Assimilating global δ^{18}O data into the MIT general circulation model

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1. Introduction & Motivation

- Combining ocean general circulation models with observational data via data assimilation is a powerful means to obtain more reliable estimates of the ocean's state.
- We used the adjoint method to assimilate global temperature, salinity and δ^{18}O data to estimate the state of the global modern ocean.
- The ability to simulate stable water-isotopes and hence the possibility to directly assimilate δ^{18}O opens a wide perspective for paleo-oceanographic studies, as δ^{18}O from calcite shells of foraminifera belongs to the most abundant proxies for the past ocean state.

2. Material and Methods

MITgcm

- coupled ocean - sea-ice general circulation model
- "cubed-sphere" grid with approx. 2.8 ° horizontal resolution, 15 vertical levels
- enabled with **water isotope package** including fractionation processes during evaporation

Adjoint method

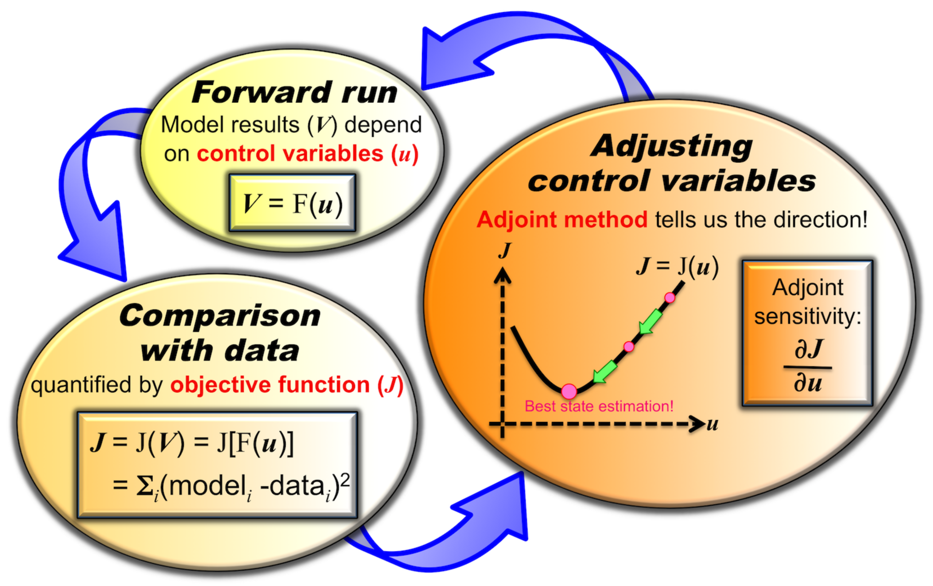

Figure 1 : The adjoint method for variational data assimilation reduces an objective or cost function by adjusting control variables. Courtesy of T. Kurahashi-Nakamura.

Control Variables

- initial conditions for salinity, temperature, $H_2^{16}O$ and $H_2^{18}O$
- boundary conditions (six types of atmospheric forcing and isotopic ratios in precipitation and water vapor)
- vertical diffusion coefficient

Assimilated data

Temperature - monthly means from 1950 - 1980 climatology, World Ocean Atlas database, Locarnini et al. (2010)

Salinity - monthly means from 1950 - 1980 climatology, World Ocean Atlas database, Antonov et al. (2010)

$\delta^{18}O_{sea\text{-}water}$ - monthly means, NASA GISS Global Seawater Oxygen-18 database, Schmidt et al. (1999)

