Impacts of small-moderate magnitude eruptions on historical climate change

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Key words:	
Research theme(s):	• Geodesy, Tectonics, Volcanology and related hazards • Oceanography, Climate and Palaeoenvironment
Eligible courses for this project:	• DPhil in Earth Sciences (3-4 years) • Interdisciplinary Life and Environmental Science Landscape Award (ILESLA) • Intelligent Earth (UKRI CDT)

Overview

Historical (1850-present) climate simulations are crucial to evaluate climate models on which future climate projections rely, as well as to disentangle the contributions of anthropogenic and natural forcings to past climate change. One of the most important natural forcings is stratospheric aerosols injected by explosive volcanic eruptions which cool climate globally. Whereas large magnitude eruptions are well reconstructed, smaller but more frequent eruptions are very poorly constrained before 1979, the beginning of the satellite era. Yet, these small-magnitude eruptions contribute half of the total aerosol emissions, suggesting a crucial bias in the last generation of climate model simulations.

In this project, the student will leverage a novel inventory of small-magnitude eruptions produced by our group for Phase 7 of the Coupled Model Intercomparison Project (CMIP7), the climate modelling backbone of the upcoming 7th Assesment Report (AR7) of the Intergovernmental Panel on Climate Change (IPCC). Implementing this inventory in the latest version of the UK Earth System Model (UKESM), the UK's flagship climate model, they will quantify the impact of small eruptions on historical temperatures, precipitations and on key modes of climate variability. The student will work hand in hand with the UK Met Office, who is a CASE partner for the project, the National Centre for Atmospheric Science (NCAS) which co-develops UKESM, as well as with international partners including Aubry's network within CMIP and IPCC.

Methodology

The project will mostly rely on Earth System Modelling including. The student will have freedom to take the project in directions they see most exciting such as:

- Use machine learning techniques, e.g. to better detect and quantify small eruption impacts, or emulate simulations of the computationally expensive UK Earth System Model
- Use new ice-core or geological dataset to develop an improved volcanic eruption inventory for the next CMIP phase
- Use satellite observations and large ensemble of simulations to rigorously evaluate the performance of UKESM for 1991-2021

Timeline

Year 1: Acquiring of background knowledge, training in climate modelling and climate data analysis, and start running UKESM simulations. Some of the training can be undertaken at the UK Met Office as part of the CASE partnership.

Years 2 and 3: Continued running of simulations, analysis of data, and writing of first two papers. Presentation at international workshop and conferences. Definition of final direction for the thesis.

Year 4: Data analysis and writing of last paper(s). Integration of papers as a thesis and thesis completion.

Training & Skills

The student will receive intense, targeted training in climate modelling and climate data analysis. These skills are in high demand both in academia and in the private sector. Additional training will depend on how the student and supervisory team develop the project, but could include machine learning for climate science or satellite data analysis; and a range of environmental skills training offered by NCAS, including courses on the UK Chemistry and Aerosols Model (UKCA).

References & Further Reading

List of relevant texts formatted as follows:

Aubry, T.J., Schmidt, A., Kovilakam, M., Toohey, M., Khanal, S., Sigl, M., Chim, M.M.*, Johnson, B., Carn, S., Verkerk, M.*, Nicholls, Z., Smith, I.*, Stiller, D. Ziegler, E., Rieger, L., Thomason, L., Feng, J., Naik, V. and Durack, P. (2025), CMIP7 historical stratospheric aerosol optical properties and stratospheric volcanic sulfur emissions: version 2.2.1 dataset and preliminary documentation. https://doi.org/10.5281/zenodo.15556387

Chim, M.M., Aubry, T.J., Smith, C. and Schmidt, A. (2025), Neglecting future sporadic volcanic eruptions underestimates climate uncertainty, accepted in Communications Earth and Environment, 6, 236. https://www.nature.com/articles/s43247-025-02208-1.

Chim, M. M., Aubry, T. J., Abraham, N. L., Marshall, L., Mulcahy, J., Walton, J., & Schmidt, A. (2023). Climate projections very likely underestimate future volcanic forcing and its climatic effects. Geophysical Research Letters, 50, e2023GL103743. https://doi.org/10.1029/2023GL103743

Further Information

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