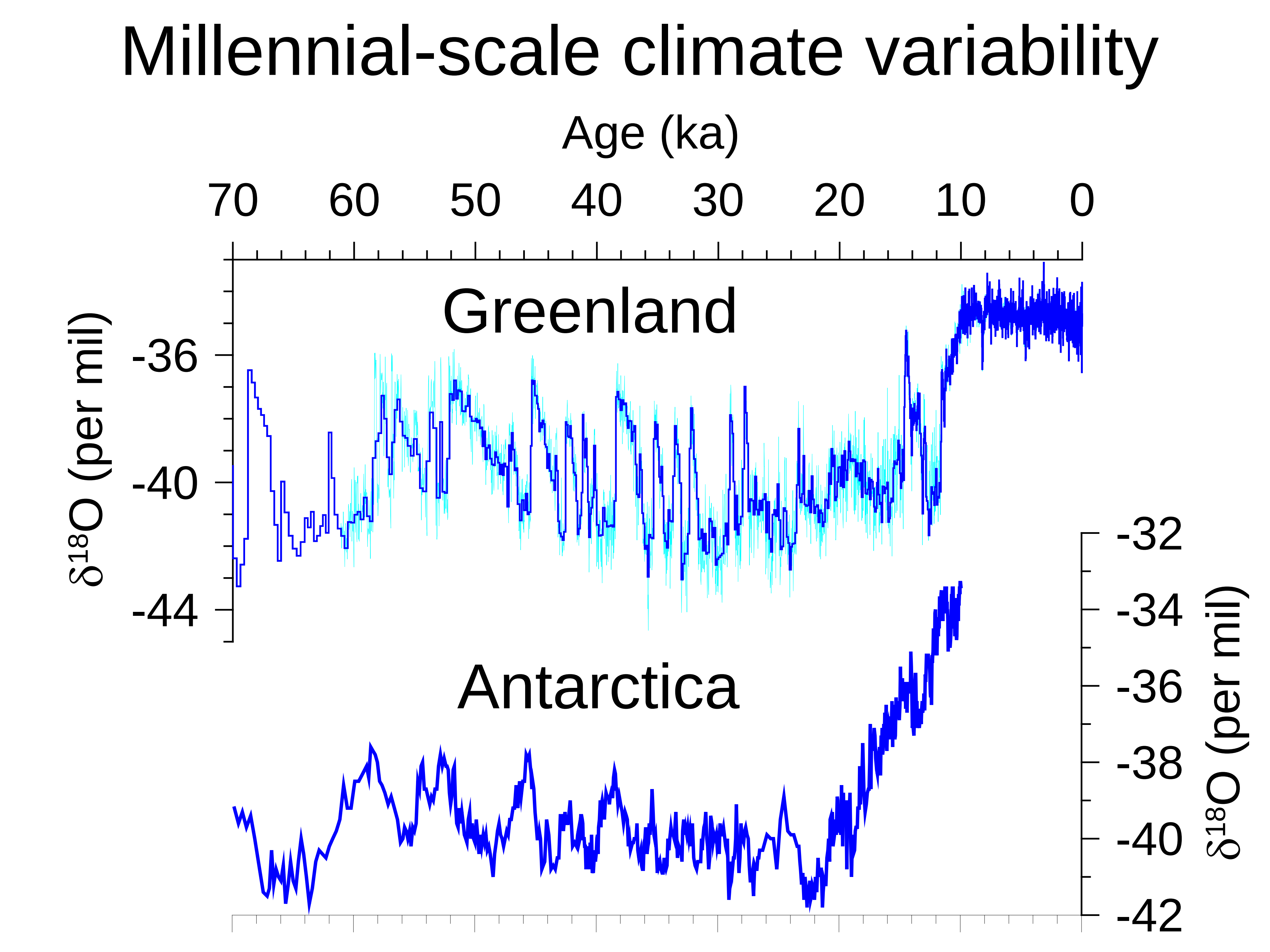
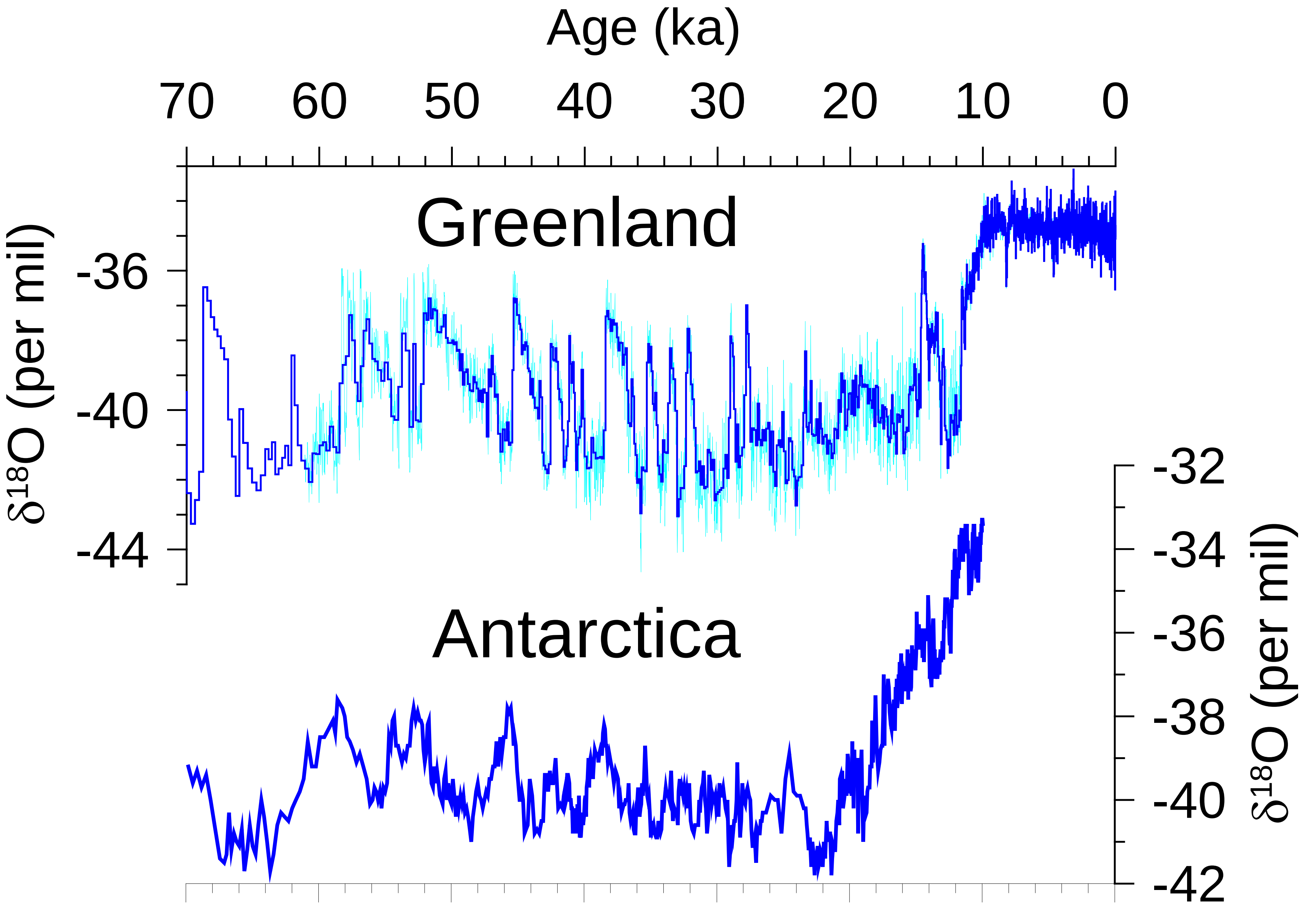
Late Pleistocene ice sheet-ice shelf-ocean interactions and abrupt climate and sea level change

