Project: **959**

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

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Report period: **2018-01-01 to 2018-12-31**

The focus of eVolv2k is the production of the next-generation of volcanic climate forcing for climate models, based on improved data and implementation strategies. 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 2018:

(1) Continued 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. The eVolv2k database contains estimates of volcanic stratospheric sulfur injection (VSSI) derived from ice cores, and is included in a forcing "package" which also includes the EVA forcing generator. 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 (Bader et al., submitted; Brovkin et al., submitted). 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 volcanic forcing time series based on synchronized Greenland and Antarctic ice cores has been used for a new simulation.

Development of EVA and the eVolv2k forcing data has continued in 2018 based on input and requests from users and colleagues. EVA has been successfully used in ECHAM simulations at various resolutions and in other climate models. Forcing ensembles have been constructed, with multiple forcing realizations representing the uncertainty in volcanic forcing estimates (Fig. 1), which are being used to improve comparisons of simulations with reconstructions (e.g., Zanchettin et al., submitted).

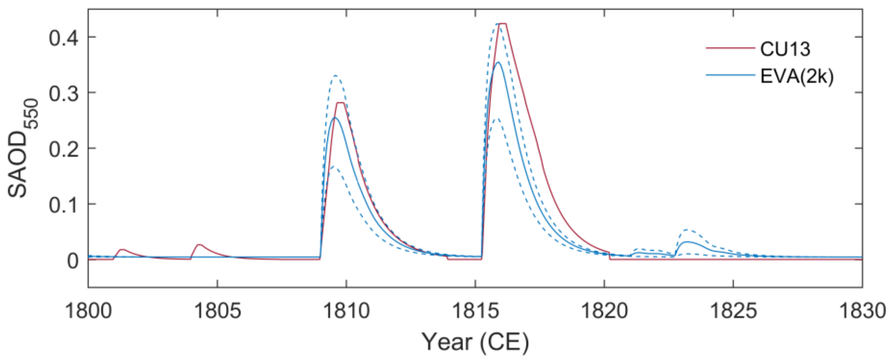

Figure 1: Reconstruction of volcanic stratospheric aerosol optical depth (SAOD) in the early 19th Century. Estimates are shown for the EVA(eVolv2k) best (central) estimate, and 2σ high and low estimates, based on uncertainties in the estimated stratospheric sulfur injection of the eruptions. SAOD from a prior reconstruction (Crowley and Unterman, 2013) is shown in red.

(2) Climate response to volcanic forcing in the 1450s

The mid-15th Century is marked by one or more large-magnitude, explosive volcanic eruptions and a strong multi-decadal-scale drop in Northern Hemisphere (NH) temperature often considered the beginning of the Little Ice Age (LIA). While a connection between mid-15th century volcanic activity and NH temperature is generally well accepted, scientific debate persists with respect to the number of eruptions, their source volcanoes, their exact timing, apparent discrepancies between the estimated eruption magnitudes and the corresponding temperature changes, and the possible connection between volcanic forcing and the long-term regional climate anomalies of the LIA. A collaborative activity is underway (Toohey et al., in prep) within the Past Global Changes (PAGES) Volcanic Impacts on Climate and Society (VICS) working group to bring together interdisciplinary evidence to piece together an improved picture of the connections between volcanism and climate in the mid-15th Century.

MPI-ESM simulations of the 1450s eruptions have not yet been carried out as planned, however colleagues in the UK have performed an ensemble of simulations with the CESM(WACCM) which have formed the basis of the study to this point. The volcanic forcing produced by the interactive aerosol module of CESM is significantly stronger than that estimated using EVA (Fig. 2), and also demonstrates the sensitivity of forcing in the NH extratropics to meteorological conditions. Comparison of simulated surface temperatures with reconstructions from tree rings (Fig. 3) suggests that the simulated temperatures anomalies following the 1453 extratropical eruption are realistic—a result consistent with prior findings of the eVolv2k project (Toohey et al., in review). On the other hand, the strong NH temperature anomalies simulated following the 1458 eruption are absent in the tree ring reconstructions. Work is continuing to understand the role of forcing uncertainties and potential biases in the tree ring reconstructions.

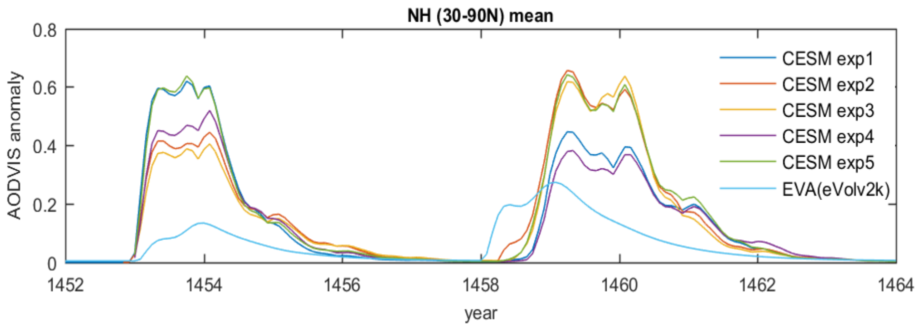

Figure 2: Northern Hemisphere extratropical stratospheric aerosol optical depth (SAOD) from 5 realizations of CESM simulations of the 1453 and 1458 eruptions, along with the EVA(eVolv2k) SAOD reconstruction.

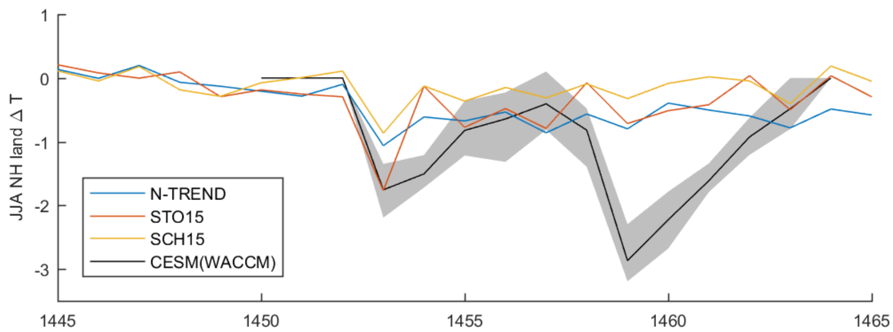

Figure 3: Northern hemisphere land temperature anomalies from 3 tree-ring-based reconstructions and from the CESM simulations. CESM ensemble spread is indicated by the gray shading.

References:

Bader, J., Jungclaus, J., Krivova, N., Lorenz, S., Maycock, A., Raddatz, T., Schmidt, H., Toohey, M., Claussen, M., Global temperature modes shed light on the Holocene temperature conundrum, submitted to Nature Communications.

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Zanchettin, D., Timmreck, C., Toohey, M., Jungclaus, J. H., Bittner, M., Lorenz, S. J., Rubino, A.: Clarifying the relative role of forcing uncertainties and initial-condition unknowns in spreading the climate response to volcanic eruptions, submitted to Geophysical Research Letters.