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SPARC

Stratospheric Processes and Their Role in Climate
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Cirrus clouds above Zurich's local mountain Uetliberg (871m). Cirrus clouds exist in the upper troposphere, at altitudes between 7 and 17 km. Because cirrus clouds cover up to 30% of the Earth surface they play an important role in atmospheric chemistry and climate (photo: SPARC Office; feel free to provide photos for future SPARC newsletters).

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Report on the 19th Session of the SPARC Scientific Steering Group 7-10 February 2012, Zurich, Switzerland

Johannes Staehelin[1], **Ted Shepherd**[2], **Greg Bodeker**[3]

[1]SPARC Office, Zurich, johannes.staehelin@env.ethz.ch, [2]University of Reading, UK, theodore.shepherd@reading.ac.uk, [3]Bodeker Scientific, New Zealand, greg@bodekerscientific.com

The 19th Session of the SPARC Scientific Steering Group (SSG) was held at the Swiss Federal Institute of Technology (ETHZ), Switzerland. The meeting was organised by the new SPARC Office team based in Zürich and the outgoing SPARC co-chair Thomas Peter. At the meeting, the 20th anniversary of SPARC was celebrated, as well as the relocation of the SPARC Office from Toronto, Canada, to Zürich, Switzerland (see separate article).

Opening session and WCRP/ SPARC update

T. Shepherd (SSG co-chair) opened the meeting by welcoming all participants, particularly the new members of the SSG, and thanked the local organisers of the meeting. In a short presentation he also introduced the main goals of SPARC, its structure, projects and activities.

A. Busalacchi (chair of the WCRP Joint Scientific Committee (JSC) – the JSC oversees the work of the WCRP) reported on the very successful WCRP Open Science Conference (OSC) which took place from 24-29 October 2011, in Denver, CO, USA. The OSC provided a broad overview of the state of the science related to climate change and the scientific activities of the WCRP. The OSC also included presentations that discussed the aspects of climate most relevant for society (for a description of the OSC, and the aspects most relevant to SPARC, see SPARC Newsletter No. 38, January 2012). After the OSC a short JSC meeting took place in Boulder, CO (30-31 October). Besides a short review of the OSC, the important elements of the structural renewal of the WCRP (to be fully implemented in 2013) were discussed. The important elements of this renewal are:

1. New mandates for the individual core projects;
2. The establishment of a WCRP Modelling Advisory Council and a WCRP Data Advisory Council. These councils have been tasked with co-ordinating modelling and measurement/ data related activities across the WCRP and, if required, to make recommendations. The councils will meet annually, for the first time in parallel with the next JSC meeting, which will take place in Beijing in July 2012;
3. The definition of Grand Challenges, which represent topics that are scientifically challenging, of great interest to society, in which significant scientific progress can be expected within a few years, and which profit from the collaboration between the four core projects of the WCRP.

T. Shepherd brought attention to SPARC's role in the WCRP's grand challenges, with SPARC particularly focusing on the improvement of models and the use of the "imperfect" information provided by them, as well as the improvement of current reanalyses and observational records. With the establishment of climate services organisations the evolution of models and observations, and science in general, will be more synergistic with end users needs.

SPARC Measurement Requirements and ESA activities

G. Bodeker introduced the process for developing a SPARC Measurement Requirements document and led the associated discussion. The main idea behind this activity is to develop an explicit account of the kind and quality of measurements that are needed to support SPARC activities. This will allow SPARC to provide co-ordinated input to the WCRP Data Advisory Council and other international bodies such as GCOS (Global Climate Observing System) and CEOS (Committee on Earth Observation Satellites), as well as to respond to requests from funding and space agencies concerning SPARC measurement needs and priorities. The process should also help stimulate greater use of observational products by SPARC activities. It is important that the outcomes of this activity outline why the data are required and will be of scientific interest, and give concrete examples of what can be accomplished with (or without) the data. It is not intended to be a laundry list of measurement requirements, but a unified view of SPARC's data needs. It was decided that the activity leaders will receive (within two months of the SGG meeting) a template summarizing the type of information required in order to write their contributions to the measurement requirement document which will be discussed again at the next SSG meeting.

G. Bodeker also reported on SPARC activities funded by ESA (the European Space Agency). In March 2010 SPARC was approached by ESA to submit a proposal to promote the scientific use of ESA and third party mission data. In October 2010 a meeting took place in Zürich and it was decided to explore the use of four types of satellite-based instrumental records for the creation of long-term climate data records including stratospheric temperature, ozone, aerosols and water vapour. Thereafter a "SPARC Scientific Requirements Document for ESA" was developed and discussed at the SSG meeting in February 2011. This led to an ESA invitation to tender (ITT). A proposal was submitted by a consortium led by Michel von Roozendael. The project kick-off meeting took place in Cambridge in February 2012. Some of the primary outputs are: (1) improvement of the data sets of SCIAMACHY and OSIRIS aerosol, SCIAMACHY water vapour, short-lived species climatologies, and GOMOS ozone; (2) merging and extending data sets: GOMOS and SAGE II ozone, extending the SSU-based upper stratospheric temperature record, improving the UTLS temperature record, and merging of GOMOS and SAGE aerosol records. An ESA review will be carried out at the end of the first year, at which point the SPARC measurement requirements will also be discussed.

Reports on SPARC activities

M. Hegglin and **S. Tegtmeier** reviewed the status of the SPARC Data Initiative activity, which is an inter-comparison of different satellite measurements of vertically-resolved chemical trace gas and aerosol climatologies. As identified in previous SPARC activities, and in particular in CCMVal-2, some satellite products show ambiguous results when used to validate chemistry-climate models. This can be particularly problematic when trying to deduce long-term changes from composite satellite time series. The main objectives of the SPARC Data Initiative are: (i) assessing the state of data availability from the multi-national suite of space-based instruments; (ii) establishing a data portal for chemical observations in collaboration with space agencies; (iii) compiling climatologies of chemical trace gases and carrying out a detailed inter-comparison of the climatologies; and (iv) documenting useful information and highlighting differences between datasets. In addition, seasonal and interannual variability of the time series have been studied. The work is nearing completion and the associated report is planned to be available in late 2012.

N. Harris presented the progress made by the SPARC Initiative on Changes in the Vertical Distribution of Ozone (supported by SPARC, IGACO-O3, IOC (International Ozone Commission) and NDACC, abbreviated as SI2N). The main motivation for this study was the lack of reliable and critically evaluated data to assess changes in the vertical distribution of ozone over multi-decadal timescales. Secular changes in ozone might not only be affected by decreases in stratospheric concentrations of Ozone Depleting Substances (ODSs) but also by changes in climate. The initiative is organised into working groups looking at satellite measurements of the last decade (primarily focussing on inter-annual variability), ground-based systems operated under NDACC, long-term satellite records, ozonesondes, and Umkehr measurements. Another working group focuses on the merging of datasets. A crucial question is the extension of the long-term satellite dataset provided by the SAGE I and II records using measurements from other occultation instruments such as GOMOS and OSIRIS. The study is well integrated with current NASA and ESA projects and liaises with the SPARC Data Initiative. Last November a SI^2N meeting took place as part of the NDACC symposium, and in April 2012 a workshop was held in Washington DC in which the work of the second year of the project was structured and plans for publications and the contributions to the next WMO Ozone Assessment made (see article in this issue of the newsletter).

S. Reimann discussed the progress of the ODS (Ozone Depleting Substances) lifetimes activity, a SPARC project which was approved at the 2011 SSG meeting in Pune. Atmospheric lifetimes are affected by emissions, chemistry (which is likely to be temperature and altitude dependent), and transport (e.g., a stronger Brewer-Dobson circulation could reduce the atmospheric lifetimes of long-lived ODSs), and can therefore change in time. For instance, the lifetimes of CFC-11 and carbon tetrachloride (CCl4) now appear to have longer lifetimes than expected, affecting the interpretation of reported emission rates and the prediction of the expected ozone layer recovery. The aims of this activity are to produce estimates of the numerical values for lifetimes, estimate their uncertainties, assess the influence/use of different lifetime definitions (e.g., steady-state vs. instantaneous lifetimes), and assess the lifetime changes associated with the changing climate. The envisaged structure of the review is as follows, Chapter 1: Importance of global lifetimes, history of lifetimes; Chapter 2: Theory of lifetimes using models and observations; Chapter 3: Update on kinetic and photochemical data that determine lifetimes; Chapter 4: Lifetimes inferred from observed trace gas distributions; Chapter 5: Model estimates of lifetimes. The activity is making good progress within an ambitious schedule (drafts of chapters are currently under review, second draft to be sent to the reviewers by September 2012 so that the document can be released by April 2013).

J. Alexander presented recent progress and current plans for the SPARC gravity wave activity. From 28 February to 4 March 2011 an AGU Chapman Conference on Atmospheric Gravity Waves and their Effects on General Circulation and Climate took place in Honolulu, Hawaii, and a small workshop was held at the International Space Science Institute (ISSI) in Bern, Switzerland (11-15 April 2011). The goal of the second workshop was to compare gravity wave momentum fluxes from observations and models. In addition to assessing the degree of agreement/disagreement, future parameterisation applications and measurement needs were discussed. Two publications from this workshop are in preparation. Two small workshops (12-14 participants each) are planned in 2012-2014 to be supported by a new ISSI proposal (submitted in March 2012). The scientific foci are: (i) better constraints on existing climate model parameterisations; and (ii) better understanding of gravity wave sources (local momentum flux values and intermittency). The final goal is to obtain the information required to develop source parameterisations that are needed for climate model simulations. Furthermore, the activity plans to collaborate with other closely related SPARC activities by participating in the DynVar workshop (planned for early 2013), the Data Assimilation workshop, and the Brewer-Dobson Circulation workshop. An evening meeting is planned at the DA workshop to discuss the ISSI project and other possible joint projects with interested participants.

B. Funke and **K. Kodera** discussed the recent development of the SPARC solar influences on climate activity (SOLARIS). An important recent development is the planned closer collaboration between SOLARIS and HEPPA (High Energy Particle Precipitation in the Atmosphere). Within the HEPPA project, coordinated studies are planned to investigate a particularly strong solar proton event that took place from the 29-30 October 2003 (the so-called "Halloween solar proton event").

V. Eyring spoke about CCMVal and the lessons learned from AR5 on model validation. Within CCMVal, quantitative performance metrics were introduced mainly based on comparison with specific measurements or quantities derived from measurements. These metrics were designed to support model evaluation and intercomparisons of model performance. Relating model performance to projections is, however, a difficult task and such evaluations are part of on-going studies relevant to all climate models. Future coordinated experiments designed specifically to understand the link between model errors and model parameterisations are likely to be a focus of the WGCM, as well as other groups (WGNE, etc). The most recent CCMVal workshop was broadened into an IGAC/SPARC Chemistry-Climate Modelling and Evaluation Workshop, and was held from 21-24 May 2012, in Davos Switzerland (see further discussion below).

E. Manzini presented recent results from the Dynamical Variability ("DynVar") activity. DynVar is currently working with the output of numerical simulations performed for CMIP5 (Coupled Model Intercomparison Project phase 5). Two synthesis papers are planned from this work: one focusing on climate and variability of the stratosphere in the CMIP5 models, and another discussing the role of the stratosphere on surface climate in the CMIP5 multi-model ensemble. A DynVar workshop is planned for early 2013, and aimed at addressing the representation of stratosphere-troposphere coupling in climate and earth-system models. The workshop will also include some focus on gravity waves.

D. Jackson presented an overview of the SPARC Data Assimilation (DA) working group. The short term goals of this activity include: (i) a summary describing how the stratosphere is represented in global Numerical Weather Prediction (NWP) systems; (ii) development of greater interaction between the communities working with chemical data assimilation and satellite retrievals; and (iii) an update of the SPARC section of the WMO Observations Rolling Requirements document (last updated in 1998).

A SPARC DA workshop was held in Brussels in June 2011. This workshop focused on data assimilation within reanalyses, the tropics and observational needs in these regions, as well as on possible SPARC – NWP linkages. Chemical data assimilation was also discussed, with suggestion of greater focus on this topic in future. The next two annual workshops are planned for New Mexico, USA, from 11-13 June 2012, and possibly in Japan in 2013.

Two new stand-alone activities were proposed, arising from the DA working group:

1. The Reanalysis/analysis Intercomparison Project (S-RIP), which will include co-operation between analyses centres and scientists from SPARC and other groups. Two to three dedicated workshops are planned for 2013 and 2014, with a final SPARC Report scheduled for 2015 or 2016.
2. The SPARC Network on Assessment of Predictability (SNAP), which has the following scientific goals: (i) assessing current skill in forecasting the extra-tropical stratosphere; (ii) investigating the extent to which accurate forecasts of the stratosphere contribute to improved tropospheric predictability; and (iii) understanding the partitioning of any gains in predictability with a well resolved stratosphere between improvements in the estimation of initial conditions and improvements in forecast skills. The central aim of SNAP will be to design and organise a new intercomparison of stratospheric forecasts. This will also leave a legacy of datasets to be used by a broad community of researchers.

These two projects will foster closer links between NWP centres and SPARC, as well as between SPARC and the WGNE (Working Group on Numerical Experimentation). A third, long-term goal of the DA working group is to assess missing drag due to sub-grid scale gravity waves.

T. Peter discussed the status of the WAVAS-2 (Water Vapour Phase 2) activity, the main leaders of which were Cornelius Schiller, Thomas Peter and Karen Rosenlof. After the SSG meeting in Pune 2011, it was decided that WAVAS-2 should generate two review papers and a SPARC summary report. The first paper is to contain a UTLS water vapour climatology and to look at- trends and related radiative effects, consisting primarily of satellite datasets plus ground-based measurements. This paper is proceeding according to plan and is planned for submission in 2012 under the leadership of Karen Rosenlof. The second review paper, also planned for submission in 2012 and led by Thomas Peter, will include issues such as supersaturation and related data quality issues primarily connected with in situ data, including data from AquaVIT and MACPEX. The measurements include a comparison of different hygrometers. Given the circumstances (the passing away of Cornelius Schiller, see obituary, this issue) further delays in the summary report are expected.

H. Vömel briefly introduced the concept and philosophy of the data quality assurance of water vapour measurements as used in GRUAN (GCOS Reference Upper Air Network). The goals of GRUAN are to provide long-term high quality climate records, constrain and calibrate data from more spatially-comprehensive global observing systems (including satellites and current radiosonde networks), and fully characterize the properties of the atmospheric column.

D. Thompson discussed recent progress in the SPARC Stratospheric Temperature Trends activity. The group is presently chaired by Dave Thompson and Bill Randel. Analyses presented in 2009 showed that global mean temperatures derived from MSU channel 4 brightness temperatures and radiosonde observations indicate that the lower stratosphere cooled at a rate of ~0.5K/decade from 1979 to 2007, whereas in the global mean, the lower stratosphere has not noticeably cooled since 1995. Recently, however, the temperature trends have been re-evaluated using longer SSU datasets (Wang, et al., 2012). The new NOAA product shows substantial deviations from the previous dataset (Mears et al., 2003; Christy et al., 2000), particularly indicating large negative temperature trends over the tropics. Current activities by the group include: (i) combining new SSU data with AMSU observations (C. Mears, C. Long, C.-T. Zhou); (ii) comparing extended SSU with research satellite data from MIPAS/GOMOS (V. Sofieva); (iii) comparisons with CCMVal-2 (D. Thompson, W. Randel, D. Seidel); (iv) use of COSMIC/CHAMP to aid in merging AMSU data; and (v) links to stratospheric reanalysis inter-comparisons. A co-ordination meeting is planned for late spring 2012.

M. Baldwin advertised the upcoming Brewer-Dobson Circulation Workshop, which took place 25-29 June 2012 in Grindelwald, Switzerland. Brewer-Dobson circulation is a fundamental stratospheric transport pathway and climate models predict a strengthening of this feature under climate change. However, it is difficult to observe any such changes in the available measurements. Because of the vital role of the Brewer-Dobson circulation in the stratosphere, a review meeting is an important step to evaluate and discuss the different views of the community. The main results of the workshop are to be published as an invited review paper in the Quarterly Journal of the Royal Meteorological Society.

A. Robock presented plans for collaboration with the GeoMIP project. GeoMIP is a CMIP coordinated experiment, and therefore part of the Climate Model Intercomparison Project 5 (CMIP5). In this framework, the new GCMs being run for CMIP5 will be used to run similar standard experiments to investigate whether results from earlier simulations estimating the impacts of geo-engineering are robust. Important questions in this context are: How will the hydrological cycle respond to stratospheric geo-engineering? For example, will there be a significant reduction of Asian monsoon precipitation? How will ozone and UV change? A workshop was held at the end of March (see article in this issue of the newsletter).

New proposed activity

M. Rex and **C. Timmreck** presented a progress report on the emerging SPARC activity Stratospheric Sulphur and its Role in Climate (SSiRC – see article this issue). The purposes of the proposed activity include: (i) providing a coordinating structure for the various individual activities already underway in different research centres; (ii) encouraging and supporting new instrumentation and measurements of sulphur containing compounds, such as COS, DMS, and non-volcanic SO_2 in the UT/LS globally; and (iii) initiating new model/data inter-comparisons. SSiRC is expected to feed into the GeoMIP activity as it deals with more fundamental questions relating to sulphur and aerosols in the stratosphere, while GeoMIP will use the outcomes to better understand its own results. A more comprehensive implementation plan will be presented at the next SSG meeting.

Coordination with IGAC and tropospheric chemistry activities

C. Granier spoke in her role as IGAC (International Global Atmospheric Chemistry) liaison on the current activities of IGAC. IGAC is a core project of the IGBP (International Geosphere Biosphere Programme) which, in addition to including atmospheric chemistry as a core activity, also includes "Sustainability Connections" which look at the effects of atmospheric composition on climate, human health, and ecosystems, covering individual and societal responses to choices related to energy sources, material resource uses, economic priorities, etc. IGAC activities cover measurement campaigns and observation networks, with projects such as Halogens in the Troposphere, the GEIA Global Emission InitiAtive, the China working group, Atmospheric Chemistry and Climate (AC&C), and synthesis reports such as "Bounding the role of Black Carbon in Climate" and "Impacts of Megacities on Air Pollution and Climate", a science policy dialogue, thus including many important aspects of tropospheric chemistry. IGAC will be having their next biennial conference in Beijing, China, from 7-12 September 2012.

IGAC and SPARC currently work in collaboration on several modelling activities, including ACCMIP, HTAP and CCMval. With the convergence of stratospheric and tropospheric chemistry-climate models CCMval is to evolve into a merged IGAC-SPARC activity. The initiation of common model simulations, output and diagnostics were discussed at the IGAC-SPARC workshop held in Davos, Switzerland, in May (see this issue and a more complete description of these activities to be included in the upcoming SPARC newsletter, no. 40). An additional possible new area of common focus could be aerosols and their impacts on climate.

J. Staehelin presented a report on "The second international workshop on tropospheric ozone changes", which took place in Toulouse from 11-14th April 2011. The workshop was an opportunity for discussions between scientists engaged in data analysis, data quality or interpretation with colleagues performing numerical simulations. Amongst other discussions, the results from two recent studies were summarized at the workshop: a study by Logan *et al.* (2012) presenting a critical evaluation of long-term ozone time series over Europe, which found particular data quality issues with earlier ozonesonde measurements comprising the longest European records (using Brewer Mast ozonesondes) when comparing these with ozone measurements of high mountain peaks and regular aircraft measurements; and a study by Parrish et al.(2012), in which selected reliable ground-based sites were evaluated, confirming the large surface ozone increases in baseline values between World War II and around 2000 in northern mid-latitudes. Ozone mixing ratios at most of the ground-based remote European sites, except in the marine boundary layer, show a flattening of upward trends since around 2000, whereas sites from Japan and the western part of North America indicate continuous increases.