(1) Heinrich events
(2) Meltwater pulse 1A (MWP-1A)
(3) Dansgaard-Oeschger (D-O) events

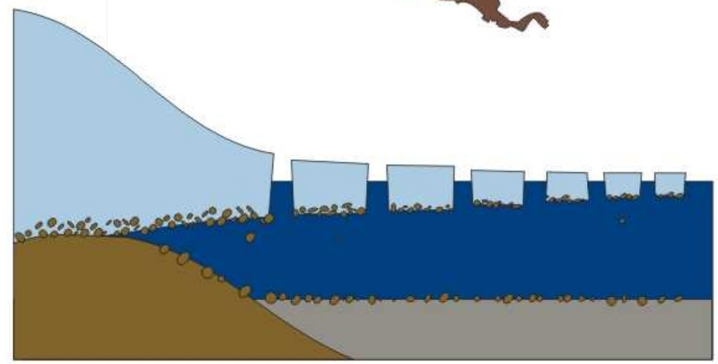

Millennial-scale climate variability
Age (ka)
70
60
50
40
30
20
10
0
Greenland
δ18O (per mil)
-36
-40
-44
Antarctica
-32
-34
-36
-38
-40
-42
δ18O (per mil)

Two modes: Heinrich and D-O

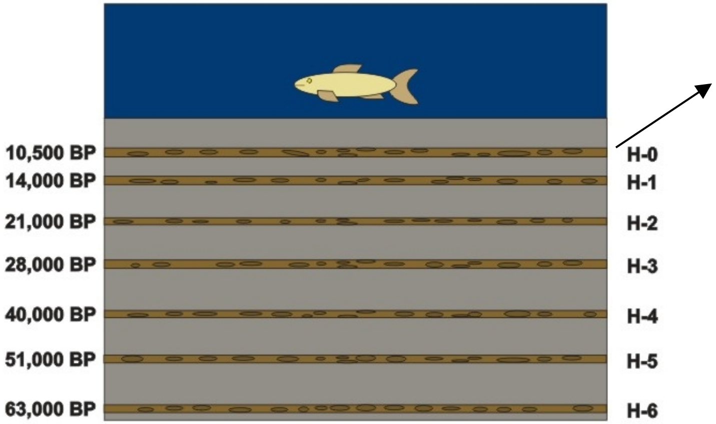


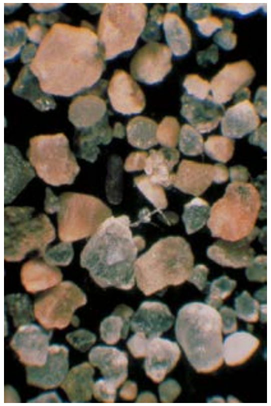
Heinrich Events

Ice-Rafted Debris



Heinrich Layers





Heinrich events and climate

BINGE/PURGE OSCILLATIONS OF THE LAURENTIDE ICE SHEET AS A CAUSE OF THE NORTH ATLANTIC'S HEINRICH EVENTS

D. R. MacAyeal

1993

Massive iceberg discharges as triggers for global climate change

Wallace S. Broecker

1994

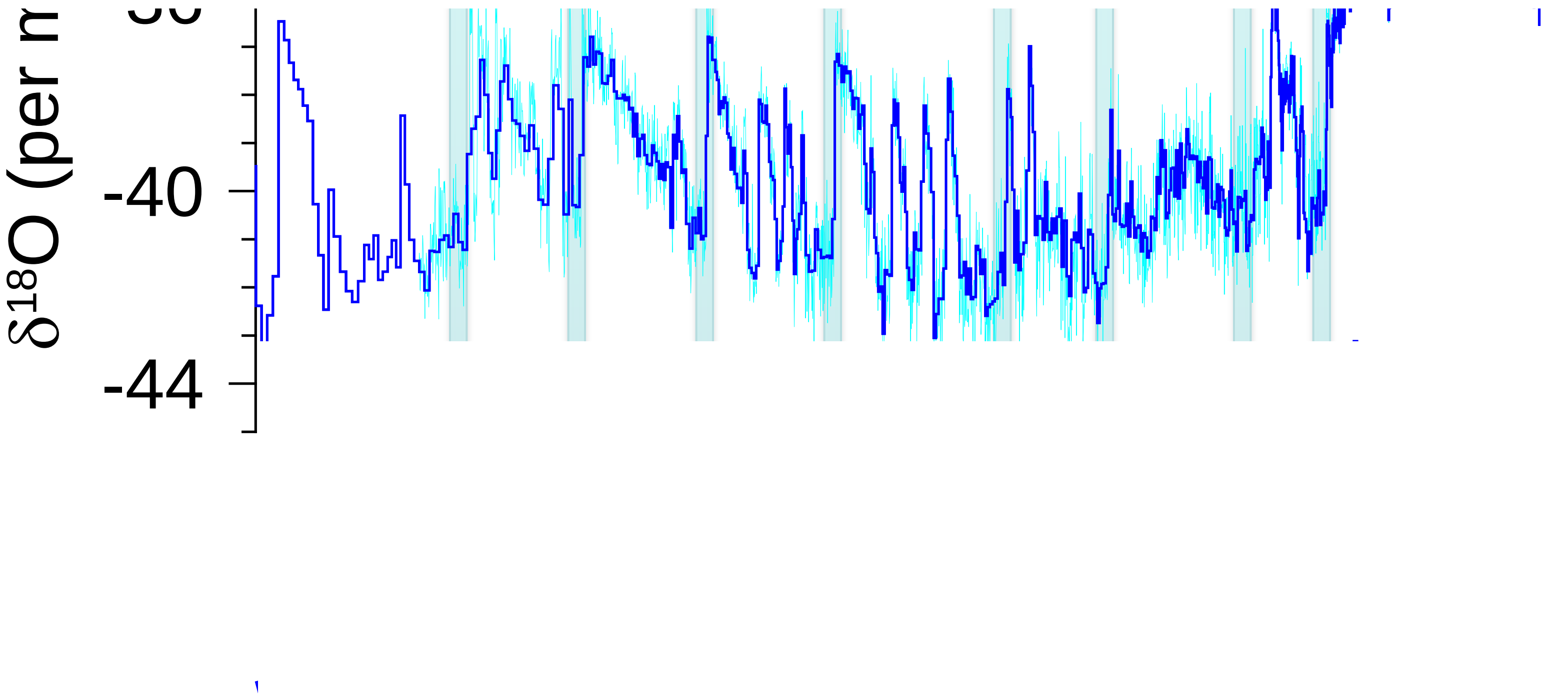
Observations of large and abrupt climate changes recorded in Greenland ice cores have spurred a search for clues to their cause. This search has revealed that at six times during the last glaciation, huge armadas of icebergs launched from Canada spread across the northern Atlantic Ocean, each triggering a climate response of global extent.

