2016 SSiRC Workshop

Stratospheric Sulfur and its Role in Climate

Potsdam, Germany - 25-28 April 2016

AGENDA
and
Practical information

Welcome

We would like to welcome you to the 2nd SSiRC - Stratospheric Sulfur and its Role in Climate Workshop in Potsdam, Germany.

The WCRP's (World Climate Research Programme) SPARC (Stratospheric Processes and their Role in Climate) Stratospheric Sulfur and its Role in Climate (SSiRC) activity is sponsoring a workshop from the 25th to the 28th April 2016 at the Alfred Wegener Institute in Potsdam, Germany. The workshop theme is the stratospheric sulfur burden and seeks to address questions like: What can be established through gas and particle phase measurements? What processes are instrumental in causing variations in the stratospheric sulfur burden, e. g. volcanoes, the summer Asian monsoon, and other processes that lead to cross-tropopause transport? How well are these processes captured by measurements and by models? First results of the SSiRC Model and data Intercomparison Project will also be discussed. While contributions on a range of topics around the broad theme of stratospheric sulfur and its role in climate are welcome, the workshop will be organised around the following primary themes:

The sulfur burden:

- Measurements of gas precursors (e.g., SO2, COS)
- Measurements of particle phase sulfur in the stratosphere and upper troposphere
- Analyses of changes and interannual variability of these components
- Climate model sulfur burden and the processes affecting its partitioning

Volcanoes and stratospheric aerosol variability:

- The impact of sulfur injection into the stratosphere by volcanic eruptions on climate
- How well do global aerosol models do in reproducing observations from the last decades?
- Preparing for the next major volcanic eruption: How well do models reproduce the effects from past large eruptions and how can they be improved? What measurements are needed? How do we do it?

The upper troposphere/lower stratosphere (UTLS):

- The role of the Summer Asian Monsoon in the UTLS aerosol budget

- Studies of the climate response to variations in UTLS aerosol
- Process studies of sulfur chemistry, gas to particle conversion, microphysics and aerosol removal and the interactions with dynamics and transport in the tropical troposphere, the Tropical Tropopause Layer and the global UTLS and parameterization schemes for these processes suitable for global models.

SSiRC Coordination Team

Markus Rex, Claudia Timmreck, Larry Thomason, Jean-Paul Vernier and Stefanie Kremser

Agenda and Registration

Registration to the workshop is available until 21 April 2016 via the Workshop website at http://www.sparc-ssirc.org/

Please note, that submitting an abstract **does not mean you are registered for the Workshop!**

A registration fee of 120€ will be collected in cash on site. The registration fee includes workshop attendance, lunches on Tuesday and Wednesday, tea breaks during the workshop and a river cruise conference dinner.

AGENDA

Monday 25.4.2016	Theme A: Stratospheric aerosol of the past		
12.00 - 13.00	**Registration**		
13.00-13.15	Welcome and Overview		Markus Rex
13.15-13.45	SSiRC Activity: Status and Future Directions	ISSI, Chapman conference	Larry Thomason
13.45-14.15	Highlights of the review paper: Stratospheric aerosol - Observations, processes, and impact on climate	Invited Talk	Stefanie Kremser
14.15-14.45	Overview about StratoClim and other measurements activity related to SSiRC	Talk	Markus Rex
14.45-15.00	Current stratospheric activities in Aerosol_CCI around GOMOS	Talk	Christine Bingen
15.00-15.15	VoMIP: The CMIP6 model intercomparison project on the climatic response to volcanic forcing	Talk	Claudia Timmreck
15.15-16.00	**Afternoon Tea**		
16.00-16.15	Winter Warming and Summer Monsoon Reduction after Volcanic Eruptions in Coupled Model Intercomparison Project 5 Climate Models	Talk	Alan Robock
16.15-16.30	Volcanoes and Climate: Sensitivity to ENSO phase and Eruption Magnitude	Talk	Evgeniya Predybaylo

Monday 25.4.2016	Theme A: Stratospheric aerosol of the past		
16.30-16.45	Stratospheric aerosols from major volcanic eruptions: a model study of the aerosol cloud dispersal and e-folding time	Talk	Daniele Visioni
16.45-17.00	Radiative and Chemical Impacts of Stratospheric Aerosols from Volcanic Eruptions as Simulated in the NASA GEOS-5 Earth System Model with Sectional Aerosol Microphysics	Talk	Peter Colarco
17.00-17.15	The influence of stratospheric dynamics on the forcing efficacy of tropical volcanic SO2 injection: a case study around the 1991 Mount Pinatubo eruption	Talk	Sandip Dhomse
17.15-17.30	Stratospheric dynamics following the eruption of Mt. Pinatubo	Talk	Aaron Match
17.30-17.45	The impact of chlorine and bromine emissions from large Plinian eruptions on stratospheric ozone	Talk	Kristin Krueger
17.45-18.00	Using coupled regional Ocean/- Atmosphere modeling system to study effects of Pinatubo and Tambora eruptions on the Middle East and Red Sea	Talk	Sergey Osipov
18.00-19.00	**Reception at the workshop venue**		

Tuesday 26.4.2016	Theme B : Stratospheric aerosol and precursor sources of the past two decades		
8.45-9.15	NASA Current and Future planning for stratospheric aerosol measurements and such	Invited Talk	Ken Jucks
9.15-9.30	A New Generation of Balloon Borne Aerosol Sizing Instruments to Extend the Midlatitude Stratospheric Aerosol Record	Talk	Lars Kalnajs
9.30-9.45	The planned ALTIUS satellite instrument and its potential to observe stratospheric and upper tropospheric aerosols and clouds.	Talk	Filip Vanhellemont
9.45-10.00	OMPS LP aerosol extinction coefficient measurements	Talk	Ghassan Taha
10.00-12.00	**POSTER SESSION**	**Morning Tea**	
12.00-12.15	The role of the ocean in the atmospheric budget of carbonyl sulfide	Talk	Sinikka Lennartz
12.15-12.30	Carbonyl sulfide in the stratosphere	Talk	Corinna Kloss

Tuesday 26.4.2016	Theme B : Stratospheric aerosol and precursor sources of the past two decades		
12.30-12.45	Dimethylsulphide (DMS): A potential marine source for stratospheric sulphur?	Talk	Susann Tegtmeier
12.45-13.00	UT/LS Measurements of SO2 Using a New Airborne Sensor	Talk	Andrew Rollins
13.00-14.30	**Lunch**		
14.30-15.00	Sulfur budget from a model perspective	Invited Talk	Thomas Peter
15.00-15.15	Stratospheric Sulphur – 3D Chemical Transport Model Simulations and MIPAS/ENVISAT Satellite Measurement	Talk	Annika Günther
15.15-15.30	Modeling stratospheric aerosol with the GEOS-5 Chemistry Climate Model	Talk	Valentina Aquila
15.30-15.45	What is the limit of climate engineering by stratospheric injection of SO2?	Talk	Ulrike Niemeier
15.45-16.00	Model calculations of the contribution of SO2 to the stratospheric sulfur layer	Talk	Ingo Wohlmann
16.00-16.15	The influence of meteoric smoke particles on stratospheric aerosol properties	Talk	Graham Mann
16.15-16.45	**Afternoon Tea**		
16.45-18.00	Stratospheric Aerosol Climatologies	Breakout Groups	Moderated by: Larry Thomason and Thomas Peter
16.45-18.00	Sulfur transport by the Asian Monsoon	Breakout Groups	Moderated by: NN

Wednesday 27.4.2016	Theme B: Stratospheric aerosol and precursor sources of the past two decades		
8.30-9.00	Characterising the Asian Tropopause Aerosol Layer using in situ balloon borne measurements, satellite observations, and chemical transport modeling.	Invited Talk	Duncan Fairlie
9.00-9.15	Long-term measurements of UT/LMS aerosol particles by the IAGOS-CARIBIC observatory: size distributions, elemental composition, and black carbon	Talk	Markus Hermann
9.15-9.30	UTLS time series of aerosol derived from infrared limb emission measurements	Talk	Sabine Griessbach

Wednesday 27.4.2016	Theme B: Stratospheric aerosol and precursor sources of the past two decades		
9.30-9.45	In situ measurements of aerosol size distributions inside the Asian Summer Monsoon Anticyclone	Talk	Ru-Shan Gao
9.45-10.00	Anthropogenic and volcanic contributions to aerosol composition and decadal variations in the upper troposphere and lower stratosphere	Talk	Mian Chin
10.00-12.00	**POSTER SESSION**	**Morning Tea**	
12.00-12.15	Sensitivity of thermal infrared nadir instruments to the chemical and microphysical properties of UTLS secondary sulfate aerosols	Talk	Pasquale Sellitto
12.15-12.30	Vertical distribution of stratospheric aerosols using LOAC under weather balloons at different latitudes – Comparisons with other observations and characterization of sources	Talk	Damien Vignelles
12.30-12.45	Implementation of volcano eruptions and the stratospheric sulfur budget in a chemistry circulation mod	Talk	Christoph Bruehl
12.45-13.00	Organic and anthropogenic contributions to stratospheric aerosols	Talk	Daniel M. Murphy
13.00-14.30	**LUNCH**		
14.30-15.00	Long-range transport, air quality and climate impacts of volcanic sulfur emitted by Icelandic volcanic eruptions	Invited Talk	Anja Schmidt
15.00-15.15	The persistence of ash in the lower stratosphere after the Kelud eruption	Talk	Jean-Paul Vernier
15.15-15.30	The vertical distribution of volcanic SO2 plumes measured by IASI	Talk	Elisa Carboni
15.30-15.45	Global volcanic aerosol properties derived from emissions, 1990-2015, using CESM1(WACCM)	Talk	Michael Mills
15.45-16.00	Revisiting the expected radiative forcing from extra-tropical vs. tropical volcanic eruptions	Talk	Matt Toohey
16.00-16.30	**Afternoon Tea**		
16.30-18.30	ISA_MIP Modelintercomparison of Interactive Stratospheric Aerosol models	Breakout Groups	Graham/ Claudia
16.30-18.30	Summer 2016 measurements in Asia StratClim/SWOP/BATAL ?	Breakout Groups	Jean-Paul/ Markus

Wednesday 27.4.2016	Theme B: Stratospheric aerosol and precursor sources of the past two decades		
19.00-22.00	**River Cruise Dinner**		

Thursday 28.4.2016	Theme C : Stratospheric aerosol of the Future		
8.30-9.00	In situ/satellite observations of stratospheric aerosol and gas precursors	Invited Talk	Terry Deshler
9.00-9.15	On the stratospheric aerosol budget at Northern mid-latitudes from 21 years of ground-based lidar and satellite observations	Talk	Sergey Khaykin
9.15-9.30	Sulfur containing species from the upper troposphere to the upper stratosphere: an overview on MIPAS measurements of SO2, COS and aerosol mass 2002-2012	Talk	Michael Hopfner
9.30-9.45	In-Situ Stratospheric Size Distribution Measurements over the last 10 years – comparisons with OSIRIS and OMPS extinction, and COBALD backscatter measurements.	Talk	Katie Foster
9.45-10.00	Global morphology of stratospheric aerosols from 2003 – 2011 retrieved from SCIAMACHY limb-scatter observations	Talk	Christian v. Savigny
10.00-10.30	**Morning Tea**		
10.30-11.30	Feedback from the Breakout groups (15 min each group)	Summary	BG leaders
11.30-12.15	Are we ready for the next volcanic eruptions?	Discussion	Jean-Paul Vernier
12.15-13.00	Suggestions for SSiRC from the Attendees	Feedback	Larry/ Markus/ Claudia
13.00-13.15	**Adjourn**		
15.00-17.30	SSiRC SSG Meeting	SSG Members only	

List of Posters

Nelson **BEGUE** et al.	Long-range transport of volcanic aerosols plume over the Indian Ocean region during the Calbuco eruption
Steffen **Dörner**, Janis Pukite, Marloes Penning de Vries , Mike Fromm, Thomas Wagner	Black Saturday bushfire smoke plumes as seen from SCIAMACHY measurements in limb geometry
G. Pitari, I. Cionni , G. Di Genova , E. Mancini, D. Visioni , and I. **Gandolfi**	Stratospheric aerosols from major volcanic eruptions: impact on age-of-air and transport of long-lived species
Rene **Hommel**, Christian von Savigny, Alexei Rozanov, John Burrows	On aerosol microphysics in the lower stratosphere
Einar **Karu** Carl Brenninkmeijer, Jonathan Williams	Fluxes of Airborne Sulphur Compounds IN Atmospheric Troposphere-stratosphere Exchange (FASCINATE)
Christoph **Kleinschmitt** Olivier Boucher, Ulrich Platt	Studying the limitations of stratospheric aerosol injections using a sectional 3D aerosol-climate model
Eivind Wærsted and Kirstin **Krüger**	Surface-to-UTLS transport in the tropics inferred from Lagrangian calculations
Francis **Kudjoe**	Investigation of Cloud Filters for Stratospheric Aerosol Data Abstract
E. **Malinina**, A. Rozanov, V. Rozanov, J.P. Burrows, H. Bovensmann	Aerosol particle size distribution in the Stratosphere from Sciamachy limb measurements
Graham **Mann** et al.	Whole-atmosphere aerosol microphysics simulations of the Mt Pinatubo eruption: Part 2: Quantifying the direct and indirect (dynamical) radiative forcings
Graham **Mann** , Sandip Dhomse , Jianxiong Sheng , and Mike Mills	The ISA-MIP Historical Eruption SO2 Emissions Assessment (HErSEA): an intercomparison for interactive stratospheric aerosol models
Lindsay Lee , Graham **Mann**, Ken Carslaw , Matthew Toohey , and Valentina Aquila	Pinatubo Emulation in Multiple Models (POEMs): co-ordinated experiments in the ISA-MIP model intercomparison activity component of the SPARC Stratospheric Sulphur and it's Role in Climate initiative(SSiRC)
Winfried **Markert**, Mathias Palm, Thorsten Warneke, Matthias Buschmann, Justus Notholt	First Results of FTIR measurements from the West Pacific warm pool area

Lauren **Marshall**, Anja Schmidt, Graham W. Mann, Kenneth S. Carslaw, Sandip Dhomse, Jim Haywood, Andy Jones	Disentangling the eruption source parameters that control the climate effects of volcanic eruptions
Narcisa **Nechita -Banda**, Maarten Krol, Michiel van Weele, Twan van Noije, Ed Dlugokencky, Marco de Bruine, and Thomas Röckmann	Methane budget variations after the Pinatubo eruption
Amit **Kumar Pandit**, Harish Gadhavi, M. Venkat Ratnam, K. Raghunath and A. Jayaraman	Cirrus clouds in Changing Climate: Long-term Lidar observations from a tropical Indian station
Landon **Rieger**, Adam Bourassa, Doug Degenstein	Merging the SAGE II and OSIRIS Stratospheric Aerosol Records
Anja **Schmidt**, Mike Mills, Piers Forster, Timothy Andrews, and Andrew Gettelman	Volcanic radiative forcing of climate since 1990 in CESM1(WACCM)
Giorgio **Taverna** M. Chipperfield, Richard Pope and Piers Forster	Simulations of the transport of idealised bromine VSLSs and OCS in the UTLS via the Asian Summer Monsoon
Larry W. **Thomason**	Inferring aerosol properties from optical properties: Alternatives to direct retrieval
Claudia **Timmreck** et al.	ISA-MIP: A co-ordinated intercomparison of Interactive Stratospheric Aerosol models
Claudia **Timmreck**, H. Pohlmann, S. Illing, C. Kadow	The impact of stratospheric aerosol on decadal-scale climate predictions
Matthew **Toohey**, Bjorn Stevens, Hauke Schmidt, Claudia Timmreck	Easy Volcanic Aerosol: an idealized stratospheric volcanic aerosol forcing for climate models
J.-P. **Vernier** and L. W Thomason	SAGE III on ISS validation
Debra **Weisenstein**	Background Sulfur Source Gas Sensitivities with GEOS-Chem
Jacob **Zalach**	Aerosol data obtained from SCIAMACHY solar occultation measurements

Presentations - practical information

Oral presentations

Presenters with a talk are allocated 10 minutes for the presentation + 5 minutes for Q/A.

Invited talks are allocated 25 minutes + 5 minutes for Q/A.

Please, bring your presentation as a PowerPoint or PDF document.

Poster presentations

Preferred poster size and orientation is Portrait / A0 (max.1,40 m x 1,00 m).

Abstracts

In alphabetical order by presenter

Modeling stratospheric aerosol with the GEOS-5 Chemistry Climate Model

V. Aquila, P. Colarco, A. Darmenov, L. Oman, M. Chin, P. K. Bhartia, G. Taha

Volcanic eruptions constitute the major source of aerosol in the stratosphere. The detection of a region of enhanced aerosol extinction over Asia during the monsoon period, however, suggests that convective lifting of tropospheric aerosol can also be an important source of aerosols in the lower stratosphere. Additionally, photolysis and oxidation of carbonyl sulfide (OCS) produces a layer of aerosol between 20 km and 30 km altitude.

