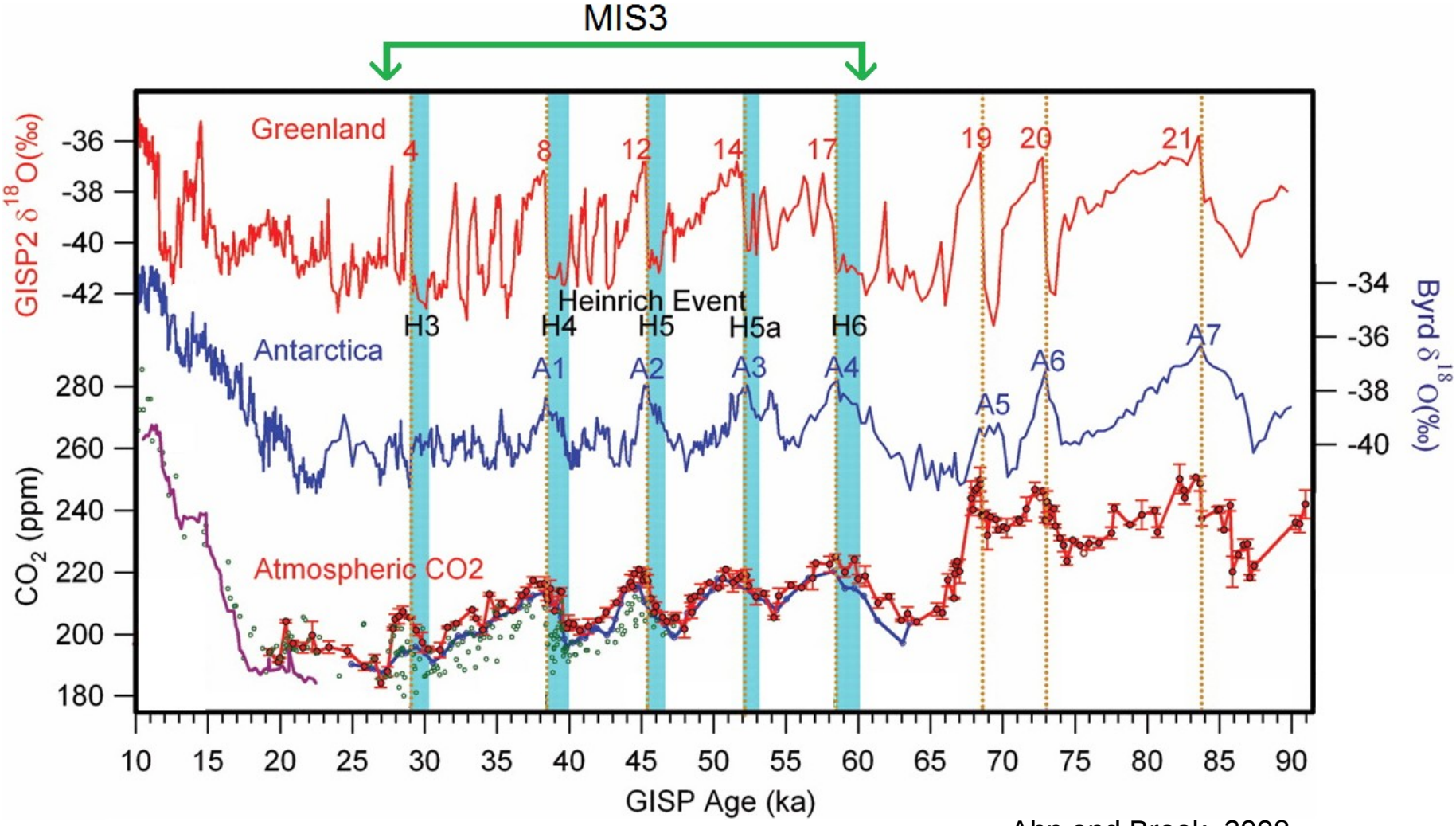
Transient simulations of Marine Isotope Stage 3 with a $\delta^{18}O$-enabled Earth System Climate Model

Witold Bagniewski, Katrin Meissner, Laurie Menviel

Climate Change Research Centre, University of New South Wales
ARC Centre of Excellence for Climate System Science

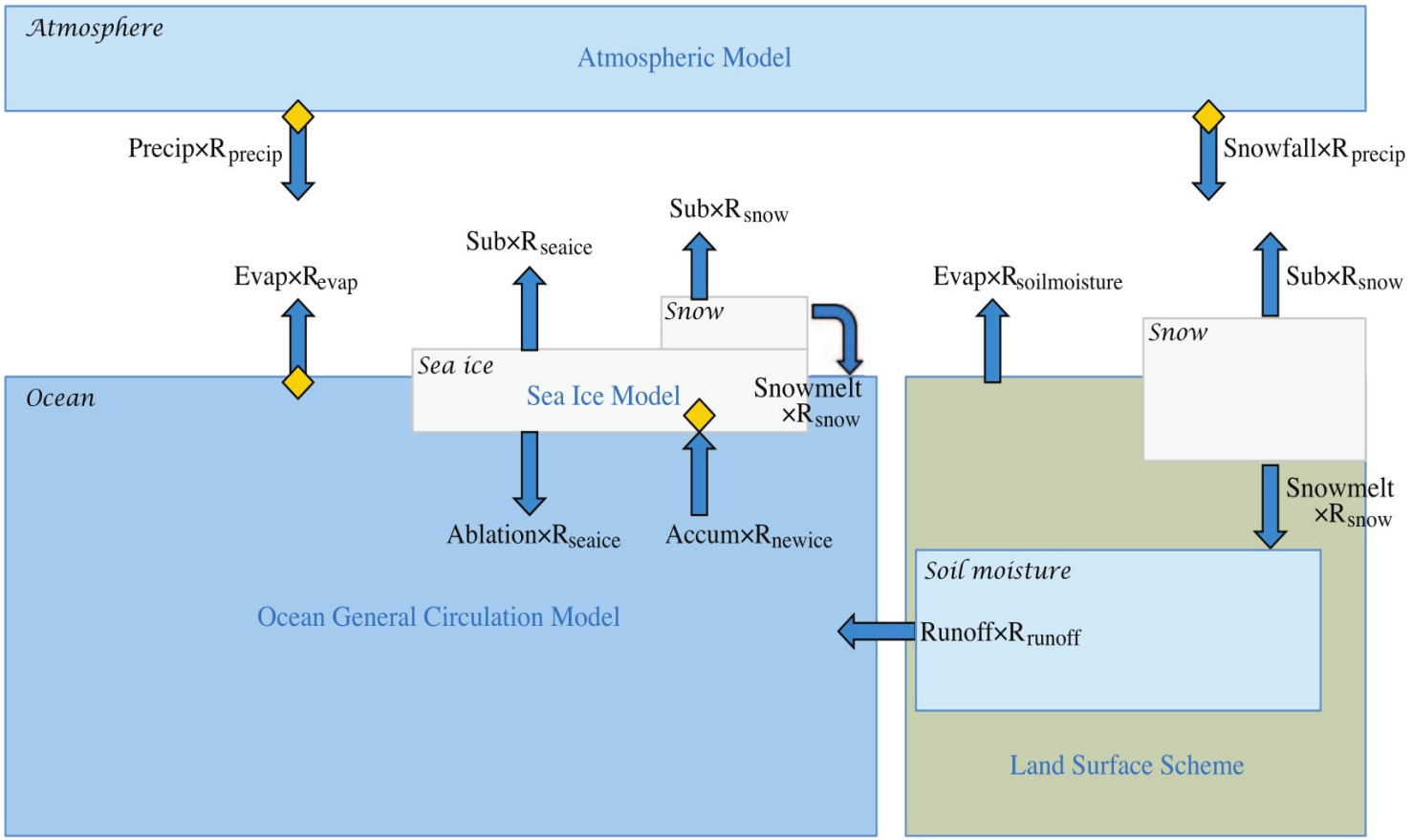
Marine Isotope Stage 3 (MIS3, 60-28 ka B.P.)