Iceberg Discharges into the North Atlantic on Millennial Time Scales During the Last Glaciation

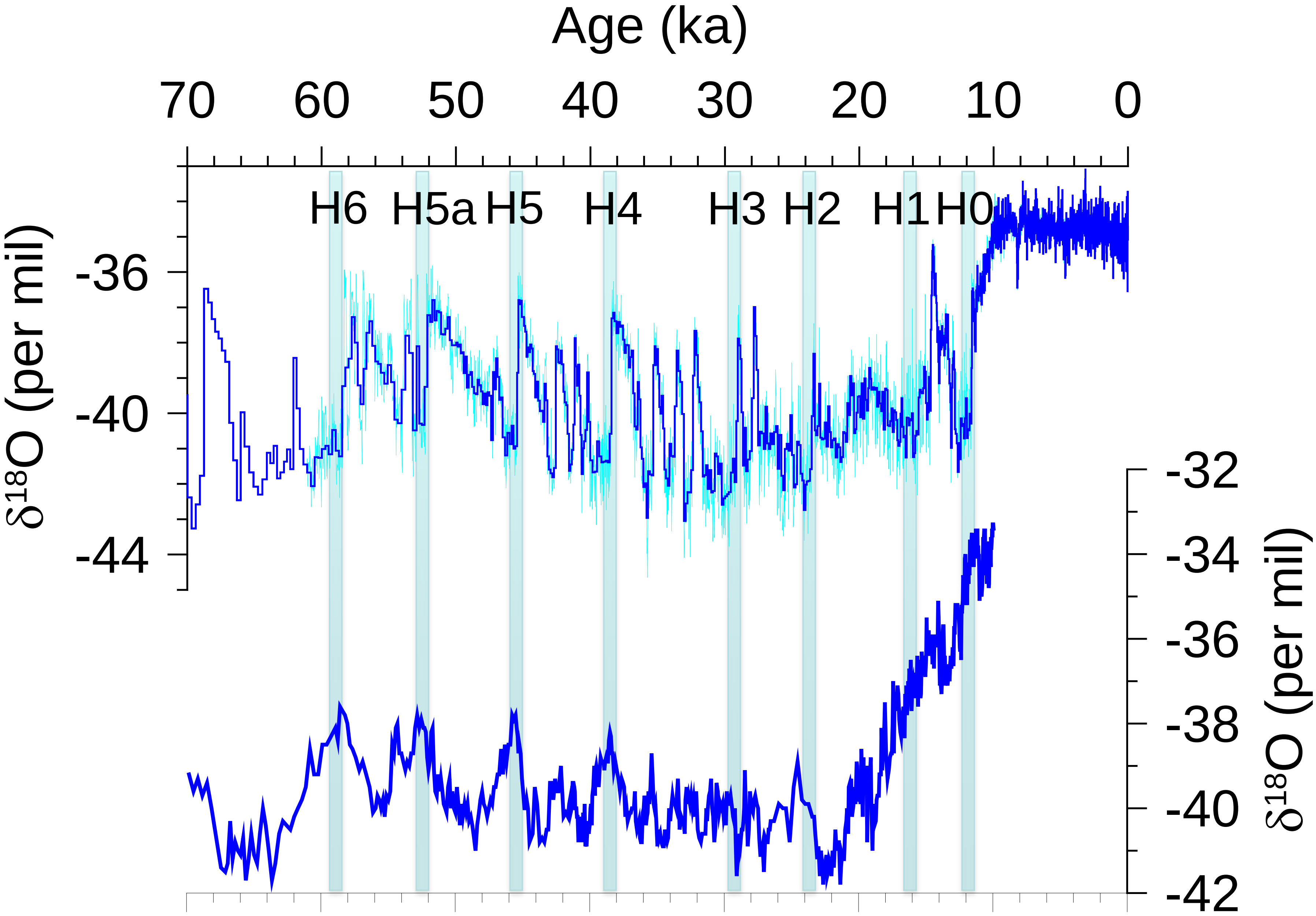
Gerard C. Bond and Rusty Lotti 1995

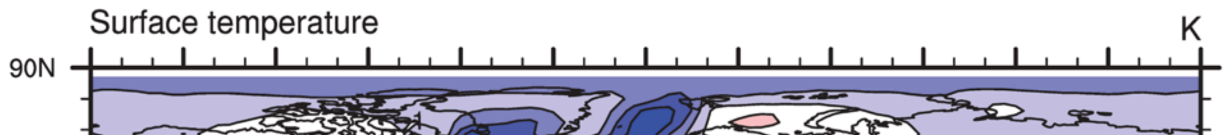
Age (ka)

The iceberg discharges…appear to have been triggered by climate or a climate-related mechanism rather than vice versa.