We present here an assessment of the new model capabilities of the Goddard Earth Observing System Chemistry Climate Model (GEOSCCM) to simulate stratospheric aerosol, which include a new parameterization for the formation of sulfate aerosol from OCS, improved scavenging, and the implementation of the microphysical model CARMA. We performed simulations spanning the period from 2000 to present, including natural and anthropogenic emissions of precursor gases and tropospheric aerosols (sulfate, black carbon, organic carbon, dust, and sea salt), volcanic sulfate emissions, and stratospheric sulfate aerosol resulting from the photolysis and oxidation of carbonyl sulfide (OCS). In these simulations we ran two aerosol modules: the bulk model GOCART, which prescribes a fixed aerosol radius, and the microphysical model CARMA, which simulates the aerosol size distribution with a sectional approach. By comparing results from GOCART and CARMA to observations of extinction coefficients by OSIRIS and OMPS/LP we were able to assess the importance of an explicit simulation of the aerosol size distribution in reproducing the observed the vertical transport of volcanic plumes and of the improved scavenging in the transport of tropospheric aerosol across the tropopause in convective systems. From the size distributions simulated by CARMA we also derived a simple parameterization for bulk models that ties the effective radius of stratospheric aerosol to its mass mixing ratio. Such a parameterization will be useful for models that cannot afford the computational costs of a microphysical model in order to perform long climate simulations.

Long-range transport of volcanic aerosols plume over the Indian Ocean region during the Calbuco eruption

N. Bègue[1], D. Vignelles[2], G. Berthet[2], T. Portafaix[1], F. Jégou[2], H. Benchérif[1], G. Payen[1], J-P. Vernier[4], J. Jumelet[3], T. Lurton[2], J-B. Renard[2], F. Posny[1], V. Duverger[2] and J-M Metzger[1]

[1] Laboratoire de l'Atmosphère et des Cyclones, UMR 8105 CNRS, Université de la Réunion, Réunion Island, France. [2] Laboratoire de Physique et Chimie de l'Environnement et de l'Espace, Université d'Orléans, CNRS/INSU UMR7328, Orléans, France [3] Laboratoire Atmosphères Milieux Observations Spatiales, UPMC, Université Paris 06, Université Versailles Saint Quentin, CNRS/INSU UMR8190, LATMOS-IPSL, Paris, France [4] NASA Langley Research Center, Hampton, Virginia, USA.

After 43 years of inactivity, the Calbuco (Chilie) erupted on 22 April 2015 and two intense explosive events followed during one week. The transport of the volcanic aerosols plume is investigated by combining satellite (IASI, CALIPSO), ground-based and in-situ (LOAC sonde) observations and the three high-resolution advection model of potential vorticity called MIMOSA. Given that the amount of SO_2 emitted (0.41 Tg) and in comparison to previous volcanic eruption, it is possible to consider the Calbuco eruption as a moderate volcanic eruption which has impacted the stratospheric aerosols loading. The SO_2 is manly injected into UTLS over Brazil which was oxidized quickly to gaseous sulphuric acid that almost condensed into H_2SO_4-H_2O liquid aerosols and transported toward Indian Ocean on the 450 K potential temperature level. The plume has reached the South-West Indian Ocean on the 6th May. Over the Reunion site, the volcanic aerosols plume is located between 17 and 19 km above sea level (asl) with a structure in two layers. The maximum of aerosols is located at 18 km asl with a concentration of 150 particles.cm^{-3} mainly dominate by the small particles (less than 0.5 µm in diameter). According to CALIPSO observations the spread of the volcanic aerosols is confined to the South Hemisphere. In this study, we discuss also on the dynamic context which has favored to confine the spread of the plume in the Southern hemisphere. In particular, we analyze the localization of the dynamic barrier which could modulate the content of aerosols over tropical site such Reunion.

Current stratospheric activities in Aerosol_CCI around GOMOS

Christine Bingen[1], Charles Robert[1], Kerstin Stebel[2], Christoph Brühl[3], Filip Vanhellemont[1], Nina Mateshvili[1], Emmanuel Dekemper[1], Didier Fussen[1] and the Aerosol_CCI team

[1] BIRA−IASB, Brussels, Belgium [2] NILU, Oslo, Norway [3] MPI for Chemistry, Mainz, Germany

Five years ago started the ESA Climate Change Initiative, an ambitious program aiming at the production of high quality climate data records for the various Essential Climate Variables, in response to the GCOS requirements. Aerosol_CCI is one of these projects, addressing both tropospheric and stratospheric aspects of aerosols based on remote measurements from space by a suite of ESA sensors.

Concerning the stratospheric activities, the development of aerosol products makes use of the GOMOS dataset produced by a new retrieval algorithm called AerGOM. This algorithm presents improved performances with respect to the GOMOS operational algorithm (called IPF), mainly by using a revised aerosol spectral model and an inversion methodology better taking into account the correlations between species. This results in a significantly improved spectral dependence and data quality of the stratospheric extinction profile with respect to IPF.

During the five years of CCI activities, the quality reached by the GOMOS dataset improved continuously. Key aspects of this success are the organization of the project in annual cycles of algorithm development and reprocessing, the validation by an independent team, and the use of the dataset in climate modelling applications. Feedbacks of the User and Validation teams and their close collaboration with the Earth Observation team provide a determining added value for the development of aerosol records optimally tailored to the needs of the Climate Modelling Community.

This work presents the current status of the stratospheric activities in Aerosol_CCI, including a description of the stratospheric products, results from the validation, examples of time series used in climate applications, and the perspectives for the near future.

Implementation of volcano eruptions and the stratospheric sulfur budget in a chemistry circulation model

C. Brühl, J. Schallock, J. Lelieveld, MPI for Chemistry, Mainz, Germany; C. Bingen, C. Robert, BIRA, Brussels, Belgium; M. Höpfner, KIT, Karlsruhe, Germany

Volcanic eruptions have important radiative effects on climate through impacts on the stratospheric aerosol layer. They have been estimated by analyzing satellite data for anomalies in stratospheric SO_2 concentration and aerosol extinction. For this work we used the data of different satellite instruments: MIPAS, GOMOS, OMI, TOMS, HALOE, SAGE and GOME to cover the time period 1992-2012. It is important to use multiple satellite data sources to compensate for data gaps of individual sensors. The result is a list of about 200 volcanic eruptions (small to medium) that reach the stratosphere directly or by transport from the upper troposphere. It is demonstrated that the neglect of smaller eruptions or the application of only the MIPAS data set significantly underestimates volcanic radiative forcing. Some eruptions have only a regional effect while other SO_2 plumes are transported globally. This depends on injection height, latitude, season and circulation patterns (e.g. monsoon). Because of dispersion and advection it is difficult to identify single eruptions in a 2D data field with monthly zonal means, therefore, it is important to use 3D data fields of SO_2 which can be used directly as input for the model simulation or as integral over the UT/LS (or sections of it) if point sources are preferred. This is especially required for months with several volcanic eruptions. An estimate of the total injected mass based on column measurements is not sufficient. We find that a temporal resolution of about 5 days and a spatial resolution of 60 degrees longitude, 10 degrees latitude and 1km altitude is a good compromise to have sufficient coverage.

The volcanic SO_2 data in different complexity were used in transient simulations with the atmospheric chemistry circulation model (EMAC). This model contains also SO_2 from oxidation of COS and DMS as well as anthropogenic emissions.

The vertical distribution of volcanic SO_2 plumes measured by IASI

Elisa Carboni[1] , Roy G. Grainger[1] , Tamsin A. Mather[2] , David M. Pyle[2] , Gareth Thomas[3] , Richard Siddans[3] , Andre" Smith[1] , Anu Dudhia[1] , MariLiza Koukouli[4] , Dimitris Balis[4]

1 COMET, Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, UK. 2 COMET, Department of Earth Science, University of Oxford, Oxford, UK. 3 Rutherford Appleton Laboratory, Didcot, United Kingdom. 4 Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Greece.

Sulphur dioxide (SO_2) is an important atmospheric constituent that plays a crucial role in many atmospheric processes. Volcanic eruptions are a significant source of atmospheric SO_2 and its effects and lifetime depend on the SO_2 injection altitude. The Infrared Atmospheric Sounding Instrument (IASI) on the Metop satellite can be used to study volcanic emission of SO_2 using high- spectral resolution measurements from 1000 to 1200 cm^{-1} and from 1300 to 1410 cm^{-1} (the 7.3 and 8.7 μm SO_2 bands). The scheme described in Carboni et al. (2012) has been applied to measure volcanic SO_2 amount and altitude for fourteen explosive eruptions from 2008 to 2012. The work includes a comparison with independent measurements: (i) the SO_2 column amounts from the 2010 Eyjafjallajökull plumes have been compared with Brewer ground measurements over Europe; (ii) the SO_2 plumes heights, for the 2010 Eyjafjallajökull and 2011 Grimsvötn eruptions, have been compared with CALIPSO backscatter profiles. The results of the comparisons show that IASI SO_2 measurements are not affected by underlying cloud and are consistent (within the retrieved errors) with the other measurements. The series of analysed eruptions (2008 to 2012) show that the biggest emitter of volcanic SO_2 was Nabro, followed by Kasatochi and Grímsvötn. Our observations also show a tendency for volcanic SO_2 to be injected to the level of the tropopause during many of the moderately explosive eruptions observed. For the eruptions observed, this tendency "as independent of the maximum amount of SO_2 (e.g. 0.2 Tg for Dalafilla compared with 1.6 Tg for Nabro) and of the volcanic explosive index (between 3 and 5).

Anthropogenic and volcanic contributions to aerosol composition and decadal variations in the upper troposphere and lower stratosphere

Mian Chin, Huisheng Bian, Thomas Diehl, Tom Kucsera, Valentina Aquila, Peter Colarco

We present our study of decadal variations (2000-2009) of aerosols in the upper troposphere and lower stratosphere (UTLS) in terms of the origins and transport mechanisms through modeling and analysis of observations. We use a global model that incorporates emissions from anthropogenic, biomass burning, volcanic, and other natural sources to simulate the aerosols and track their origins. The model results are compared to satellite observations from OSIRIS, SCIAMACHY, GOMOS, and CALIOP and aircraft observations from the CARRIBIC project. Although volcanic sources exerts large, sporadical perturbation to the UTLS aerosol composition, mainly due to the nature of volcanic eruptions and relatively high altitude injections, anthropogenic aerosols, especially from Asia, are transported from surface to high altitudes mainly via the monsoon convective transport with well-organized seasonal cycles in the UT region. We estimate the relative contributions of natural and anthropogenic aerosols in different altitudes in UTLS and discuss the implication of the continuous increase of Asian anthropogenic emissions. Finally, we will describe a proposed multi-model study for AeroCom to diagnose the sources of volcanic aerosols in the stratosphere (emissions and transport pathways) in the “transient” time period (1998-2012) that is directly relevant to the SSiRC experiment.

Radiative and Chemical Impacts of Stratospheric Aerosols from Volcanic Eruptions as Simulated in the NASA GEOS=5 Earth System Model with Sectional Aerosol Microphysics

Peter Colarco, Valentina Aquila*, Luke Oman, and Paul Newman NASA Goddard Space Flight Center
Greenbelt, MD, USA *also with Johns Hopkins University

We revisit the 1991 eruptions of Mt. Pinatubo and Cerro Hudson in simulations performed in the NASA GEOSO5 Earth System Model. Recent updates to the model include introducing the production of the naturally occurring background stratospheric aerosol layer from oxidation of OCS, radiative and chemical coupling of aerosol modules to the stratospheric chemistry mechanism (e.g., use of interactivaly computed aerosol surface area to drive heterogeneous reactions), and the inclusion of a sectional aerosol microphysical model as an alternative to our bulk aerosol module. Model results are compared to available observations, and we discuss implications of sectional versus bulk aerosol treatment. We also discuss the relative contribution of the Cerro Hudson eruption to southern hemisphere aerosol loading and ozone loss versus simulations that include only the Pinatubo effects.

The stratospheric sulfur burden: an assessment based on gas and particle phase measurements

T. Deshler, C. Kloss, L. Thomason, M. Höpfner, B. Martinsson, S. Kremser, A. Bourassa, N. Glatthor, J. Barnes, M. von Hobe, M. Hermann, N. Jones, T. Trickl, J. Notholt, J. Wilson, M. Palm, B. Clemesha

The primary component of stratospheric aerosol is sulfate through the condensation and subsequent dissolution of sulfuric acid in the water which condenses on the sulfuric acid droplets. The primary sources of the sulfuric acid are through the oxidation of sulfur dioxide (SO_2) and the photolysis and subsequent oxidation of carbonyl sulfide (OCS), both of which are transported from the troposphere to the stratosphere through the upwelling caused by tropical convection, the Brewer Dobson circulation, and sporadic volcanic eruptions, both large and small. Volcanic eruptions are particularly important for SO_2. To assess the sulfur burden in the stratosphere profile measurements of stratospheric aerosol, SO_2 and OCS are required. Regular profile measurements of particle phase sulfur began in the 1970s at selected locations using lidar and balloon-borne instruments. The particle measurements became global in the 1980s with satellite-borne instruments. Regular measurements of gas phase sulfur did not become available until the 2000s with satellite-based instruments and a few ground-based instruments. Here we will present some of the details of how to extract the sulfur component from the particle measurements of either aerosol extinction, backscatter, limb scatter, or size distribution, and from gas phase measurements of SO_2 and OCS using Fourier transform spectroscopy. The temporal and spatial coverage of the measurements will be described, as well as inherent measurement uncertainties arising from instrumental factors, and the assumptions required. Integrals of the sulfur mixing ratios derived will provide a map of the stratospheric sulfur burden available from measurements. Interpolation and extrapolation of the sulfur burden can be used to provide a rudimentary temporal history of the global stratospheric sulfur burden since the beginning of this century.

The influence of stratospheric dynamics on the forcing efficacy of tropical volcanic SO2 injection: a case study around the 1991 Mount Pinatubo eruption

Dhomse S. S., Mann, G. W., Marshall, L., Schmidt, A., Bellouin, N., Dalvi, M., Morgenstern, O., Yoshioka, M., Johnson, C. E. and Carslaw, K. S.

Major tropical volcanic eruptions exert significant climate impacts principally via enhanced scattering of solar radiation due to the injected SO2 greatly elevating particle concentrations in the stratospheric aerosol layer. The size distribution of stratospheric aerosol particles also shifts to larger sizes in volcanically-enhanced conditions, which promotes absorption and subsequent heating of the layer as well as causing faster sedimentation. How the volcanic sulphur cloud is dispersed also strongly affects the longevity of its radiative effects. In this presentation we investigate the role of stratospheric dynamical variability in affecting the temporal evolution of the volcanic aerosol, and how that then influences subsequent radiative effects. The Quasi-Biennial Oscillation (QBO) is the dominant mode of dynamical

variability in the tropical stratosphere and plays a key role in determining the meridional dispersion of the volcanic cloud generated by major tropical eruptions. In easterly phase, the plume from such eruptions remains confined to the tropics for a longer time-period than in the westerly phase when it is dispersed meridionally more rapidly. We test this hypothesis in a composition-climate model with well-resolved stratospheric dynamics and aerosol microphysics by carrying out a series of Pinatubo-type simulations initialised to give easterly or westerly QBO phase in the 1^{st} year after the eruption. This will allow us to explore the range in volcanic radiative forcing efficacy for this type of eruption. By analysing the co-variation of simulated effective radius and extinction at different wavelengths, we will assess how post-eruption particle size changes and meridional transport modulate the subsequent climate impacts.

Black Saturday bushfire smoke plumes as seen from SCIAMACHY measurements in limb geometry

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The so called Black Saturday bushfires started on the 7th of February 2009 in southeastern Victoria, Australia. Resulting smoke plumes contaminated the lower stratosphere in the following weeks as measured by a variety satellite instruments. Particle extinction profiles retrieved from SCIAMACHY measurements in limb geometry provide a complementary view on the development of the smoke plume, especially on the first days of the event when measurements of other instruments were sparse. Earlier studies showed that commonly used 1D retrieval algorithms for limb observations of particle extinction potentially underestimate optical thickness and altitude of such injections into the stratosphere. In this study, a 2D particle extinction retrieval algorithm for SCIAMACHY limb measurements is used to track optical thickness and plume altitude of the Black Saturday bushfires over the month of February. The required information about the horizontal distribution of the plume is determined by the absorbing aerosol index (AAI) derived from SCIAMACHY measurements in nadir geometry. First results indicate enhanced particle scattering above 18 km on the 9th of February while the smoke plume is drifting to the north east above the Pacific ocean.

