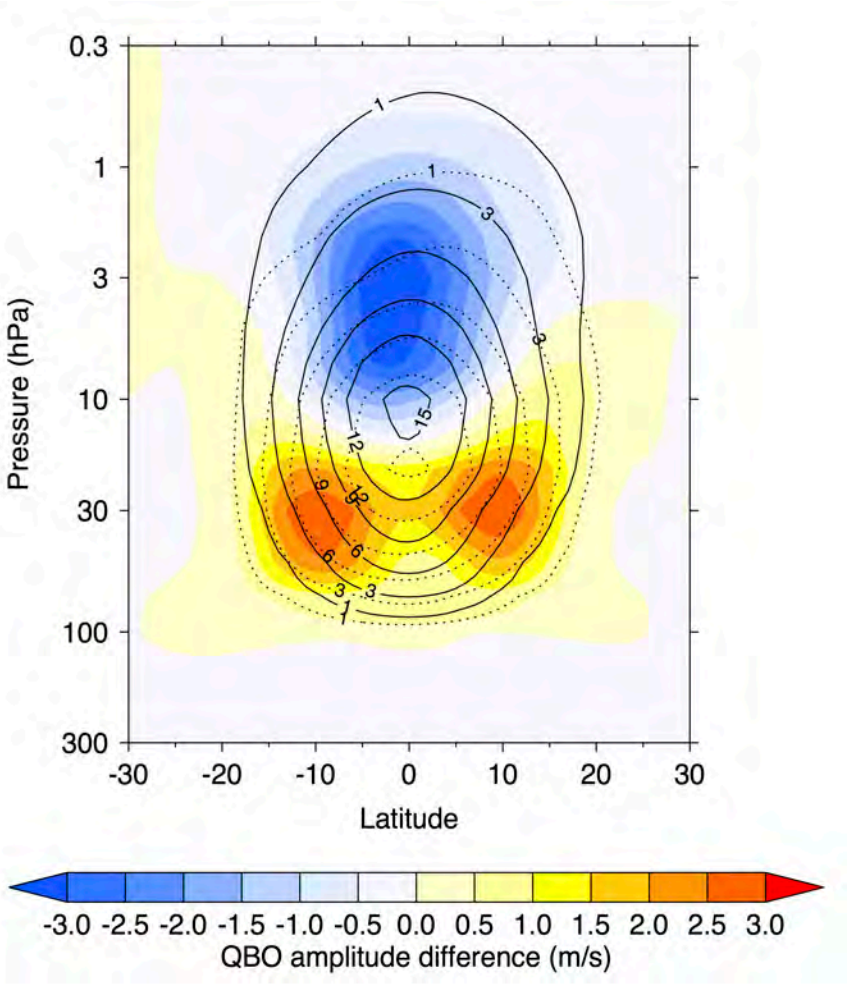

Figure 16: Multi-model and reanalyses mean QBO amplitude and difference. Multi-model (solid) and reanalyses (dotted) mean QBO Fourier-amplitude of zonal mean eastward wind. Data is compiled using 10 models with an internally-generated QBO from groups participating in QBOi, including contributions from CCMVal2 and CMIP5. Reanalyses datasets include MERRA, JRA55, and ERA-Interim. Shading highlights differences between reanalyses and the multi-model mean; cool colours indicating where the models are biased towards a too strong QBO, warm colours where models are weak. Common model biases are identified including: the QBO peaking too high in altitude, and not penetrating deeply enough and decaying in latitude more quickly in the lowermost stratosphere. At the height of maximum QBO (10hPa in models, 20hPa in reanalyses), the latitudinal extent in models is realistically represented. Figure from Schenzinger *et al*. 2016 – manuscript in preparation.

Two outcomes for the meeting included identifying those coordinated experiments required to address the challenges and identifying a list of simple and process-based metrics to analyse results. An action group was set up to formulate the requisite experiment details in the weeks following the meeting, and an experiment protocol was subsequently distributed to the wider QBOi group.

Details of the workshop appear as a July 2015 EOS meeting report and in the July 2015 SPARC Newsletter. A major milestone was achieved with the agreement on a suite of coordinated experiments to address the key outstanding QBO questions identified at the workshop. The experiments emerged from "bottom-up" discussion rather than being imposed by the activity leaders, and strong continuing community engagement is expected.

