3rd International Workshop on Stratospheric Sulfur and its Role in Climate (SSiRC)

Book of Abstracts – Poster Presentations

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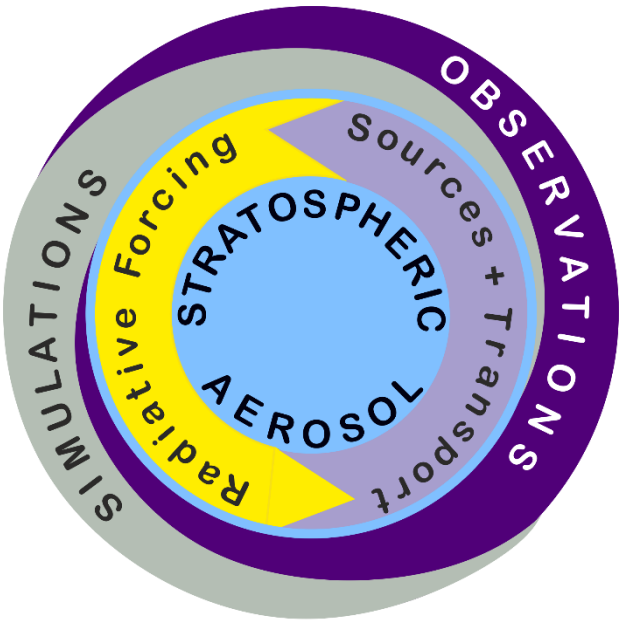

SSiRC bridges observations and models and connects scientists from different fields to gain quantitative understanding of stratospheric aerosol processes from emissions to radiative forcing.

Comprehensive analysis of observational data and UKESM1 simulations of the 2019 Raikoke eruption

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Abstract (100 - 500 Words)

In June 2019 the Raikoke volcano located in the Kuril Islands, northeast of Japan, erupted explosively and emitted approximately 1.5Tg ± 0.2 Tg of SO2 into the upper troposphere and lower stratosphere. Using a wide range of available observational data, we assess the skill and the limitations of the Met Office's UK Earth System Model (UKESM1) to simulate the distributions of SO2 and sulfate aerosol and we will discuss the synergy and coherence of our results. Recent studies have drawn attention to the presence of ash in volcanic eruption and the influence it can have on self-lofting and the evolution of the volcanic plume (e.g., Muser et al., 2020; Kloss et al., 2021). Previous studies (e.g., Haywood et al., 2010, Kloss et al., 2021) did not include ash emissions which can alter the dynamics of sulfate aerosol formation (Kloss et al., 2021). The differences between observations and the model simulations in these studies suggests that ash prolongs the lifetime of the stratospheric aerosol optical depth (sAOD) (Kloss et al., 2021).

This study highlights the necessity of including ash in the model emission scheme to provide a more accurate simulation of the evolution of the volcanic plume. We perform simulations using a nudged version of UKESM1 that includes a detailed 2-moment aerosol microphysical scheme (Dhomse et al., 2014) designed for modelling the oxidation of SO2 to sulfate aerosol and the detailed evolution of aerosol microphysics in the stratosphere. Sensitivity tests to determine injection altitudes were completed and included a range of SO_2 only and SO_2 + ash simulations. The results shown include an injection of 1.5 Tg SO_2 (and 1.1 Tg ash for SO_2 + ash) at 10km (20%) and between 13-15km (80%).

We confront the model with a wide set of observations including:

- SO2 data from the Ozone Mapping and Profiling Suite-Nadir Mapper (OMPS-NM).
- AOD derived from the Ozone Mapping and Profiling Suite-Limb Profiler (OMPS-LP).
- Vertical profiles of aerosol extinction from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP).
- AOD measurements from the high-altitude Mauna Loa AERONET site.

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Acknowledgements

This work was supported by the UKRI Centre for Doctoral Training in Environmental Intelligence, EP/S022074/1.