3. Results

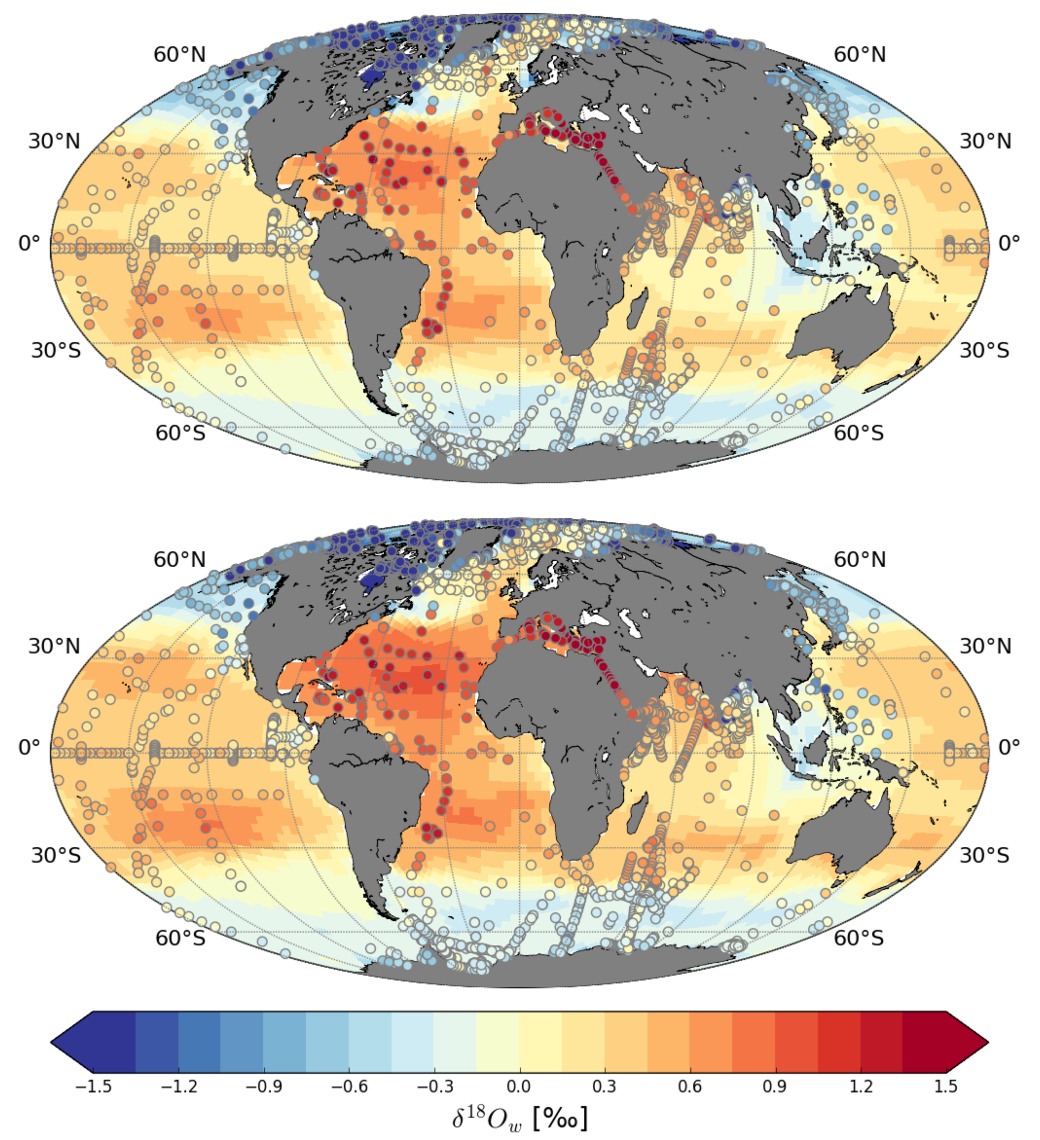

Figure 2 : Simulated surface $\delta^{18}O_w$ from our "first guess" forward run without data constraint (upper panel) and our 200-year optimized run (lower panel) and assimilated GISS $\delta^{18}O_w$ data (circles).