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



◆ = Isotopic fractionation

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

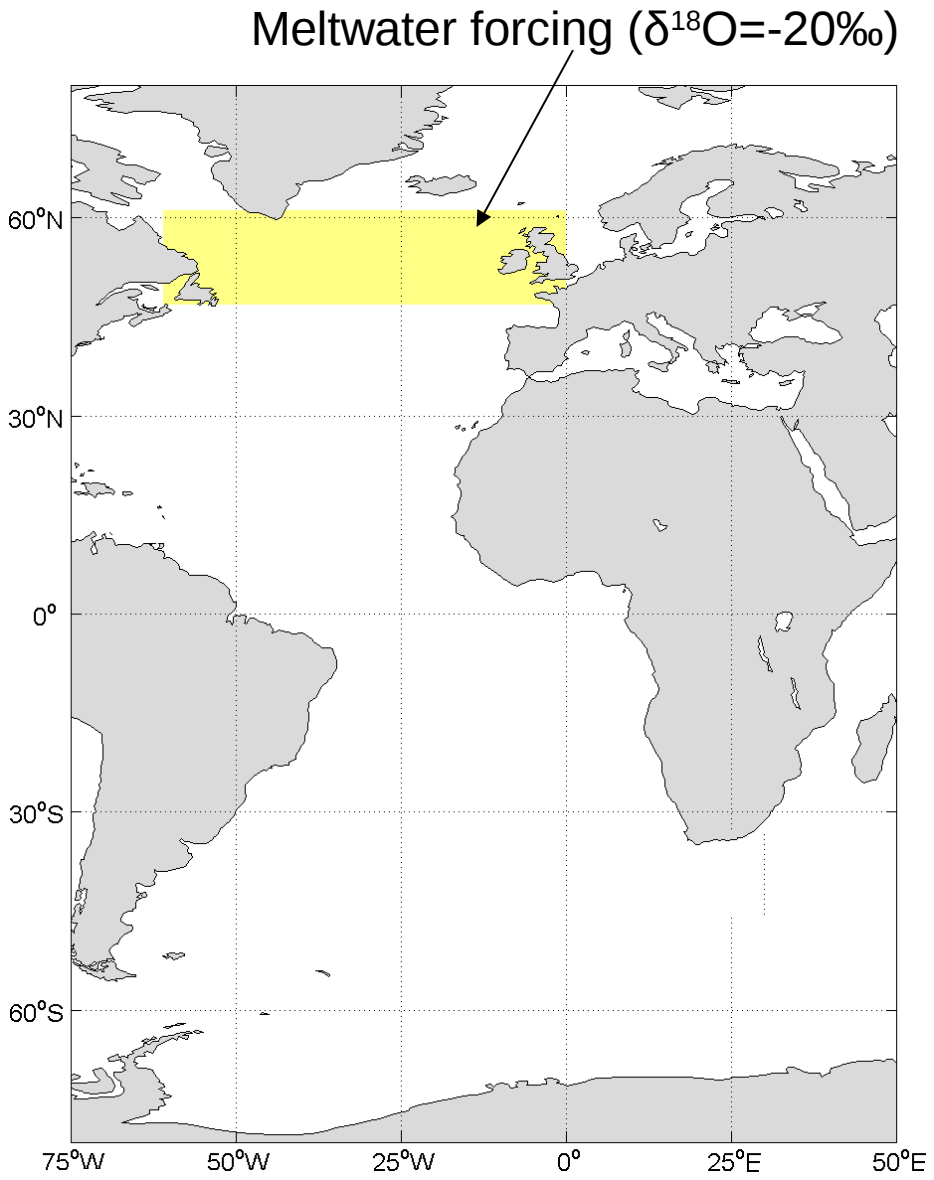
Brennan, 2012

UVic ESCM: transient simulations

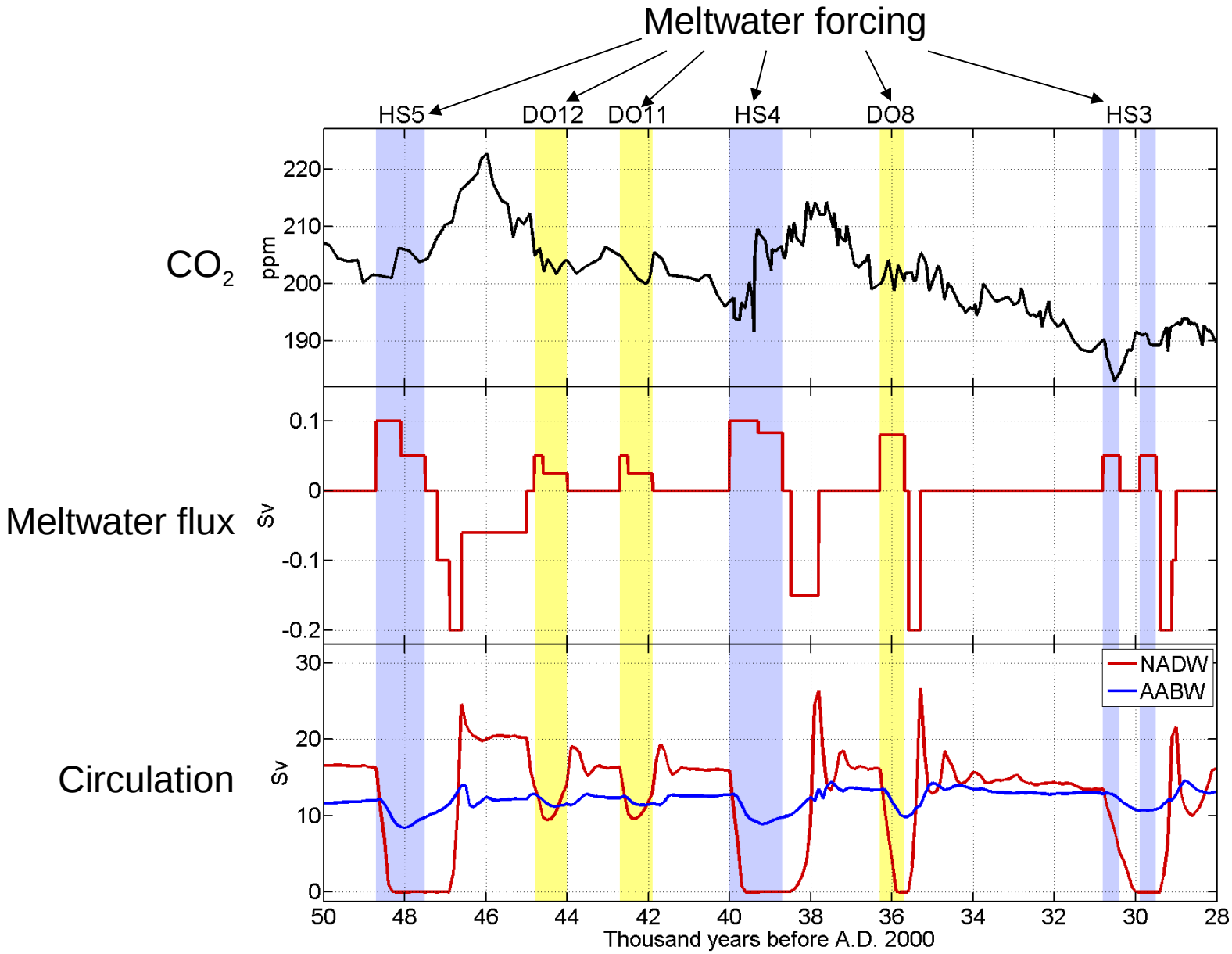
50 ka – 28 ka BP

Forcing:

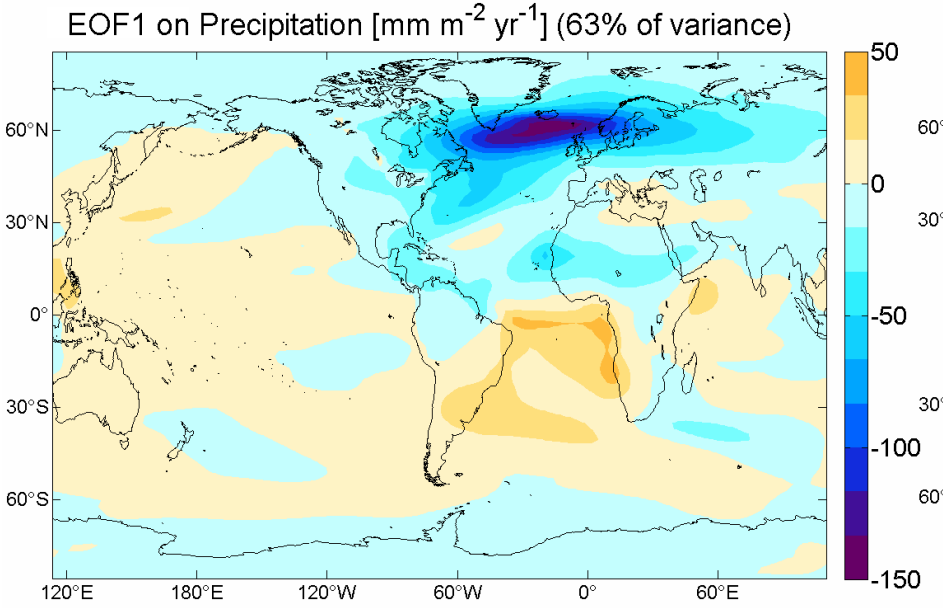
- orbital parameters
- atmospheric CO_2
- ice sheet topography
- meltwater fluxes

