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Understanding abrupt climate shifts during glacial-interglacial cycles: New Modeling Perspectives

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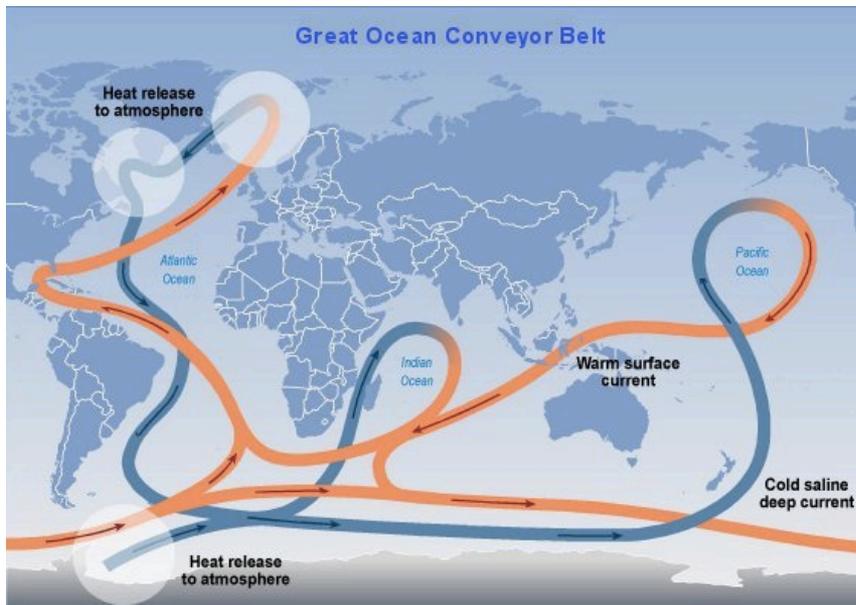
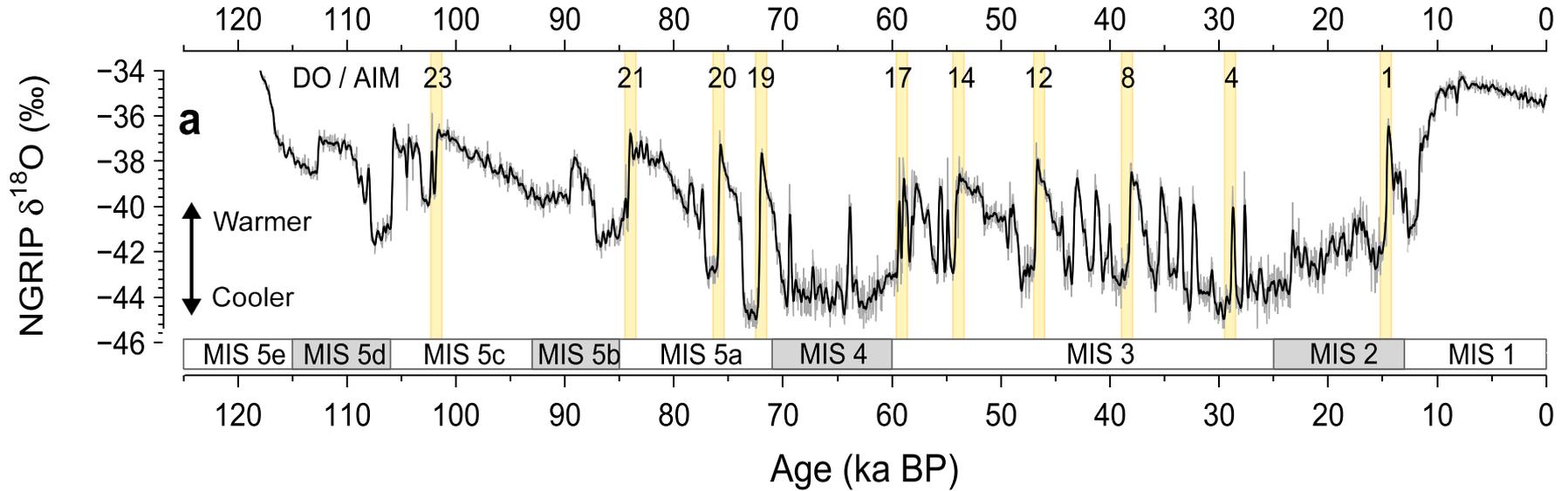
20.09.2016
CLIVAR, Qingdao, China



Greenland Temperature

Dansgaard-Oeschger Events

(Dansgaard et al 1993)



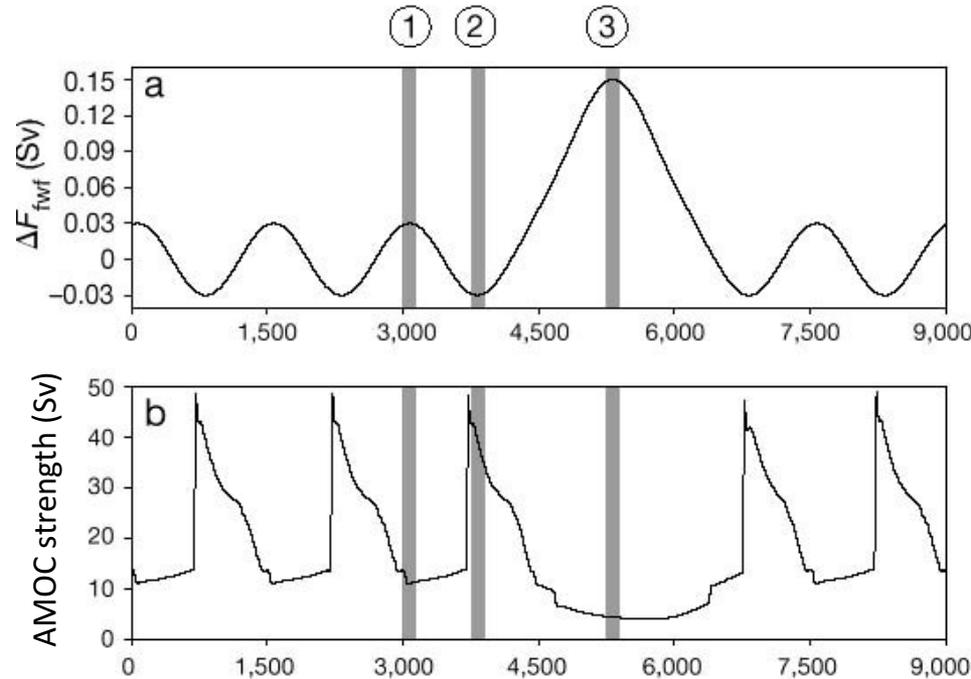
Atlantic Meridional Overturning Circulation

