Horizon 2020 Societal challenge
5: Climate action, environment,
resource efficiency and raw materials

CONSTRAIN
Constraining uncertainty of multi-decadal climate projections
GA number 820829
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Deliverable number (relative in WP)	**D1.2**
Deliverable name:	Short report from workshop on aerosol-cloud interactions
WP / WP number:	**1**
Delivery due date:	(30/06/2022)
Actual date of submission:	07/06/2022
Dissemination level:	Public
Lead beneficiary:	WP1
Responsible scientist/administrator:	
Contributor(s):	Jim Haywood (Met Office Hadley Centre) George Jordan (Met Office Hadley Centre)
Internal reviewer:	Cath Senior, Jim Haywood

1.Changes with respect to the DoA

No changes.

2.Dissemination and uptake

Those interested in aerosol-cloud interactions. The fidelity of aerosol models against the observations is yet to be universally assessed but could have implications for constraining climate sensitivity.

3.Short Summary of results (< 250 words)

The Volcanic Aerosol-Cloud Interactions workshop, held at the Met Office in Exeter on the 25th - 26th April 2022, brought together scientists from both CONSTRAIN and the wider community to discuss modelled and observed aerosol-cloud interactions (ACI) perturbed by volcanic eruptions. The workshop hosted 19 participants from 9 organisations and consisted of 9 presentations varying in length from 15 to 45 minutes. These talks focused on improving our understanding of small- and large-scale ACI using both inter-model comparison and machine learning approaches.

The main aims of the workshop were:

(a) Assess current progress on utilising observations of volcanic eruptions to quantify aerosol-cloud interactions and model errors
(b) Gather updates on the progress of current and future publications
(c) Identify common elements between works which can be utilised to further them
(d) Identify opportunities for future collaboration

When complete, these results will be used to inform the CONSTRAIN community of the ability of models to replicate ACI interactions and to investigate whether this approach can be used to refine estimates of climate sensitivity.

4.Evidence of accomplishment

Attached report.

Volcanic Aerosol-Cloud Interactions Workshop Report

Summary Report

Monday 25th – Tuesday 26th April 2022

Met Office, FitzRoy Road, Exeter, Devon, EX13PB, UK

Prepared By:

George Jordan and Jim Haywood

Executive Summary

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Schedule

Monday 25th April 2022

13:30 Welcome

Jim Haywood

13:45 Aerosol-Cloud Interactions: Multi-Model Comparison Approach (Part 1)

George Jordan

14:30 Lagrangian Evaluation of UKESM1 Simulation of 2014 Eruption at Holuhraun

Ellie Duncan

14:50 Coffee Break

15:10 Robust Constraints from Machine-Learning on Aerosol-Cloud-Climate Interactions

Ying Chen

15:55 Aerosol-Cloud Interactions: Multi-Model Comparison Approach (Part 2)

George Jordan

16:25 Aerosol General Circulation Model Trajectory Experiment (GCMTraj)

Paul Kim

16:45 Constraining Marine Boundary Layer Cloud Properties in Climate Models (CLOSURE)

Daniel Partridge

Tuesday 26th April 2022

09:30 Welcome

Jim Haywood

09:35 Impact of Volcanic Aerosol on Clouds in Cloud-System Resolving Simulations

Mahnoosh Haghighatnasab

10:20 High Resolution Simulations of Hawaiian Volcanic Emissions Interactions with Clouds

Daniel Grosvenor

11:05 Coffee Break

11:25 Ship-Track and Volcano Track Detections Using Machine Learning with MODIS data

Duncan Watson-Parris

11:55 Workshop Conclusion and Discussion of Future Works and Opportunities

Jim Haywood

Summary

Monday 25th April 2022

The first day of the workshop focused on large-scale aerosol-cloud interactions (ACI) caused by volcanic eruptions. George Jordan presented preliminary results from his evaluation of the ACI within general circulation models (GCMs) with observations using the Holuhraun 2014-2015 eruption. This inter-model comparison brings together 10 model participants, remote sensing observations from the MODIS and IASI products, and ground-based observation from EMEP and AERONET monitoring stations. The preliminary results focused on 5 models. All models, aside from ECHAM-HAM-P3, displayed a decrease in the liquid droplet effective radius due to the eruption in agreement with observations. There was a mixed model response in the liquid water path as 3 models (UKESM1, HadGEM3, CNRM-CM6-1) showed no clear volcanic impact on the liquid water path as is observed. 2 models (ECHAM-HAM-P3, ECHAM-HAM2.3) project an increase in the liquid water path following the eruption suggesting their behaviour deviates away from that of the observations. With regards to the ground-based observations, George Jordan concluded that, on the days when the monitoring stations experience the plume, the models underestimate and overestimate the surface mass concentration of SO_2 and sulphate respectively.