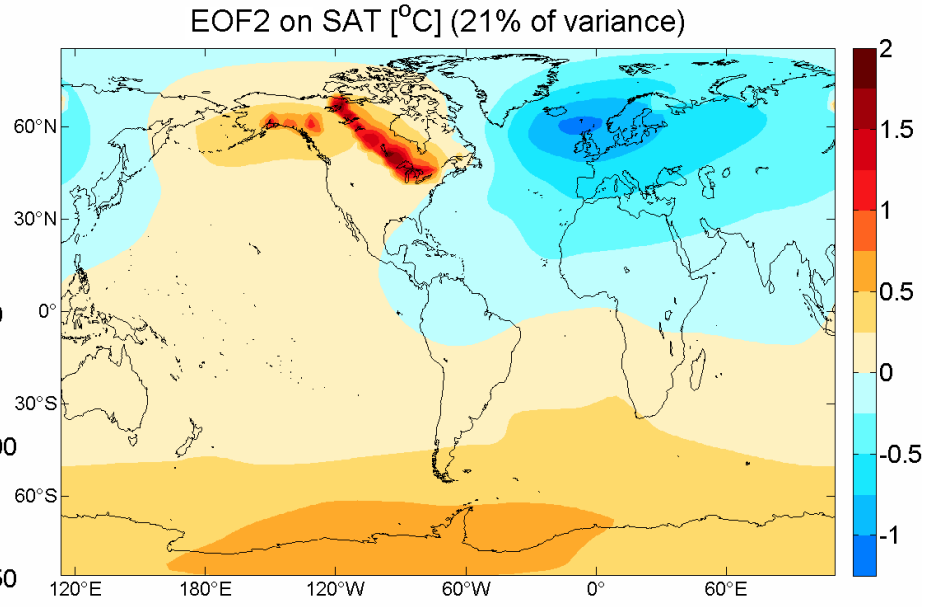


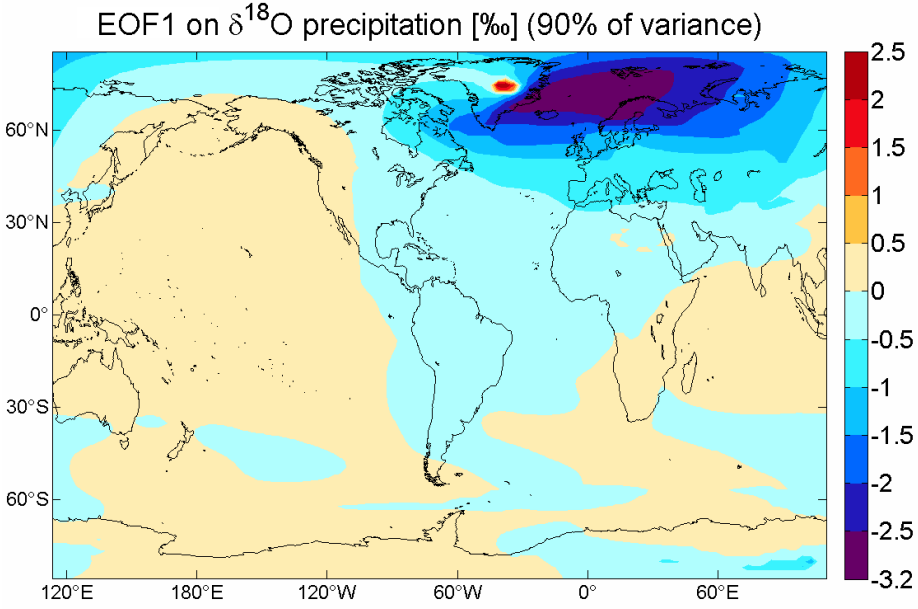
Transient simulations



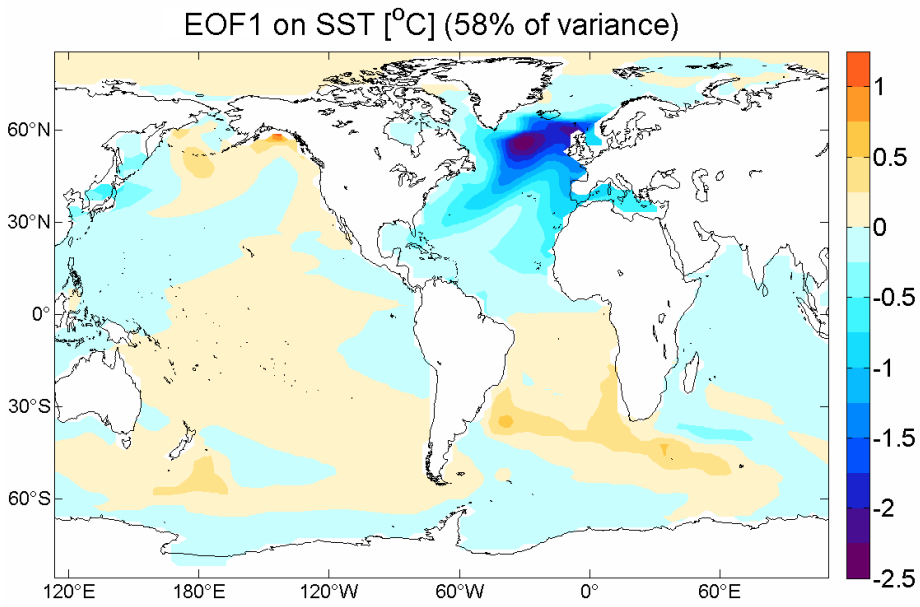
Climate response

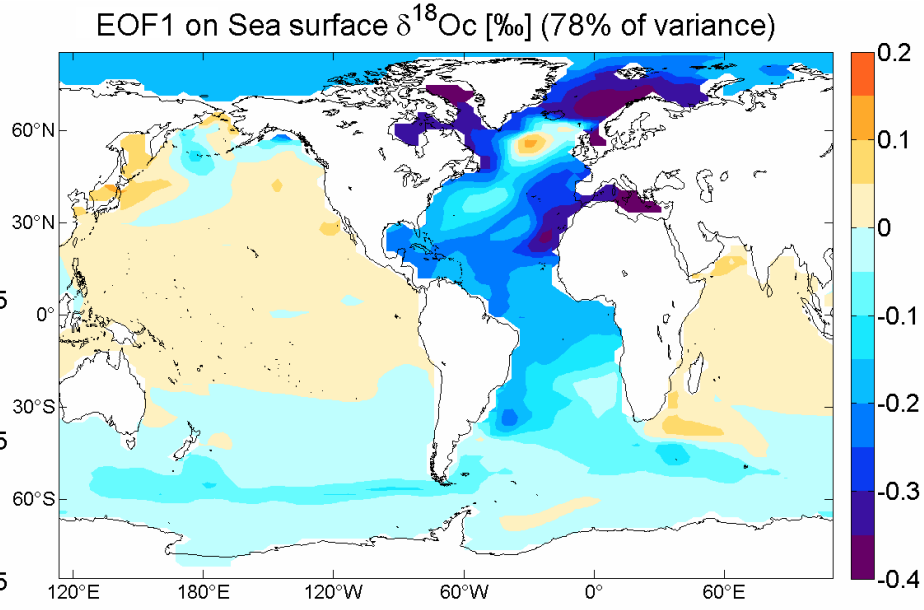


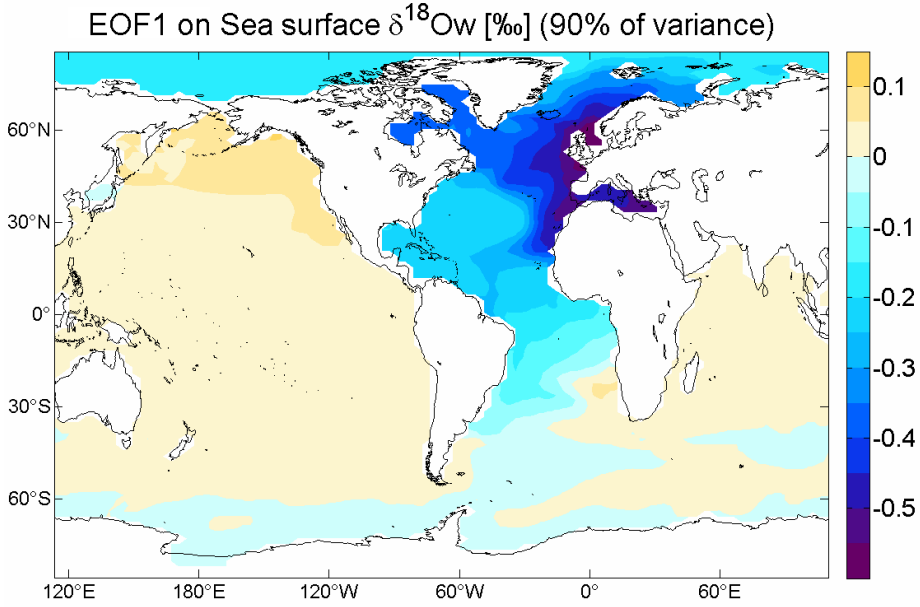




Ocean response







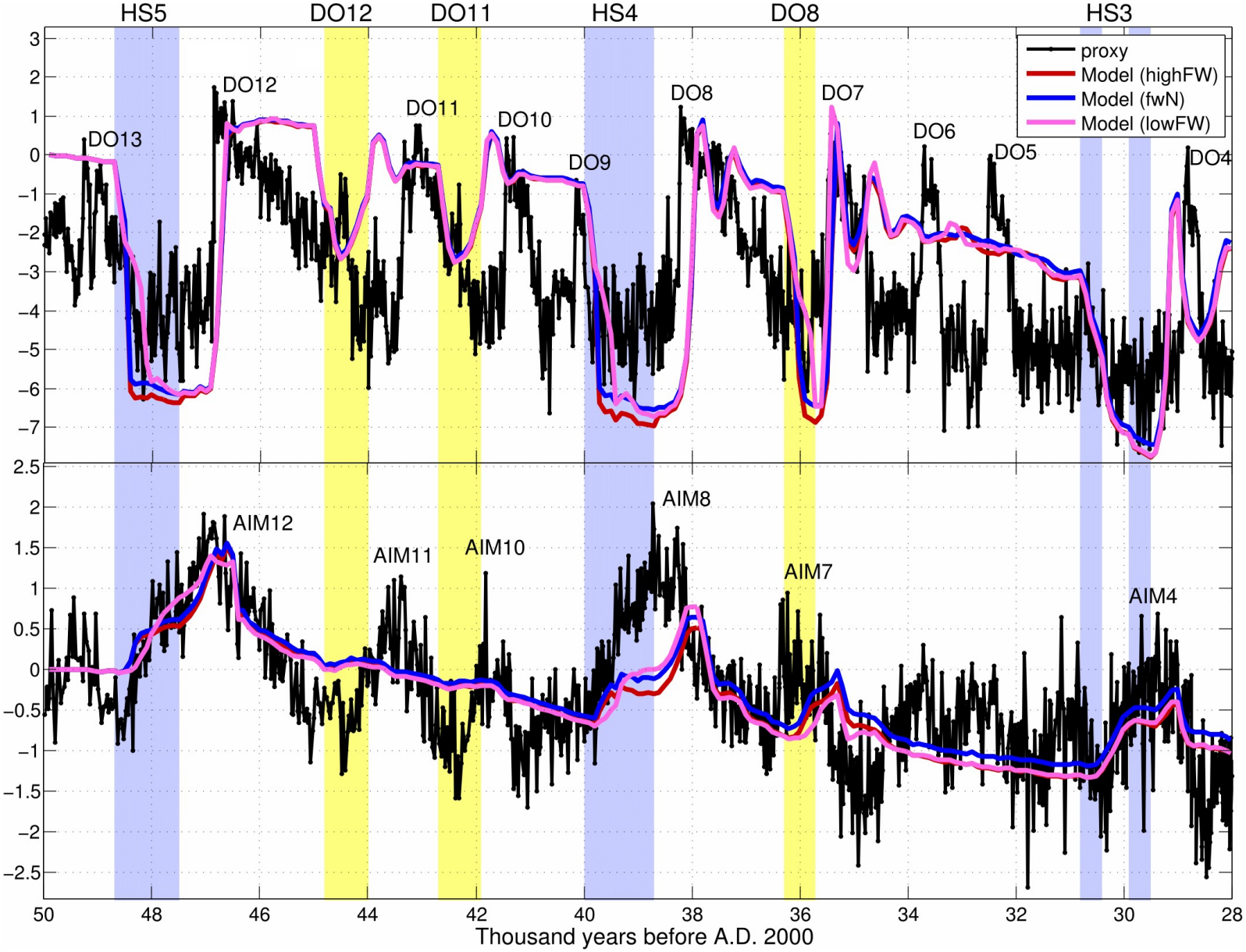
$\delta^{18}O_c = f(\delta^{18}O_w, SST)$

