Project: **1251**

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

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The anchor point of our work has been the impact the Laacher See Eruption (LSE, around 13000 BP in the Allerød climatic period) had on weather, climate, and hunter-gatherer societies in western Europe. The first starting point has been the work of Riede (2014) who finds that northern European societies suffered much more in the wake the LSE than their southern European counterparts. Since this cannot be explained by ash from the LSE a weather/climate related component has been suspected.

The second starting point has been that Dreibrodt et al. (2021) find strong evidence of extremely windy conditions after the LSE from the sediments of a north European lake. This together with a potential vulnerability of hunter-gatherers to storms and extremely windy conditions (e.g. Tejsner 2012) has let us to investigate the impact of the LSE on storms in the mid-latitudes. This approach has been two-pronged: Earth system model (ESM) simulations and the ice core record (ICR). We will present each in separate sections. The conclusions from both analytical trajectories are consilient and clear: The ESM shows clear evidence for more stormy conditions in the regions of greatest human impact as pointed out by Riede (2014), and the ICR suggest that a connection between strong volcanic eruption and strong mid-latitude storms is in fact a general feature of the Earth system.

Earth system simulations

Since we have no spin-up simulation with Allerød conditions, we instead performed our simulations in both a pre-industrial (PI) setup and a last glacial maximum (LGM) setup. We ran ten ensemble runs for each setup so far, all with MPIESM1.2-LR. The model was forced by the EVA model and stratospheric sulphur estimates of Abbott et al. (2021). The simulations did not suggest any difference in temperature between northern and southern European regions (cf. Riede 2014). To address increase in storminess we used two measures of storminess: The Eady growth rate, which a well-known indicator for the development and intensification of low-pressure systems (Eady, 1949), and the surface westerly wind, which is known as the eddy-driven jet due to its dependency of momentum transfer from low-pressure systems (Vallis, 2017). As shown in figures 1 and 2 both measures show a clear increase in the Northern European regions, but not in Southern Europe.

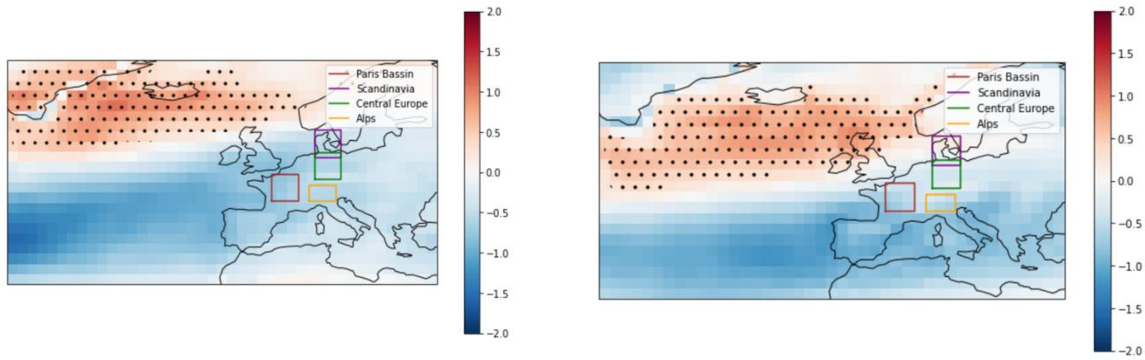

Figure 1: *Average ensemble mean change in Eady growth rate in first 5 years after the eruption. Changes are measured in standard deviations. Left shows PI configuration and right shows LSE. Dots indicates significant increase at 0.05-level from a permutation test (compares to unperturbed reference simulation)*

The divide between more and less windy conditions is further north in the LGM setup than the

PI. We expect the divide to be somewhere in between for the Allerød, since this period falls between PI and LGM in terms of temperatures, ice sheet extent and chronology. This would also likely lead to a good fit with the human impact patterns described by Riede (2014).

