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Long-lived ultra-fine ash particles within the Pinatubo volcanic aerosol cloud and their potential impact on its global dispersion and radiative forcings

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Volcanic aerosol simulations with interactive stratospheric aerosol models mostly neglect ash particles, due to a general assumption they sediment out of the volcanic plume within the first few weeks and have limited impacts on the progression of the volcanic aerosol cloud (Niemeier et al., 2009).

However, observations, such as ground-based and airborne lidar (Vaughan et al., 1994; Browell et al., 1993), along with impactor measurements (Pueschel et al., 1994) in the months after the Mount Pinatubo eruption suggest the base of the aerosol cloud contained ash particles coated in sulphuric acid for around 9 months after the eruption occurred. Impactor measurements from flights following the 1963 Agung and 1982 El Chichon eruptions also show ash remained present for many months after the eruption (Mossop, 1964; Gooding et al., 1983).

More recently, satellite, in situ and optical particle counter measurements after the 2014 Mount Kelud eruption showed ash particles ~0.3 µm in size accounting for 20-28% of the volcanic cloud AOD 3 months following the eruption (Vernier et al., 2016; Deshler, 2016). This evidence suggests that sub-micron ash particles may persist for longer in the atmosphere than is often assumed.

We explore how the presence of these sub-micron ash particles affects the progression of a major tropical volcanic aerosol cloud, showing results from simulations with a new configuration of the composition-climate model UM-UKCA, adapted to co-emit fine-ash alongside SO2.   In the UM-UKCA simulations, internally mixed ash-sulphuric particles are transported within the existing coarse-insoluble mode of the GLOMAP-mode aerosol scheme.

Size fractions of 0.1, 0.316 and 1 μm diameter ash were tested for the 1991 Mount Pinatubo eruption with an ultra-fine ash mass co-emission of 0.05 and 0.5 Tg, based on 0.1% and 1% of an assumed fine ash emission of 50Tg. Whereas the 0.316 and 1 μm sized particles sedimented out of the stratosphere within the first 90 days after the eruption, the 0.1 μm persisted within the lower portion of volcanic cloud for ~9 months, retaining over half its original mass (0.035 Tg) February 1992.

We investigate model experiments with different injection heights for the co-emitted SO2 and ash, analysing the vertical profile of the ultra-fine ash compared to the sulphate aerosol, and explore the effects on the volcanic aerosol cloud in terms of its overall optical depth and vertical profile of extinction.

The analysis demonstrates that although fine-ash is more persistent than previous modelling studies suggest, these particles have only modest impacts with the radiative heating effect the dominant pathway, with the sub-micron particles not scavenging sufficiently.

Future work will explore simulations with a further adapted UM-UKCA model with an additional “super-coarse” insoluble mode resolving the super-micron ash, then both components of the fine-ash resolved to test the magnitude of sulfate scavenging effect.