Impact of Asian pollution on the Asian summer monsoon anticyclone

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The Asian summer monsoon involves complex transport patterns with large scale redistribution of trace gases in the upper troposphere and lower stratosphere (UTLS). We employ the global chemistry-climate model ECHAM5-HAMMOZ in order to evaluate the transport pathways and contributions of nitrogen oxide species PAN, NO_X, and HNO_3 from Asian Southern Asia boundary layer to the UTLS. Simulated long term seasonal mean mixing ratios are compared with trace gas retrievals from the Michelson Interferometer for Passive Atmospheric Sounding aboard ENVISAT (MIPAS-E) and aircraft campaigns during the monsoon season (June-September) in order to evaluate the model's ability to reproduce these transport patterns.

India and China are NOx-limited regimes for ozone photochemical production, and thus we use the model to evaluate the contributions from enhanced NOx emissions to the changes in PAN, HNO_3 and O_3 concentrations in the UTLS. From a set of sensitivity experiments with emission changes in particular regions it can be concluded that Chinese emissions have a greater impact on the concentrations of these species in the upper troposphere while Indian emissions are injected deeper in the lower stratosphere.

The model simulations show that the North American Monsoon (NAM) and the West African monsoon (WAM) transport pollution to the Asian Summer Monsoon (ASM) region. Remote transport also occurs in the extratropical UT where westerly winds drive North American and European pollutants eastward where they can become part of the ASM convection and lifted into the lower stratosphere. In the lower stratosphere the injected pollutants are transported westward by easterly winds.

Characterizing the Asian Tropopause Aerosol Layer using in situ balloon borne measurements, satellite observations, and chemical transport modeling.

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Satellite observations and numerical modeling studies have demonstrated that the Asian Summer Monsoon (ASM) can provide a conduit for gas-phase pollutants in south Asia to reach the lower stratosphere. Now, observations from the CALIPSO satellite have revealed the Asian Tropopause Aerosol Layer (ATAL), a summertime accumulation of aerosols associated with ASM anticyclone, in the upper troposphere and lower stratosphere (UTLS). The ATAL has potential implications for regional cloud properties, climate, and chemical processes in the UTLS. Here, we show in situ measurements from balloon-borne instrumentation, aircraft and satellite observations, combined with trajectory and chemical transport model (CTM) simulations to explore the origin, composition, physical and optical properties of aerosols in the ATAL. In particular, we show balloon-based observations from our BATAL-2015 field campaign to India and Saudi Arabia in summer 2015, including in situ backscatter measurements from COBALD instruments, and some of the first observations of size and volatility of aerosols in the ATAL layer using optical particle counters (OPCs). Back trajectory calculations initialized from CALIPSO observations point to deep convection over North India as a principal source of ATAL aerosols. Available aircraft observations suggest significant sulfur and carbonaceous contributions to the ATAL, which is supported by simulations using the GEOS-Chem CTM. Source elimination studies conducted with the GEOS-Chem indicate that 80-90% of ATAL aerosols originate from south Asian sources, in contrast with some earlier studies.

In-Situ Stratospheric Size Distribution Measurements over the last 10 years – comparisons with OSIRIS and OMPS extinction, and COBALD backscatter measurements.

Katie Foster, Terry Deshler, Landon Rieger, Jean-Paul Vernier, Frank Wienhold

The University of Wyoming has been flying Optical Particle Counters (OPCs) on high-altitude balloons since 1971 (Deshler et al., 2003). These measurements constitute the only long-term in-situ observational record of stratospheric aerosol size distributions. In the early 2000's, the program began flying a new OPC with detection capability down to 75 nm radius, but fewer size bins than the previous instruments. As part of the characterization of the new instrument, 10 years of balloon-borne measurements are compared to three independent datasets: extinction profiles from the satellite instruments OSIRIS and OMPS, and backscatter profiles from COBALD during the recent KIAsh and BATAL campaigns. At each altitude, a bimodal size distribution is fit to the OPC data and then converted to extinction and backscatter for the appropriate wavelengths via Mie theory. The results are mixed. The OMPS dataset is only recently released; thus for this comparison we examine coincident profiles between March 2012 and January 2015. The extinction derived from OPC size distribution measurements is 40% low relative to OMPS on average. The OSIRIS extinction product is compared to the OPC dataset for 8 coincident profiles between 2006 and 2013. In three cases, the two extinction profiles are similar, while for the remaining five cases the OPC measurements are half of the OSIRIS estimates. In all cases the Stratospheric Aerosol Optical Depth (SAOD) between 18 and 25 km from OSIRIS is > than the OPC estimates, although there is no trend to this bias. The ratio between the two varies from ~1.2 – 4, with a mean value of 2.7. The extinctions derived from the OPC are highly sensitive to the mode radii in the size distribution parameters, in particular the coarse mode. A 20% increase in coarse mode radius will double the extinction in some cases. When the SAOD is recalculated by augmenting the coarse mode in this way across all eight profiles, the average ratio between the OSIRIS SAOD and OPC SAOD is shifted from 2.7 to 1.6. Preliminary comparisons with COBALD indicate similar underestimations of backscatter by the OPC, while laboratory checks of the instrument are nominal, leaving the cause of the discrepancy still uncovered.

Stratospheric aerosols from major volcanic eruptions: impact on age-of-air and transport of long-lived species

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The radiative perturbation associated to stratospheric aerosols formed after SO_2 injection from large explosive volcanic eruptions may induce significant changes in stratospheric dynamics. Sulfur gases injected above the tropopause (namely SO_2 and H_2S) are readily oxidized by OH in sulfuric acid, causing increases in stratospheric aerosol optical depth even larger than one order of magnitude. In case of tropical eruptions, the resulting heating rates warm up the tropical lower stratosphere and cause a mid-high latitude westerly wind anomaly, with additional tropical upwelling. Large scale transport of stratospheric trace species may be perturbed as a consequence of this intensified Brewer-Dobson circulation. The radiatively forced changes of the stratospheric circulation during the first two years after the eruption of Mt. Pinatubo (June 1991) may help explain the observed trend decline of long- lived greenhouse gases (approximately 10 and 0.5 ppbv/yr for CH_4 and N_2O, respectively), as a result of the increased mid- to high-latitude stratospheric downward flux. Results from the University of L'Aquila climate-chemistry coupled model (ULAQ-CCM) are presented for both long-lived trace species and the stratospheric age-of-air, which results to be younger by approximately 0.5 years during 1991/92, as a result of the volcanic aerosol radiative perturbation. This type of analysis is made comparing the results of two ensembles of model simulations, one for a reference case (1960-2000) with no volcanic aerosols (REF) and a second one including sulfate aerosols formed in the stratosphere during five major explosive volcanic eruptions (*i.e,* Agung, St. Helens, El Chichón, Nevado del Ruiz and Pinatubo), along with their radiative interactions (VE). The ULAQ-CCM results for tropical upwelling, age of air and its latitudinal gradient, and finally for the mixing ratios of N_2O and CH_4 are evaluated using available aircraft, balloon and satellite observations.

In situ measurements of aerosol size distributions inside the Asian Summer Monsoon Anticyclone

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Three aerosol number density and size distribution profiles have been measured from the surface to 30 km using balloon borne printed optical particle spectrometer (POPS) instruments from Kunming, China in August 2015. These profiles show enhanced aerosol near the local tropopause inside the Asian Summer Monsoon Anticyclone (ASMA). The enhancement extended up to 2 km into the stratosphere. The corresponding aerosol optical depth and the contribution to the local heating rate will be discussed. We also compare measurements inside ASMA to these made in the tropical tropopause layer (TTL) and show that ASMA aerosol particle number density (140 – 3000 nm) is about 3 times of that previously measured in the TTL.

UTLS time series of aerosol derived from infrared limb emission measurements

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Stratospheric aerosol is known for its impact on climate. The stratospheric sulfate aerosol is sig- nificantly influenced by volcanic eruptions. In the last decade the stratospheric aerosol burden has increased likely due to several smaller volcanic eruptions. However, for these eruptions, the quantification of the contribution to the stratospheric sulphur budget and the exact pathways of sulphur to the stratosphere remains uncertain. Recent research found that especially volcanic aerosol in the lower stratosphere at mid and high latitudes has been underestimated regarding its impact on radiative forcing due to a lack of measurements in this region.

For the polar orbiting infrared limb sounder Envisat MIPAS we recently published an aerosol detection method that is capable of filtering out ice clouds and hence provides vertical profiles of aerosol measurements covering the upper troposphere and the stratosphere. The MIPAS aerosol measurements are dominated by volcanic sulfate aerosol. However, also volcanic ash, mineral dust, bush fires and non-ice polar stratospheric clouds can be identified in the MIPAS aerosol data. Here, we present further information on the altitude of the aerosol and detection sensitivity by comparing with space-based and ground-based lidar measurements.

The MIPAS aerosol measurements provide global coverage (up to 88 N and 89 S) at day- and nighttime during all seasons. We applied the new aerosol detection method to the 10 years of Envisat MIPAS measurements and calculated zonal means. As one day of MIPAS measurements comprises 14 orbits with about 96 profiles in each orbit this results in about 200 profiles in the latitude range 20 S to 20 N contributing to the daily mean (>100 profiles at 20 to 40 N, >100 profiles at 40 to 60 N and >150 profiles at 60 to 90 N). The time series of the vertically resolved zonal mean in the tropics shows a aerosol tape recorder pattern for the aerosol that is fed by smaller volcanic eruptions in the tropics. However, we also found that the Sarychev aerosol (48.5 N) contributes to the tropical aerosol. At mid and high latitudes the volcanic eruptions of the Kasatochi, Sarychev, Grimsv¨otn (all high latitude volcanoes) and the Nabro (tropical volcano) have a strong impact on the UTLS aerosol. To investigate the transport pathways of the volcanic aerosol the high sensitivity and the global coverage of the MIPAS measurements allows us to trace single volcanic eruptions in the horizontal as well as in the vertical on a daily basis for several months.

Stratospheric Sulphur – 3D Chemical Transport Model Simulations and MIPAS/ENVISAT Satellite Measurements

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In this study processes that regulate the atmospheric distribution, and the budget of carbonyl sulphide (OCS), sulphur dioxide (SO2) and stratospheric sulphate aerosols are investigated in the upper troposphere / lower stratosphere. Sulphate aerosols impact the Earth's climate by backscattering parts of the incoming solar radiation. This negative radiative forcing can lead to reduced surface temperatures and is thought of as one reason for the recent global warming “hiatus”.

Our study is based on the comparison of modeled and observed data. An isentropic chemical transport model is used, spanning the region from 330 to 3000 K potential temperature (~ 8 – 66 km), driven by ERA-Interim Reanalysis data. The simulations are compared to observations from MIPAS (Michelson Interferometer for Passive Atmospheric Sounding), a limb sounder on the satellite ENVISAT that was operational from July 2002 to April 2012.

The focus of our study lies on volcanically emitted SO2 and its dispersion, as main precursor for sulphate aerosol during volcanically perturbed times, with its simulated distribution and lifetime, in comparison to MIPAS SO2 measurements. Moreover data for OCS, as the main source for stratospheric sulphur during volcanically quiescent periods is analysed. First results of sulphuric aerosol-mass retrievals from MIPAS are presented. These will be combined with the gaseous sulphur species to obtain a global budget of stratospheric sulphur.

Long-term measurements of UT/LMS aerosol particles by the IAGOS-CARIBIC observatory: size distributions, elemental composition, and black carbon

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Passenger aircraft represent cost-efficient platforms for atmospheric measurements. Recently, the atmospheric research passenger aircraft projects MOZAIC and CARIBIC have merged into the European Research Infrastructure IAGOS (in-Service Aircraft for a Global Observing System, www.iagos.org). The IAGOS-CARIBIC part (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrumented Container, www.caribic-atmospheric.com) applies remote sensing, in situ measurements, and sample collection of aerosol particles and air in the UT/LMS (8-12 km). An instrumented airfreight container of 1.6 tons is deployed monthly on four consecutive intercontinental flights on a Lufthansa Airbus, presently from Munich, Germany.

In the course of years the scientific payload is repeatedly upgraded. Present measurements comprise particle number concentrations (CPCs), the particle size distribution (OPSS), the particle elemental composition (particle impactor and post-flight PIXE and PESA analyses), and since late 2014, the particulate soot concentration (SP2). Here we highlight some recent results and give an overview of the entire data set. Earlier work discussed the first northern hemispheric UT/LMS aerosol maps, the role of clouds as particles sources in the UT, as well as the radiative impact of volcanic aerosol particles in the LMS. IAGOS-CARIBIC measurements of sulfur containing trace gases will be described in a second presentation by Karu et al.

Particle concentrations show steep gradients over the tropopause and a strong decrease in variability from the troposphere into the stratosphere. Maps of particle number, surface-area, volume, and element concentration, representative for large parts of the northern hemispheric UT/LMS, describe the aerosol at the lower border of the stratosphere and help to constrain model results and aerosol budget calculations.

Sulfur containing species from the upper troposphere to the upper stratosphere: an overview on MIPAS measurements of SO2, COS and aerosol mass 2002-2012

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For evaluation of atmospheric model and process studies, it is essential to obtain information about the global distribution and temporal evolution of the key components involved in the sulfur budget, namely sulfur dioxide (SO2), carbonyl sulfide (COS) and the mass of sulfate aerosols. Measurements of these parameters in the upper troposphere and stratosphere are, however, sparse.

Due to their observation geometry in combination with a broad spectral coverage and a high spectral resolution, FTIR limb-sounding measurements are especially suited to obtain altitude resolved information of a large variety of atmospheric trace gases and particles. Thus, using the observations by MIPAS on Envisat it is possible to derive global distributions of SO2, COS and aerosol mass. In case of SO2, for the first time a global picture of the vertically resolved distribution of SO2 between 15 and 45 km altitude has been obtained. MIPAS SO2 measurements after volcanic eruptions allow to calculate vertically resolved lifetimes of this gas and thereby evaluate the results derived from satellite based nadir measurements in the infrared and UV/Vis spectral range. MIPAS COS observations help to analyse its global source and sink processes which are not well understood due to the extremely sparse global distribution of ground-based observations. One open issue which will be addressed here is biomass burning as a source of OCS. Finally, by the simultaneous determination of aerosol mass together with SO2 and COS from MIPAS spectra we will show first attempts to close the budget between source gases and particulate matter.

On aerosol microphysics in the lower stratosphere

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The stratospheric aerosol layer (so-called Junge layer) is an inherent part of the Brewer-Dobson circulation (BDC). Stratospheric aerosols play a large role in the Earth's climate system because they interact with catalytic cycles depleting ozone, directly alter the atmosphere's radiative balance and modulate the strength of polar vortices, in particular when this system is perturbed. In terms of mass the layer is predominantly composed of liquid sulphate-water droplets and is fed from the oxidation of gaseous precursors reaching the stratosphere either by direct volcanic injections (mainly supplying SO2) or troposphere-stratosphere exchange processes. In volcanically quiescent periods, latter processes predominantly maintain the so-called background state of aerosol layer through oxidation of OCS above 22 km, and SO2 below.

The layer forms directly above the tropopause and reaches a height of about 35 km, with a largest vertical extent in the tropics and spring-time polar regions. Above the TTL, the layer's vertical extent varies between 2 km and 8 km (about 35% of its mean vertical expansion), depending on the phase of the QBO (Hommel et al., 2015). The authors showed that the QBO induced meridional circulation, overlying the BDC, and accompanied signatures in the stratospheric temperature directly affect the life cycle of stratospheric aerosol. Mainly by modulating the equilibrium between microphysical processes that maintain the layer. And to a lesser extent by QBO modulations of the thermodynamical state of the upwelling region of the BDC.

In this study we further explore relationships between QBO forcing and aerosol processes in the lower stratosphere. We provide indications that similar process interferences are likely caused by variations of the spectral solar irradiance. We compare our modeling studies with observations from the Envisat/SCIAMACHY limb sounder. The data set has recently been released in a new version (von Savigy et al., 2015).

NASA Current and Future planning for stratospheric aerosol measurements and such

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NASA continues to maintain a set of satellite observations that are critical for understanding the impacts of changes in sulfate aerosols in the stratosphere. The Aura satellite has been operating since 2004, and should continue for the foreseeable future. The limb instrument within the Ozone Mapping Profiler Suite (OMPS) suite on-board the satellite Suomi National Polar-orbiting Partnership (S-NPP) produces high quality aerosol profiles globally for three years now. A follow on OMPS-Limb will be deployed by NASA in the future on the NOAA Joint Polar Satellite System-2 (JPSS-2) satellite in about five years. NASA also will be deploying the last of the existing Stratospheric Aerosol and Gas Experiment (SAGE)-III instruments onto the International Space Station near the end of 2016, providing a well understood aerosol extinction data sets to tie to the past SAGE observations. NASA also is working on developing a plan that could be implemented in very short term using one or more NASA aircraft in the event that a large scale volcanic eruption on the scale of Pinatubo occurs. This plan will initially be discussed at a small and focused workshop in May at NASA's Goddard Space Flight Center. This workshop will focus on what the required observations would be for understanding changes in stratospheric composition and radiative balance in a way that compliments and enhances information that will be obtained by the existing satellite data sets.