Joint IGAC/SPARC activities were considered through a panel discussion led by Thomas Peter, Johannes Staehelin, Veronika Eyring, and Claire Granier. Attention focused on how to bring together current

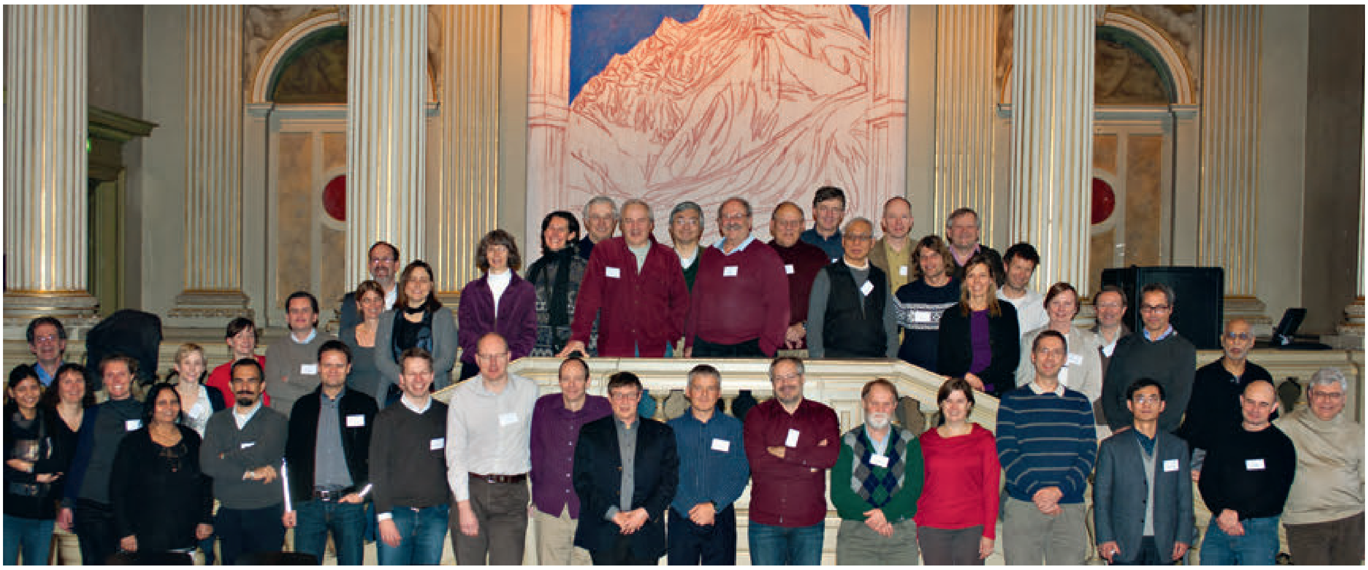

Figure 1: Participants at the 19th session of the SPARC Scientific Steering Group Meeting held in Zurich (photo courtesy: Geir Braathen).

activities --- ACC-MIP (Atmospheric Chemistry-Chemistry Model Intercomparison Project), the IGAC/SPARC Hindcast activity, and CCMVal in order to reflect the increasing integration of the scientific questions and achieve practical synergies. It was acknowledged that the existing AC&C activity was not proving to be an effective mechanism for doing this. Over the past year, it was decided that the CCMVal workshop planned for May 2012 be broadened into an IGAC/SPARC Chemistry-Climate Modelling and Evaluation Workshop, in order to accelerate the integration of IGAC and SPARC global chemistry climate modelling and evaluation activities (see separate report elsewhere in this newsletter). The SPARC SSG welcomed this development, and looks to this workshop for providing the main concrete mechanism for IGAC/SPARC cooperation going forward.

Other coordination of SPARC with activities within and outside WCRP

G. Bodeker presented an update on GCOS when reporting on a meeting of WOAP (the WCRP Observation and Assimilation Panel) that took place in ESRIN, Frascati, Italy from 18-20 April 2011. The focus of the workshop was on the evaluation and assessment of satellite-related global climate datasets. He reported that the work of SPARC was viewed as a model for producing independent assessments, such as WAVAS and the SPARC climatologies report. The focus was on generating and evaluating climate data records (CDRs) of essential climate variables (ECVs) from satellite measurements. The outcome of the workshop included a report detailing the existing ECV datasets, using a range of satellite measurements, evaluated against the GCOS guidelines. The conclusions of the workshop were that the formal evaluation of CDRs is a major task which needs proper funding support, confirming the commitment of agencies to transparency and the generation of quality climate datasets. Independent expert-group assessments of the datasets associated with ECVs enhance their utility and are expected to lead to improvements in individual datasets (as happened in many SPARC assessments). However, if SPARC gets more involved in the generation of CDRs the level of investment of time and effort required to meet the GCOS guidelines will likely increase and these efforts might exceed the possibilities of volunteer efforts.

V. Eyring reported on activities of the WGCM (Working Group on Coupled Modelling. The WGCM has a broad mandate, including reviewing and fostering the development of climate models, coordination of model experiments and inter-comparisons (including CMIP5), as well as promotion and facilitation of model validation. The WGNE/WGCM Climate Model Metrics panel plays an important role in the latter aspect, since it is vital to determine in an objective manner whether models are improving over time. SPARC provides an active contribution to this work with the quantitative performance metrics developed in the CCMVal activity. The Obs4MIP initiative was also presented. This activity, with a website hosted by the ESG (Earth System Grid), aims at integrating observational data from several sources for model validation purposes. Technical documents describing satellite instruments and techniques as well as some data are already available on the portal.

A. Scaife summarized the work of WGSIP (Working Group on Seasonal to Interannual Prediction) relevant to SPARC. The most important link between SPARC and WGSIP is the Stratospheric Historical Forecast Project, which is part of the larger Climate-system Historical Forecast Project (CHFP). In this context, the stratosphere-resolving hindcast experiments are analysed to compare models with high and low model tops. The most important aspects include the ENSO teleconnection and comparison of strong and weak vortex events. The results are to be published in 2012.

D. Jackson presented results arising from the collaboration between SPARC and WGNE (Working Group on Numerical Experimentation). In the past, the liaison between WGNE and SPARC was managed by Saroja Polavarapu, who has now handed over to David Jackson. WGNE recognizes that the SPARC Reanalysis Intercomparison Project (S-RIP) and the Stratospheric Network on Assessment of Predictability (SNAP) are relevant to WGNE's activities. In future, there could also be collaboration between the Gravity Wave Initiative and Boundary Layer projects in WGNE and it was suggested that this point be considered at the next WGNE meeting.

J. Arblaster discussed the role of the stratosphere in climate from an AR5 perspective. She explained the different model runs being carried out within CMIP5, under the auspices of the WCRP's Working Group on Coupled Modelling (WGCM), in support of the next IPCC Assessment. In contrast to the previous IPCC Assessment, there is now widespread recognition of the role of ozone forcing in driving changes in surface climate, especially in the Southern Hemisphere. To better simulate the effects of changes in the stratosphere on surface climate, 15 of the models contributing to CMIP5 are high-top models. The CCMVal/SPARC/AC&C ozone database was prescribed for use by those models that do not simulate ozone. In general, the models have large biases in jet location and are quite likely exhibiting a jet response that is excessively sensitive to both greenhouse-gas (GHG) and ozone forcing. Key conclusions from this presentation were:

- The models contributing to CMIP5 are now much better placed to assess the role of the stratosphere on surface climate. All contributing models include increasing stratospheric ozone into the future, and many of the models simulate changes in stratospheric chemistry (i.e. they are chemistry-climate models).
- Many recent publications have highlighted advances in diagnosing changes in the annular models, jet shifts and storm tracks and the relative roles of changes in GHGs and stratospheric ozone in driving changes in these climate patterns. Current indications are that ozone recovery will largely offset the summertime response of the southern hemisphere circulation to GHGs.
- The new simulations based on the Representative Concentration Pathways (RCPs) present an opportunity to contrast the impacts of ozone recovery and GHGs in future projections of climate change.

T. Shepherd presented an update on the WCRP polar climate predictability initiative. The present frontiers of science include understanding and predicting the rate of Arctic sea-ice loss and understanding the drivers of change in the Antarctic, including connections to ocean circulation, carbon uptake, and ice-shelves. Several science topics could provide foci for the planned initiative, for example, ocean/ice-shelf interactions, the response of southern ocean circulation to surface winds or the seasonal predictability of Arctic summer-time sea ice. The planning continued at a meeting that took place in Toronto from 2-4 April 2012, involving around 30 participants, representing science topics and partner activities. A draft implementation plan will result, for consideration at the WCRP JSC meeting in July 2012.

K. Rao spoke about the Indian monsoon. It is well known that the monsoon is a very important feature of weather and climate in India. A co-operation between SPARC and the Indian atmospheric science community was planned at the last SSG meeting in Pune, India, to focus on this theme. In a second part of the presentation the planning status of the Indian-SPARC (I-SPARC) was shown. In June 2011 "Tropical stratosphere-troposphere: Implications for the Indian monsoon and climate" was selected as a broad theme by the Indian Science Council. The first meeting was attended by 25 scientists and took place on November 30, 2011 in Bangalore. Eight proposals from India and one from outside India were received. The recommendations are to form a National Steering Committee (NSC-ISPARC) to oversee the I-SPARC programme and to produce a scientific programme. The I-SPARC themes are chemistry-climate interactions over the Indian region, the impact of organised monsoon convection on the tropopause layer as seen from observational campaigns and satellite data, and numerical modelling of stratosphere-troposphere dynamical coupling. In addition, 10 topics for focused research were identified.

A. Gettelman discussed a number of international flight campaigns planned over Asia as well as aircraft and balloon campaigns in the Asia-Pacific region planned for the next few years. These are designed, in part, to address key science questions regarding the tropical tropopause layer (TTL), including how the TTL cirrus layer is maintained, the radiative impact of TTL clouds, and the transport of key chemical species into the stratosphere. These activities could mutually benefit from international collaboration and co-ordination, but presently only informal contacts and letters of support exist. Work in progress also includes data sharing agreements. Discussion of science objectives, co-ordinated planning, information on aircraft flight planning, multiple balloon locations and co-ordination of balloons with aircraft are believed to be valuable tasks. For this purpose a TTL observation workshop is tentatively scheduled to take place in Honolulu, Hawaii, 15-19 October 2012. SPARC was asked to consider the possibility of contributing to this workshop/co-ordination exercise.

Capacity Development

Capacity development is a focus of the WCRP as a whole since the success of the research community depends crucially on the next generation of scientists. However, apart from encouraging the participation of young scientists in its activities, capacity development has not historically had a prominent role in SPARC. **R. Diab** discussed ways in which SPARC could engage more actively in capacity development with a particular focus on African countries. Several obstacles hinder science training in Africa: (i) African countries often have few job opportunities for researchers so relatively few aspire to such jobs; (ii) well-trained scientists are often promoted to managerial jobs too soon; (iii) pressure to earn money; (iv) lack of infrastructure and people in the same field; (v) need to overcome the isolation - importance of being a member of a network/international research group; (vi) students often have weak backgrounds due to poor schooling. Before SPARC becomes engaged in capacity development, its motivation in this process needs to be determined, and it is essential that the motivation be aligned with the needs and abilities of the partner countries. Motivation could include: regional inclusivity, increase in science manpower/human capital, need to fill in the regional gaps, data needs or in-country verification of model/satellite products, and for altruistic reasons. In addition, it is important to understand the limitations imposed by the lack of local infrastructure in some countries. A possible focus for SPARC could be doctoral and post-doctoral training and mentoring partnerships to ensure that individuals are well networked. Summer/winter schools in developing countries, and inclusion of local institutions in field campaigns are also possible opportunities, but it is essential that the partner countries be included in the beginning stages of the planning process in order to benefit both SPARC and the partners.

SPARC items

J. Staehelin warmly thanked Norm McFarlane and all former co-workers of the SPARC Office in Toronto for their invaluable help with the transfer of the SPARC Office to Zürich, which was completed at the beginning of 2012, after the 2011 transition year.

M. Geller spoke about the SPARC Data Center, which contains datasets relevant to SPARC research such as the SPARC reference climatology, and the US high-resolution radiosonde and rocketsonde data. The Data Center has always been funded by NASA through M. Geller's research grants, and funding has been secured for the next year. However, M. Geller is planning to retire in the next few years and it is therefore critical that a more permanent solution to funding and maintainenance of the Data Center be found. The acquisition of high-resolution US radiosonde data for 2009-2011 is currently being undertaken. The high-resolution data exhibits great potential for studies of the tropopause and the effect of vertical resolution in studying this region. A workshop supported by NSF funding is in the planning process, and it was suggested that SPARC could be a co-sponsor.

G. Bodeker discussed the possibility of a new SPARC members database that would allow for the inclusion of additional characteristics of the people in the current SPARC database, such as research interests. This information would be attractive for the database members who might choose to be informed about specific SPARC activities, as well as for the SPARC activity leaders and SSG members who could more easily find people willing to participate in new activities. Such an extended database would require the help of the database members to fill out the questionnaire with details such as their expertise and scientific interest, and security and privacy issues would need to be considered.

C. Arndt, the new SPARC communication manager, introduced the new SPARC web site (www.sparc-climate.org). The opportunity for fast and easy communication is crucial in a programme like SPARC, and she discussed the potential for advertising new high-impact papers that are relevant to the SPARC community on the SPARC website.

SPARC future

An open discussion was held on the future evolution of SPARC, picking up from the earlier discussion of the outcomes of the OSC and the evolution of the WCRP itself. The overall context is that there is a rapidly increasing demand for "actionable" climate information based on sound science, as reflected in the Global Framework for Climate Services (GFCS), as well as a growing emphasis on an inter-disciplinary approach to global sustainability, as reflected in the "Future Earth" initiative. At the same time, models still have major systematic deficiencies, and the global climate observing system is not only inadequate but is in a very real danger of deteriorating. The challenge for the WCRP is to keep focusing on the imperatives of improving models, and improving observations (including data quality — a big issue), while demonstrating the value of these fundamental activities for applied research. In particular, the WCRP needs to help make stronger links between climate science and risk-based frameworks such as food security and water security. The hope is that climate research can actually be empowered by a user-driven approach, which will identify key sources of uncertainty for practical issues.

SPARC has long been interdisciplinary (with an equal focus on dynamics and chemistry) and focused on deliverables and user needs (e.g. assessments, space agencies), so is well positioned to respond to these overall developments. Moreover, the various SPARC activities are themselves evolving naturally to develop a greater emphasis on stratosphere-troposphere coupling, as this is where the science is headed, so SPARC is already evolving in a way that matches its new mandate from the WCRP. In the future, SPARC will continue to focus on the key imperatives of: (i) improving models through model-measurement comparison; (ii) improving the use of imperfect model information through model assessment and process-oriented diagnostic analysis; (iii) improving reanalyses through assessment of the products; and (iv) improving the observational record through assessment of the products and development of climate data records. SPARC will also continue to contribute to assessments. For the GFCS, SPARC would expect to work mainly through the various WCRP working groups.

One apparent gap in WCRP activity lies in the area of direct and indirect aerosol radiative forcing, which represents a key uncertainty in climate. This could be a future area of activity for SPARC, in collaboration with other projects. There is already an emerging activity within SPARC focused on sulphate aerosols, which could provide a starting point.

More generally, SPARC will need to become actively engaged in the relevant WCRP Grand Challenges, which emerged from the short JSC meeting in Boulder in October 2011. The Grand Challenges are defined more from a user-driven point of view, in contrast to the previous cross-cutting activities (which they are essentially replacing) which were defined more from a process/science-driven point of view, and should thus provide key "pathways to impact" for the WCRP. For SPARC, the most relevant Grand Challenges are (i) Provision of skilful future climate information on regional scales (including decadal and polar predictability), and (ii) Interactions of clouds, aerosols, precipitation, and radiation and their contributions to climate sensitivity. It is probably fair to say that SPARC is reasonably well positioned to contribute to (i), although it was emphasized that SPARC needs to ensure that the stratosphere is included in the planning for the Regional Production Centres that will underpin the GFCS, and that its own activities (such as CCMVal) provide appropriate diagnostics for regional climate issues. On the other hand, contributing to (ii) will be more of a challenge for SPARC as the mechanisms for doing so do not yet exist, and will need to be developed. In particular, it will be necessary to build chains from measurements and models to climate sensitivity, through climate system components such as sulphate aerosol, cirrus, and upper tropospheric water vapour, which are all of direct interest to SPARC. This area could be an appropriate place for Climate Process Teams to address key systematic model errors such as tropical tropopause temperature and water vapour.

T. Peter led the discussion regarding a possible name change for SPARC. The name is important for the identity of SPARC, and a change may be appropriate given that the WCRP will be extending the mandate of SPARC to include tropospheric processes (to be implemented in 2013). A possible name change was already discussed at previous SSG meetings, and a blog was initiated to allow the SPARC community to comment and make any suggestions. The blog was very active and a large number of opinions were presented with several potential names put forward. The blog has recently been reinitiated with the hope that the community will use this dialogue opportunity again. The final decision about the new name will be made at the next SSG meeting.

G. Bodeker presented the arrangements for the next SPARC General

Assembly, which will take place 12-17 January 2014 in Queenstown, New Zealand. The planning process is already well under way. Greg Bodeker is in contact with the Air New Zealand Environment Trust to develop novel ideas for carbon offsets for the General Assembly, since the long-distance flights to New Zealand will lead to a significant carbon footprint and may discourage some colleagues from attending. To help drum up interest in the region, Julie Arblaster is organizing a special SPARC session at the next Australian Meteorological and Oceanographic Society meeting, in February 2013.

The next SSG Meeting will take place in Buenos Aires, Argentina, with a 1.5 day Regional Workshop from 26-27 November 2012 followed by a 3.5 day SSG meeting from 27-30 November 2012, hosted by the University of Buenos Aires. These SPARC meetings will be followed by a WCRP Workshop on Climatic Effects of Ozone Depletion in the Southern Hemisphere, from 3-7 December 2012, which will be of obvious interest to the SPARC community.

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Report on the Regional SPARC Science Workshop 6-7 February 2012, Zurich, Switzerland

Thomas Peter[1], Fiona Tummon[2]

[1]ETH Zurich, Switzerland, thomas.peter@env.ethz.ch, [2]SPARC Office, Switzerland, fiona.tummon@env.ethz.ch

Holding a "regional workshop" in combination with the annual SPARC Scientific Steering Group (SSG) meeting has become a tradition since this was first tried out at the 2007 SSG meeting in Bremen[1]. The purpose of these workshops is to bring international and regional SPARC science together. The workshop participants are then invited to participate as guests in the first half-day of the regular SSG meeting. The workshop in Zurich consisted of a series of invited and contributed presentations in poster and oral sessions featuring (1) Long-Term Climate Variability, (2) Stratospheric Trace Gases and their Trends, (3) the UT/LS and related Processes, and (4) Modelling of Tropospheric Trace Gas Variability. This report highlights only those aspects of the workshop that led to further discussions amongst participants[2].

[1]See report by Sinnhuber *et al.* in SPARC newsletter No. 30, January 2008 (**http://www.sparc-climate.org/publications/newsletter/**)

[2]The full programme of the workshop can be found here: **http://www.sparc-climate.org/fileadmin/customer/0_shortcut/SSG2012_WorkshopAgenda.pdf**.

