SSiRC Meeting at ISSI

Larry Thomason[1] and Stefanie Kremser[2]

[1]NASA Langley Research Center, Hampton, Virginia, USA, (**l.w.thomason@nasa.gov**), [2]Bodeker Scientific, Alexandra, New Zealand

DATES:
30 January – 2 February 2017

ORGANISERS:
Larry Thomason (NASA, USA), Claudia Timmreck (Max Planck Institute for Meteorology, Germany), Stefanie Kremser (Bodeker Scientific, New Zealand), and Jean-Paul Vernier (SSAI, USA)

HOST INSTITUTION:
International SpaceScience Institute (ISSI), Bern, Switzerland

NUMBER OF PARTICIPANTS: 12

SPONSORS:

BACKGROUND:
SSiRC is focused on understanding the role of sulphur and particularly sulphate aerosol in climate processes. SSiRC as an International Team (SSiRC_IT) held its first meeting at ISSI in Bern, Switzerland, from 30 January to 2 February 2017. This meeting also served as a SSiRC Science Steering Group (SSG) meeting.

ACTIVITY WEBSITE:
www.sparc-climate.org/activities/stratospheric-sulfur

Stratospheric Sulfur and its Role in Climate (SSiRC) is a SPARC activity and has been supported by the International Space Science Institute (ISSI). ISSI support was recently renewed and the first meeting of the international team, SSiRC_IT, was held at the ISSI facility in Bern, Switzerland, from 30 January to 2 February 2017. The SSiRC Science Steering Group (SSG) has undergone some changes recently. Markus Rex has stepped down from the leadership team while remaining on the SSG. Graham Mann (UK) and Suvarna Fadnavis (India) recently joined the SSiRC SSG.

SSiRC_IT helped in the past to formulate the SPARC SSiRC activity and was key to the production of the Review of Geophysics paper on stratospheric sulfur (Kremser *et al*., 2016). The new SSiRC_IT is focused on a subset of SPARC SSiRC activities, including efforts to: 1) Assess and advocate for the ability to forecast likely climate impacts following a major volcanic eruption. This includes identifying key activities required ahead of a major eruption, and promoting activities designed to improve historical observation-based stratospheric aerosol datasets; 2) Estimate the measured stratospheric sulfur burden (both gas-phase and aerosol); and 3) Leverage the relatively modest contribution of volcanic activity to the stratospheric burden over the past decade to assess non-volcanic aerosol and aerosol precursor levels, transport, and microphysical processes. This effort is focused on the upper troposphere/lower stratosphere (UT/LS) and how these factors are represented in climate models. Ultimately, SSiRC remains focused on investigations that improve our understanding of the feedback between stratospheric aerosol and climate, by developing tools to improve aerosol representation in climate models and investigating how a changing climate affects non-volcanic stratospheric sulfur sources and their transport. SSiRC has cooperated with a number of other SPARC activities such as the CCMI (Chemistry-Climate Model Initiative). In future, we foresee interactions with emerging activities such as OCTAV-UTLS (Observed Composition Trends and Variability in the Upper Troposphere and Lower Stratosphere) and TUNER (Towards Unified Error Reporting). Parties interested in SSiRC activities can join the SSiRC community email list (which currently has about 240 members) at **https://listserv.gwdg.de/mailman/listinfo/ssirc**.

SSiRC is in the process of developing two meetings. A proposal for an American Geophysical Union (AGU) Chapman

Conference has been accepted and this meeting will be focused on the role of aerosol during volcanically quiescent periods; a topic motivated by an extended period (1999 to the present) where stratospheric aerosol have been at or near the lowest levels observed by modern instrumentation. The conveners are Terry Deshler, Larry Thomason, and Mian Chin and the meeting will take place in March 2018 in Tenerife, Spain. SSiRC is also sponsoring a workshop on stratospheric aerosol measurements focused on facilitating communications and collaborations among scientists responsible for observations of stratospheric aerosol using *in situ*, ground-, and space-based instruments. Key goals are to develop strategies for understanding and reducing differences among instruments, and for characterising the continuity of the measurement record as instruments and measurement paradigms change. The end goal for the workshop is to facilitate providing data users, particularly the climate modelling community, more robust and better-characterised datasets than normally obtained from single instruments. The workshop is scheduled for 6-8 September 2017 in Boulder, Colorado. See the SPARC SSiRC webpage for further information.

Jean-Paul Vernier and **Claudia Timmreck** are leading the SSiRC Volcanic Response Plan (or VolRes) effort to produce a blueprint for how the scientific community should respond to a new large volcanic eruption, should one happen in future. The primary objective is to facilitate the ability of climate scientists to predict climate impacts of such a major eruption, so that they can provide robust estimates to national and international organisations. The products will consist of an assessment of readiness and what is needed to characterise such an eruption in detail, as well as a website that would coordinate sharing data following the event. The goal is to submit the document for publication by mid-2017. The SSiRC ISSI team suggested interacting with people involved in a similar NASA-organised activity to avoid duplication of effort. More than 100 members of the SSiRC community indicated interest in this effort and more than 30 are actively involved in producing the white paper on this topic.