e.g. Boehm et al 2015; Henry et al 2016

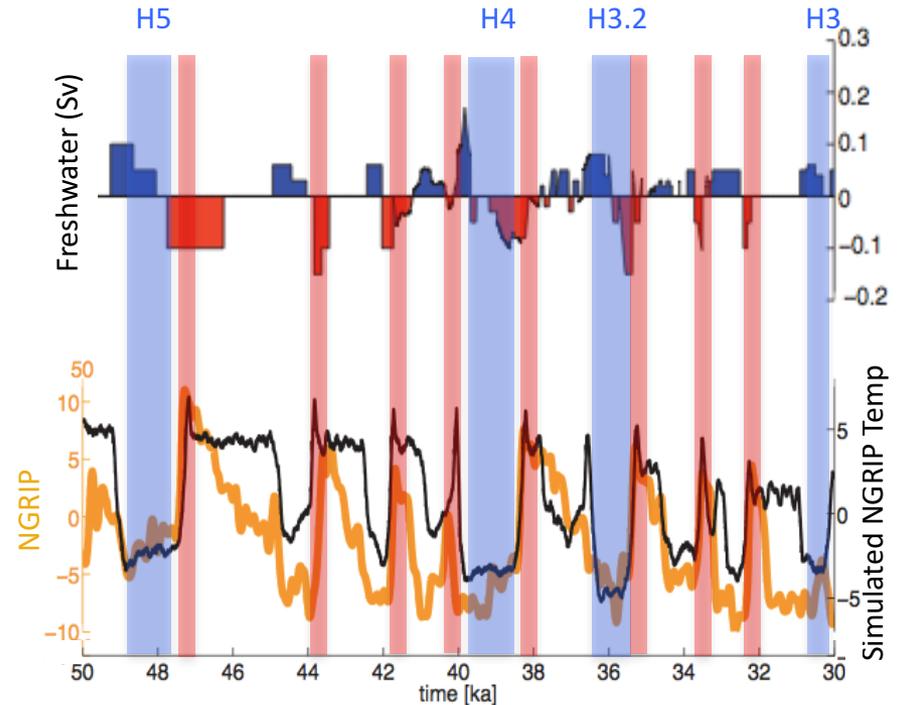
AMOC Changes => DO events



Or Freshwater perturbation is supposed to be the main trigger for DO events.
Freshwater controls climate stability (AMOC stability)



Ganopolski and Rahmstorf, 2001, Nature



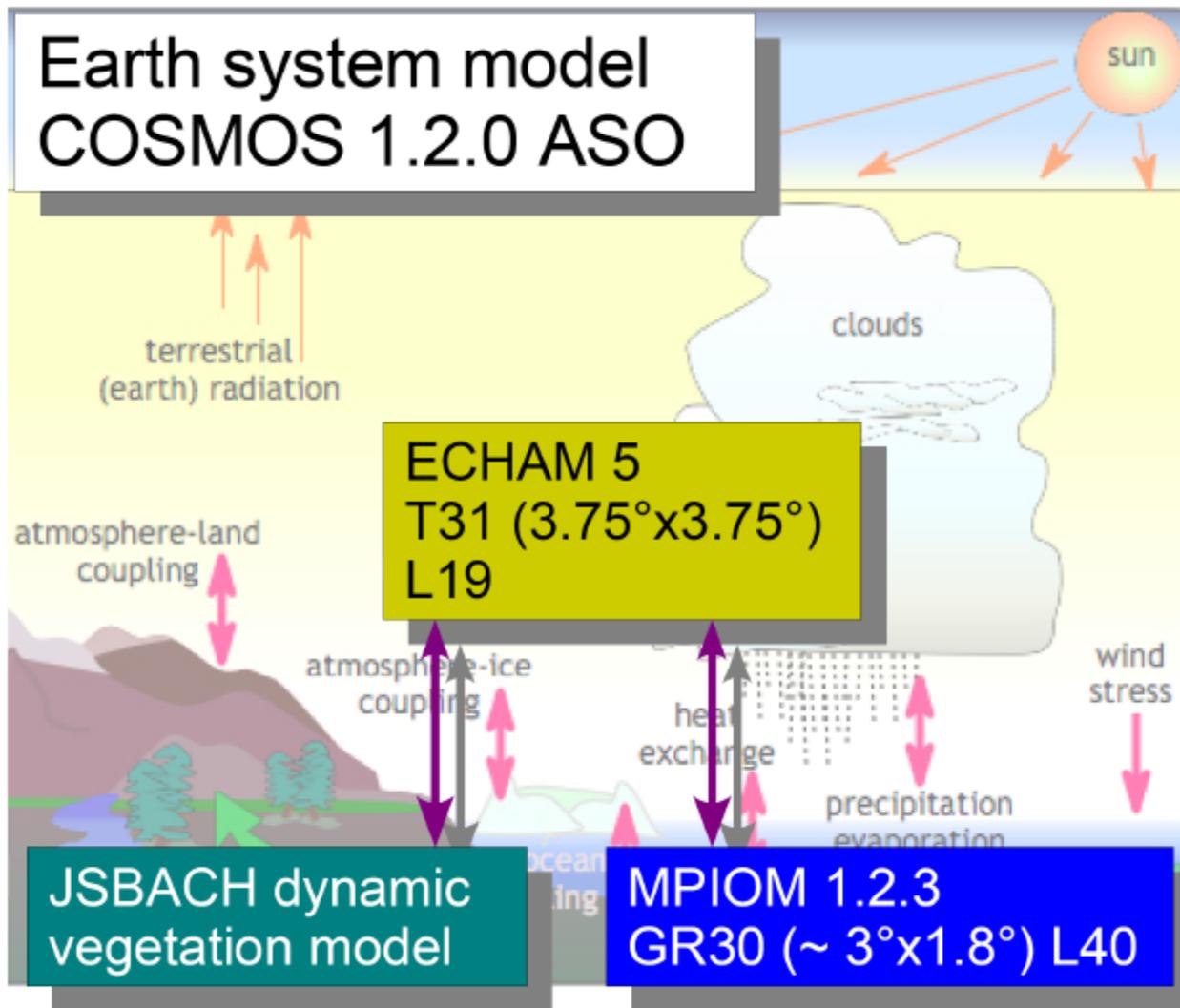
Menviel et al., 2014, Clim. Past

Debate:

1. Freshwater timing, magnitude and history
(e.g. Bond et al 1995, Alvarez-Solas et al 2010, Barker et al 2015)
2. Linear response of AMOC to freshwater in AOGCMs (e.g. Liu et al 2009)

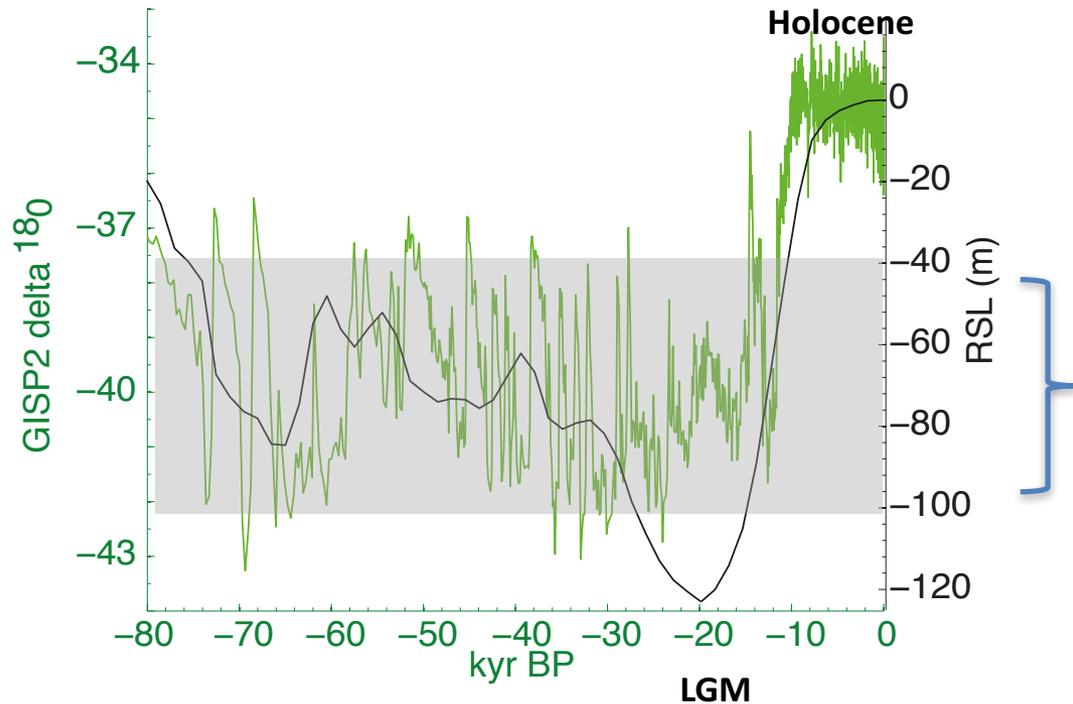


Model setup





Millennial variability at intermediate sea level



Empirical evidence:

**Abrupt climate shifts occur
at intermediate sea level**

(e.g. Schulz et al., 2002, GRL)