A New Generation of Balloon Borne Aerosol Sizing Instruments to Extend the Mid<latitude Stratospheric Aerosol Record.

Lars Kalnajs[1] and Terry Deshler[2]

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For the past 40 years, balloon borne measurements from the University of Wyoming have provided the only regular in situ measurements of aerosol size distributions and condensation nuclei concentrations. This long term data set has been used to address multiple scientific topics including the trends in background aerosol concentrations and the stratospheric impact of large volcanic eruptions. Additionally, these are the only measurements to provide the detailed in situ measurements of aerosol size distributions that are required to retrieve remotely sensed aerosol properties using satellite limb sounders and ground based lidars, and to accurately represent stratospheric aerosols in climate models. Both the principle scientist behind these measurements and the current generation of instrumentation are nearing retirement.

We will describe a project in development to establish both new expertise and new instrumentation to continue these measurements and to expand their capabilities. A new aerosol size spectrometer, with higher resolution sizing, and condensation nuclei counter are being developed. The new technologies will facilitate reduced cost, size and weight. This next generation of instruments will be used to continue the mid latitude record of stratospheric aerosol size distributions with regular measurements from Boulder, Colorado. Furthermore, the reduced weight, size and cost, along with new technologies for data retrieval, will improve the ability to deploy these instruments rapidly and from remote locations in response to future volcanic eruptions or other geophysical events affecting stratospheric aerosol.

Fluxes of Airborne Sulphur Compounds IN Atmospheric Troposphere-stratosphere Exchange (FASCINATE)

Einar Karu, Carl Brenninkmeijer, Jonathan Williams

Between 10 – 30 km above the Earth surface is a layer of microscopic aerosol particles composed of sulphuric acid (H_2SO_4) and water (H_2O) – termed the Stratospheric Aerosol Layer. Satellite measurements have demonstrated that the background stratospheric aerosol layer is persistently variable, even in the absence of major volcanic eruptions (Solomon et al. 2011)[1]. This is important as these particles reflect some incoming solar energy back to space and so can affect the global radiation balance (Crutzen 1976)[2]. Moreover, recent work using CARIBIC particulate sulphur measurements showed that even UTLS volcanic sulphate is of importance for radiative forcing (Andersson et al. 2015)[3]. Besides aerosol measurements, CARIBIC (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container, part of IAGOS) collects 116 whole air samples in the upper troposphere and stratosphere during 4 consecutive long haul Lufthansa Airbus A340-600 passenger flights on a monthly basis. The air samples are analysed for a suite of trace gases, now to include reactive organosulphur compounds with sample analysis using cryofocusing preconcentration system combined with Gas Chromatography – Atomic Emission Detector (GC-AED). So far, the prevalent sulphur species monitored within this project is carbonyl sulphide (COS). The sensitivity will increase with the 3rd generation AED detector, which will help to increase the number of compounds analysed to include shorter lived species such as CS_2, DMS, H_2S, and CH_3SH. The measurements will provide a basis data set for understanding more about the poorly constrained compounds, their reactions and fluxes to the stratosphere.

The assessment of the lifetime, effect, cause and origins of the sulphur compounds in the atmosphere will be investigated with the help of the state of the art global modelling (EMAC model) techniques.

On the stratospheric aerosol budget at Northern mid-latitudes from 21 years of ground-based lidar and satellite observations

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The paper presents a new high-quality 21-year series of continuous stratospheric aerosol observations at Observa- toire de Haute-Provence (OHP, 44˚N, 6˚E) in Southern France using two powerful and well-maintained lidar sys- tems. In contrast to previous studies making use of the observations by aerosol-dedicated lidars operating within the Network for Detection of Atmospheric Composition Change (NDACC), we exploit the backscatter measure- ments from the off-line 355 nm channel of stratospheric ozone lidar (LiO3S) and low-gain 532 nm channel of stratospheric temperature lidar (LTA). The presented series of stratospheric aerosol backscatter and extinction at 532 nm, spanning from January 1994 through 2016, include on average 10-11 lidar acquisitions per month after careful quality screening.

The OHP lidar observations are compared with global space-borne measurements of zonal-mean stratospheric extinction by SAGE II, GOMOS, OSIRIS and CALIOP instruments, altogether covering the time span of OHP lidar data sets. Both ground-based and satellite monthly-mean stratospheric Aerosol Optical Depth between 17 and 30 km altitude ($sAOD_{1730km}$) series are in good cross-agreement with discrepancies well below the measurement errors, thereby ensuring the quality and coherency of all data sets exploited for our study. The global satellite observations are then used to identify the drivers of stratospheric aerosol variability observed locally by the OHP lidars.

The 21-year aerosol series reflect two essential periods in the global volcanic activity over the past two decades. The first one, a long volcanically-quiescent period of low aerosol burden ($0.002<sAOD_{1730km}<0.003$) starts after the complete removal of Pinatubo aerosol in late 1996 and extends until late 2003. This ‘background’ period is followed by a volcanically-active one, dominated by several moderate and strong $sAOD_{1730km}$ enhancements up to 0.008 after tropical and Northern mid-latitude volcanic eruptions of VEI 4. We note that $sAOD_{1730km}$ values tend to drop to 0.003 level or below within several months after each eruption-induced aerosol outbreak.

The annual cycle of aerosol scattering ratio profile, as seen by both ground-based and satellite observations during both volcanically quiescent and active periods, shows a minimum between 15-19 km altitude during late spring – early summer season. This minimum is argued to be due to quasi-isentropic poleward transport of tropical air processed by overshooting convection, as the latter acts to transport clean tropospheric air into the tropical lower stratosphere. The convective ‘cleansing’ process, described in detail by Vernier et al. (2011), takes place mainly during the southern tropics convective season, which together with the timescale of poleward transport is compatible with the observed seasonality of aerosol in the mid-latitude stratosphere.

Studying the limitations of stratospheric aerosol injections using a sectional 3D aerosol-climate model

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Climate Engineering (CE) is currently being discussed as an option to prevent or at least reduce the magnitude of global warming. Stratospheric aerosol injection (SAI) in analogy to major volcanic eruptions is probably the most prominent of the proposed techniques. Numerous modeling studies on SAI and its effect on climate have been published during recent years (e.g. in the framework of the geoengineering model intercomparison project GeoMIP), mostly proving its power to reduce the global mean surface temperature significantly, but also revealing potential risks and undesirable side effects on the climate system.

For a robust estimate of the cooling potential of SAI we developed a 3D aerosol model with a sectional approach fully coupled to the radiative scheme and other aspects of the IPSL climate model, but without complete atmospheric chemistry. Processes included are precursor gas conversion, nucleation of sulfuric acid, condensation, evaporation, coagulation and sedimentation of particles. This allows us to study physical effects limiting the radiative forcing, such as absorption and reemission of infrared radiation, particle growth and changes in particle lifetime and distribution due to transport within the stratosphere.

Recent results of model experiments with various SAI scenarios (e.g. time, place, magnitude of injections) will be presented.

Carbonyl sulfide in the stratosphere

C. Kloss, K. A. Walker, T. Deshler, M. Hobe

Carbonyl sulfide (OCS) is the most abundant sulfur containing gas in the atmosphere in the absence of volcanic eruptions. With a tropospheric lifetime of 2 to 6 years, it reaches the stratosphere where it is photolyzed and the sulfur oxidized and condensed to aerosols, contributing to the stratospheric aerosol layer. The aerosol layer has a direct impact on the Earth's climate by scattering incoming solar radiation back to space. A model study by Sheng et al. (2015) suggests that OCS makes up about 70 % of the stratospheric sulfur burden under volcanically quiescent conditions. To validate and quantify the contribution of OCS to the aerosol layer more observation based OCS studies remain crucial.

In this work, data from the Atmospheric Chemistry Experiment – Fourier Transform Spectrometer (ACE- FTS) were used for an observation based estimate of the global stratospheric OCS burden. ACE-FTS is an infrared solar occultation spectrometer providing high-resolution profile observations since 2004. The stratospheric OCS burden was found to be ~515 Gg, which is equivalent to 275 Gg S. This is in good agreement with the Shen et al. model.

While the ACE-FTS data and other satellite based OCS records provide a global picture, high resolution in- situ data can help to investigate transport processes, sources and sinks of stratospheric OCS in more detail. These data will be provided by the newly developed instrument AMICA (Airborne Mid-Infrared Cavity enhanced Absorption Spectrometer) on the high altitude research aircraft Geophysica during the two campaigns of StratoClim. While old stratospheric processed air is analyzed during the first Campaign in north Sweden, the second Campaign in the Asian Monsoon region will provide information about the entrance of biomass burning plumes into the Asian Monsoon Anticyclone and the global stratosphere.

Highlights of the review paper: Stratospheric aerosol - Observations, processes, and impact on climate

S. Kremser and L.W. Thomason

The stratospheric aerosol layer is a key element in the climate system as it affects the radiative balance of the atmosphere directly through interactions with solar and terrestrial radiation. Furthermore, stratospheric aerosol also provides surfaces for heterogeneous reactions that influence the chemistry with large effects on the ozone layer and play a major role in the formation of the polar ozone holes, introducing additional important interactions with climate. The most recent comprehensive assessment on stratospheric aerosol has been published in 2006 (SPARC, 2006). Since then new measurement systems and techniques, both in situ and space-based, have been developed measuring physical aerosol properties with greater accuracy and for characterizing aerosol composition. Furthermore, fully 3- dimensional models of the stratospheric sulfur and aerosol system were developed. A crucial development since 2006 is the substantial improvement in the agreement between in situ and space-based inferences of stratospheric aerosol properties during volcanically quiescent periods. This presentation will present the highlights of the first comprehensive review paper of stratospheric aerosol since 2006. The review paper has been submitted to Reviews of Geophysics and is currently under review.

The impact of chlorine and bromine emissions from large Plinian eruptions on stratospheric ozone

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Large Plinian volcanic eruptions inject large amounts of atmosphere-relevant gases (e.g. S, Cl, Br) and reactive particles into the stratosphere. If an eruption occurs in the tropics, it can have a global impact due to dispersal of aerosols and gases through the large-scale meridional overturning circulation. Most climate studies concentrate on the sulfate aerosol effects on chemical and dynamical processes only. So far, ozone-depletion initiated by volcanic halogens from tropical eruptions was and still is believed to play a negligible role for the global atmosphere, based on observations from the recent El Chichon and Pinatubo eruptions. New results regarding the halogen release from large explosive eruptions, as well as recent volcanic plume observations and model simulations, facilitate now the evaluation of effects that combined chlorine and bromine emissions from large halogen-rich tropical eruptions have on ozone and the atmosphere in general.

For this study, a nearly complete halogen data set for the last 200 ka from paleo-eruptions of the Central American Volcanic Arc (CAVA) (Kutterolf et al., 2015), determined with the petrological method, is used to force simulations with the advanced chemistry climate model WACCM (Whole Atmosphere Community Climate Model). The goal is to quantify the impact of volcanic halogens on the preindustrial atmosphere when the background chlorine levels were low compared to the present day with the main focus on stratospheric ozone. We carried out 5 model simulations assuming that 10% of the average Cl and Br (9.51e+6 kg Br and 2.93e+9 kg Cl) CAVA emissions are injected into the tropical stratosphere during January. The model response reveals a global impact on the ozone layer affecting via radiation also atmospheric dynamics for more than 5 years. Given the current decline in anthropogenic chlorine, the results are also relevant for future halogen-rich Plinian eruptions in the tropics.

Surface-to-UTLS transport in the tropics inferred from Lagrangian calculations

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Sulfur emissions from the surface contribute to the stratospheric sulfur burden in form of gas and particle phases. They can either be natural or anthropogenic origin. In this study, we will investigate the preferred Surface to Upper Troposphere/ Lower Stratosphere (UTLS) transport in the tropics, focusing on the source gas origin and UTLS entrainment locations.

The timescales of transport from the surface to the UTLS is studied using the Lagrangian transport model Flexpart. The model was driven by the ERA-Interim reanalysis from the European Center for Medium-Range Weather Forecasts (ECMWF). Trajectories were released each month within the period 1. June 2002 - 1. May 2013 at 15 km and 17 km over the whole tropics and simulated 90 days backward in time. The age of air at 15 km and 17 km relative to the last contact with the boundary layer (BL) was computed using a constant BL- height of 1 km above sea level. The seasonal cycle, interannual variations and long-term changes are analysed in more detail for the median age of air and for the air mass origin. The annual mean results reveal a median age of air for the tropics of 26 and 50 days at 15 and 17 km altitude respectively with 40-50% UTLS air origin from the tropical West and Central Pacific. During this 11 year period a decrease of the annual median age of air is projected which seem to be partly connected with the observed ENSO variability. Consequences for the potential role of sulfur emissions from the ocean, such as DMS and OCS, on the stratospheric sulfur burden are discussed at the end.

Investigation of Cloud Filters for Stratospheric Aerosol Data Abstract

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This work deals with an optimization of cloud filters using extinction coefficients of the stratospheric aerosols retrieved from SCIAMACHY limb data. Previous investigations have shown that retrieved vertical profiles of the extinction coefficient of the stratospheric aerosol become unstable if clouds are present in the instrument field of view at a tangent height within the retrieval range. To improve the existing stratospheric aerosol database all profiles measured in the presence of clouds in the instrument field of view need to be sorted out. The SCODA 2.0 cloud database currently used for this purpose is found to identify thick aerosol layers as clouds, which results in an underestimation of the aerosol content during volcanic eruptions. This work outlines an improved approach for cloud detection. The algorithm optimizes the reliability of the existing cloud detection algorithm and makes it nearly insensitive to thick aerosol layers. The algorithm is based on vertical profiles of colour ratio between 1550 nm and 1670 nm. Different options for cloud thresholds were used to study the effect on profiles of stratospheric aerosol. Cloud filters from the 1550/1670 colour ratio were investigated by applying tangent height dependent cuts. Two cloud filters (loose and strict) each of which consists of tangent height dependent cuts were obtained. A loose filter was found to be more appropriate under high aerosol load conditions while the strict filter performs better under background conditions. A year with no major volcanic eruption and one with volcanic eruption were considered in all scenarios.

The role of the ocean in the atmospheric budget of carbonyl sulfide

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Carbonyl sulfide (OCS) is the most abundant sulfur gas in the atmosphere, and it is an important precursor for sulfate aerosols in the stratosphere. The ocean is believed to be the major source of atmospheric OCS, either by direct emissions or the emission of the OCS precursors, dimethylsulfide (DMS) and carbon disulfide (CS_2). To assess its impact on current and future climate, for example in chemistry climate models, knowledge about sources and sinks of atmospheric OCS is crucial. However, there are currently major uncertainties in the atmospheric budget of OCS: known sinks are larger than known sources by several hundreds of Gg S per year. Inverse modelling studies together with satellite data suggest that the missing source is located in the tropical ocean. We present the first high resolution measurements of OCS from the tropical Indian and Pacific Ocean surface and marine boundary layer. We show that direct oceanic emissions are unlikely to account for the missing source. Using our cruise measurements as case studies, we apply a box model to give a range for global emission estimates. In order to reduce uncertainty in the global oceanic emission estimate, our understanding of the production and consumption processes of OCS and its precursors needs improvement. Therefore, we further investigate the influence of additional parameters, e.g. the composition of dissolved organic matter and biological parameters, on the biogeochemical cycling of OCS and CS_2 in the surface ocean and their subsequent emission to the atmosphere.

AEROSOL P ARTICLE SIZE DISTRIBUTION IN THE STRA TOSPHERE FROM SCIAMACHY LIMB MEASUREMENTS

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Aerosols in the stratosphere affect crucially not only the radiative budget of the Earth by changing the way radiation is transmitted through the atmosphere, but also play an important role in the chemical processes which lead to the ozone layer depletion. Widely used characteristics of the stratospheric aerosol are the particle size distribution described by the mode radius and distribution width as well as the particle number density. A reliable knowledge on these parameters is crucial not only for analyzing the distribution of the aerosols in the stratosphere but also for various modeling activities related to stratospheric processes. One of the ways to obtain global information on aerosol characteristics in the stratosphere is to use space borne measurements of the transmitted or scattered solar light in visible and near infrared spectral region performed in occultation or limb viewing geometry, respectively. This kind of measurements provide vertically resolved global information on stratospheric aerosol characteristics. In this study limb measurements from space borne spectrometer SCIAMACHY, operated on board the ENVISAT satellite from August 2002 to April 2012, are used. SCIAMACHY was operating in a wide spectral range from 214 nm to 2386 nm, which gives a possibility to derive information about several aerosol related parameters. A vertical sampling of 3.3 km and vertical field of view of 2.5 km allow vertical distributions of stratospheric aerosol parameters to be retrieved with a moderate vertical resolution. In this study a method to retrieve aerosol particle size distribution parameters as well as aerosol particle number density from SCIAMACHY limb measurements are discussed. Furthermore, sensitivity studies and first retrieval results are presented.

