Explicit simulation of $\delta^{18}O$ and δD changes in atmosphere and ocean induced by a freshwater hosing

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Objectives

Here, we report results of a set of idealised freshwater hosing (FWH) experiments performed with the fully-coupled ECHAM5/MPI-OM model, enhanced by explicit water isotope diagnostics.

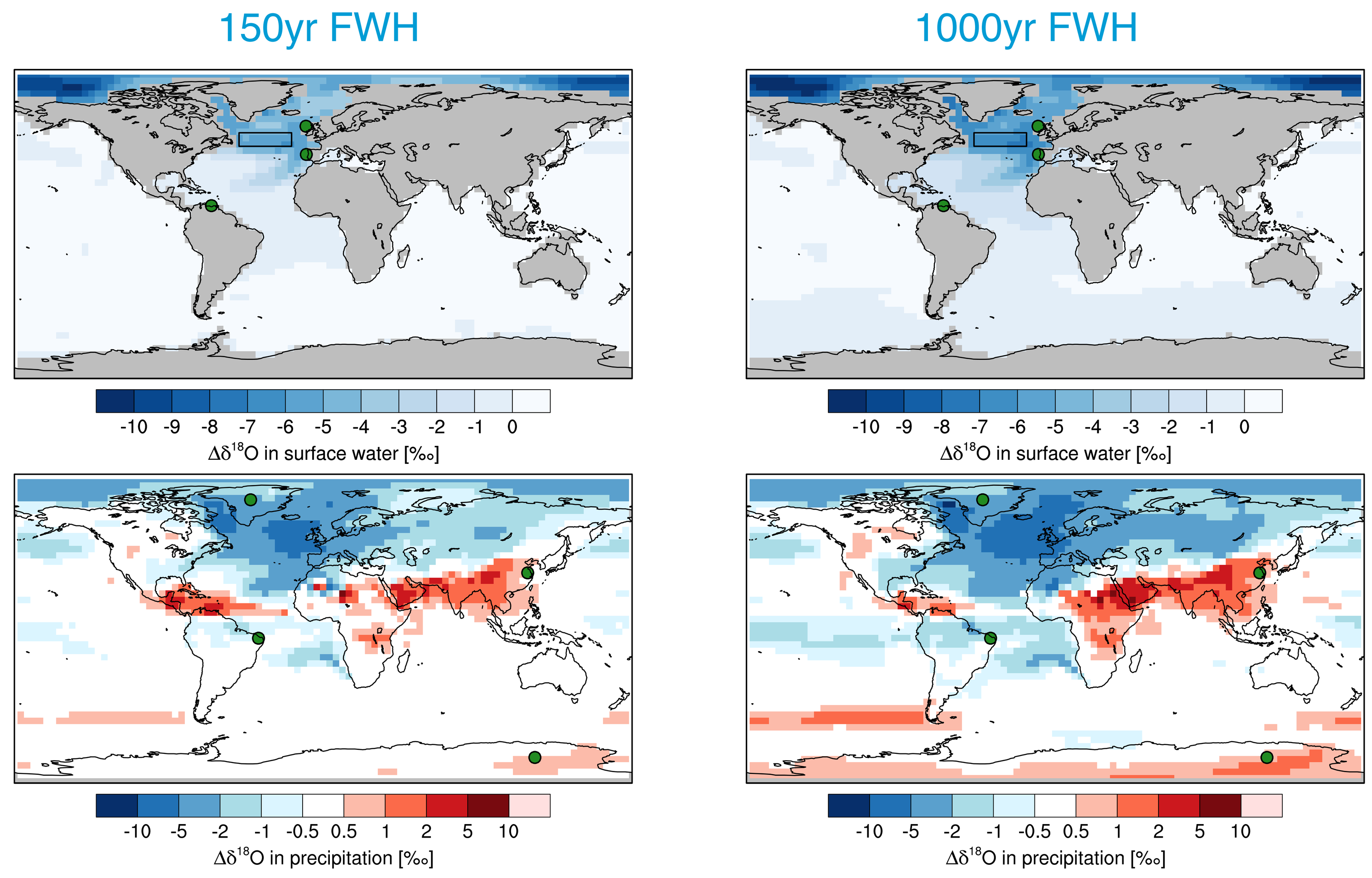
The aim of the study is an improved understanding regarding changes of the water isotope signals in various paleoclimate archives during FWH events in the North Atlantic, which may be seen as an idealised surrogate for Heinrich events during the last glacial.

