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Investigating the direct meltwater effect in terrestrial $\delta^{18}O$ records using the iCESM

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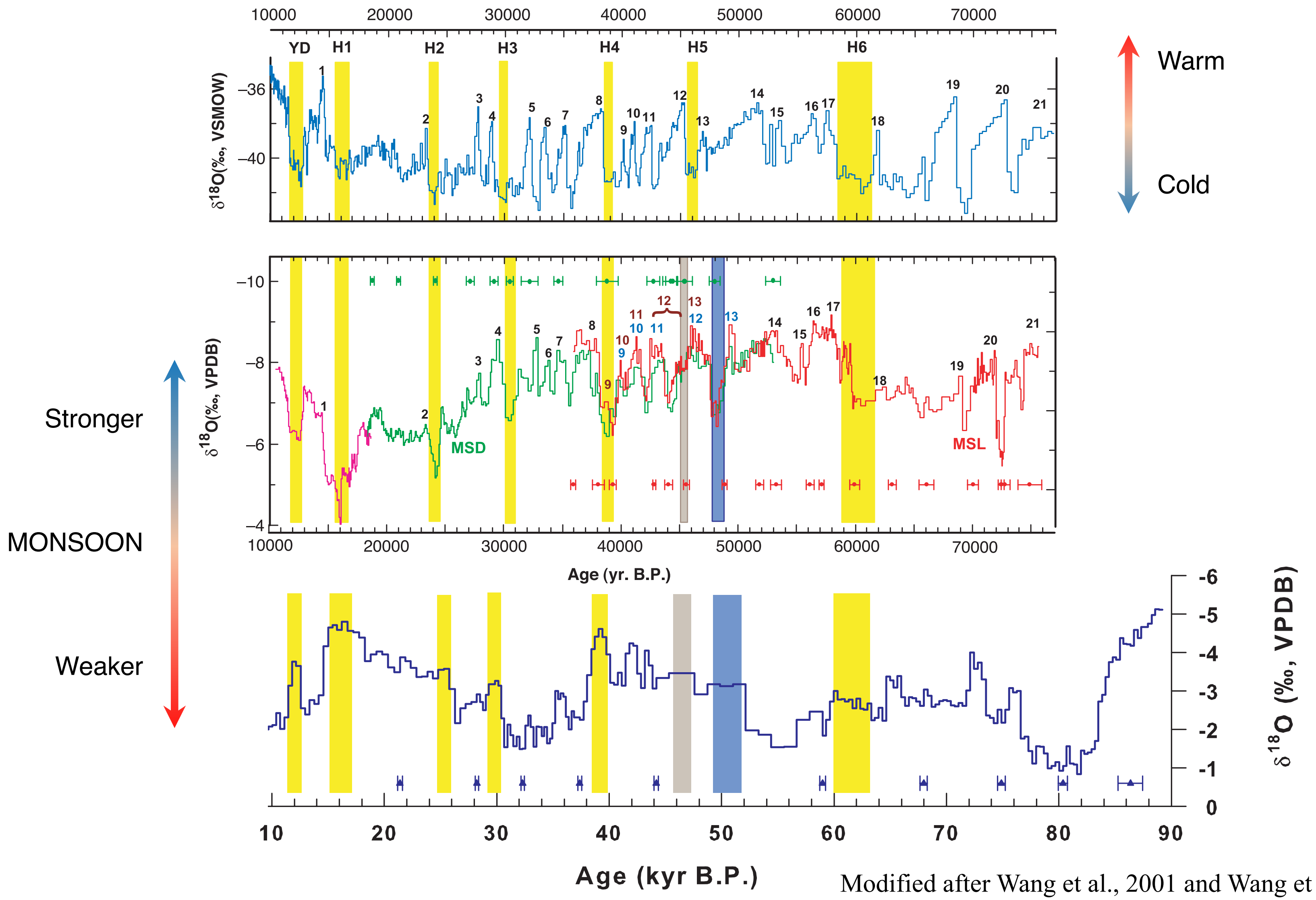
CESM Paleo Working Group Meeting, Austin, March 1, 2018

Deciphering the δ¹⁸O signal in terrestrial records

Greenland ice core

E. Asian Speleothem

Eastern Brazil Speleothem



Modified after Wang et al., 2001 and Wang et al., 2007

Deciphering the δ^{18}O signal in terrestrial records

Climatic Signal (indirect)

High latitude δ^{18}O and the "temperature effect"

- Moisture sources (e.g., Charles et al., 1994; Liu et al., 2012)
- Atmospheric circulations (e.g., Hendricks et al., 2000; Noone, 2008)
- Sea-ice margin positions (Sime et al., 2013)
- Post-depositional processes (e.g., Town et al., 2008)