Investigating stratospheric carbonyl sulfide removal and transport using age-of-air parameters

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Abstract (100 - 500 Words)

Carbonyl sulfide (OCS) is the longest lived and the most abundant reduced sulfur gas in the atmosphere. It can reach the stratosphere where it undergoes photochemical conversion to sulfate aerosol. Chemistry transport models suggest that this conversion occurs in the 'tropical pipe' region while along the lower branch of the Brewer-Dobson circulation (BDC), OCS is passively transported without significant chemical loss. To verify this, the relation of OCS mixing ratios and mean age of air as well as mass fractions of air with different transit times have been investigated. For this, we used OCS satellite observations from MIPAS/Envisat (Michelson Interferometer for Passive Atmospheric Sounding) and ACE-FTS (Atmospheric Chemistry Experiment- infrared Fourier Transform Spectrometer) as well as high-resolution in-situ observations in the upper troposphere lower stratosphere (UTLS) region obtained during the SouthTRAC campaign from September to November 2019 by AMICA (Airborne Mid-Infrared Cavity enhanced Absorption spectrometer) on board the HALO research aircraft. Age of air spectra corresponding in space and time to the OCS observations were obtained using CLaMS (Chemical Lagrangian Model of the Stratosphere). A robust anti-correlation between OCS and the mass fraction of air older than 24 months (F_{24}) was found, with a quasi-linear relationship. The observed OCS distribution and its correlation with F_{24} support the picture that OCS is removed mainly in the 'tropical pipe' region and the OCS depleted air is transported through the deep branch of the BDC.

GOMOS stratospheric aerosol measurements and retrievals with the AerGOM algorithm

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Abstract (100 - 500 Words)

The GOMOS experiment was launched on-board the ENVISAT satellite and observed the Earth's atmosphere from 2002 to 2012 in the UV-visible-near IR range, based on the stellar occultation technique. From these measurements, atmospheric species such as ozone, NO2, NO3 and other atmospheric trace gases were monitored, as well as aerosols.

Despite the difficulties posed by the use of stellar occultation in GOMOS, which provide a large rate of measurements though with a limited signal-to-noise ratio, aerosol extinction was successfully retrieved from the AerGOM algorithm[1, 2]. While the ESA operational retrieval algorithm (IFS) was only partly successful in retrieving the aerosol in the upper troposphere and lower stratosphere (UTLS), AerGOM was specifically designed for this task and could successfully retrieve the aerosol extinction and its spectral dependence. In a next step, an algorithm was set up for the particle size distribution retrieval from the extinction spectral dependence using a sectional particle size distribution.

Although AerGOM was specifically developed to retrieve aerosols in the UTLS, this algorithm also retrieves ozone, NO2 and NO3 as secondary products (contrarily to IFS which retrieves them as primary products). The performance of AerGOM in the retrieval of trace gas species was investigated in the framework of the EXPANSION project (ESA Living Planet Fellowship), leading to alternative versions and strategies for the retrieval of the trace gases.

In this work, we will present the result of these new developments from the point of view of the aerosol retrieval. We will give an overview of the current status of the AerGOM activity and draw perspectives for the future.

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Acknowledgements

This work was support by ESA in the framework of the Aerosol_CCI project (Climate Change Initiative) and, the EXPANSION project (Living Planet Fellowship), and by Copernicus in the framework of the Copernicus Climate Change Services (C3S) project C3S_312b_Lot2.

Compiling a high vertical resolution volcanic SO2 data-set, and future modelling work

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We present means to set vertical coordinates on SO2 data from satellite sensors that lack vertical resolution. The climate impact of volcanic SO2 strongly depends on its injection height into the stratosphere. The work is motivated by the fact that volcanic layers are often thinner than what can be vertically resolved by SO2 instruments. Today's sensors provide vertical resolutions of 1-2 km at best, and have difficulty retrieving or resolving situations with multiple volcanic SO2 layers.