(1) Long-Term Climate Variability

In his contribution on "Long-term climate variability attributable to solar variability" **J. Beer** explained that solar physicists are predicting a period of low solar activity for the second half of this century (similar to the Dalton minimum in the early 19th century). The subsequent cooling might partly compensate GHG-induced warming, and lead to some delay of ozone recovery. This triggered discussion as to what degree such a development could be exploited by climate sceptics, which should be of concern to SPARC, since many of the mechanisms coupling the solar and terrestrial changes work via the stratosphere and mesosphere, as was also argued by **E. Rozanov** in his talk.

Strong volcanic eruptions such as those of Tambora or Krakatoa could also initiate multi-year climate effects, including high-latitude winter warmings. In a modelling study, **S. Brönnimann** demonstrated that winter warmings were the average response in an ensemble corresponding to more than 500 eruptions, whereas individual ensemble members might not produce a winter warming. The question was raised whether one should also include a coupled deep ocean, which may affect the simulated results. For very large eruptions with decadal effects this is certainly the case.

Model weighting strategies, such as ensemble weighting of individual models and multi-model weighting is important not only for CCMVal, but also played a large role for CH2011, the Swiss Climate Change Scenarios initiative. An important conclusion from CH2011, as presented by **C. Appenzeller**, was that in seasonal forecasting a multi-model weighting is a very successful approach, as we have typically 30 years of hindcast data available. For climate projections on the other hand, a multi-model weighting was found to be "very risky, since no observed climate change" exists that can be used as a hindcast. "When internal variability is large, more information may be lost than could be gained", therefore CH2011 decided not to apply a weighting. A statistical framework using a Bayes algorithm was, however, applied in order to better constrain model uncertainty. Repercussions for future CCM validation work need to be discussed.

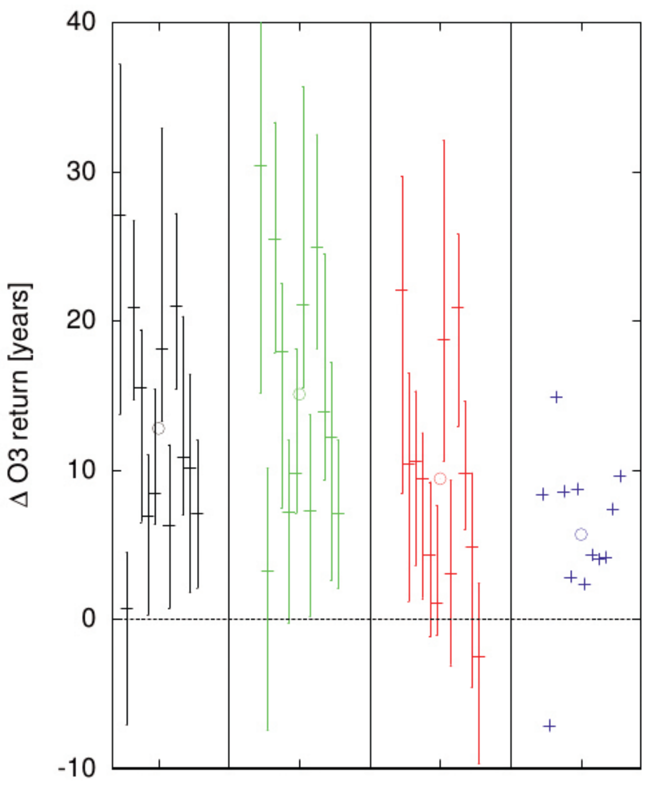

Figure 2: Height dependence of hemispheric difference in return dates to 1980 values for 12 CCMs (circles are the multi-model means, lines the error estimates). Return dates are calculated for the total column ozone (black), from partial ozone columns from 1000-100 hPa (green) and 100-10 hPa ((red). The right most column (blue) is the difference between the total column ozone return dates and the return dates of the partial column above 100 hPa (only multi-model means shown, crosses). Close to half of the hemispheric difference in dates of return to 1980 values results from ozone changes between the surface and 100 hPa. Stratospheric cooling above 10 hPa and the associated effects on ozone reduces the hemispheric asymmetry.

(2) Stratospheric Trace Gases and their Trends

G. Bodeker asked the question why do chemistry-climate models predict that southern mid-latitude ozone will return to 1980 values 10-15 years later than in the northern mid-latitudes? The explanation provided by the 2010 WMO/UNEP Ozone Assessment hints at the hemispheric asymmetry in the strengthening of the Brewer-Dobson Circulation and the effects of the Antarctic ozone hole. In contrast, a new finding is that a combination of changes in meridional transport below the 100 ha surface and larger increases in tropospheric ozone over NH mid-latitudes may account for up to 50% of the hemispheric asymmetry, calling attention to the importance of reliably modelling tropospheric chemistry in CCMs (see **Figure 2**). Long-term homogenized and altitude-resolved global ozone records spanning the period from prior to ozone hole formation and extending into the next century will be essential for detection and attribution of such developments, as was also emphasized by **J. Staehelin**.

S. Reimann reported on measurements of sources and long-term trends of CFC, HCFCs and HFCs, as deduced from ground-based measurements. Continuous high precision measurements, for example at the high alpine site of Jungfraujoch, have recently become important, as they can be used to check compliance with the Montreal Protocol and to identify unreported sources of ozone depleting gases. HFCs (hydrofluorocarbons) deserve particular attention since these gases have been introduced as CFC-replacements, i.e. they do not deplete ozone, but are, however, strong greenhouse gases and show massive atmospheric increases. At

Table 1: Conceptual sequence of transport, exchange and mixing. Adapted from Heini Wernli's presentation.

Process	Time scale
Transport (far range)	
Troposphere: ABL to tropopause	Deep convection: < 1 h
	Warm conveyor belts (WCBs): 1-2 days
Stratosphere: intra-hemispheric journey	In the vortex: ~ 5 days
	Elsewhere: 1 week – 1 month
	Large-scale transport well captured by models and reanalyses, convective transport less certain
Exchange (intermediate range)	
Irreversible PV changes due to latent heat release, radiation, turbulence, …	D/Dt (PV) ~ 1-10 PVU / day
	establishes an equilibration of originally different air mass PVs
Mixing (small range)	
of tropospheric and stratospheric constituents	Time scale:
	hours to weeks (?)
	Representation in models uncertain:
	Where does it occur? Patchiness?

Jungfraujoch the largest discrepancies have been found with respect to CHF_3 (HFC-23 or fluoroform) from Italian sources, where measurement-deduced estimates exceed the national inventory by more than an order of magnitude. SPARC is presently undertaking a re-evaluation of the lifetimes of important halogen source gases, since evidence has emerged that in many cases the actual lifetimes may be considerably longer than those currently assumed in the WMO/UNEP Ozone Assessment. This represents a major uncertainty in reconciling top-down and bottom-up emission estimates. **V. Eyring** pointed out in her presentation that the results of the lifetime assessment are expected to feed directly into development of troposphere-stratosphere CCMs within the upcoming IGAC-SPARC CCM activities.

M. Santee demonstrated the advances in the understanding of trace gas concentrations, their variability and changes deduced from satellite observations. She showed unprecedented evidence of extensive polar processing – denitrification, chlorine activation, and ozone loss – occurring throughout the lowermost vortex and sub-vortex in both hemispheres. Export of chemically-processed, ozone-depleted air from the polar (sub) vortex in late winter and spring can significantly affect trace gas distributions throughout the extra-tropical lowermost stratosphere. With the breakdown of the polar vortex, there is a transition from the vortex being the major transport barrier to the subtropical jet and tropopause being the major transport barriers.
Knowledge gaps exist concerning how interactions between the upper tropospheric and lower stratospheric jets and transport (including STE) affect trace gas distributions, and how these interactions will evolve in a changing climate.

(3) UT/LS and related Processes

T. Shepherd reported on the effects of climate change on stratosphere-troposphere dynamics. Models consistently predict a strengthened Brewer-Dobson circulation (BDC), mainly in the northern hemisphere. This appears to result from a reasonably well-understood mechanism, namely increased wave drag in the subtropical lower stratosphere. While many studies have appealed to "improved propagation conditions" from strengthened subtropical winds, details remain uncertain. In the Canadian Middle-Atmosphere Model (CMAM) critical-layer control of Rossby-wave breaking provides a robust mechanism for a strengthened BDC.

J. Alexander highlighted that orographic gravity waves in the southern hemisphere, e.g. leeward energy propagation of Andes mountains or above the South Georgia Islands, are seen in AIRS observations and in ECMWF analysis fields, but remain unresolved in high-resolution CCMs. SPARC will continue to focus on these questions in the CCM and gravity wave initiatives.

A. Gettelman shifted the focus to the upper troposphere and tropopause region. He asked: we know that the troposphere will warm and the stratosphere will cool – but what will the tropical tropopause temperature do? Models suggest that Brewer-Dobson circulation will accelerate; hence there should be more ozone in the lowermost stratosphere, more transport of ozone into troposphere, and thus significant climate effects on tropospheric oxidative capacity and air quality. The observed and simulated changes in tropospheric jets and storm tracks clearly demand models with an interactive ozone layer such as those used in CCMVal. Many details of the controlling mechanisms remain uncertain, such as cloud feedbacks in CCMs, which are strongly linked to uncertainties in circulation feedbacks.

Meteorological processes near the extra-tropical tropopause and their relevance for SPARC were also the focus of **H. Wernli**'s talk. Conceptually, interchange between the stratosphere and troposphere can be separated into three distinct processes: transport, exchange, and mixing (see **Table 1**). These processes act on different spatial and temporal scales, and models represent these processes with variable accuracy. Stratospheric intrusions can impact surface chemistry, while warm conveyor belts were shown to be very efficient transport mechanisms of tropospheric pollutants into the stratosphere. Several issues related to these processes are yet to be fully understood: the effects of stratospheric aerosols on cirrus cloud formation; the mixing of stratospheric air deep into the troposphere; impacts on air quality; and in the reverse direction, what is the impact of subtropical air mixed into the lowermost stratosphere? Lots of future work for SPARC.

(4) Modelling of Tropospheric Trace Gas Variability

I. Bey devoted her presentation to the question of whether state-of-the-art CCMs can reproduce observed global and regional trends in tropospheric ozone. Her answer was: only to some extent so far! Anthropogenic precursor gases for tropospheric ozone (NO_x and VOCs) have decreased over Europe and North America, however, climate-related effects, such as global warming, partly counteract this evolution, making it difficult to understand seasonal differences. Possible issues concern model representations of emissions and their trends, how natural emissions (BVOC, NOx) are affected by climate change, year-to-year variations in stratosphere-to-troposphere transport as well as non-linear processes during long-range tropospheric transport. This calls for trend analysis in global tropospheric chemistry models to become a standard test. This is not that easy (lots of observations, model data, etc.) and will require a concerted community effort.

A. Stenke called attention to large uncertainties in available emission datasets, which make it difficult to identify feedback processes. She exemplified this by modelling methane lifetime using the SOCOL CCM with flux boundary conditions for methane, isoprene, NO_x and CO. The model reproduces CH_4 mixing ratios at long-term measurement stations very well, with correct seasonal phases and amplitudes of the annual cycle, north-south-gradients, and decadal increases until the early 1990s. However, after 1992 the model shows a sudden deviation of CH_4 concentrations, varying strongly depending on the dataset applied for anthropogenic CH_4 emissions (ACCMIP vs. EDGAR) and CH_4 biomass burning emissions (ACCMIP vs. GFED3 vs. RETRO). The ACCMIP emission datasets lead to the largest errors. This work demonstrates the importance of reliable emission data, in particular for simulations predicting future air quality, which will become a part of the upcoming IGAC-SPARC CCM activities.

Finally, **D. Brunner** reported on regional tropospheric chemistry modelling, the biggest challenge to which is probably the accurate modelling of tropospheric aerosols. Particle number density, size, shape and chemical composition determine the impacts of aerosol on health as well as their direct and indirect effects on climate . Validation of COSMO-ART simulations (the new online coupled regional model developed by KIT Karlsruhe) was performed in a very systematic manner, for example, by testing with idealized 2-D studies simulating cloud processing in mountain passages. These studies helped identify some deficiencies with respect to nitrate, sulphate and SOA aerosol optical depths. One particular topic of interest concerns the "nitrate puzzle", i.e. that strong reductions of SO_2 and NO_x emissions in Europe have led to strong reductions in particulate sulphate but not at all of nitrate – for largely unclear reasons. Three possible explanations are: reduced sulphate in the aerosol makes place for more nitrate; or, more ozone and nighttime chemistry produces more nitrate; or, the emission partitioning (NO/NO_2) has changed, favouring nitrate formation. Future work will address these possibilities in light of the identified model deficiencies, which comprise investigations of the strongly non-linear cloud processes as well as the role of ammonia in controlling nitrate levels. A topic, which no longer seemed fashionable, namely the sulphate/nitrate partitioning, is back on the map.

Report on the 6th Atmospheric Limb Conference
29 November – 1 December 2011, Kyoto, Japan

Takuki Sano[1], Makoto Suzuki[2], Masato Shiotani[3], John P. Burrows[4], Christian von Savigny[5]

[1]Japan Aerospace Exploration Agency (JAXA), Japan, sano.takuki@jaxa.jp, [2]JAXA, Japan, suzuki.makoto@jaxa.jp, [3]Kyoto University, Japan, shiotani@rish.kyoto-u.ac.jp, [4]University of Bremen, Germany, burrows@iup.physik.uni-bremen.de, [5]University of Bremen, Germany, csavigny@iup.physik.uni-bremen.de

The 6th International Atmospheric Limb Conference was held at Kyoto University in Japan from 29 November to 1 December 2011. This meeting was originally scheduled to take place in mid-March 2011, but regrettably it had to be postponed due to the terrible earthquakes and related disasters in northeastern Japan at that time. The number of participants was less than that expected for the pre-disaster meeting, but over 40 colleagues attended the meeting. The venue was the conference hall, Shiran-Kaikan, on the Kyoto University campus in Kyoto city. There were 30 oral presentations and 10 poster presentations. Sessions focused on instruments and missions, data intercomparison and assimilation, and radiative transfer, and covered the mesosphere, the stratosphere, and the upper-troposphere and lower-stratosphere (UTLS) region. To highlight Japanese activity in this field, special sessions on the Superconducting Sub-millimeter-Wave Limb-Emission Sounder (SMILES) were included.

At the beginning of the first session, **M. Suzuki** from the Japan Aerospace Exploration Agency (JAXA), **Y. Kasai** from National Institute of Information and Communications Technology (NICT), and **M. Shiotani** from Kyoto University welcomed the participants of the Limb Conference. A summary of the presentations made at the workshop follows.

In Session 1, ongoing and future missions as well as space-borne instruments were discussed. **K. Walker** gave an overview of the Atmospheric Chemistry Experiment (ACE) on-board the Canadian satellite Scisat-1, as well as some recent scientific results related to the chemistry and dynamics of the atmosphere in the Arctic and Antarctic regions from an enormous quantity of observational data (8 years of data). **D. Rault** discussed the limb profiler in the OMPS (Ozone Mapper and Profile Suite) instrument on-board the NPOESS Preparatory Project (NPP), which was launched just before the conference. His talk was especially aimed at the expected data quality and the spatio-temporal distribution of ozone and related species from these data. **D. Murtagh** outlined two upcoming instruments: PREMIER and STEAM-R. PREMIER is proposed as a candidate instrument for the next Earth Explorer Core mission led by ESA, and STEAM-R is also planned, in order to make a Swedish national contribution to PREMIER.

Session 2 was named the "SMILES Special Session," in which the current status of the instrument and the latest results, from the half-year of observations of the SMILES instrument (October 2009 to April 2010) on-board the International Space Station, were presented. **M. Shiotani** gave a general introduction about the operation of the instrument and showed early validation results of the minor atmospheric constituents in the middle atmosphere. **C. Mitsuda** explained the design of the algorithm and the latest improvements for retrieving the official level 2 products (vertical profiles of atmospheric constituents). **S. Mizobuchi** presented the current status and near-future plans for processing and analysing of the level 1 products (brightness temperature spectra in the sub-millimetre wavelength region). **Y. Kasai** reported the preliminary results from research at the NICT, which is an independent effort from that of the official level 2 processing activities.

In Session 3, the main theme of the presentations was the comparison of data from multiple missions, and monitoring the long-term variation of the Earth's atmosphere. **P. Q. Xu** described the expected data assimilation results from the upcoming OMPS Limb Profiler data using the Goddard Earth Observation System (GEOS-5/6) global prediction model data, which are hoped to improve the quality of operational mesoscale numerical forecasts. **J. Hakkarainen** presented a study that combined the datasets from GOMOS (Global Ozone Monitoring by Occultation of Stars) and SAGE II/III (Stratospheric Aerosol and Gas Experiment II/III). He also discussed some inter-comparison results with these datasets during the period when all three instruments were active. **A. Bourassa** showed a one-decade data collection of stratospheric aerosol retrievals from OSIRIS (Optical Spectrograph and InfraRed Imaging

Figure 3: Participants at the 6th Atmospheric Limb Conference held in Kyoto.

System) on-board the Swedish Odin satellite, and compared these results with the SAGE series and CALIPSO measurements.

The second day began with Session 4, in which some talks on mesospheric observations were presented. **J.-H. Yee** began with a presentation on the global atomic oxygen distribution measured with SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) and TIDI (TIMED Doppler Interferometer) on-board the TIMED (Thermosphere Ionosphere Mesosphere Energetics and Dynamics) satellite, and HRDI (High Resolution Doppler Imager) on-board UARS (Upper Atmosphere Research Satellite). **K. Hultgren** presented algorithm studies of noctilucent clouds observed with the special mesospheric mode operation of the OSIRIS instrument. **C. von Savigny** discussed OH* emission rate profiles including vertical shifts in the OH emission originating from different vibrational levels, based on limb measurements with the SCIAMACHY (Scanning Imaging Absorption spectroMeter for Atmospheric CHartographY) instrument.

Session 5 was a mini poster session, in which 10 posters were presented, mainly by young researchers in Japan. All posters were related to the Japanese SMILES mission.

In Session 6, stratospheric chemistry and dynamics were discussed. **J. P. Burrows** introduced the recent update of the limb and occultation measurements and data product retrievals from the SCIAMACHY instruments, which were studied in the IUP group at the University of Bremen. **M. Suzuki** and **T. Sugita** concentrated on the chemical aspects, such as the distribution of chlorine and bromine compounds, found via statistical analysis of SMILES data, while **T. Sakazaki** and **P. Baron** presented the dynamical characteristics, such as diurnal variations in temperature or horizontal winds, derived from these products. **A. de Lange** reported the first results of HCl and ClO retrieval with TELIS (Terahertz and submillimeter Limb Sounder) on the balloon experiment mission in Kiruna, Sweden.

Session 7 was a discussion of retrieval and radiative transfer. **J. Xu** presented the recent results of TELIS level 2 data processing. He studied the performance of forward and inversion models for retrieving diurnal profiles of atmospheric constituents. **J. Puķīte** showed a tomographic approach for obtaining 2-dimensional distributions of trace gases from one-time inversion. He also indicated that this approach contributed to improvements in the treatment of the horizontal gradients in the trace gas distribution on the profile retrieval.

The last session, consisted of talks related to the UTLS. **J. Burrows** presented K. Weigel's paper on global time series of water vapour distribution retrieved from SCIAMACHY limb measurements for the observations from 2003 to 2006. **J. Urban** presented long-term variation in water vapour for the tropics and mid-latitudes using data from several instruments (SAGE-II, HALOE, Odin/SMR, SABER, etc.). He also showed a decade of water isotopologues (H_2O-17, H_2O-18 and HDO). **H. Sagawa** presented his attempt to retrieve the global distribution of water vapour and its temporal evolution by detecting water vapour opacity in the SMILES frequency region. **F. Khosrawi** showed a study on possible causes for large mixing ratios of N_2O using satellite observations such as Odin/SMR, some ground-based measurements, and model simulations using WACCM (Whole Atmosphere Community Climate Model).