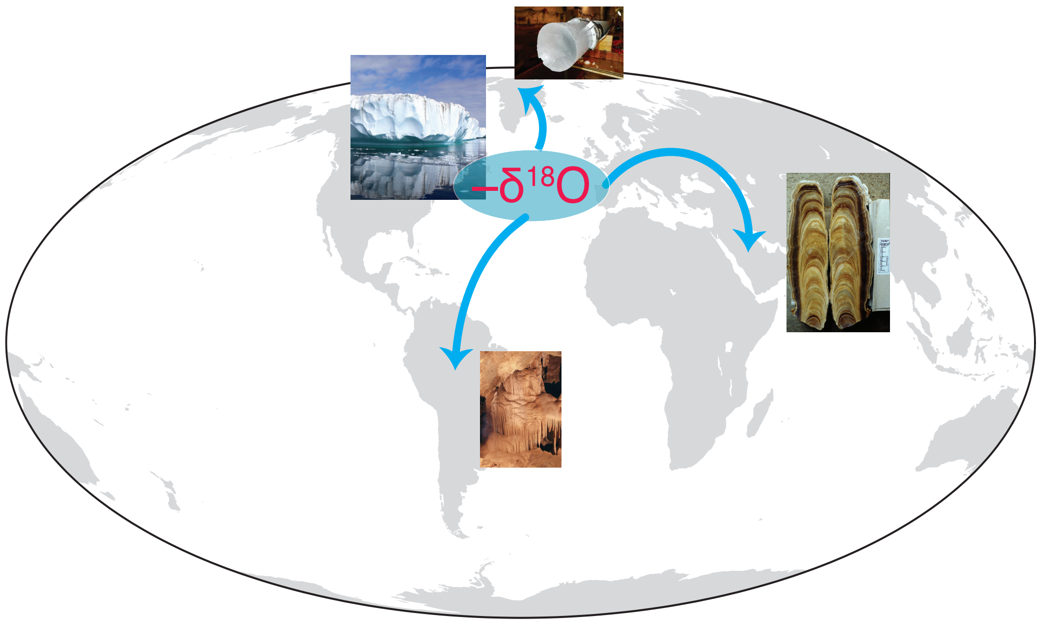
Low latitude δ^{18}O and the "amount effect"

- Source composition and transport trajectory (Lewis et al., 2010; Liu et al., 2014; Rozanski et al., 1993; Yuan et al., 2004)
- Seasonality (Cheng et al., 2009)
- Cloud type and processes (Aggarwal et al., 2016; Moore et al., 2014; Risi et al., 2008)

Non-Climatic Signal

The *direct* meltwater effect

A non-climatic $\delta^{18}O$ signal: the direct meltwater effect (DME)



- DME: Super depleted meltwater (–30‰) propagates throughout the hydrological cycle, ***without involving climate alterations.***
- *Studied qualitatively in a much lesser extent* (Werner et al., 2000; *LeGrande and Schmidt*, 2008)
- Important questions remain

1. How large is the DME compared with climatic effects?
2. How does the DME depend on details of the freshwater forcing?

Water isotope-enabled model and simulations

Water isotope-enabled CESM (iCESM)

~2° (atm,lnd) & ~1° (ocn, ice)

- Nusbaumer et al., 2017
- Wong et al., 2017
- Zhang et al., 2017
- Zhu et al., 2017
- Brady et al., in preparation

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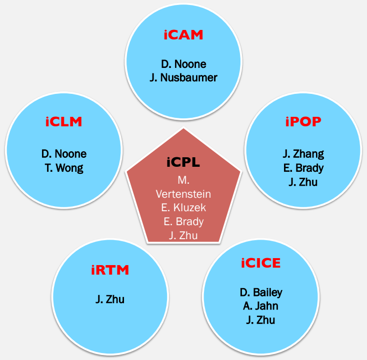


