Assimilating global $\delta^{18}O$ 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 $\delta^{18}O$ data to estimate the state of the global modern ocean.
- The ability to simulate stable water-isotopes and hence the possibility to directly assimilate $\delta^{18}O$ opens a wide perspective for paleo-oceanographic studies, as $\delta^{18}O$ 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, $H_{16}^2O$ and $H_{18}^2O$
- boundary conditions (six types of atmospheric forcing and isotopic ratios in precipitation and water vapor)
- vertical diffusion coefficient

**Assimilated data**


**$\delta^{18}O_{sea-water}$** - 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 $\delta^{18}O$ 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.

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.