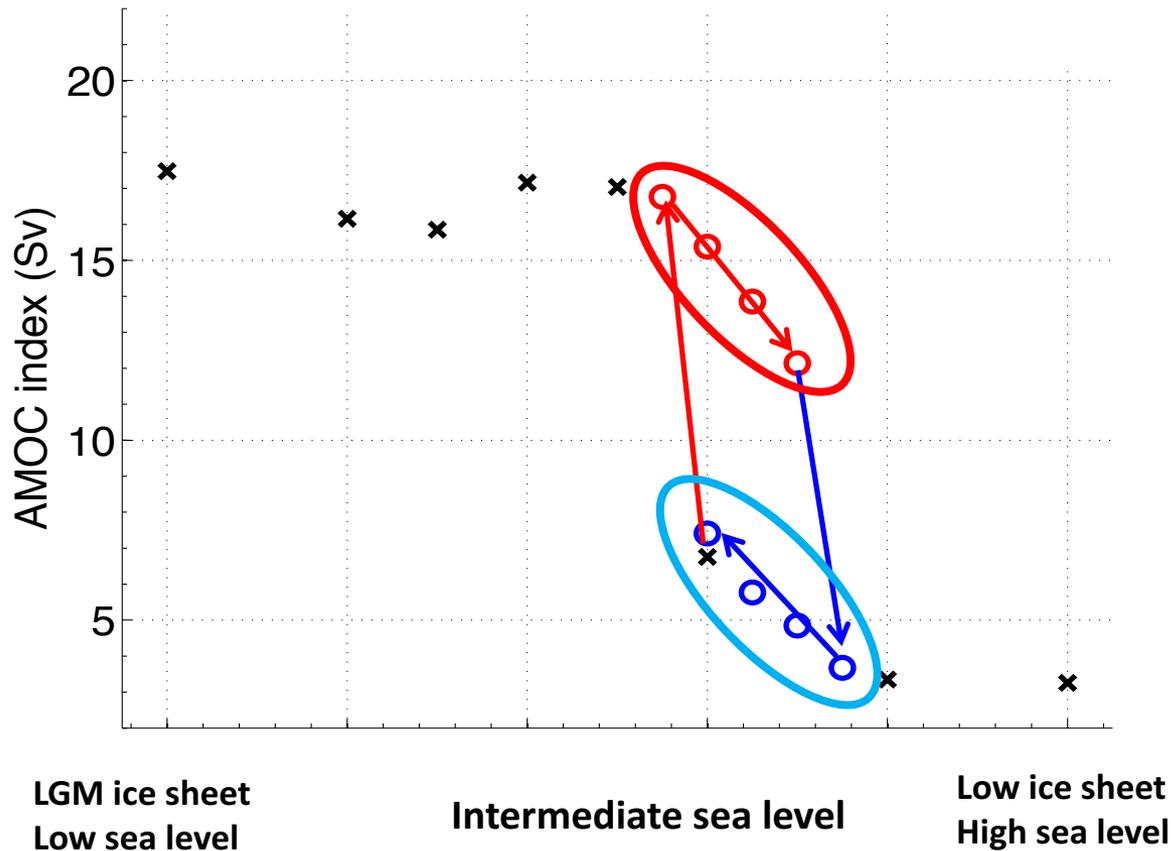
Sea level: Waelbroeck et al. 2002

Ice Core: Grootes et al., 1993

**Not during the Holocene
& the Last Glacial Maximum**



Bistable system at intermediate sea level

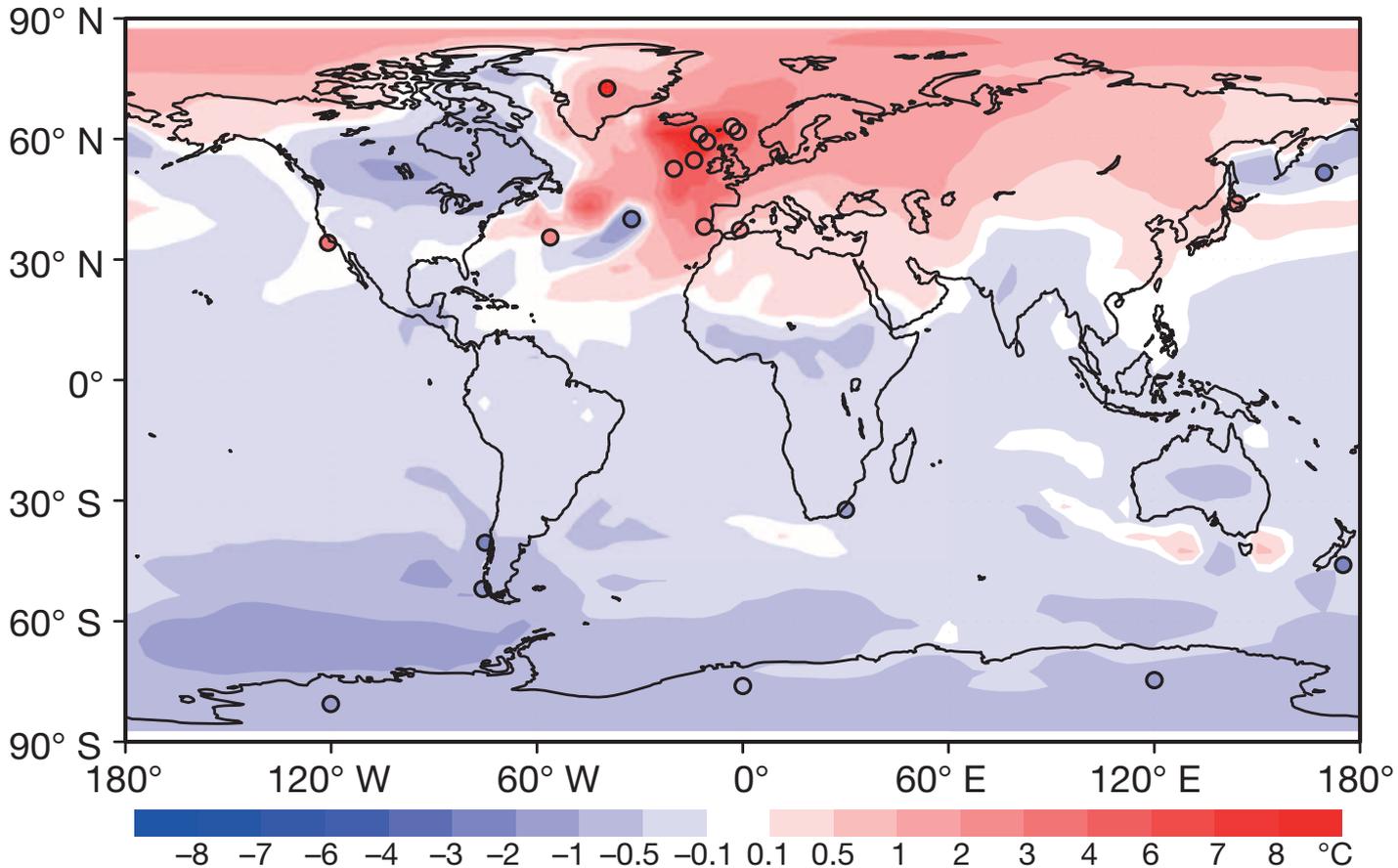


Note: other boundary conditions are fixed to the LGM



Bipolar thermal seesaw: Model & Data