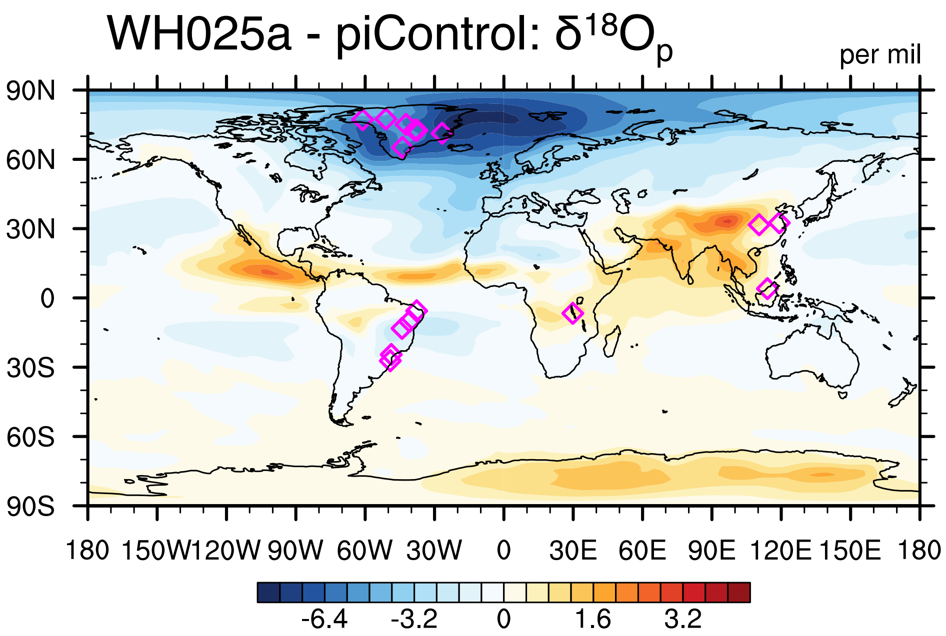
Experiments

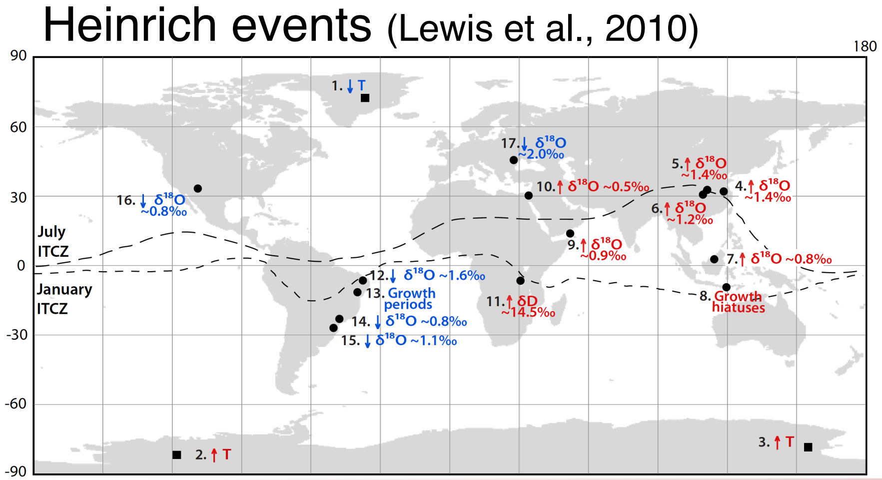
Experiment	FWF (Sv)	$\delta^{18}O$ of meltwater	Location	Length
piControl	---	---	---	500
WH025a	0.25	–30‰	N. Atlantic	300
WH025aC	0.25	0‰	N. Atlantic	300

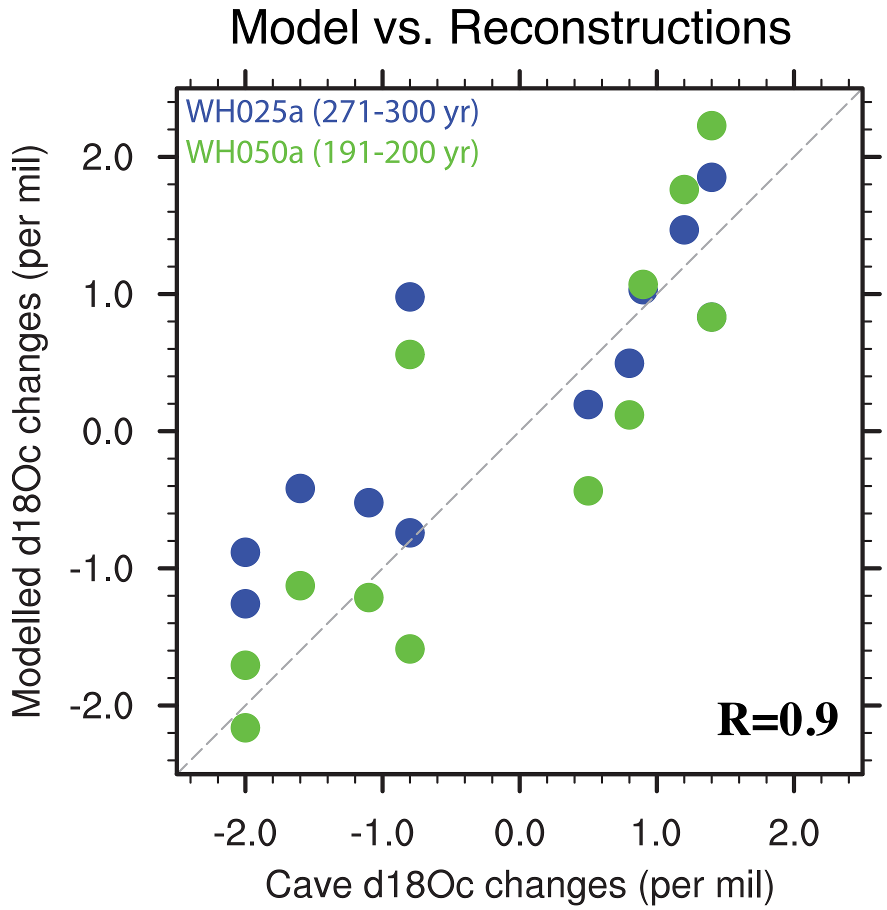
Test magnitude and location (100 yrs)

