HELMHOLTZ | EGU General Assembly 2020 Online | 4–8 May 2020 | AWI ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

The influence of orbital configurations on Northern Hemisphere ice sheet evolution during MIS 13 with a coupled climate-ice sheet model

Lu Niu, Paul Gierz, Evan J. Gowan, Gerrit Lohmann

Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany

Introduction

Antarctic ice core and deep ocean sediment core records imply that the interglacial climate during Marine Isotope Stage 13 (MIS 13, ~524 to 474 kyr BP) was relatively cold, and ice sheets were likely larger than today (Lisiecki and Raymo, 2005; EPICA Community Members, 2006; Jouzel et al., 2007). The CO_2 values were also relatively low of around 240 ppm. MIS 13 is a long-lasting interglacial that can be divied into three sub-stages (MIS 13a-c), corresponding to marine isotopic events MIS 13.1-13.3. MIS 13.1 is also divided into three sub-stages (with MIS 13.11-13.13). Here we model the MIS 13 climate with a coupled climate-ice sheet model AWI-ESM1.2-LR under different orbital configurations at 495, 506 and 517 kyr BP.

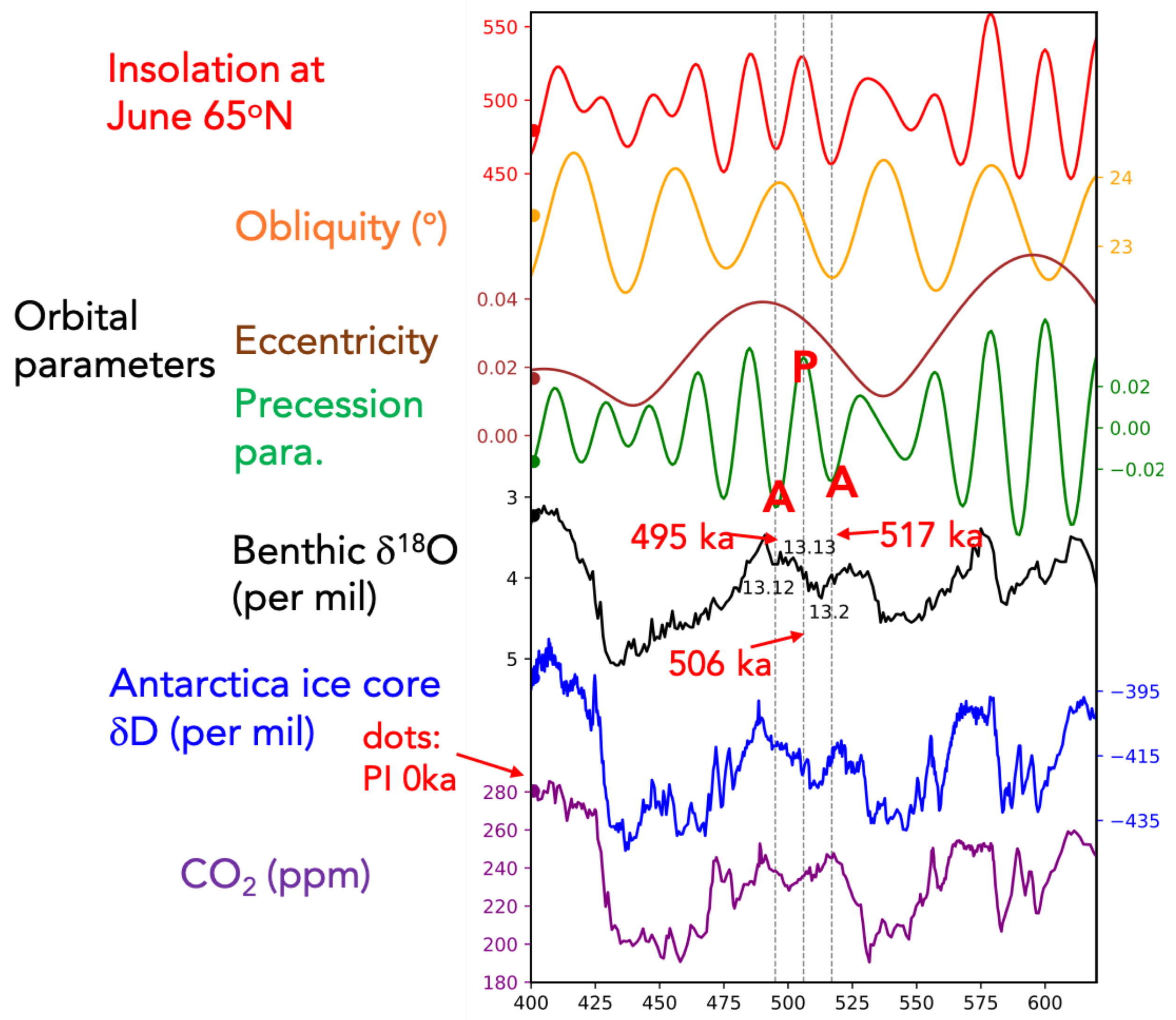


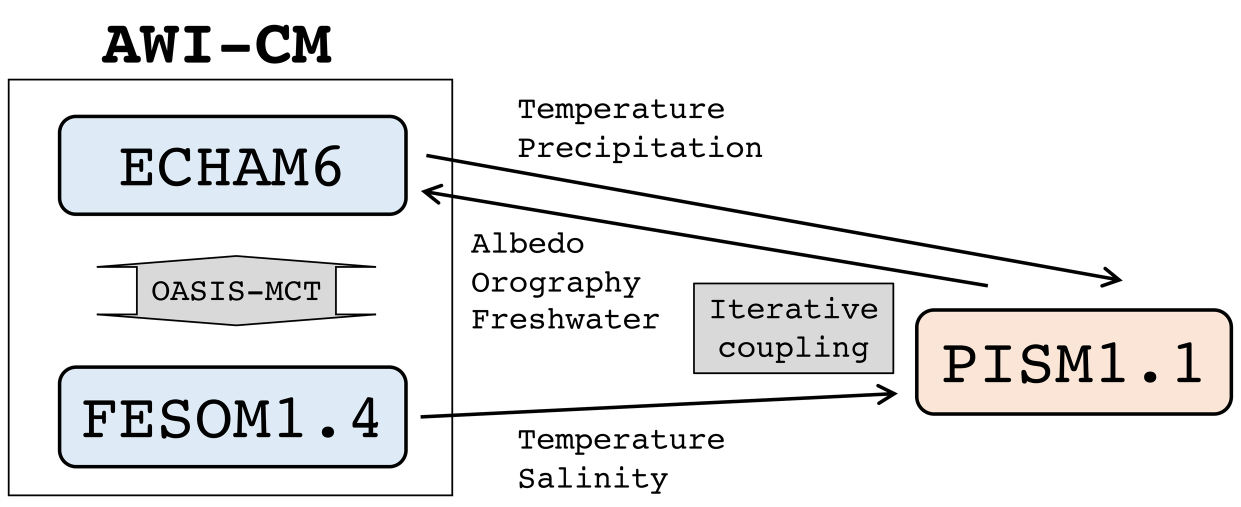
Fig.1 The boreal summer insolation at 65 °N (red). The orbital parameters from Berger (1978): Obliquity (yellow), Eccentricity (brown) and Precession parameter (green). Benthic $\delta^{18}O$ from Lisiecki and Raymo (2005, black). δD from Antarctic ice core (Jouzel et al., 2007, blue). CO_2 record from Hönisch et al. (2009, purple). The dots indicate the respective values for preindustrial (PI).

Experimental design

Table 1 Orbital parameters and greenhouse gases concentrations.