The SSiRC Interactive Stratospheric Aerosol Model Intercomparison Project (ISA-MIP) is well under way. This project is focused on understanding how well interactive stratospheric aerosol models represent several key processes, including representation of the stratospheric aerosol layer during volcanically quiescent periods, the observed trend in stratospheric aerosol load since 2000, and the basic mechanisms driving variability in stratospheric aerosol levels.

Much of the ISSI team meeting consisted of talks focused on topics of key interest to SSiRC. For instance, **Claudia Timmreck** updated the team regarding the progress of the ongoing Model Intercomparison Project on the Climatic Response to Volcanic Forcing (VolMIP, Zanchettin *et al.*, 2016). VolMIP is a CMIP6-endorsed activity that defines a common protocol focused on multi-model assessment of climate model performance under strong volcanic forcing conditions. For this, VolMIP has defined a set of idealised volcanic perturbations based on historical eruptions using aerosol optical parameters from available observations. The experiments are ensemble simulations using initial climate states sampled from an unperturbed pre-industrial simulation. Recent evaluations of CMIP5 models suggest that most models correctly produce warm winters and reduced summer monsoon precipitation after large volcanic eruptions (**Alan Robock**). They also support the idea that volcanic eruptions increase the probability of an El Niño in the year following an eruption. Based on these evaluations, it appears likely that volcanic eruptions were necessary for the initiation and maintenance of the Little Ice Age by inducing a new Arctic sea-ice or ocean circulation state.

A key SSiRC activity is producing a historical record for stratospheric aerosol based on observations. For CMIP6 the record extends from 1850 to 2014 (updated from 1960 to 2012) and has undergone a number of improvements (**Larry Thomason**). These include a new treatment of high latitude

***Figure 16**: The SSiRC ISSI Team during the team meeting in Bern, Switzerland.*

winter where observations are unavailable for much of the SAGE period (1979 to 2005). The Pinatubo gap in the SAGE II record is now primarily filled using CLAES, though issues remain unresolved for the first several months after the eruption. Substantial improvements have been made to the post-SAGE period, which is now based on a combination of OSIRIS and CALIPSO data. The CMIP5 dataset only used CALIPSO data equatorward of 50°. This lack of true polar data created several issues that have been rectified in the new CMIP6 version by using CALIPSO and OSIRIS data up to 80° in both hemispheres. Aerosol size distribution and radiative parameter data customised for a number of chemistry climate models (CCMs) have been created and delivered to the CMIP modelling groups (**Beiping Luo**). Several improvements have been made to the model used to retrieve these data, including avoiding the use of a weak SAGE II measurement at 386nm and using HALOE 3.40µm observations as a verification of the robustness of fits rather than as a constraint.

SSiRC is coordinating the first effort to estimate the stratospheric sulfur (gas and aerosol) burden based on measurements (**Terry Deshler**). The effort focuses on a compilation of all relevant measurements from 1979 onwards, which will necessarily be constrained to a limited number of sulfur-bearing gas species and aerosol. Particular emphasis will be placed on 2004/2005 when the essential measurements were nearly completely covered. These include measurements of sulfur dioxide (SO_2) by MIPAS and carbonyl sulfide (OCS) from several instruments. The result will provide valuable comparison opportunities for sulfur burdens estimated with climate models (*e.g.*, Sheng *et al.*, 2015). An important note is that there is an ongoing debate with respect to the tropospheric OCS budget. Results and hypotheses in recent publications are far from converging; resolving obvious discrepancies in quantifying the important OCS sources and sinks is an area of active research. This potentially has significant impacts on attempts to implement a process-based OCS flux into the stratosphere in climate models. Another source of aerosol, meteoric smoke particles (MSP), have the potential to contribute substantially to the production of condensation nuclei for sulfate aerosol in much of the stratosphere (**Graham Mann**). The winter poles are an area where the input of meteoritic material from the mesosphere (and above) is the highest. However, the inferred MSP mass flux at high latitudes is much smaller than would be expected based on current estimates of meteoritic input at the top of the atmosphere. This is also an area subject to active research.

Recent advances in the NCAR Community Earth System Model Community Aerosol and Radiation Model for Atmospheres (CESM/CARMA) component of the Whole Atmosphere Community Climate Model (WACCM) demonstrate how far the interactive modelling of aerosol within chemistry-climate models CCMs has progressed (**Pengfei Yu**). CARMA correctly represents stratospheric aerosol at the low levels observed since 2000 according to comparisons with ground- and space-based measurements. The model suggests that while even the background stratospheric aerosol is predominately sulfate, about 30% of the non-volcanic aerosol column mass is due to the presence of organic materials in the lower stratosphere. It also suggests that the Asian Tropopause Aerosol Layer (ATAL) accounts for about 15% of the non-volcanic stratospheric aerosol mass. CESM/CARMA allows the study of historic events such as the Laki eruption of 1783-1784, and simulations using this model suggest that while the warm summer of 1783 in Europe was caused by internal climate variability, it would have been even warmer without Laki (**Alan Robock**). Laki was also responsible for a negative North Atlantic Oscillation and El Niño in the boreal winter of 1783-1784 and responsible for large precipitation reductions in Africa and Asia with devastating impacts on local populations.