The influence of meteoric smoke particles on stratospheric aerosol properties

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The ablation of meteors in the thermosphere and mesosphere introduces a significant source of particulate matter into the polar upper stratosphere. These meteoric smoke particles (MSP) initially form at nanometre sizes but in the stratosphere have grown to larger sizes (tens of nanometres) following coagulation. The presence of these smoke particles may represent a significant mechanism for the nucleation of polar stratospheric clouds and are also known to influence the properties of the stratospheric aerosol or Junge layer.

In this presentation we present findings from experiments to investigate the influence of the MSP on the Junge layer, carried out with the UM-UKCA composition-climate model. The UM-UKCA model is a high-top (up to 80km) general circulation model with well-resolved stratospheric dynamics, includes the aerosol microphysics module GLOMAP and has interactive sulphur chemistry suitable for the stratosphere and troposphere (Dhomse et al., 2014).

We have recently added to UM-UKCA a source of meteoric smoke particles, based on prescribing the variation of the MSP from previous simulations with the Whole Atmosphere Community Climate Model (WACCM). In UM-UKCA, the MSP are transported within the modal GLOMAP aerosol framework, alongside interactive stratospheric sulphuric acid aerosol. For the experiments here, we have

activated the interaction between the MSP and the stratospheric sulphuric acid aerosol. The MSP provide an important sink term for the gas phase sulphuric acid in the model, with subsequent effects on the formation, growth and temporal evolution of stratospheric sulphuric acid aerosol particles.

By comparing simulations with and without the MSP-sulphur interactions we quantify the influence of the meteoric smoke on the properties of volcanically-quiescent Junge layer. We also investigate the extent to which the MSP may modulate the effects from SO2 injected into the stratosphere from volcanic eruptions. Powerful eruptions injecting the sulphur above 30km may be particularly
influenced by interactions with the MSP since sulphuric acid droplets tend to evaporate at that altitude, with subsequent particle formation at high latitudes then being modulated by the presence of the MSP.

Whole-atmosphere aerosol microphysics simulations of the Mt Pinatubo eruption: Part 2: Quantifying the direct and indirect (dynamical) radiative forcings

Graham Mann (1), Sandip Dhomse (1), Ken Carslaw (1), Martyn Chipperfield (1), Lindsay Lee (1), Kathryn Emmerson (2), Luke Abraham (3), Paul Telford (3), John Pyle (3), Peter Braes icke (4), Nicolas Bellouin (5), Mohit Dalvi (6), and Colin Johnson (6)

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The Mt Pinatubo volcanic eruption in June 1991 injected between 10 and 20 Tg of sulphur dioxide into the tropical lower stratosphere. Following chemical conversion to sulphuric acid, the stratospheric aerosol layer thickened substantially causing a strong radiative, dynamical and chemical perturbation to the Earth's atmosphere with effects lasting several years.

In this presentation we show results from model experiments to isolate the different ways the enhanced stratospheric aerosol from Pinatubo influenced the Earth's climate. The simulations are carried out in the UK Chemistry and Aerosol composition-climate model (UKCA) which extends the high-top (to 80km) version of the UK Met Office Unified Model (UM). The UM-UKCA model uses the GLOMAP-mode aerosol microphysics module coupled with a stratosphere-troposphere chemistry scheme including sulphur chemistry.

By running no-feedback and standard integrations, we separate the main radiative forcings due to aerosol-radiation interactions (i.e. the direct forcings) from those induced by dynamical changes which alter meridional heat transport and distributions of aerosol, ozone and water vapour.

The ISA-MIP Historical Eruption SO2 Emissions Assessment (HErSEA): an intercomparison for interactive stratospheric aerosol models

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Major historical volcanic eruptions have injected huge amounts of sulphur dioxide into the stratosphere with observations showing an enhancement of the stratospheric aerosol layer for several years (ASAP, 2006). Such long-lasting increases in stratospheric aerosol loading cool the Earth's surface by scattering incoming solar radiation and warm the stratosphere via absorption of near infra- red solar and long-wave terrestrial radiation with complex effects on climate (e.g. Robock, 2000).

Two recent modelling studies of Mount Pinatubo (Dhomse et al., 2014; Sheng et al. 2015) have highlighted that observations suggest the sulphur loading of the volcanically enhanced stratospheric aerosol may have been considerably lower than suggested by measurements of the injected SO2.

This poster describes a new model intercomparison activity "ISA-MIP" for interactive stratospheric aerosol models within the framework of the SPARC initiative on Stratospheric Sulphur and its Role in Climate (SSiRC).

The new "Historical Eruption SO2 emissions Assessment" (HErSEA) will intercompare model simulations of the three largest volcanic perturbations to the stratosphere in the last 50 years, 1963 Mt Agung, 1982 El Chichon and 1991 Mt Pinatubo. The aim is to assess how effectively the emitted SO2 translates into perturbations to stratospheric aerosol properties and simulated radiative forcings in different composition-climate models with interactive stratospheric aerosol (ISA).

Each modelling group will run a mini-ensemble of transient AMIP-type runs for the 3 eruptions with a control no-eruption run followed by upper and lower bound injection amount estimates and 3 different injection height settings for two shallow (e.g. 19-21km amd 23-25km) and one deep (e.g. 19-25km) injection. First order analysis will intercompare stratospheric aerosol metrics such as 2D-monthly AOD(550nm, 1020nm) and timeseries of tropical and NH/SH mid-visible extinction at three different models levels (15, 20 and 25km). To allow the global variation in size distribution to also be intercompared, models will also diagnose 3D-monthly effective radius and integrated concentrations of particles with radius larger than 10nm, 150nm and 500nm.

The mini-ensemble is designed to be straighforward to assess several historical major eruptions and will be a precursor to the larger perturbed parameter ensemble study of the Pinatubo eruption (PoEMS) which will more rigorously assess sources of uncertainty in volcanic forcings simulated by the different models.

Pinatubo Emulation in Multiple Models (POEMs): co-ordinated experiments in the ISA-MIP model intercomparison activity component of the SPARC Stratospheric Sulphur and it's Role in Climate initiative (SSiRC)

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The World Climate Research Program's SPARC initiative has a new international activity "Stratospheric Sulphur and its Role in Climate" (SSiRC) to better understand changes in stratospheric aerosol and precursor gaseous sulphur species.

One component of SSiRC involves an intercomparison "ISA-MIP" of composition-climate models that simulate the stratospheric aerosol layer interactively. Within PoEMS each modelling group will run a "perturbed physics ensemble" (PPE) of interactive stratospheric aerosol (ISA) simulations of the Pinatubo eruption, varying several uncertain parameters associated with the eruption's SO2 emissions and model processes.

A powerful new technique to quantify and attribute sources of uncertainty in complex global models is described by Lee et al. (2011, ACP). The analysis uses Gaussian emulation to derive a probability density function (pdf) of predicted quantities, essentially interpolating the PPE results in multi- dimensional parameter space. Once trained on the ensemble, a Monte Carlo simulation with the fast Gaussian emulator enabling a full variance-based sensitivity analysis.

The approach has already been used effectively by Carslaw et al., (2013, Nature) to quantify the uncertainty in the cloud albedo effect forcing from a 3D global aerosol-microphysics model allowing to compare the sensitivity of different predicted quantities to uncertainties in natural and anthropogenic emissions types, and structural parameters in the models.

Within ISA-MIP, each group will carry out a PPE of runs, with the subsequent analysis with the emulator assessing the uncertainty in the volcanic forcings predicted by each model.

In this poster presentation we will give an outline of the "PoEMS" analysis, describing the uncertain parameters to be varied and the relevance to further understanding differences identified in previous international stratospheric aerosol assessments.

First Results of FTIR measurements from the West Pacific warm pool area

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While the main transport of air into the stratosphere occurs above the tropical West Pacific warm pool, this area constitutes a gap in existing observational networks and information on the atmospheric composition from this region is very limited. The StratoClim project closed this key observational gap by setting up a new ground station in Palau (7.3° N, 134.5° E), right in the centre of the warm pool area.

The station is equipped with a ground based solar absorption Fourier Transform Infrared (FTIR) Spectrometer and a tropospheric aerosol LIDAR system, as well as ECC ozone soundings performed on a regular schedule. Based on the FTIR measurements the total column densities of up to 20 trace gases including the species O_3, CO, C_2H_2, C_2H_6, CH_2O, HCN and COS can be retrieved. Our main research focus is the influence of COS updraft on the stratospheric sulfur budget.

To meet this target we set up a Bruker IFS 120M FTIR spectrometer with upgraded electronics and partly upgraded optics inside an air conditioned 20ft container. Operation started at the end of December 2015 and is supposed to generate a continuous dataset until 2018. First results from the COS measurements are presented here.

Disentangling the eruption source parameters that control the climate effects of volcanic eruptions

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Climatic cooling in the 1-2 years following a major volcanic eruption does not scale linearly with the mass of SO_2 injected into the atmosphere. The injection height of the emissions, the latitude of the volcano, the season and large scale atmospheric circulations, also influence the climatic response. Complex couplings exist between stratospheric chemistry and circulations, and aerosol induced heating and aerosol microphysical processes such as condensation and evaporation. As yet, there has been no systematic assessment of these relationships when considering different eruption source parameters. A series of simulations with a global composition-climate model with interactive stratospheric chemistry and aerosol microphysics are conducted, in which the eruption latitude and injection height are varied. Parameter combinations are chosen such that injections sample areas in the atmosphere where different chemical and dynamical influences are important (e.g. tropical vs. high latitude eruptions, injections near the tropopause vs. injections in the upper stratosphere). Each experiment is repeated for varying SO_2 injection magnitudes. We focus on the analysis of aerosol properties such as the stratospheric aerosol optical depth, effective radius and heating rates, and resultant perturbations to radiative fluxes. Initial results demonstrate the non-linearity in the climatic response as the injection magnitude is increased. Future work will focus on disentangling the contribution of each parameter to the climatic response with additional simulations to investigate the effect of season and the Quasi Biennial Oscillation. Results will aid in the understanding of the impact of past, present and future volcanic eruptions. By analysing sulfate deposition to the polar ice caps, we will assess the uncertainty in, and validity of, the historic volcanic radiative forcing deduced from ice cores.

Stratospheric dynamics following the eruption of Mt. Pinatubo

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Large volcanic eruptions at low latitudes such as that of Mt. Pinatubo in June 1991 can lead to massively enhanced stratospheric aerosol loading for up to about two years. The enhanced aerosol loading leads to a global cooling in the troposphere as a result of the larger albedo. In the lower stratosphere, the enhanced aerosol leads to a warming of several Kelvins as a result of enhanced absorbed radiation. It has been argued that the characteristic temperature change from volcanic aerosols in the stratosphere - a warming of the low latitudes relative to the high latitudes - tends to induce a more stable polar vortex, and as such a reduced residual circulation. More recently, however, a number of studies have presented calculations of the residual circulation from meteorological reanalyses that suggest that the residual circulation may have been anomalously strong following the Mt. Pinatubo eruption. Similarly, unexpected ozone anomalies in the Southern Hemisphere stratosphere have been linked to a stronger residual circulation. Here, we will present General Circulation Model results, using models ranging in complexity from a primitive equation model to Chemistry- Climate Models, in combination with reanalysis data that aim to provide a mechanistic understanding of the anomalous stratospheric state following the eruption of Mt. Pinatubo. Of particular interest are the impact on model results of the relatively large di↵erences in heating rate perturbations between di↵erent datasets of stratospheric aerosol, and the responses in atmospheric dynamics arising from, on the one hand, the specific sea surface temperature pattern of that period and, on the other hand, the response arising from the stratospheric radiative heating perturbation. Our model results suggest that the adjustment in the stratospheric state in response to the in-situ radiative heating perturbation from the volcanic aerosol is probably insu cient to explain the enhanced residual circulation seen in observations.

Global volcanic aerosol properties derived from emissions, 1990-2015, using CESM1(WACCM)

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Accurate representation of global stratospheric aerosols from volcanic and non- volcanic sulfur emissions is key to understanding the surface cooling effects and stratospheric ozone losses that may be linked to volcanic activity. Attribution of climate variability to volcanic activity is of particular interest in relation to the post-2000 slowing in the rate of global average surface temperature increases. We have compiled a database of volcanic SO_2 emissions and plume altitudes for eruptions from 1990 to 2015, and developed a new prognostic capability for simulating stratospheric sulfate aerosols in the Community Earth System Model (CESM). We used these combined with other non-volcanic emissions of sulfur sources to reconstruct global aerosol properties from 1990 to 2015. Our calculations show remarkable agreement with ground- based lidar observations of stratospheric aerosol optical depth (SAOD), and with *in situ* measurements of stratospheric aerosol surface area density (SAD). These properties are key parameters in calculating the radiative and chemical effects of stratospheric aerosols. Our SAOD calculations represent a clear improvement over available satellite-based analyses, which generally ignore aerosol extinction below 15 km, a region that can contain the vast majority of stratospheric aerosol extinction at mid- and high-latitudes. Our SAD calculations greatly improve on that provided for the Chemistry-Climate Model Initiative, which misses about 60% of the SAD measured *in situ* on average during both volcanically active and volcanically quiescent periods. In light of these results, the impact of volcanic aerosols in reducing the rate of global average temperature increases since the year 2000 should also be revisited.

Organic and anthropogenic contributions to stratospheric aerosols

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We will present a combination of PALMS aerosol composition measurements and global model results on the anthropogenic contributions to stratospheric aerosol. Updated PALMS data continue to show a large contribution by organic carbon to aerosol mass in the lowermost stratosphere. A global model that reasonably matches the PALMS and other data shows that organics can contribute over 30% of the stratospheric aerosol column, with the organics almost entirely below 20 km. Simulations also show that the non-volcanic stratospheric aerosol has approximately doubled since the pre-industrial era. Most of the modeled increase is due to SO_2 emissions with a smaller but still significant contribution from emissions of primary organic aerosol.

Methane budget variations after the Pinatubo eruption

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The eruption of Pinatubo in 1991 caused global scale changes in climate and radiation. Large perturbations in the methane growth rate were observed after the eruption, caused by variations in either methane sources or methane sinks. Natural methane emissions from wetlands are influenced by changes in temperature and precipitation, having a significant contribution to methane variability. The main removal of methane from the atmosphere is the reaction with the hydroxyl radical (OH). OH concentrations are in turn sensitive to temperature, humidity and the amount of UV radiation. Enhanced exchange between the stratosphere and the troposphere due to the sudden stratospheric warming after the eruption was also proposed as a potential mechanism for the observed methane decrease.

Using the 3D chemistry and transport model TM5, we quantified the variability in methane sources and sinks in the 5 years following the eruption, using the 3D chemistry and transport model TM5 (Bândă et al. 2016). We found significant contributions from methane emissions from wetlands and from OH variations caused by stratospheric aerosols, by enhanced stratospheric ozone depletion and by an expected temperature driven decrease in NMVOC emissions. The magnitude of the observed variations can be represented reasonably well using bottom-up inventories of methane emissions. However, their exact timing could not be matched by our simulations. Based on simulated OH variability, we further use the TM5-4DVAR framework to quantify the methane emissions needed to match the methane variations observed in weekly air samples collected in NOAA's Cooperative Global Air Sampling Network.

Model uncertainties in the simulated transport, including stratosphere-troposphere exchange, may be of considerable importance, affecting both the simulated stratospheric aerosols and the simulated methane concentrations. Timescales related to atmospheric transport are investigated by performing simulations, with which we contribute to the TRANSCOM (The Atmospheric Tracer Transport Model Intercomparison Project) Age of Air (AoA) experiment.

What is the limit of climate engineering by stratospheric injection of SO2?