The space borne CALIOP lidar retrieves aerosol data with a vertical resolution of 60 m in the lower stratosphere. Sulfate particles formed from the SO2 have negligible settling velocity making them co-located with the SO2 layers. The strength of the CALIOP signals are therefore a measure of the relative amounts of SO2 at different altitudes, and can thus be used as a means of distributing the SO2 over the vertical column. However, CALIOP retrieves only thin slices of the atmosphere, whereas the vertical SO2 profile can vary by many kilometres within a single SO2 swath. We used the dispersion model FLEXPART to interconnect the vertical profiles from CALIOP with the horizontally distributed SO2 data [1]. FLEXPART simulations were run from the time of SO2 observations both forwards and backwards in time to interconnect CALIOP and the SO2 data. This enabled us to increase the amount of CALIOP slices used in the SO2 swaths by about an order of magnitude. We have, so far, produced vertically resolved SO2 data for the eruptions of Sarychev in June 2009 [1].

We are currently investigating the importance of using high vertically resolved data in a climate model (WACCM), and the importance of putting the SO2 data in the correct atmospheric layers. Our present dataset has a vertical resolution of 250 m, i.e. higher than today's climate models, but may be more similar to tomorrow's.

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Lidar observations of volcanic aerosol over the UK since July 2019

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Abstract (100 - 500 Words)

On 22nd June 2019 the Raikoke volcano in the Kuril islands erupted, sending a plume of ash and sulphur dioxide into the stratosphere. A Raman lidar system at Capel Dewi, UK (52.4°N, 4.1°W) [1] has been used to measure the extent and optical depth of the stratospheric aerosol layer following the eruption. The lidar was modified to give it much enhanced sensitivity in the elastic channel, allowing measurements up to 25 km, but the Raman channel is only sensitive to the troposphere. Therefore, backscatter ratio profiles were derived by comparison with aerosol-free profiles derived from nearby radiosondes, corrected for aerosol extinction. Lidar ratios of 40-50 were found to be optimum for this retrieval. Small amounts of stratospheric aerosol were measured prior to the arrival of the volcanic cloud, probably from pyroconvection over Canada. Volcanic ash began to arrive as a thin layer at 14 km late on 3 July, extending over the following month to fill the stratosphere below around 20 km. Aerosol optical depths reached around 0.05 by mid-August, declining slowly for the remainder of the Autumn. The location of peak backscatter varied considerably but was generally around 15 km. However, on one notable occasion on August 25, a layer around 300 m thick with peak lidar backscatter ratio around 1.5 was observed as high as 21 km.

Reference

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High-latitude explosive volcanic eruptions and their sensitivity to source parameters

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Abstract (100 - 500 Words)

The climatic impact of a volcanic eruption depends on its source parameters. Eruption latitude is considered a key parameter alongside the mass of injected sulphur dioxide and the altitude of the injection, since these control to what degree the volcanic aerosols spread globally.

When considering high-latitude eruptions, the eruption season and the atmospheric initial condition are also decisive for the atmospheric impacts, because the high-latitude stratosphere is characterised by strong seasonal and interannual variations in chemistry and dynamics. Furthermore, high-latitude volcanic hotspots such as Iceland have magmas that are rich in halogens, which, if injected into the stratosphere can further perturb the atmospheric chemistry. On this basis, we explore the question of how volcanic aerosols and the atmospheric composition evolve after a high-latitude stratospheric injection of sulphur and halogens, such as could result from a large explosive Icelandic eruption, and how this relates to the source parameters. We use the high-top, coupled Earth system model CESM2-WACCM6 with prognostic aerosols and comprehensive chemistry to simulate Icelandic eruptions of Pinatubo-magnitude, co-injecting sulphur, chlorine, and bromine into the lower stratosphere. We simulate an ensemble sampled from six different polar vortex initial conditions and test the sensitivity to co-injection of halogens, injection season, and injection altitude. Here, we present key results relating to the evolution of volcanic aerosols and atmospheric chemistry following the eruptions. We show how the oxidation time of volcanic sulphur dioxide into sulphate aerosols is modulated by availability of the hydroxyl radical, which in turn depends on the season, co-injection of halogens, and injection altitude, and how combinations of these parameters can amplify or reduce this effect. Both the season and the co-injection of halogens change the lifetime and transport of the sulphate aerosols. This regulates how large the aerosols grow and determines the global mean stratospheric aerosol optical depth. The volcanic halogens, with lifetimes of several years in the stratosphere, cause long-lasting changes to the atmospheric chemistry, most notably by depleting stratospheric ozone to ozone hole conditions over the Northern Hemisphere for up to two years after injection. Stratospheric cooling due to ozone loss overwhelms the longwave heating of sulphate, which both reduces the lifetime of the volcanic sulphate and leads to a global dehydration of the stratosphere. Our results show that the atmospheric impacts of high-latitude explosive eruptions are highly variable depending on basic source parameters and the initial conditions.

