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Atmospheric impact of the 1783–1784 Laki eruption: Part I Chemistry modelling

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Abstract. Results from the first chemistry-transport model study of the impact of the 1783–1784 Laki fissure eruption (Iceland: 64°N, 17°W) upon atmospheric composition are presented. The eruption released an estimated 61 Tg(S) as SO_2 into the troposphere and lower stratosphere. The model has a high resolution tropopause region, and detailed sulphur chemistry. The simulated SO_2 plume spreads over much of the Northern Hemisphere, polewards of ~40°N. About 70% of the SO_2 gas is directly deposited to the surface before it can be oxidised to sulphuric acid aerosol. The main SO_2 oxidants, OH and H_2O_2, are depleted by up to 40% zonally, and the lifetime of SO_2 consequently increases. Zonally averaged tropospheric SO_2 concentrations over the first three months of the eruption exceed 20 ppbv, and sulphuric acid aerosol reaches ~2 ppbv. These compare to modelled pre-industrial/present-day values of 0.1/0.5 ppbv SO_2 and 0.1/1.0 ppbv sulphate. A total sulphuric acid aerosol yield of 17–22 Tg(S) is produced. The mean aerosol lifetime is 6–10 days, and the peak aerosol loading of the atmosphere is 1.4–1.7 Tg(S) (equivalent to 5.9–7.1 Tg of hydrated sulphuric acid aerosol). These compare to modelled pre-industrial/present-day sulphate burdens of 0.28/0.81 Tg(S), and lifetimes of 6/5 days, respectively. Due to the relatively short atmospheric residence times of both SO_2 and sulphate, the aerosol loading approximately mirrors the temporal evolution of emissions associated with the eruption. The model produces a reason-able simulation of the acid deposition found in Greenland ice cores. These results appear to be relatively insensitive to the vertical profile of emissions assumed, although if more of the emissions reached higher levels (>12 km), this would give longer lifetimes and larger aerosol yields. Introducing the emissions in episodes generates similar results to using monthly mean emissions, because the atmospheric lifetimes are similar to the repose periods between episodes. Most previous estimates of the global aerosol loading associated with Laki did not use atmospheric models; this study suggests that these earlier estimates have been generally too large in magnitude, and too long-lived. Environmental effects following the Laki eruption may have been dominated by the widespread deposition of SO_2 gas rather than sulphuric acid aerosol.

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