- WH010a & WH010aC (N. Atlantic)
- WH050a & WH050aC (N. Atlantic)
- WH100a & WH100aC (N. Atlantic)
- WH050b & WH050bC (Gulf of Mexico)
- WH050c & WH050cC (Weddell Sea)

Performance of simulating water isotopes







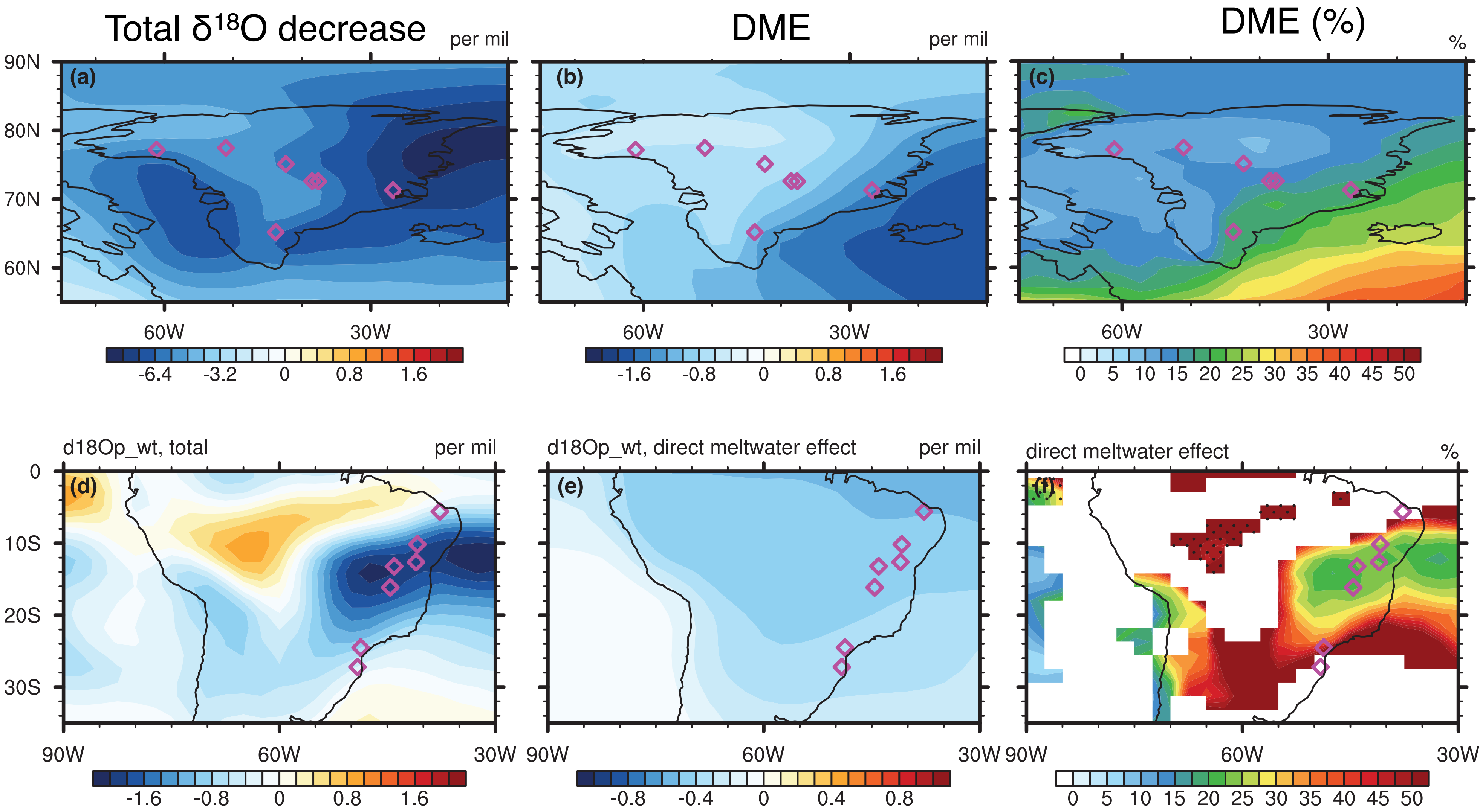
Temperature effect corrected using Kim and O'Neil (1997)

