Quantifying the influence of natural forcing on water isotopes and climate in polar and alpine regions using HadCM3

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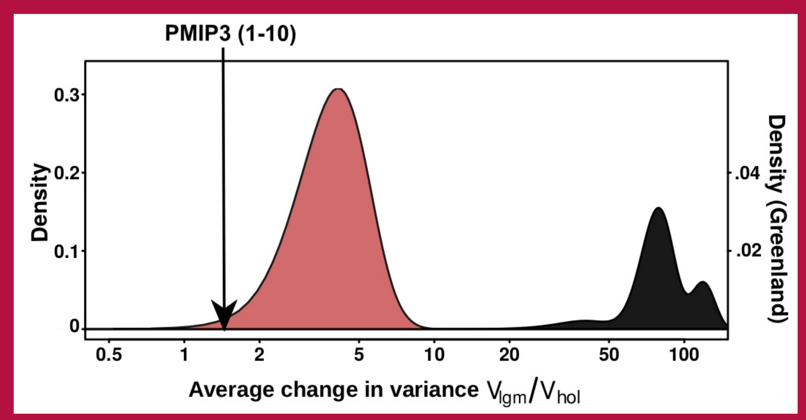
1 Motivation

Climate variability governs the probability of extreme events[1] and thus living conditions on Earth. How projected changes in mean climate will affect climate variability remains uncertain[2-5]. To this end, comparing the last glacial to the present interglacial can provide new insights. However, models simulate a lower change in variability during that period than reconstructions from proxies like $\delta^{18}O$ suggest[3,5]. Comparison is difficult, since paleoclimate equilibrium simulations are typically run for few centuries and do not yet incorporate water isotope tracers.

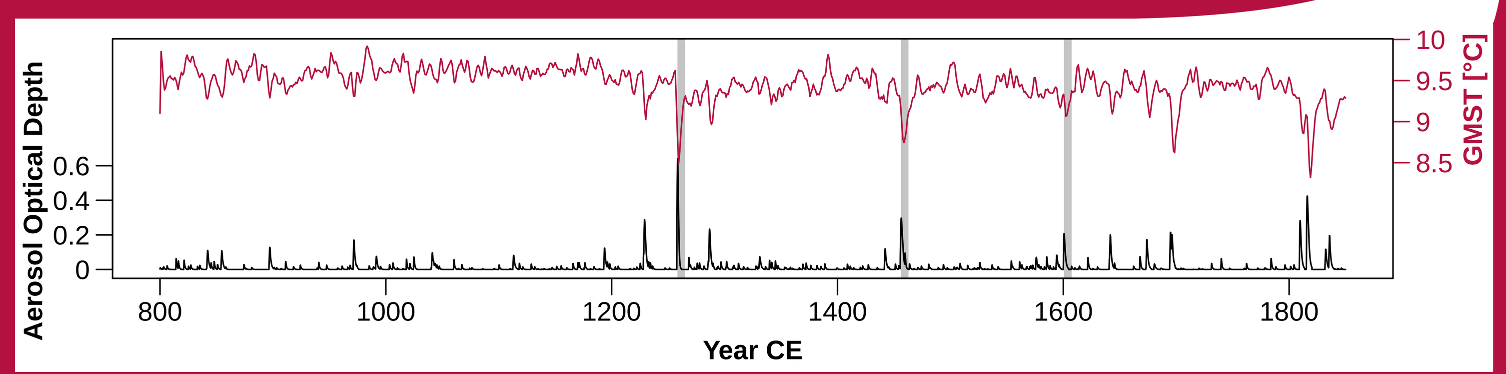


Variability change in proxy data from LGM to Holocene[3].