(Shackleton, 1974)

Climate response

Greenland
$\Delta\delta^{18}O$ [‰]

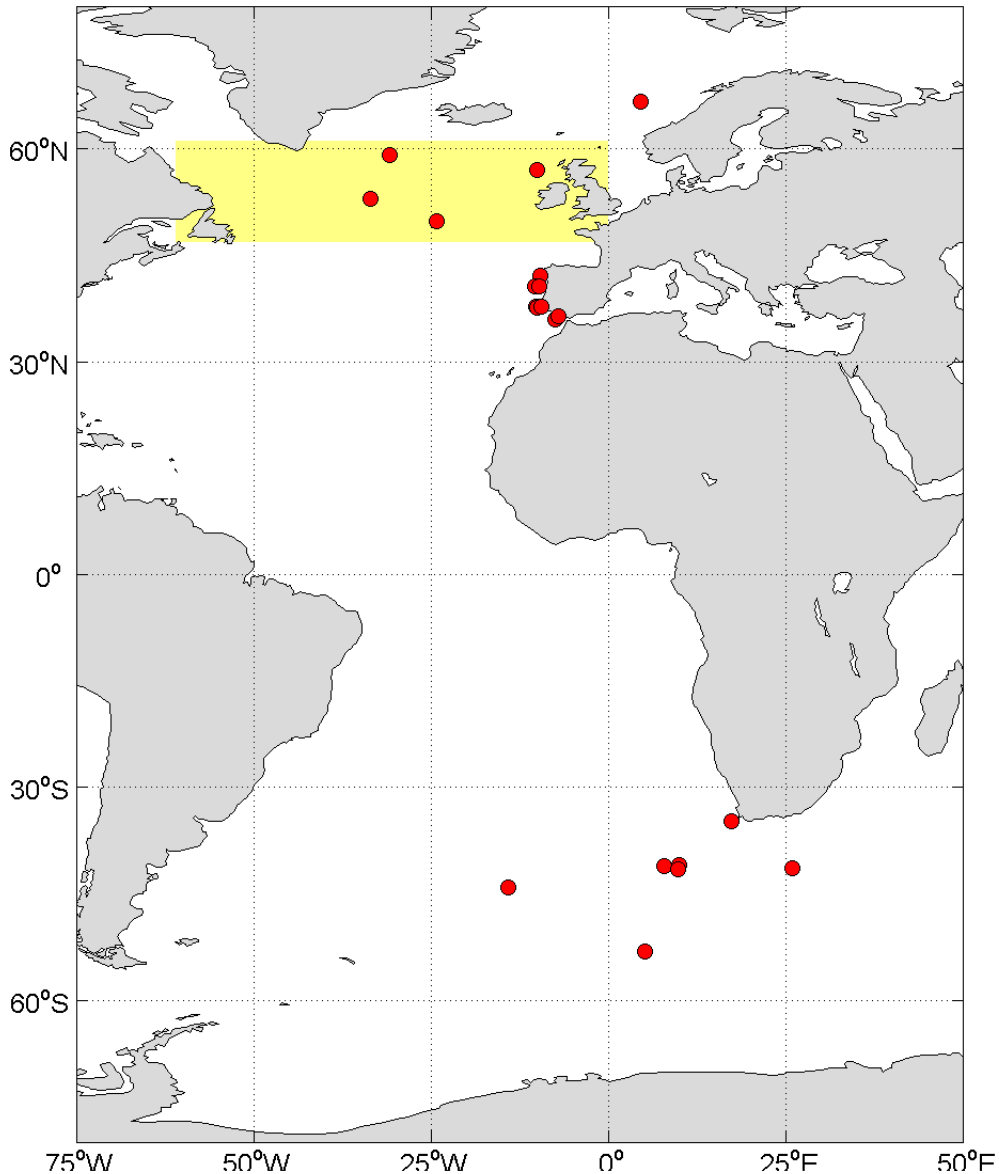
Antarctica
$\Delta\delta^{18}O$ [‰]