Ulrike Niemeier, Claudia Timereck

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The injection of sulfur dioxide (SO_2) into the stratosphere to form an artificial stratospheric aerosol layer is discussed as an option for solar radiation management. The related reduction of radiative forcing depends upon the injected amount of sulfur dioxide but aerosol model studies indicate a decrease in forcing efficiency with increasing injection rate. None of these studies, however, consider injection rates greater than 20 Tg(S) $yr^{-1.}$ But this would be necessary to counteract the strong anthropogenic forcing expected if “business as usual” emission conditions continue throughout this century. To understand the effects of the injection of larger amounts of SO_2 we have calculated the effects of SO_2 injections up to 100 Tg(S) yr^{-1}. We estimate the reliability of our results through consideration of various injection strategies and from comparison with results obtained from other models. Our calculations show that the efficiency of the aerosol layer, expressed as the ratio between sulfate aerosol forcing and injection rate, decays exponentially. This result implies that the sulfate solar radiation management strategy required to keep temperatures constant at that anticipated for 2020. Maintaining “business as usual” conditions, would require atmospheric injections of approximately 45 Tg(S) yr^{-1} (± 15% or 7 Tg(S) yr^{-1} at a height corresponding to 60 hPa. This emission is equivalent to 5 to 7 times the Mt. Pinatubo eruption each year.

Using coupled regional Ocean/Atmosphere modeling system to study effects of Pinatubo and Tambora eruptions on the Middle East and Red Sea

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In this study we focus on the Middle East regional climate responses to the Pinatubo and Tambora eruptions. The study is motivated by a severe winter cooling in the Middle East observed after the Mt. Pinatubo eruption of 1991, which is yet not thoroughly investigated. It is also observed that the Red Sea surface temperature decreased more than 1K and deep water mixing caused coral bleaching for a few years. To better understand the mechanisms of the Middle East climate response and evaluate the dynamic and radiative impacts on the Red Sea we conducted a study employing regional coupled ocean-atmosphere model (Regional Ocean Modeling system, ROMS and Weather Research and Forecasting Model, WRF) using both Pinatubo and Tambora-size forcing. The WRF model parent and nested domains have been configured over the Middle East and North Africa (MENA) region and over the Red Sea with 30 and 10 km resolution, respectively. The ROMS model has been configured over the Red Sea with 2 km resolution. The WRF code has been modified to interactively account for the radiative effect of volcanic aerosols. Spectral optical properties of sulfate aerosols are computed using Mie based on the Sato's optical depth. The Tambora's optical depth is assumed three times of Pinatubo's optical depth. Both atmosphere and ocean models capture the main features of the MENA climate response and show that the dynamic effects prevail the direct radiative cooling from volcanic aerosols.

Cirrus clouds in Changing Climate: Long-term Lidar observations from a tropical Indian station

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In the present era of climate change, distribution of the ingredients pre-requisite (low temperature, water vapour and ice-nuclei) for the formation of cirrus clouds in tropics is changing. Consequently, this change is expected to alter the spatial distribution, micro and macrophysical properties of tropical cirrus clouds. Using the longest duration (from year 1998-2013) cirrus cloud observations obtained from a ground-based Lidar situated at a tropical south-Indian station: Gadanki (13.45˚N, 79.18˚E and 375 m amsl), we investigated the changes in the properties (viz. altitude, temperature, geometrical and optical thickness) of cirrus clouds. We present trend analyses which reveal a statistically significant upward shift in the altitude of cirrus clouds at a rate higher than that predicted by recent climate model simulations. Only sub-visible type of cirrus clouds (having optical thickness less than 0.03) which are known to cause warming and dehydration in the upper troposphere exhibited this upward shift while the other two types (thin and thick) of cirrus cloud did not. Also, the fraction of sub-visible cirrus clouds is found to be increasing in the last sixteen years. The sub-visible and thick cirrus clouds showed decreasing trends in their optical thickness. These changes would significantly impact the temperature and water vapour budget in the upper- troposphere and lower-stratosphere (UTLS) region.

Volcanoes and Climate: Sensitivity to ENSO phase and Eruption Magnitude

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Studies of the climate response to past strong low-latitude volcanic eruptions, in the real world and in simulations, suggest a doubling of the likelihood of El Niño during eruption years -- though results have been inconclusive and model dependent. To shed light on the physical mechanisms of volcano/ENSO interaction, we employ the GFDL CM2.1 global coupled GCM to simulate the climate response to radiative forcing from the Pinatubo and Tambora eruptions. We investigate probabilistic responses to eruptions during El Niño onset, La Niña onset, or neutral ENSO conditions, using simulated cases extracted from a 300-year control run of CM2.1 with all non-volcanic forcings fixed at 1990 levels. For ENSO-neutral conditions or the onset of a moderate-amplitude El Niño, the volcanic cooling induces a pronounced El Niño-like response in the year following the eruption. In contrast, at the onset of strong El Niño and La Niña events, the eruption has a much weaker impact. The simulated ENSO is sufficiently synchronized to the end of the calendar year, and its ensemble evolution sufficiently sensitive to noise and chaotic dispersion, that the climate impact of the Pinatubo eruption is actually more statistically significant than that of the much stronger Tambora eruption that occurs earlier in the year. Calculation of the frequency of El Niño-like conditions in post-volcanic years shows that our results are consistent with the observations, and help explain the observed doubling of El Niño likelihood induced by eruptions. That the climate response is sensitive both the eruption magnitude, and the timing relative to ENSO and the calendar year, may help reconcile many of the apparent inconsistencies among past studies.

Merging the SAGE II and OSIRIS Stratospheric Aerosol Records

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The Stratospheric Aerosol and Gas Experiment (SAGE) II was launched in 1985 and provided vertical profiles of stratospheric aerosol extinction at several visible and near infrared wavelengths until 2005. This data has been used extensively in climate modelling studies, but with several smaller volcanic eruptions in the last decade, there is also a need for additional measurements that extend the SAGE II time-series to the present. This work explores extending the SAGE II record using the Optical Spectrograph and InfraRed Imaging System (OSIRIS), which has measured limb scattered radiance since 2001, providing profiles of aerosol extinction at 750nm. Comparisons between the SAGE II and OSIRIS aerosol extinction measurements during the four years of instrument overlap by interpolating the SAGE II data to 750nm using the 525 and 1020nm channels show good agreement in the tropics and mid-latitudes with differences less than 10% for the majority of the aerosol layer. However, near the UTLS and outside of the tropics agreement is poorer and reasons for this are investigated. This analysis is used to guide a merging of the two datasets, and errors due to assumptions in the OSIRIS retrieval are explored through a series a simulation studies. Also investigated is the possibility of merging aerosol extinction profiles retrieved from the Ozone Mapping and Profiler Suite – Limb Profiler (OMPS-LP). For this work the OMPS-LP measurements are inverted using the OSIRIS retrieval algorithm to obtain aerosol extinction profiles at 745nm, and compared with coincident OSIRIS measurements.

Winter Warming and Summer Monsoon Reduction after Volcanic Eruptions in Coupled Model Intercomparison Project 5 Climate Models

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While it is common wisdom that state-of-the-art climate models are rather imperfect in their simulations of the climate response to large volcanic eruptions, the results depend on how the analyses were done. Observations show that all recent large tropical eruptions were followed by winter warming in the first Northern Hemisphere (NH) winter after the eruption, with little such response in the second winter, yet a number of the evaluations have combined the first and second winters. We have looked at just the first winter after large eruptions since 1850 in the Coupled Model Intercomparison Project 5 (CMIP5) historical simulations, and find that most models do produce a winter warming signal, with warmer temperatures over NH continents and a stronger polar vortex in the lower stratosphere, which corresponds to a positive mode of the Arctic Oscillation. In addition, large volcanic eruptions simulated in the Last Millennium Ensemble of climate model simulations carried out with the Community Earth System Model at the National Center for Atmospheric Research also produce winter warming in the first winter after the eruptions. We also examined NH summer precipitation responses in the first year after these large volcanic eruptions in both the CMIP5 archive and Last Millennium Ensemble, and find clear reductions of summer monsoon rainfall. While we would not expect climate models on average to exactly simulate the observed response, which includes random variability, these results help us to diagnose what models currently do well and where we might look for improvements.

UT/LS Measurements of SO_2 Using a New Airborne Sensor

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InQsitu measurements of SO_2 in the upper troposphere and lower stratosphere (UT/LS) have been sparse and are much needed to evaluate the understanding of transport and chemical process controlling stratospheric sulfate. Measurements made during volcanically quiescent periods as well as readiness to acquire observations following major volcanic eruptions are of interest. We have recently developed a new laserQinduced fluorescence (LIF) instrument for this purpose and demonstrated it on the NASA WBQ57F. During October 2015 we acquired 18.4 hours of SO_2 data in the UT/LS with flights based from Houston, TX, spanning 10.8–45.4 °N latitude and up to 19.4 km altitude.

Here we will present the principles of operation of the instrument as well as the performance on this first deployment. Typical detection limit for 10 seconds of integration was 2 ppt, which allowed us to determine the background levels of SO_2 in the UT/LS. Comparisons with chemical transport models (e.g. GMAO, CESM1) indicate generally good agreement at background levels as well as a few cases of convectively enhanced SO_2 in the UT. Both the LIF measurements and model calculations of background UT/LS SO_2 appear to be significantly lower than the observed climatology retrieved using data from the MIPAS satellite.

Volcanic radiative forcing of climate since 1990 in CESM1(WACCM)

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We have compiled a database of volcanic sulfur dioxide (SO_2) emissions and plume altitudes for volcanic eruptions since 1990. In Mills et al. (2016), the volcanic emission database has been used to evaluate the new prognostic stratospheric sulfate aerosol capability in the Community Earth System Model (CESM1). Here we apply existing and novel methods to diagnose the volcanic radiative forcing including a decomposition into direct and indirect forcing contributions since 1990. We discuss the differences that arise from diagnosing the forcing based on specified dynamics and free-running simulations. We also discuss the magnitude of the volcanic forcing since 1990 in relation to the decades prior to 1990, the occurrence frequency of volcanic eruptions and the global temperature record.

Long-range transport, air quality and climate impacts of volcanic sulfur emitted by Icelandic volcanic eruptions

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I will discuss how recent and historic volcanic eruptions in Iceland affected air quality and climate. For instance, the 2014-2015 effusive Holuhraun (Bárðarbunga) eruption produced about 1.5 km^3 of lava, making it the largest-volume eruption in Iceland in more than 200 years. Daily sulfur dioxide (SO_2) emissions from the eruption exceeded daily SO_2 emissions from all anthropogenic sources in Europe by at least a factor of three. I will show that air quality measurements from across Europe provide an opportunity to evaluate the ability of satellite remote-sensing instruments to detect and characterise tropospheric volcanic plumes. Also, the range of available observations makes the Holuhraun eruption a unique case for evaluating the skill of current chemistry-climate models to simulate volcanic plumes. I will also discuss to what degree Icelandic eruptions of different magnitudes can affect the brightness of low-level clouds and induce a significant aerosol indirect forcing of climate on regional to hemispheric scales.

Sensitivity of thermal infrared nadir instruments to the chemical and microphysical properties of UTLS secondary sulfate aerosols

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The observation of upper-tropospheric–lower-stratospheric (UTLS) secondary sulfate aerosols (SSA) and their chemical and microphysical properties from satellite nadir observations (i.e. with better spatial resolution than limb observations) is a fundamental tool to better understand their formation and evolution processes and then to estimate their impact on UTLS chemistry, and on regional and global radiative balance. Thermal infrared (TIR) observations are sensitive to the chemical composition of the aerosols due to the strong spectral variations of the imaginary part of the refractive index in this band and, correspondingly, of the absorption, as a function of the composition. These observations are, then, well adapted to detect and characterize UTLS SSA, in principle. Unfortunately, the exploitation of nadir TIR observations for sulfate aerosol layer monitoring is today very limited.

Here we present a study aimed at the evaluation of the sensitivity of TIR satellite nadir observations to the chemical composition and the size distribution of idealised UTLS SSA layers. The sulfate aerosol particles are assumed as binary systems of sulfuric acid/water solution droplets, with varying sulphuric acid mixing ratios. The extinction properties of the SSA, for different sulfuric acid mixing ratios and temperatures, are systematically analysed. The extinction coefficients are derived by means of a Mie code, using refractive indices taken from the GEISA (Gestion et Étude des Informations Spectroscopiques Atmosphériques: Management and Study of Spectroscopic Information) spectroscopic database and log-normal size distributions with different effective radii and number concentrations. IASI (Infrared Atmospheric Sounding Interferometer) pseudo-observations are generated using forward radiative transfer calculations performed with the 4A (Automatized Atmospheric Absorption Atlas) radiative transfer model, to estimate the impact of the extinction of idealised aerosol layers, at typical UTLS conditions, on the brightness temperature (BT) spectra observed by this satellite instrument. We isolated a marked and typical spectral signature of these aerosol layers between 700 and 1200 cm-1, due to the absorption bands of the sulfate and bisulfate ions and the undissociated sulfuric acid, with the main absorption peaks at 1170 and 905 cm-1 (sulfuric acid vibrational bands).

The dependence of the aerosol BT spectral residual signature to the sulfuric acid mixing ratio, and effective number concentration and radius, as well as the role of interfering parameters like the ozone, sulfur dioxide, carbon dioxide and ash absorption, and temperature and water vapour profile uncertainties, are analysed and critically discussed. The information content (degrees of freedom and retrieval uncertainties) of synthetic satellite observations is estimated for different

instrumental configurations. High spectral resolution (IASI-like pseudo- observations) and broadband spectral features (Moderate Resolution Imaging Spectroradiometer (MODIS) and Spinning Enhanced Visible and InfraRed Imager (SEVIRI)-like pseudo-observations) approaches are proposed and discussed. An application of the mentioned broadband spectral features scheme, aimed at the characterization the evolution of Nabro volcano eruption (Eritrea, 13.37°N, 41.70°E, 12 June 2011) at a very high temporal resolution using SEVIRI data, is finally shown.

OMPS LP aerosol extinction coefficient measurements

Ghassan Taha, P. K. Bhartia, Philippe Xu, Robert Loughman, Glen Jaross

The Ozone Mapping and Profiler Suite (OMPS) on board Suomi National Polar-orbiting Partnership (S- NPP) was launched on October 28, 2011. It consist of three instruments: Nadir Mapper (NM), Nadir Profiler (NP) and Limb Profiler (LP). The OMPS LP instrument is designed to provide high vertical resolution ozone and aerosol profiles from measurements of the scattered solar radiation in the 290-1000 nm spectral range. It collected its first Earth limb measurement in January 10, 2012, and continues to provide daily global measurements of ozone and aerosol profiles from the cloud top up to 60 km and 40 km respectively.

Although the instrument was designed primarily for vertical ozone profiles measurement, it has a high sensitivity to stratospheric aerosols, cirrus cloud in the upper troposphere, as well as stratospheric (PSC) and mesospheric (PMC) clouds. The relatively high vertical and spatial sampling allow detection and tracking periodic events when aerosol particles are injected into the stratosphere, such as volcanic eruptions or meteor explosions. The current aerosol retrieval algorithm is based on Chahine's non-linear relaxation method, using single wavelength at 675 nm.

In this presentation, we will provide early assessment of OMPS LP aerosol extinction profile measurements by comparing it to OSIRIS on board ODIN. Initial comparison of OMPS version 0.5 aerosol extinction shows agreement with OSIRIS measurements to within 20%. In addition, results showing latitudinal, and temporal variability of stratospheric aerosol extinction and optical depth for both instruments will also be presented.

We will also present OMPS LP aerosol observations of the dispersal of volcanic aerosols in the stratosphere following the eruptions of Kelut and Calbuco in 2014 and 2015 respectively.

Simulations of the transport of idealised bromine VSLSs and OCS in the UTLS via the Asian Summer Monsoon

Giorgio S. Taverna, M. Chipperfield, Richard Pope and Piers Forster.

Halogenated and sulfur species are considered to be very important in atmospheric chemistry. Despite their small concentration, e.g., about 20 pptv of bromine in the stratosphere and 0.4 ppbv of sulfur in clean troposphere (*Seinfeld and Pandis, 2006*), these trace gases impact phenomena ranging from air quality to potential climate change. This poster shows the results obtained through a series of tracers experiments designed to investigate and quantify the boundary layer-to-upper troposphere lower stratosphere transport by the Asian Summer Monsoon (ASM) associated deep convection of COS and bromine Very Short Lived Substances (VSLSs), such as CHBr3 and CH2Br2. These compounds can eventually contribute to the stratospheric ozone depletion and aerosol layer. The experiments were carried out using the TOMCAT 3D CTM transport model, in high resolution mode (1°x1°, 31 levels) forced by ECMWF analyses. We used the idealised and artificial tracers concepts to simulate this transport. A ten years (2000-2010) simulation of idealised CH2Br2, CHBr3 and OCS with parametrized loss rates, has been run. An important question for bromine VSLS is whether ASM associated transport can take place on timescales which are short relative to their chemical lifetime. To try to solve this problem we released “artificial” CH2Br2 and CHBr3 in the boundary layer of the ASM associated deep convection areas with fixed lifetime, 120 and 26 days respectively, for 2001 (under neutral El Nino conditions). The results of the two experiments have been compared.