Results: the direct meltwater effect (0.25 Sv, 300 years)

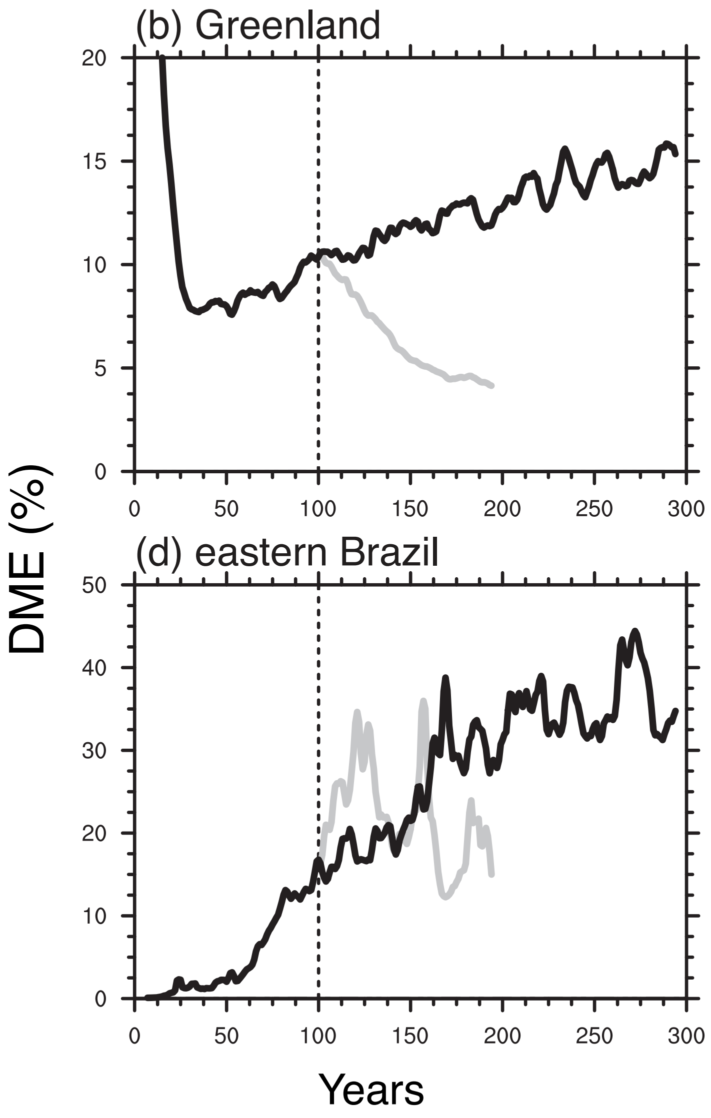
Greenland
15-20%

eastern Brazil
20-40%

