Dansgaard-Oeschger and Heinrich events: results from a 22-thousand-year transient climate simulation

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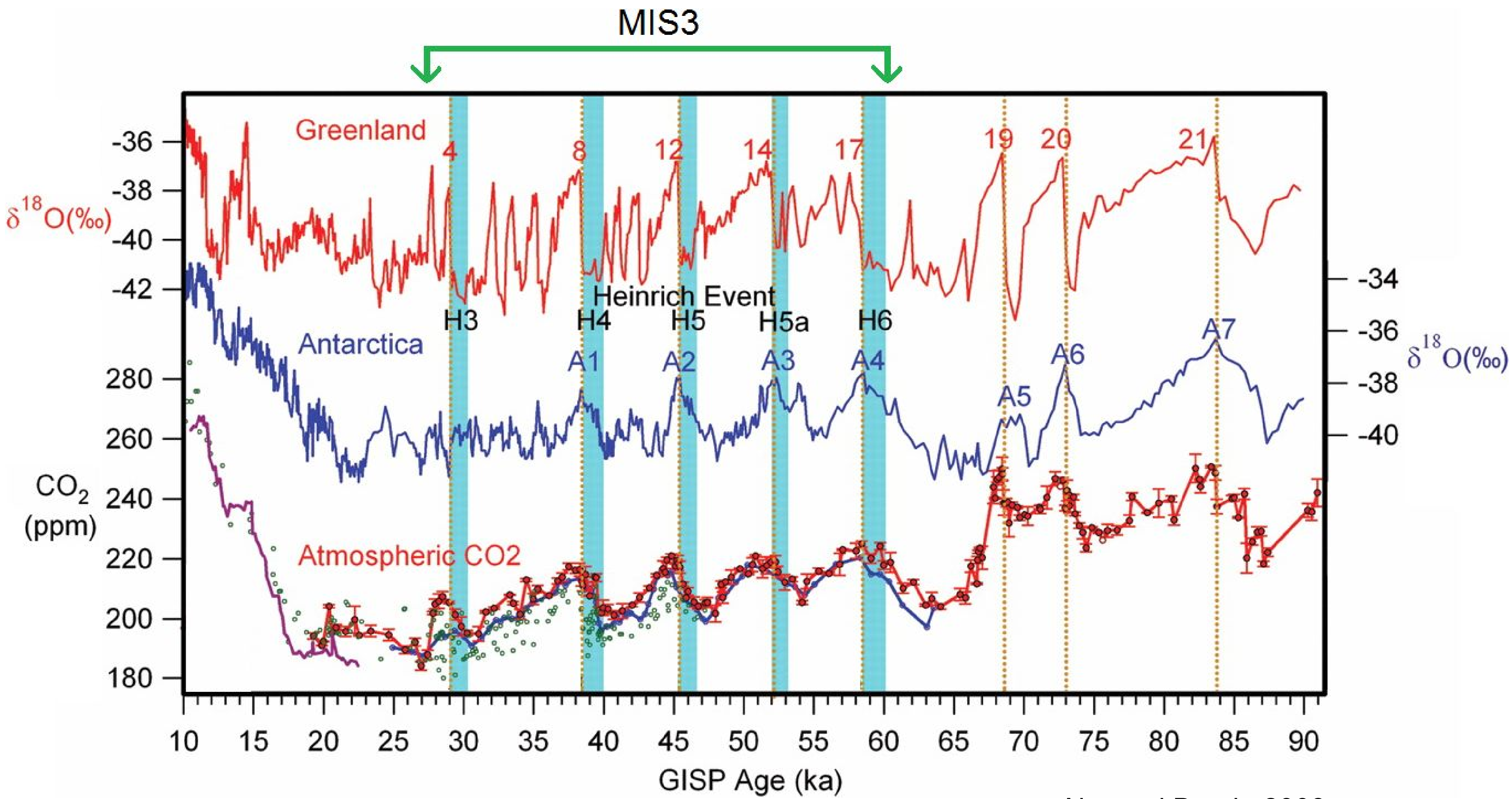
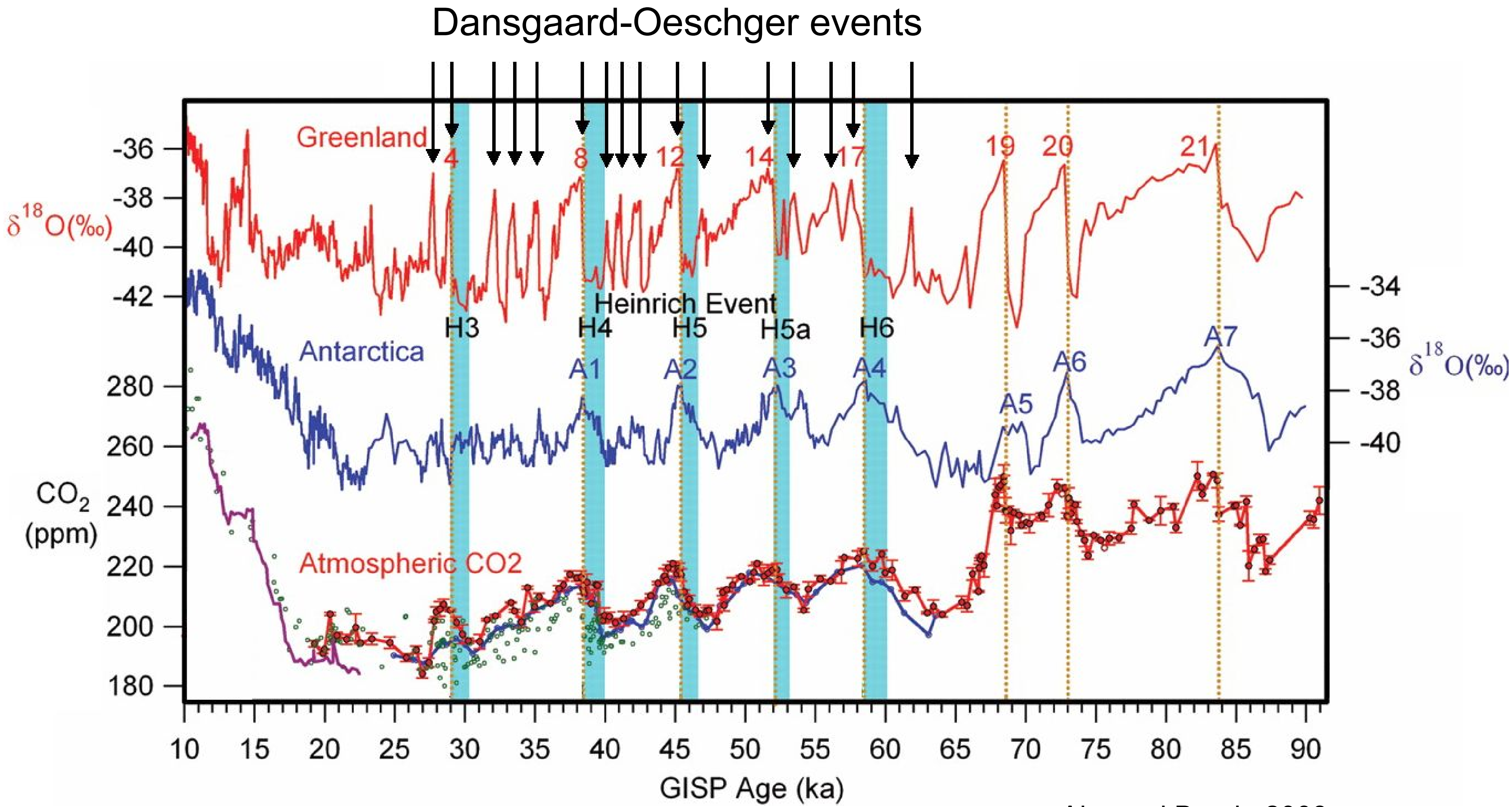
Marine Isotope Stage 3 (MIS3, 60-28 ka B.P.)



Ahn and Brook, 2008

Marine Isotope Stage 3 (MIS3, 60-28 ka B.P.)