The meeting was closed with an open discussion session about strategies for future Earth observation as well as cooperation between Earth science and molecular chemistry, etc. At the end of the discussion, the University of Bremen's proposal to host the next meeting in March 2013 was approved by the participants.

Report on the Workshop on Stratospheric Sudden Warming and its Role in Weather and Climate Variations 22-24 February 2012, Kyoto, Japan

Shigeo Yoden[1], Mark Baldwin[2], Paolo Davini[3], Daniel M. Mitchell[4]

[1]Kyoto University, Japan, yoden@kugi.kyoto-u.ac.jp, [2]University of Exeter, UK, M.Baldwin@exeter.ac.uk, [3]Euro-Mediterranean Centre for Climate Change / Università Ca' Foscari, Italy, paolo.davini@cmcc.it, [4]University of Oxford, UK, mitchell@atm.ox.ac.uk

A three-day workshop on stratospheric sudden warming (SSW) and its role in weather and climate variations was held from February 22-24 2012 at Shiran-Kaikan, Kyoto University, Japan. There were 105 registered participants, including 46 from abroad (**Figure 4**). The program, presentations, and other relevant information can be found at the workshop homepage, **http://www-mete.kugi.kyoto-u.ac.jp/Kyoto2012/**

An SSW is a breakdown event of the winter polar vortex and is associated with a sudden rise of temperature, of several tens of degrees, occurring in the polar stratosphere within a few days. SSWs are highly nonlinear dynamical events of planetary scale, although it is recognized that they are also associated with smaller spatial-scale gravity waves, and longer time-scale intraseasonal and interannual variations or climate change of the polar vortex. Interactions with radiative and chemical processes have also drawn much attention from viewpoints of fundamental or applied sciences. At present, the remote influence and association of SSWs with variations in some components of Earth's climate system are investigated widely, including the troposphere, mesosphere and lower thermosphere, oceans, hydrosphere, and the cryosphere.

It is 60 years since the discovery of SSW by Richard Scherhag (1952), over 40 years since the pioneering dynamical theory by Taroh Matsuno (1971), and 30 years since the publication of some well known articles on SSWs in the special issue of the Journal of the Meteorological Society of Japan in 1982 on the occasion of the centennial anniversary of the Society. In this workshop, we invited several speakers from the first generation of SSW research to promote intensive discussions with the second and third generations to inform the future. We repeated Michael McIntyre's (1982) question "How well do we understand the dynamics of stratospheric warmings?", and expanded the question to include their remote influence on the climate system and the role of SSWs in weather and climate variations. There were 10 oral sessions with 42 presentations (including 15 from Japan) and one poster session in the first day afternoon with 30 presentations (including 13 from Japan).

Figure 4: Participants at the Workshop on Stratospheric Sudden Warming held in Kyoto.

The workshop was opened by the keynote speech on SSW events and their role in weather and climate variations by **S. Yoden**. He gave a brief historical review of the observational, theoretical and numerical studies, as well as his personal views about SSWs and also the current state of the science. By referring to the words of Confucius "To the past to inform the future", it was anticipated that the participants of this workshop use the opportunity to discuss their perspective of the challenging subjects in future research.

Stratosphere-Troposphere Coupling

The influence of the troposphere on the stratosphere, and vice versa has gained much interest over the past decade. Certain SSW events stand out as of particular interest, and during this workshop the 2009 vortex split was considered as such a case (see **Figure 5**). The session was

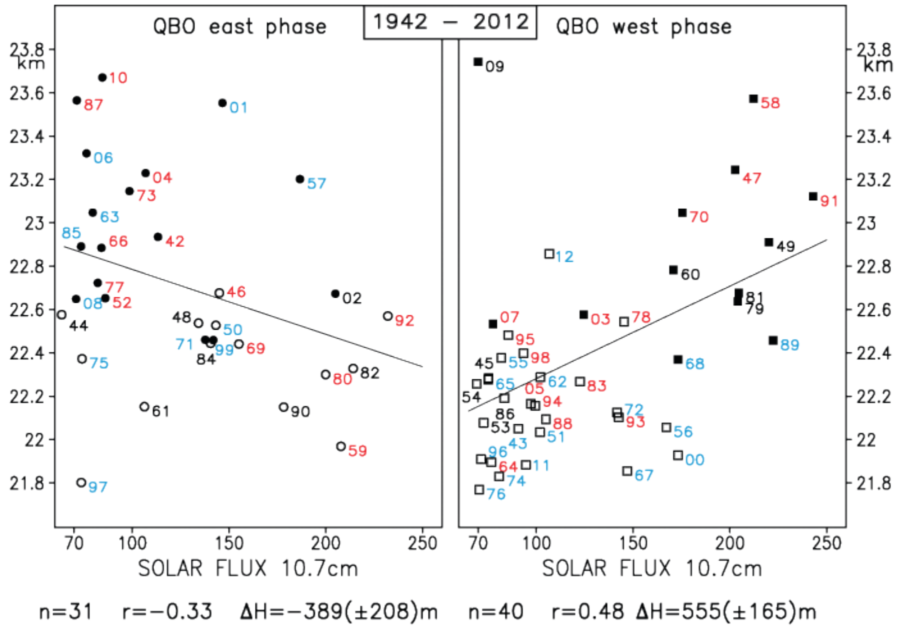

Figure 5: Scatter diagrams of the monthly mean 30 hPa geopotential heights (km) in February at the North Pole (1942-2011), plotted against the 10.7 cm solar flux. Left panel is for years in the east phase of the QBO (n = 31), and right for years in the west phase (n = 39) (Labitzke and Kunze, 2009, updated).

opened by a talk on this topic by **K. Krüger**, emphasising this event's uniqueness considering the various phases of natural forcings, such as the solar cycle, Quasi-Biennial Oscillation (QBO), and El Niño-Southern Oscillation (ENSO), at the time. It was noted that the wave activity was the strongest on record, with a clear domination of wave-2 over wave-1. **H. Naoe** showed that a large part of this could be due to the intensification of the subtropical Pacific jet, which led to a blocking high over the eastern north Pacific basin. Tropospheric blocking activity was a repeated theme throughout the workshop.

K. Nishii showed that the geographical location of the blocking is fundamental to wave propagation prior to influencing SSW events; with blocking over the West Pacific tending to suppress planetary wave propagation, and blocking over the Euro-Atlantic sector enhancing it. **D. Peters** expanded by showing that induced wave trains, similar to those observed in Southern Hemisphere (SH) during 2002, could lead to strong wave-2 planetary scale waves after about 2 weeks. Although **T. Birner** demonstrated that the time-scales of the forcings were more important than their strength, with moderately strong wave activity lasting for around 10 days prior to an SSW event. **S. Bancalà** investigated the role of blocking in association with the development of wave-1 and wave-2 SSW events, suggesting that Euro-Atlantic blocks tend to be precursors for wave-1 events but also noting that not all wave-1 forcing led to displacement events. Following an SSW event, **P. Davini** showed that the blocking frequency may increase over Greenland and decrease elsewhere over the Atlantic basin, while opposite effects are observed after a Vortex Intensification (VI) event.

Together with tropospheric blocking, the role of antecedent sea surface temperatures (SSTs) was also addressed by the conveners. **Y. Zyulyaeva** noted, using 3D Eliassen-Palm (EP) flux diagnostics, that decadal variations in the ocean temperature could have a strong impact on planetary wave activity and hence stratospheric circulation anomalies, although this only held true during early winter. **C. Garfinkel** and **R. Ren** both investigated the linkage between SSWs and the occurrence of ENSO, the former arguing that both La Niña and El Niño can lead to increased SSW frequency, the latter that colder temperatures were also observed in the mid-latitude stratosphere.

Both **D. Domeisen** and **K. Kodera** studied the surface response following SSWs. The latter also looked specifically at the 2009 SSW, concluding that tropical convective activity shifted southward following the event, and that this was associated with an abrupt change in the tropospheric Hadley circulation. While both used traditional analysis techniques, the issue of suitable diagnostics was also a topic of interest during the workshop. **M. Baldwin** raised issues about dealing with annular modes, commenting that as we have no fundamental equations that govern them, they are often hard to interpret dynamically. Instead he opted for potential vorticity (PV) based diagnostics, demonstrating that an elevated tropopause would cause tropospheric PV stretching and could lead to lower pressures over the polar cap. **D. Mitchell** argued that in some cases the use of zonal mean diagnostics was not suitable since SSW events are inherently asymmetric. Instead he suggested using geometric based diagnostics, known as 2D-moments, which provide a higher sample size of SSWs, allowing the distinction of splits and displacements to be more easily characterised, as well as providing a relative vortex centric framework. In doing so it was shown that in order to correctly predict surface weather and climate following SSW events, one must have knowledge of whether the event is a split or a displacement.

Special session: "To the past to inform the future"

The group of four talks held by the invited speakers provided a historical review of what has been carried out in the past and what the state of the art is regarding the comprehension of SSW phenomenology and dynamics. An introductory talk by **K. Labitze** (presented by **U. Langematz**) gave a fascinating overview of the discovery of SSW in 1952 by Richard Scherhag and the team at the Free University of Berlin, after a long-lasting and advanced campaign of balloon measurements and map analyses. Thereafter, **T. Matsuno** introduced his personal walk-through of the stratospheric world from the 1960s, facing the complex challenge of SSWs and the QBO. **M. McIntyre** provided a different viewpoint on SSWs, highlighting the fundamental role of PV and the nonlinear Taylor-Bretherton identity in describing the disturbance of the wintertime stratospheric polar vortex. Finally, **A. Plumb** described the main effects of SSWs that go beyond the extra-tropical stratosphere, focusing on the cooling in the equatorial stratosphere, stratosphere-troposphere coupling (and on the missing dynamics regarding its projection on the Northern Annular Mode) as well as on the signatures of the SSW in the upper atmosphere. The entire special session was webcasted through USTREAM Live, **http://www.ustream.tv/channel/ssw2012**, and the video is now available at **http://www.ustream.tv/recorded/20636442**.

Dynamical and chemical processes

The two sessions on dynamical and chemical processes provided a series of talks which gave further insight into these processes related to the occurrence of SSW events. The dynamical session opened with **T. Horinouchi** detailing the formation of large-scale fronts during SSW events, specifically during the January 2008 event. **P. Hitchcock** went on to describe the polar night jet oscillation events through an Eliassen adjustment framework. **A. O'Neill** argued that the development of the SH 2002 SSW could be induced by a synoptic scale tropospheric cyclogenesis when the stratospheric vortex was highly elliptical. The upward penetration of the localised potential vorticity anomaly lying under the disturbed vortex may therefore favour splitting events. **S. Liu** also used the idea of 2D-vortex moments as a set of diagnostic tools, performing experiments with a single-layer shallow water model on the vortex response to slowly varying tropospheric wave number 2 forcing, and demonstrating the importance of excitation of the barotropic mode in vortex splitting events. **N. Nakamura** provided yet another new diagnostic method, showing that Lagrangian information of PV fields can be combined with Eulerian mean quantities to better partition the pseudo-momentum between the mean flow and the waves.

The role of the middle atmospheric chemical components and their processes was also discussed in a separate session. **Z.-Y. Chen** and **M. Suzuki** showed how ozone and other chemical tracers were subjected to strong changes before and after the SH 2002 SSW and the Northern Hemisphere 2009/2010 winter. A final talk by **M. Fujiwara** focused on the SPARC Reanalysis/Analysis Intercomparison Project (SRIP), aimed at improving the quality of the current reanalyses products in the middle atmosphere.

Upper Atmosphere Responses

An entire session was dedicated to observational analyses and numerical experiments of the upper

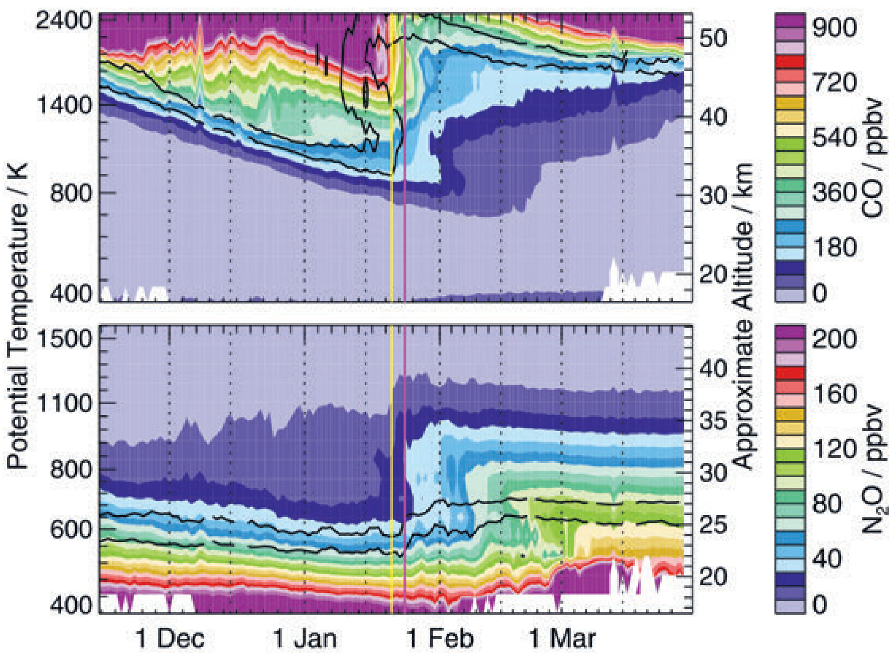

Figure 6: Pressure-time sections at 70°N of (top) MLS zonal mean temperature, and (bottom) MLS-derived zonal mean zonal wind (Manney et al., 2009).

atmospheric response before and after SSW events. One of the most frequently cited figures (Manney *et al.*, 2009) in this workshop is shown in **Figure 6**. **K. Oyama** presented a detailed analysis of the effects on the ionosphere during the 2009 SSW event, reporting exceptional changes in plasma density and temperature profiles. In a related talk, **X. Liu** analysed a series of SSW events adopting station and satellite measurements and assessed a semi-diurnal perturbation in the ionosphere and strong cooling in the thermosphere (>300 km) associated with both minor and major SSWs. **K. Thayer** argued that front-like disturbances observed through LIDAR measurements from Greenland and Norway may be due to baroclinic instability, similarly to synoptic-scale tropospheric disturbances. **Y. Orsolini**, made use of climate model data to suggest that both planetary and gravity waves could contribute to reformation of the stratopause after SSWs at high altitude (75 km). The role of planetary and gravity waves was also addressed by **K. Sato** in a high resolution climate model, suggesting that the polar night jet recovery may be due to planetary waves as well as radiative processes. Changes in the general mesospheric circulation after SSW events were investigated by **T. Hirooka**, while the simulation of both major and minor SSW events and their characteristics in climate models was also addressed by **A. Chandran** and **C. Zuelicke**.

Predictability and climate change

The final sessions dealt with SSW predictability and future changes in their variability. Most of the forecasting talks considered the SSW events over the last decade, and dealt with the annular mode response to these events. For instance **Y. Kuroda** showed that the timing of SSW events is often of the utmost importance when considering the tropospheric Northern Annular Mode response, and that forecasts initialised before and after the event can often have opposing results. **H. Mukougawa** looked specifically at the 2001 December SSW, and concluded that due to a persistent blocking event over the Atlantic, predictability of the SSW could be achieved 2 weeks in advance. **S. Mahmood** found, looking at the 2010 February event, that predictability time scales were considerably shorter than this and only meaningful when using high-top models. **M. Taguchi** also noted that predictability was highly dependent on the state of tropospheric wave patterns, a conclusion shared by **M. Sigmond** who showed results using the Canadian Middle Atmosphere Model.

U. Langematz and **K. Shibata** both talked about the change in frequency of SSWs under increased Greenhouse Gas (GHG) scenarios compared with fixed GHG scenarios using chemistry-climate models. Both reported no significant change in SSW frequency towards the end of the 21st century, a conclusion also noted by **D. Mitchell** in a previous session. However, **U. Langematz** showed that the stratospheric influence on surface variability may decrease, or at least become masked by surface climate change, into the future. **P. Braesicke** expanded by suggesting that late winter wave-2 warmings may increase into the future. While all the studies in this session were in broad agreement with each other, it was noted that in the current literature significant increases and decreases in SSW frequency towards the end of the 21st century have also been reported.

Poster session

A poster session was also held on the first day. Students, researchers and professors from around the world presented 30 posters in three groups: influence of natural forcings on SSWs, remote influences of SSWs, and association with chemical processes. The presented posters covered a wide variety of topics, making use of reanalyses as well as observational and model data. These included the role of natural forcing (such as the QBO, solar cycle, ENSO and extra-tropical SST changes) on the Arctic polar vortex, ozone changes, modulation of tropical circulation patterns, diagnosis and predictability of SSWs and many others.

Closing remarks

Closing remarks were given by two Japanese leaders in middle atmosphere science: **T. Tsuda**, co-chair of Climate And Weather of the Sun-Earth System (CAWSES) –II, and **M. Shiotani**, a member of the SPARC Scientific Steering Group. Both of them highlighted current and future challenges facing the international collaborations in the fields of middle atmosphere sciences. The final remarks were given by **A. O'Neill**, the former co-chair of the SPARC Scientific Steering Group. He praised the scientific research coming from the Japanese community as a whole, making reference not only to the experienced scientists who performed the fundamental research many years ago, but also to the young scientists of today. A. O'Neill concluded by emphasising the importance of truly visualising and studying, for example synoptic maps or animations of relevant dynamic fields, in order to approach a problem from many different angles and to increase our awareness of how chosen diagnostics can evolve with each other.

Acknowledgments

The workshop conveners (M. Baldwin, T. Shepherd and S. Yoden) would like to thank the generous sponsors of the meeting: The SPARC project of the World Climate Research Programme (WCRP), the International Commission on the Middle Atmosphere (ICMA) of the International Association of Meteorology and Atmospheric Sciences (IAMAS), the Grants-in-Aid for Scientific Research (KAKENHI) of the Japan Society for the Promotion of Science (JSPS) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Kyoto University Global COE Program on Sustainability / Survivability Science for a Resilient Society Adaptable to Extreme Weather Conditions (KU GCOE-ARS), and Kyoto University Foundation. Thanks also to local technical support by the staff of the Integrated Earth Science Hub, Kyoto University (F. Furutani and Y. Uemoto). We also thank invited speakers and all attendees whose participation made it a most successful workshop.

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Progress Report on The SI²N Initiative on Past Changes in the Vertical Distribution of Ozone

Neil Harris[1], Johannes Staehelin[2], Richard Stolarski[3]

[1]University of Cambridge, UK, Neil.Harris@ozone-sec.ch.cam.ac.uk, [2]SPARC Office, Switzerland, johannes.staehelin@env.ethz.ch, [3]NASA Goddard Space Flight Center, USA , richard.s.stolarski@nasa.gov

In early 2011, a joint initiative was started under the auspices of SPARC, the International Ozone Commission (IOC), the ozone focus area of the Integrated Global Atmospheric Chemistry Observations (IGACO-O3) programme, and the Network for Detection of Atmospheric Composition Change (NDACC). To aid digestion, an acronym of acronyms, SI2N, was adopted. A report on the first workshop was published in SPARC Newsletter 37 (Harris *et al.*, 2011). This and much other information is available on the SI²N website at **http://igaco-o3.fmi.fi/VDO/index.html**.