Exp.	Obliquity (°)	Eccentricity	Perihelion (lon, °)	CO_2 (ppm)	CH_4 (ppb)	N_2O (ppb)
PI 0-ka	23.446	0.016724	102.157	280	760	270
495-ka	23.907	0.038638	97.617	240	510	280
506-ka	23.376	0.034046	274.100	240	510	280
517-ka	22.543	0.025640	91.309	240	510	280

The model AWI-ESM1.2-LR



- Asynchronous coupling: 1x100
- Initial condition: present-day ice sheets
- Quasi-equilibrium

Results

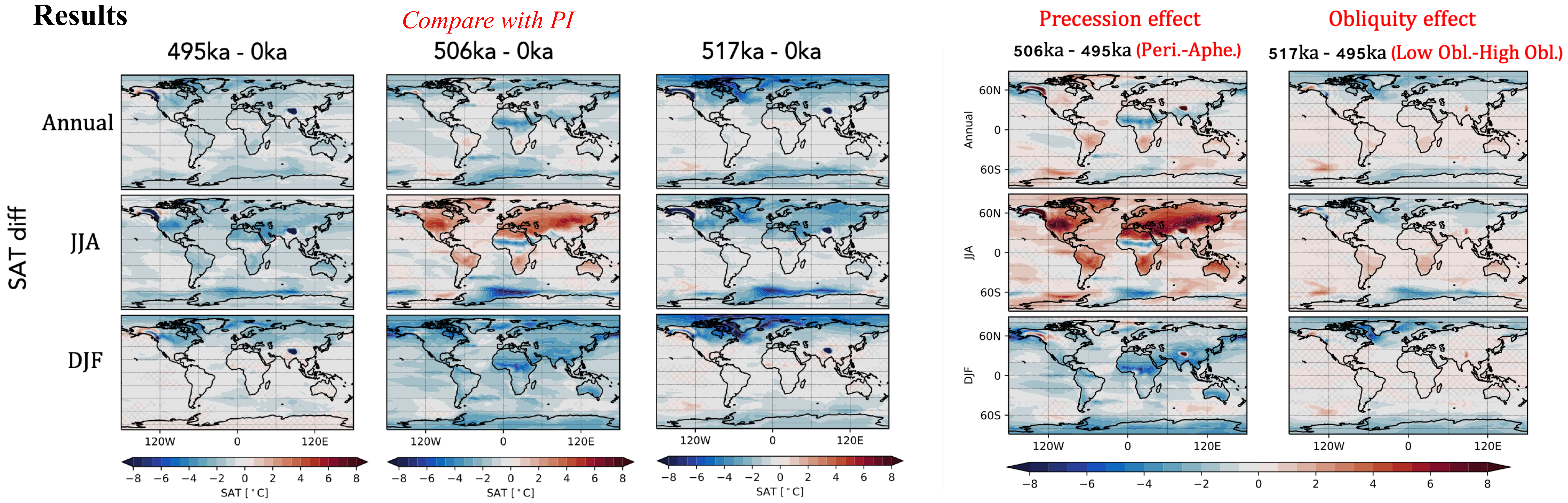


Fig.2-3 The simulated annual mean (Annual), summer (JJA), winter (DJF) surface air temperature (SAT) differences between different experiments.