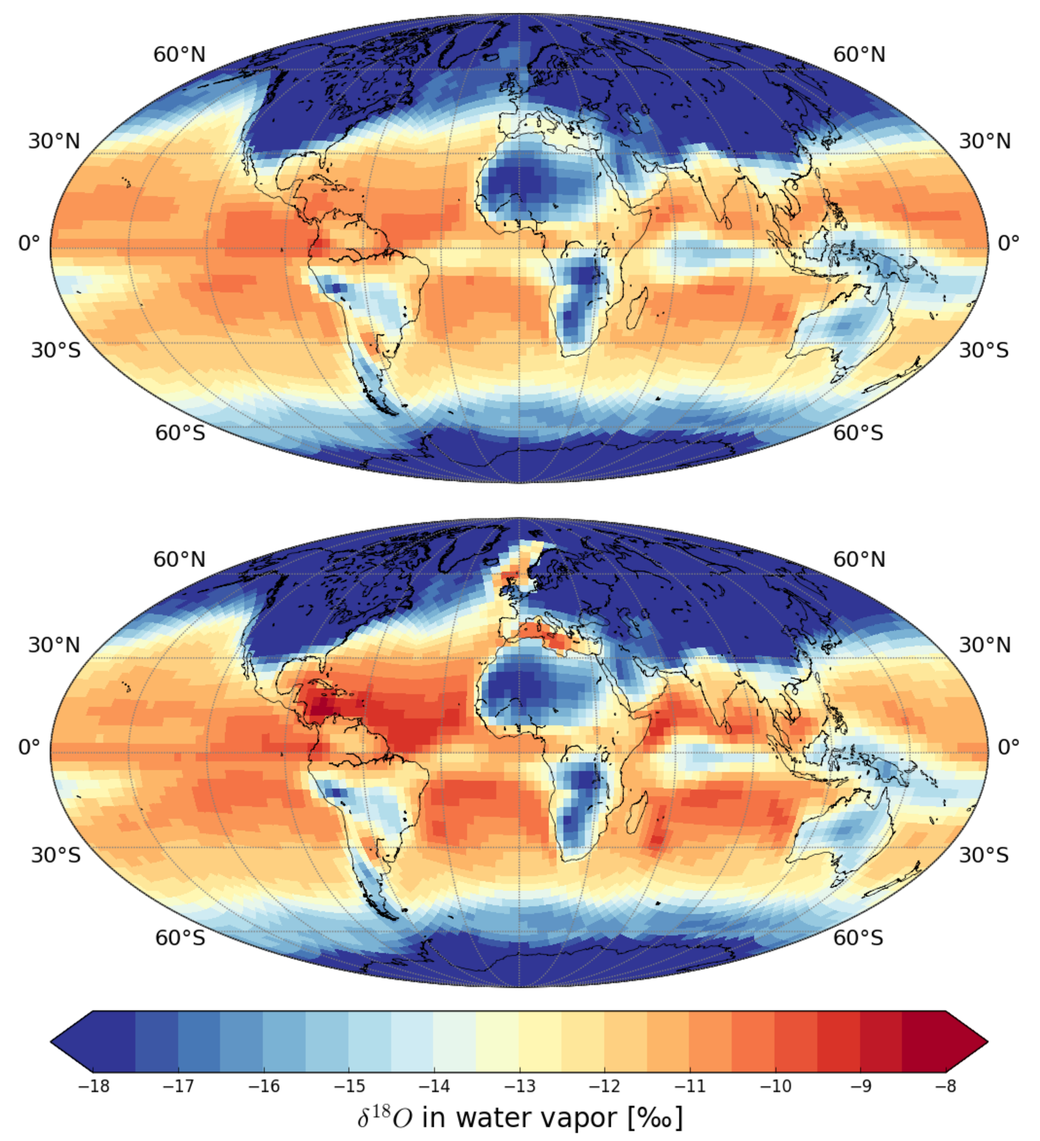

Figure 3 : Adjustment of control variable δ^{18}O in water vapor. Original (upper panel) from the National Center for Atmospheric Research Community Atmosphere Model (Tharammal et al., 2013) and adjusted (lower panel).