The main objective of SI²N is to assess and extend the current knowledge and understanding of measurements of the vertical distribution of ozone, with the aim of providing input to the next WMO Scientific Assessment of Ozone Depletion anticipated for 2014. No detailed mechanism for achieving this goal was agreed upon at the first workshop, though great enthusiasm was shown for tackling the issue. Rather, six working groups were identified that would coordinate and promote activities in their areas, with a view to meeting a year or so later to review progress. This report is the summary of the second SI²N workshop.

Working Group progress

Two 'new' long-term datasets of ozone profiles from satellites will be released in 2012. First, a consistent retrieval will be applied to all the BUV and SBUV instruments, covering the period from 1970 to 2011. This record will be unique in that it will be based on a single instrument type. It will provide valuable information about ozone changes in the middle and upper stratosphere as well as in the total column. Second, the SAGE record (comprising SAGE I/II/III and SAM II) has been analysed using the same retrieval for all four solar occultation instruments and will cover the period from 1979 to 2005. Significant improvements are expected for the SAGE I and SAM II records, most notably as a result of a new altitude registration for SAGE I to avoid the long-standing need to use an empirical adjustment (Wang *et al.*, 1996). Both these developments are significant steps forward and will lead to much better knowledge of changes in the vertical ozone distribution over the last 30-40 years.

The problem with the new SAGE record is that it ends in 2005. It is thus important to be able to extend the record from that time – this inevitably involves 'merging' datasets (see below). Several approaches are being developed and tested, all of which are promising, but none of which is proven. From a purely instrumental view, there are advantages to using instruments with similar characteristics. OSIRIS (limb scatter) and GOMOS (stellar occultation) are prime candidates as they measure in a similar spectral region (GOMOS is also an occultation instrument), have good temporal overlaps with SAGE II, and measure on an altitude-based grid like SAGE, thus avoiding the use of meteorological fields to transpose between pressure and altitude coordinates. Preliminary time series have been produced and show real promise, particularly at altitudes between about 20 and 50 km and latitudes between 50°S and 50°N. Further work is required on quantifying the errors associated with the merging of data, and to see whether it is possible to extend the analysis outside this region.

Since the early 2000's several other instruments have measured ozone. In addition to OSIRIS, ODIN (launched 2001) carries the microwave sounder SMR. ENVISAT (launched 2002) has three atmospheric chemistry experiments which all measure ozone: GOMOS (stellar occultation), MIPAS (thermal emission), and SCIAMACHY (limb scatter). Unfortunately, communication with ENVISAT was lost in April 2012 and measurements may have ceased. Since 2004, the SCISAT mission carried ACE-FTS and MAESTRO (both solar occultation) and the AURA platform carried the MLS instrument (microwave). A great deal of work is being done to assess the quality of these ozone measurements made over the last decade or so. This is being done through the SPARC Data Initiative and as part of projects supported by a number of space agencies. These studies will also lead to combined datasets of the vertical distribution of ozone.

The level of agreement is generally encouraging, and the comparisons are clearly leading to a greater understanding of any problems associated with individual instruments. Again, the region of reasonable agreement is at altitudes between 20 and 50 km and latitudes between 50°S and 50°N. Outside this region, the measurements are fundamentally harder for most instruments and the natural variability is higher, so there is a limit to the improvements that can be reasonably expected. However, the overall picture was encouraging, with the various presentations giving a strong impression that agreement within 5%, and quite possibly 2-3%, is possible between different instruments over much of the stratosphere.

A similar impression is given by comparisons of satellite measurements with NDACC lidar measurements (*e.g.*, Nair *et al.*, 2012). These show good stability as well as good agreement. It would be valuable to extend these comparisons to include measurements with other ground-based instruments (microwave, infrared and Umkehr) that measure in different altitude ranges and with different vertical resolutions. An important factor when making these comparisons (and when merging data sets) is to allow for the diurnal variation in ozone, which occurs in and above the upper stratosphere.

Umkehr measurements have been made at many sites by either Dobson or Brewer instruments, with some of the records going back to the 1950s or '60s. However, aside from a few stations with good records, their full potential has not been realised. A major part of the SI2N activity is thus to improve the existing records by applying and validating new algorithms and by increasing the number of stations reporting the full data files. It is particularly hoped that the coverage by the Brewer network will increase significantly. An important issue is how to use the overall record effectively as many individual records are short, so that there is a real need to homogenise and merge the data correctly.

The aim of the ozonesonde working group is to provide a revised, homogeneous dataset with corrections being applied for biases related to instrumental changes (such as sonde type or electrolyte solution) in those cases where comparisons or laboratory experiments provide strong evidence for such corrections. This exercise should result in a significantly improved ozonesonde record, giving more solid information about the atmospheric changes that have occurred, as well as a better dataset for comparison with satellite measurements.

Merging and homogenisation of data sets

The general issue of 'merging' or 'homogenising' datasets was discussed at some length and with real feeling. In an ideal world, one instrument would have provided global measurements for several decades without any change in instrumental performance or quality. However, in the real world, SAGE II with its 21-year record is the only one to come close (1984-2005) in the lower stratosphere, although it is noteworthy that the ODIN satellite, launched in 2001 with the OSIRIS and SMR instruments, is still operational after 11 years. Even with these long records, measurements from several instruments are needed to provide truly multi-decadal records. The situation is noticeably simpler when several versions of the same instrument type are used successively, such as the SBUV instruments, which together have made continuous records since 1979. The situation is not fundamentally different for ground-based instruments as they are either replaced (ozonesondes being the extreme case, with a new sonde for each measurement) or adjusted. These changes tend to have local effects, but sometimes changes are introduced across networks and so have effects over larger areas.

At first glance, a distinction can be drawn between 'merging' and 'homogenisation' by describing the former as the formation of a master dataset by collating several different datasets, and describing the latter as the formation of a master data set by joining a series of measurements made by the same type of instrument. However, in practice this distinction is blurred when one considers that factors such as different platforms with varying orbit characteristics or small variations in instrument design (*e.g.*, wavelength range, sonde electrolyte solution) can lead to equally large differences in ozone as variations in instrument type (*e.g.*, limb vs. occultation, sonde manufacture). In both cases, great care is needed when compiling these master datasets, and the compilation benefits enormously when instrumental expertise is included in the process. Finally, the concept of the 'best' dataset is not particularly useful. Each will have its own strengths and weaknesses and is thus more or less suited to addressing a particular scientific issue. In particular, it is clearly advantageous to have datasets with different spatial and temporal coverages.

An example in a parallel field is the development of the new time series for stratospheric temperatures based on the Stratospheric Sounding Unit instruments (SSU), which gives strikingly different results to the previous version (Wang *et al.*, 2012). The challenges in providing a self-consistent record were remarkably similar - satellites with drifting orbits, individual sensor degradation, changing background atmosphere, etc. But the lessons are the same – careful instrumental analysis and statistically rigorous determination of adjustments leads to useful long-term datasets.

Within the SI^{2}N initiative, the aim is to move forward on both fronts, with better understood instrumental records and with improvements in methods of merging them. Validation of each measurement record by other measurements will be integral to this, but it has to be recognised that merely comparing datasets reduces their independence to some degree, and it is very important that any adjustments to the core datasets are based on solid instrumental grounds wherever possible. In this regard, for example, the new retrieval of the SAGE I record is welcome, as previously an empirical correction to its altitude registration had to be used (Wang *et al.*, 1996). Without such solid reasoning, we risk fooling ourselves about how firmly our results are based.

The Way Ahead

In order to provide valuable information for consideration in the WMO-UNEP 2014 Scientific Assessment of Ozone, it was decided to organise a special issue of a journal in which most of the individual on-going studies would be published. Additionally, three overview papers would be prepared covering Measurements, Validation, and Analysis and Interpretation. Discussions are progressing well with the Copernicus journals, Atmospheric Chemistry and Physics (ACP), Atmospheric Measurement Techniques (AMT) and Earth System Science Data (ESSD), and the details of the SI^{2}N Special Issue (special editors, dates, etc.) will be announced soon.

This approach has a number of advantages:

1. It is fully peer-reviewed, with the journal review process being strengthened for the overview papers by merging it with the normal report review process (extra reviews and a meeting).
2. The use of open access journals means that the whole process is transparent and open to public scrutiny. All the material is readily accessible.
3. The scientists involved get full credit for their efforts in terms of publications (not always the case with reports or assessments), without having to write separate papers.
4. The joint special issue means that papers covering more tech-

nical issues (AMT) and more scientific issues (ACP) can be published jointly with the databases (ESSD) making the process more traceable.
5. While the general shape is quite clear, there is no need to precisely define the limits of the material included and so new developments will be easy to include either in the overview papers or in the WMO-UNEP Assessment itself.
6. The facility for publishing supplementary material gives the opportunity to make more of the underlying analyses widely available.

The first overview chapter will summarise the measurements themselves and will include information about the instruments and the algorithms used to convert a measurement signal into atmospheric quantities. The lead author will be Birgit Hassler. The Validation chapter will describe the methodologies used to validate or evaluate long-term measurements using existing data and provide an assessment of the agreement (or otherwise) between time series along with a rigorous error analysis. The lead author will be Jean-Christopher Lambert. The third overview paper on Analysis and Interpretation will describe and assess the merged products that are used for time series analysis, as well as the time series analyses of the long-term datasets. The lead author will be Neil Harris. It is important to note that these will be overview papers, with the emphasis on summarising and assessing information available in other papers and reports.

A review meeting focusing on these three overview papers will be held in September 2013, with the papers submitted a couple of months earlier so that the regular journal review process can take place before the meeting. The special issue itself will open much earlier, hopefully by the time this report is published. In this way, the overview papers can take full account of the published literature and themselves be subject to a clear and transparent peer review process.

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Summary of the Second GeoMIP Stratospheric Aerosol Geoengineering Workshop 30-31 March 2012, University of Exeter, UK

Ben Kravitz[1], Alan Robock[2], Jim M. Haywood[3]

[1]Carnegie Institution for Science, USA, bkravitz@carnegie.stanford.edu, [2]Rutgers University, USA, robock@envsci.rutgers.edu, [3]Met Office/University of Exeter, UK, J.M.Haywood@exeter.ac.uk

Anthropogenic climate change is largely caused by emissions of greenhouse gases from fossil fuel combustion (IPCC, 2007). This has caused and will almost certainly continue to cause adverse consequences to many aspects of the planet, including humanity's way of life. The only permanent solution to preventing these potentially adverse changes is to cease emissions of greenhouse gases, a process which is difficult, costly, and has thus far been very slow to be adopted, if it has been implemented at all. This lack of progress in emissions mitigation, as well as the threat of dangerous climate change, has prompted some scientists to assess the viability of direct manipulation of the climate system to counteract some of the consequences associated with emissions of greenhouse gases (Crutzen, 2006). These intervention technologies are broadly known as geoengineering.

Although the original definition of the term geoengineering referred to pumping carbon dioxide into a sequestration site in the deep ocean (Marchetti, 1977), many technologies to manipulate the climate system have been proposed (*e.g.*, Keith, 2000). One particular technology that, arguably, has received the most attention is stratospheric injections of sulphate aerosol precursors. This method is inspired by large volcanic eruptions, which have the potential to inject several teragrams of sulphur dioxide into the stratosphere. In the presence of solar radiation, this gas oxidises, forming sulphate aerosols. These aerosols are efficient at scattering solar radiation, some of which is scattered back to space, reducing the energy input into the climate system. One of the effects of this aerosol layer is cooling of the surface for a few years after the eruption, which has been observed after many major eruptions in the past (Robock, 2000). The recent large eruption of Mount Pinatubo in 1991 injected 20Tg of sulphur dioxide into the lower stratosphere resulting in reductions of surface air temperature by approximately 0.5°C the year after the eruption (*e.g.,* Soden *et al.*, 2002).

If a means of purposefully injecting sulphate aerosol precursors into the stratosphere could be developed, the planet could be cooled, helping to alleviate some of the dangerous impacts of anthropogenic warming. Additionally, depending on the degree of geoengineering undertaken, this cooling could reverse some of the expected impacts on sea level and Arctic sea ice. However, large volcanic eruptions show evidence of circulation changes, as well as a weaker summer monsoon in India, Asia, and the Sahel (*e.g.*, Oman *et al.*, 2006). These consequences of volcanic eruptions, which have the potential to negatively impact billions of people, could also apply to stratospheric geoengineering with sulphate aerosols (Robock *et al.*, 2008). Moreover, due to dynamics inherent in the climate system, a uniform or near-uniform layer of stratospheric sulphate aerosols likely will not cause uniform impacts across the globe, resulting in disparities of regional impacts of geoengineering (Ricke *et al.*, 2010). Stratospheric aerosols would also provide surfaces for heterogeneous chemistry and deplete ozone (Tilmes *et al.*, 2008; Robock, 2008, Rasch *et al.*, 2008).

Several groups have conducted climate model simulations involving a sustained layer of stratospheric sulphate aerosols in an attempt to assess the climate impacts of geoengineering. However, assessing these model results is difficult, as each model has inherent features and shortcomings that affect the results, and the simulated scenarios frequently differ. Past studies comparing multiple model simulations of geoengineering have been inadequate. In one case, two modelling groups did different experiments, involving both different greenhouse gas scenarios and different amounts of sulphate aerosol, rendering the results incomparable (Rasch *et al.*, 2008). In another study, two modelling groups performed the same experiment, and although the temperature responses were similar, the precipitation responses had large differences in many locations (Jones *et al.*, 2010).

In light of these studies, as well as the uncertainty in the expected effects of geoengineering, the need for coordination and standardization of experiments became apparent. The Geoengineering Model Intercomparison Project (GeoMIP) provides a framework of four standardized geoengineering experiments, allowing inter-comparability of climate models and revealing the robust features (or lack thereof) of climate model responses to geoengineering scenarios (Kravitz *et al.*, 2011). This project is a "Coordinated Experiment" as part of the Coupled Model Intercomparison Project Phase 5 (CMIP5; Taylor *et al.*, 2012).

The initial stage of GeoMIP involves four experiments simulating geoengineering. Experiment G1 seeks to balance the radiative forcing from an abrupt quadrupling of ambient carbon dioxide concentration with a reduction in the total solar irradiance. Experiment G2 seeks a similar balance, but with the transient simulation of an increase in ambient greenhouse gas concentrations by one percent per year. Both of these experiments are purposefully idealised, seeking to reveal basic climate responses to simple radiative forcings, although they can serve as analogues of the proposed geoengineering method of "space mirrors." Experiment G3 seeks to balance the radiative forcing of RCP4.5 by a layer of stratospheric sulphate aerosols. Experiment G4 involves a background of RCP4.5, on top of which a continuous annual injection of 5Tg of sulphur dioxide into the lower stratosphere (equivalent to one Pinatubo every four years) is imposed. All simulations were conducted with 50 years of geoengineering. Experiments G2, G3, and G4 were followed by an additional 20 years in which geoengineering ceased.

Participants in GeoMIP include nearly all major climate modelling centres throughout the world. Currently, we have participants from 17 climate modelling centres in 12 different countries. Model output is being made available on the Earth System Grid network and is publicly available for analysis.

When GeoMIP was first organised, the plan was for comprehensive atmosphere-ocean general circulation models to participate in all four experiments, and for chemistry-climate models, which in general did not include an ocean, to be provided with forcing data sets and oceanic boundary conditions for them to be able to conduct G3 and G4 experiments. It now seems like this distinction is rapidly disappearing, with comprehensive models that include the full climate system and stratospheric chemistry performing full scenario simulations. Potential participants who will need such forcing and boundary conditions are urged to contact the GeoMIP organizers to obtain standardized datasets for the experiments.

The first GeoMIP workshop was held at Rutgers University from 10-12 February 2011 (Robock *et al.*, 2011). The purpose of that meeting was to outline the project, assess participation, and discuss in detail simulation protocols. The following workshop, held on 30-31 March 2012 at the University of Exeter, primarily focused on current assessment of progress on the project. Present at the meeting were 26 members of the science research and communication communities from seven different countries.

At the meeting, we discussed preliminary results, mainly from individual modelling groups, but also including some preliminary co-ordinated analysis. We also discussed methods of co-ordinated analysis and our contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Included in this contribution is an analysis of the so-called "termination effect," or how the climate system responds if geoengineering were to cease immediately (*e.g.,* Wigley, 2006).

Also discussed at the meeting were potential future projects that could be coordinated under the GeoMIP framework. The discussion primarily focused on experiments involving brightening of marine stratocumulus clouds, another often-proposed method of geoengineering (Latham, 1990). This technology seeks to enhance the aerosol indirect effect on a global scale by injecting sea salt aerosols into the clouds that can serve as cloud condensation nuclei. In theory, that would brighten clouds, causing reductions in global radiative forcing that would in turn cause cooling. However, since marine stratocumulus clouds, especially those that can be effectively brightened by increasing the number of cloud condensation nuclei, are not ubiquitous, cooling would be highly spatially heterogeneous. Moreover, preliminary climate model simulations suggest that through dynamical interactions and teleconnections, effects on the hydrologic cycle, particularly in the Amazon, have the potential to be severe (Jones *et al.*, 2009).

To date, simulations of marine stratocumulus brightening suffer problems that are similar to those that motivated the founding of GeoMIP. Namely, modelling studies are isolated and incomparable. At the second GeoMIP meeting, three experiments were suggested to investigate robust responses of climate models to this particular method of geoengineering. Since the meeting, discussion has progressed, and the three experiments are being finalized.

We intend for our model output to be used beyond the community of climate modellers. As we discussed in the meeting, our output can be provided to social scientists, agricultural modellers, and other interested parties who may wish to apply our results to their studies. Interest from some of these communities has already been expressed, and collaboration is currently underway.

The official web site of the Geoengineering Model Intercomparison Project (**http://climate.envsci.rutgers.edu/geomip**) discusses in detail specifications of the project and will be updated continually as new information, results, and publications become available.

Acknowledgments

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HALO - UTLS Workshop

21-23 September 2011, Glashütten, Germany

Harald Bönisch[1], Peter Hoor[2], Thomas Birner[3], Paul Konopka[4]

[1]J. W. Goethe University of Frankfurt, Germany, boenisch@iau.uni-frankfurt.de, [2]Johannes Gutenberg University Mainz, Germany, hoor@uni-mainz.de, [3]Colorado State University, Fort Collins, USA, thomas@atmos.colostate.edu, [4]Forschungszentrum Jülich, Germany, p.konopka@fz-juelich.de

The Upper Troposphere/Lower Stratosphere (UTLS) plays a crucial role in the coupled troposphere/stratosphere system and hence in the global climate system (see recent review articles by Fueglistaler *et al.* (2009) and Gettelman *et al.* (2011) on the tropical and extra-tropical UTLS, respectively). The UTLS is characterized by a complex interplay of dynamics, radiation, microphysics and chemistry, which makes the UTLS both susceptible to climate change and challenging to understand. The crucial role of the ULTS has been emphasised by the SPARC community in several workshops, in particular in Mainz and Boulder (Law *et al.*, 2006; Gettelman *et al.*, 2007; Randel *et al.*, 2010). Our current picture of UTLS composition is to a large extent based on airborne in situ measurements of recent years.

The long-term investigations of SPURT (Engel *et al.*, 2006, Hoor *et al.*, 2004) have provided a seasonal overview of the composition of the UTLS, which was extended in particular by the G5 data during START05 and START08 (Pan *et al.*, 2010), regular measurements on commercial airliners (CARIBIC and MOZAIC) and satellite observations (Hegglin *et al.*, 2009).

HALO - The High Altitude and LOng Range Research Aircraft - is the new research aircraft for atmospheric research and Earth observation of the German science community, and is particularly well suited for UTLS research. HALO is funded by the Federal Ministry of Education and Research, the Helmholtz-Gemeinschaft, and the Max-Planck-Gesellschaft, and is based on a production G550 business jet from Gulfstream Aerospace Cooperation and is operated by the Flight-Department of the German Aerospace Centre (DLR) in Oberpfaffenhofen. The first atmospheric science mission will take place in summer 2012.