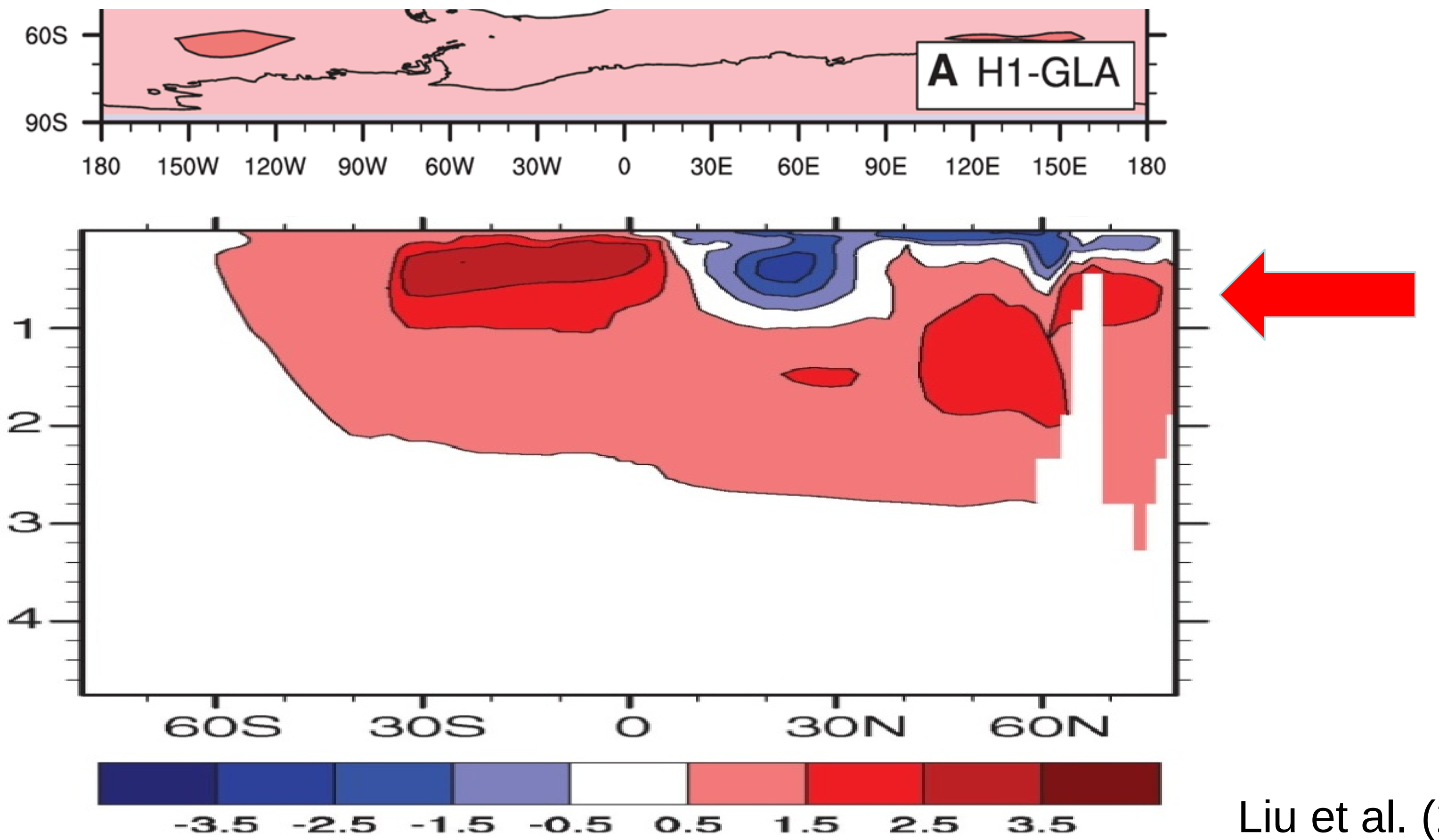
Heinrich events – cold in N, warm in S





Subsurface warming with reduced AMOC. Basal melting of ice shelves and/or G.L.'s

"oceanic lowblows"



Liu et al. (2009)

Heinrich events – response to climate

Ocean subsurface warming as a mechanism for coupling Dansgaard-Oeschger climate cycles and ice-rafting events

Gary Shaffer,[1,2] Steffen Malskær Olsen,[3] and Christian J. Bjerrum[4]

