Aerosol microphysics simulations of the Mt. Pinatubo eruption with the UM-UKCA composition-climate model

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Abstract. Accurate quantification of the the volcanic forcing from the volcanic eruptions is important for better understanding of recent climate change. Here we use chemistry-composition climate model UM-UKCA with an interactive stratospheric chemistry and aerosol microphysics to assess evolution of stratospheric aerosol and associated radiative forcings from the three largest tropical eruptions over last century: Mt Agung (March 1963), El Chichon (April 1982) and Mt. Pinatubo (June 1991). Aligning with the design of the Interactive Stratospheric Aerosol Model Intercomparison Project (ISA-MIP) co-ordinated multi-model "Historical Eruption SO_2 Emissions Assessment", we have carried out 3-member ensembles of simulations with each of upper, low and mid-point best estimates for SO_2 injection for each eruption. Simulated aerosol properties of volcanic aerosol plume are evaluted against range of observation based data sets. Overall, our model simulations suggests that comparted to previous esmtimates much lesser amount of SO_2 injection is sufficient to simulate stratospheric aerosol evolution for each of the eruption, suggesting much higher climate efficacy to the stratspheric SO_2 injection. Here we show that up to 10, 7 and 6 Tg SO_2 injection in the stratosphere is enough to simulate stratospheric aerosol evolution following Mt. Pinatubo, El-Chichon and Agung eruption, respectively.

1 Model Setup

We use United Kingdom Chemistry Climate Model (UM-UKCA), which is combination of UK Met Office Unified Model (UM v8.4) general circulation model coupled with the whole atmosphere UK Chemistry and Aerosol scheme (UKCA). Model has a horizontal resolution of 1.875° by 1.25° with 85 vertical levels from surface to about 85 km. In present configuration, the whole-atmosphere chemistry combines detailed stratospheric chemistry and simplified tropospheric chemistry schemes (Morgenstern et al., 2009; O'Connor et al., 2014).

The model set-up is similar to the one used to simulate and evaluate evolution of Mount Pinatubo aerosol in (Dhomse et al., 2014). Briefly, stratospheric aerosol scheme includes GLOMAP aerosol micro-physics module coupled with UKCA stratospheric chemistry. Greenhouse Gases (GHGs) and ozone depleting substance (ODSs) concentrations are from refC1 simulation recommended in Chemistry–Climate Model Initiative (CCMI-1; Eyring et al. (2013); Morgenstern et al. (2017)) activity. Simulations are performed in atmosphere-only mode, and we use CMIP6 (Coupled Model Intercomparison Project 6) recommended sea-surface temperatures and sea-ice concentration that are obtained from https://esgf-node.llnl.gov/projects/cmip6/. Some of key updates since Dhomse et al. (2014) are i) improved vertical and horizontal resolution (N96L60 vs N192L80) II) coupling between aerosol and radiation scheme (Mann et al., 2015) and iii) inclusion of sulfuric particles to form heterogeneously on transported meteoric s moke particle cores (Brooke et al., 2017), iv) improvements in wet and dry deposition scheme Marshall et al. (2018) and v) we use prescribed sulphate aerosol surface area (SAD) data from Arfeuille et al. (2013).

For each eruption, first we performed 20-year time-slice simulations for a given time period. First 10-year data are considered as a model spin-up. From remaining 10 years, we selected appropriate three initialization files (3-member ensemble) where model QBO phase at 50 hPa is in approximate agreement with QBO50 index from Climate Prediction Center (http://www.cpc.ncep.noaa.gov/data/indices/qbo.u50.index; last accessed 18 August 2018). Control simulations are performed without any simulations. For each eruption, 10-simulations are performed with different combinations of SO_2 amount with fixed injection height (21-23km), as shown in Table 1. Due to large uncertainties about SO_2 injection amount for each eruption, we decided to perform three sensitivity simulations with minimum, mid and maximum SO_2 amount. For e.g. for Agung, simulations are performed with 6, 9 and 12 Tg. Hence, **Agu06** indicate Mt. Agung eruption with 6 Tg SO_2 injection between 21-23 km. And **Agu09** and **Agu12** are similar to **Agu06** but with 9 and 12 Tg SO_2 injection, respectively, whereas **Agu06** is the control simulation without any emission (background conditions). To avoid complexities due to heterogeneous chemical loss, control simulations use climatological SAD values in the stratospheric (mean 1995–2006) and rest of the simulations use time varying SAD from Arfeuille et al. (2013) in the stratospheric chemistry scheme.