The HALO-UTLS workshop was aimed at bringing together the German HALO user community related to UTLS research, and to discuss the current status, the future perspectives, and the role of HALO in UTLS research. The workshop discussed the crucial dynamical, chemical, radiative, and microphysical processes and their feedbacks in shaping UTLS composition and structure, focusing on the needs and requirements of future HALO in situ measurements and observations to address open questions in UTLS research. The workshop included invited overview presentations and contributed talks on: dynamics and coupling; trace gas transport, observations and modelling strategies; chemistry and air pollution; clouds, radiation, and aerosols; and upcoming satellite perspectives.

Stratosphere-troposphere exchange (STE) affects the composition of the UTLS (**Figure 7**) and involves a broad range of temporal and spatial scales. The tropopause region has been recognized as a transition layer connecting the turbulent troposphere governed by short dynamical time scales with the more stably stratified stratosphere governed by long time scales for tracer transport driven by the Brewer-Dobson circulation (BDC). The interaction between both involves fast eddy-driven mixing processes at the tropopause related to the jet stream, gravity wave breaking, convection, and upper level cloud radiative processes. In the extra-tropical UTLS (ExUTLS) the tropopause inversion layer (TIL) (Birner *et al.*, 2002) is collocated with the transition of both regimes, and therefore may potentially affect the coupling processes between both regimes. Baroclinic waves strongly modify the dynamical structure and the stability over a whole range of scales (**Figure 8**), as well as radiative processes and the stratospheric circulation. However, the role of the TIL in the climate system as well as in mixing and transport across the tropopause remains an open question. Despite its immense significance, the UTLS is one of the least understood regions of the atmosphere due to the complex multi-scale interactions between dynamics and chemistry. Uncertainties in the representation of physical and chemical processes in models have a large effect on simulated distributions of radiatively active gases in the UTLS (*e.g.*, **Figure 9**) and the associated radiative forcings, which trigger climate change (Solomon *et al.*, 2007). Because of relative minimum temperatures in this region, the UTLS has a key influence on radiation escaping the troposphere to space and hence affecting surface climate and climate feedbacks (Gettelman *et al.*, 2011).

The composition of the air enter-

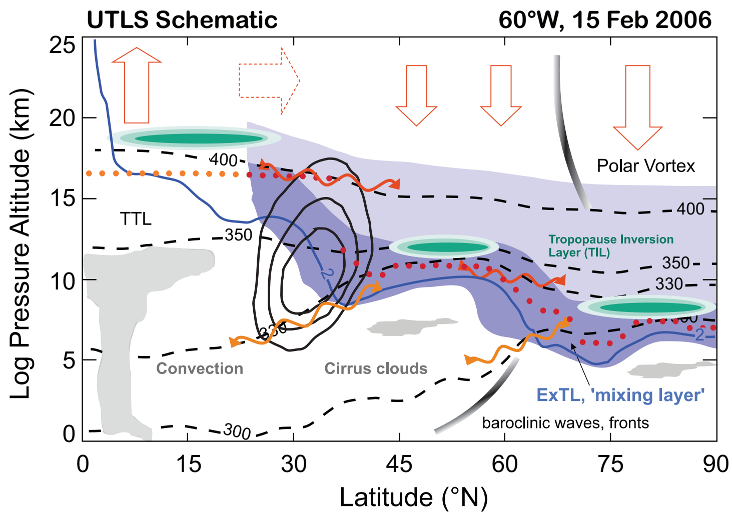

Figure 7: Schematic of key structures and processes determining the structure of the ExUTLS. Close to the tropopause, short-term processes and rapid two-way eddy driven mixing (wiggly arrows) determine the composition of the ExTL (dark blue). Above, the tropospheric influence acts on longer time scales (light blue) due to the strength of the subtropical jet barrier. The TIL (green ovals) is situated in between these two regions. The upper part of the ExUTLS is affected by the large-scale mass circulation in the stratosphere constituting an upper branch of the residual circulation (solid arrows), but might also be affected by mass transport to high latitudes above 380K (dashed arrow) and eddy driven mixing above the subtropical jet (Figure after from Gettelman et al., 2011).

ing the stratosphere is strongly determined by the transport processes within the tropical tropopause layer (TTL), which couples the Hadley circulation in the tropical troposphere with the much slower Brewer-Dobson circulation (BDC) in the stratosphere (Fueglistaler *et al.*, 2009). Complementary to the upward transport through the TTL, the downwelling branch of the BDC leads to stratosphere to troposphere transport (STT) that mainly occurs in the extra-tropics. Rossby wave breaking leads to large-scale quasi-horizontal mixing, which occurs roughly along isentropic surfaces and with faster transport timescales than the slowly overturning BDC. Furthermore, the BDC may be thought of as consisting of two branches (Birner and Bönisch, 2011), which act on different time scales and might respond differently to future climate changes (Bönisch *et al.*, 2011) (**Figure 10**).

P. Hoor opened the workshop with an overview talk on the current status of (extra-tropical) UTLS research and about the observations, current understanding and open questions in this research field. He noted that the overall qualitative picture of the ExUTLS is self-consistent and that the ExUTLS can be regarded as a transition in mixing and transport time scales (Hoor *et al.*, 2004, 2010). However, the driving processes and their relative importance are still poorly understood, since a range of temporal and spatial scales are involved: feedbacks and coupling between dynamics and chemistry interact from the micro-turbulence to global scales and vice versa. Therefore a more detailed understanding of the active processes and their feedbacks is necessary to gain a quantitative understanding of the ExUTLS and future changes.

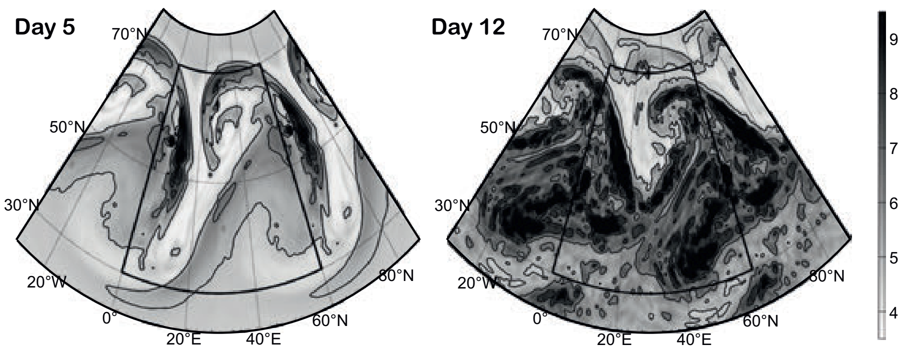

Figure 8: Simulation of the stability N_2 at the tropopause during a baroclinic wave breaking in an idealised model (Figure after Erler and Wirth, 2011).

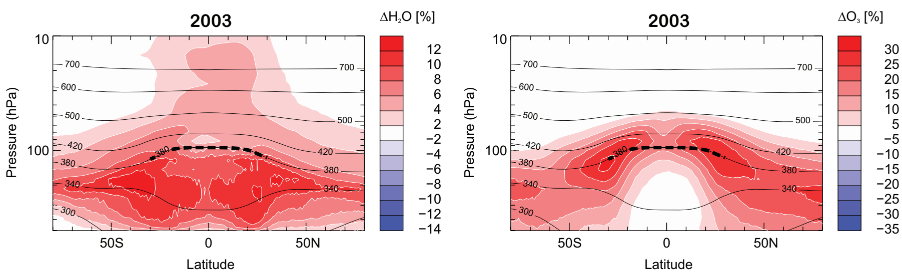

Figure 9: Zonally averaged annual mean (2003) differences of ozone and water vapour mixing ratios obtained from two CLaMS simulations with different assumptions on the atmospheric mixing strength (well within current uncertainties). These differences from the uncertainties of mixing result in radiative forcing uncertainties of 0.172 W/m² and 0.725 W/m² for ozone and H_2O, respectively (Figure adapted from Riese et al., 2012).

The first major atmospheric mission planned with the new German research aircraft HALO will be the UTLS mission TACTS (Transport and Chemistry in the Tropopause Region), currently planned for August and September 2012. **A. Engel** presented the mission as co-ordinator and explained that the goal is to investigate the spatial and temporal evolution of trace gases during the summer to fall period, when exchange between the UT and the LS in the Northern Hemisphere (NH) is expected to maximise due to the weak subtropical jet during this time of the year.

Dynamics and Coupling

The dynamics governing the trace gas transport in the tropopause region and the coupling of the UT and the LS are very complex and the processes involved are still not well understood. The sharpness of the extra-tropical tropopause is a remarkable feature of the Earth's atmosphere. Previous research has shown that synoptic scale dynamics play an important role in the extra-tropical tropopause region, although non-conservative processes (especially radiation) are likely to be important too. **V. Wirth** discussed the role of synoptic-scale dynamics for the structure of the extra-tropical tropopause and presented simulations from idealised baroclinic life cycles (Erler and Wirth, 2011). He showed that the sharpness of the simulated tropopause increases markedly at the time of wave breaking.

However, the structure of the global tropopause is also set by the dynamics of the stratosphere. **T. Birner** provided an overview of dynamics and transport in the UTLS, highlighting the importance of the Brewer-Dobson circulation in setting the equator-to-pole contrast

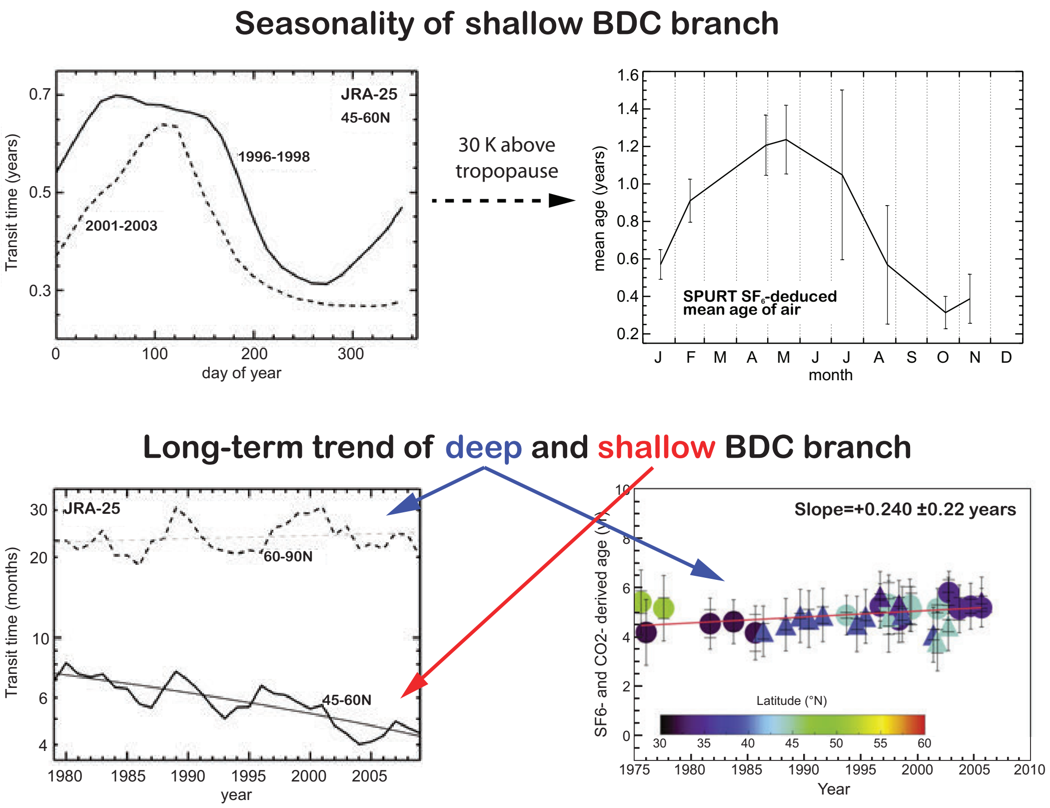

Figure 10: Seasonality of transit time from the troposphere to the ExUTLS from analysis data (upper left) and mean age deduced from SPURT measurements (upper right), which determine the lower part of the BDC (adapted from Birner and Bönisch, 2011). The ExUTLS is also affected by downward transport from the mid-stratosphere with possible long-term changes depending on latitude. (Adapted from Bönisch et al., 2011. Bottom right panel reprinted by permission from Macmillan Publishers Ltd: Nature Geoscience (Engel et al., 2009), copyright (2009).)

in tropopause height, the formation and maintenance of the tropopause inversion layer (TIL) in midlatitudes, and the quasi-horizontal transport of air from the tropical into the extra-tropical lowermost stratosphere (LMS) related to the lower BDC branch. He also discussed feedbacks between radiation and dynamics in the extra-tropical UTLS related to the distribution of radiatively active tracers (such as water vapour and ozone) within the extra-tropical tropopause transition layer (ExTL) on the one hand, and the dynamical structure related to the TIL on the other hand.

Understanding the coupling between the UT and LS is important for understanding trace gas distribution and the radiative budget in this climate sensitive region. In particular, the lower branch of the BDC connects the tropics (TTL) with the extra-tropical lower stratosphere through: (i) deep tropospheric intrusions from winter to spring (*e.g.*, Vogel *et al.*, 2011), (ii) flushing of the LMS with young tropospheric air in summer (e.g., Bönisch *et al.*, 2009), and (iii) in-mixing into the TTL (reverse process) in summer (*e.g.*, Ploeger *et al.*, 2012). Using age of air diagnostics applied to results from the Chemical Lagrangian Model of the Stratosphere (CLaMS), **P. Konopka** showed that the seasonal variation of the composition of air in the UTLS is characterized by strong hemispheric differences. In particular, during boreal summer, the subtropical jet in the NH is a much weaker isentropic transport barrier for STE than in the respective season in the Southern Hemisphere (SH). In the NH, the composition of the LMS during the boreal summer is dominated by transport of tropospheric air from the tropics (flushing, enhanced H_2O) whereas the composition of the TTL is strongly influenced by the Asian monsoon anticyclone (in-mixing, enhanced O_3). The quantitative contribution of these pathways is sensitive to the scenarios of the vertical winds used and of the mixing intensity in the model. Furthermore, he emphasised that the Asian monsoon is still a "white spot" on the map of in situ data.

Another important aspect of coupling in the UTLS region is the strong seasonality of time scales and extent of TST. Using simultaneous CO_2 and SF_6 in situ measurements and trajectories driven by ERA-Interim assimilated wind fields, **H. Bönisch** showed that the transport time scales from the troposphere into the LMS have a strong seasonality, varying from 0.1 to 0.7 years. This seasonality is mainly driven by the lower branch of the BDC and the strength of the subtropical jet as a mixing barrier. Additionally, the lower branch of the BDC, feeding younger and more polluted air with tropospheric characteristics into the LMS, exhibits not only seasonal but also interannual variability. It has been demonstrated that the step-like decrease of stratospheric water vapour is associated with an increased stratospheric upwelling in the tropics (Randel *et al.*, 2006) and with a change in the lower branch of the BDC (Bönisch *et al.*, 2011, **Figure 10**).

Trace gas transport, observations and modelling strategies

C. Schiller discussed the planning strategy of future aircraft campaigns using statistics of in situ measurements of water vapour and ozone, two trace gases with main sources in the troposphere and stratosphere, respectively. Water vapour and ozone are characterized by variability on synoptic to seasonal time scales due to distinct processes such as freeze-drying, photochemistry and transport (*e.g.*, Krebsbach *et al.*, 2006; Tilmes *et al.*, 2010). The results of the statistical analysis suggest that a SPURT-type campaign (one per season) is sufficient to represent the variability of ozone in the UTLS, whereas the high variability of water vapour requires a higher sampling frequency for climatological investigations (Kunz *et al.*, 2008).

For the planning strategy of complex aircraft campaigns such as the upcoming HALO missions, model support is essential. **P. Jöckel** presented new approaches for the direct comparison of in situ and remote sensing observations with the results from the global/regional atmospheric chemistry general circulation model MECO(n) (Kerkweg and Jöckel, 2012). The key aspect is the tailor-made, on-line (during run time) sampling of model data with the highest possible frequency (at each model time step) at those locations and times where measurements have been performed. Specific diagnostic techniques for the sampling at stationary observatories along moveable research platform trajectories (such as research aircraft) and for sun-synchronously orbiting satellites have been implemented (Jöckel *et al.*, 2010). Exemplary results from a simulation of the Eyjafjallajokull eruption plume in 2010 in comparison with LIDAR and in situ ash observations were shown.

A fundamental prerequisite for all kinds of analysis of trace gas distributions, and transport and chemistry in the UTLS region is the definition of the tropopause as a surface where strong thermal and chemical gradients are observed. **A. Kunz** introduced a new concept for the extra-tropical tropopause based on isentropic potential vorticity (PV) gradients (Kunz *et al.*, 2011a). It is validated with isentropic trace gas fields based on START08 observations and WACCM model simulations (Kunz *et al.*, 2011b). The discontinuities in the dynamical and chemical fields agree fairly well suggesting the PV gradient-based tropopause is an effective tool in identifying the physical boundary in the UTLS. Transport barriers resulting in strong trace gas gradients are clearly associated with the PV-gradient based tropopause rather than with the classical concept of the dynamical tropopause, in particular on isentropes above 350K.

An alternative definition is to use a chemical-based tropopause. **A. Zahn** reported on results from the regular and long-term observations on board the passenger aircraft CARIBIC (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container). He suggested an ozone-based altitude above the extra-tropical tropopause that specifies the degree of mixing of tropospheric and stratospheric air in the LMS (Sprung and Zahn, 2010) and that enables the creation of very representative distributions and seasonal variations relative to the tropopause (*e.g.*, of O_3, CO, H_2O, CH_4, N_2O, SF_6, acetone, ethane, and acetylene). By using different trace gases he showed a selection of different mixing lines across the ExTL, on which the height of the ExTL could be inferred to within 1.5-2.0 km in January to May and within 2.0-3.0 km thereafter. The chemical (ozone) tropopause was found to be, on average, about 666 m below the thermal tropopause, with strong seasonal variation (from about 200 m in winter to about 1500 m in August).

R. Koppmann explained how measurements of stable isotope ratios in volatile organic compounds (VOCs) can help to improve our knowledge of atmospheric time scales. The "isotope hydrocarbon clock" is used to determine the photochemical age and the source of the VOCs, as well as the impact of photochemistry and transport on their distribution. He reported on the successful deployment of the MIRAH (Measurements of Isotope Ratios in the Atmosphere on HALO) whole air sampler during the first HALO flights with operational scientific instruments (TECHNO-Mission) in September 2010. During the TECHNO-Mission, the DLR water vapour differential absorption LIDAR (DIAL) was also installed onboard the HALO aircraft. **S. Gross** showed an investigation of relative humidity variability in cirrus clouds using the HALO water vapour LIDAR measurements. The DIAL measurements were validated with simultaneous in situ measurements from the FALCON aircraft. They were used to calculate the 2-dimensional relative humidity field, and to study the variability of relative humidity inside cirrus clouds. The results were compared with ECMWF analyses.