Interstadial - stadial





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ICE SHEET CONTROL

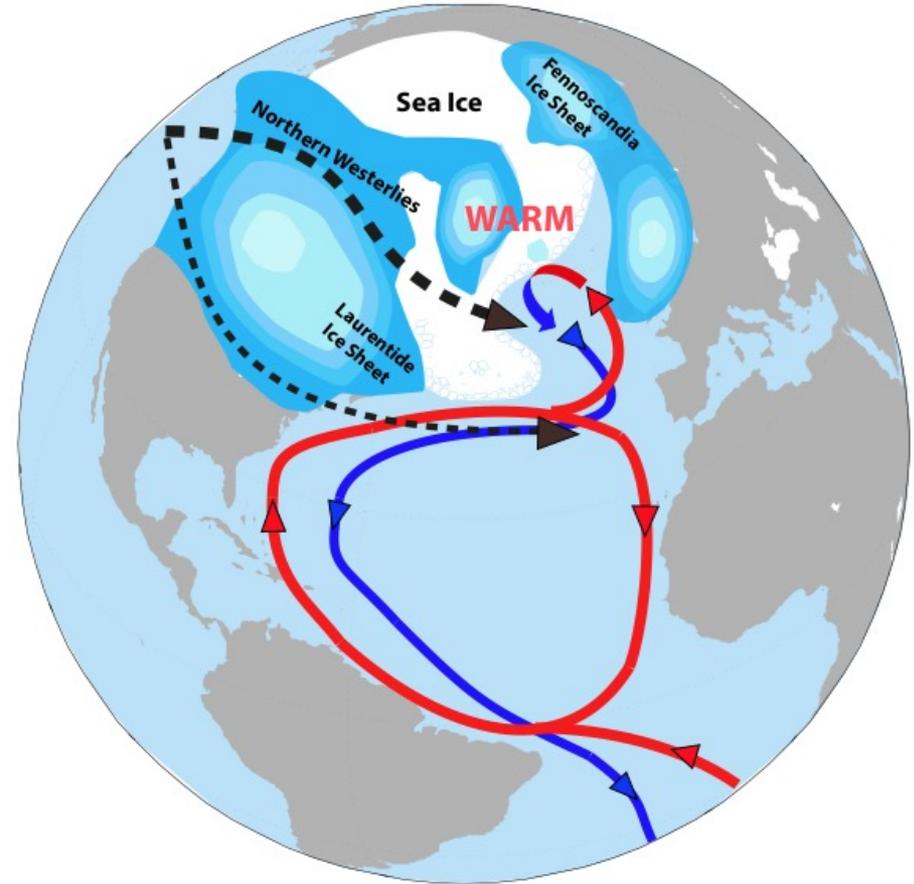
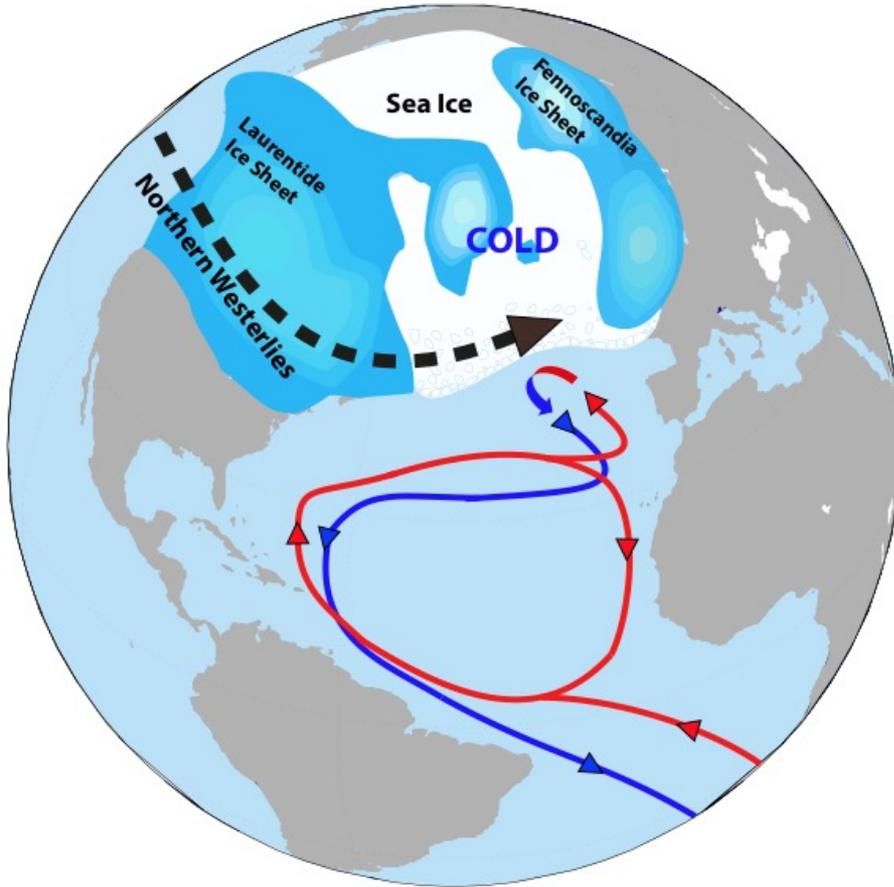


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Stadials

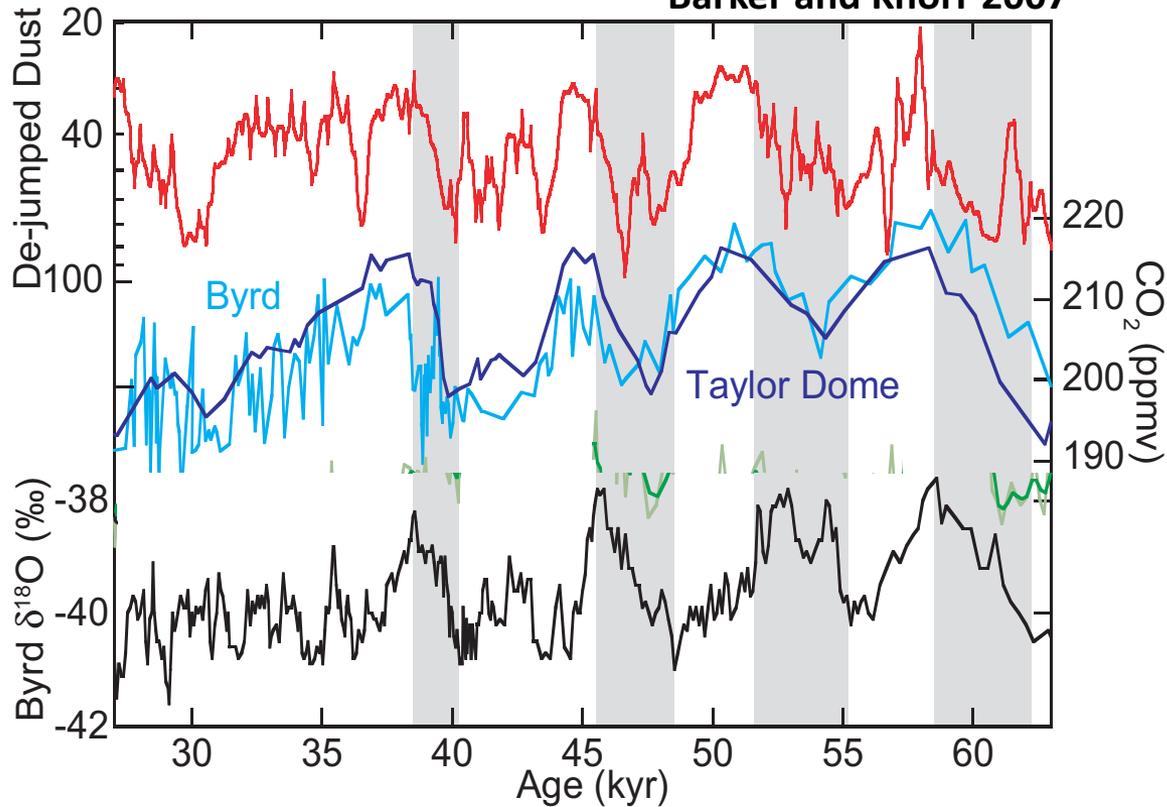
Interstadials



Nevertheless ...