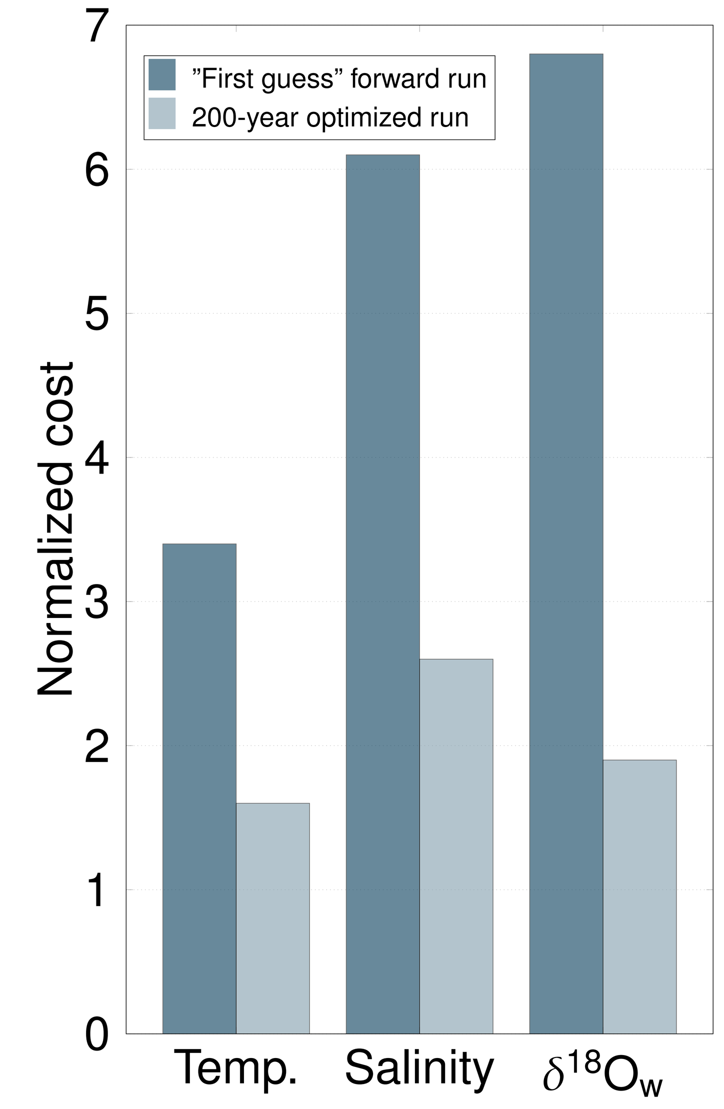

Figure 4 : Reduction of the normalized cost (= cost function / number of model-data comparisons) during the optimization for the different data types.