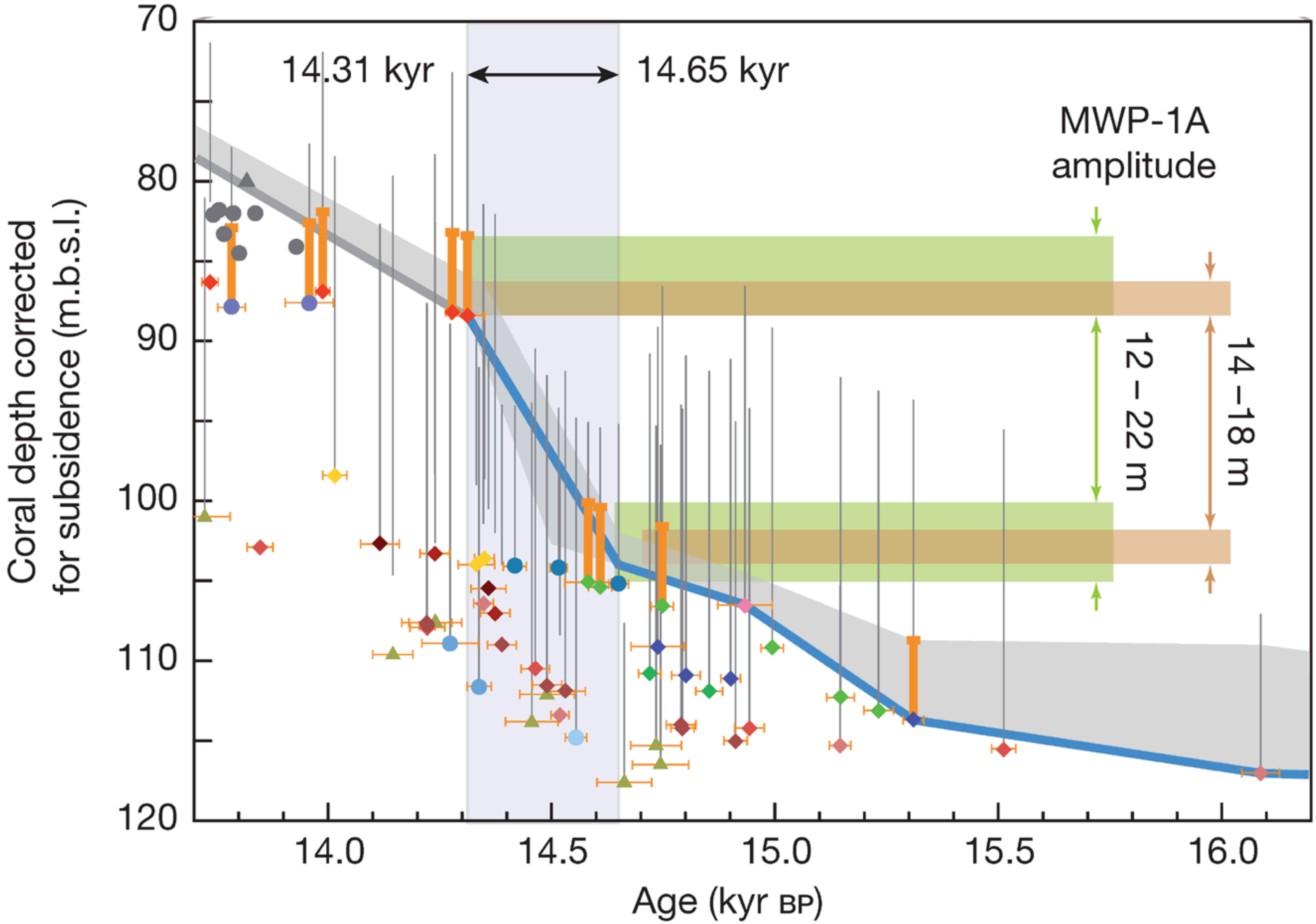
Links between ocean temperature and iceberg discharge during Heinrich events

Jorge Alvarez-Solas[1]*, Sylvie Charbit[1], Catherine Ritz[2], Didier Paillard[1], Gilles Ramstein[1] and Christophe Dumas[1]

Ice-shelf collapse from subsurface warming as a trigger for Heinrich events

Shaun A. Marcott[a,1], Peter U. Clark[a], Laurie Padman[b], Gary P. Klinkhammer[c], Scott R. Springer[d], Zhengyu Liu[e], Bette L. Otto-Bliesner[f], Anders E. Carlson[e,g], Andy Ungerer[c], June Padman[c], Feng He[e], Jun Cheng[h], and Andreas Schmittner[c]