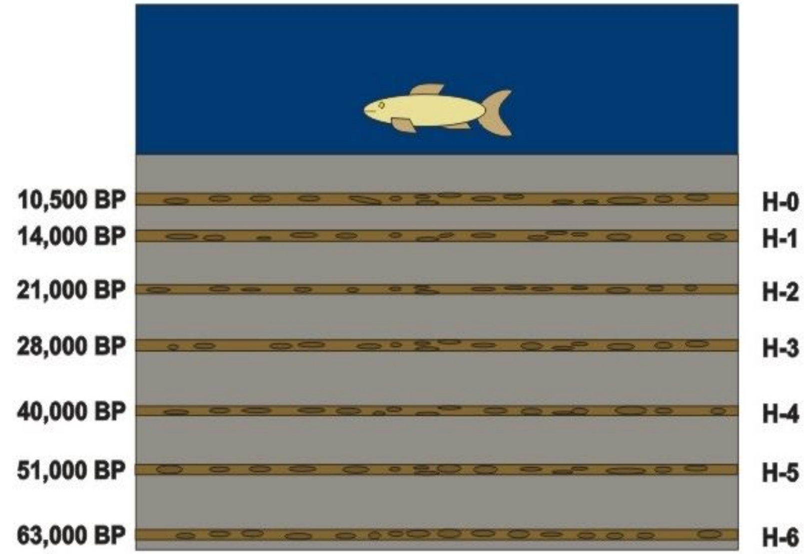


Ahn and Brook, 2008

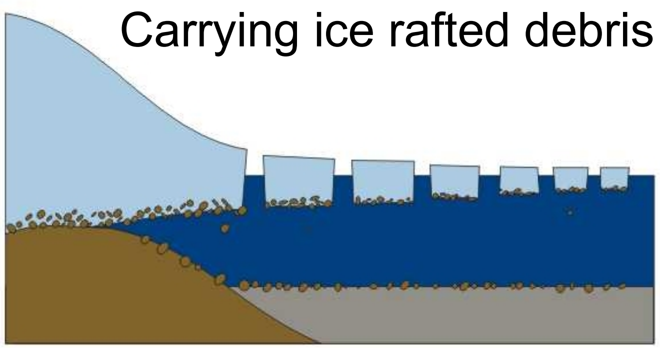
Heinrich Events

Massive release of icebergs in the North Atlantic

Heinrich layers in sediments

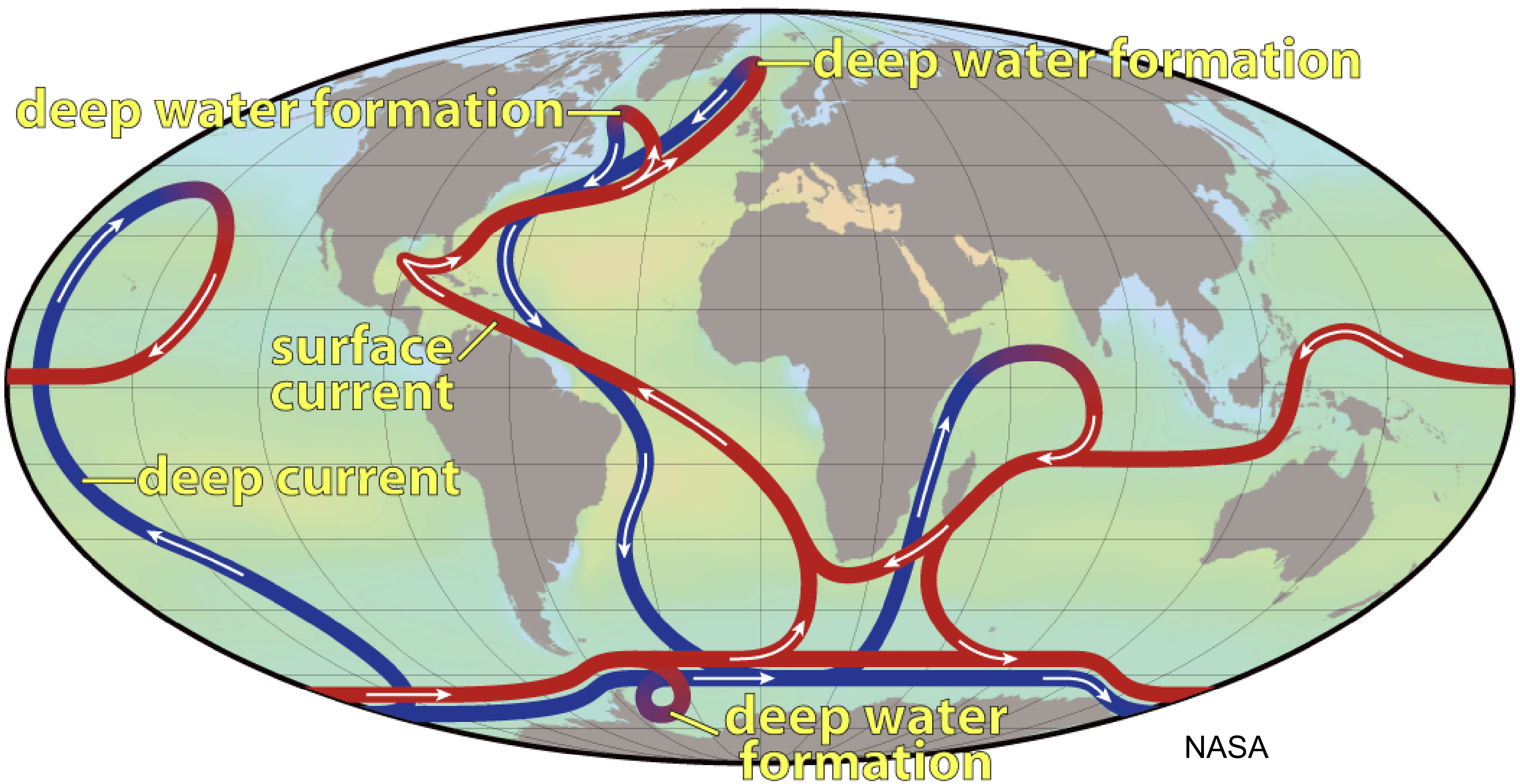


Carrying ice rafted debris



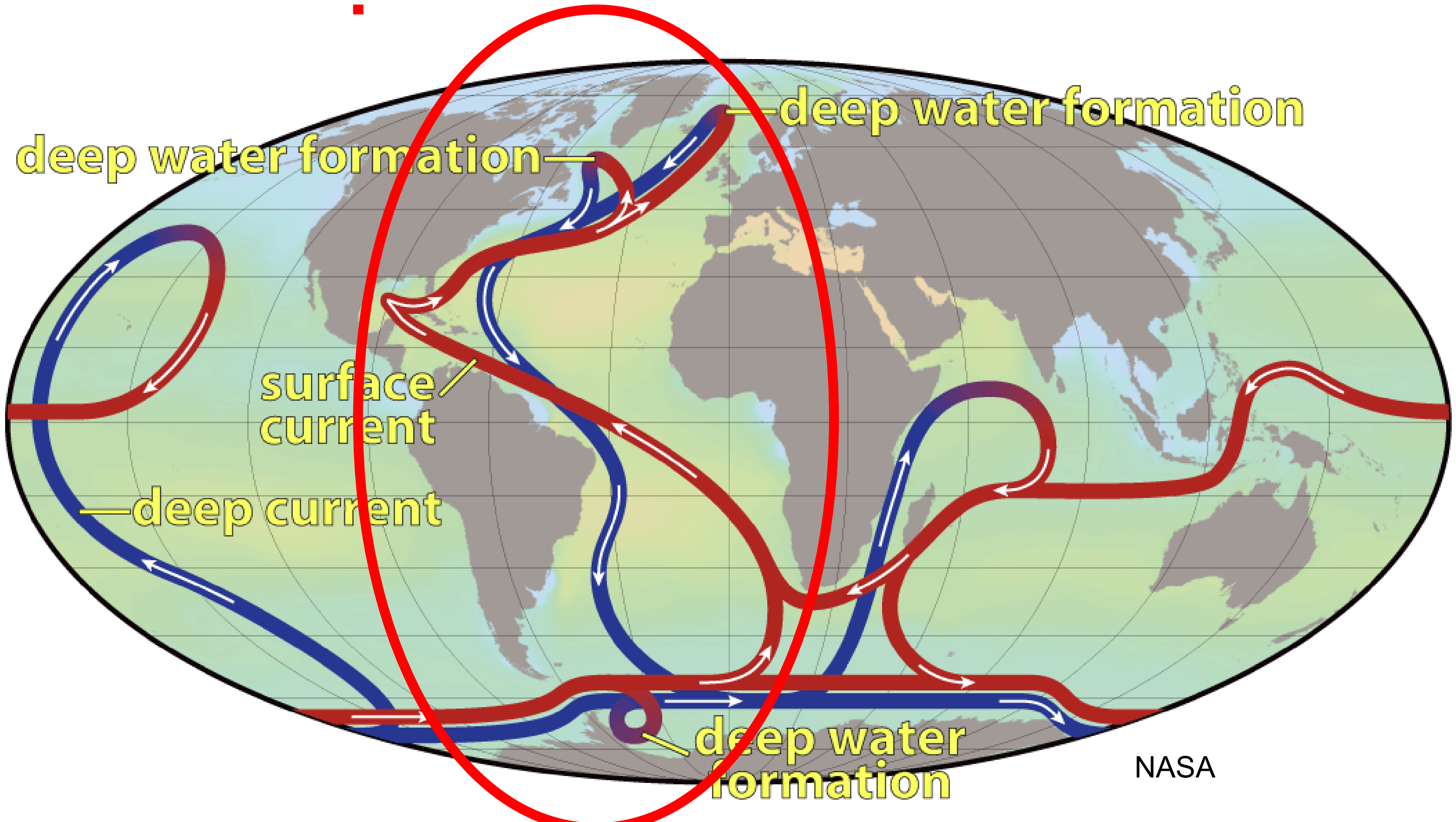
http://www.eos.ubc.ca/research/glaciology/research/HeinrichEvents.html

Thermohaline circulation



Thermohaline circulation

AMOC: Atlantic meridional overturning circulation

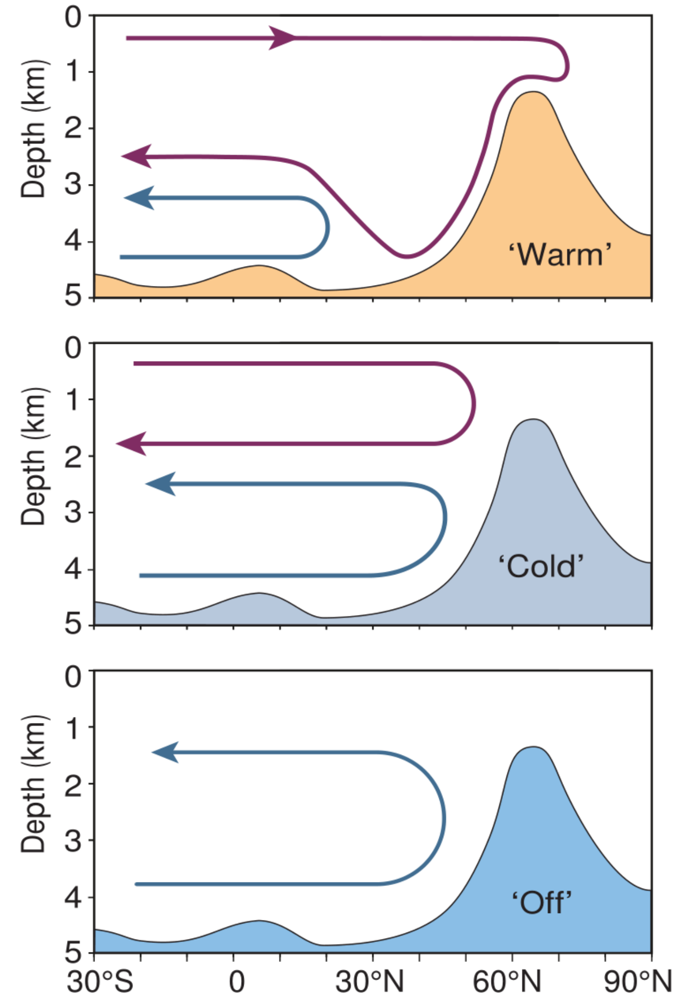


Heinrich Events

changes in ocean circulation and climate:

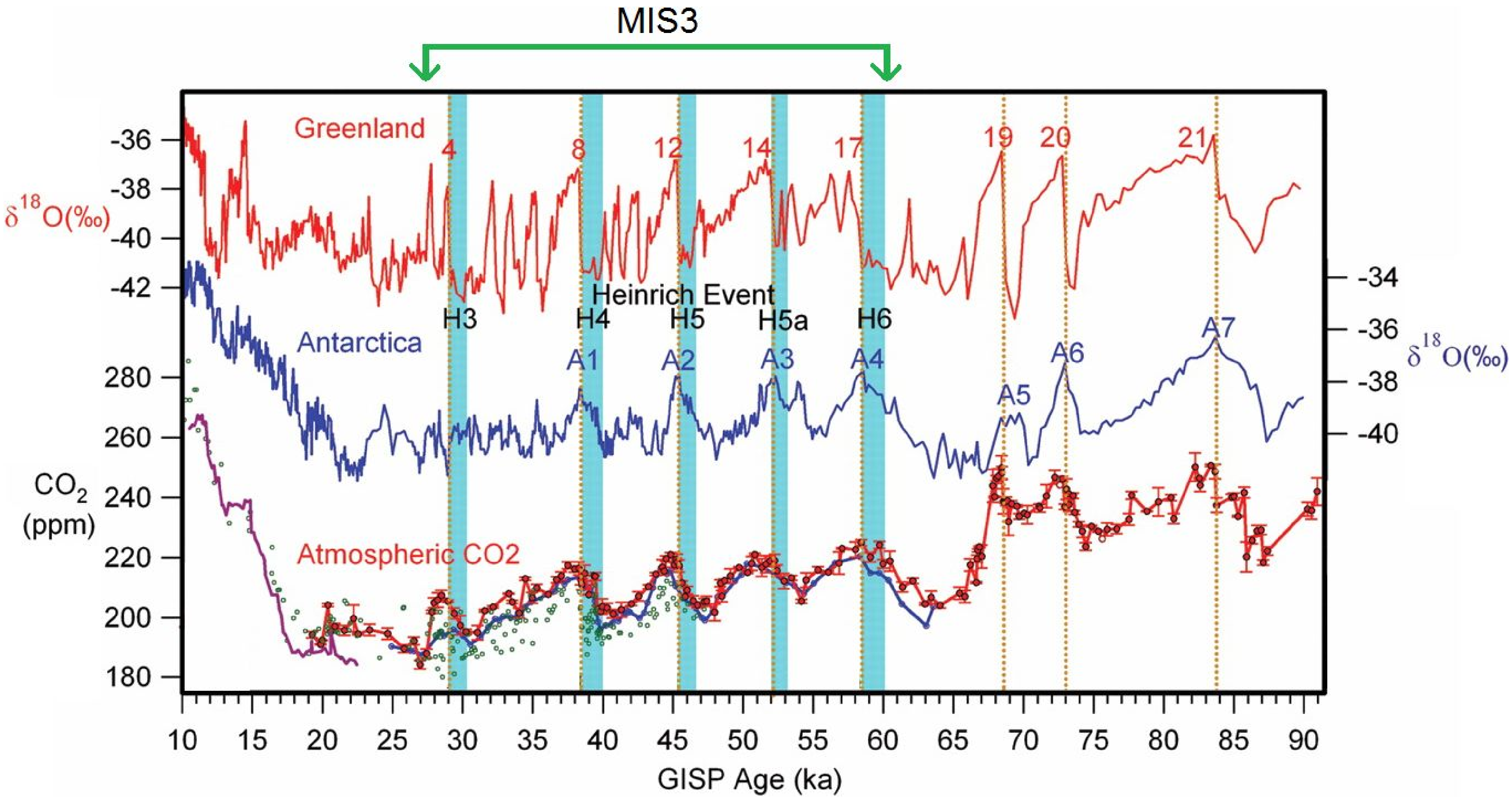
Meltwater fluxes:

http://www.eos.ubc.ca/research/glaciology/research/HeinrichEvents.html



Rahmstorf, 2002

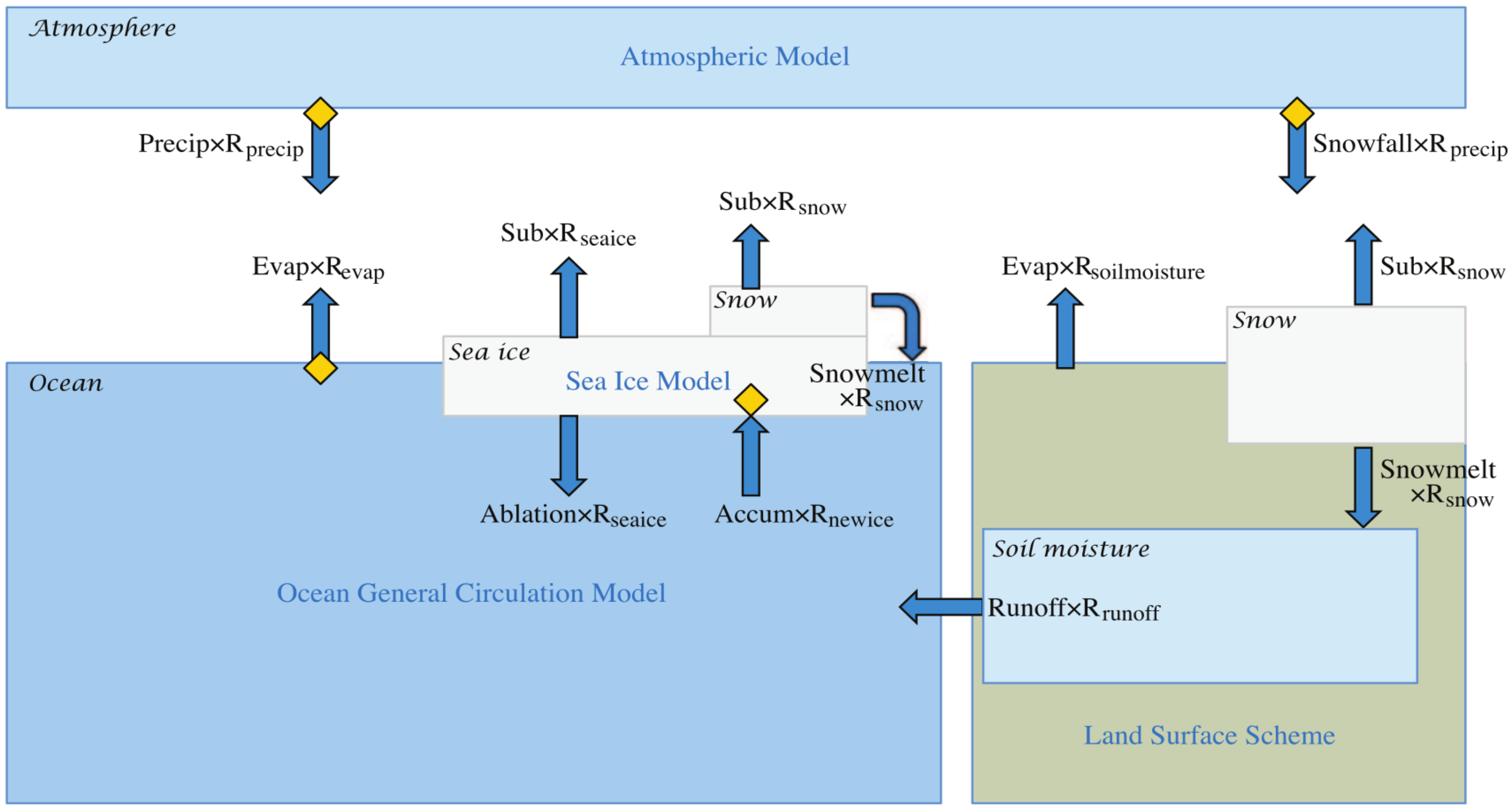
Marine Isotope Stage 3 (MIS3, 60-28 ka B.P.)



Ahn and Brook, 2008

UVic Earth System Climate Model

- Coupled ocean, atmosphere, sea ice, sediment, vegetation components
- Includes oxygen isotopes ($\delta^{18}O$)
- 3.6° x 1.8° grid, 19 vertical levels in the ocean
- EMIC (Earth System Model of Intermediate Complexity)



= Isotopic fractionation $R={}^{18}O/{}^{16}O$

Brennan, 2012

UVic Earth System Climate Model

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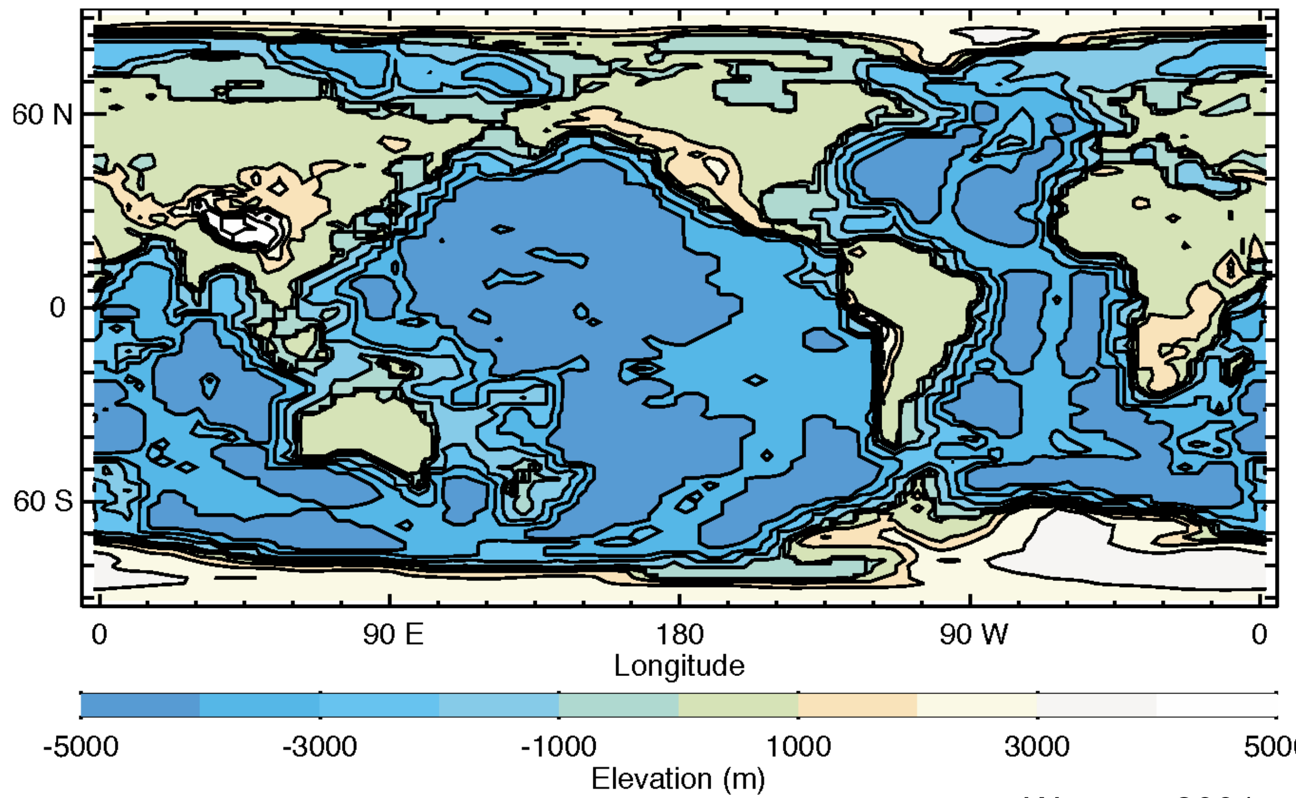


