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Ash dispersion modelling as a tool to constrain source parameters of past volcanic eruptions

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Understanding the relationship between volcanic eruptions and their associated climate response requires a view extending further back than historical records can provide. Polar ice cores offer one of the best continuous records of past volcanism in the form of sulphates and ash particles preserved in the ice. Because of their light scattering effect, these sulphate aerosols are the dominant volcanic product contributing to annual and muti-annual climate perturbations. The ice-core sulphate record underpins our ability to reconstruct the climate forcing potential of past eruptions but translating the sulphate concentrations within polar ice cores to atmospheric sulphate loading requires knowledge of the volcanic source's latitude and plume height. While geochemical analysis of the ash particles can identify the source volcano, for prehistoric eruptions there is no primary record of plume height information available.

Here we assess the efficacy of ash dispersion modelling to predict minimum plume height, eruption season and meteorological conditions for events in which there is knowledge only of the source volcano, ash deposition at a given distal location, and ash grain size and shape. We use the eruption of Novarupta-Katmai 1912 as a case study, as ash from this eruption has previously been identified in the North Greenland Ice Core Project (NGRIP) ice core. Using Ash3d software, we model ash dispersion from Novarupta using historical information about the eruption and meteorology to evaluate the sensitivities of the model to parameters such as total grain size distribution, particle shape, ash cloud concentrations over the deposition site and duration of the suspended ash cloud. Using size and shape data from the NGRIP Novarupta-Katmai ash and randomly sampled values of erupted mass, column height, start dates tied to NCEP-NCAR Reanalysis meteorological data, and eruption duration, we run Ash3d simulations of a large series of eruptions from Novarupta, to compare conditions common to "successful" simulations (i.e., those that deposit ash at NGRIP coring site) with known parameters. Our results show that particle shape and size influence the longevity of the ash cloud, requiring longer simulation runs to ensure deposition is captured. We consider the value and limitations of our approach for reconstructing past volcanic plumes and the potential for further developments to aid in our knowledge of past volcanic impacts on climate.