Plans for the Coming Year

In the coming year, a paper summarising the results of the QBOi questionnaire will be prepared as well as a white paper on the current state of QBO modelling. Participating groups will undertake simulations and analysis in fulfilment of their commitments to the core experiments. These experiments will form the bulk of the QBOi activity over the next year and discussion of the early results from the experiments will be one of the major focal points of the 2nd QBOi workshop being held in Oxford, UK, from 26-30 September 2016.

Activity Website: http://users.ox.ac.uk/~astr0092/QBOi.html

Capacity Development

2015 was a very active year in terms of SPARC capacity development, beginning with a dedicated two-day workshop held in January prior to the 22nd SSG meeting in Granada, Spain. The workshop brought together members of the SPARC community from various regions of the world to discuss and outline a strategy for SPARC capacity development. This strategy took shape throughout the year and was finalised at the 23rd SSG meeting held in November. It is now available online at: www.sparc-climate.org/fileadmin/customer/6_Publications/ProgPlan_PDF/SPARC_CDstrategy_final.pdf.

Participants of the SPARC Capacity Development Workshop held in Granada, Spain, in January 2015.

Besides continuing its work distributing WCRP travel funding to support participation in SPARC meetings and workshops, particularly for early career researchers and scientists from developing countries, several notable activities were organised throughout the year. The first ACAM training school was held in Bangkok, Thailand, and was extremely successful, being heavily over-subscribed. SPARC made connections with the Young Earth System Scientists network (YESS), which is aimed at providing a platform for early career researchers from multiple disciplines across the Earth system sciences to connect more easily. The first SPARC regional working group has been established for the Asia-Pacific region, with participation of members from the group in several regional workshops and conferences. SPARC also organised a lunch-time breakout session at the 11th International Conference on Southern Hemisphere Meteorology and Oceanography in Santiago, Chile, where SPARC was promoted. Finally, capacity development has also been made more visible on the SPARC website through a new 'Get Involved' page.

WCRP Grand Challenges

SPARC is contributing to three of the WCRP Grand Challenges and helping to develop two new Grand Challenges that have recently been proposed.

Clouds, Circulation, and Climate Sensitivity

As contribution to the Grand Challenge on 'Clouds, Circulation, and Climate Sensitivity', which is being led by GEWEX (see below), SPARC organised a workshop on 'Storm Tracks' in August in Grindelwald, Switzerland. Ninety scientists from 16 different countries attended, including 55 early career researchers. The workshop was structured around five themes: storm track processes, coupling to boundaries, coupling with radiation and clouds, climate change, and state-of-the art modelling. The workshop was aimed at reviewing recent advances related to the dynamics of storm tracks and jets, and in particular focused on key questions concerned with the regional response to climate change. A review paper summarizing many of the key results discussed at this workshop was submitted at the end of 2015.

Climate Extremes

SPARC is also working with GEWEX on the 'Climate Extremes' Grand Challenge, which GEWEX is leading. SPARC's main contribution is through the organisation of a workshop on 'Atmospheric Blocking and Extremes', which is to be held in Reading, UK, from 6-8 April 2016. Atmospheric blocking strongly modulates the variability of mid-latitude circulation patterns from sub-seasonal all the way to interannual timescales. It can significantly affect surface weather, causing both large-scale cold spells in winter and persistent heat waves in summer. A better quantification of these phenomena is essential to improving sub-seasonal to decadal predictions of extremes as well as reducing uncertainties in longer-term climate projections. The workshop will focus on providing a better overview of our current understanding of blocking events and their relations to extremes, including how these events are simulated in models and the mechanisms behind why their representation may be biased in these models.

Melting Ice and Global Consequences

As part of the WCRP Grand Challenge "Cryosphere in a Changing Climate", SPARC and CliC are coordinating the WCRP Polar Climate Predictability Initiative (PCPI, see details below). Other areas where SPARC could further contribute to this Grand Challenge are related to the relationship between polar climate change and mid-latitude circulation patterns (see CliC section below).

Proposed new Grand Challenges

Two new WCRP Grand Challenges have been proposed. One is to focus on "Near-term Climate Predictions" while the other will consider "Biogeochemistry" in particular in terms of the carbon cycle. Both Grand Challenges are currently under development and SPARC is involved in this process.