Chemistry and Air pollution

A pathway that directly connects the ExTL with the polluted tropospheric boundary layer is the uplift by warm conveyor belts (WCBs). A

WCB is a strongly ascending moist airstream ahead of a surface cold front that transports air from the boundary layer to the UTLS within about 2 days. The airflow is typically 1 km in depth and a few 100 km across. The frequency of WCBs is highest downstream of major pollution source regions and thus they are important for direct injection of pollutants into the ExTL. **H. Schlager** reported about first observations of WCB transport into the ExTL and showed a case study of anthropogenic SO_2 pollution transport into the LMS from East Asian source regions (Schlager *et al.*, 2012). The pollution layer was observed over Central Europe by measurements from the new German research aircraft HALO during the TECHNO-Mission. The layer contained enhanced SO_2, HNO_3 and water vapour and caused increased LIDAR backscatter radiation. Meteorological analysis and air mass transport and dispersion model simulations reveal that the detected pollutants were released from ground-based sources in East China, South Korea, and Japan. The pollution plume was uplifted by a WCB associated with a West Pacific cyclone and finally injected into the LMS. The HALO measurements were performed 5 days after the air mass uplift event, when significant parts of the Northern Hemisphere were already covered by the pollution plume. **A. Roiger** presented another event of pollution uplift from East Asia by a WCB. The polluted air mass was measured with the DLR Falcon in the polar ExTL over Greenland well above the dynamical tropopause and contained unusually high concentrations of CO, CO_2, PAN and H_2O. The East Asia pollution was uplifted within a WCB connected to a low pressure system over Northern Russia and transported across the North Pole (Roiger *et al.*, 2011).

The oxidation capacity of the troposphere - a measure for the ability of the atmosphere to "clean up" organic pollutants - is strongly related to the ozone budget in this region. **H. Bozem** and **H. Fischer** reported on chemical processes related to ozone production in the UTLS. They used in situ measurements of ozone, ozone precursors and radicals to calculate net ozone tendencies (ozone production minus loss) obtained over the tropical rainforest (GABRIEL campaign fall 2005) and Europe (HOOVER campaign fall 2007 and summer 2008). The observed tendencies (net production in the extra-tropical boundary layer and the upper troposphere, destruction in the middle troposphere and the tropical marine boundary layer) are qualitatively but not quantitatively reproduced by state of the art 3D chemical transport models. Deep convection was shown to strongly enhance ozone production above 6-8 km altitude both at mid-latitudes and in the tropics. Besides the net photochemical ozone production in the troposphere, the amount of transported ozone from the LS into the UT is also a major player in the upper tropospheric ozone budget.

The chemical processing of nitrogen oxide NO_x (sum of NO and NO_2) is important for the tropospheric ozone budget because the net ozone production depends on the amount of available nitric oxide (NO). The latter is driven by various anthropogenic processes like biomass burning and combustion. **H. Ziereis** presented a dataset of six years of NO_y (sum of NO_x and the compounds produced from the oxidation of NO_x which include nitric acid) and NO measurements from CARIBIC. Since 2004 the NO_y and NO detectors are part of the CARIBIC instrumentation. Since that time more than 250 measurement flights have been performed in the UTLS between Frankfurt and different destinations in North and South America, Asia and South Africa. Therefore the dataset is of global coverage and allows for analysis of large-scale regional and seasonal variations. This analysis provides a solid base for model measurement inter-comparison.

Clouds, Radiation and Aerosols

S. Borrmann gave an overview of recent results from the SCOUT and AMMA campaigns between 2005 and 2007. For submicron aerosols, recent results showed that as much as 50% of the particles in the tropical UTLS are non-volatile, which implies that the particle composition consists not only of pure sulphuric-acid water droplets. The existence of a "tropical belt" of enhanced particle number densities between 360 K and 420 K was confirmed by in situ measurements from South and Meso-America, West Africa and Northern Australia. At the TTL bottom there seems to be a region of increased occurrence of homogeneous new particle formation, both in clear air as well as inside clouds. This may be a source of the particle enhancement in the tropical UTLS (Borrmann *et al.*, 2010).

In **P. Spichtinger**'s talk a possible relationship between ice supersaturation/cirrus clouds and the tropopause structure was investigated. Since cirrus clouds can frequently be found close to the tropopause, they might influence tropopause structure and exchange processes due to their radiative properties. Additionally, shallow convection inside ice-supersaturated regions might change the local structure of the tropopause.

J. Schmale presented measurements of aged aerosol layers (between 85 to 112 days) in the European tropopause region that stem from the volcanic eruptions of Mounts Okmok and Kasatochi. The data were obtained with an aerosol mass spectrometer (AMS) during the CONCERT campaign (Voigt *et al.*, 2010). Aerosol concentrations of greater than 2 $\mu g.m^{-3}$ were observed. About 80 % of the emitted SO_2 had been converted to particulate sulphate since the eruptions, and more than 20 % of the volcanic aerosol mass was composed of carbonaceous matter (Schmale *et al.*, 2010).

Upcoming satellite Perspectives

M. Riese gave a brief overview of PREMIER, one of three candidates for ESA's 7th Earth Explorer mission. The primary objective of PREMIER is to quantify physical and chemical processes controlling global atmospheric composition in the UTLS and to allow for a more realistic representation of these processes in global models. The presentation highlighted the sensitivity of simulated surface climate to uncertainties in transport schemes (**Figure 9**). Radiative effects of water vapour and ozone, both characterized by steep gradients in the UTLS, are particularly sensitive to uncertainties of the atmospheric mixing strength, as demonstrated by multi-annual simulations with the Chemical Lagrangian Model of the Stratosphere (CLaMS) in combination with a state-of-the-art radiance code.

M. Höpfner and **H. Oelhaf** reported on the global data products in the UTLS, as derived from the MIPAS/Envisat satellite measurements retrieved at the Institute for Meteorology and Climate Research/ Karlsruhe Institute of Technology (IMK-KIT). Global fields for T, cloud top height, H_2O, HDO, O_3, HNO_3, N_2O, CH_4, CO, HNO_4, PAN, HCN, C_2H_6, C_2H_2, HCOOH, CFC-11, CFC-12, HCFC-22, CF_4 and SF6 are presently available. Recent validation work has been related to T, H_2O, O_3 (Stiller *et al.*, 2012) and HDO (Lossow *et al.*, 2011). The data have been used for studies on the H_2O and delta-D tropical tape recorder, transport of H_2O and O_3 through the Asian monsoon anticyclone, CCMVal activities, and chemical pollution of the UTLS, especially SH biomass burning and pyro-convection from the Australian fires in February 2009.

The capabilities of the GLORIA instrument (Gimballed Limb Observer for Radiance Imaging of the Atmosphere) to sound the UTLS region in 3 dimensions were discussed by **M. Kaufmann**. GLORIA is an infrared remote limb sounder which combines the high horizontal resolution of a nadir sounder (tens of km) with the altitude resolution (a few hundred metres) provided by a limb-sounding instrument. The tomographic retrieval scheme applying 3D regularization, iterative solvers and an adjoint forward model were presented. The capabilities of the new measurement system were demonstrated for a filamentary structure occurring in a mixing event.

Concluding Remarks and Outlook

The meeting brought together very different perspectives on processes affecting the UTLS and specific open research questions were identified. The fact that uncertainties in the understanding of the dynamics of mixing lead to significant effects on the radiative forcing estimates (**Figure 9**) opens a number of research questions involving small scale dynamics as well as long-term observations.

1. What is the role of the TIL in shaping ExUTLS composition? What maintains the TIL? Radiatively active tracers appear to play a role in maintaining the TIL. However, does the TIL in turn affect transport and dynamics and what is the role of potential feedback processes between the TIL, dynamics and transport? What is the role of the TIL with respect to future changes and in the climate system?
2. How do small scale processes associated with radiation and cirrus clouds at the tropopause affect dynamics and chemistry in the UTLS?
3. What are typical time scales for mixing and transport? Do we see long-term changes related to stratospheric circulation changes and changes of these time-scales (*e.g.*, the mean age)?
4. What are the most important coupling mechanisms and feedbacks of the ExUTLS and the tropics?
5. Can we better constrain the relevant mechanisms for downward transport of ozone from the UTLS into the troposphere?

To address and answer these questions, high-resolution measurements are needed, which allow process-oriented investigations covering a large range of scales. These can only be provided by state-of-the-art in situ measurements. After the successful and pioneering role for investigation of the global view on the UTLS, these resolutions are now needed to gain insight into the details of the coupling between dynamics and chemistry. The TIL provides an example for this, since it is affected by scales ranging from small-scale turbulence resulting from wave breaking, to global scales due to the impact from the residual circulation, thereby in turn modifying tracer transport and dynamics. The new upcoming high-resolution measurements will be complemented by the new generation of satellite observations of unprecedented, but still limited resolution. The improved process understanding is essential to allow for better predictions of future changes from global models.

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Dr. Cornelius Schiller

29 July 1961 – 3 March 2012

Cornelius Schiller, an active member of the international atmospheric research community, passed away on March 3, 2012 in Neuss, Germany, after a battle with cancer. He died peacefully, but much too early and with many unfinished plans amidst his family whom he held dear. He is survived by his wife, Barbara, his children, Katharina, Andreas, Christoph, and his father Klaus.
Cornelius studied physics at the University of Bonn. Early on he became interested in the physics and chemistry of the atmosphere. He joined the atmospheric chemistry department of the Jülich Research Centre in 1986, where he started to develop spectroscopic methods for the observation of the total column of stratospheric trace gases. He led the water vapour group in the stratospheric research program for the past 20 years.

With the development of FISH, the "Fast In situ Stratospheric Hygrometer", in the 1990s, he and colleagues at Jülich Research Centre, started a new era of the measurement of water vapour in the adverse conditions of the upper troposphere and lower stratosphere. Accurate H_2O measurements under such conditions are exceedingly difficult, but Cornelius together with a few colleagues around him, succeeded in pushing the boundaries of science and technology by taking measurements with this instrument on multiple plat-forms and from the tropics to the high latitudes. FISH is considered to be one of the most accurate hygrometers in the world.

Although at times his work has necessarily been quite technical, his motivation always remained very clear: striving for scientific truth and a better understanding of Earth's atmosphere and climate. He was inspired by environmental protection and by the quest to safeguard the creation for future generations. Amongst his peers he was highly regarded, because of his always friendly and encouraging attitude. He led large international measurement campaigns, and we all followed him because of his strong scientific integrity and his kind and genial nature.

Cornelius left us behind far too early. He was still full of plans, for example, concerning his initiative for improved water vapour measurements. We will not forget him, but continue to work in his spirit on the questions that he raised. We grieve for one of our great scientists, an altruistic colleague and truly good friend!

By Tom Peter and Karen Rosenlof

Brief Report on the IGAC / SPARC Workshop on Global Chemistry-Climate Modelling and Evaluation 21-24 May 2012, Davos, Switzerland

Veronika Eyring[1], Jean-François Lamarque[2]

[1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany, Veronika.Eyring@dlr.de, [2]National Center for Atmospheric Research (NCAR), Boulder, USA, lamar@ucar.edu

Increasingly, the chemistry and dynamics of the stratosphere and troposphere are being studied and modeled as a single entity in global models. As evidence, several groups performed simulations for the Coupled Model Intercomparison Project Phase 5 (CMIP5) in support of the upcoming Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5), using global models with interactive chemistry, extending from the surface to the stratosphere and above. In addition, tropospheric and stratospheric global chemistry-climate models are continuously being challenged by new observations and process analyses. Some recent intercomparison exercises have, for example, highlighted shortcomings in our understanding and/or modeling of long-term ozone trends and methane lifetimes. There is also growing interest in the impact of stratospheric ozone changes on tropospheric chemistry via both ozone fluxes (*e.g.*, from the projected strengthening of the Brewer-Dobson circulation) and actinic fluxes. This highlights that there is a need to better coordinate activities focusing on the two domains, and to assess scientific questions in the context of the more comprehensive stratosphere-troposphere resolving models with chemistry. To address these issues, the IGBP's (International Geosphere Biosphere Program) and iCACGP's (international Commission on Atmospheric Chemistry and Global Pollution) International Global Atmospheric Chemistry (IGAC) and WCRP's (World Climate Research Program) Stratospheric Processes And their Role on Climate (SPARC) projects convened a joint workshop to discuss emerging themes in chemistry-climate modeling of the stratosphere and troposphere, as well as associated process-oriented model evaluation.

Figure 11: Participants at the CCMVal workshop held in Davos, Switzerland.

Approximately 130 scientists from 16 different countries spanning four continents attended the workshop. Through a combination of invited and contributed talks, poster sessions and working group discussions, workshop participants identified science questions relevant to chemistry-climate model evaluation, the specific physical or chemical processes associated with each question, the relevant observations (in-situ, ground-based, aircraft and satellite communities were represented) and the associated model diagnostics to be used. While it is clear that in several cases a full understanding of the main processes still lacks, the various working groups specifically identified research topics that aimed at resolving these issues. In addition, the workshop participants agreed on a new set of community-wide simulations to support upcoming ozone and climate assessments, as well as to make progress in terms of the understanding of various processes .

The workshop participants recommended the creation of a joint IGAC / SPARC Chemistry-Climate Model Initiative (CCMI) to coordinate future (and to some extent existing) IGAC and SPARC chemistry-climate model evaluation and associated modeling activities. A white paper summarizing the goals of the CCMI, including a more detailed summary of the workshop, will be published in the IGAC and SPARC newsletters in early 2013.

Stratospheric Sulphur and its Role in Climate (SSiRC)

Markus Rex[1], Claudia Timmreck[2], Stefanie Kremser[3], Larry Thomason[4], Jean-Paul Vernier[5]

[1]Alfred Wegener Institute, Germany, Markus.Rex@awi.de, [2]Max-Planck-Institut für Meteorologie, Germany, Claudia.Timmreck@zmaw.de, [3]Bodeker Scientific, New Zealand, stefanie@bodekerscientific.com, [4]NASA Langley Research Center, USA, l.w.thomason@larc.nasa.gov, [5]NASA Langley Research Center, USA, jeanpaul.vernier@nasa.gov

The stratospheric aerosol layer is a key element in the climate system. It affects the radiative balance of the atmosphere directly through interactions with solar and terrestrial radiation, and indirectly through its effect on stratospheric ozone. Because the stratospheric aerosol layer is prescribed in many climate models and Chemistry-Climate Models (CCMs), model simulations of future atmospheric conditions and climate generally do not account for the interaction between the sulphur cycle and changes in the climate system. The present understanding of how the stratospheric aerosol layer may be affected by future climate change and how the stratospheric aerosol layer may drive climate change is, therefore, very limited.

In the stratosphere, the aerosol layer is controlled by the transport of sulphur-containing species (mainly carbonyl sulphide (COS) (Brühl *et al.,* 2012), sulphur dioxide (SO_2)) and aerosol particles from the troposphere across the tropical tropopause to the stratosphere, and by direct injection from large volcanic eruptions. Other potential sources of sulphur in the lowermost stratosphere are quasi-isentropic transport from the tropical upper troposphere, and convection outside the deep tropics (*e.g.*, Randel *et al.*, 2010). Over the past decade, significant progress in our understanding of the Tropical Tropopause Layer (TTL) has been made (*e.g.*, Fueglistaler *et al.*, 2009), leading to an improved understanding of the dynamical, microphysical, and chemical processes that control the composition of air passing through the TTL into the stratosphere. Climate-change-induced changes in the chemical and transport properties of the TTL can result in climate feedbacks by modifying the delivery of sulphur to the stratosphere. However, most studies of the stratospheric sulphur budget were carried out before the improved understanding of atmospheric processes in the TTL emerged.

The wildcard in the future development of the stratospheric aerosol layer is large volcanic eruptions; a major driving factor of natural climate variability. The climate effect of a large volcanic eruption is mainly dependent on the strength of its stratospheric sulphur injection, which is determined not only by the magnitude of the eruption and sulphur release, but also its injection height and the active transport process through the TTL. However, since the Mt. Pinatubo eruption in 1991, the mid-stratosphere has not been disrupted by a major volcanic eruption (volcanic explosivity index (VEI) $\geq$ five), although several minor eruptions have affected the lower stratosphere (*e.g.*, Jurkat *et al.,* 2010). This provides an opportunity to study the variability of the stratospheric aerosol layer during a time of relative volcanic quiescence, and thus, both the natural variability from sources other than volcanic eruptions and potential anthropogenic effects over the past two decades may be investigated.

Neglecting these natural changes in aerosol likely contributed to an over-estimation of projected global warming by climate models, compared to the observed global temperature record for the past decade (Solomon *et al.*, 2011). In addition, a sound understanding of the processes that determine the background state and variability of the stratospheric aerosol layer is a prerequisite for assessing its future development, and for determining the possible potential for and risks of an artificial enhancement of it (solar radiation management/geoengineering).

The role of non-sulphate aerosol, which is often ignored, could be important, particularly in the tropical upper troposphere/lower stratosphere (UTLS). New aerosol composition measurements in the TTL (Fryod, 2009; 2010) have revealed a large fraction of particles composed of organic material located as high as 4 km above the tropopause. These new results underline the potential complexity of aerosol composition populating the TTL region. In addition, microphysical properties of sub-visible cirrus (Jensen *et al.*, 2010) seem to contradict the common homogeneous freezing theory, which is usually assumed in climate simulations. These findings stress the possible importance of solid particles (ammonium sulphate) or glassy aerosols in the UTLS region (Peter *et al.*, 2006; Zobrist *et al.*, 2008), which would lower the super-saturation threshold to form cirrus clouds. Last but not least, stratospheric water vapour concentrations are extremely important for the nucleation and growth of sulphuric acid particles in the stratosphere, and consequently for the size distributions, which in turn are important mainly for radiative properties of the stratosphere and for polar stratospheric cloud formation.

Although several microphysical schemes are currently available for global climate models, up to now, no global stratospheric aerosol model that explicitly treats microphysical processes interactively and that includes a temporally varying aerosol size distribution has been applied in long term IPCC/CMIP5 scenario runs. Even the existing simplified schemes are too computationally expensive to carry out the required ensemble runs of several hundred years. Therefore, aerosol climatologies, with their own deficiencies, are commonly used in future simulations as a constant stratospheric background. This limits our ability to assess the potential impact of anthropogenic sulphur emissions on climate and our understanding of chemistry-climate feedbacks that result from changes in stratospheric sulphur. Also, CCMs show a considerable spread in their simulated temperature and ozone response to volcanic eruptions (SPARC CCMVal, 2010) since none of these models explicitly treat the formation and development of volcanic aerosol particles.

In order to address these issues, we have brought to life a new SPARC initiative on Stratospheric Sulphur and its Role in Climate (SSiRC). The overall goal of this new initiative is to improve our understanding of the processes that sustain the stratospheric aerosol layer, and to study their variability. More specifically, the activity would have the following scientific and programmatic goals:

1. Encourage and support new instrumentation and measurements of sulphur containing compounds, such as carbonyl sulphide (COS), dimethyl sulphide (DMS), gaseous sulphuric acid (H2SO4) and non-volcanic SO_2 in the UTLS.
2. Provide a forum that facilitates critical examination of key stratospheric aerosol and aerosol precursor datasets, including the development of composite datasets and "best effort" multi-decadal datasets for stratospheric aerosol optical depth, surface area density, and multi-wavelength optical properties for use in climate simulations.
3. Assess our understanding of the stratospheric sulphur budget and the stratospheric aerosol layer in the current climate, using existing observations, identifying data gaps and needs, and using model inter-comparison and comparison with observations (including comparisons of variability and trends in the aerosol layer). This entails:
   - Investigating key processes in the TTL that control the flux of sulphur containing source gases from the upper troposphere to the stratosphere, and the role of non-sulphur sources of aerosols (*e.g.*, organics, black carbon, meteoric dust etc.);
   - Assessing the role of deep convection in controlling lower stratospheric aerosol levels and the role of anthroogenic activities on changes in stratospheric aerosol levels (particularly Asia);
   - Investigating the role of biogeochemical cycling of sulphur containing compounds.
4. Assess how climate change and changing anthropogenic emissions of SO_2 and COS can alter the stratospheric sulphur budget and the stratospheric aerosol layer in the future, including:
   - Changes in the BDC;
   - Changes in microphysical processes (nucleation, particle growth, sedimentation);
   - Transport and microphysical processes in the TTL, including the effect of sulphate aerosols on cirrus clouds;
   - Particle formation and sedimentation in the UTLS and the effects on the aerosol distribution in global climate models;
   - Chemical processing of COS, DMS and SO_2 in the troposphere and stratosphere;
   - Sensitivity of changes in the anthropogenic emissions of aerosol precursors such as SO_2 and COS;
   - Trends in stratospheric aerosol levels due to changes in non-volcanic sources, and their inference in the presence of ongoing volcanic activity.
5. Assess the effect of volcanic eruptions of different strength, sulphur content, geographic location and season of the eruption using:
   - Sensitivity experiments for moderate and large volcanic eruptions with comparisons to existing observational datasets (*e.g.*, Pinatubo);
   - Assimilation/inverse modelling techniques to calculate source strength, including the time-varying vertical emission rate from volcanoes, by combining data with Lagrangian dispersion modelling;
   - Quantification of volcanic impact on the UTLS through heating, chemistry and cirrus clouds.
6. Assess our understanding of the radiative effect of disturbances of the aerosol layer and related temperature changes. In this context, investigate the impact of changes in the aero-

sol layer on surface climate using analysis of coupled climate simulations (*e.g.*, CMIP5).

