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Impact of the 1783-84 AD Laki Eruption on Cloud Condensation Nuclei, Cloud Droplet Concentrations and Aerosol Indirect Radiative Forcing

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The 1783-84 AD Laki flood lava eruption commenced on 8 June 1783 and released 122 Tg of sulphur dioxide gas over the course of 8 months into the upper troposphere and lower stratosphere above Iceland. Previous studies have examined the impact of the Laki eruption on sulphate aerosol and climate using general circulation models. Here, we study the impact on aerosol microphysical processes, including the nucleation of new particles, their growth to cloud condensation nuclei (CCN) and their subsequent activation into cloud droplets using a comprehensive global aerosol microphysics model (GLOMAP-mode).

Our simulations show that the microphysical processes leading to the growth of particles to CCN sizes are fundamentally different during and after the eruption when compared to the unperturbed atmosphere. The simulations suggest that the Laki eruption completely dominated as a source of CCN in the pre-industrial atmosphere by increasing 3-month mean concentrations by up to a factor 65 in the upper troposphere. Averaged over the Northern Hemisphere, the eruption caused a factor 4 increase in CCN concentrations at low-level cloud altitude. The impact on CCN is very widespread, with CCN concentrations increasing by a factor $\sim$6 in Europe and by a factor >14 in Asia due to the long range transport of nucleated particles.

The impact on CCN and subsequently on cloud droplet number (CDN) concentrations is most substantial in the Northern Hemisphere. However, our simulations indicate that the Laki eruption can significantly affect CCN concentrations in the Southern Hemisphere. At 20S, the eruption increases CCN concentrations at low level cloud altitude by up to 35 cm-3 (factor 1.4). Although the mass of sulphate is quite small far from the eruption, it is present in a large number of small particles that are very effective CCN. We also show that there is a widespread impact of the Laki eruption on CDN concentrations and indirect forcing, which extends into the Southern Hemisphere.