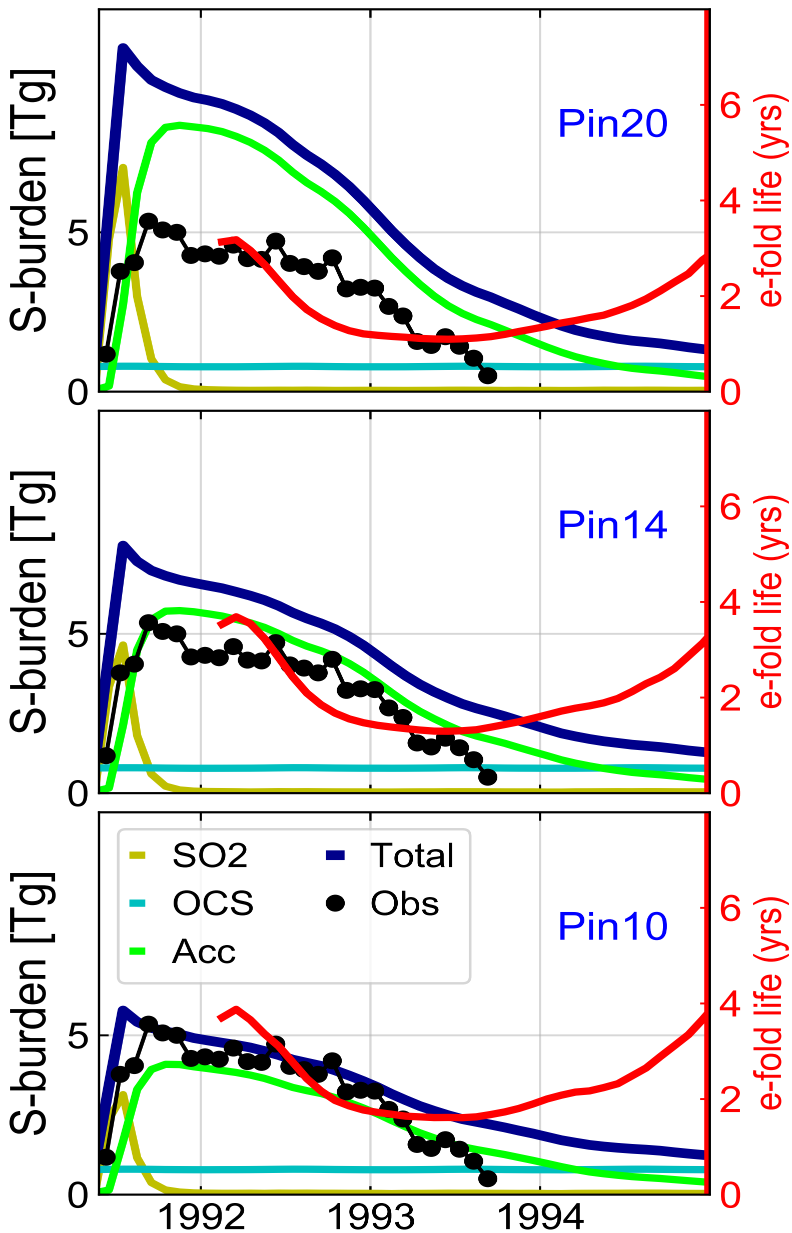

Figure 1 . XXX XXX XXX

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