We analyse both the strength of simulated isotope changes in precipitation and ocean waters as well as related changes of climate variables, e.g. temperature, precipitation amount, salinity.

Model & Methods

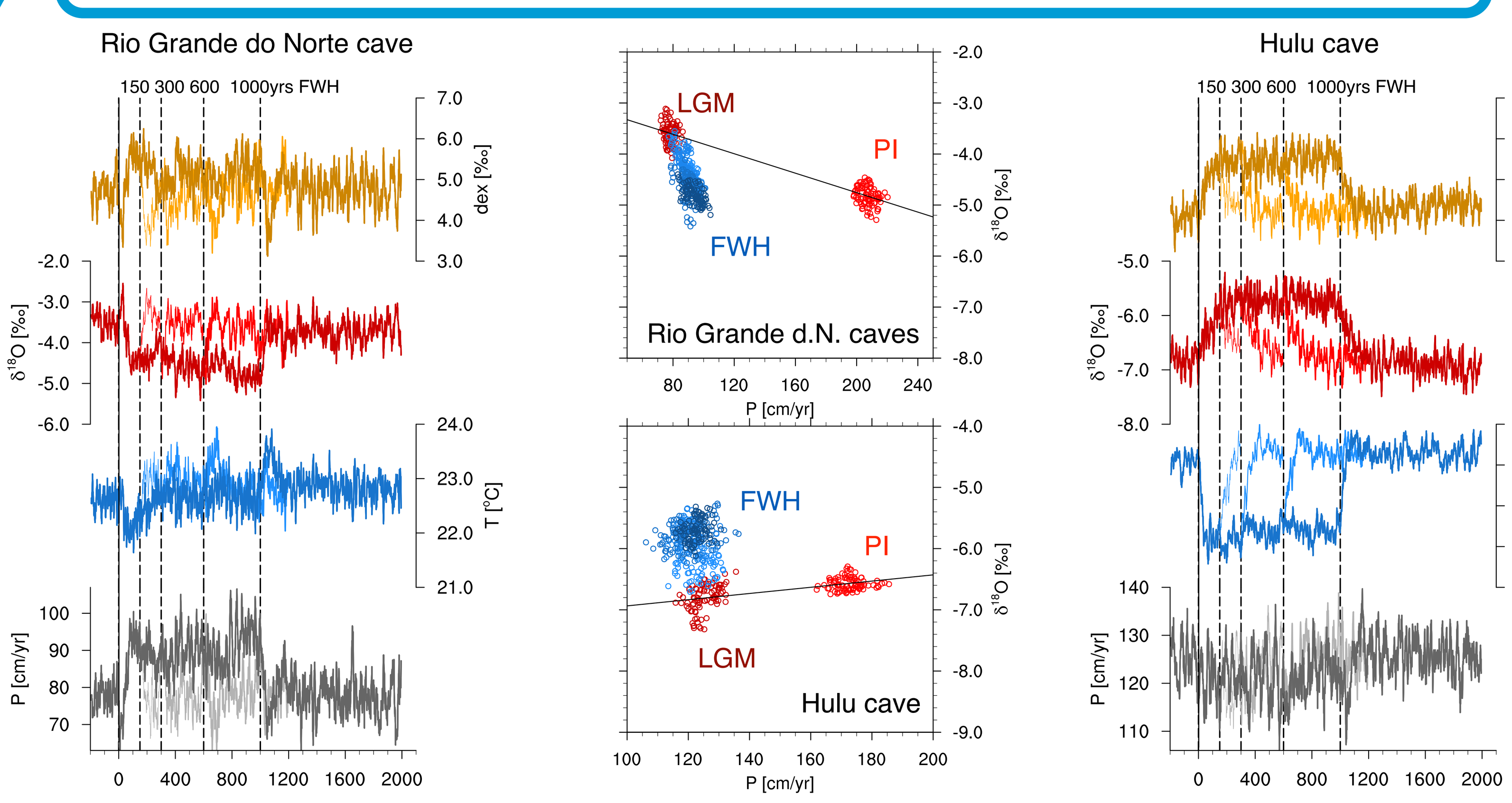
- coupled ocean-atmosphere model ECHAM5/MPI-OM with $H_2^{18}O$ and HDO fully included in the hydrological cycle of all model components (atmosphere, ocean, land biosphere)
- atmosphere: horizontal model resolution of approx. 3.8°x3.8°, 19 vertical levels
  ocean: formal horizontal resolution of approx. 3°x1.8° (refinement at poles), 40 vertical levels
- Last glacial maximum (LGM) greenhouse gases, ice sheets, sea level and orbital parameters are set in accordance with the PMIP3 protocol
- LGM and pre-industrial (PI) simulation have both been run into equilibrium
- 4 FWH experiments are performed starting from the LGM background state: freshwater input into the North Atlantic for 150yrs, 300yrs, 600yrs, and 1000yrs (0.2Sv for all simulations)