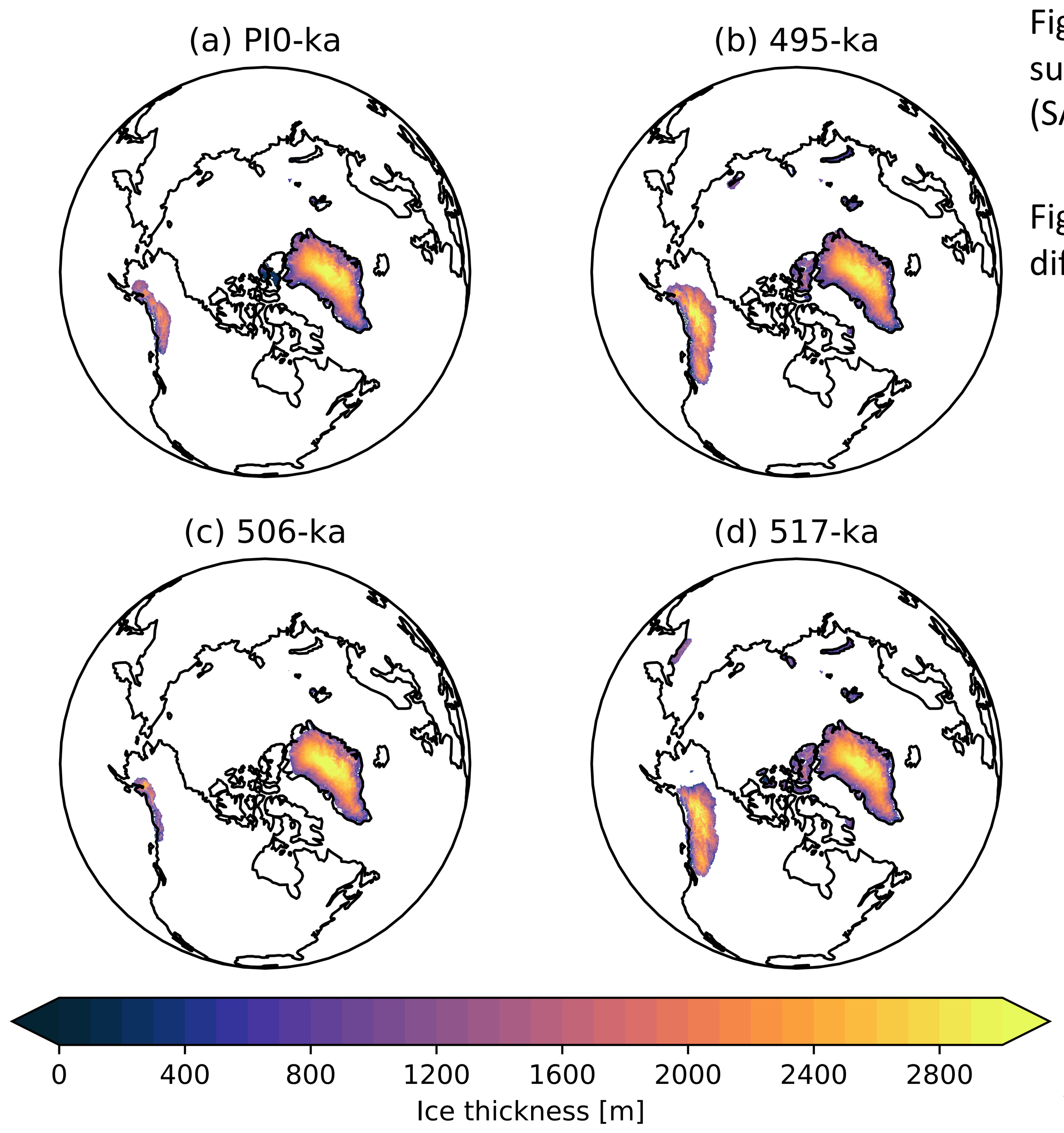


Fig.4 The simulated ice thickness for different experiments.

Table 2 Simulated global mean surface air temperature and Northern Hemisphere ice sheet volume.

Exp. Name	Global mean SAT (°)	NH Ice Volume (m SLE)
PI 0-ka	12.80	~11
495-ka	11.88	~25
506-ka	11.90	~10
517-ka	11.60	~27.5

Conclusions

I. Different astronomical configurations have different influence on Earth's climate:
   a) Boreal summer at perihelion → warmer NH summer → NHIS decrease;
   b) Lower obliquity → cooling over polar, high elevation regions → NHIS increase

II. The Cordilleran Ice Sheet is more sensitive and has a faster response to boreal summer insolation change than the other large scale Northern Hemisphere ice sheets. This indicates that different ice sheets might have different development processes.

III. No ice sheets build up over northeastern North America and Eurasia in our simulations. Probably because of the multi-stability of the ice sheets which could be a reason for causing this phenomenon.

Berger, A., 1978. Long-term variations of daily insolation and Quaternary climatic changes. Journal of the Atmospheric Sciences 35, 2362-2367.
Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic 18O records. Paleoceanography 20.
EPICA Community Members, 2006. One-to-one coupling of glacial climate variability in Greenland and Antarctica. Nature 444, 195-199.
Jouzel, J., Masson-Delmotte, V., Cattani, O., Dreyfus, G., Falourd, S., Hoffmann, G., Minster, B., Nouet, J., Barnola, J.M., Chappellaz, J., et al., 2007. Orbital and millennial Antarctic climate variability over the past 800,000 years. science 317, 793-796.

Federal Ministry of Education and Research