Barker and Knorr 2007

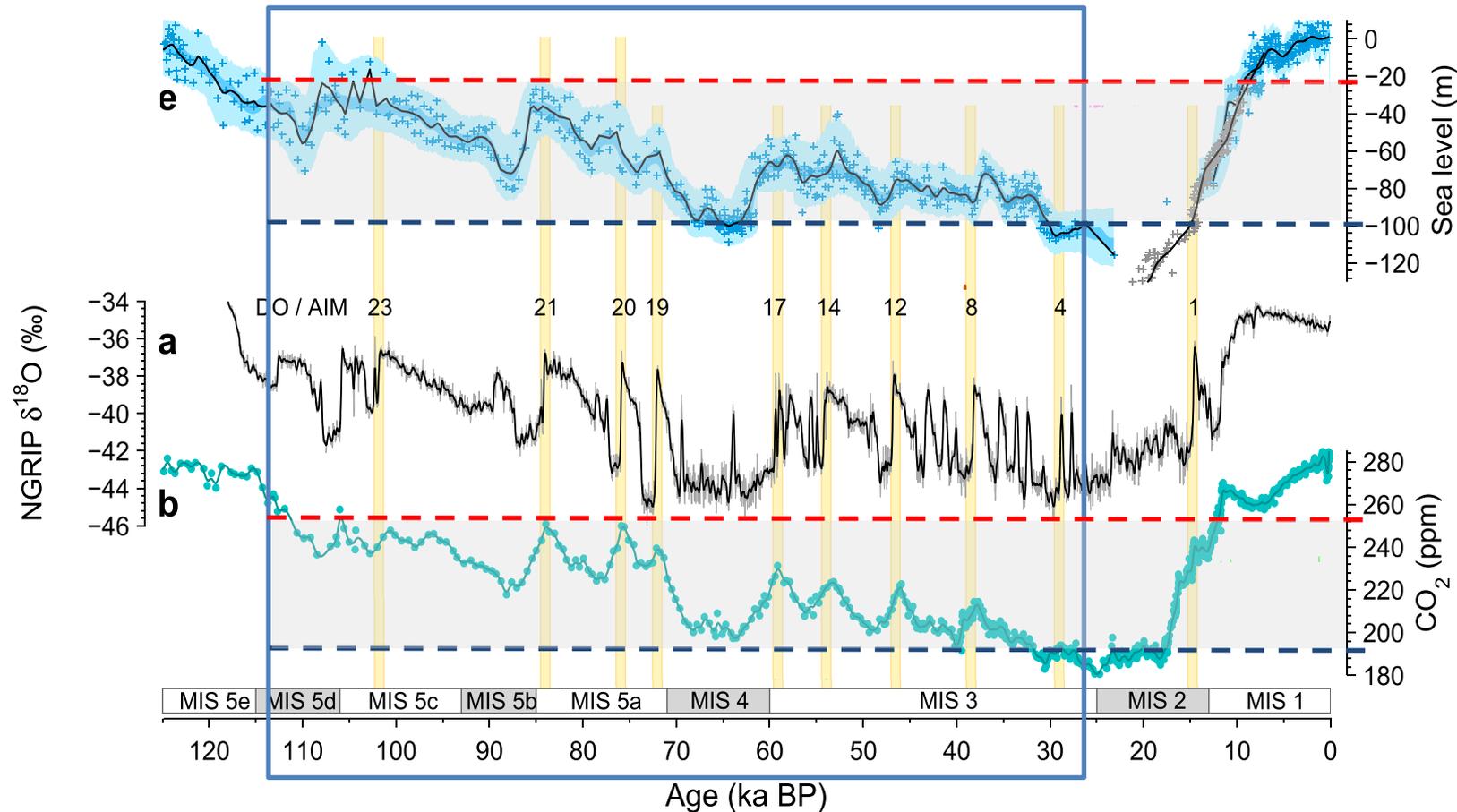
Greenland Dust
(de-jumped)



Antarctic Temp.

Records in Greenland ice core are characterized by **an Antarctic-style climate variability**, which cannot be explained by nonlinearity of the AMOC alone.