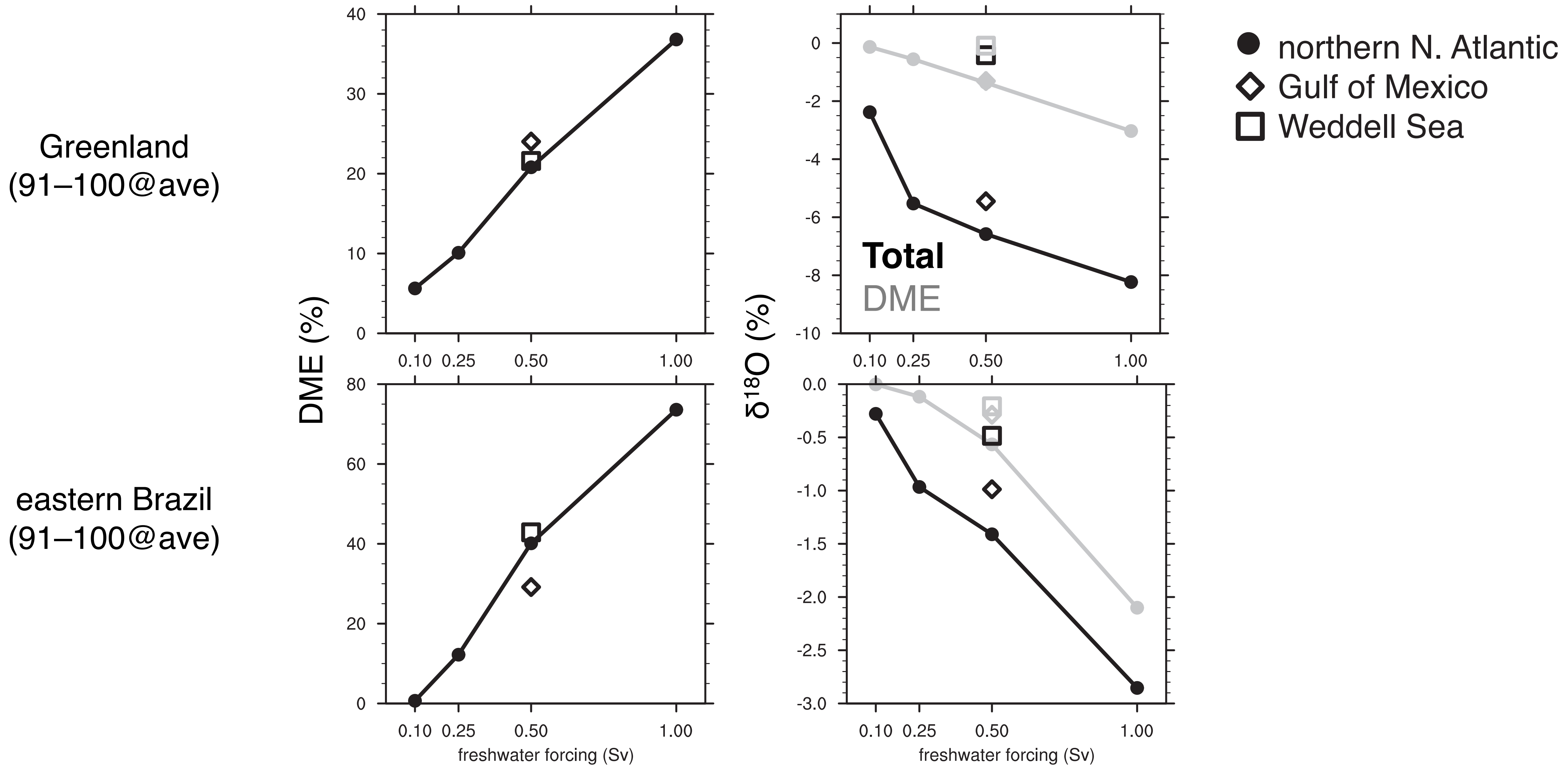
(271-300@ave)



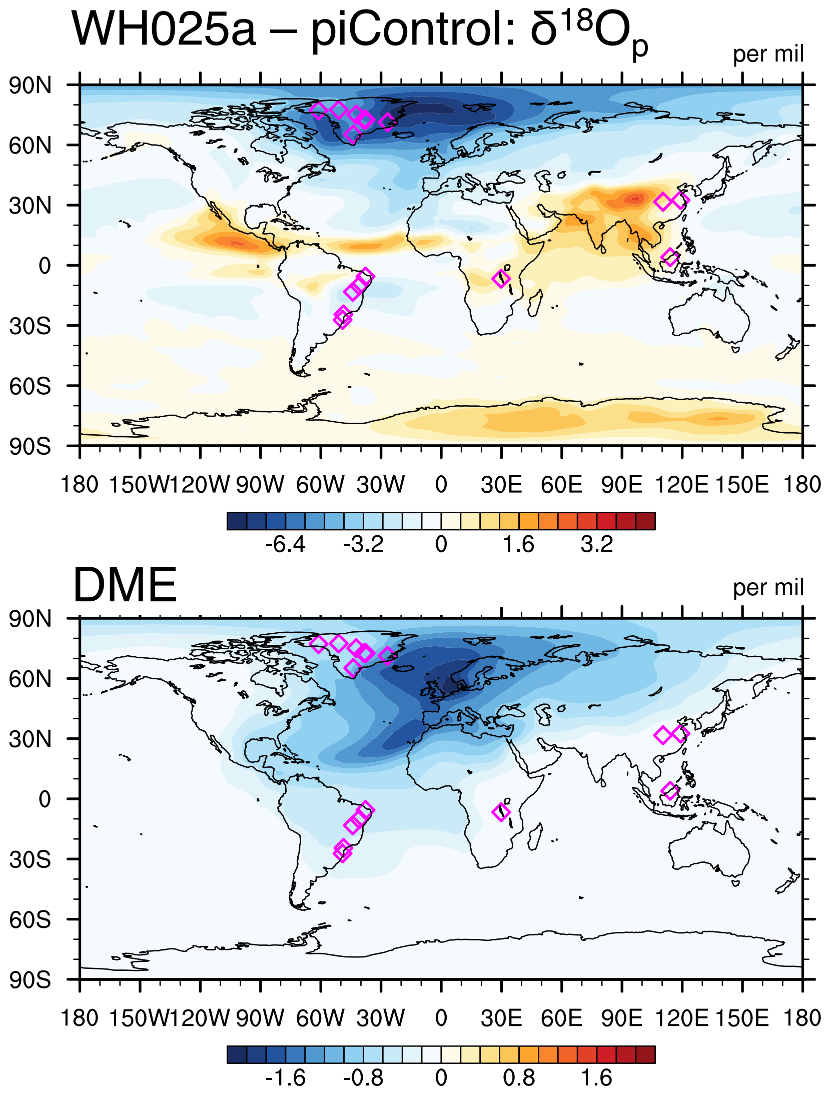
Results: dependence on the duration of the FWF (0.25 Sv, 300 years)

