Stable water isotopes in paleoclimate simulations – results from the ECHAM5/MPI-OM and MPI-ESM model

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Scientific Goals & Methods

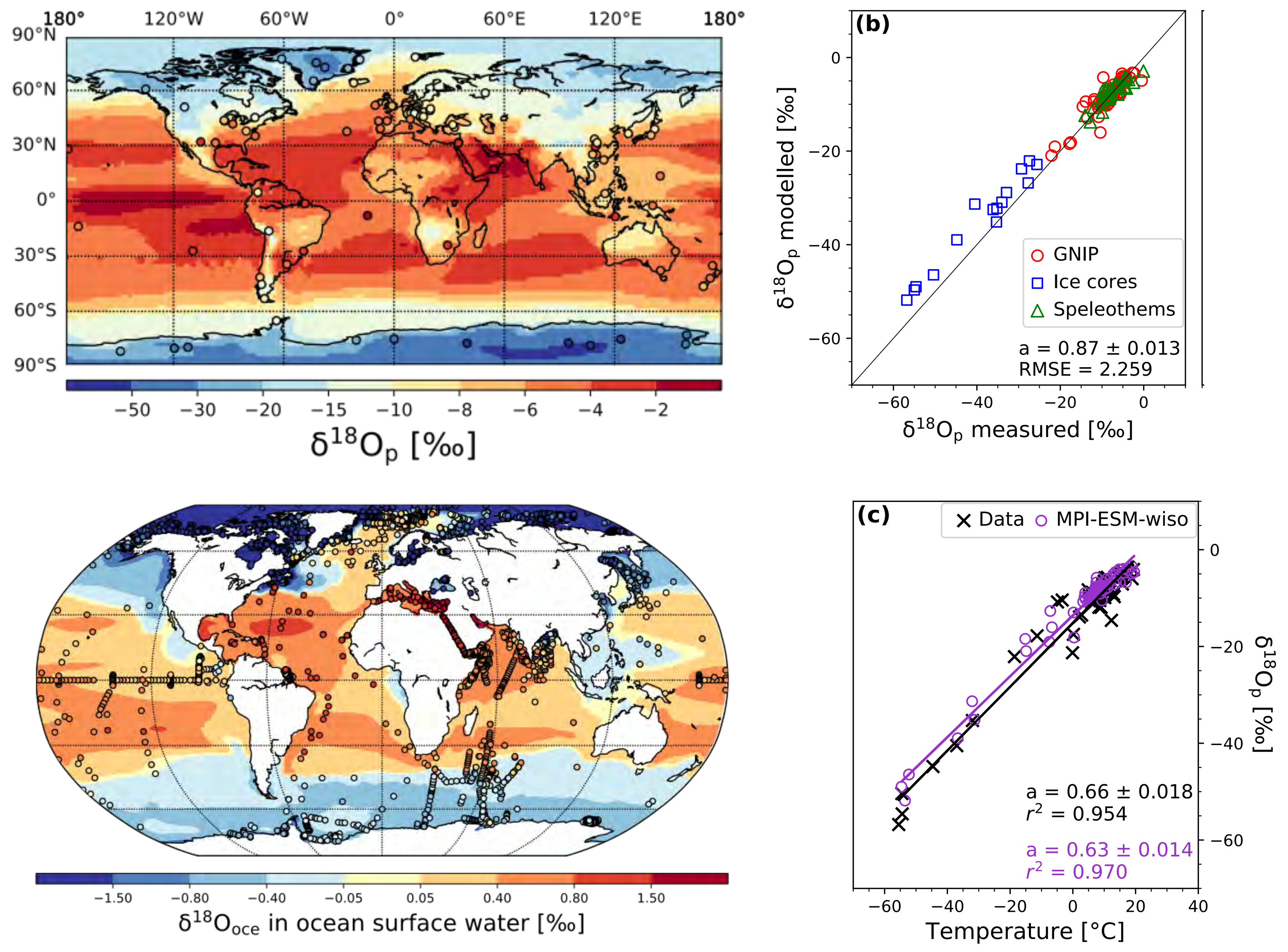
Summary

- The explicit modelling of stable water isotopes ($H_2{}^{18}O$, $HD^{16}O$) in complex climate models (GCMs) is one way to improve our understanding of the mechanisms controlling the water isotopes distribution in link with the variations of climate and to evaluate the GCM model performance.
- Here, we present simulation results using two different GCMs with explicit isotope diagnostics, run under pre-industrial (PI), mid-Holocene (6k), last glacial maximum (LGM, 21k), and last interglacial (LIG, 125k) conditions.