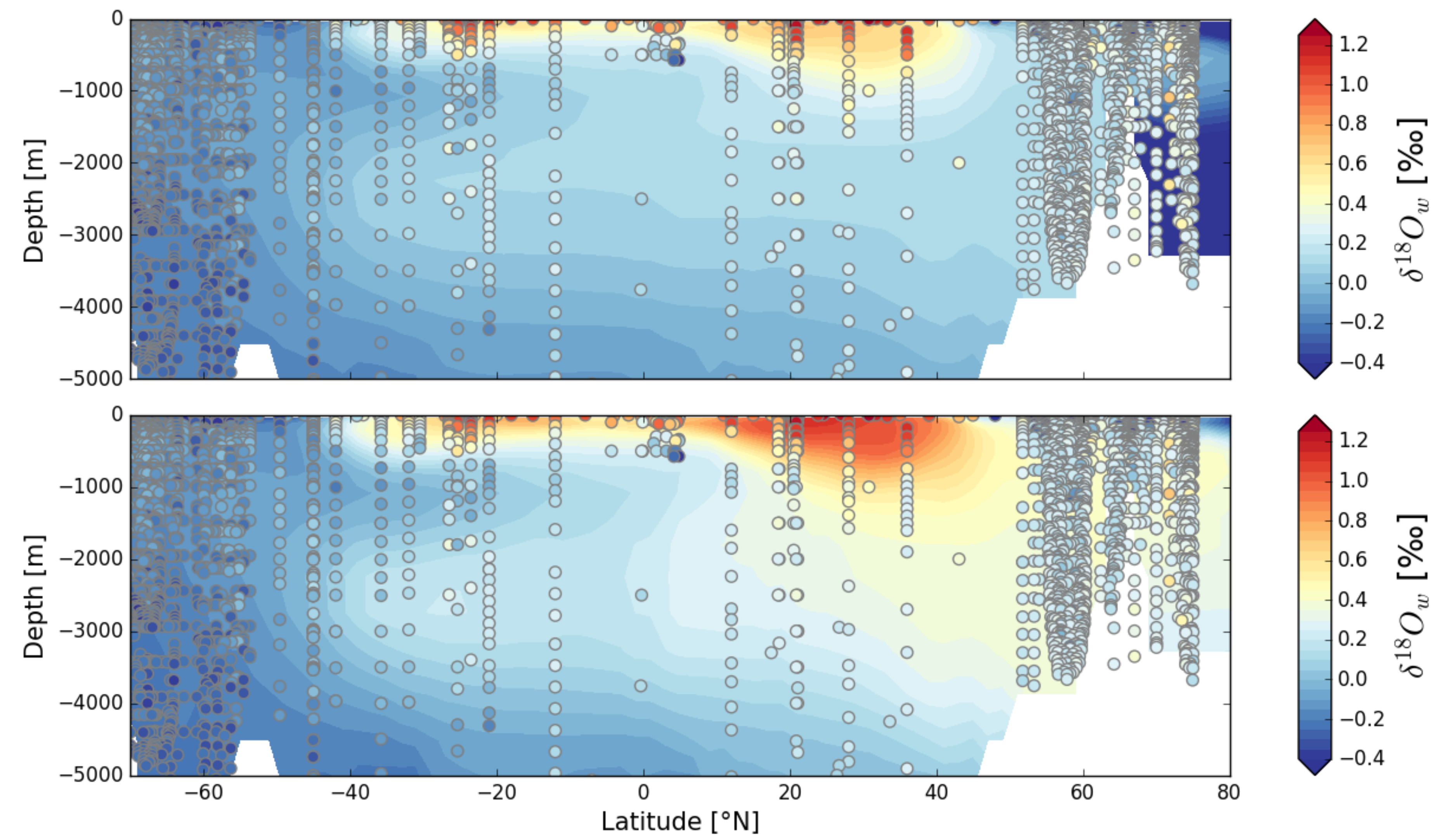

Figure 5 : Zonal mean of simulated $\delta^{18}O_w$ from our "first guess" forward run without data constraint (upper panel) and our 200-year optimized run (lower panel) and assimilated GISS $\delta^{18}O_w$ data (circles). Note that the GISS data does not represent a zonal mean, but values from specific locations.

4. Conclusions and Outlook

- Successful assimilation of temperature, salinity and $\delta^{18}O_w$ data into the MITgcm, and hence, optimization of the simulated $\delta^{18}O_w$ distribution in the ocean.
- The adjoint method is an effective tool to estimate a state of the ocean that is consistent with model physics and with assimilated data.

In the making:

→ Application of the adjoint method to estimate the state of the ocean during the **Last Glacial Maximum** (LGM, 19-23 ka BP).

→ Investigation of the constraint given by the **limited data coverage of the LGM** by reducing the amount of data for the modern ocean estimate.