2 Data

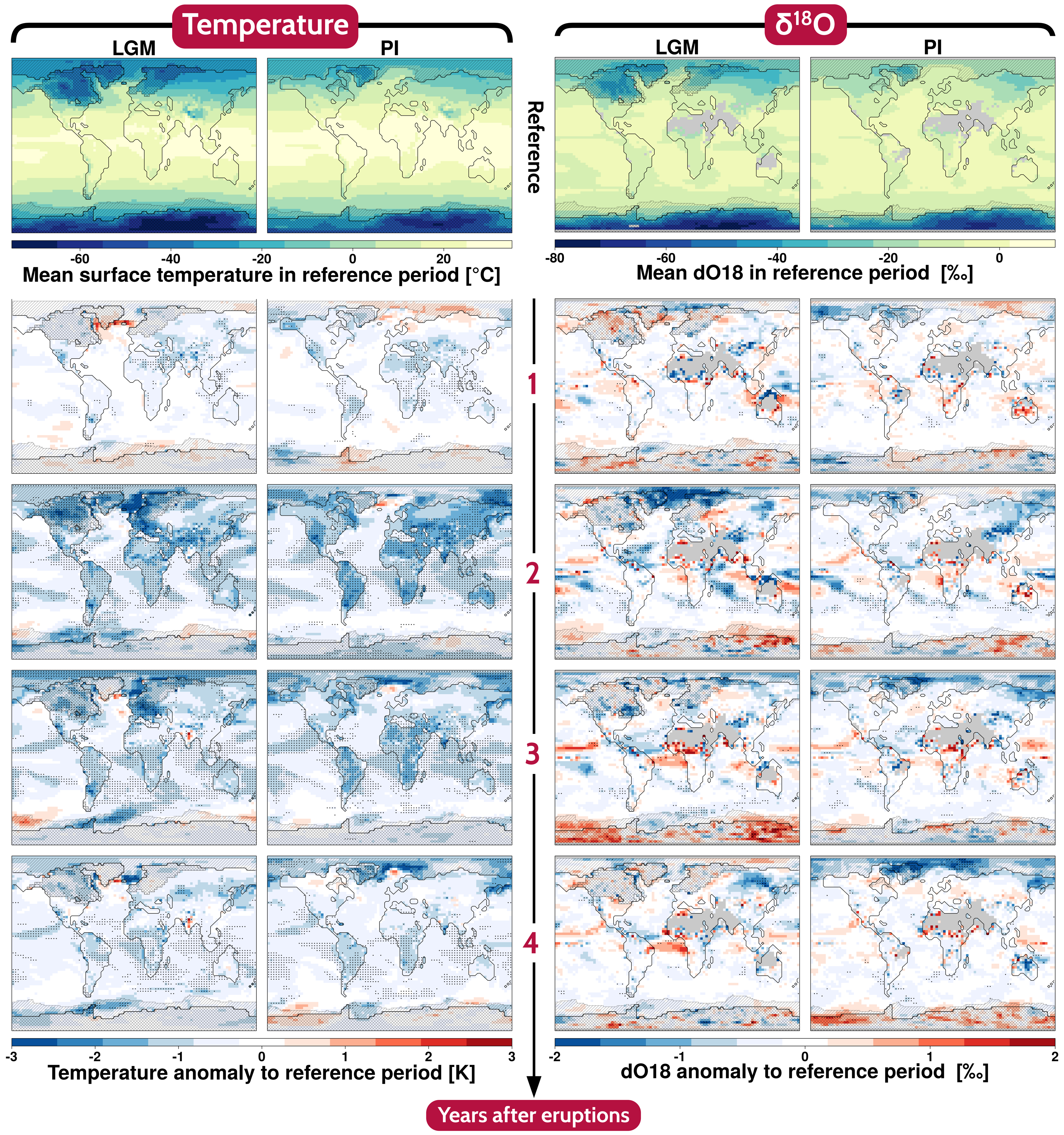
Model: Isotope-enabled GCM (HadCM3)[6]
Land/Ocean res.: 3.75°x2.5°/1.25°x1.25°
19 Levels / 20 Levels
Input: Crowley 2008 (Volcanic)[7], Steinhilber et al. 2009 (Solar)[8], Land-Sea-Mask, Ice Shields, CO_2
Runs: (Un)forced LGM/PI (pre-industrial) (3 runs each)
Time: Output saved monthly for 1000+ years

Eruptions	
1257CE	Samalas
1455CE	Kuwae
1600CE	Huaynap.



Aerosol optical depth (AOD) from volcanic forcing shown with global mean surface temperature (GMST) taken from a forced LGM simulation. Vulcanoes later analyzed in 3 highlighted in gray.