Acknowledgements

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Abstract Title: Using the Infrared Atmospheric Sounding Interferometer (IASI) to study emissions from the Hunga Tonga-Hunga Ha'apai eruption

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Abstract (100 - 500 Words)

The January 2021 eruption of Hunga Tonga-Hunga Ha'apai in Tonga produced volcanic plumes at several heights. The plumes were unusual in many ways including the height, with part of the plume reaching the mesosphere: something which has not previously been seen in satellite data. The eruption was widely observed with satellite instruments. This study is looking at the plumes with the Infrared Atmospheric Sounding Interferometer (IASI). This is a hyperspectral instrument sensor with a wide spectral range on-board the Metop platforms. Within the spectral range there is sensitivity to multiple trace gases and aerosols making it a valuable instrument for studying volcanic emissions. Multiple methods have been used in this study to track and quantify information about the plume. Firstly, a linear retrieval [1] has been used to identify the location of SO_2. An iterative retrieval [2] was then used to try and retrieve the SO_2 column amount and height from the IASI spectra with the extreme nature of the plume creating some challenges. Finally, a general optimal estimation retrieval is being used to examine the vertical profile of the SO_2.

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Acknowledgements

We acknowledge EUMETSAT for providing the IASI data.

Tropical Climate Variability in Indian Ocean with special reference to Bay of Bengal , India: Implications Climate Change

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The Indian Ocean (IO) has been discovered to have a much larger impact on climate variability than previously thought. Over the past decades, IO sea surface temperatures and heat content have been increasing, and model studies suggest significant roles of decadal trends in both the Walker circulation and the Southern Annular Mode. Prediction of IO climate variability is still at the experimental stage, with varied success. Indian Ocean (IO), a unique ocean in several aspects, is sparsely sampled compared to other oceans. This ocean has attracted more attention due to its global impacts through Monsoon and Indian Ocean Dipole (IOD) and several regional features that are important for the surrounding climate . With in the IO, the subsurface information is very sparse compared to the surface and the first ever known expedition in the IO. However, availability of subsurface temperature at regular intervals started only after launching of TOGA program. Under the auspice of TOGA/WOCE and several other regional programs, temperature in the upper ocean has been available on a regular basis. From the above scientific achievements it is very clear that a good deal of basic understanding of the IO mechanisms, which is the primary basis for future network, is achieved from available data analysis together with the analysis of either numerical model simulations or historical data. Variability in the sea surface temperature and salinity are the certain parameters to be understood from the Bay of Bengal in order to understand Monsoon and other sea induced processes. This paper attempts to understand the climate phenomena and processes in which the south IO is, or appears to be, actively involved. It is followed by reviews of ocean/atmosphere phenomenon at intraseasonal, interannual, and longer time scales. Essential requirements for better predictions are improved models and enhanced observations.

The Aerosol Limb Imager: a HAWC instrument for stratospheric aerosol and cloud profiling

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Abstract (100 - 500 Words)

The High-altitude Aerosol Water and Cloud (HAWC) mission has been proposed as a potential Canadian contribution to NASA's Atmosphere Observing System (AOS). The Aerosol Limb Imager (ALI) on HAWC provides two-dimensional hyper spectral images of the Earth's limb from 600 to 1500nm as well as polarization information. This work examines the level 2 products the ALI instrument will provide. In particular, aerosol retrievals in the presence of cirrus clouds and the ability to discriminate aerosol types is explored, as is the additional particle size information provided by polarization measurements. Simulations are performed with realistic input scenes, including two- and three-dimensional atmospheres developed from current measurements and high-resolution models. An instrument simulator package is used with realistic optics, sensor, and electronic properties to accurately estimate noise and resolution characteristics.

