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Uncertainties in the Climate Forcing of a Large Volcanic Eruption: An Earth System Model Study of the Unknown 1258 AD Eruption

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Large volcanic eruptions constitute an extremely strong forcing to the Earth's climate by scattering incoming radiation back to space and absorbing outgoing longwave radiation in the atmosphere system. This leads to considerable negative temperature anomalies at the surface and significant warming in the aerosol containing stratospheric layers. This can substantially alter both atmospheric and oceanic circulation. The largest signal of volcanic activity in the last 7,000 years recorded in ice core data of both hemispheres is the 1258 AD eruption at an unknown location. However, palaeo temperature reconstructions suggest that the temperature reduction after this eruption was not as big as one would expect, given the size of the sulphate signal in the ice cores of both hemispheres.

In order to assess the uncertainty in the aerosol forcing and its implication for the climate response to the 1258 AD eruption we performed ensemble experiments with a comprehensive Earth System Model (the COSMOS model, based on ECHAM5/MPIOM), in particular by varying the time dependent size distribution of the volcanic aerosols. We analyse the effect of this volcanic forcing on the atmosphere and surface energy fluxes as well as on the global carbon cycle. Comparison with a recently updated 30°N to 90°N boreal summer temperature reconstruction indicate that a cause for the limited temperature response to such a large volcanic eruption could be a shift of the aerosol size distribution to larger particles. Larger particles exhibit a reduced aerosol optical depth for the same aerosol mass and enhanced absorption in the far-infrared. These results suggest that the particle size distribution is a prominent factor for the temperature response to large volcanic eruptions and should be incorporated into future forcing data sets for climate simulations.