Methods

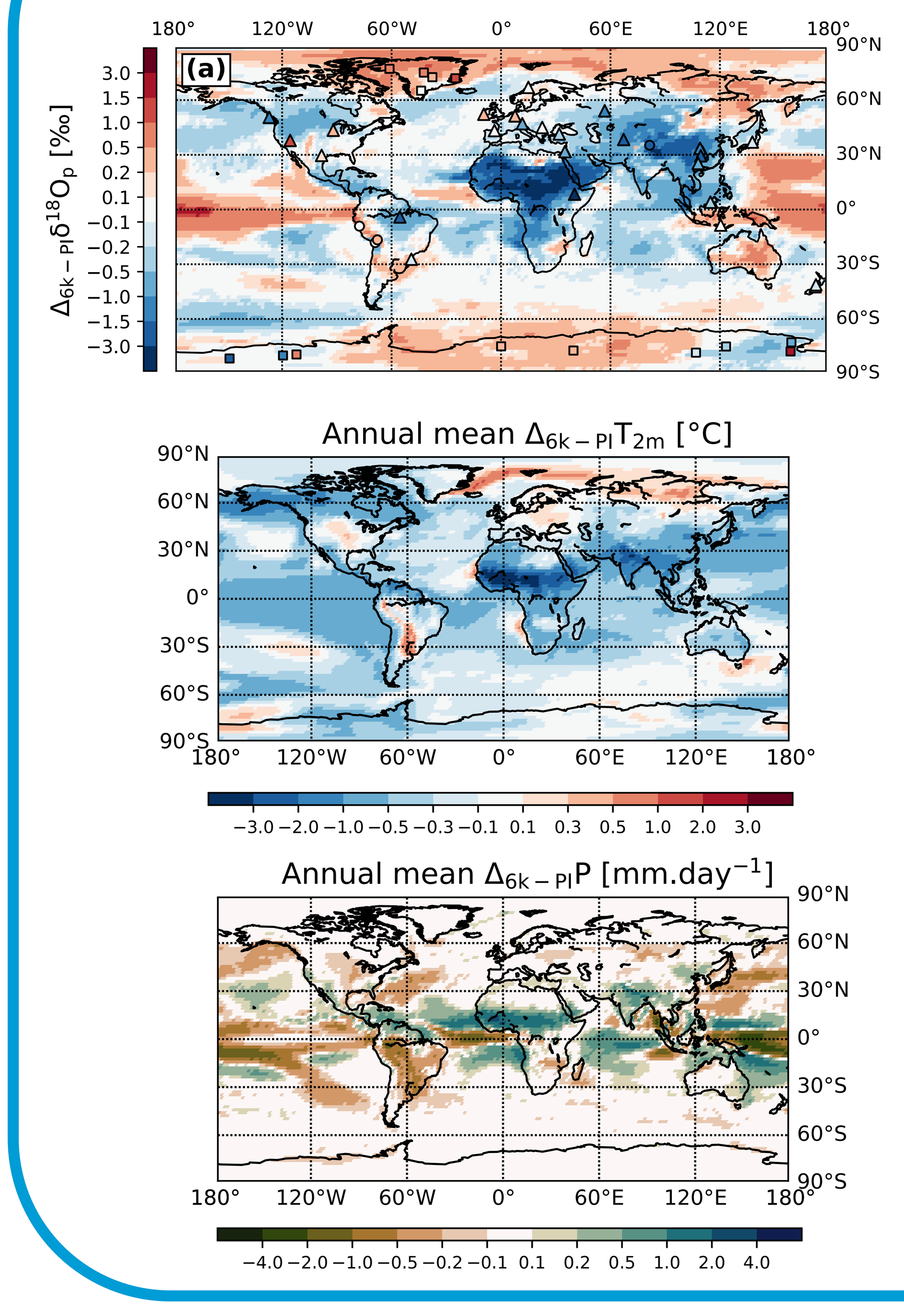
- $H_2{}^{18}O$ and $HD^{16}O$ have been incorporated in all parts of the hydrological cycle of the coupled models ECHAM5/MPI-OM and MPI-ESM.
- Paleoclimate simulations have been performed in accordance with the PMIP3 (for LGM, LIG) and PMIP4-CMIP6 (for 6K) protocols.
- ECHAM5/MPI-OM resolution
  - atmosphere: horizontal grid size 3.8°x3.8°, 19 vertical levels (T31L19)
  - ocean: bipolar grid, 3° near the equator, 40 z-levels (GR30L40)
- MPI-ESM resolution
  - atmosphere: horizontal grid size 1.9°x1.9°, 47 vertical levels (T63L47)
  - ocean: bipolar grid, 1.5° near the equator, 40 z-levels (GR15L40)