A comparison of stratospheric smoke events seen by SAGE II (1984-2005) and SAGE III (2017-2021)

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Abstract

The Stratospheric Aerosol and Gas Experiment (SAGE II) operated for over 20 years (1984-2005) and collected near global observations of aerosol extinction coefficient from the upper troposphere to about 40 km. SAGE III has flown aboard the International Space Station (ISS) since 2017 and has collected comparable aerosol measurements during this period. The SAGE II record is dominated by recovery from El Chichón (1982) and the Pinatubo eruption of 1991 with a few smaller volcanic events that are detectable in the data set. In addition, a number of pyrocumulus events injected smoke into the lower stratosphere with magnitudes that are comparable to the smaller volcanic events. The shorter SAGE III/ISS record is qualitatively different than SAGE II's with a number of small to moderate volcanic eruptions in both low and high latitudes (e.g., Ambae in 2018 and Raikoke in 2020) as well several smoke events including the two largest events seen by SAGE-like instruments: the BC pyrocumulus event in 2017 and the Australian brush fires of 2020/2021. In this paper, I will review the detection and quantification of the magnitude of these smoke events with a particular focus on the differences between the two data periods.

Examining the climate impacts of future volcanic eruptions

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Abstract

Large explosive volcanic eruptions can induce global climate impacts on decadal to multi-decadal timescales. In current climate models, future volcanic eruptions are represented in terms of a time-averaged volcanic forcing that ignores the sporadic nature of volcanic eruptions. This conventional representation does not account for how climate change might affect the dynamics of volcanic plumes and the stratospheric sulfate aerosol lifecycle and, ultimately, volcanic radiative forcing. To account for these climate-volcano feedbacks in climate projections, we perform model simulations from 2015 to 2100 with two key innovations: (1) a stochastic resampling approach to generate realistic future eruption scenarios based on historical volcanic eruptions recorded by ice cores and satellites in the past 11,500 years; and (2) a new modelling framework, UKESM-VPLUME, which couples a 1-D eruptive plume model (Plumeria) with an Earth System Model (UKESM) to consider the impacts of changing atmospheric conditions on eruptive plume heights. Our results show that considering sporadic small-magnitude volcanic eruptions in a future warming scenario can lead to a noticeable difference in global surface temperatures as well as on the time at which temperatures exceed 1.5°C above pre-industrial levels. Our study highlights the importance of considering sporadic eruptions and the changes in eruptive plume heights in a future warmer climate. The UKESM-VPLUME model framework enables us to quantify the impacts of climate change on volcanic radiative forcing in an Earth System model, which in future research allows us to better evaluate the climate impacts of volcanic eruptions under global warming.

Impact of Pinatubo-like Eruptions on Stratospheric Ozone With Varying Halogen Loadings

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The eruption of Mt Pinatubo in June 1991 caused a large increase of stratospheric sulphate aerosol, which led to increased ozone depletion. This depletion was caused by enhanced chlorine heterogeneous chemistry on the aerosol particles. The impact of such a Pinatubo-like eruption will be expected to change as the chlorine loading of the stratosphere changes in response to the Montreal Protocol.

We have performed simulations with a detailed 3-D chemical transport model (CTM) to study the impact of a Pinatubo eruption occurring in different decades. The model was run from 1950 to 2100 with repeating meteorology. A 10-year cycle of Pinatubo-like eruptions was imposed. We discuss the impact on ozone as the chlorine loading changes from near-natural levels, through its a peak around the 1990s, followed by a decay throughout this century.

There is also debate about whether volcanos can co-emit halogens (chlorine and bromine) which reach the stratosphere to enhance ozone depletion. We have repeated selected eruption years with the addition of halogen emissions as a sensitivity test of such perturbations to the ozone layer.