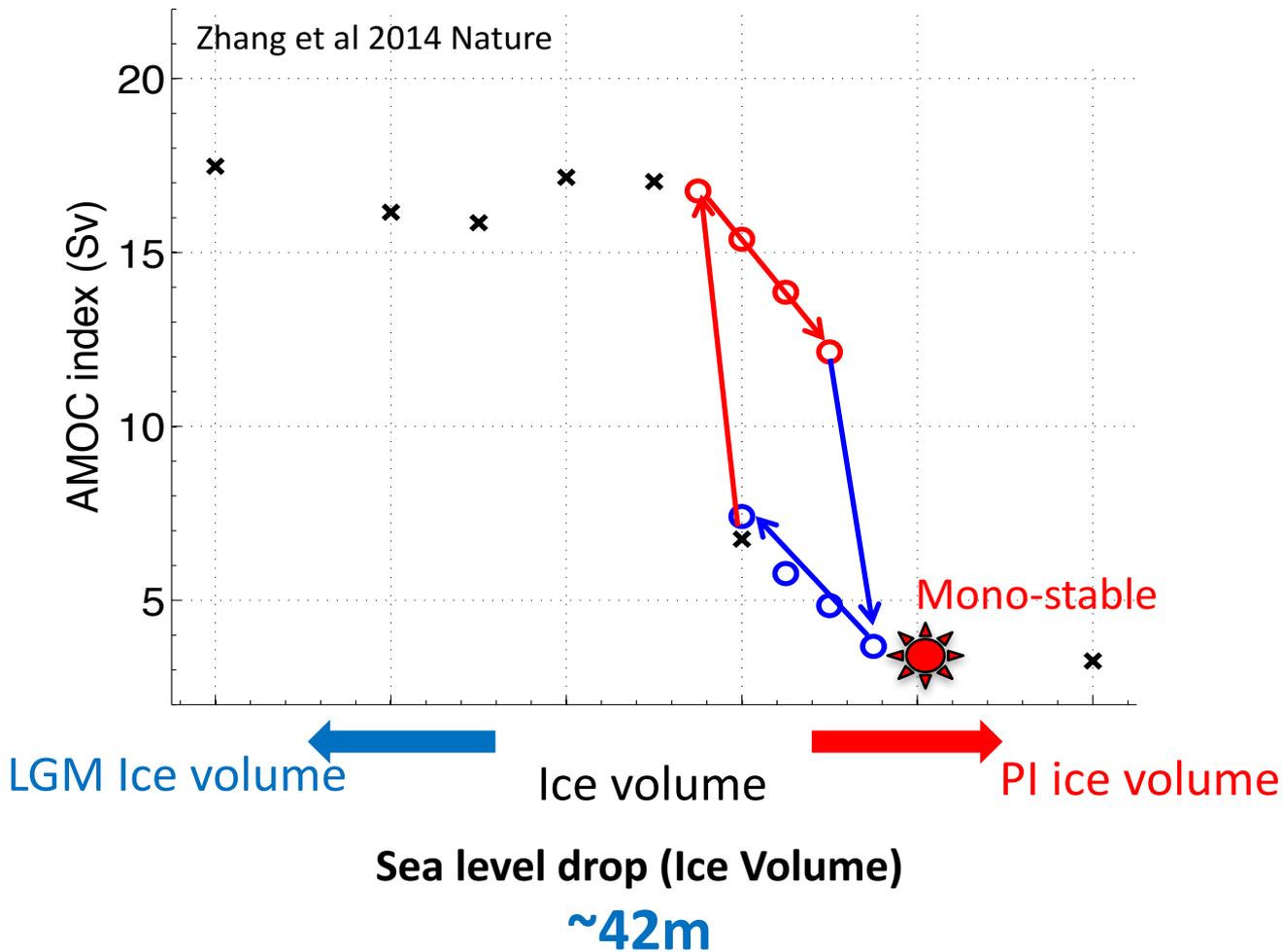
The Antarctic-style signal (**temperature and atmospheric CO₂**) can also be found in other proxy data, indicating existence of a global agent controlling on millennial-scale climate variability.



1. DO events are very evident when atmospheric CO₂ levels are at intermediate level, in addition to intermediate ice volume.
2. **Big DO events** are in company with **CO₂ variations**.



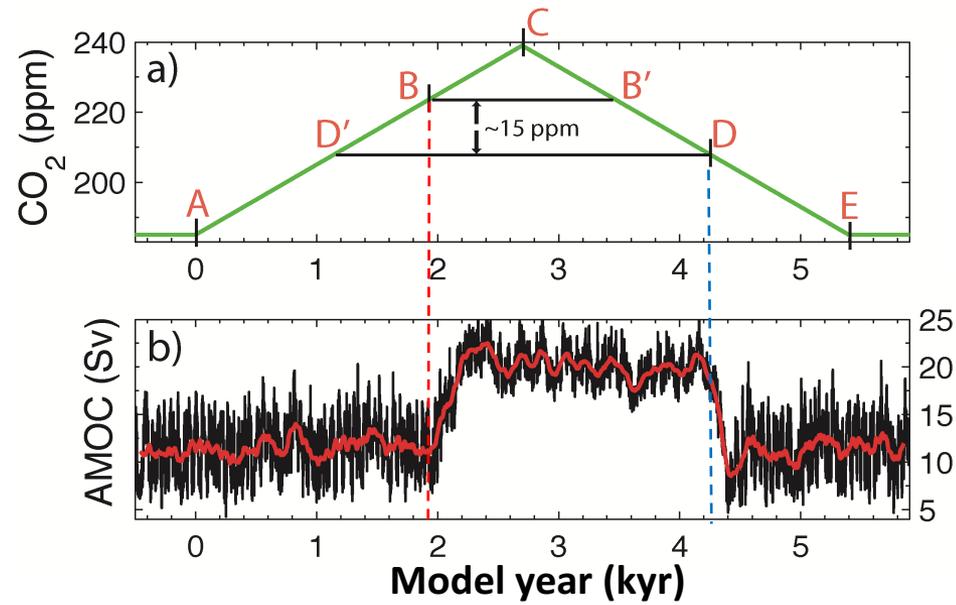
Bistable system at intermediate sea level



CO₂: <185-240> ppm (0.02ppm/yr)

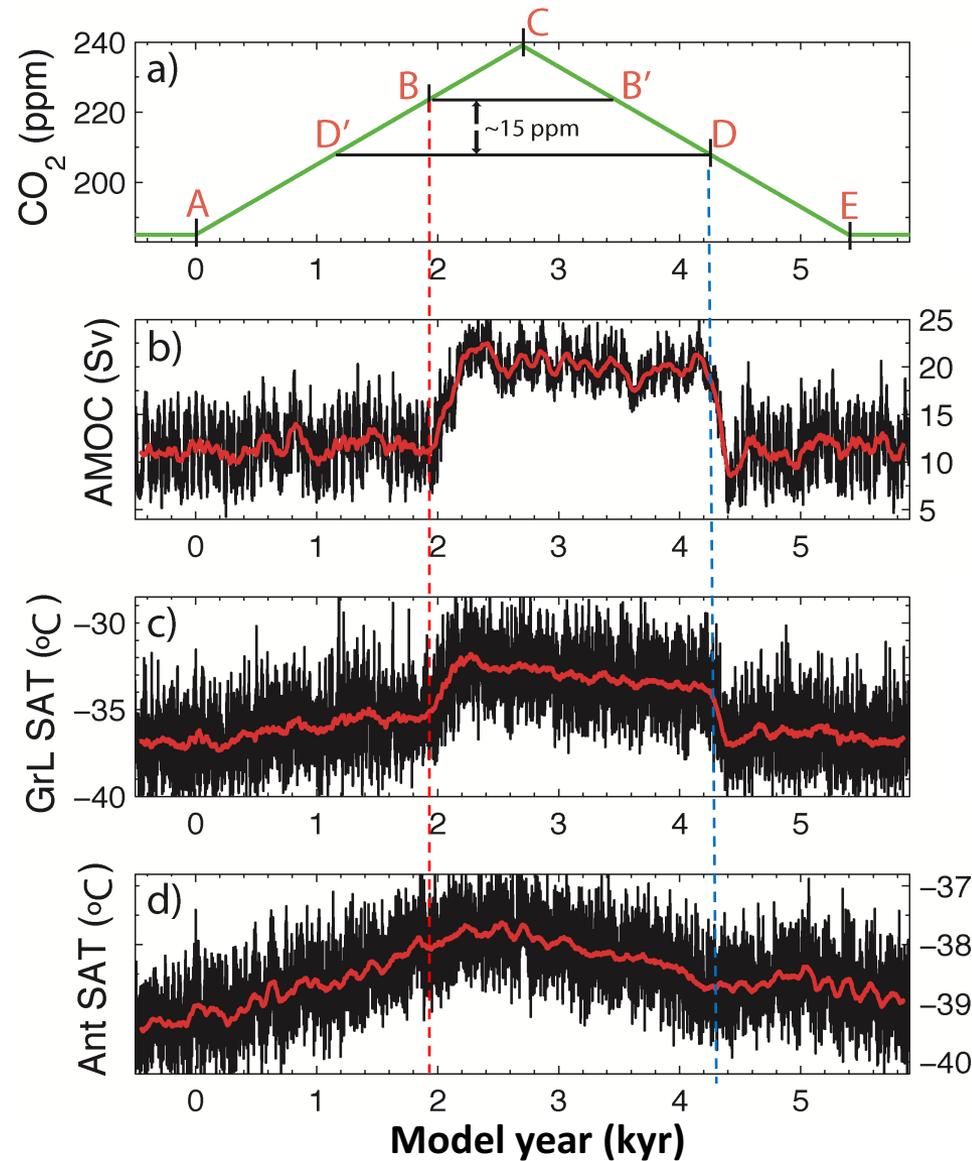
Other boundary conditions are fixed to the LGM