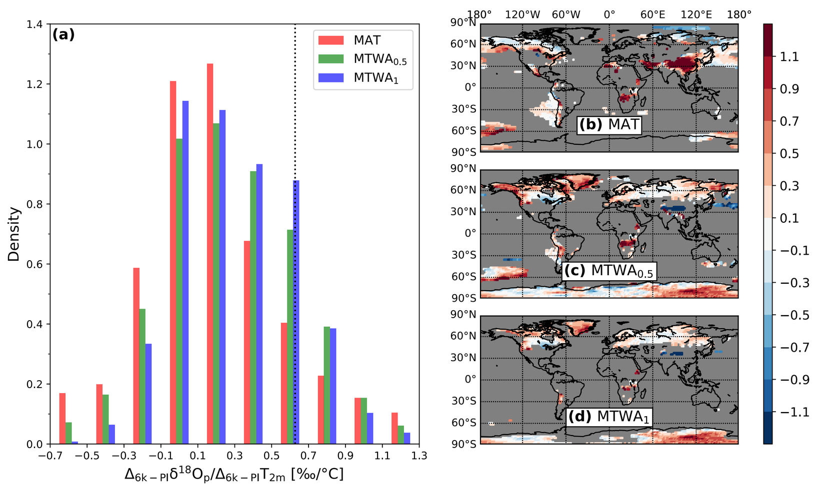
Pre-Industrial Climate



all plots: Cauquoin et al., CP, 2019

Mid-Holocene (6K)





δ18O-T-gradients in polar regions:

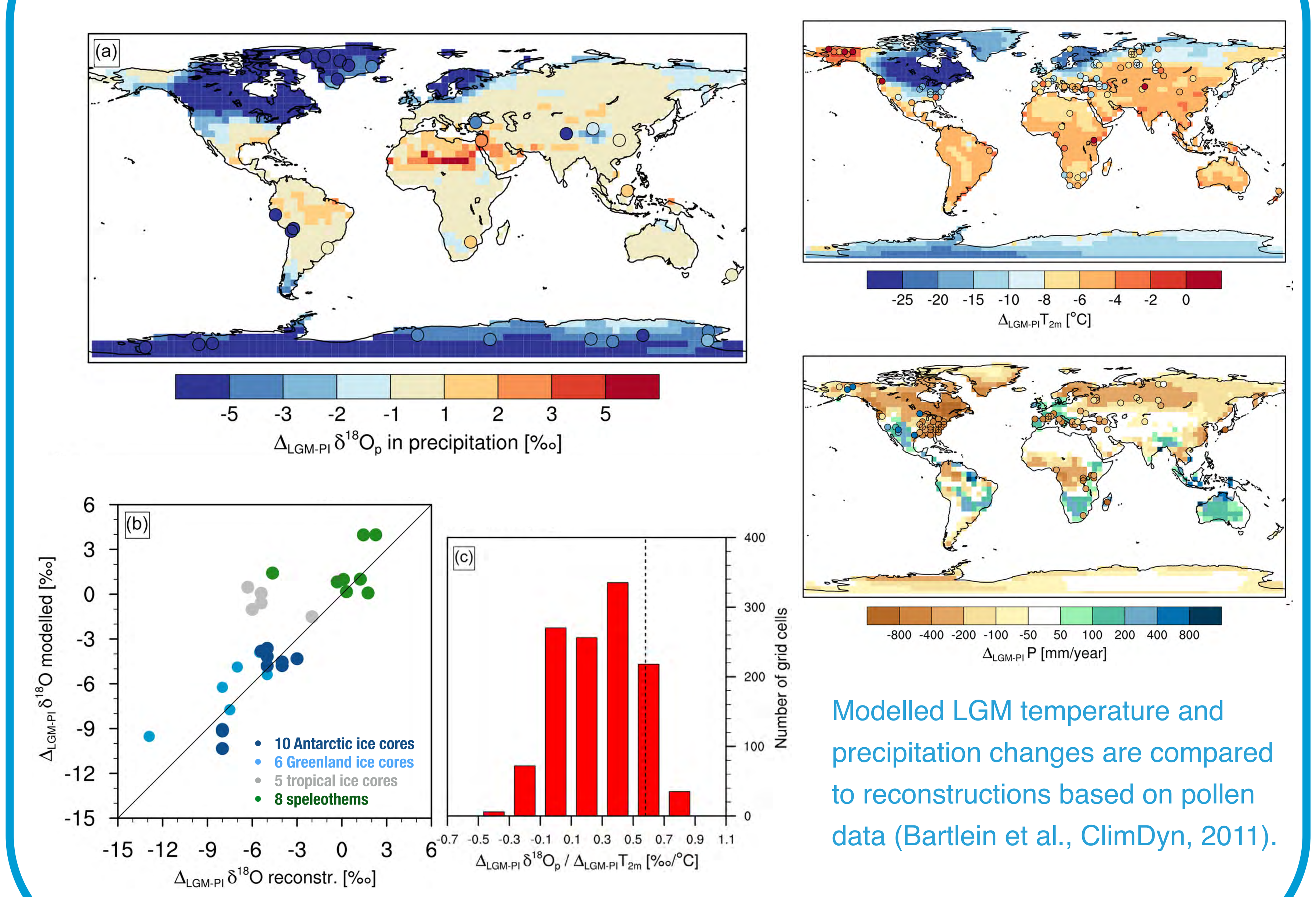
MAT:
6k temperature changes very low, both in Greenland and East Antarctica