Connections

CliC

SPARC is collaborating with CliC (Climate and Cryosphere, WCRP core project) on the WCRP Polar Climate Predictability Initiative (PCPI, see details below) as well as on the Year of Polar Prediction (YOPP) planned for mid-2017 to mid-2019. The stratosphere exerts a discernible impact on the processes determining seasonal and longer time-scale predictability of the troposphere, as do certain aspects of the cryosphere, primarily, sea-ice and snow. CliC and SPARC both contribute to research on seasonal to decadal climate predictability through projects such as the Stratospheric Historical Forecast Project and Sea-Ice Historical Forecast Project. Other areas for potential SPARC-CliC collaborations concern the interaction between polar climate change and mid-latitude circulation as well as the biogeochemistry of sea-ice.

GEWEX

SPARC and GEWEX, the WCRP Global Energy and Water Exchanges project, have continued to work together in 2015. SPARC has helped organise two workshops as contributions to the Grand Challenges on 'Clouds, Circulation, and Climate Sensitivity' and 'Climate Extremes' (see above). SPARC is also involved in the developing GEWEX Upper Troposphere Clouds and Convection (UTCC) PROcess Evaluation Study (PROES). An initial workshop was held in Paris, France, in October, where issues related to the interplay between convection and clouds, particularly in the upper troposphere, were discussed. The UTCC activity will provide an excellent opportunity to bring scientists from several communities together to explore the impacts of high altitude clouds on climate through both modelling and observational studies.

CLIVAR

CLIVAR (Climate Variability and Predictability), also a WCRP core project, deals with climate aspects related to the atmosphere and ocean as well as on the interactions between atmosphere and ocean relevant to climate variability and climate change. Through focused research on climate dynamics and predictability, SPARC and CLIVAR are contributing to improving climate predictions at scales from sub-seasonal to decadal. CLIVAR is organising a major Open Science Conference in Qingdao, China, from 18-25 September 2016. It will provide a dynamic forum for the WCRP community to review progress towards an improved understanding of the dynamics, interactions, and predictability of the coupled ocean-atmosphere system. An early career researchers event is being organised in conjunction with the main meeting as well as a special stakeholder day.

IGAC

SPARC collaborates extensively with the International Global Atmospheric Chemistry project (IGAC), particularly through two joint activities, the Atmospheric Composition and Asian Monsoon (ACAM) and Chemistry Climate Model Initiative (CCMI) (see above). SPARC will continue to work closely with IGAC as they transition into the Future Earth programme and in particular as SPARC develops its focus on the troposphere further. Potential areas for new joint activities include composition and transport in the tropics as well as short-lived climate forcers. Furthermore, IGAC may also become involved in the proposed WCRP Grand Challenge on Biogeochemical cycles.

WGNE

The Working Group on Numerical Experimentation (WGNE), established by the WCRP and the WMO Commission for Atmospheric Sciences, aims to foster the development of atmospheric circulation models for use in weather prediction and climate studies. SPARC activities were presented at the 30th WGNE session, held in March 2015, including S-RIP, SNAP, Gravity Waves, QBOi, and DAWG. Clear connections appeared between the WGNE Drag project and SPARC's Gravity Wave activity, and both groups will continue to work together to explore an expansion of the Drag project to include a focus on momentum budgets in collaboration with SPARC. Other common areas of interest include the Polar Prediction Project (PPP) and the Year of Polar Prediction (YOPP), particularly in terms of how the Polar Regions may influence lower latitudes through atmospheric teleconnections. The next WGNE session will be held in April 2016 in Pretoria, South Africa.

WGSIP

The Working Group on Seasonal to Interannual Prediction (WGSIP) is the WCRP modelling group for initialized climate predictions. WGSIP coordinates research projects to improve climate predictions and recently completed projects on the effects of Arctic Sea Ice and the stratosphere, with the latter topic lead by the SPARC community (Amy Butler). WGSIP has now begun new projects on tropical-extra-tropical interactions, model drift and shocks following initialization, and the effects of snow cover on seasonal forecasts. WGSIP has also co-developed the CMIP6 Decadal Climate Prediction Project protocol with CLIVAR and WGCM. Many WGSIP members also come from WMO-designated Global Producing Centres for seasonal forecasts and provide real-time forecasts each month via the WMO Lead Centre for long-range forecasts: www.wmolc.org . A database of retrospective hindcasts is now also up and running and serves data from leading seasonal forecast systems to researchers worldwide: http://chfps.cima.fcen.uba.ar/ .