Intermediate ice volume



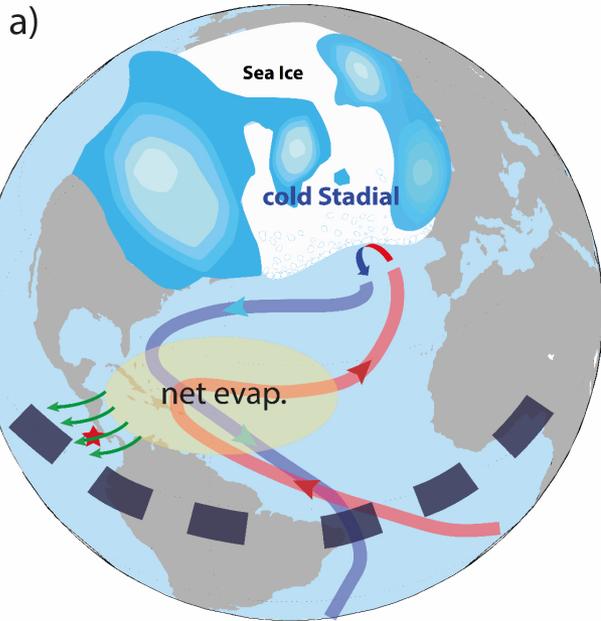


Intermediate ice volume

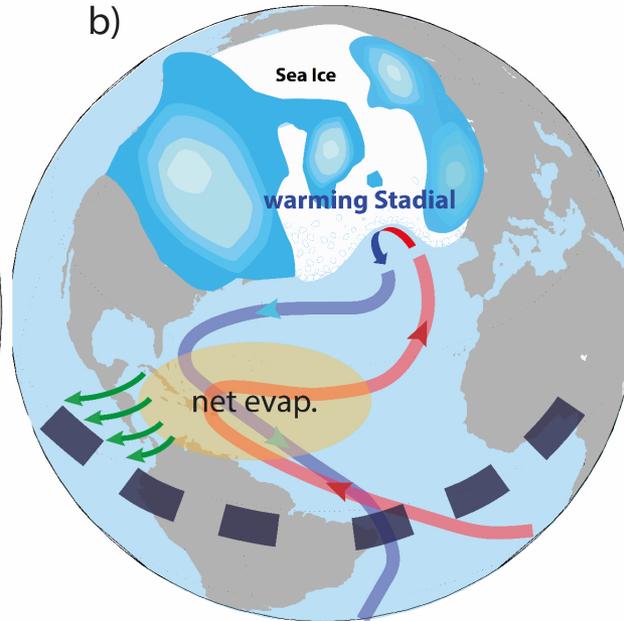




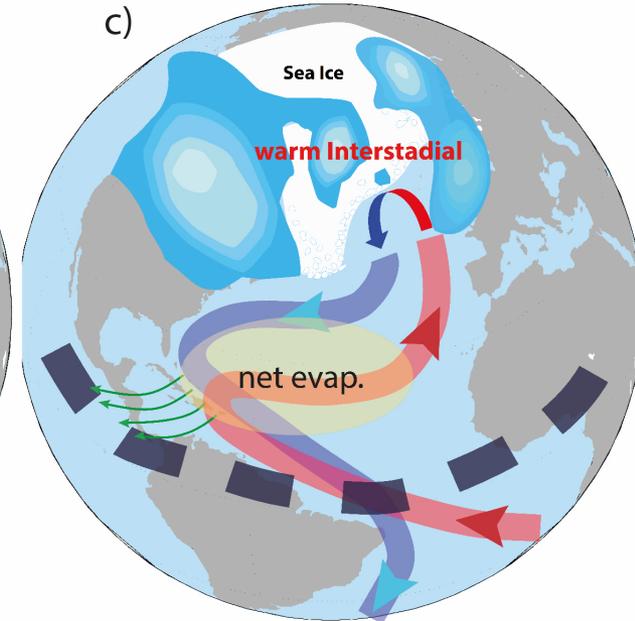
Stadials with low CO₂



Stadials with rising CO₂



Interstadials with high CO₂



Poster: TUE-224

Taking home message ...

Ice sheet height and **atmospheric CO₂** are key control on glacial climate (AMOC) stability within glacial-interglacial cycles.

CO₂ might represent **an internal feedback agent** by promoting spontaneous transitions between climate states during glacials.

A combination of the three controlling factors (**ice sheet height, atmospheric CO₂ and freshwater**) can explain a broader spectrum of millennial-scale variability and abrupt climate transitions, e.g. Bølling-Allerød warming (~14.6ka BP) during the last deglaciation.

Thanks for your attention, questions are warmly welcome!