Changes of $\delta^{18}O$ in precipitation and surface waters



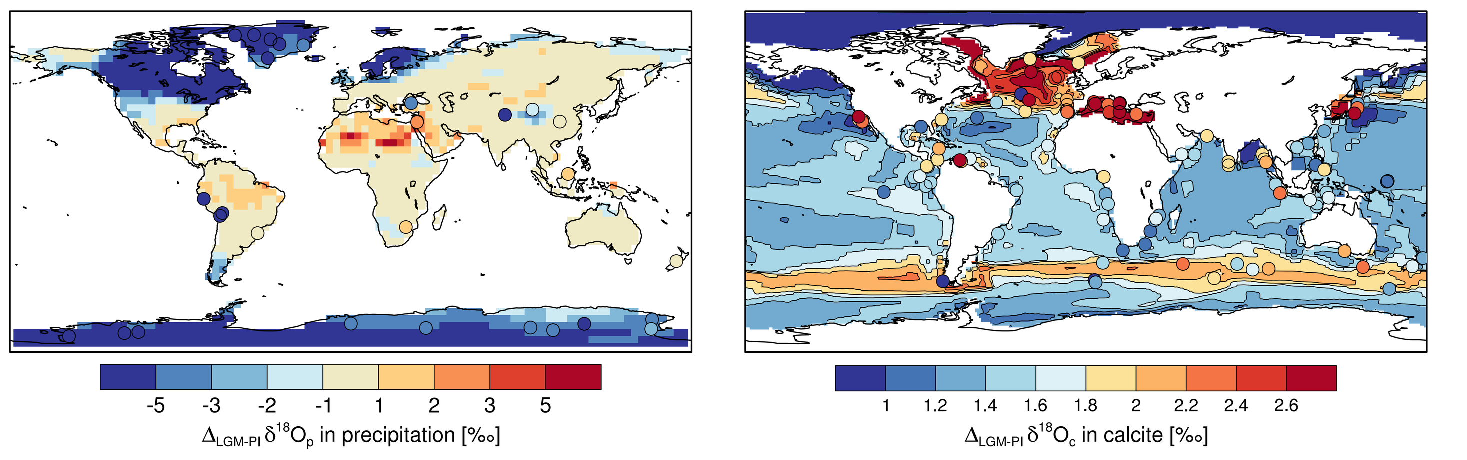
For the FWH, a strongly depleted isotopic value ($\delta^{18}O_{meltwater}$ = -30‰) is assumed. This leads to a depletion of down to -10‰ of $\delta^{18}O_{oce}$ in surface waters of the North Atlantic and Arctic Sea. The pattern of depletion is only slightly enlarged between 150yrs and 1000yrs of FWH. For $\delta^{18}O$ in precipitation, positive isotope anomalies are caused by a shift in the ITCZ. These are partly counterbalanced by a negative $\delta^{18}O_{oce}$ source change, e.g. for precipitation over Central America.

(Sub)tropical change of $\delta^{18}O$, temperature and precip.