Short overview of the stratospheric aerosol variability over the Reunion Island site: Evidence of volcanic eruptions and biomass burning impacts

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Abstract (100 - 500 Words)

Aerosol layers observed in the stratosphere following biomass burning events or volcanic eruptions are likely to impact significantly the atmospheric radiation budget. The optical characteristics and the composition of aerosol plumes derived from observations are crucial inputs to Climate-Chemistry models and radiative effect calculations. There is particularly a lack of information on these parameters in the Southern Hemisphere due to the low number of ground-based observation stations in comparison with the Northern Hemisphere. Being located in the subtropical southern Indian Ocean at around 800 km east of Madagascar, Reunion Island (21,0°S, 55.5°E) is ideally located to study the effect of long-range transport of plumes in the stratosphere over the south-western Indian Ocean. The Maïdo Observatory is one of the three sites of the Atmospheric Physics Observatory of La Réunion (OPAR). This French instrumented site provides data for international monitoring networks (e.g. NDACC, GAW, AERONET, ICOS), scientific research and satellite validation.

The Maïdo facility has been hosting since 2013 three lidar systems capable of aerosol observations at two wavelengths (355 and 532 nm). In addition, Light Optical Aerosol Counter (LOAC) flights have been also performed since 2014. These remote-sensing and in-situ instruments, alone or in synergy, have allowed us to derive the content and the optical and microphysical properties of the aerosols in the tropical lower stratosphere following volcanic eruptions and extreme biomass burning events over the past decade. We will illustrate the interest of these observations in this remote part of the world with three case studies: the 2015 Calbuco volcanic plume, the 2020 Australian wildfire smoke and the 2022 Hunga Tunga volcanic plume.

The impact of the 1991 eruption of Cerro Hudson on Antarctic ozone as simulated in the NASA GEOS Earth system model

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Abstract (100 - 500 Words)

The August 15, 1991, eruption of the Chilean stratovolcano Cerro Hudson (46°S) was largely overshadowed by the larger eruption of Mount Pinatubo which occurred two months earlier. Using a coupled sectional aerosol microphysics model, we simulate the lifetime of this plume and its impact on Antarctic ozone over the subsequent months. We compare our simulations with observations of the SO_2 plume from the Total Ozone Mapping Spectrometer (TOMS); balloon-borne in situ optical particle counter observations of the Cerro Hudson aerosol above McMurdo Bay, Antarctica; and ozonesonde observations from the 1991 Austral Spring at the South Pole. These ozonesonde observations indicate anomalous October ozone depletion, between 12-15 km, below the primary ozone hole. This altitude coincides with the observed location of the Cerro Hudson aerosol as they were observed in September above McMurdo Bay. Our model connects these observations in time and space and provide some evidence that the anomalous, low altitude ozone depletion was caused by the Cerro Hudson volcanic aerosol plume. We perform these simulations using a version of the Goddard Earth Observing System (GEOS) Earth System Model with the Community Aerosol and Radiation Model for Atmospheres (CARMA) coupled to the GEOS-Chem tropospheric and stratospheric chemistry mechanism.

Acknowledgements

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What can we know for sure about the climate response to stratospheric aerosol geoengineering? A meta-analysis of CMIP5- and CMIP6-era runs"

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Abstract (100 - 500 Words)

Stratospheric Aerosol Injection (SAI) is a proposed climate intervention that would artificially thicken the stratospheric aerosol layer, scattering light, lowering global temperatures and, it is hoped, reducing the risks of climate change (Irvine et al., 2016). Much is uncertain about the climate response to proposed deployments of SAI: the distribution and properties of the aerosol layer following a given deployment, the impacts on the ozone layer, and the regional hydrological consequences. However, we can be certain that SAI would lower global temperatures and given that temperature change drives many aspects of climate change, we can be certain of some aspects of its climate effects.

By comparing 2 generations of simulations from the Geoengineering Model Intercomparison Project I will identify aspects of the climate response to SAI that are robust to uncertainties in the spatial pattern and character of the aerosol layer produced and to uncertainties in the climate response to this forcing (Kravitz et al., 2011, 2015). The GeoMIP G3, G4 (Coupled Model Intercomparison Project 5, CMIP5-era) and G6sulfur (CMIP6-era) are not directly comparable as they have different baseline emissions scenarios and different magnitudes of SAI deployment. To address this, I will normalize the climate response in these experiments by their respective global-temperature response. By comparing these normalized SAI responses for G3, G4 and G6sulfur against their respective normalized global warming responses I will identify which aspects of the climate response to SAI are robust across model generations and experiment.