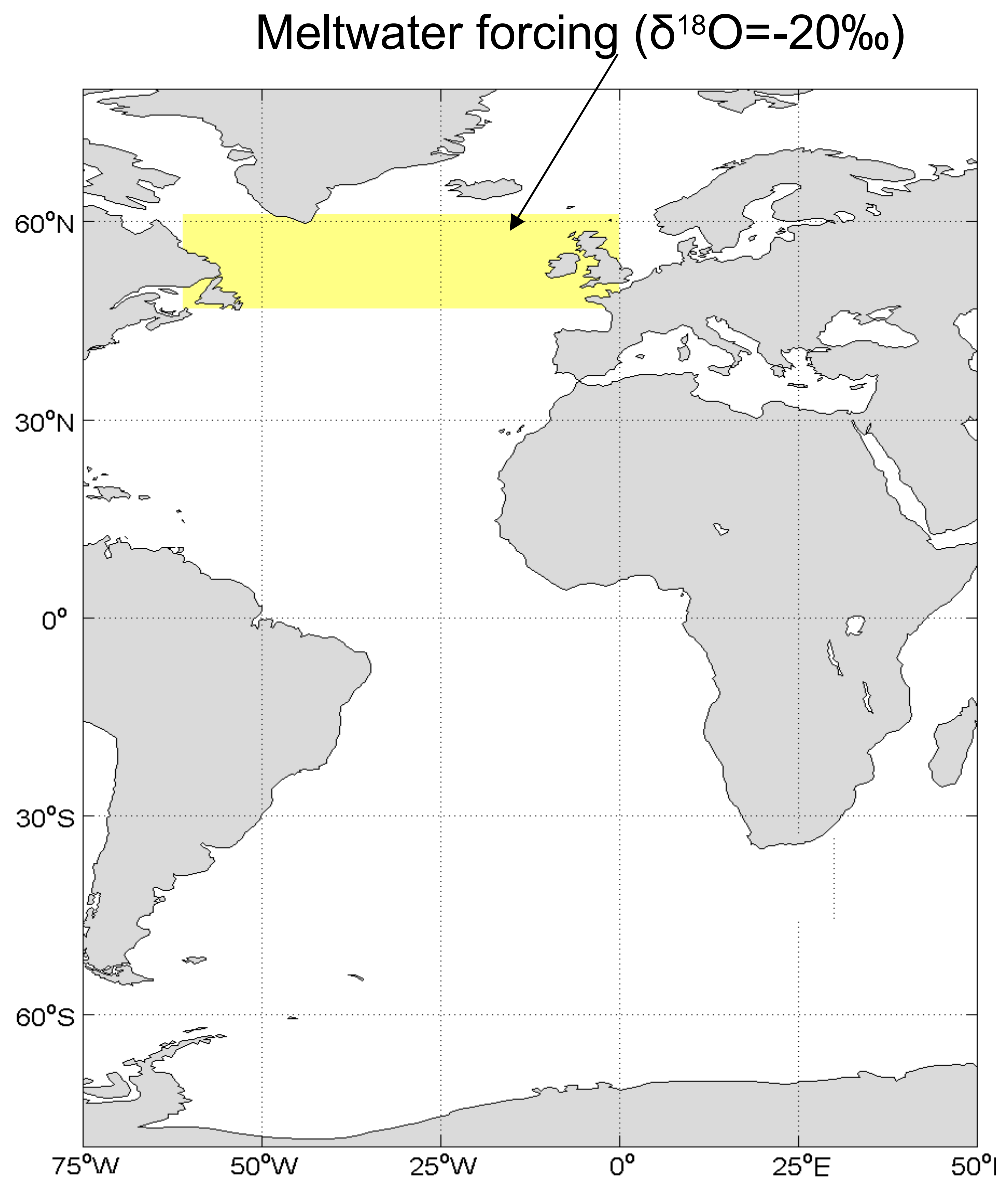
Weaver, 2001

UVic ESCM: transient simulations

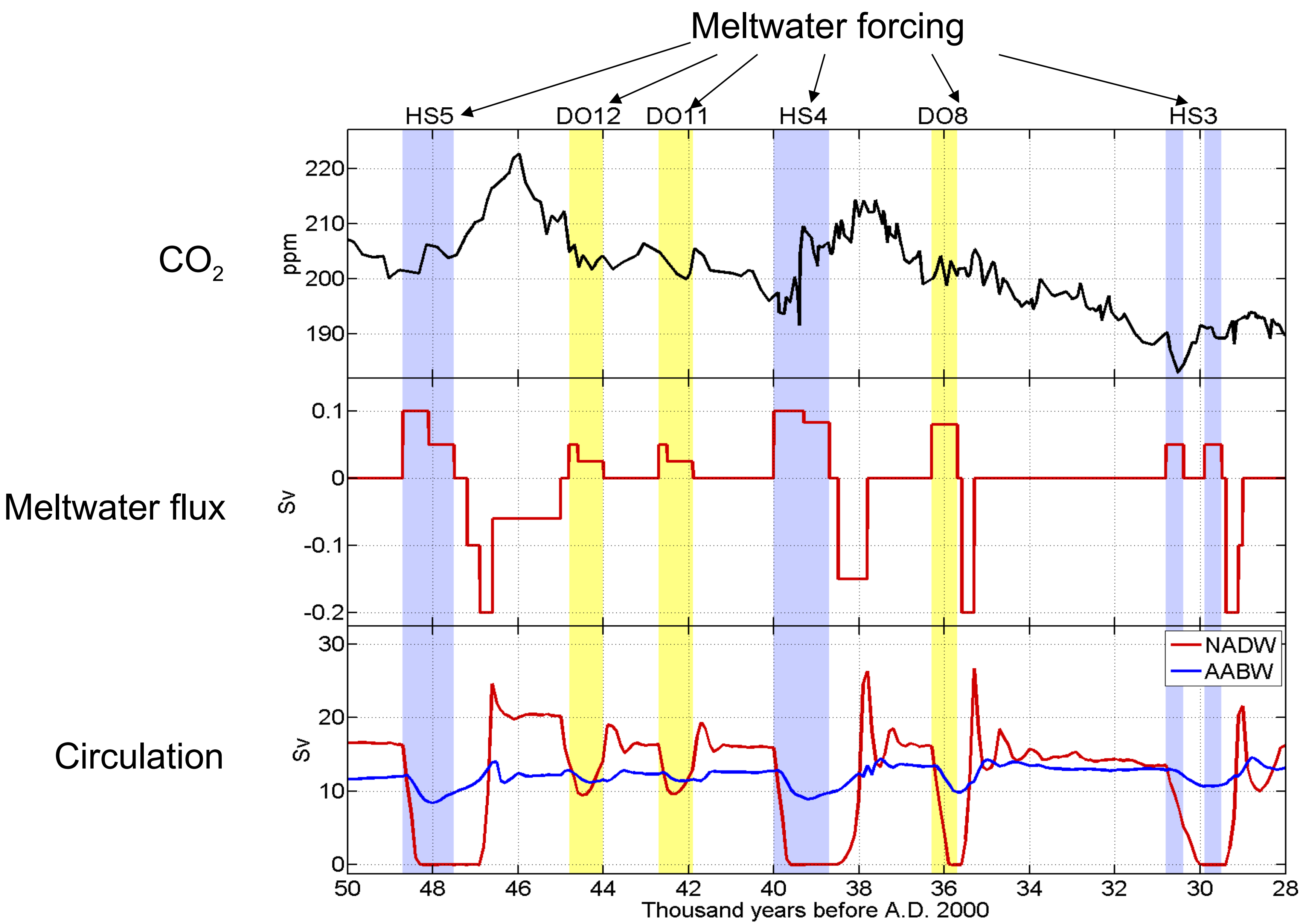
50 ka – 28 ka B.P.

Forcing:

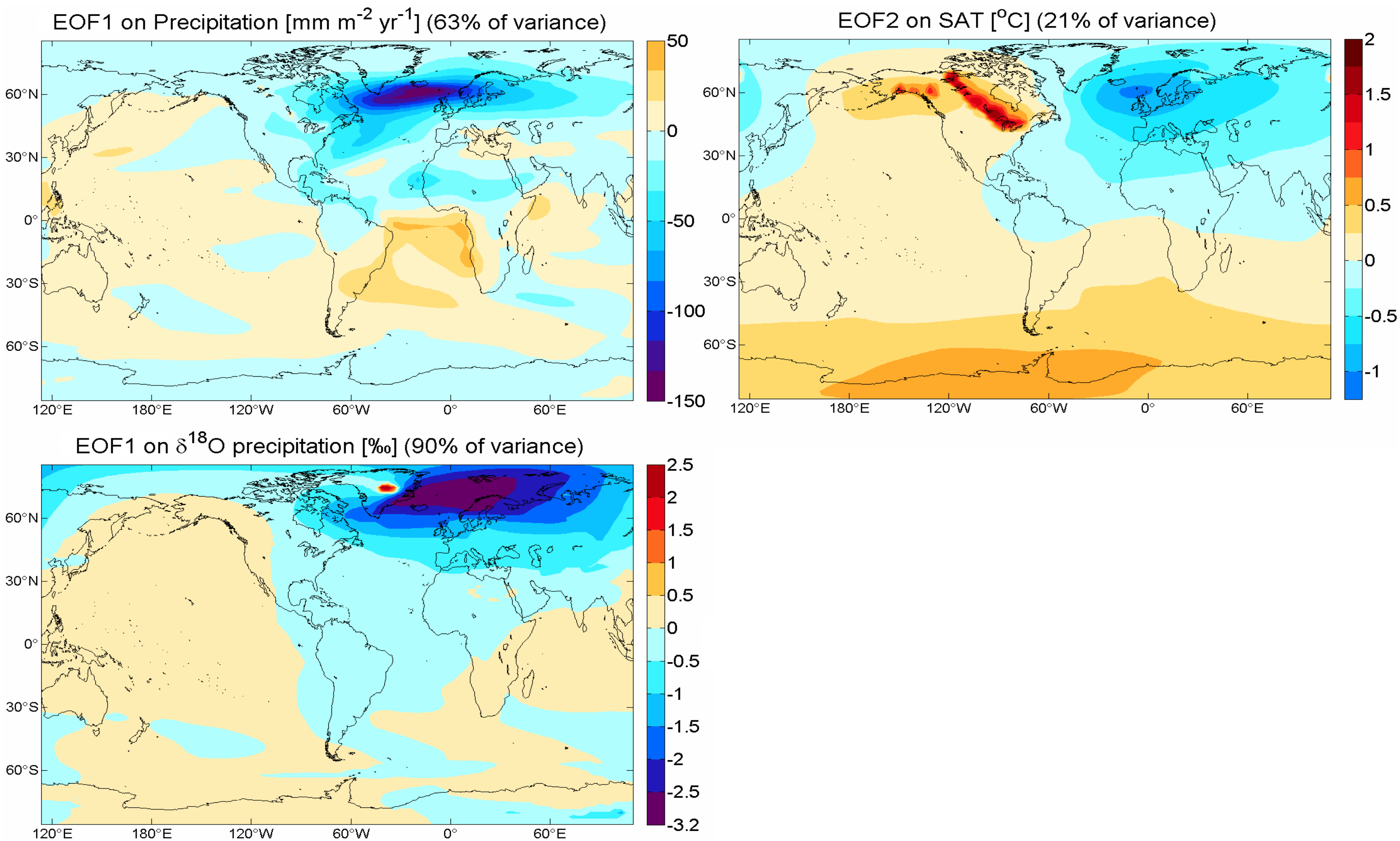
- orbital parameters
- atmospheric CO_2
- ice sheet topography
- meltwater fluxes