Of particular relevance to SPARC is the publication of an article in the Quarterly Journal of the Royal Meteorological Society: "The Climate Historical Forecast Project: Do stratosphere-resolving models make better seasonal climate predictions in boreal winter?" (Butler *et al*., 2016; http://onlinelibrary.wiley.com/doi/10.1002/qj.2743/abstract). The paper shows that while it is often hard to detect differences in overall skill between different forecast systems, there is now clear evidence that seasonal forecasts benefit from inclusion of the stratosphere, for example in ENSO teleconnections. A second SPARC related study " Seasonal forecasts and the stratosphere" by Adam Scaife and colleagues has also concluded that the stratosphere plays an important role in seasonal forecasts for northern winter (Scaife *et al*., 2016; http://onlinelibrary.wiley.com/doi/10.1002/asl.598/abstract). This study shows that the skill of winter predictions of the North Atlantic Oscillation vanishes when sudden stratospheric warming cases are excluded from a set of ensemble forecasts.

WGSIP welcomes further interaction with SPARC scientists, for example to exploit the CHFP database, which is becoming the equivalent of the CMIP database for seasonal forecasting and will provide a record of the historical improvements in seasonal forecasts.

WGCM

The 19th session of the Working Group on Coupled Modelling (WGCM) was held in Dubrovnik, Croatia, from 18-20 October 2015. It was followed by a workshop from 20-23 October 2015 on 'CMIP5 Model Analysis and Scientific Plans for CMIP6' that was organised jointly by WGCM and the European Commission FP7 project EMBRACE (Earth system Model Bias Reduction and assessing Abrupt Climate). Most of the WGCM session was dedicated to reviewing progress of the CMIP6 implementation in close consultation with representatives from modelling groups and the CMIP6-Endorsed Model Intercomparison Project (MIP) co-chairs. A particular focus was placed on the discussion of the CMIP6 forcing datasets.

After wide community consultation, a new and more federated structure has been put in place for CMIP6 (Eyring *et al.*, 2015). It consists of three major elements: (1) a handful of common experiments, the DECK (Diagnostic, Evaluation and Characterization of Klima) and CMIP historical simulations (1850 – near-present) that will maintain continuity and help document basic characteristics of models across different phases of CMIP, (2) common standards, coordination, infrastructure and documentation that will facilitate the distribution of model outputs and the characterization of the model ensemble, and (3) an ensemble of CMIP-endorsed Model Intercomparison Projects (MIPs) that will be specific to a particular phase of CMIP and that will build on the DECK and CMIP historical simulations to address a large range of specific questions and fill the scientific gaps of previous CMIP phases.

A special issue of Geoscientific Model Development (GMD) describes the new design and organization of CMIP as well as the suite of CMIP6 experiments in a series of invited contributions (see www.geosci-model-dev.net/special_issue590.html). The papers provide the required information to produce a consistent set of climate model simulations that can be scientifically exploited to address the three broad scientific questions of CMIP6: (1) How does the Earth system respond to forcing? (2) What are the origins and consequences of systematic model biases? and (3) How can we assess future climate changes given climate variability, predictability, and uncertainties in scenarios? The special issue includes an overview paper on CMIP6 design and organization, contributions from CMIP6-Endorsed MIPs and descriptions of the forcing data sets. Up-to-date information on CMIP6 can be found on the CMIP Panel website at: www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6.

The Polar Climate Predictability Initiative

The Polar Climate Predictability Initiative (PCPI) aims to advance understanding of the sources of polar climate predictability on timescales ranging from seasonal to multi-decadal, which stems from the unique persistence of signals in ice and snow as well as through exchange with the ocean at all depths and the stratosphere. PCPI is a sub-initiative of the "Melting Ice" Grand Challenge, and is jointly supported by CliC and SPARC. PCPI also work closely with the WWRP, in particular the joint WWRP/WCRP Polar Prediction Project (PPP). PCPI focuses on six themes each of which has two champions. The PCPI leadership met in Reading, UK, in September 2015 to discuss ways to expand involvement in the activity, amongst other things. The group are organising several workshops over the coming two years, including a workshop on polar predictability to be held at Lamont-Doherty in 2016, one on Southern Ocean coupled processes and predictability, as well as on zonal asymmetry in the Southern Hemisphere; the latter two likely to be held in 2017.