Science typically and rightly focuses most of its attention on uncertainties, but when it comes to informing policy, it is important to not just dwell on these uncertainties but to also communicate clearly what we know. While many details of the climate response to SAI remain uncertain, in this presentation I will outline some of those aspects of the climate response that we can be sure of.

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Rapid formation of sulphate aerosols following the January 2022 eruption of Hunga Tonga-Hunga Ha'apai

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Abstract (100 - 500 Words)

On 15 January 2022, Hunga Tonga-Hunga Ha'apai volcano sent shockwaves around the globe originating from what may have been the largest explosive volcanic eruption since that of Mt Pinatubo (Philippines) in 1991. The event has sparked scientific interest across a range of disciplines from climate scientists and atmospheric dynamicists to volcanologists and seismologists. The volcano is a remote, undersea caldera, located ~70 km NNW of the main island of Tongatapu (Tonga) in the South Pacific. Satellite observations were critical to assess the size and composition of the volcanic clouds that Hunga Tonga-Hunga Ha'apai produced. Here we present a new technique, applied to the Advanced Himawari Imager (AHI), to quantitatively retrieve stratospheric sulphate aerosol particle size and optical depth based on broadband imager measurements. We provide an estimate of the total mass of sulphate produced by the 15 January eruption and use 10-minute, geostationary data to estimate the rate of sulphate formation during the first 24 hours of atmospheric residence. We speculate that the rapid formation of sulphate aerosols was due to significant amounts of water vapour present in the plume, which may partly explain why polar orbiting satellites measured relatively low SO_2 amounts given the strength of the eruption

Volcanic eruptions and operational seasonal forecast systems

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Abstract

Seasonal forecast systems are run operationally at centres around the world. The forecast systems integrate the effects of the ocean, land surface, sea-ice and tropospheric and stratospheric initial conditions in ensemble forecasts to predict the range of seasonal climate anomalies to be expected in the months ahead. The latest generation of systems run at relatively high resolution (e.g. 0.25 deg ocean, 36 km atmosphere), and real-time forecasts are issued one or more times per month, with many users accessing and processing the resulting forecast data, for example through the COPERNICUS C3S. However, a major weakness of the forecasting systems is their limited or non-existent ability to represent the impacts of volcanic sulphate aerosol on forecasts initiated after a major volcanic eruption.

When a major eruption next occurs, the VolRes community will provide both estimates of the SO2 and aerosol produced and modelling studies of the expected climate impact. However, the modelling studies in many cases will be missing most of the important drivers of seasonal climate variability for timescales of a few months, namely the detailed ocean and land initial conditions. The outputs would also typically not be integrated into the downstream climate services sector that makes use of operational seasonal forecast outputs.

The best guidance on the expected impacts in the months following a volcanic eruption is likely to come from the volcanic and operational seasonal forecasting communities working together. At present the ECMWF system has a very crude representation of volcanic aerosol which captures some of the cooling effect of a major eruption but is not adequate to represent the dynamic impacts on winter circulation driven by stratospheric heating. As part of the CONFESS project [1] a better empirical scheme based on EVA_H [2] is being developed for predicting volcanic aerosol evolution. This will provide a low-cost solution which can be integrated into an operational context.

Simulations of past eruptions to assess the impact of such a specification on operational seasonal forecast models will be made and benchmarked against VolMIP results. A further requirement is an operationally robust method of specifying the parameters of volcanic injections. A combination of past datasets such as the extension of Carn et al. (2016) [3], processing of real-time satellite data by the Copernicus Atmosphere Monitoring Service (CAMS), and help from the VolRes community is likely to be needed.