3 What happens after a volcano erupts?

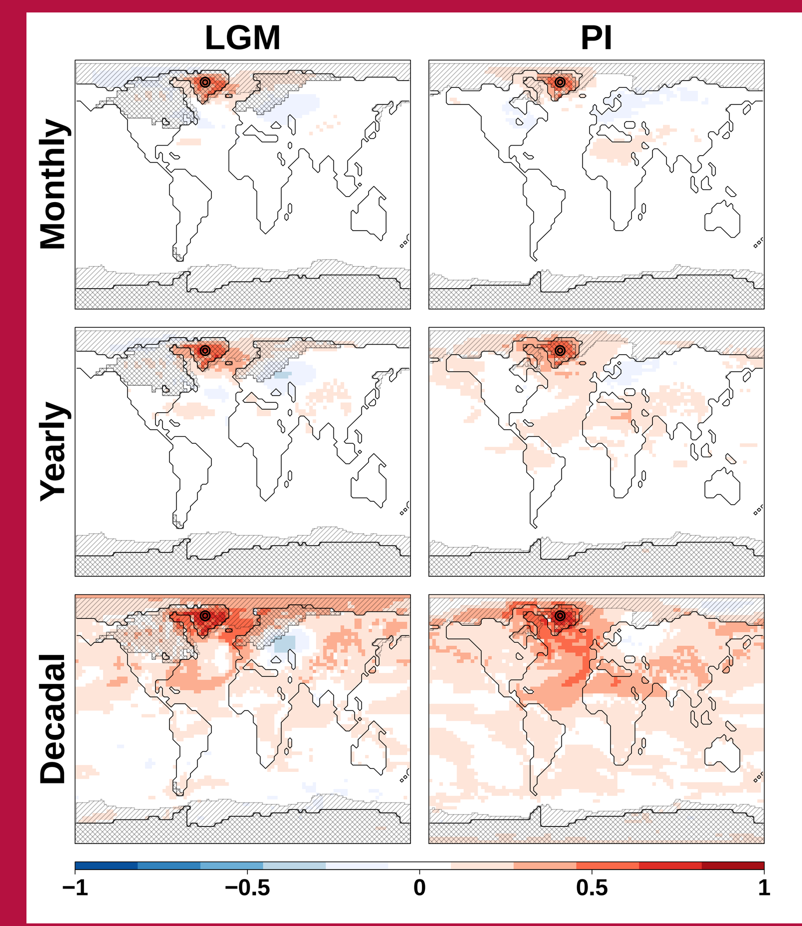


Surface temperature (TAS) and $\delta^{18}O$ anomalies averaged over 9 eruptions (from 3 simulations). Reference period is an average of the three years before each eruption. Gray values are not available due to an insufficient amount of precipitation. Hatched areas indicate ice shields and a greater or equal to 50% yearly coverage of sea ice. Dots indicate anomalies greater than 2σ (w.r.t. the reference period) and a greater than 60% same sign response rate.

➡ On short timescales, local $\delta^{18}O$ response may not be in line with TAS response

4 Results

- Volcanic eruptions resulted in GMST cooling with regional warming near sea ice edge
- $\delta^{18}O$ response around Antarctica different from TAS response
- $\delta^{18}O$ correlation with TAS is spatially limited but reaches global scales for longer timescales
- Even on decadal timescales, there are regional modes that govern $\delta^{18}O$-TAS relationship



Pearson correlation coefficient for TAS time series at each grid box and $\delta^{18}O$ time series near NGRIP ice core drill site (Marked on map). Results shown are from forced simulations, unforced results are highly similar. When time series are smoothed to represent longer time scales (e.g., decadal instead of monthly data), correlation radius increases.

5 Conclusion

$\delta^{18}O$ is a powerful proxy for TAS, however on short time scales, regional modes are still not understood and a major source of uncertainty.

Outlook

- Test correlation between $\delta^{18}O$ and other climatic variables
- Test stationarity assumption

References

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This work used the ARCHER UK National Supercomputing Service (http://www.archer.ac.uk)

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Additional plots