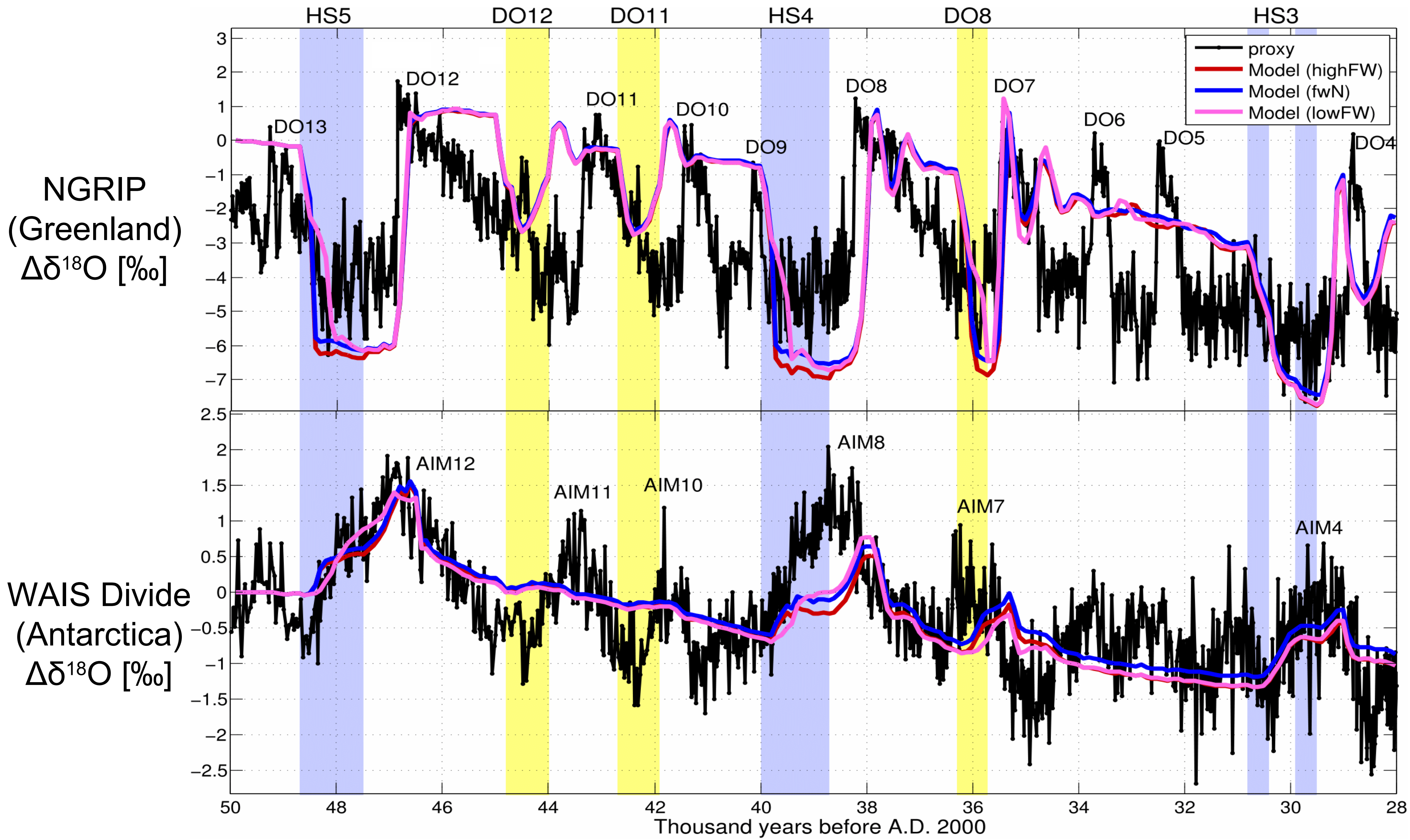
Transient simulations



Climate response

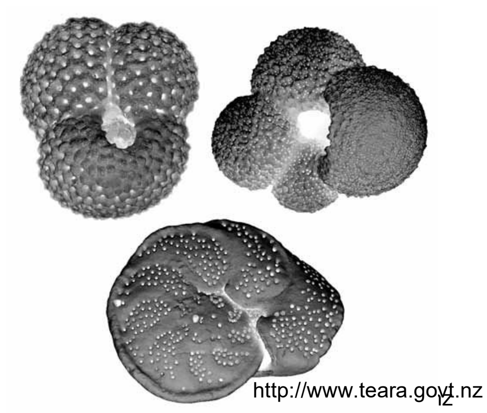


Climate response



Ocean sediment cores

Ocean sediment $\delta^{18}O$ is measured in foraminiferal calcite shells

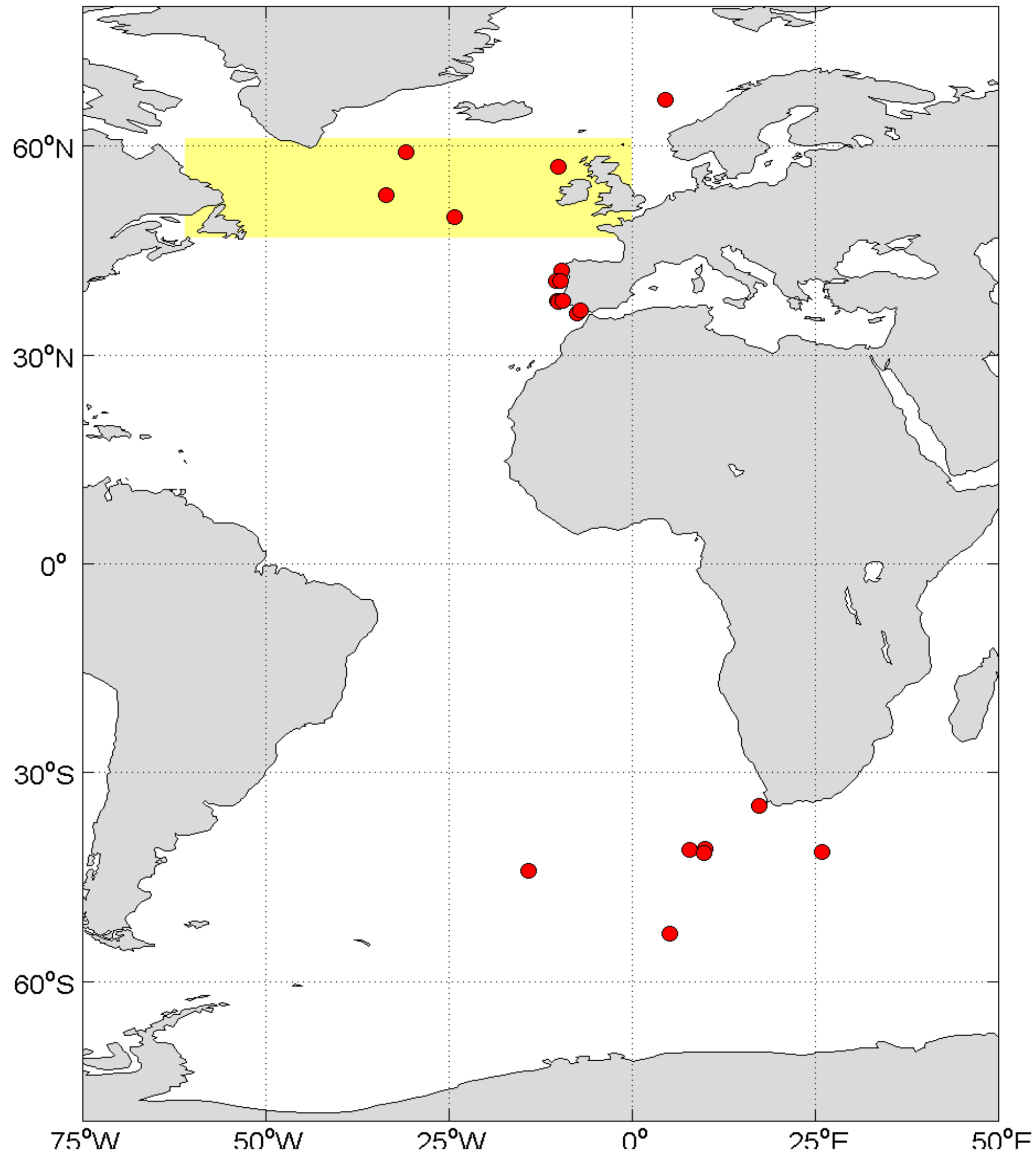


- Planktic: near the surface
- Benthic: ocean bottom

- Foraminiferal $\delta^{18}O$ a function of water $\delta^{18}O$ and temperature:

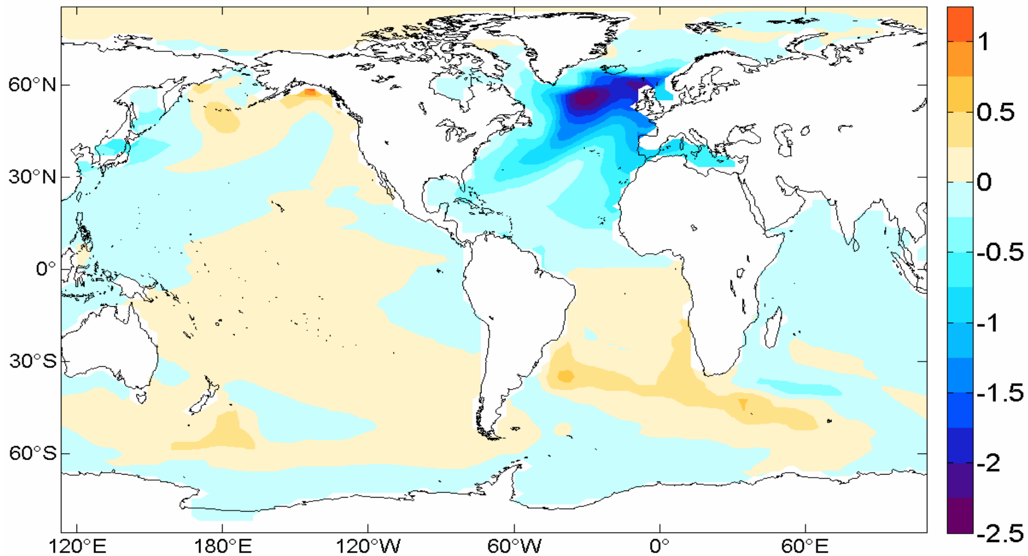
  $\delta^{18}O_c = f(\delta^{18}O_w, T)$

  (*Shackleton, 1974*)

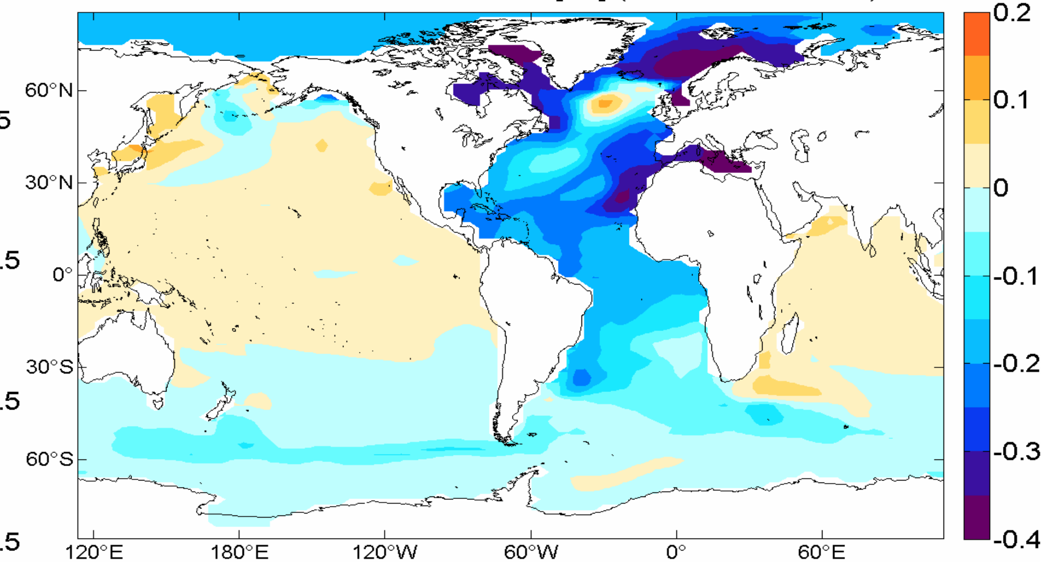


Ocean response

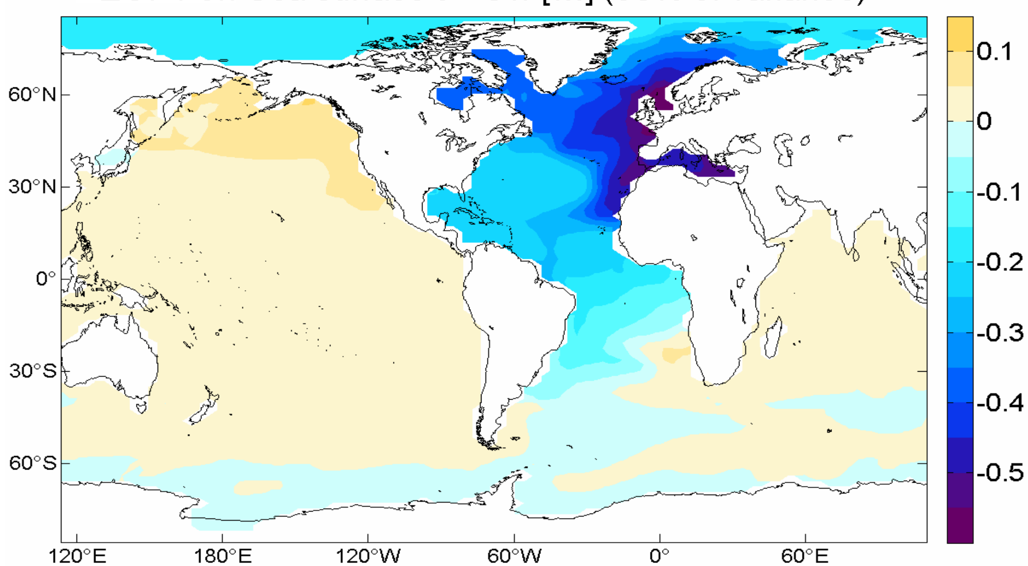
EOF1 on SST [^{o}C] (58% of variance)



EOF1 on Sea surface δ^{18}Oc [‰] (78% of variance)