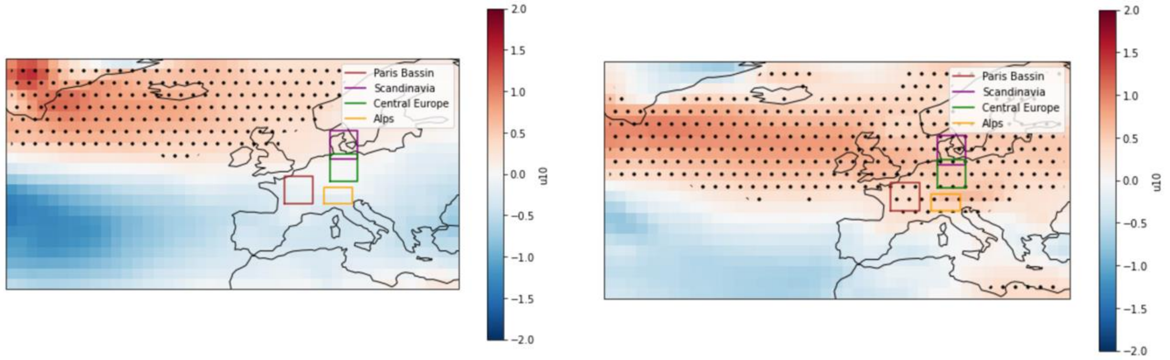

Figure 2: *Average ensemble mean change in surface zonal wind in first 5 years after the eruption. Changes are measured in standard deviations. Left shows PI configuration and right shows LSE. Dots indicates significant increase at 0.05-level from a permutation test (compares to unperturbed reference simulation)*

The ice core record

To ensure that the increased storminess is not a model artifact the NEEM ice core data (Sigl et al. 2022) were used to test a relation between a proxy of volcanism – sulphur – and a proxy for storms – sea salt (Na). Interestingly, we found that the years characterised by high levels of sulphur also displayed significantly higher mean and maximum Na values (Fig. 3).

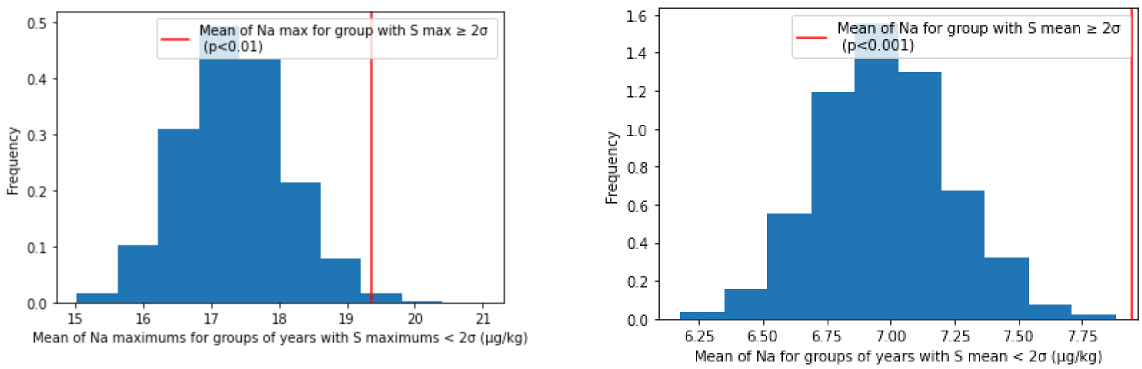

Figure 3: *Left: Red line indicates the average yearly maximum Na values for volcanically active periods (high S) to the distribution of similar periods with less volcanic activity. Right: Similar to left plot but shows average of yearly means of Na instead of yearly maximums.*

Taken together, these results make us confident that volcanically induced mid-latitude storminess is a genuine feature of the Earth system – and that storms hence constitutes a potential downstream impact mechanism for volcanism on societies. In future simulation work, we will seek to explore these new findings further.

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