The long continuous *in situ* stratospheric aerosol dataset from the University of Wyoming has undergone one recent major revision (Kovilakam and Deshler, 2015) and is currently going through additional evaluations to more fully account for the counting efficiency problem identified by Kovilakam and Deshler. This affects the measurements since 1991 (**Terry Deshler**). The update is expected to be completed later in 2017. Improved agreement between the optical particle counter (OPC) and SAGE II suggests that leveraging *in situ* measurements to improve inferences of aerosol characteristics from space-based measurement systems is possible (**Larry Thomason**). Work on this topic is underway and a related SSiRC workshop should help illuminate the promise and issues related to this approach.

BATAL is a collaborative effort between NASA and several institutions in India and Saudi Arabia (**Jean-Paul Vernier**). Its primary goal is to understand the properties of the ATAL, its importance to climate, and its role in transport of anthropogenic material to the stratosphere. Funding for flights in 2017 and 2018 has been acquired and a new sonde site at Naintal, India, is well situated to support ATAL studies as well as the monsoonal circulation (**Suvarna Fadnavis**). Data taken during a pilot program in August 2016 showed that the monsoon anticyclone was dynamically active and played a role in the exchange of low latitude and extra-tropical air. Other campaigns are planned for August 2017 and 2018. These include flights into the monsoon anticyclone and ATAL with the high altitude (20km) M55-Geophysica research aircraft carrying a comprehensive aerosol, sulfur gas, and tracer payload that will be carried out as part of the EU StratoClim project. The main goals of these flights are to understand the dynamics of the anticyclone and to determine the microphysical and chemical properties of the ATAL.

A new measurement campaign, Strateole 2, promises a unique platform to investigate the Tropical Tropopause Layer (TTL) from long-duration balloons. The balloons will be confined to the equatorial layer, ±10° latitude, stay aloft for up to three months, and drift at altitudes of 18-20km. Measurements are planned to characterise fine scale gravity waves, infrared fluxes, aerosol size distribution, and the temperature, water vapour, and cloud structure across the TTL, between 16 and 18km. The gondolas at 20km will contain remote sensing instruments while the gondolas at 18km will contain *in situ* instruments. Of these a reel down platform will carry existing, proven, balloon-borne instruments: a COBALD for clouds, FLASH B for water vapour, and a temperature package. These instruments will provide ten profiles of cloud, water vapour, and temperature across the TTL each night. A 2 km-long optical fibre on another *in situ* gondola will provide continuous temperature profiles both day and night. Both of these measurements, along with all others, will extend for the duration of the gondola flights (2-3 months). Engineering test flights are planned in late 2018 and science flights from October 2020 to January 2021. A brief description of the campaign is provided at **www-das.uwyo.edu/~deshler/research/Strateole2**. Other SSiRC-relevant instrument developments include the new SAGE III mission that NASA launched on 19 February 2017 and that begun operations

Figure 17: *Balloon launch from the TFIR Balloon Facility in Hyderabad, India, during the BATAL 2015 campaign.*

on the International Space Station in April 2017 (**Larry Thomason**). Collaborative efforts form a key component for validation of this instrument (**https://sage.nasa.gov/missions/about-sage-iii-on-iss**). Finally, OSIRIS continues to operate after more than 15 years (**Landon Rieger**) and represents a key component of long-term stratospheric aerosol (and ozone) datasets.

References

Kremser, S., *et al.*, 2016: Stratospheric aerosol - Observations, processes, and impact on climate. *Rev. Geophys.*, **54,** 256-276, doi:10.1002/2015rg000511.

Kovilakam, M., and T. Deshler, 2015: On the accuracy of strato-spheric aerosol extinction derived from *in situ* size distribution measurements and surface area density derived from remote SAGE II and HALOE extinction measurements. *J. Geophys. Res.*, **120**, 8426–8447, doi:10.1002/2015JD023303.

Sheng, J. X., *et al.*, 2015: Global atmospheric sulfur budget under volcanically quiescent conditions: Aerosol-chemistry-climate model predictions and validation. *J. Geophys. Res.-Atm.*, **120**, 256-276.

Timmreck, C., *et al.*, (subm.): The Interactive Stratospheric Aer-osol Model Intercomparison Project (ISA-MIP): Motivation and experimental design. *Geosci. Model Dev.*

Zanchettin, D., *et al.*, 2016: The Model Intercomparison Project on the climatic response to Volcanic forcing (VolMIP): experi-mental design and forcing input data for CMIP6. *Geosci. Model Dev.*, **9**, 2701-2719, doi:10.5194/gmd-9-2701-2016.