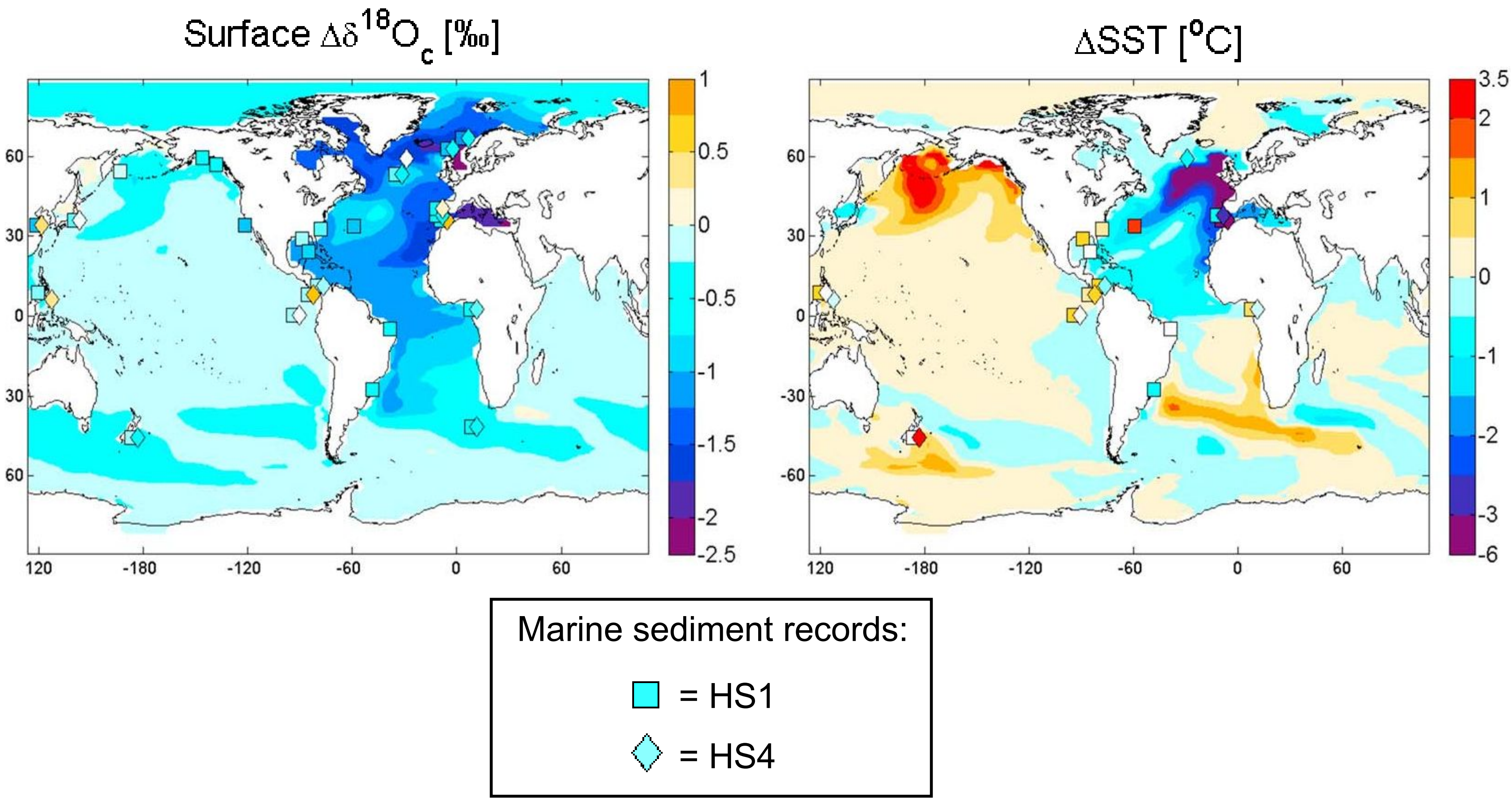
EOF1 on Sea surface δ^{18}Ow [‰] (90% of variance)



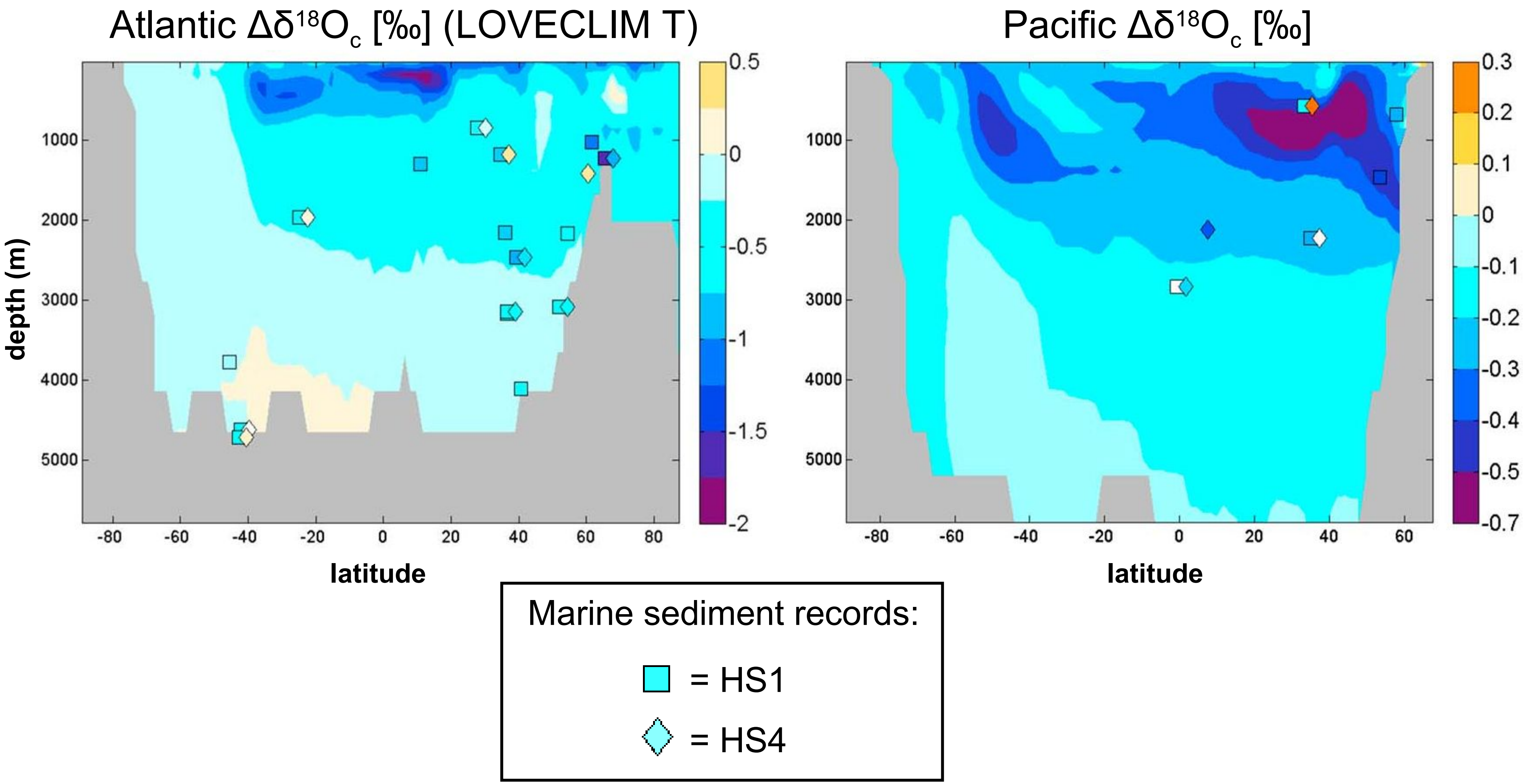
$$\delta^{18}O_c = f(\delta^{18}O_w, T)$$

(Shackleton, 1974)

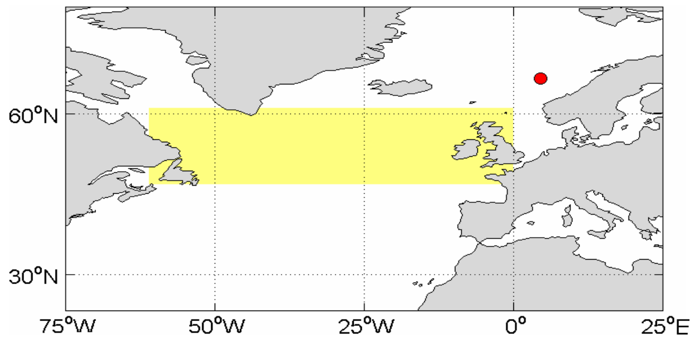
Ocean response (Heinrich event)



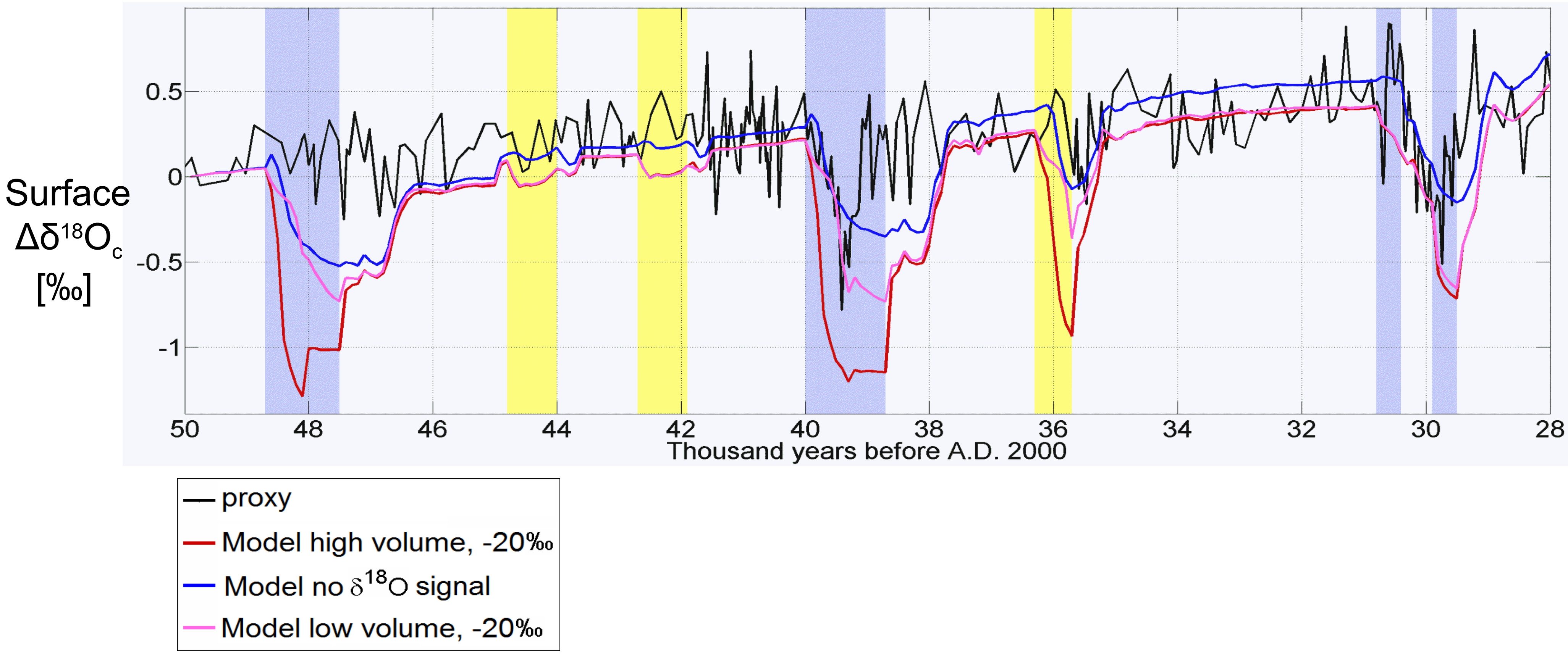
Ocean response (Heinrich event)