7. Assess the impact of low, yet variable, stratospheric aerosol on stratospheric chemistry (in particular ozone chemistry) including the importance of cold sulphate and related aerosols.
8. Develop approaches that allow CCMs to include the stratospheric aerosol layer as an interactive element, assessing:

- Lagrangian schemes for transport and chemistry in the TTL, including different approaches to the treatment of vertical transport;
- The validity of microphysical, radiative transfer and sedimentation schemes;
- Develop numerically efficient parameterisations based on comprehensive models of complete processes.

Links to other activities

SSiRC will link with other SPARC activities. In particular, it follows naturally from the previous study comparing global stratospheric aerosol models (SPARC ASAP, 2006). The resulting report revealed that global model projections and satellite observations of aerosol extinction agree fairly well for visible wavelengths, but not very well in the infrared. Furthermore, none of the models could reproduce the sharp observed vertical gradient in optical extinction between 17 and 20 km. SSiRC will pick up on some of the outstanding issues from SPARC ASAP (2006), and use the recent scientific developments to extend our understanding of the stratospheric aerosol layer and the processes that affect it.

Existing SPARC activities that have links to SSiRC include DynVar, which amongst other things analyses CMIP5 output to improve our understanding of the mechanisms by which volcanic eruptions can affect atmospheric dynamics (the volcanic forcing research group; M. Toohey), and to improve our understanding of the role of the tropopause in atmospheric dynamics (the tropopause and UTLS research group; T. Birner). In addition, the SPARC Data Initiative (M. Hegglin, S. Tegtmeier) will include stratospheric aerosol and look at aerosol extinction measurements from OSIRIS, GOMOS, SCIAMACHY, SAGE II/III, and POAM II/III. It will also establish a data portal for compiled zonal-mean monthly-mean time series of chemical species in the stratosphere and the UTLS.

Further SPARC activities with strong links to SSiRC are the geoengineering activity (A. Robock, T. Peter) and CCMVal (V. Eyring). The geoengineering activity focuses on solar radiation management studies by analysing the Geoengineering Model Inter-comparison Project (GeoMIP) sulphate experiments G3 investigating the climate response to geoengineering.

In a broader context, SSiRC will also have links to the Global Energy and Water Cycle Experiment (GEWEX) through the Cloud System Study activity, which considers transport of sulphur in deep convective systems, the Surface Ocean – Lower Atmosphere Study (SOLAS), in regard to sulphur cycling, and to IGAC with its expertise in studying sulphur in the troposphere.

Next Steps

The SSiRC was established as an official SPARC initiative at the SSG meeting in February 2012 (see report in this issue of the newsletter). The interaction within the SSiRC community occurs via a mailing list (currently about 150 members). A white paper that provides an overview of the current status of our knowledge of the stratospheric aerosol layer and relevant research questions is currently being compiled in interaction with the community. Based on feedback from the community, a tentative implementation plan will be developed during a focused meeting of a core group in August/September/October 2012 and will be presented at the next SPARC SSG meeting. An internal structure for the activity will be defined, outlining individual research topics, topic leads and task groups. The tentative implementation plan will be further developed during a broad SSiRC kick-off workshop in 2013.

SSiRC will coordinate the setup of multi-national consortia studying stratospheric sulphur, especially for specific field campaigns and extra model and measurement work.

How to get involved

If you are interested in participating in SSiRC and/or becoming part of the SSiRC mailing list please contact Markus Rex (**Markus.Rex@awi.de**).

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SNAP: The Stratospheric Network for the Assessment of Predictability

Andrew Charlton-Perez[1], David Jackson[2]

[1]University of Reading, UK, a.j.charlton@reading.ac.uk, [2]Met Office, UK, david.jackson@metoffice.gov.uk

During winter and spring the stratosphere is a dynamically exciting place, with intense and dramatic stratospheric major warming events occurring typically in two out of every three years in the Northern hemisphere (Charlton and Polvani, 2007) and minor warming events occurring more frequently still. It is not surprising, therefore, that there has long been interest in understanding what role the stratosphere might play in influencing tropospheric weather and climate. Following the studies of Baldwin and Dunkerton (1999, 2001) there has been a renewed interest in this topic over the past fifteen years. One particular aspect of this problem, first captured succinctly by Boville and Baumhefner (1990), is the idea that an enhanced representation of the stratosphere in models used for forecasting tropospheric weather on short to medium ranges might enhance the tropospheric skill in those models. Many recent studies have confirmed and enhanced these original ideas (*e.g.*, Charlton *et al.*, 2004; Jung and Barkmeijer, 2006; Kuroda, 2010; Roff et al., 2011) leaving atmospheric scientists with a general picture of the stratosphere-troposphere link as one which can add skill to tropospheric forecasts on timescales of 5-15 days, on large planetary scales and in both the northern and southern hemisphere extra-tropics.

In this article, we describe a new initiative jointly supported by SPARC and the UK Natural Environment Research Council (NERC) and stemming from discussions in the SPARC Data Assimilation group: the Stratospheric Network for the Assessment of Predictability (SNAP). SNAP will seek to answer several outstanding questions about stratospheric predictability and its tropospheric impact, namely:

- Are stratosphere-troposphere coupling effects important throughout the winter season or only when major stratospheric dynamical events occur?
- How far in advance can major stratospheric dynamical events be predicted and usefully add skill to tropospheric forecasts?
- Which stratospheric processes, both resolved and unresolved need to be captured by models to gain optimal stratospheric predictability?

Why a new international network?

Answering these scientific and technical questions requires collaboration between the parts of the scientific community interested in stratospheric predictability (both stratospheric dynamicists and forecast providers) and it requires carefully planned experiments that objectively compare the stratospheric skill of different numerical models and understand its source. SNAP will provide a central forum by which this expertise can be regularly shared and improved. The centrepiece of SNAP will be to design and perform a new inter-comparison of stratospheric forecasts, producing and maintaining a rich dataset to be used by a broad community of researchers.

Ten years of diligent work by the stratospheric research community has convinced many operational centres to raise the top of their numerical weather prediction models to include the stratosphere and the time is now ripe to seize the opportunity to understand and quantify stratospheric predictability. This is not a task any one individual research group or forecast organisation can achieve on their own, since representation of the stratosphere in NWP models is still in its infancy. Although many models now place their model lid above the stratopause, there are many fundamental unanswered questions about how to represent stratospheric physics properly and appropriately in those models. Examples of poorly studied or understood stratospheric processes in the context of NWP are the role of varying chemical composition in the stratosphere (particularly ozone) and the optimal way to incorporate small-scale gravity waves which are crucial for many stratospheric processes.

The representation of the stratosphere in NWP models can be compared to that of the ocean in climate models in the 1990s; the first step is to add the physical system to a model but the second and much more demanding task is to consider how best to develop and optimise that system for the task at hand. As in many other areas of atmospheric science, comparing models and collaborating on their improvement is often the best way to spur on rapid progress, since it allows all the groups involved to understand the best and worst aspects of the choices which must be made in modelling a complex physical system.

We have currently established a nascent SNAP network with partnership from the organisations and scientists listed in **Table 2**, but we hope very much to expand participation in SPARC to other institutes and interested scientists.

What will SNAP do?

The most important and fundamental task of SNAP will be to organise and analyse a joint experiment on stratospheric predictability. In order to prepare and stimulate this experiment it will be necessary to form a strong community of scientists and institutes interested in stratospheric predictability. The UK NERC has agreed to provide funding for a SNAP project manager who will work under the direction of the project to develop the community through regular newsletters and a project web site. The project manager will be appointed by around August 2012 and in post by January 2013.

The planning of the SNAP experiment will take place at the first SNAP workshop which will be held at the University of Reading, April 24-26 2013. In order to facilitate good collaboration with the existing SPARC DynVar project, this workshop will follow on from the second DynVar workshop which will be held in Reading, 22-24 April 2013 with a joint DynVar/SNAP discussion day on the 24th. We would encourage participants to attend both meetings. At the SNAP workshop, an experimental plan and methodology will be agreed between SNAP partners, and experiments will be carried out from mid-2013. Each modelling centre will be encouraged to run extended-range ensemble hindcasts for several different start dates (50-100) for winter/spring seasons in both hemispheres. Experiments will be arranged in a flexible way so that centres can participate by submitting only the runs in tier 1 or play a deeper role by submitting runs in tiers 2 and 3. The draft experimental protocols for the three experimental tiers are shown in **Table 3**.

There are several interesting recent events that might form the basis of some of the SNAP experiments, including the very large major stratospheric sudden warming in January 2009, the major warming in February 2010 and the anomalously strong vortex in March and April 2011. During the process of completing the predictability experiments, the SNAP project manager will be available to visit partner institutes to discuss progress and to collect data and add it to an easily and publically accessible archive at the British Atmospheric Data Centre (**http://badc.nerc.ac.uk/home/index.html**). A key part of the SNAP experimental design will be to ensure that a wide range of dynamically relevant parameters are output and archived by the models to allow a meaningful dynamical inter-comparison of the models.

Name	Institute
Andrew Charlton-Perez	Univ. of Reading (UK)
David Jackson	Met Office (UK)
Edwin Gerber	New York University (USA)
Greg Roff	Bureau of Meteorology (Australia)
Mark Baldwin	Univ. of Exeter (UK)
Martin Charron	Environment Canada (Canada)
Stephen Eckerman	Naval Research Laboratory (USA)
Yuiji Kuroda	Meteorological Research Institute (Japan)

Table 2: Current SNAP partners in addition to SPARC and the Working Group of Numerical Experimentation (WGNE).

We will encourage and promote members of the SNAP and broader stratospheric community to access this data and perform crowd-sourced analysis of stratospheric predictability in preparation for a SPARC report and peer-reviewed publication on stratospheric predictability, which will be produced by SNAP. Analysis of the experiment will be discussed at a second SNAP workshop to be held in Reading in April 2015.

Table 3: Draft SNAP experimental protocol

Tier 1	Best High – model with a high-top above the stratopause and with all stratospheric processes included, initialised from data assimilation of the high-top model.
Tier 2	Best Low – standard version of low-top model with parameter settings and physics appropriate for the low-top model, initialised with the same state as the best high run. Tropospheric levels should be identical to best high.
Tier 3	Degraded – model with a low-top (possibly around 10 hPa), degraded from the high-top version with parameter settings identical to the best high-top run, initialised with the same state as the best high-top run. High common – best version of high-top model as above but initialised with a standard common analysis (most likely from ECMWF). This set of integrations will be used to quantify the forecast improvement resulting from the improved initial conditions from the high-top model.

How do I get involved?

SNAP will only succeed as a project through the engagement and involvement of the NWP and stratospheric dynamics communities. We are very keen to hear from other modelling centres or scientists who are interested in participating in SNAP and we offer an open invitation to attend the SNAP workshop in April 2013. Details of the workshop and how to register to attend will be published on the SPARC and University of Reading websites in summer 2012. In the meantime please do get in touch with Dr. Charlton-Perez (**a.j.charlton@reading.ac.uk**) for more details regarding SNAP or to express your interest.

Celebration of the 20th anniversary of SPARC and move of the SPARC Office to Zurich

Johannes Staehelin[1], Thomas Peter[2], Carolin Arndt[1], Fiona Tummon[1], and Anke Witten[1]
[1]SPARC Office, Switzerland, office@sparc-climate.org, [2]ETH Zurich, Switzerland, thomas.peter@env.ethz.ch

The SPARC SSG meeting held from 6-10 February 2012 in Zurich provided an excellent opportunity to celebrate the 20th anniversary of SPARC and the move of the SPARC Office from North America (Toronto, Canada, where it was hosted from 2004-2011) to Europe (Zurich, Switzerland). A booklet, "20 Years of SPARC, Recollections of the First Two Decades (1992-2012)", featuring short articles authored by all past and present Co-Chairs and Directors of SPARC and liaison persons at the WCRP, was put together for the occasion. The booklet can be downloaded from **www.sparc-climate.org/publications/brochures/**. The individual contributions provide personal views on the role and importance of SPARC, emphasising the many different aspects that are relevant to SPARC.
SPARC was founded in 1992, when the investigation of the Antarctic ozone hole was a key topic in science. From its establishment, the scope of SPARC has been broad, aiming at interdisciplinary research to bridge the initially deep gap between atmospheric dynamics and chemistry. The relation to climate has been a leading topic since the very beginning, as witnessed by the "C" in SPARC's name. Amongst the participants of the celebration events were all past and present SPARC Co-Chairs, Office Directors, and WCRP Liaisons, as well as most of the past and present staff of the SPARC International Project Offices in Paris (1992-2004), Toronto (2004-2011) and Zurich (2011-) (see **Figure 12**).

The SPARC celebrations included an *Apéro riche* and Anniversary Dinner. The *Apéro riche* on the evening of Tuesday, 7 February 2012, was held at the "Dozentenfoyer" - on the top floor of the main building of the ETHZ (Swiss Federal Institute of Technology Zurich), which provided a wonderful view of the city of Zurich, its lake and the snow-capped Alps on the horizon. Short addresses were given by representatives of the present SPARC Office sponsors. They all highlighted the important role of SPARC in global environmental research and acknowledged the many advantages of having the Project Office in Switzerland. The speakers were **Ralph Eichler** (ETHZ President), **Peter Edwards** (Head of Department, Environmental Systems Science, ETHZ), **Alex Rubli** (Federal Office of Meteorology and Climatology, MeteoSwiss), **Paul Filliger** (Federal Office for the Environment FOEN) and **Ghassem Asrar** (WCRP Director).

The following day, the celebrations continued with a SPARC Anniversary Dinner sponsored by MeteoSwiss. This event took place in the *Haus zum Rüden*, one of the city's famous guild houses located in the historical centre of Zurich. A series of short speeches were given. **M.-L, Chanin** and **M. Geller**, the first Co-Chairs, who shaped SPARC during its first decade, highlighted the many challenges the SPARC project faced in the beginning. "SPARC had to overcome several obstacles before it was accepted as a core project of the WCRP, because SPARC includes not only atmospheric physics (like all the other WCRP core projects) but also atmospheric chemistry", said Marie-Lise Chanin. This special focus on atmospheric chemistry still remains a distinguishing characteristic of SPARC within the WCRP family. In his speech Dr. **Gerhard Müller** (MeteoSwiss) expressed his conviction that having the SPARC Office in Zurich will help to strengthen Switzerland's role in international research. Dr. Müller was one of the key people making the move of the SPARC Office to Zurich possible. **Michael Kurylo** (NDACC) took the opportunity to thank G. Müller for his outstanding contributions to several international initiatives, not only SPARC, but also several other programmes, such as the Global Atmosphere Watch (GAW). All speakers emphasised the importance of SPARC and wished their colleagues, presently holding particular responsibilities in SPARC, a fruitful continuation of their work. One important aspect that was mentioned in several of the speeches was that SPARC should keep its identity and continue facilitating international research cooperation in key areas, particularly where coordination leads to added value in scientific research. Without a doubt this includes keeping a high degree of flexibility in order to adapt to new scientific challenges, such as the extension of work into the troposphere.

Finally, all the sponsors that supported SPARC during its first twenty years in France and in Canada deserve a special acknowledgement. Without their generous support, most of the research coordination activities would never have been realised.

Figure 12: Current and former SPARC Co-Chairs, Directors, WCRP Liaisons and office staff. Photo taken during the Celebration of the 20th Anniversary of SPARC. From left to right: Carolin Arndt (Science Communication Manager 2011-), Tom Peter (Co-Chair 2007-2011), Roger Newson (WCRP Liaison 1992-2001), Diane Pendlebury (Project Scientist 2004-), Marv Geller (Co-Chair 1992-2002), Marie-Lise Chanin (Co□Chair 1992-2000 and Director 1992-2004), Ted Shepherd (Co-Chair 2007-), Johannes Staehelin (Director 2011-), Fiona Tummon (Project Scientist 2012-), Norm McFarlane (Director 2004-2011), Greg Bodeker (Co-Chair 2012-), Vladimir Ryabinin (WCRP Liaison 2001-), Anke Witten (Office Manager, 2011-), A. R. Ravishankara (Co-Chair 2002-2007), Alan O'Neill (Co-Chair 2001-2004), Catherine Michaut (Office Manager 2000-2004), Ghassem Asrar (Director WCRP 2008-). Not shown: Marie-Cécile Torre (Office Secretary 1992-1995), Yuri P. Koshelkov (Project Scientist 1995-2003), Celine Philips (Project Scientist 1996-2000), Marie-Christine Gaucher (Office Secretary 1996-2002), Emmanouil K. Oikonomou (Project Scientist 2003-2004), Victoria De Luca (Office Manager 2004-2011) (photo courtesy: Josef Kuster, ETH Corporate Communications).

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SPARC meetings

09-12 October
4th International HEPPA Workshop in conjunction with SPARC/SOLARIS, Boulder CO, USA

26-27 November
Regional SPARC Workshop, Buenos Aires, Argentina

27-30 November
SPARC 20th SSG Meeting, Buenos Aires, Argentina

SPARC-related meetings

27-31 August
Quadrennial Ozone Symposium 2012, Toronto, Canada

03-06 September
10-year Anniversary Conference: Climate Change in High Latitudes, Bjerknes Centre, Bergen, Norway

17-21 September
3rd International Conference on Earth System Modelling, Hamburg, Germany

17-21 September
Atmospheric Chemistry in the Anthropocene, IGAC Open Science Conference, Beijing, China

17-20 September
NTU International Science Conference on Climate Change: Multidecadal and Beyond, Taiwan, China

18-21 September
Atmospheric dynamics Research InfraStructure in Europe (ARISE) workshop, Reading, UK

03-07 December
Climatic Effects of Ozone Depletion in the Southern Hemisphere: Assessing the Evidence and Identifying Gaps in Current Knowledge, Buenos Aires, Argentina

www.sparc-climate.org/meetings/

SPARC General Assembly 2014

12-17 January 2014
Queenstown, New Zealand

www.sparc2014.org

SPARC Office

Director:
Johannes Staehelin
Project Scientists:
Diane Pendlebury
Fiona Tummon
Office Manager:
Anke Witten
Communication Manager:
Carolin Arndt

Contact:

SPARC Office
c/o ETH Zurich
Institute for Atmospheric and Climate Science (IAC)
Universitaetsstrasse 16
CH-8092 Zurich
Switzerland
office@sparc-climate.org