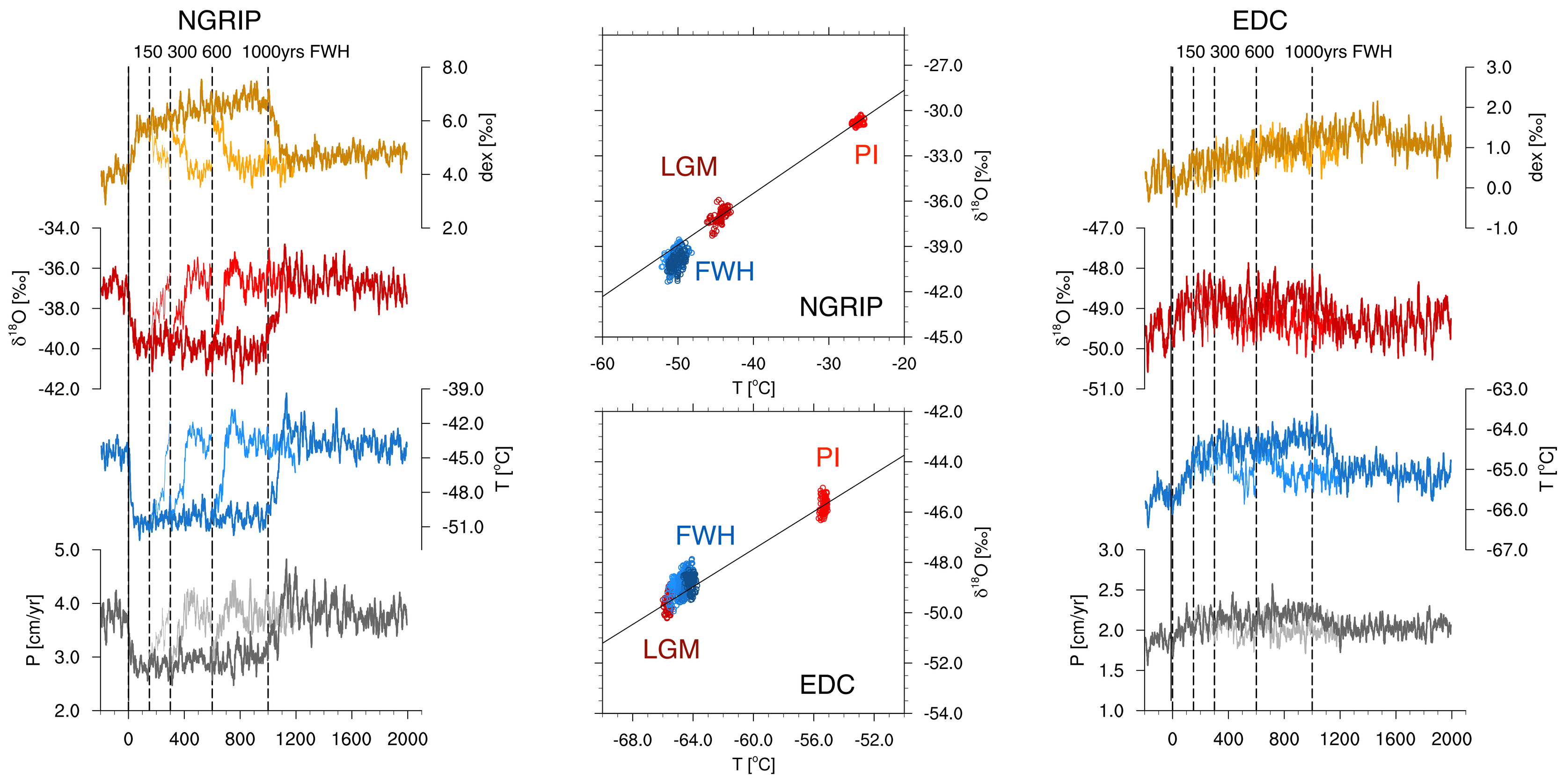
For Northeastern Brasil (Rio Grande do Norte cave) a clear drop of $\delta^{18}O_p$ in precipitation is seen for the FWH experiments. It correlates with a change of the precipitation amount, and both changes scale with the duration of the FWH.
For eastern China (Hulu cave), an increase in $\delta^{18}O_p$ during FWH is modelled. As the precipitation amount stays constant, the $\delta^{18}O_p$ increase might indicate a change of water transport pathways.