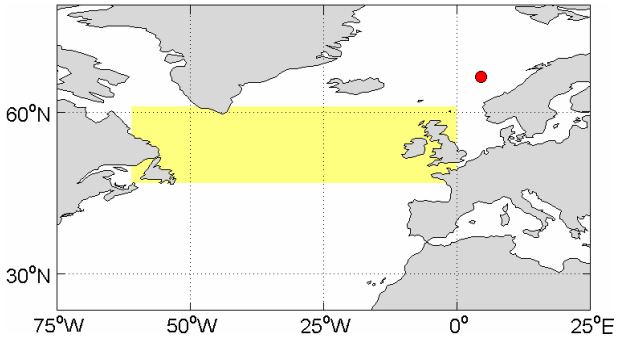
Ocean response

20 sediment cores

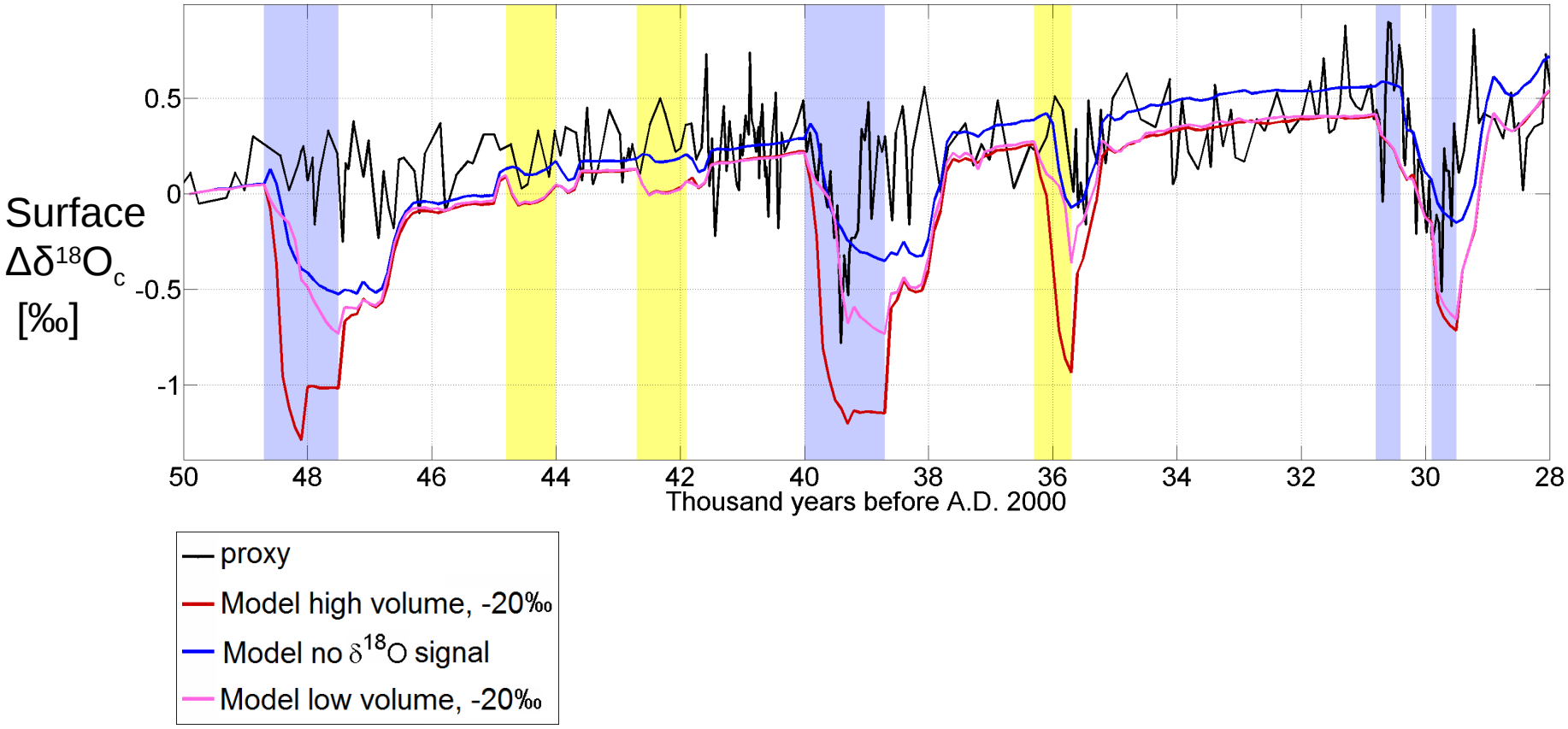
Planktic and benthic



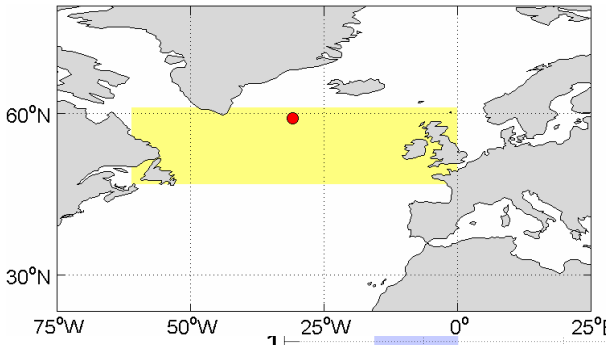
Ocean response



MD95−2010 core



Ocean response



SO82−5 core

ΔSST [ºC]

Surface $\Delta\delta^{18}O_c$ [‰]

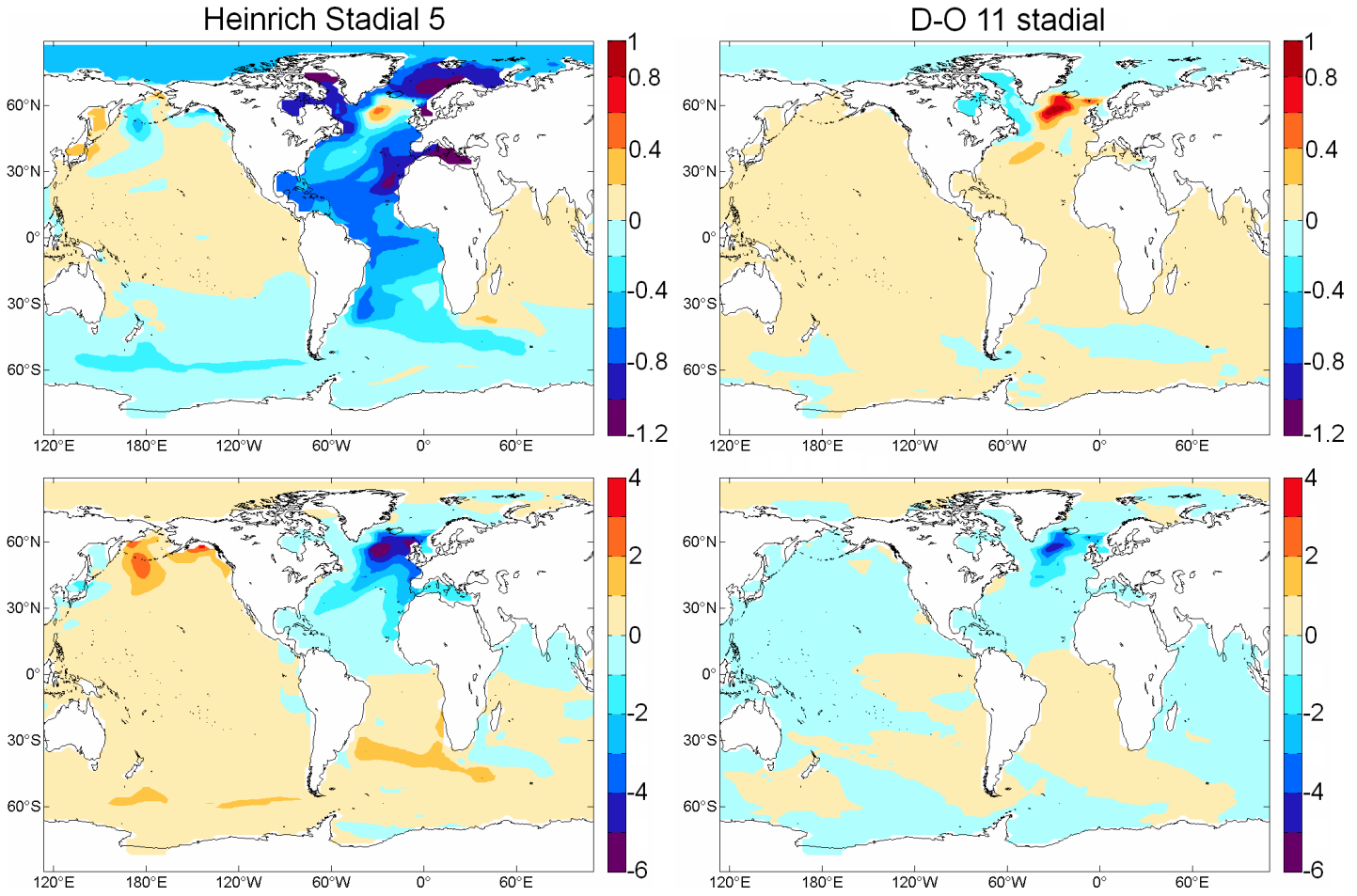
proxy
Model high volume, -20‰
Model no $\delta^{18}O$ signal
Model low volume, -20‰