MTWA - 0.5°C cutoff:
Greenland: 0.39 ‰/°C
East Antarctica: 1.05 ‰/°C

MTWA - 1°C cutoff:
Greenland: 0.60 ‰/°C
East Antarctica: 0.54 ‰/°C

all plots: Cauquoin et al., CP, 2019

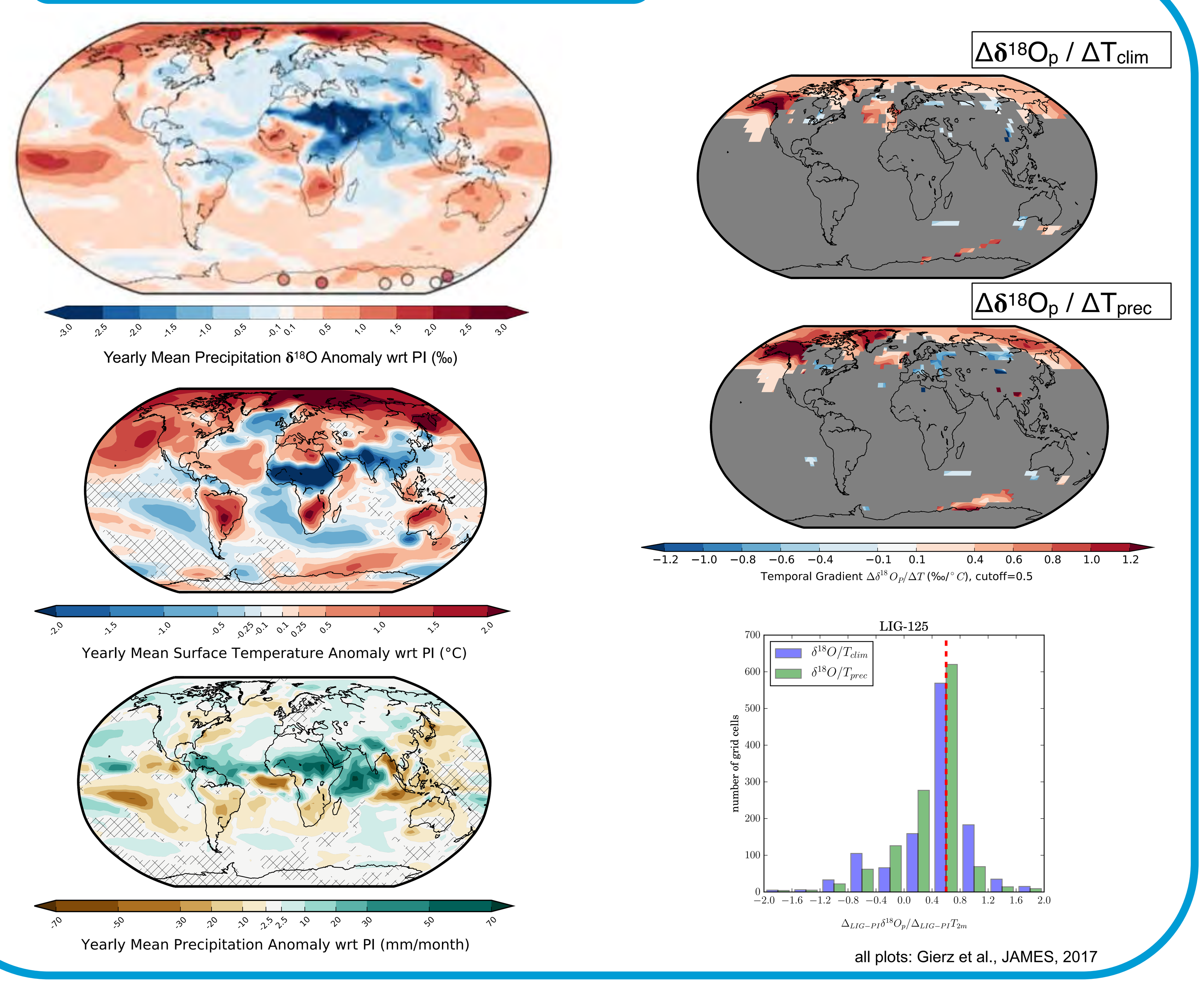
Last Glacial Maximum (LGM)



Modelled LGM temperature and precipitation changes are compared to reconstructions based on pollen data (Bartlein et al., ClimDyn, 2011).

all plots: Werner et al., GMD, 2016

Last Interglacial (LIG, 125k)



all plots: Gierz et al., JAMES, 2017

Results & Conclusions

Results

- Simulation results of both isotope-enabled GCMs agree well with modern observations of δ18O and δD on a global scale.
- Comparison of ice core and speleothem records with simulation results reveals a good model-data agreement in many places for the mid-Holocene (6k), LGM (21k), and last interglacial (LIG, 125k) climate.
- Temporal isotope-temperature relationships are spatially variable for all three investigated periods, and in many locations the temporal gradients are lower than the modern spatial ones.

Conclusions

- For the LGM, δ18O changes in precipitation are dominated by the glacial cooling, but the temporal δ18O-T gradient is substantially lower than the present-day spatial one for most mid- to high-latitudinal regions.
- For the 6K and LIG climate, simulated temperature changes are small in many regions, and temperature-independent processes dominate past δ18O and δD changes in precipitation.

References
- Cauquoin, A., Werner, M. and Lohmann, G.: Water isotopes - climate relationships for the mid-Holocene and pre-industrial period simulated with an isotope-enabled version of MPI-ESM, Clim. Past, 1–38, doi:10.5194/cp-2019-72, in review, 2019.
- Gierz, P., Werner, M. and Lohmann, G.: Simulating climate and stable water isotopes during the Last Interglacial using a coupled climate–isotope model, J. Adv. Model. Earth Syst., 9(8), 624, doi:10.1002/2017MS001056, 2017.
- Werner, M., Haese, B., Xu, X., Zhang, X., Butzin, M. and Lohmann, G.: Glacial–interglacial changes in H218O, HDO and deuterium excess – results from the fully coupled ECHAM5/MPI-OM Earth system model, Geosci. Model Dev., 9(2), 647–670, doi:10.5194/gmd-9-647-2016, 2016.

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