Modelling the impact of large volcanic eruptions on global and regional climate

Why this is important: Major tropical volcanic eruptions have a large impact on climate from monthly to centennial time scales, but there have only been three major eruptions during the recent relatively well-observed time period. Understanding these impacts can help with prediction and planning of how weather might be affected when a future large volcanic eruption happens. In the absence of additional observational data, models are an important tool that can be applied to better understand and predict the impacts of a large volcanic eruption.

Eruption of Mount Pinatubo, Philippines, on June 12, 1991 (credit: US Geological Survey)

What the UKCR programme is doing: This work focused on the question of whether models are able to respond realistically to volcanic emissions, specifically examining the impact of volcanic aerosols on climate using five state-of-the-art models initialised with the observed climate state before volcanic aerosols are introduced. The three volcanic eruptions included in the study are the largest ones during the recent well observed period; Agung (started erupting March 1963), El Chichón (April 1982) and Pinatubo (June 1991). Combining all the models and volcanic eruptions into one large set allows a robust response to be found, even if the signal is small.

Results so far: The study finds that for the global mean surface temperature (GMST) the models and observational record agree following the volcanic eruption. A cooling of the global mean surface temperature of -0.2°C develops over the first year, which continues at this level for at least another 18 months. The general atmospheric response is a warming of the tropical lower stratosphere and a cooling of the troposphere (particularly in the tropics), a pattern seen clearly in both the models and the observations. The mean zonal wind response in northern hemisphere winter is largely in the Northern Hemisphere, where the stratospheric vortex is strengthened, and northern edge of the mid-latitude jet stream weakened.

One of the significant responses during northern hemisphere winter is a low-pressure anomaly over the Arctic and a high-pressure anomaly over Europe producing an atmospheric circulation that gives mild temperature anomalies over Scandinavia and northern Russia (Siberia) despite the cooling signal over most of the rest of the world. For the UK this atmospheric pattern would lead to winds from the west or south likely leading to average or above average temperatures. In the second northern hemisphere winter following the eruption, the models produce a coupled atmospheric-ocean response in the Pacific that cannot be seen clearly in the observations (it may be obscured by noise) but is consistent with other published studies and requires further research to better understand.

What is next? The results of this paper will be utilised by other activities within the UKCR programme and are aimed at the wider academic community. The authors of this study also aim to further investigate how initialization of the models can help in providing a better forecast. This is something that can be understood better when model data from the 6^{th}

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phase of the Coupled Model intercomparison Project (CMIP6) becomes available over the coming months.

Reference: Hermanson, L., Bilbao, R., Dunstone, N., Ménégoz, M., Ortega, P., Pohlmann, H., et al., (2020) Robust multiyear climate impacts of volcanic eruptions in decadal prediction systems, *Journal of Geophysical Research: Atmospheres*, Vol. 125, e2019JD031739. https://doi.org/10.1029/2019JD031739