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Prolonged impact of volcanic eruption on stratospheric water vapour

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Abstract (100 - 500 Words)

Large tropical volcanic eruptions are reported to cause an increase in stratospheric water vapour (SWV) through warming of the tropopause by aerosol-induced heating. However, there is far from universal agreement on the quantitative magnitude of the effect and its mechanism due to scarce observations and large internal variability after eruptions. Using the 27 volcanic forcing experiments carried out with the UK Earth System Model in alignment with the volc-pinatubo-full protocol, this study examines the impact of stratospheric aerosol on the SWV entry. Significant increases in SWV are found three months after the volcanic eruption in June 1991 for the mean over all ensemble members. However, this increase does not decay in the following year but instead dramatically increases, with a prolonged effect throughout the following two years. This increase in SWV peaks in the second post-eruption winter (1992/93), reaching 1 ppmv and then decaying in accordance with the one-month-lead peak increase in the absolute tropical cold point temperature at ~2.3 K in November 1992. The prolonged increase in cold-point temperature, leading to the longer duration of the SWV increase, is not in line with the decaying aerosol optical depth throughout the post-eruption years. This underlines that as well as the heating effect from volcanic aerosols, an additional amplification of the warming due to anomalous descent in the tropics associated with the decelerated Brewer-Dobson circulation is critical in favoring the long duration of the post-eruption increase in SWV.

1963-64 searchlight measurements of the Agung aerosol cloud from New Mexico and comparisons to UM-UKCA HErSEA-Agung and CMIP6 volcanic aerosol datasets

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Abstract (100 - 500 Words)

The March 1963 Agung volcanic eruption projected material into the tropical stratosphere (Self and Rampino, 2012), and the resulting aerosol clouds led to detectable and sustained surface cooling in the historical climate record (Hansen et al., 1978). The surface temperature decreased by about 0.7K because the aerosol increased the albedo for solar radiation (Newell, 1981).

As part of a Data Rescue Activity of the Stratospheric Sulfur and its Role in Climate (SSiRC) (http://www.sparc-ssirc.org/ Activities → Data Rescue), lidar observations from the 1st ever multi-year profile dataset of the stratospheric aerosol layer, were recovered a programme of lidar measurements from Lexington from January 1964 to July 1965 (Antuña-Marrero et al., 2021).

In this presentation, we present results from re-digitizing an even earlier vertical profile measurement dataset of the stratospheric layer, from searchlight soundings from White Sands, New Mexico in 1963 and 1964. This research re-digitized Figures from a US Air Force Cambridge Research Laboratories (AFCRL) 'Atlas of Aerosol Attenuation' report (Elterman, 1966), to recover the 105 searchlight profiles measured from Sacramento Peak observatory between December 1963 and December 1964.

This research assessed the stratospheric aerosol layer variations at this mid-latitude location, and clearly shows the dispersion of the Agung aerosol to the Northern Hemisphere. A comparison of the New Mexico searchlight and the Lexington lidar dataset with model simulations indicates that the CMIP6 volcanic forcing dataset shows 25-40% lower stratospheric aerosol optical depth than these measurements suggest was present in the Northern Hemisphere stratosphere in 1965. The comparison indicates more of the Agung aerosol was dispersed to the Northern Hemisphere than represented in CMIP6 climate models.

This dataset is also compared with an existing set of interactive stratospheric aerosol model simulations of the Agung (Dhomse et al., 2020) and the historical volcanic forcing dataset used by all CMIP6 climate models, assessing the altitude and vertical profile of the aerosol dispersed to Northern Hemisphere mid-latitudes

Whereas most of the Agung aerosol was transported to the Southern Hemisphere, these comparisons suggest that more of the aerosol cloud was transported to the Northern Hemisphere than represented by the CMIP6 volcanic aerosol dataset (Luo, 2016), and agrees best with the 6Tg UM-UKCA Agung simulation from Dhomse et al. (2020).

For the altitude of the Agung aerosol at the NH mid-latitudes, the UM-UKCA simulations are in reasonable agreement with the searchlight observation of 18-20.5 km, while the model simulations are 16–18 km. The Agung aerosol within the CMIP6 dataset descends from a much higher altitude in 1963 and was found to be about 2-3 km higher than the observations in December 1963, but in good agreement during 1964.

(433 words)

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