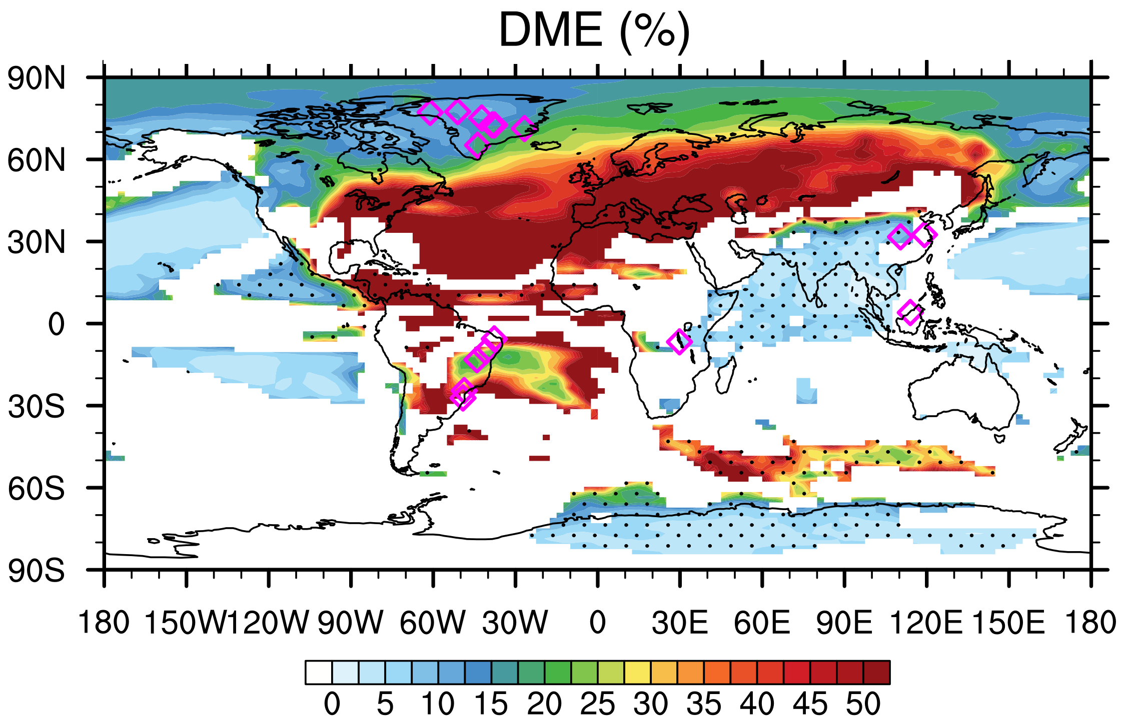


Results: dependence on the magnitude and location of the FWF



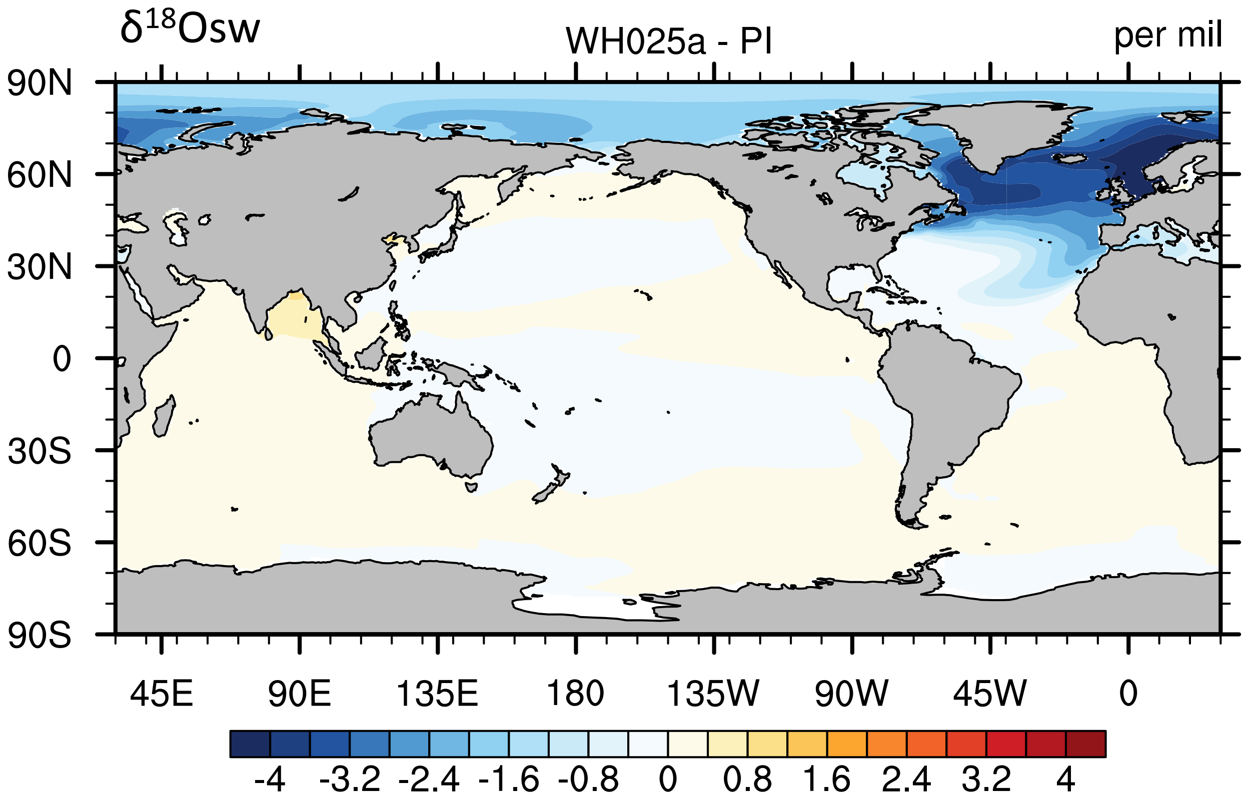
Results: important for lots of regions (0.25 Sv, 300 years)





(271-300@ave)

Mechanism: meltwater decrease $\delta^{18}O_{sw}$ of moisture source regions



Water tagging experiments

	Northern N. Atl. (30–70°N)	Subtropical N. Atl. (10–30°N)	Equatorial Atl. (10°S–10°N)	Subtropical S. Atl. (10-30°S)
Greenland precip.	**51%**	7%	<1%	<1%
eastern Brazil precip.	1%	**2%**	**13%**	**50%**

Conclusions and implications

- The direct meltwater effect makes up ***15–35% of the $\delta^{18}O$ signals*** in precipitation in Greenland and eastern Brazil for large meltwater events.
- The direct meltwater effect ***increases with the duration and magnitude*** of the freshwater forcing, and is **location dependent**.
- *Caution should be taken when interpreting $\delta^{18}O$ as climatic signal during strong meltwater events.*
- *Detailed history of meltwater events is needed!*

Geophysical Research Letters

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Key Points:
- A portion of the δ18O signal in land-based paleoclimate proxies can be attributed to the direct meltwater effect instead of climatic changes
- The direct meltwater effect can make up 15-35% of the δ18O signals in precipitation in Greenland and eastern Brazil for large meltwater events
- The direct meltwater effect increases with the magnitude and duration of the freshwater forcing and is sensitive to location and shape dependent

Supporting Information:
- Supporting Information S1

Investigating the Direct Meltwater Effect in Terrestrial Oxygen-Isotope Paleoclimate Records Using an Isotope-Enabled Earth System Model

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Thank you for your attention!

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