Simulated LGM climate



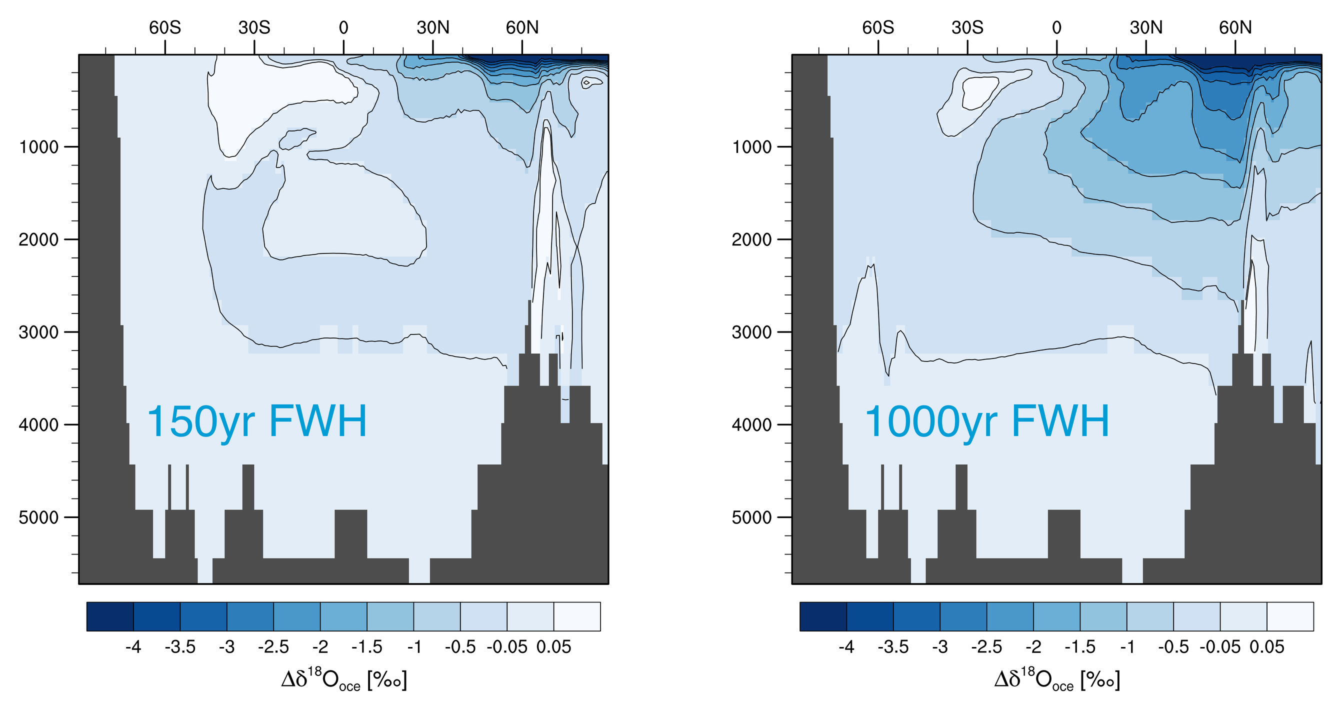
The simulated cooler LGM climate leads to strong depletion of $\delta^{18}O_p$ in precipitation over both polar regions, and a minor change in some (sub)tropical regions. For the modelled $\delta^{18}O_{calc}$ in marine calcite, largest positive anomalies are found in the North Atlantic and Mediterranean Sea. Simulation results agree well with available measurements (see Werner et al., GMD, 2016, for details).

North-South coupling of $\delta^{18}O$, temperature and precip.



