Project: **963**

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

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Report period: **2022-11-01 to 2023-10-31**

Over 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) but we have also broadened our focus and analyzed PMIP4[3]past1000[4]/simulations (Villamajor et al, 2023) and MPI-ESM Holocene simulations (van Dijk et al, in prep.).

In the frame of the PMIP/past1000/CMIP6/VolMIP volc-cluster experiments, we have tested a new volcanic forcing dataset including more small-to-moderate eruptions between 1733-1895. We find that indeed the small-to-moderate eruptions can induce significant surface cooling and help explaining the long-lasting cooling after the large eruptions in 1809 (unidentified) and in 1815 (Tambora) which is also seen in tree-ring reconstructions (Fang et al., 2023). We have now also started to analyze simulations with the early 19th century volcanic forcing but for different time periods (present day, 4 X CO_2).

From paleo proxy reconstructions and climate model simulations of the Northern Hemisphere (NH) climate during the Common Era (CE), we know that volcanic-induced cold periods like the Little Ice Age (LIA) and the mid-6th century cooling occurred. We could for example show with MPI-ESM ensemble simulations that volcanic eruptions in 536 and 540 CE lead to significant and long lasting temperature and precipitation changes in the 6th century consistent with proxy reconstructions which also had severe societal impact in Southern Norway (van Djik et al., 2022; 2023).

However, less is known about such cold periods during the Holocene period. We employ the MPI-ESM Holocene runs (Bader et al. 2020; Dallmeyer et al, 2023) with new and updated volcanic forcing to study the long-lasting cold periods of the mid to late-Holocene and the possible mechanisms behind them (van Dijk et al, in prep.). We identify 11 long-lasting cold periods like the little ice age (LIA), with a recurrence time of 1-2 per millennium (Figure 1). Grand solar minima occur during six of our long-lasting cold periods, so they do not explain all long-lasting cold periods. On the contrary, the integrated effect of volcanic forcing through ocean - sea ice feedback does explain all identified long-lasting cold periods in the model simulation. Our results demonstrate that high frequency climate forcing, and in particular the volcanic forcing, is needed to resolve the full climate variability during the Holocene, which is not present in available NH or global paleo reconstructions.

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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] PMIP4: Paleoclimate Model Intercomparison Project Phase 4 (Kageyama et al., 2018)

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

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Figures

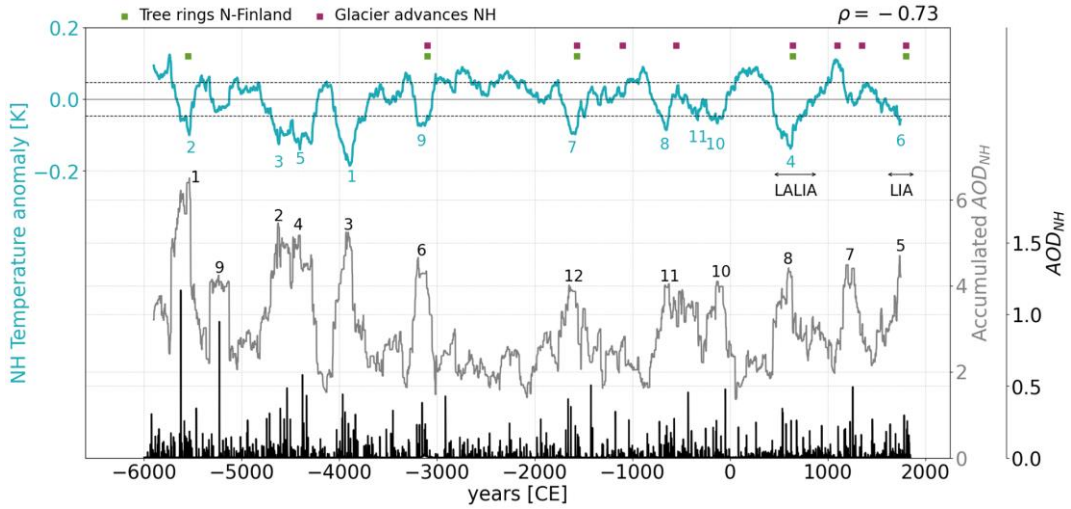

Figure 1: 200-year rolling mean 2m temperature anomaly for the all forcing run (blue), 200-year accumulated Aerosol Optical Depth (AOD) (grey), as well as annual mean AOD (black). 2σ indicated by dashed lines. Timing of glacier advances in the NH (Wanner et al, 2008) indicated by purple squares and cold periods from tree ring records from northern Finland (Helama et al, 2021) indicated by the green squares (van Dik et al, in prep).