Project: **1251**

Project title: **Computational approaches to Final Palaeolithic/earliest Mesolithic climate change**

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

Summary:

In the recent reporting period, we have finished our simulations of the Allerød period. This includes a spun-up Allerød reference climate and an Allerød climate forced by volcanic eruptions. To do this we developed tools that can modify the MPIESM ice sheet configuration and implemented the EVA_H (Aubry et al, 2020) volcanic forcing generator to work with MPIESM. The forcing was also applied to Last Glacial Maximum and Preindustrial configurations.

Further, our paper on volcanic eruptions influences on storms discussed in the last report has been published (Andreasen et al, 2024).

The Allerød reference climate

To simulate an Allerød reference climate, we first developed a tool which can add additional ice sheets to MPI-ESM. The resulting tool is fast, easy and can use any ice sheet height reconstructions as input and output a set of topographies ready for MPI-ESM. After modifying the ice sheet topography, greenhouse gas concentration and orbital parameters of MPI-ESM-1.2 we spun up the model for 5000 years until the deep ocean had reached a steady state. The resulting surface air temperatures (SAT) relative to the model's PI configuration are shown in Figure 1, which shows a slightly cooler climate with a clear fingerprint of the addition of ice sheets in North America and Scandinavia.

At the tropopause level (assumed to be at 250 hPa), the North American ice sheets appear to modify the circulation downstream in the North Atlantic and possibly in Siberia (Figure 2). The motivation for attributing the anomaly over Siberia to the North American ice sheet is the interpretation of the anomalies over the North Atlantic and Siberia together as a wavenumber-1 Rossby wave caused by the ice sheet (Löfverström et al, 2014). This may further explain the positive SAT anomaly over Siberia shown in Figure 1.

Thus, in the Northern Hemisphere, the Allerød climate appears to be slightly colder than the PI climate, but with additional modifications from a standing wave due to the North American ice sheet.

Simulations of volcanic eruptions in an Allerød climate

The Allerød configuration has been used to study the consequence of several subsequent volcanic eruptions (something that seems to have happened in the Allerød period). This has been done using the EVA_H forcing generator (Aubry et al, 2019), which is an updated version of the EVA forcing generator (Toohey et al., 2016) usually used together with MPI-ESM. Therefore, parts of the recent reporting period have been spent on adapting EVA_H to be used together with MPI-ESM.

The experiments performed were designed by Deepashree Dutta from the University of Cambridge, who has performed similar experiments using the HadGCM3 model. The experiments were run using both our new Allerød configuration and existing LGM and PI configurations. We are currently working on comparing the results between the different configurations and the different models.

Our preliminary results suggest that several subsequent major volcanic eruptions have the ability to influence the climate even more than a hundred years after the last eruption (Figure 3). We are currently investigating the mechanisms that prevent the climate from returning to its initial temperature. Since this is more pronounced for the Allerød climate than for the LGM and PI climates, it seems that the background climate plays some role.

References

Andreasen, L. et al, Changes in Northern Hemisphere extra-tropical cyclone frequency following volcanic eruptions, Environmental Research: Climate, 2024

Aubry, T. J. et al, A new volcanic stratospheric sulfate aerosol forcing emulator (EVA_H): Comparison with interactive stratospheric aerosol models, J. Geophys Res., 125, https://doi.org/10.1029/2019JD031303, 2020

Löfverström, M. et al, Evolution of the large-scale atmospheric circulation in response to changing ice sheets over the last glacial cycle, Climate of the Past, 2014 55., 2014.

Toohey, M. et al, Easy Volcanic Aerosol (EVA v1.0): an idealized forcing generator for climate simulations, Geosci. Model Dev., 9, 4049-4070, doi:10.5194/gmd-9-4049-2016, 2016.

Figures

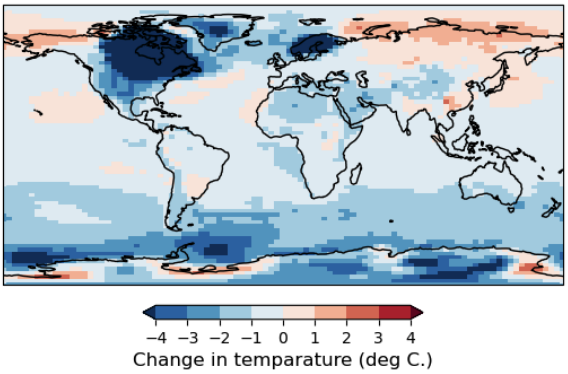

Figure 1: Annual mean difference in surface air temperature between Allerød and PI climate

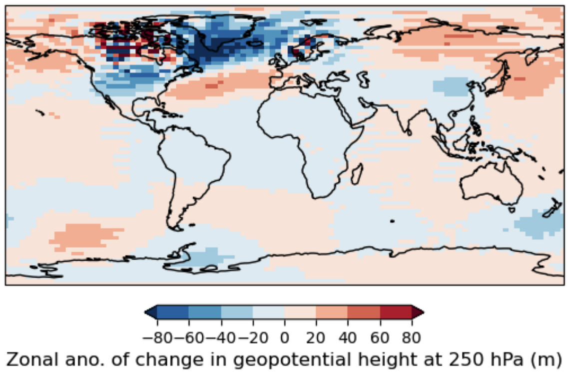

Figure 2: Annual mean difference in geopotential height (zonal mean removed) between Allerød and PI climate

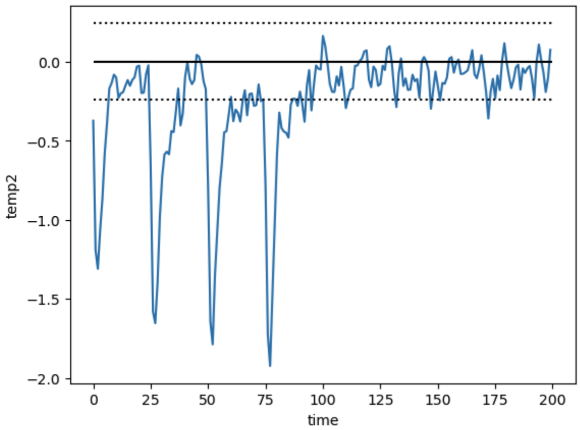

Figure 3: Annual mean global temperature response to four subsequent and identical 100 TgS volcanic eruptions relative to the reference climate. The solid line indicates zero change, and the dotted lines indicate +/- two standard deviations of the reference climate. Time indicates the post eruption years.