Additional Holuhraun studies were discussed by Paul Kim and Ellie Duncan, both focused on using a Lagrangian framework to probe the differences in GCM presentation of aerosol lifecycle during transport in the volcanic plume. Paul Kim showed observed and modelled particle size number distributions at the Hyytiälä monitoring station in Finland. Ellie Duncan compared the observed average aerosol size distributions at the Pallas monitoring station in Finland with modelled values and showed that, although the overall shapes of the model distributions were consistent with that observed, the model diameters were larger. This appears to be because of condensation and coagulation at the high concentrations experienced within the plume. However, it was noted that both the UKESM1 and ECHAM models appeared unable to replicate these results, instead projecting a universal increase in the number of particles (rather like single mode bulk aerosol schemes).

Next followed a more complete Holuhraun study, presented by Ying Chen, centred on constraining ACI using machine-learning. A dataset using 19 years of MODIS and ERA5 reanalysis data was used to train a model to predict what MODIS would have observed if the eruption had not occurred. By comparing this output with what MODIS did observe during the eruption, Ying Chen concluded that volcanic aerosol brightens clouds by reducing droplet size and has no discernible effect on liquid water path. In addition, Ying Chen found a ~10% increase in cloud cover which appears to be the leading cause of climate forcing rather than the reduction in droplet size reported previously. This has interesting implications as it is possible that the increase in LWP from the ECHAM models compensates for the observed increase in cloud fraction potentially leading to changes in the Earth's energy budget that might be in reasonable agreement with observations, but for the wrong reasons.

The first day of the workshop concluded with Daniel Partridge introducing the CLOSURE project (Constraining Marine Boundary Layer Cloud Properties in Climate Models). This project looks to embed a detailed cloud parcel model within a GCM to probe ACI in a new novel way. This GCM will be compared with observations from the NASA Earth Venture Suborbital mission named ACTIVATE (Aerosol Cloud Meteorology Interactions Over the Western Atlantic Experiment) in the hope to improve our current understanding and parametrisations of ACI.

Summary

Tuesday 26th April 2022

The second day of the workshop concentrated on small-scale aerosol cloud interaction. Mahnoosh Haghighatnasab presented an ICON-NWP regional simulation of the Holuhraun eruption which focused on the short-term cloud adjustments caused. The ICON-NWP set-up used included a double moment cloud liquid and ice microphysical scheme where the cloud droplet number concentration was coupled to the radiation scheme. By comparison to MODIS observations, Mahnoosh Haghighatnasab found an enhancement of the cloud droplet number concentration due to the volcanic aerosol, yet no changes to either the liquid water path or cloud fraction.

Similarly, Daniel Grosvenor then presented results from a finer scale model. A 4km resolution simulation of the Hawaiian Kilauea eruption showed that due to the volcanic perturbation there were increase in cloud droplet number concentration and the liquid water path. Interestingly, Daniel Grosvenor concluded that there was a decrease in cloud fraction for Kilauea whereas previously Ying Chen has shown an increase in cloud fraction for Holuhraun.

The final talk of the workshop was given by Duncan Watson-Parris which centred on a machine learning algorithm to automate the detection of ship tracks from MODIS imagery. Over one million tracks are catalogued by this machine learning approach and were used to investigate the effect of fuel regulations introduced by the International Maritime Organization on the impacts of aerosol emissions on warm ocean cloud. Although not entirely following the volcano narrative of the workshop, the work generated discussion into how to build on the results to gain insight into the regional effects marine cloud brightening could cause. Aspects such as diagnosing the radiative forcing over the susceptible regions for cloud seeding were discussed.

Status of Scientific Papers

Title	Main Author	Status
Machine-Learning of Aerosol-Cloud-Climate Interactions: Strong Increase in Cloud Fraction	Ying Chen	Accepted (Nature Geoscience)
Impact of Holuhraun Volcano Aerosols on Clouds in Cloud-System Resolving Simulations	Mahnoosh Haghighatnasab	In Review (Atmospheric Chemistry and Physics)
Aerosol-Cloud Interactions: Multi-Model Comparison Approach (Paper 1) *	George Jordan	Writing
Aerosol-Cloud Interactions: Multi-Model Comparison Approach (Paper 2) *	George Jordan	Gathering Results
Shipping Regulations Lead to Large Reduction in Cloud Perturbation	Duncan Watson-Parris	Draft
Invisible Ship Tracks Show Large Cloud Sensitivity to Aerosol	Peter Manshausen	Draft
High Resolution Simulations of the December 2020 Kīlauea Volcanic Eruption	Daniel Grosvenor	Writing

Participants

Organisers:

- Jim Haywood[1,2]
- George Jordan[1]

Speakers:

- George Jordan[1]
- Ellie Duncan[2]
- Ying Chen[3]
- Paul Kim[2]
- Daniel Partridge[2]
- Mahnoosh Haghighatnasab[4]
- Daniel Grosvenor[5]
- Duncan Watson-Parris[6]

Attendees:

- Jim Haywood[1,2]
- Andy Jones[1]
- Florent Malavelle[7]
- Jane Mulcahy[1]
- Philip Stier[6,†]
- Ben Johnson[1,†]
- Pierre Nabat[8,†]
- Cath Senior[1,†]
- Alejandro Bodas-Salcedo[1,†]
- Gunnar Myhre[9]
- Paul Field[1]

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