Thousand years before A.D. 2000

Differences between large stadials and small stadials

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

ΔSST [ºC] anomaly

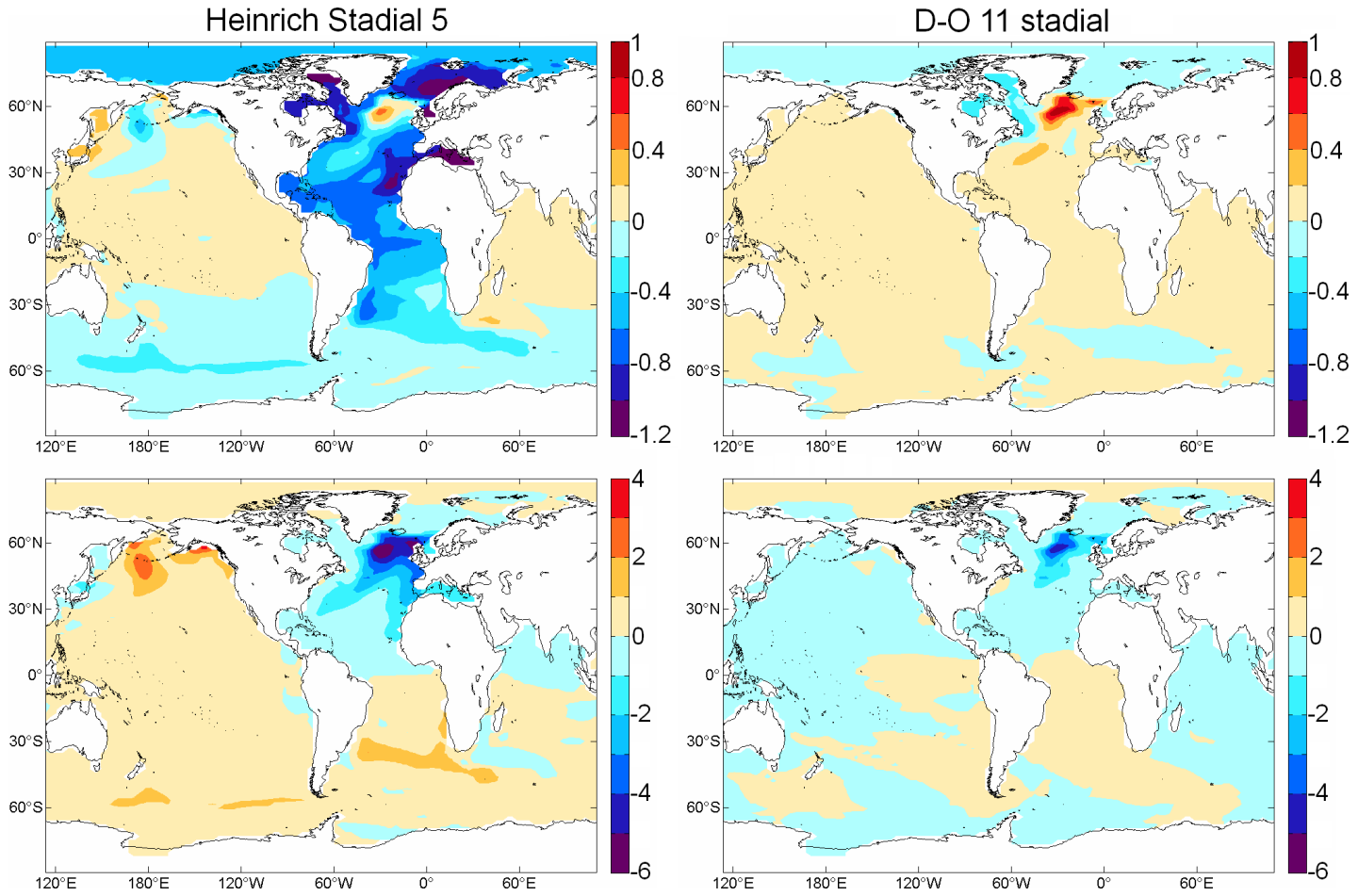


$\Delta\delta^{18}O_c$ = f(temperature , circulation , meltwater)

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:

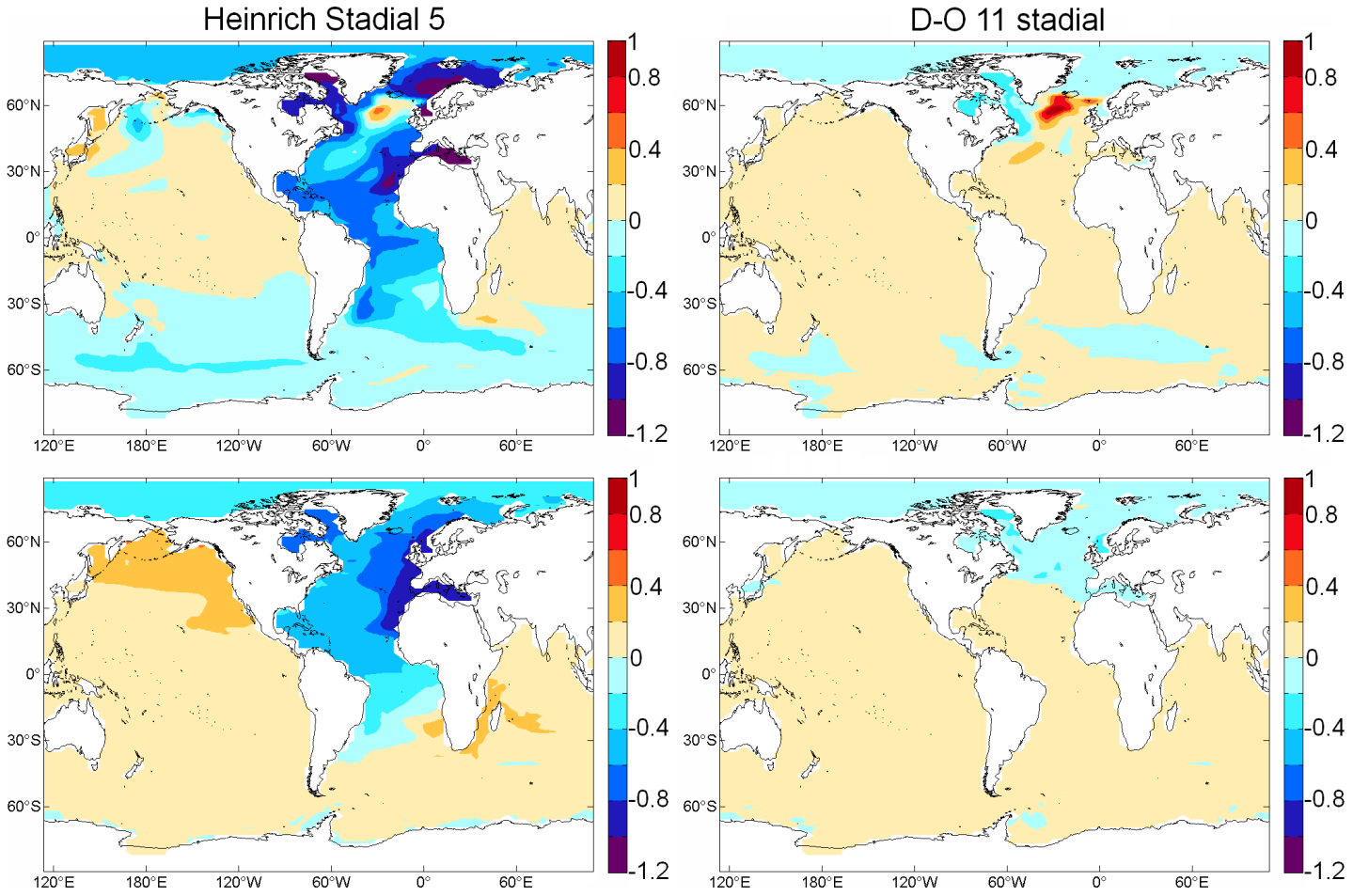
Temperature effect: 26%

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:

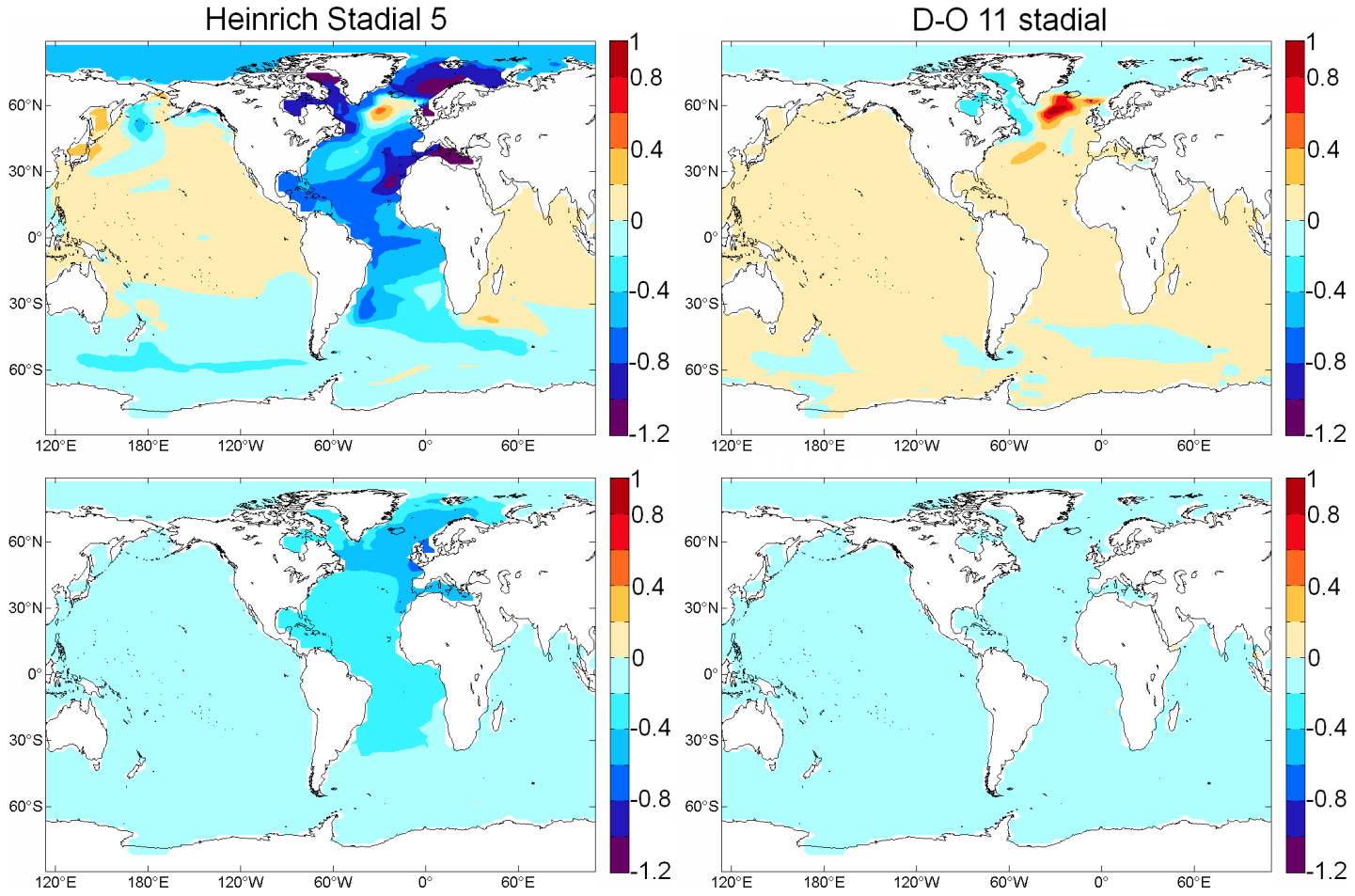
Circulation & climate: 45%

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%

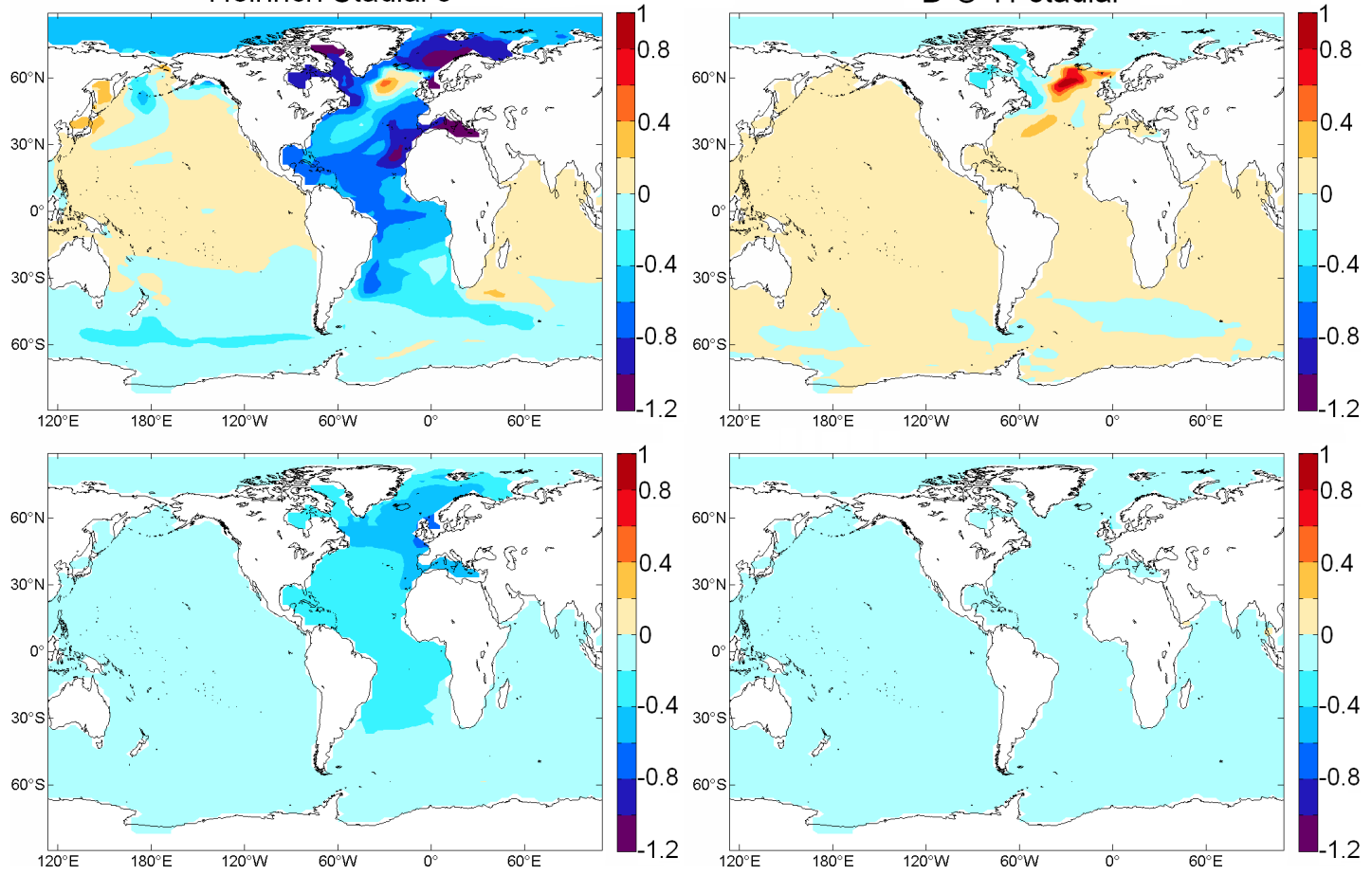
Differences between large stadials and small stadials

Heinrich Stadial 5

D-O 11 stadial

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%	Temperature effect: 47%
Circulation & climate: 45%	Circulation & climate: 27%
Meltwater: 29%	Meltwater: 26%

Summary

- The first transient simulations of Marine Isotope Stage 3, including its millennial-scale $\delta^{18}O$ variability
  - compared with 2 ice core and 20 sediment core records

- Likely a strong link between stadial-interstadial changes and AMOC
  - 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

Thank you