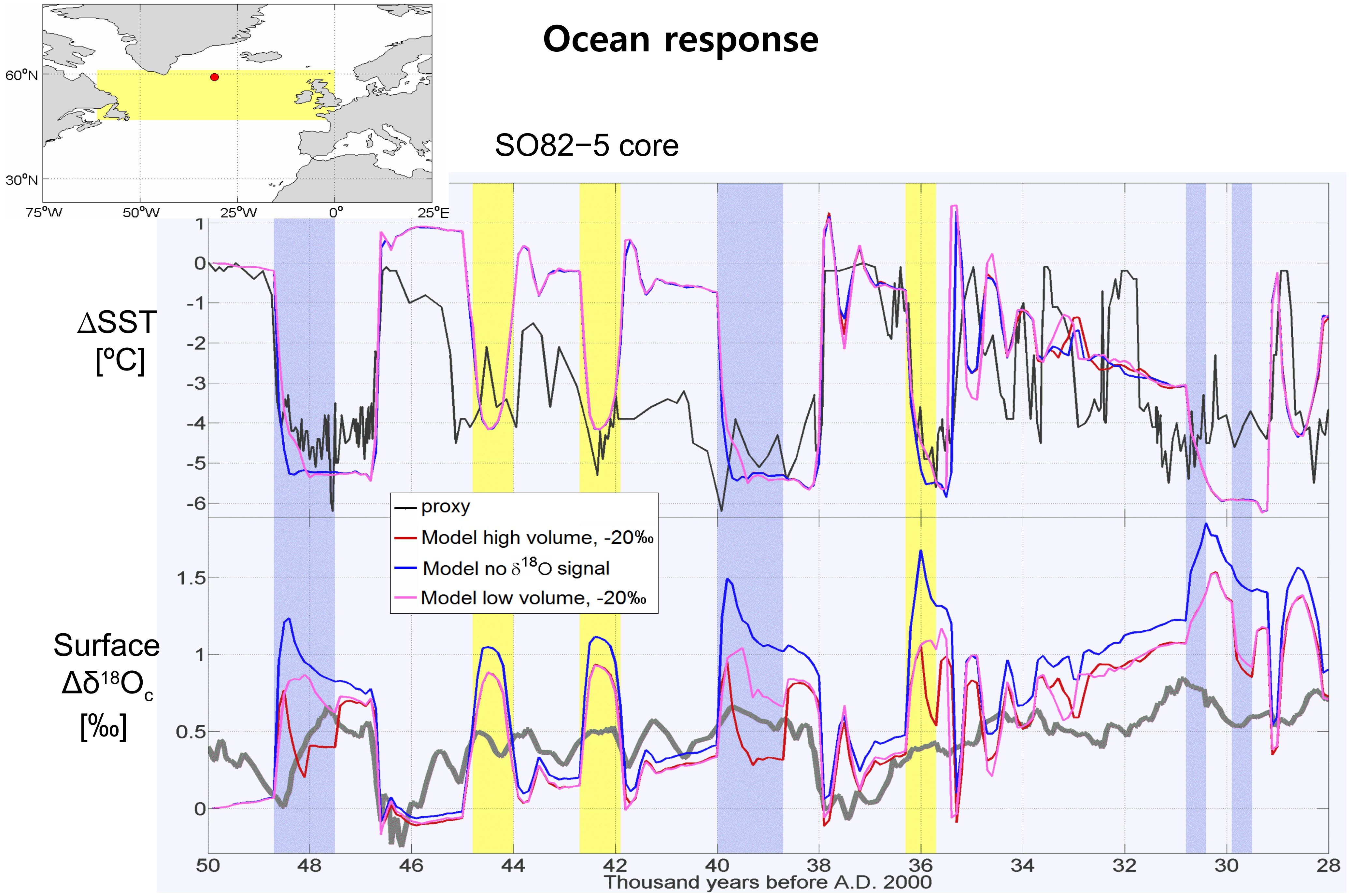
Ocean response



MD95−2010 core



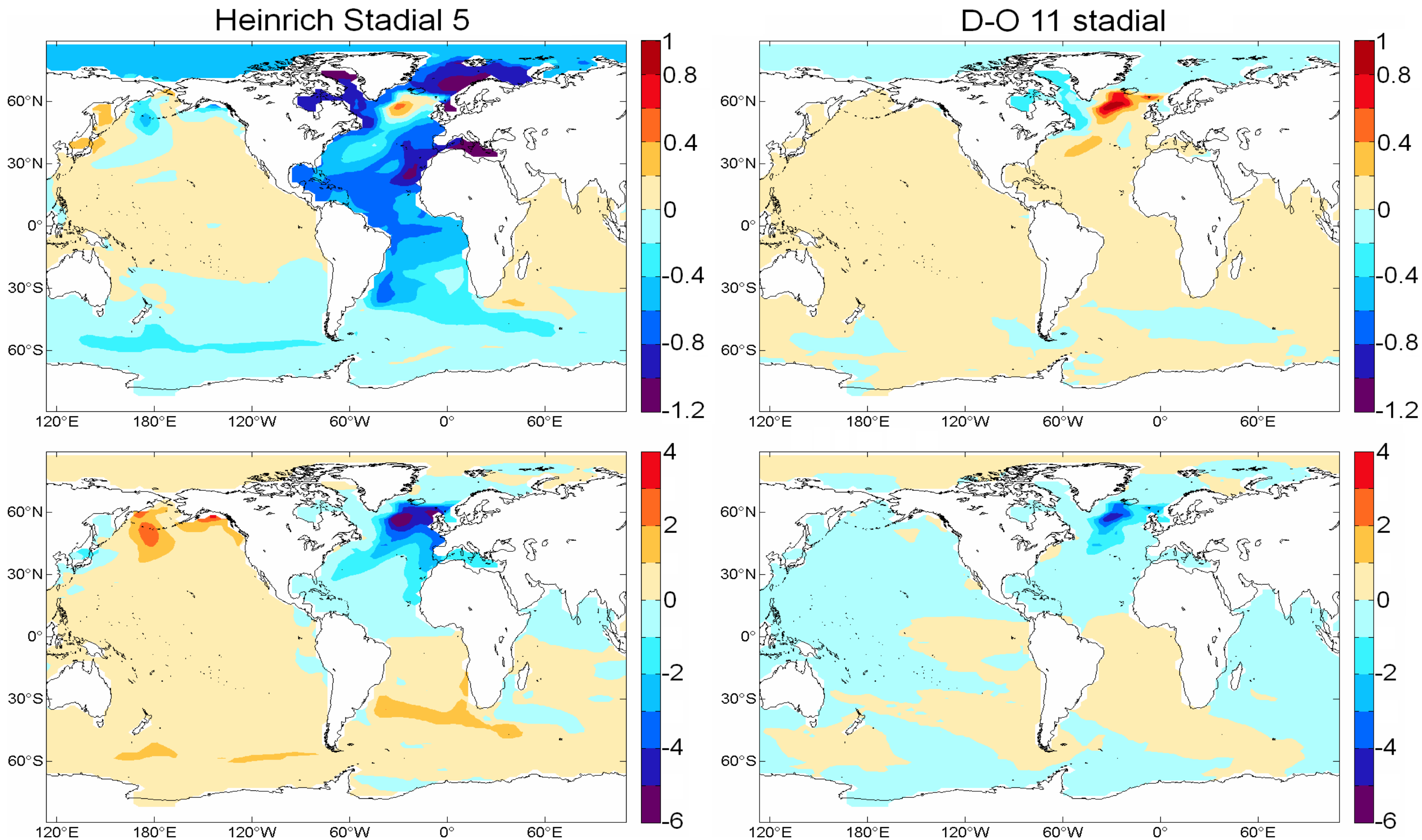
Ocean response



Differences between large stadials and small stadials

Surface $\Delta\delta^{18}O_c$ [‰] anomaly

ΔSST [ºC] anomaly

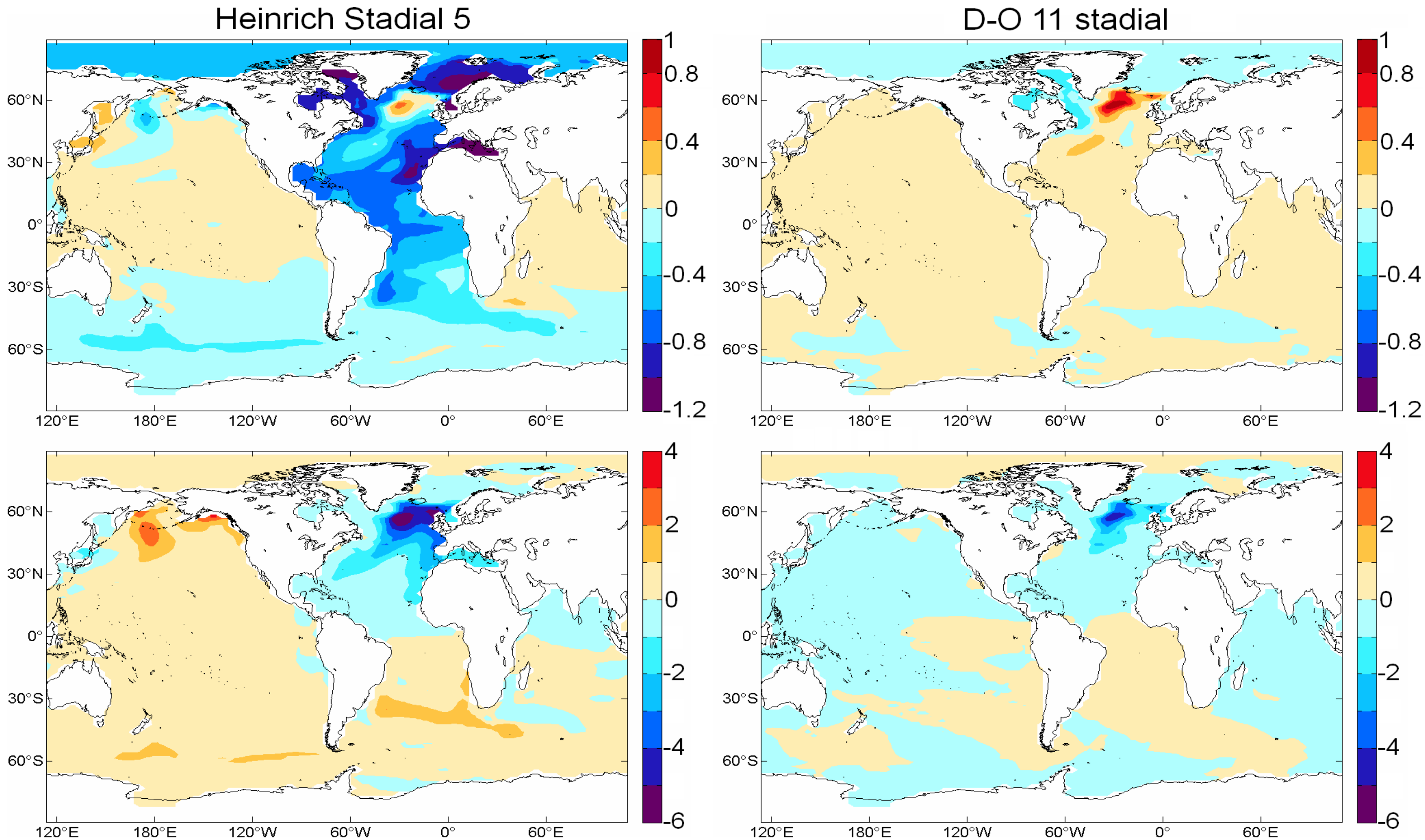


$$\Delta\delta^{18}O_c = f(\Delta\text{temperature}\ ,\ \Delta\text{circulation}\ ,\ \Delta\text{meltwater})$$

Differences between large stadials and small stadials

Surface $\Delta\delta^{18}O_c$ [‰] anomaly

ΔSST [ºC] anomaly



Factors for surface $\delta^{18}O_c$ anomalies in the North Atlantic:

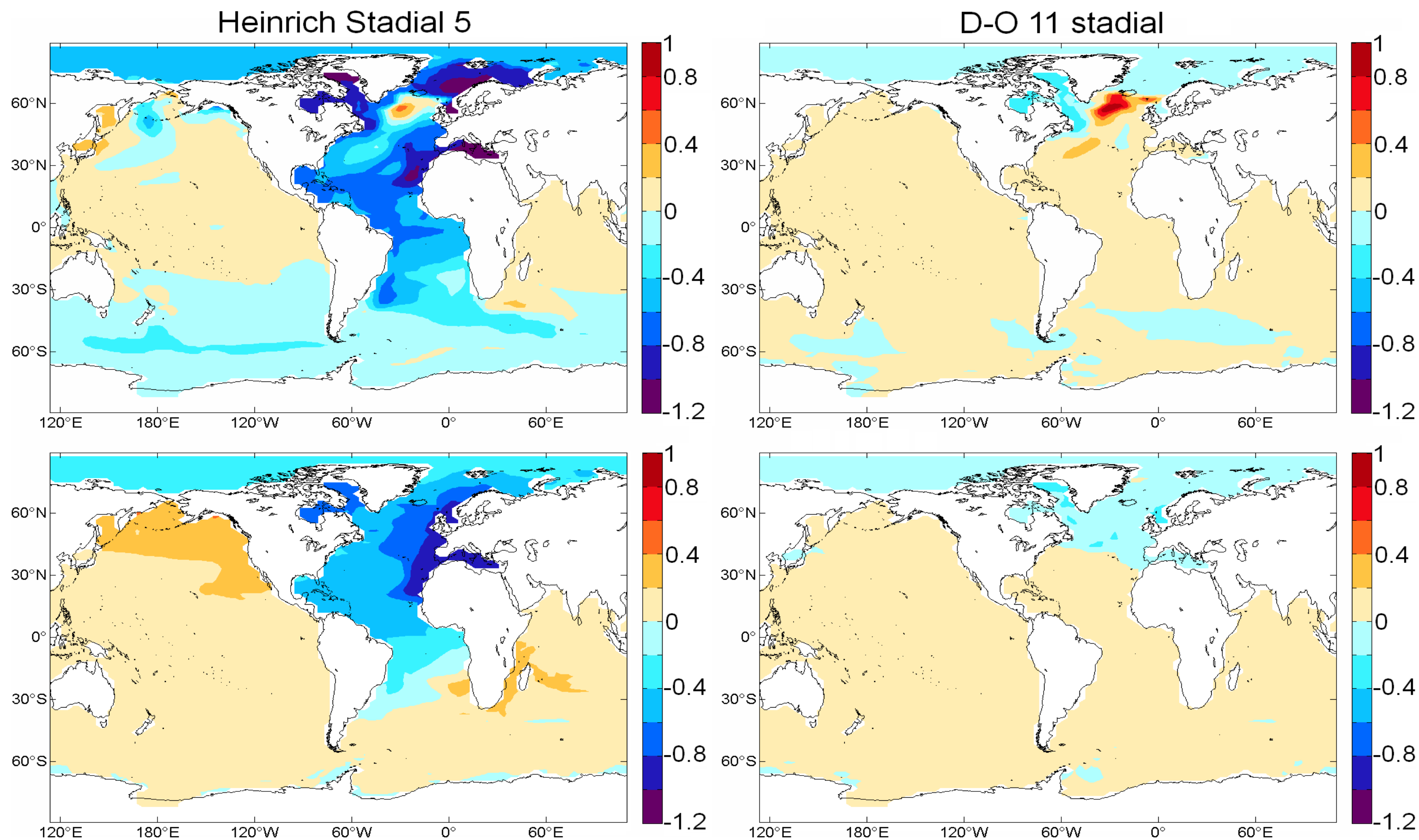
Temperature effect: 26%

Temperature effect: 47%

Differences between large stadials and small stadials

Surface $\Delta\delta^{18}O_c$ [‰] anomaly

$\Delta\delta^{18}O$ [‰] anomaly (circulation & climate)

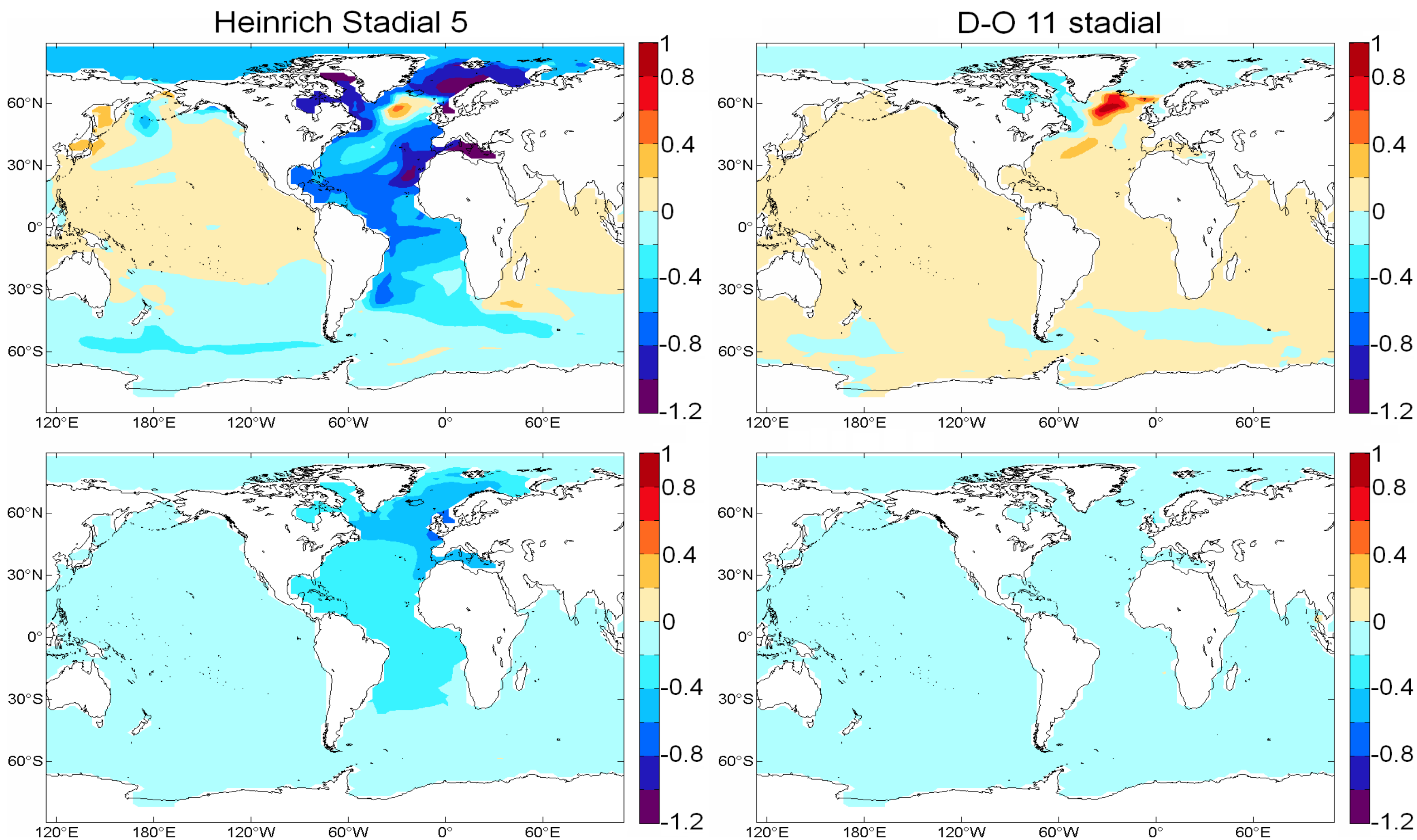


Factors for surface $\delta^{18}O_c$ anomalies in the North Atlantic:

Circulation & climate: 45%

Circulation & climate: 27%

Differences between large stadials and small stadials



Surface $\Delta\delta^{18}O_c$ [‰] anomaly

$\Delta\delta^{18}O$ [‰] anomaly (meltwater)

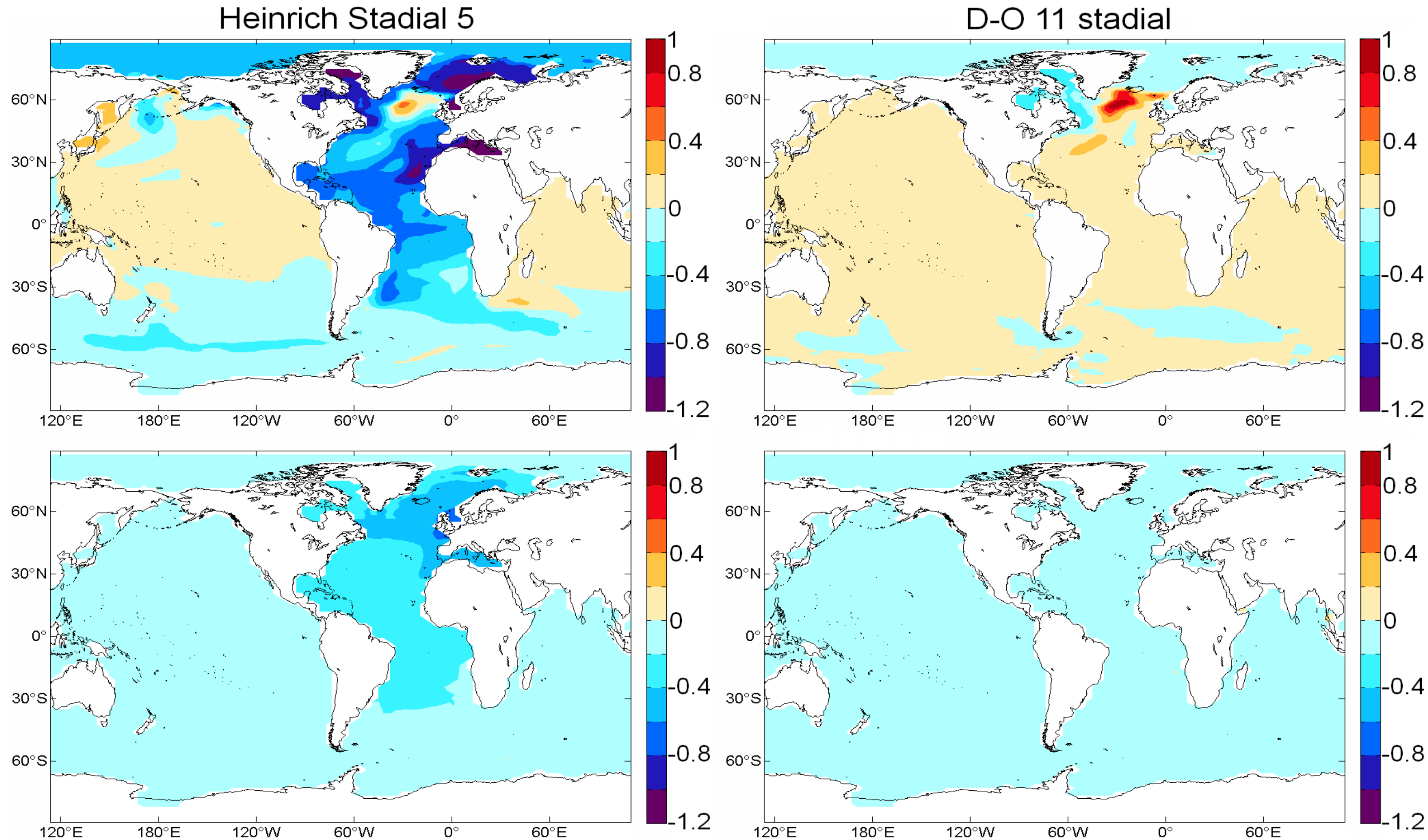
Factors for surface $\delta^{18}O_c$ anomalies in the North Atlantic:

Meltwater: 29%   Meltwater: 26%

Differences between large stadials and small stadials

Surface $\Delta\delta^{18}O_c$ [‰] anomaly

$\Delta\delta^{18}O$ [‰] anomaly (meltwater)



Factors for surface $\delta^{18}O_c$ anomalies in the North Atlantic:

	Heinrich Stadial 5	D-O 11 stadial
Temperature effect:	26%	47%
Circulation & climate:	45%	27%
Meltwater:	29%	26%

Current goals

- When studying paleoproxy records and comparing them with models, properly identifying the transition points (e.g. D-O events) is crucial

- Postdoc at ENS with Michael Ghil and Denis-Didier Rousseau:
  - part of the TiPES project (Tipping Points in the Earth System, www.tipes.dk)
  - create a method for objectively identifying abrupt transitions in paleoproxy records
  - build a database of paleo-records including well defined tipping points
  - collaborate with different teams of climate modelers

TiPES

TIPPING POINTS IN THE EARTH SYSTEM

Summary

- The first transient simulations of Marine Isotope Stage 3, including its millennial-scale $\delta^{18}O$ variability
  - compared with ice core and sediment core records

- Likely a strong link between stadial-interstadial changes and AMOC variability
  - 30-50% weakening of the AMOC during Dansgaard-Oeschger stadials
  - complete shutdown during Heinrich stadials

- Significant differences in $\delta^{18}O_c$ anomalies between Heinrich stadials and non-Heinrich stadials
  - mainly due to different responses in sea surface temperature and ocean circulation

- Further details:

  - Bagniewski, W., Meissner, K. J., and Menviel, L. (2017), Exploring the oxygen isotope fingerprint of Dansgaard-Oeschger variability and Heinrich events. *Quaternary Science Reviews*
  - Bagniewski, W., Meissner, K. J., Menviel, L., and Brennan, C. E. (2015), Quantification of factors impacting seawater and calcite $\delta^{18}O$ during Heinrich Stadials 1 and 4. *Paleoceanography*