The SPARC Data Centre

The SPARC Data Centre (SDC) continues to provide support for SPARC activities, facilitating the distribution of data and documents and providing access to data for the international climate research community. This includes data for several active SPARC activities including the SPARC Data Initiative, CCMI, the Gravity Wave activity, and WAVAS-II, as well as several past activities such as CCMVal-II and the SPARC Lifetimes activity, amongst many others. Following the migration of data from Stony Brook University and the SPARC International Polar Year data from University of Toronto in late 2014 the SDC data holdings now reside at the Centre for Environmental Data Archival (CEDA) with the SDC website integrated into the main SPARC website hosted at ETH Zurich acting as the web portal. Staff changes at CEDA have unavoidably delayed the completion of the migration process. As a result, several SPARC project data sets are still hosted by the British Atmospheric Data Centre (BADC), also at CEDA. With the establishment of the new SDC catalogue in the coming year, all SPARC data holdings will reside at CEDA under the unified banner of the SDC. NASA are thanked for providing their continuous support of the SDC from 1999-2014, including funds for the migration to CEDA. Peter Love, the SDC scientist, remains the SPARC-CEDA liaison for data ingestion and the migration process and continues to provide scientific support for SDC users.

SPARC Scientific Steering Group 2015

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Martin Schultz

Seok-Woo Son

Tianjun Zhou

Planned Workshops and Meetings 2016

This list is updated throughout the year as further meetings/workshops are planned.

16 – 19 February
SPARC Workshop on Stratospheric Change and its Role in Climate Prediction (SHARP)
Berlin, Germany

7 – 11 March
Workshop on Dynamics, Transport, and Chemistry of the UTLS Asian Monsoon
Boulder, Colorado, USA

6 – 8 April
Workshop on Atmospheric Blocking
Reading, UK

25 – 26 April
Atmospheric Temperature Changes Workshop
Graz, Austria

25 – 28 April
2nd Workshop on Stratospheric Sulfur and its Role in Climate
Potsdam, Germany

16 – 20 May
Atmospheric Gravity Waves: Sources and Effects on Weather and Climate
State College, Pennsylvania, USA

24-27 May
Joint GAW/SPARC workshop on UT/LS observations
Geneva, Switzerland

6 – 10 June
Joint DynVar and S-RIP Meeting
Helsinki, Finland

13-17 June
6th SOLARIS-HEPPA Workshop
Helsinki, Finland

30 July – 6 August
41st COSPAR Scientific Assembly
Istanbul, Turkey

26 – 30 September
SPARC QBO Workshop – The QBO and its Global Influence, Past, Present & Future
Oxford, United Kingdom

17 – 21 October
SPARC DA and S-RIP Workshops
Victoria, British Columbia, Canada

31 October – 4 November
24th SPARC Scientific Steering Group Meeting
Berlin, Germany

Find all meetings at: www.sparc-climate.org/meetings

Acronyms

BADC – British Atmospheric Data Centre
CCMI – Chemistry-Climate Model Initiative
CCM – Chemistry-Climate Models
CCMVal2 – Chemistry-Climate Model Validation project 2
CEDA – Centre for Environmental Data Archival
CliC – Climate and Cryosphere project
CLIVAR – Climate Variability and Predictability project
CMIP5 – Coupled Model Intercomparison Project 5
DynVar – Dynamical Variability
GEWEX – Global Energy and Water Exchanges project
IGAC – International Global Atmospheric Chemistry
JSC – Joint Scientific Committee
NASA – National Aeronautics and Space Administration
NDACC – Network for Detection of Atmospheric Composition Changes
NWP – Numerical Weather Prediction
PCPI – Polar Climate Predictability Initiative
PPP – Polar Prediction Project
S2S – Sub-seasonal to Seasonal Prediction Project
SNAP – Stratospheric Network for the Assessment of Predictability
SOLARIS-HEPPA –SOLAR Influences for SPARC – High Energy Particle Precipitation in the Atmosphere
S-RIP – SPARC Reanalyses Intercomparison Project
SSG – Scientific Steering Group
SSiRC – Stratospheric Sulfur and its Role in Climate
SSU – Stratospheric Sounding Unit
WCRP – World Climate Research Program
WGCM – Working Group on Coupled Modelling
WGNE – Working Group on Numerical Experimentation
WGSIP – Working Group on Seasonal to Interannual Prediction
WMO – World Meteorological Organisation
WWRP – World Weather Research Programme


WCRP
SPARC
Stratosphere-troposphere
Processes And their Role in Climate
WCRP
World Climate Research Programme
WMO
UNESCO
IOC
ICSU
International Council for Science