Project: **959**

Project title: **eVolv2k: Ice core-based volcanic forcing of climate variability for the past 2000 years**

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Report period: **2017-01-01 to 2017-12-31**

The focus of eVolv2k is the production of the next-generation of volcanic climate forcing for climate models, based on improved data and improved implementation of the forcing within climate models. The project also aims to use the new forcing in climate model simulations to investigate decadal-scale climate variability related to volcanic forcing.

Progress in 2017:

(1) Development of volcanic forcing reconstructions for the past 2500 and 10,000 years

The eVolv2k volcanic forcing data set has been developed for the past 2500 years, specifically for use in the Paleo-Modelling Intercomparison Project phase 4 (Jungclaus et al., 2016). The eVolv2k database contains estimates of volcanic stratospheric sulfur injection (VSSI) derived from ice cores (Toohey and Sigl, 2016), and is included in a forcing "package" which also includes the EVA forcing generator. A document describing the SO_2 injection estimation method, and the resulting reconstructed radiative forcing and its implications is currently in press (Toohey and Sigl, 2017).

Furthermore, a prototype volcanic forcing data set was developed for the full Holocene (past 10,000 years), for use in a special MPI-M initiative aimed at simulating the climate of the Holocene with MPI-ESM. The prototype Holocene volcanic forcing reconstruction created in 2016/17, based on a single Greenland ice core, included some instances of what are likely strong overestimates of volcanic forcing. A revised Holocene forcing time series, now based on synchronized Greenland and Antarctic ice cores, is almost ready for use.

(2) MPI-ESM/EVA radiative forcing and aerosol size distributions

The standard EVA version assumes a single-mode aerosol distribution with fixed distribution width (σ=1.2 μm) and an effective radius linearly related to the aerosol mass. MPI-ESM simulations were performed of the 1991 Pinatubo eruption with different values of the assumed distribution width, and after implementing a two-mode distribution, in closer agreement with balloon-based measurements after the Pinatubo eruption. Using different aerosol size distribution widths, the EVA-generating forcing produce instantaneous radiative forcing in MPI-ESM which are within the range span using the Stenchikov et al. (1998) (used for CMIP5) and CMIP6 volcanic forcings. This suggests that any uncertainties in the actual aerosol size distribution width are small compared to uncertainties in the extinction magnitude. Differences in radiative forcing during background aerosol conditions—when the assumed size distribution is a clear underestimate—are relatively small, with the assumed σ=1.2 width likely leading to an underestimate of the true radiative forcing of the background aerosol layer. These results will be useful in the interpretation of upcoming future simulations using the EVA forcing generator.

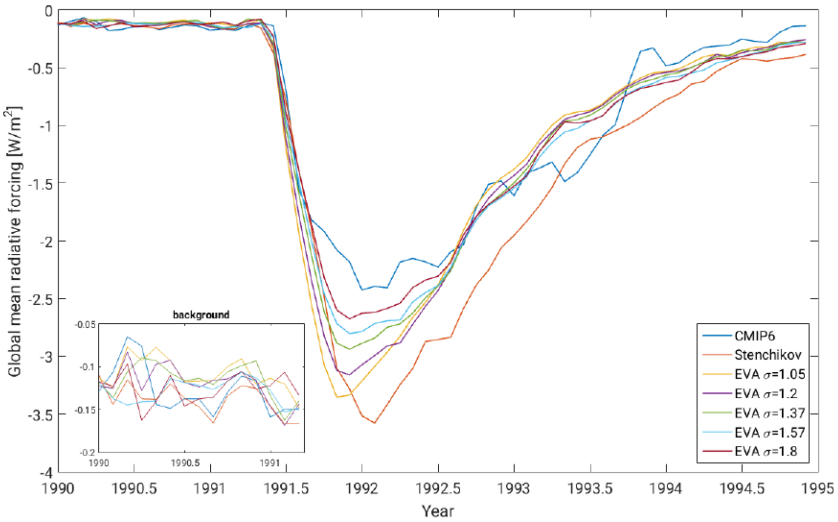

Figure 1: Time series of global mean net radiative forcing by the 1991 Pinatubo eruption in MPI-ESM simulations using the CMIP6, Stenchikov (1998) and EVA forcing reconstructions, where EVA forcings include five different assumed aerosol size distribution widths σ. Inset panel shows a zoom in to the pre-eruption "background" period, Jan 1990 - May 1991.

(3) Impact of eruption latitude and injection height on radiative forcing of volcanic aerosol

The EVA forcing generator and the EVA(eVolv2k) volcanic reconstruction assume all eruptions to be similar to the 1991 Pinatubo eruption in terms of the height of their sulfur injection. To understand the impact of injection height and eruption latitude on the evolution of aerosol and its radiative forcing, simulations have been performed in 2017 with the MAECHAM5-HAM interactive aerosol model of Pinatubo-magnitude eruptions at different latitudes and injection heights, supplementing simulations performed in the past within the **Miklip ALARM** project. These simulations suggest that for fixed Pinatubo-like injection height, the eruption latitude plays a relatively weak role in the global mean radiative forcing, and that the confinement of aerosol in the hemisphere of eruption leads to larger NH extratropical radiative forcing for extratropical eruptions than tropical eruptions, contrary to common belief. The expectation of weaker forcing resulting from extratropical eruptions is largely due to the confounding impact of injection height.

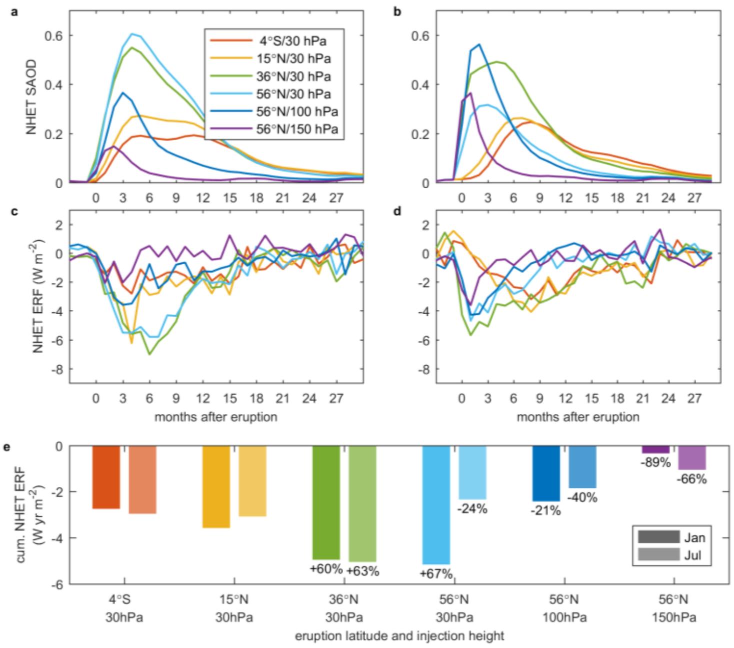

Figure 2: MAECHAM5-HAM simulated volcanic stratospheric aerosol optical depth (SAOD) and effective radiative forcing (ERF) over the NH extratropics (30-90°N). Shown are (a,b) SAOD and (d,e) effective radiative forcing (ERF) for eruptions in (left) January and (right) July. Three-year cumulative NHET ERF is shown in panel (e) as a function of injection latitude and height. For the extratropical injection cases, text labels show the percent difference of cumulative ERF with respect to the mean of the tropical (6°S and 15°N, 30 hPa) injection eruption simulations. Results from Toohey et al. (in prep).

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