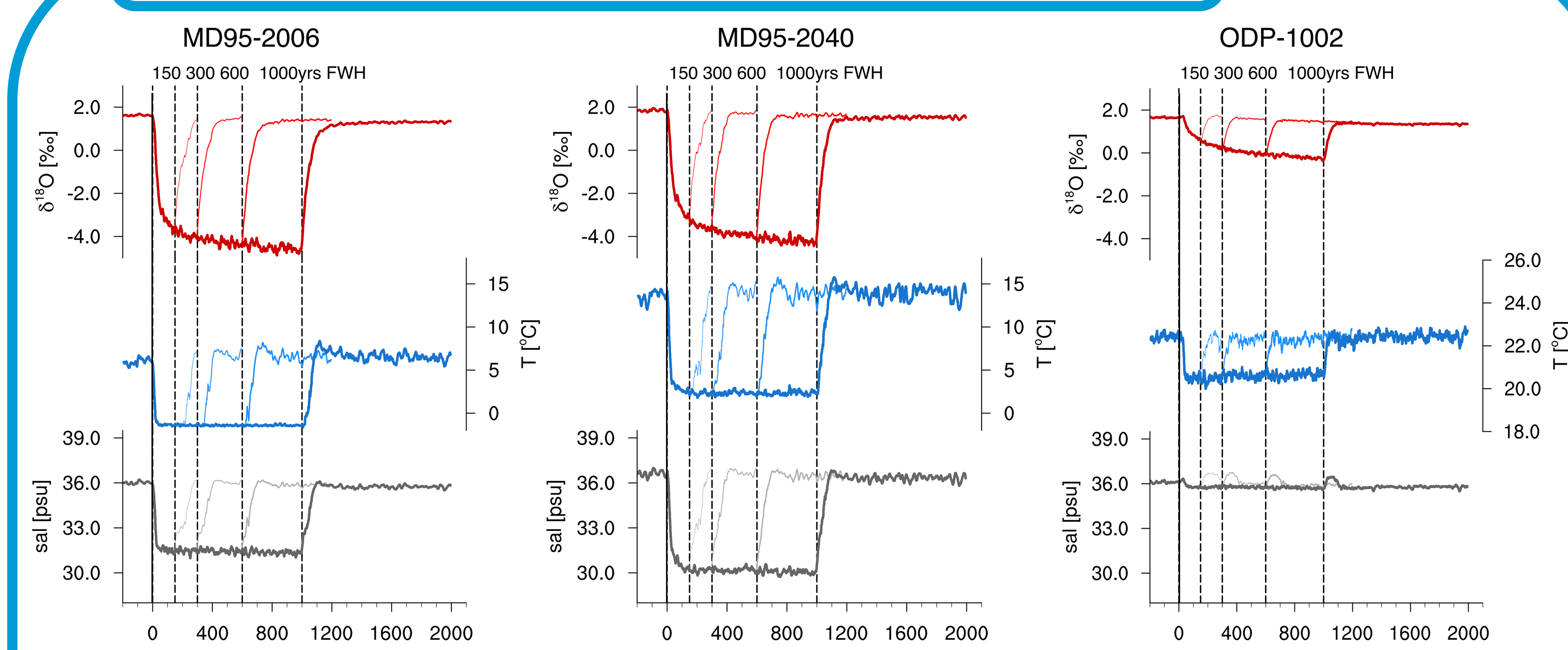
For central Greenland, the FWH leads to a temperature drop of approx. 5°C to 7°C. This is accompanied by a $\delta^{18}O_p$ change of -3‰ to -4‰. Part of this depletion is not temperature-related, but caused by the changed Atlantic $\delta^{18}O_{oce}$ values.
For East-Antarctica, a warming of up to +2°C is simulated, lagging the Greenland cooling by 200-300yrs. The associated $\delta^{18}O_p$ changes for EDC are rather small (approx. +0.5‰ to +1.0‰) and less then observed in the EDC ice core.

Changes of $\delta^{18}O$ in the Atlantic basin



Meridional section of the simulated $\delta^{18}O$ values in the Atlantic basin. The zonal mean values (averaged from 60° to 0° W) reveal a north-south transport of the $\delta^{18}O$ meltwater signal at depths between 2000-3000m. A much stronger depletion in $\delta^{18}O$ is clearly seen for deeper water layers for the long 1000yrs FWH experiment.

Correlation of $\delta^{18}O$, temperature & salinity



Simulated changes of $\delta^{18}O_{oce}$, ocean temperatures between 0-50m, and related salinity changes at 3 positions in the North Atlantic. A strong temperature-$\delta^{18}O_{oce}$ correlation is found at all three locations.

Reference
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.