Dimethylsulphide (DMS): A potential marine source for stratospheric sulphur?

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Dimethylsulphide (DMS) is the most abundant biogenic sulphur compound emitted from the sea surface. The atmospheric lifetime of DMS is very short (between 11 minutes and 46 hours) and thus it is not expected that DMS contributes directly to the persistent stratospheric sulphur layer. Here, we use model simulations as well as ship- and aircraft- campaign measurements to question this assumption and quantify DMS entrainment into the stratosphere.

First, we calculate DMS sea-to-air fluxes for the TransBrom cruise in October 2009 in the western Pacific Ocean. Simulations with the Lagrangian transport model FLEXPART suggest the direct entrainment of DMS into the stratosphere in this region due to deep convection and tropical storms. While only very few air masses reach the cold point tropopause within the short DMS lifetime, the high oceanic emissions lead to surprisingly large DMS entrainment into the stratosphere (Marandino et al., 2013). The model simulations are confirmed by recent ATTREX aircraft measurements where under special meteorological conditions, DMS was found in the upper TTL for the first time. Shifting the focus from local to global scales, we use simulations with FLEXPART and an Atmospheric Chemistry Transport Model (ACTM) to analyze the direct entrainment of DMS from various ocean basins into the stratosphere. Sensitivity studies take into account different implementations of the atmospheric DMS chemistry and of convective parametrization as well as different emission scenarios. By combining the global model simulations and various aircraft campaigns, we quantify the contribution of oceanic DMS to the stratospheric sulphur loading.

Inferring aerosol properties from optical properties: Alternatives to direct retrieval

Larry Thomason, Nicholas Ernest, Terry Deshler

Stratospheric aerosol data sets are key inputs for climate models (GCMs, CCMs) particularly for understanding the role of volcanoes on climate and as a surrogate for understanding the potential of human-derived stratospheric aerosol as mitigation for global warming. These data sets are based primarily on space-based measurements of aerosol optical properties. These properties are, in turn, used to infer size distribution and/or aerosol properties like aerosol surface area density that are required by GCMs and CCMs. It is well known that there are substantial limitations to the reliability of aerosol properties inferred from even the most robust data sets of aerosol optical properties. These limitations lead to significant uncertainties in important aerosol properties that are almost impossible to rectify. In this presentation, strategies to mitigate these issue are addressed particularly an approach that uses knowledge gained from auxiliary data set from the University of Wyoming optical particle counter (OPC) regarding the relationship between aerosol extinction coefficient and aerosol size distribution.

ISA-MIP: A co-ordinated intercomparison of Interactive Stratospheric Aerosol models

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The SPARC activity, "Stratospheric Sulfur and its Role in Climate" (SSiRC) was initiated to coordinate international research activities on modelling and observation of stratospheric sulphate aerosols (and precursor gases) in order to assess its climate forcing and feedback. With several international activities to extend and improve observational stratospheric aerosol capabilities and data sets, and a growing number of global models treating stratospheric aerosol interactively, a new model intercomparison activity "ISA-MIP" has been established in the frame of SSIRC. ISA-MIP will compare interactive stratosphericaerosol (ISA) models using a range of observations to constrain and improve the models and to provide a sound scientific basis for future work. Four ISA-MIP experiments have been designed to assess different periods of the observational stratospheric aerosol record, and to explore key processes which influence the formation and temporal development of stratospheric aerosol. The "Background" experiment will focus on the role of microphysical and transport processes under volcanically quiescent conditions, where the stratospheric aerosol size distribution is only modulated by season al circulations. The "Model Intercomparison of Transient Aerosol Record" (MiTAR) experiment will focus on the exploration of the role of small- to moderate-magnitude volcanic eruptions and transport processes in the upper troposphere – lower stratosphere (UTLS) aerosols loading over the period 1998-2011. MiTAR simulations will be compared to observations to evaluate the performances of the model and understand their strengths and weaknesses. Two further experiments investigate the radiative forcing from historical major eruptions. The Historical Eruptions SO_2 Emission Assessment (HErSEA) will involve models carrying out mini-ensembles of the stratospheric aerosol perturbations from each of the 1963 Agung, 1982 El Chichón and 1991 Pinatubo eruptions, using a range of observational datasets to constrainuncertaintiesintheinitialsulphuremissionfromthe eruptions.ThePoEMSexperimentswill involve each modelling group carried out a perturbed parameter ensemble of runs to carry out a dedicated analysis to assess how each model's simulated radiative forcing from Pinatubo is sensitive to uncertainties in emissions and model process parameters.

This presentation gives an overviewof the ISA-MIP experiments illustrating how each experiment in the assessment is seeking to improve understanding, reduce uncertainty and increase the reliability of the simulated climate effects from stratospheric aerosol changes.

The impact of stratospheric aerosol on decadal-scale climate predictions

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The possibility of a large future volcanic eruption provides arguably one of the largest uncertainties concerning the evolution of the climate system on the time scale of a few years; but also the greatest opportunity to learn about the behavior of the climate system, and our models thereof. So the question emerges how large will the uncertainty be for future decadal climate predictions if no volcanic aerosol is taken into account? And how strong has volcanic aerosol affected decadal prediction skill on annual and multi-year seasonal scales over the recent years? To understand the impact of volcanic aerosol on multi- year seasonal and decadal climate predictions we performed CMIP5-type hindcasts without volcanic aerosol using the German MiKlip prediction system system baseline 1 from 1961 to 1991 and compared them to the corresponding simulations including aerosols. We show that volcanic aerosol significantly affects the prediction skill for global mean surface air temperature in the first five years after large volcanic eruptions. On the regional scale a volcanic signal is also detectable. Neglecting volcanic aerosol leads to a reduced prediction skill over the tropical and subtropical Atlantic, Indic and West Pacific but to an improvement over the tropical East-Pacific, where the model has in general no skill. Multi-seasonal differences in the skill for seasonal-mean temperatures are evident over Continental Europe with significant skill loss due to neglection of volcanic aerosol in boreal winter over central Europe, Scandinavia and over south-eastern Europe and the East-Mediterranean in boreal summer.

VolMIP: The CMIP6 model intercomparison project on the climatic response to volcanic forcing

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Our understanding of the climatic response to volcanic forcing is limited as large uncertainties affect both the observational records, due to the limited number of observed events, and the responses simulated by different climate models. The lack of agreement between model results is crucially determined by differences in model characteristics such as resolution, complexity and implementation strategy of the forcing, and uncertainty in the eruption details including magnitude, latitude and season, input data and background climate. The multiple and varied nature of these factors prevents their contribution to inter-model spread from being distinguished within existing multi-model ensembles. It is therefore necessary to frame future modeling activities within common designs that separately focus on specific aspects, that is, uncertainties in the reconstruction of radiative volcanic or associated feedback mechanisms activated in the coupled ocean-atmosphere system for one specific volcanic forcing.

The Model Intercomparison Project on the climatic response to Volcanic forcing (VolMIP) presented here focuses on the response of the coupled ocean-atmosphere system to strong volcanic forcing. VolMIP is a CMIP6 endorsed project, which defines a common protocol to subject Earth system models and coupled general circulation models to the same volcanic forcing under a similar range of background climate conditions. By doing so, VolMIP aims at assessing to what extent simulated responses are robust across models and at identifying the causes that limit robust behavior, especially as far as different treatment of physical processes is concerned.

In a first step, VolMIP works on the identification of a consensual volcanic forcing dataset for the 1815 Tambora eruption, as it is the largest-magnitude volcanic eruption of the past five centuries and a reference for the VolMIP core experiments. Therefore five current state-of-the-art global aerosol climate models have been subject to a common experimental protocol for the 1815 Tambora eruption in order to assess the uncertainties in the derived volcanic forcing. Results indicate substantial differences among models regarding key aerosol optical properties and spatial distributions for the Tambora eruption.

Here we discuss current uncertainties regarding relevant microphysical processes possibly underlining these large differences and challenges for current global stratospheric aerosol models to derive consensual forcing for large tropical volcanic eruptions. We will also present an overview of VolMIP and how VolMIP is linked to CMIP6 and to other coordinated modeling assessments and how it will improve our understanding of past, current, and future climates.

Easy Volcanic Aerosol: an idealized stratospheric volcanic aerosol forcing for climate models

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Radiative forcing by stratospheric sulfate aerosol of volcanic origin is one of the strongest drivers of natural climate variability. Transient model simulations attempting to match observed climate variability, such as the CMIP *historical* simulations, rely on volcanic forcing reconstructions based on observations of a small sample of recent eruptions and coarse proxy data for eruptions before the satellite era. Volcanic forcing data sets used in CMIP5 were provided either in terms of optical properties, or in terms of sulfate aerosol mass, leading to significant inter-model spread in the actual volcanic radiative forcing produced by models and in their resulting climate responses. It remains therefore unclear to what degree inter-model spread in response to volcanic forcing represents model differences or variations in the forcing. In order to isolate model differences, Easy Volcanic Aerosol (EVA) provides an analytic representation of volcanic stratospheric aerosol forcing, based on available observations and aerosol model results, prescribing the aerosol's radiative properties and primary modes of spatial and temporal variability. In contrast to regriddings of observational data, EVA allows for the production of physically consistent forcing for historic and hypothetical eruptions of varying magnitude, source latitude, and season. Within CMIP6, EVA will be used to reconstruct volcanic forcing over the past 2000 years for use in the Paleo-Modeling Intercomparison Project (PMIP), and will provide forcing sets for VolMIP experiments aiming to quantify model uncertainty in the response to volcanic forcing. Here, the functional form of EVA will be introduced, along with illustrative examples including the EVA-based reconstruction of volcanic forcing over the historical period, and that of the 1815 Tambora eruption.

Revisiting the expected radiative forcing from extra-tropical vs. tropical volcanic eruptions

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The impact of eruption latitude on the aerosol evolution and radiative forcing is investigated in simulations of the coupled aerosol-general circulation model MAECHAM5-HAM. An ensemble of simulations of eruptions with magnitude and sulfur injection heights based on the 1991 Pinatubo eruption are performed at six latitudes spanning the southern tropics to the high latitude Northern Hemisphere, and in both January and July. We find that for Pinatubo-like eruptions, global mean radiative forcing by extratropical eruptions can be comparable to that of tropical eruptions, and further, that the radiative forcing in the NH mid-to-high latitudes produced by extratropical eruptions is comparable or even greater than that of tropical eruptions. Further simulations show that the radiative impact of extratropical eruptions is strongly dependent on the injection height within the stratosphere. The impact of extratropical eruptions is also shown to be quite sensitive to eruption season: for higher injection heights (30 hPa) sensitivity to season is related to seasonal differences in aerosol growth, while for lower altitudes, sensitivity is related to a combination of aerosol growth and transport loss processes. Our results contradict the widely held belief that extra-tropical or high latitude eruptions produce much smaller climate impacts than tropical eruptions of comparable magnitude.

The planned ALTIUS satellite instrument and its potential to observe stratospheric and upper tropospheric aerosols and clouds.

Filip Vanhellemont, Didier Fussen, Emmanuel Dekemper, Didier Pieroux, Ghislain Franssens, Nina Mateshvili, Quentin Errera, Christine Bingen, Charles Robert and Philippe Demoulin.

Belgisch Instituut voor Ruimte-Aëronomie / Institut d'Aéronomie Spatiale de Belgique

The possibility to obtain quality altitude-resolved aerosol/cloud extinction profiles in the UTLS and stratosphere from satellite-based solar and stellar occultation measurements has been adequately demonstrated by several satellite instruments. Also, recent studies show that the limb scatter observation mode deliver good aerosol retrievals as well, although the data inversion is more complex. The near-future Belgian ALTIUS instrument (Atmospheric Limb Tracker for the Investigation of the Upcoming Stratosphere), to be launched on a PROBA satellite, is designed to make use of all three observations modes in the UV/Vis/IR (250-1800 nm), hereby obtaining global earth coverage in day as well as night illumination conditions. ALTIUS will acquire 2D vertical transmittance/radiance images at multiple wavelengths that are selectable with Acousto-Optical Tunable Filters (AOTF) and one Fabry-Perot filter. Apart from a number of trace gases (O_3, NO_2, NO_3, H_2O, CH_4), aerosol/cloud extinction will be retrieved. An important innovation of the ALTIUS approach lies of course in the fact that the 2D altitude/lateral distribution of aerosol/cloud extinction will be obtained; aerosol layers and cloud types (PSCs, subvisual cirrus, volcanic plumes, PyroCbs) will be recognisable by their morphology in the images. Furthermore, the combined use of several subsequent along -track observations will allow tomographic retrievals. Finally, the availability of multi-wavelength extinction data unlocks the possibility to derive particle size distributions.

SAGE III on ISS validation

J.-P. Vernier[1,2] and L. W Thomason[2].
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By the middle of this year, the Stratospheric Aerosol and Gas Experiment (SAGE) III will continue the legacy of measurements of stratospheric aerosol, ozone, water vapor and nitrogen dioxide started 36 years ago by the first SAGE instrument. The primary objectives of the SAGE III on ISS mission are to : i) assess the recovery of the ozone layer, ii) monitor stratospheric aerosol levels influenced by volcanoes and/or human emission of gas precursors, ii) provide accurate measurements of water vapor in the tropical tropopause layer and study its interaction with cirrus clouds. SAGE III will be flying in a period when the number of other space-based platforms (e.g. MLS/Aura, CALIOP/ CALIPSO, and OMPS/NPP) will provide corroborative information. The SAGE validation will rely on high resolution balloon-borne data from the Froist Point Hygrometer (FPH) for water vapor, ozonesondes and COBALD backscatter sondes for aerosol extinction, launched from the Northern (e.g. Boulder) and Southern Hemisphere (e.g. Lauder). In addition, we seek to collaborate with networks of ground-based and balloon observations to extend the validation in the tropics.

The persistence of ash in the lower stratosphere after the Kelud eruption

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In order to improve our understanding of the role of volcanic eruptions on climate variability and stratospheric chemistry, we need to better assess the evolution of the chemical, physical and radiative properties of volcanic aerosol produced or directly injected after a volcanic event. On February, 13 th 2014, the Kelud volcano erupted for a few hours, injecting sulfur dioxide and ash up to 25 km. This was the highest level reached by a volcanic eruption since June 1991 and the eruption of Mt Pinatubo. During the first few weeks following the eruption, backscatter measurements from the space-borne lidar CALIOP suggested the separation between the ash and sulfate clouds along their transport in the tropical region. We found that ash particles still contributed ~ 20% of the total Aerosol Optical Depth of the plume 3 months after the eruption. We mounted a balloon field campaign in Australia to intersect this plume and flew meteorological sondes, aerosol backscatter sensors and optical particle counters (heated and unheated). The set of measurements aimed to validate satellite observations, obtain vertical profiles of the size distribution of ash and sulfate aerosols and constrain radiative calculations. Primary findings of the campaign include: i) relative inhomogeneity of the plume vertical structure over Australia during the campaign, ii) confirmation of the vertical separation between ash and sulfate particles iii) persistence of ash with a mean radius around 0.2-0.3 micron in the lower part of the plume.

These measurements are used to calculate the short and long wave radiative forcings following this eruption and evaluate the importance of volcanic ash in climate.

Vertical distribution of stratospheric aerosols using LOAC under weather balloons at different latitudes – Comparisons with other observations and characterization of sources

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The study of aerosols is of major importance both for climate and air quality. Understanding the distribution in terms of temporal and spatial concentration, distribution in size and nature represents a challenge in the comprehension of our atmosphere. LOAC (Light Optical Aerosol Counter) is an optical particle counter sufficiently light-weight to be carried by a 1000gr meteorological balloon. The instrument contains a LASER and measures the intensity of light scattered at two angles to discriminate the particle concentration over 19 size classes from 0.2 to 100 µm in diameter.

Almost a hundred balloon flights with the LOAC instrument have been performed in several conditions to study the distribution of stratospheric aerosols as a function of time, latitude, dynamical processes or volcanic influence on the stratosphere over the 2013-2016 period. A review of all this flights is presented here with focus on variability issues and on events of specific interest.

The temporal evolution of stratospheric aerosols is studied from the balloon base of Aire sur l'Adour (South of France) where the flights have been managed by the CNES French Space Agency. This middle latitude launching site has allow us to compare the local variations of the aerosol content with satellite datasets (OSIRIS on Odin) during a volcanically quiescent period in the Northern hemisphere.

