Project: **963**

Project title: **Volcanic Forcings Model Intercomparison Project (VolMIP)**

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Report period: **2023-11-01 to 2024-10-31**

During the reporting period, we have continued with the analysis of the CMIP6[1]/VolMIP[2] experiments (Khodri et al, in prep; Timmreck et al, in prep) and the analysis of the PMIP4 past1000[3]/simulations (Wilson et al, submitted). In the last year, special attention has been given to the analysis of the MPI-ESM Holocene simulations (van Dijk et al 2024; van Dijk et al in prep).

From palaeo-proxy reconstructions and climate model simulations of Northern Hemisphere (NH) climate during the Common Era, we know that volcanically induced cold periods such as the Little Ice Age (LIA) and the mid-6th century cooling occurred (van Dijk et al, 2022). However, less is known about such cold periods during the Holocene. We identify 11 long-lasting LIA-like cold periods with a recurrence rate of 1-2 per millennium in the MPI-ESM Holocene runs (van Dijk et al., 2024). The integrated effect of volcanic forcing through the ocean-sea ice feedback could explain all identified long cold periods in the model simulation. Our results show that high-frequency climate forcing, and in particular volcanic forcing, is required to resolve the full Holocene climate variability, which is not present in the available NH or global palaeo-reconstructions.

The Mt. Mazama eruption (5623 ± 35 BCE) is one of the largest Holocene eruptions, but its impact on the contemporaneous climate, environment and humans remains poorly understood. Therefore, we performed sensitivity experiments to the MPI-ESM Holocene simulations (Bader et al. 2020; Dallmeyer et al., 2023) to investigate the potential impact of the Mt. Mazama eruption on global climate and socio-ecological consequences. Our results show extreme regional temperature decreases of more than 7 ˚C in the ensemble mean of 10 realizations. In addition, a post-eruptive southward shift of the intertropical convergence zone led to severe drought over large areas in the monsoon regions. In contrast, the Mediterranean and the Near East experience an extreme increase in summer precipitation in our simulations due to the associated shift of the adjacent atmospheric circulation cells. We argue that the combined occurrence of severe cooling and large increases in precipitation (Figure 1) likely had a significant impact on early agricultural societies in these regions, with crop failures and pronounced flooding. This illustrates how large volcanic eruptions can alter the surface climate, with varying and contrasting composite climate anomalies over much of the land surface.

References

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[1] CMIP6: Coupled Model Intercomparison Project, Phase 6 (Eyring et al., 2016)

[2] VolMIP: Model Intercomparison Project on the climate response to Volcanic forcing (Zanchettin et al., 2016)

[3] past1000: Pre-industrial millennium experiment from PMIP4 (Jungclaus et al., 2017)

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Figures

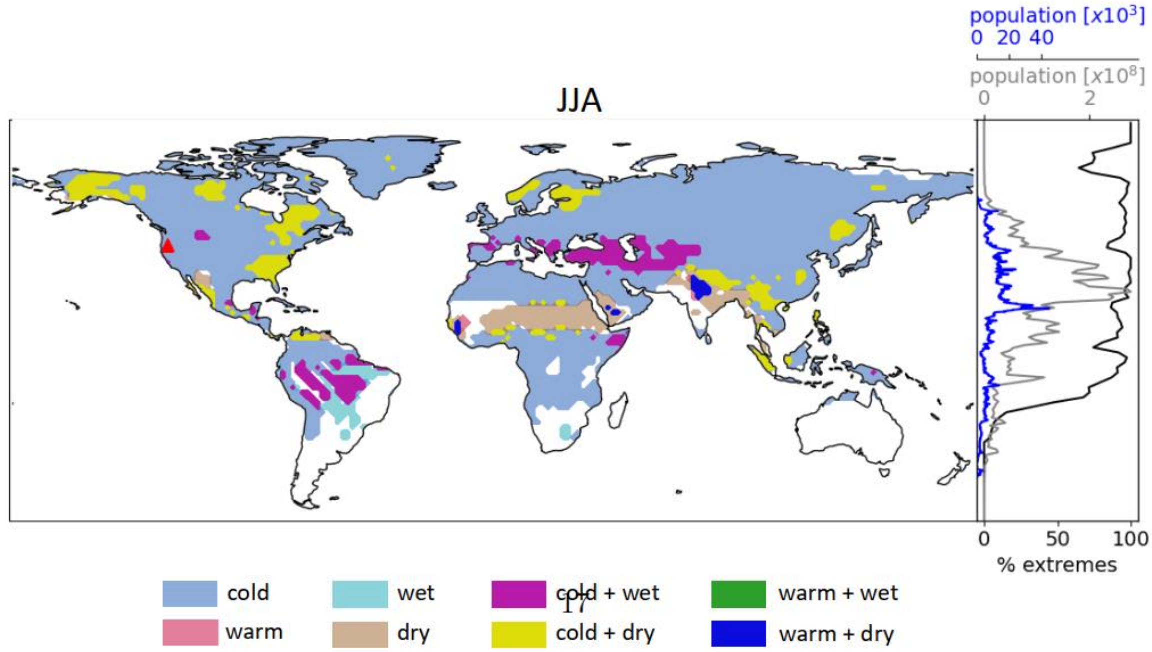

Figure 1: Occurring anomalies on the 2σ level for the 2-year mean after the Mt. Mazama eruption in boreal summer (JJA). The latitudinal distribution of any anomaly in temperature or precipitation is represented by the black line. Population per latitude for 7000 BCE (Klein Goldewijk, 2024) is given by the blue line, and population per latitude for 2020 CE (CIESIN, 2018) is given by the grey line (van Dijk et al in prep).