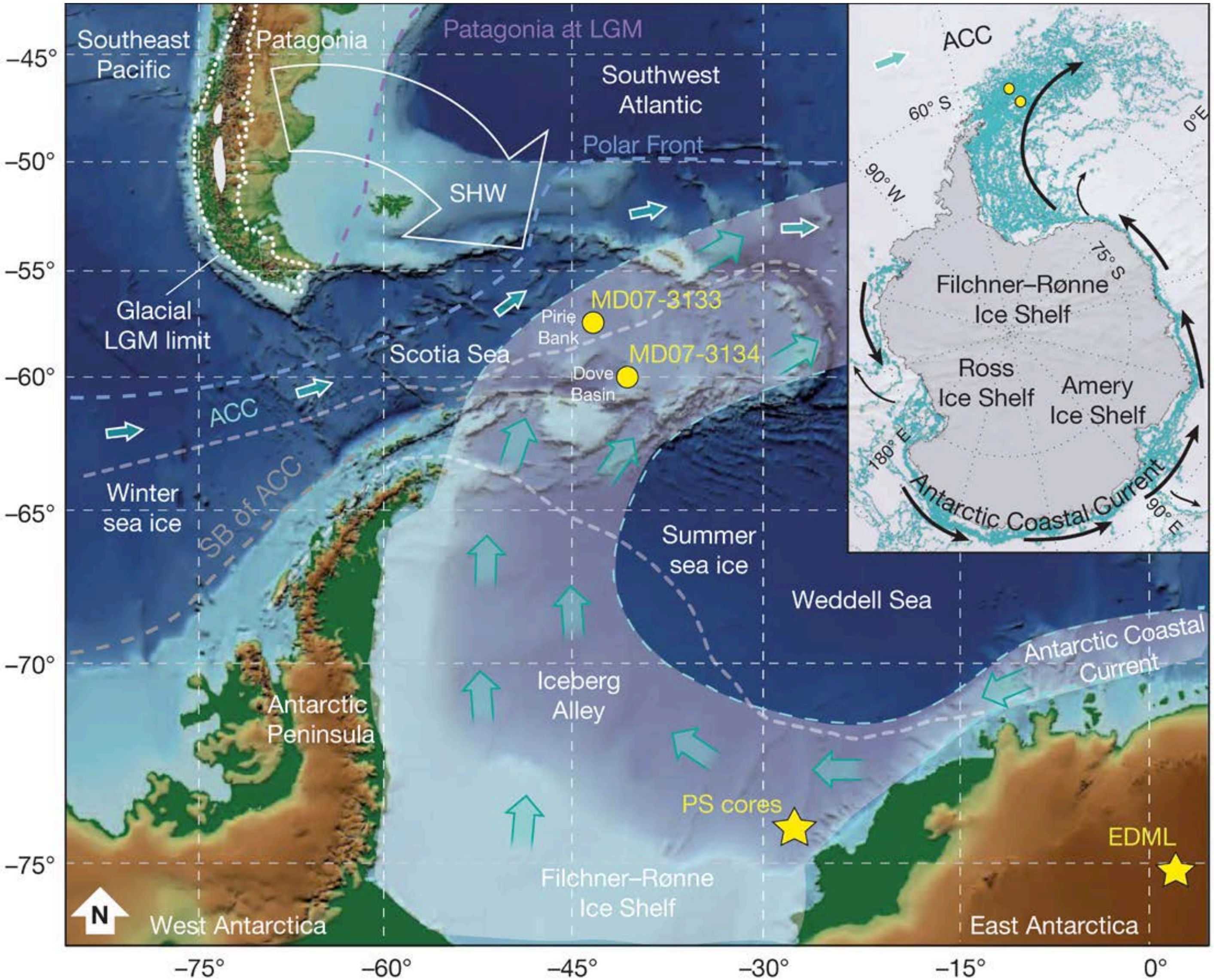
(2) MWP-1A



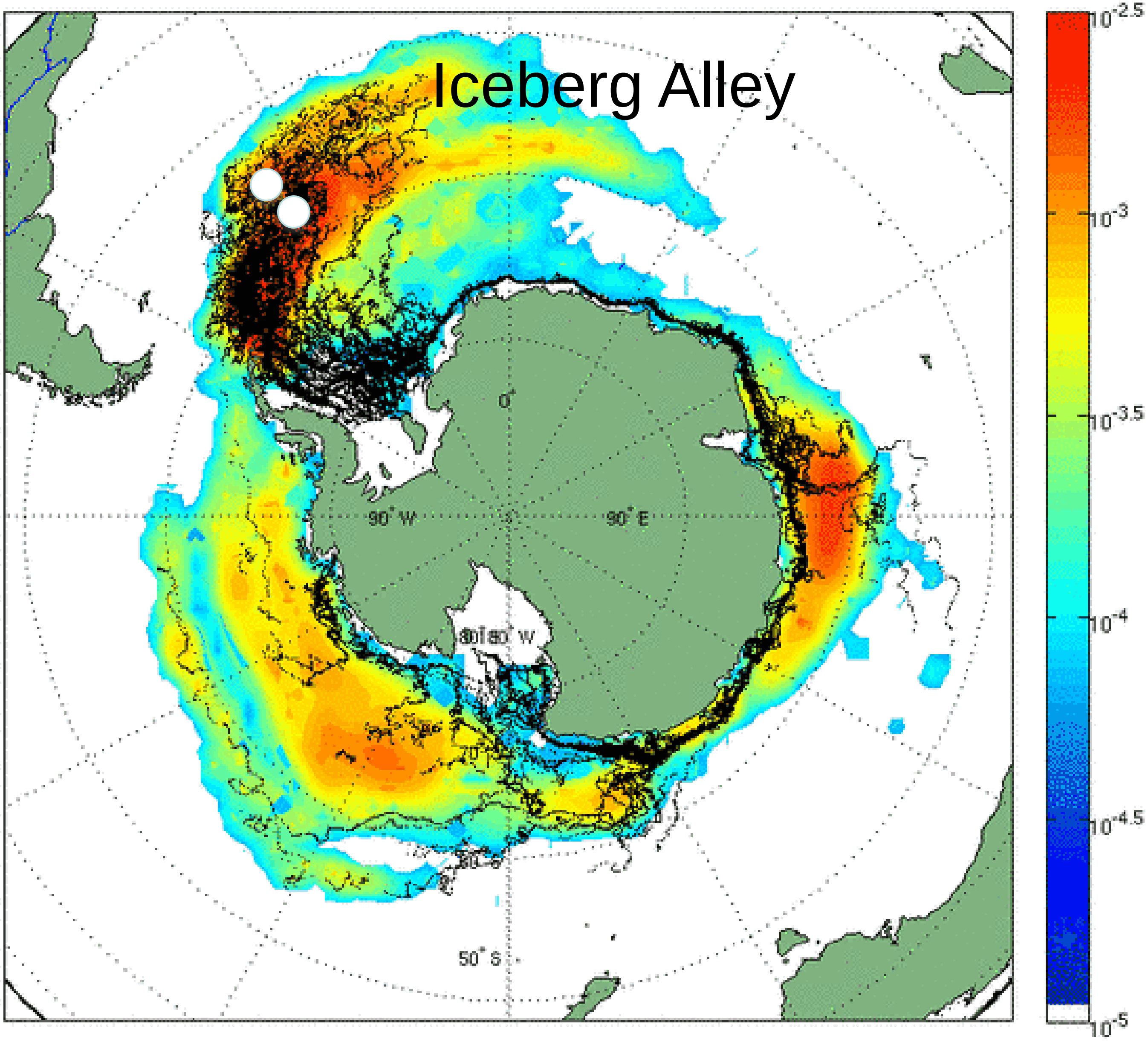
Deschamps et al. (2012)