Volcanic aerosols are also studied from two balloons launched from the Réunion Island (Indian Ocean 21°S 55°E) having intercepted the Chilean volcano Calbuco plume in the stratosphere. Vertical profiles and size distribution results are compared with outputs from the global model CESM. Two tropospheric measurements have been also performed in order to characterize the volcanic sources close to the volcano at ground at the Mt Etna and alongside a balloon flight in Iceland during the Holuhraun eruption in winter 2015. Ratios particles/SO_2, particles flux estimations and characterization of size distribution is discussed.

Three flights have been performed during the BATAL balloon field campaign which focus on ATAL over Varanasi, India. Finally, an original study on the gravity-wave effects in particular on stratospheric aerosol concentration is presented as well.

Stratospheric aerosols from major volcanic eruptions: a model study of the aerosol cloud dispersal and *e*-folding time

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Large explosive volcanic eruptions are capable of injecting considerable amounts of particles and sulphur gases above the tropopause, causing large increases in stratospheric aerosols. Five major volcanic eruptions after 1960 (*i.e,* Agung, St. Helens, El Chichón, Nevado del Ruiz and Pinatubo) have been considered in a numerical study conducted with a climate- chemistry coupled model including an aerosol microphysics code for aerosol formation and growth. Model results are compared between an ensemble of numerical simulations including the aerosol radiative effects (VE) and a reference (REF) simulations ensemble where these radiative effects are not considered. Differences VE-REF show enhanced diabatic heating rates, increase of stratospheric temperatures and mean zonal westerly winds, increased planetary wave amplitude and tropical upwelling. The impact on stratospheric upwelling is found to be larger with aerosols more confined in the tropics, which results from the easterly shear of the quasi-biennial oscillation (QBO), *i.e.,* the Pinatubo case. The dispersal of tropical volcanic aerosol clouds towards mid-high latitudes is delayed in this case, decreasing the rate of stratosphere-to-troposphere aerosol transport and then increasing the global particle lifetime. Comparing the model calculated *e*-folding time of the volcanic aerosols during the first year after every eruption, an increase is found from 8.1 and 10.3 months for El Chichón and Agung (QBO westerly shear), to 14.6 and 30.7 months for Pinatubo and Ruiz, respectively (QBO easterly shear).

Global morphology of stratospheric aerosols from 2003 – 2011 retrieved from SCIAMACHY limb-scatter observations

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We present results on the global morphology and variability of stratospheric aerosol extinction and optical depth from 2003 to 2011 based on limb-scatter observations in the optical spectral range performed with the SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) instrument on the Envisat satellite. The stratospheric aerosol profile retrieval is based on a color-index approach and employs a constrained optimal estimation scheme in combination with the radiative transfer model SCIATRAN. We will present comparisons of extinction profile retrievals of the an updated version (V1.1) of the SCIAMACHY stratospheric aerosol data product with co-located SAGE II (version 7.0) measurements, showing agreement within about 10 % in a global average sense for altitudes above 15 km. The stratospheric aerosol optical depth exhibits variability caused by different driving processes, including seasonal variations, QBO effects above 25 km, and sudden enhancements due to volcanic eruptions, which are mainly constrained to altitudes below 25 km for the time period considered. The changing radiative forcing associated with the variable stratospheric aerosol optical depth will be assessed. In addition, we present indications for a 27-day signature in aerosol extinction at low latitudes, whose origin is not yet fully established. Different hypotheses connecting this signature to the solar 27-day cycle and dynamical processes will be discussed.

Background Sulfur Source Gas Sensitivities with GEOS-Chem

Debra Weisenstein

Harvard University

Harvard's GEOS-Chem is a well-validated 3-D model of atmospheric composition using analyzed wind fields from the Goddard Earth Observing System. While this model has traditionally been used for studies of tropospheric chemistry, a recent extension of chemistry to the stratosphere (Eastham et al., 2014) makes it a good choice for sensitivity studies of sulfur budgets under background conditions. This study is a contribution to the SSiRC Background (BG) experiment. Because GEOS- Chem contains only a bulk aerosol representation in the stratosphere, we focus on the relative contributions of source gases SO_2 and OCS and the role of convective transport in moving these gases from the boundary layer into the stratosphere. We present sensitivity calculation with OCS surface concentrations increased by 20%, with anthropogenic SO_2 emissions eliminated, and with convective fluxes scaled by 2.0 globally and scaled only over the Asian monsoon region.

Model calculations of the contribution of SO_2 to the stratospheric sulfur layer

I. Wohltmann[1], S. Kremser[2], R. Lehmann[1], M. Rex[1]
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The stratospheric sulfur layer is both important for stratospheric chemistry and climate change, and is also the aim for geo-engineering proposals which propose to inject sulfur into the stratosphere to cool the climate. Considering these circumstances, it is unsatisfactory that the processes governing the transport of sulfur to the stratosphere are poorly quantified.

We present model calculations of the chemistry of sulfur dioxide (SO_2) and its transport to the stratosphere and perform numerous sensitivity runs to assess the range of uncertainty of these calculations. The transport model is based on backward trajectories from the ATLAS model driven by either ECMWF ERA Interim or GEOS-Chem data. The chemistry model is a box model including the gas phase reactions SO_2 + OH, DMS + OH and the liquid phase reactions SO_2 + H_2O_2 and SO_2 + O_3, among others. Initial values of SO_2 and DMS and background fields of OH, H_2O_2 and O_3 are taken from existing runs of the GEOS-Chem model. Some features of cloud interaction like di↵erent mix- ing ratios inside and outside the clouds are implemented, but the injection of boundary layer SO_2 by convection is so far not implemented in this early version.

Sensitivity experiments explore the sensitivity to changes in OH, H_2O_2, DMS, cloud water, cloud pH value and in the driving analysis data.

Aerosol data obtained from SCIAMACHY solar occultation measurements

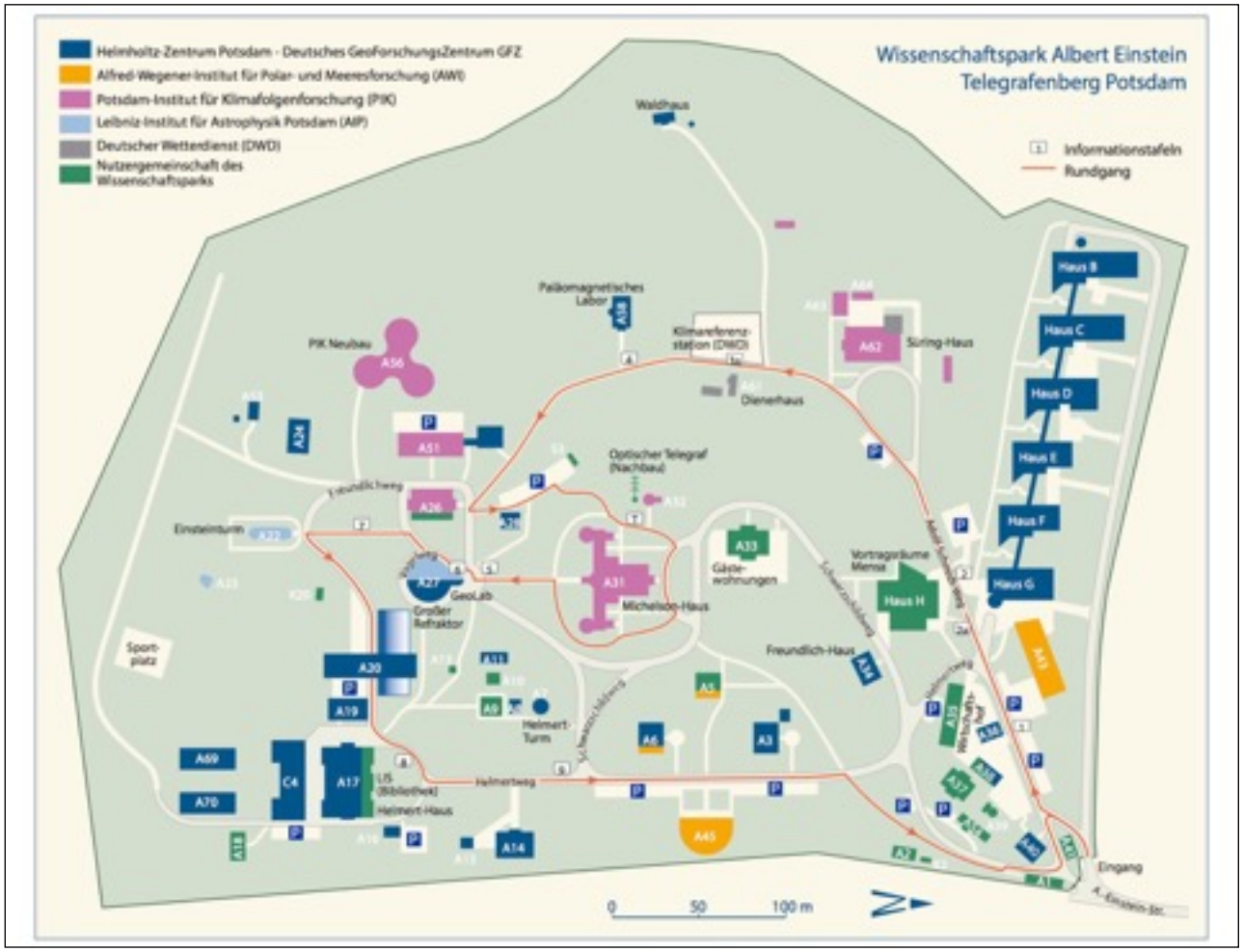
Jacob Zalach

affiliation

The ROMIC-ROSA joint project is focused on obtaining stratospheric aerosol extinction profiles and its size distribution analyzing SCIAMACHY (EnviSat) solar occultation measurements. Satellite born occultation measurements are an established method to obtain information on vertical profiles of atmospheric composition and stratospheric aerosol extinction.
The available dataset covers a time period between 2002 and 2012 with profiles within a spectral range between 240 and 2380 nm. Due to lower spatial resolution and sampling rate a direct application of existing analysis tools to SCIAMACHY solar occultation masurements is not possible.
This work gives an overview on necessary data processing, retrieval results for the entire SCIAMACHY mission and compares retrieved aerosol extinction profiles with SAGE II and SCIAMACHY Limb measurements.

Practical Information

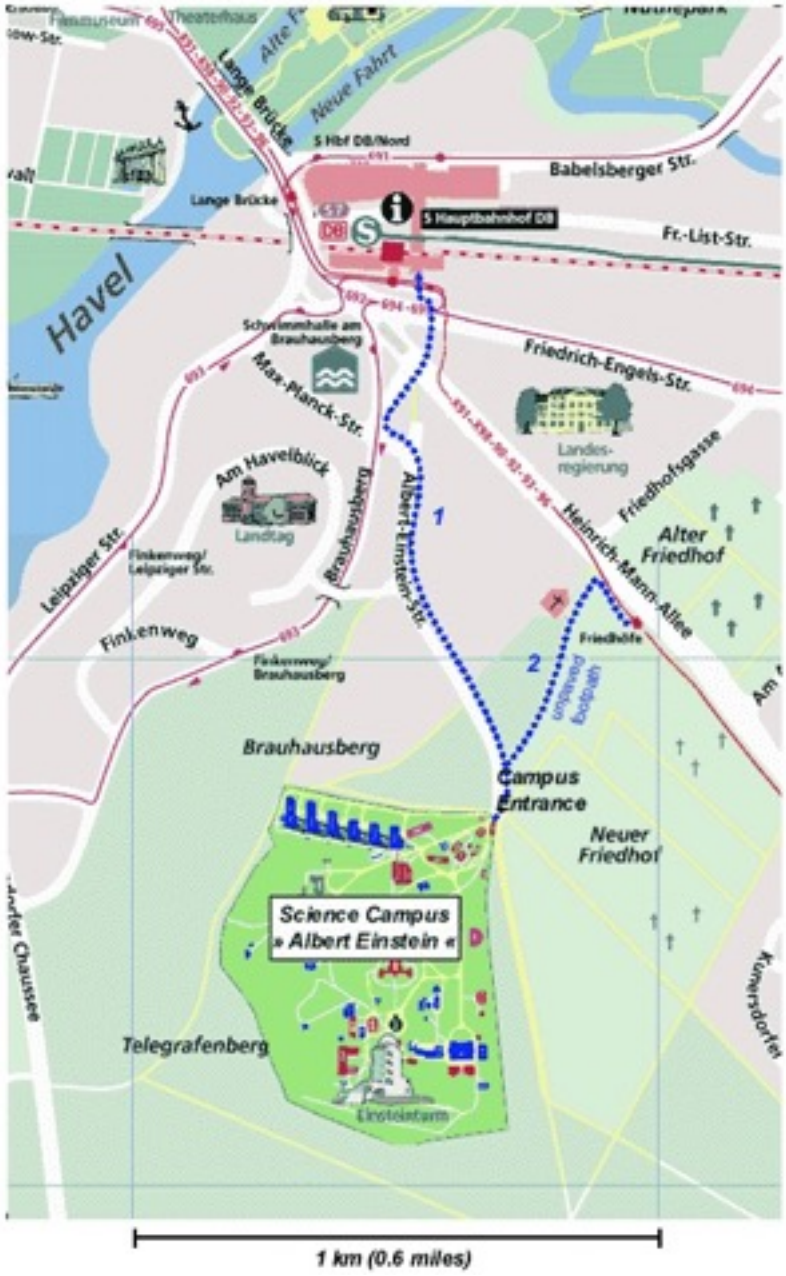
Venue



The workshop will be held in Haus H (green in the map) at Research Unit Potsdam of the Alfred Wegener Institute. AWI Potsdam is located at Telegrafenberg science campus, south of Potsdam city centre.

Alfred Wegener Institute
Helmholtz Centre for Polar and Marine Research
Research Unit Potsdam
Telegrafenberg A 43, 14473 Potsdam, Germany

From the railway station Potsdam Hauptbahnhof, it takes ca. 15 minutes to walk to the campus. Alternatively, a taxi takes less than 5 minutes and costs approximately 5 Euro. Local public transport in Potsdam (bus 691), services Telegrafenberg (last stop) only in the morning until 9:14 (every 1/2 h) and in the afternoon (15-18.30).



Traveling to Potsdam

From Tegel (TXL) airport take bus line X9 or 109 to station Zoologischer Garten in Berlin, follow the signs to the train station, then take a regional train RE1 to Potsdam main station (Potsdam Hauptbahnhof).

From Schönefeld (SFX) airport take the regional train RB 22 to Potsdam Hauptbahnhof. Alternatively, take the suburban train (S-Bahn) line S9 to direction Pankow. Change train at station Westkreuz to S7, direction Potsdam Hauptbahnhof.

From Berlin Hauptbahnhof train station take the suburban train (S-Bahn) line S9 or the regional train RE1 to Potsdam Hauptbahnhof.

Tickets for public transportation can be purchased in vending machines on the platforms or inside buses and trams (not inside trains). For the Potsdam - Berlin travel (any station, all public transport), you need a "Berlin ABC" ticket (3,30 Euro). Please note, that you have to validate your ticket in the validation apparatus on the platform before entering the trains.

By car, the simplest way to Potsdam is via the Berliner Ring (A10), exit 17 Potsdam-Süd/ Michendorf, subsequently following the road B2 to Potsdam. 600 metres past the Potsdam city limit sign, turn right into Brauhausberg street, also signposted for Landtag. After 1.2 km, turn right again into Albert-Einstein-street (signposted GeoForschungsZentrum), which will lead directly to the entrance of the campus.

Hotels

Below is a list of nearby hotels and guesthouses. Please, make your reservation directly with the hotel / guesthouse.
Hotel Mercure

Closest to the venue (about 20 minutes walking)
Hotel Mercure Potsdam
www: http://www.mercure-hotel-potsdam.de/default-en.html
phone: +49/331/2722
fax: +49/331/2720233
email: h1582-re@accor.com

A low cost B&B is about 2 km from the venue (tram to main station available):
Pension Mark Brandenburg
www: http://www.hotel-pension-potsdam.de

Downtown Potsdam (~2 km from the venue, support by tram directly to main station), there are several hotels surrounded by nice restaurants, historic buildings or next to the King Frederics II castle "Sans Soucis", e.g.:

Steigenberger Hotel
www: http://de.steigenberger.com/Potsdam/Steigenberger-Hotel-Sanssouci

NH Voltaire Potsdam
www: http://www.nh-hotels.de/hotel/nh-potsdam/

Hotel Brandenburger Tor
www: http://www.hotel-brandenburger-tor.de/en (NB: this is NOT Berlin's Brandenburger Tor!)

Altstadt Hotel Potsdam
www: http://altstadt-hotel-potsdam.de/

These hotels have a direct connection via tram to Potsdam main station ("Hauptbahnhof", 15 minutes walking from there to the venue, see "directions"). Ticket: You will need a "Potsdam AB" ticket to use the tram/busses within the town of Potsdam (single 1,90€, 7-days: 12,80€).