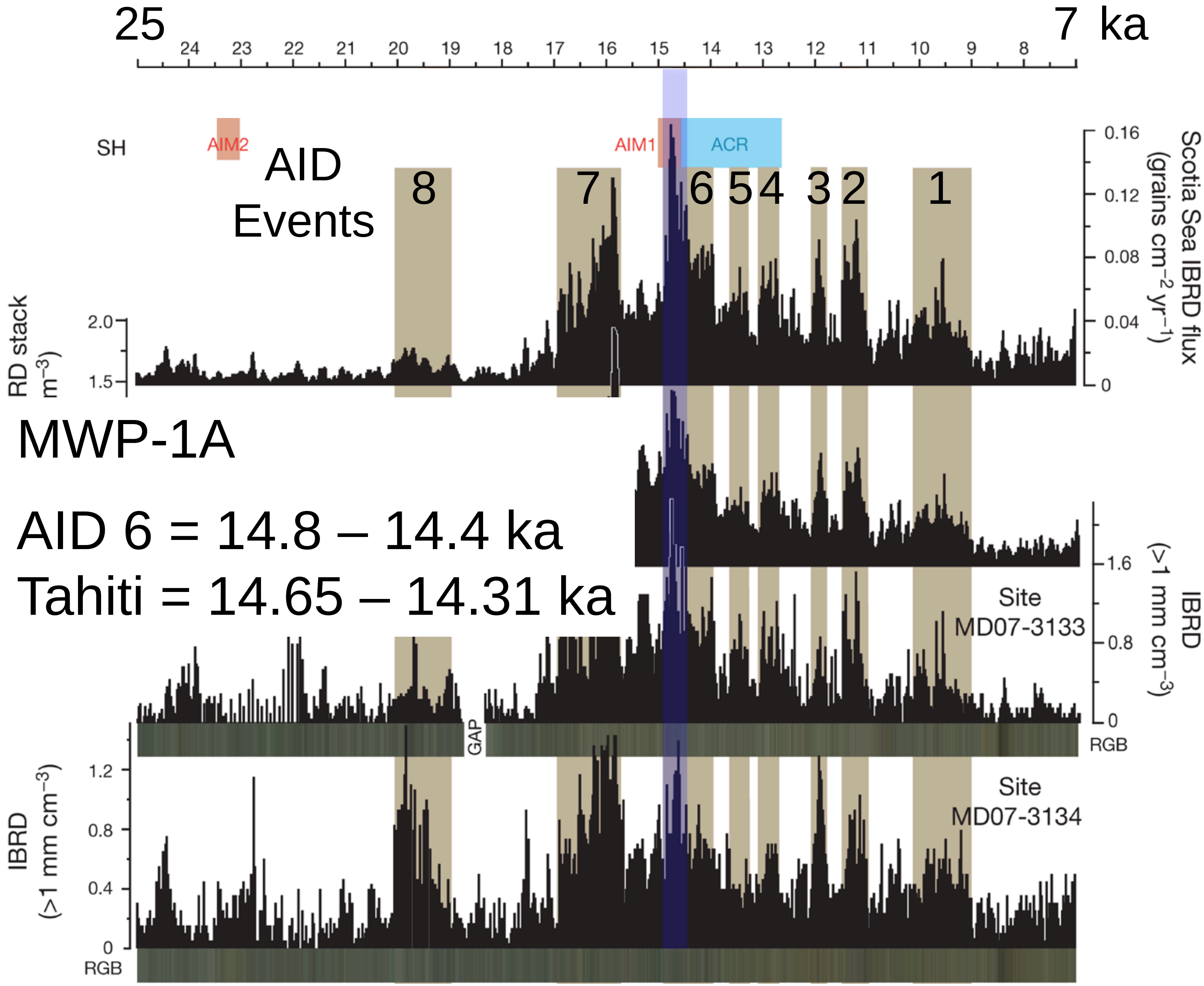
Millennial-scale variability in Antarctic ice-sheet discharge during the last deglaciation

M. E. Weber[1], P. U. Clark[2], G. Kuhn[3], A. Timmermann[4], D. Sprenk[1], R. Gladstone[5], X. Zhang[3], G. Lohmann[3], L. Menviel[6,7], M. O. Chikamoto[4], T. Friedrich[4] & C. Ohlwein[8]

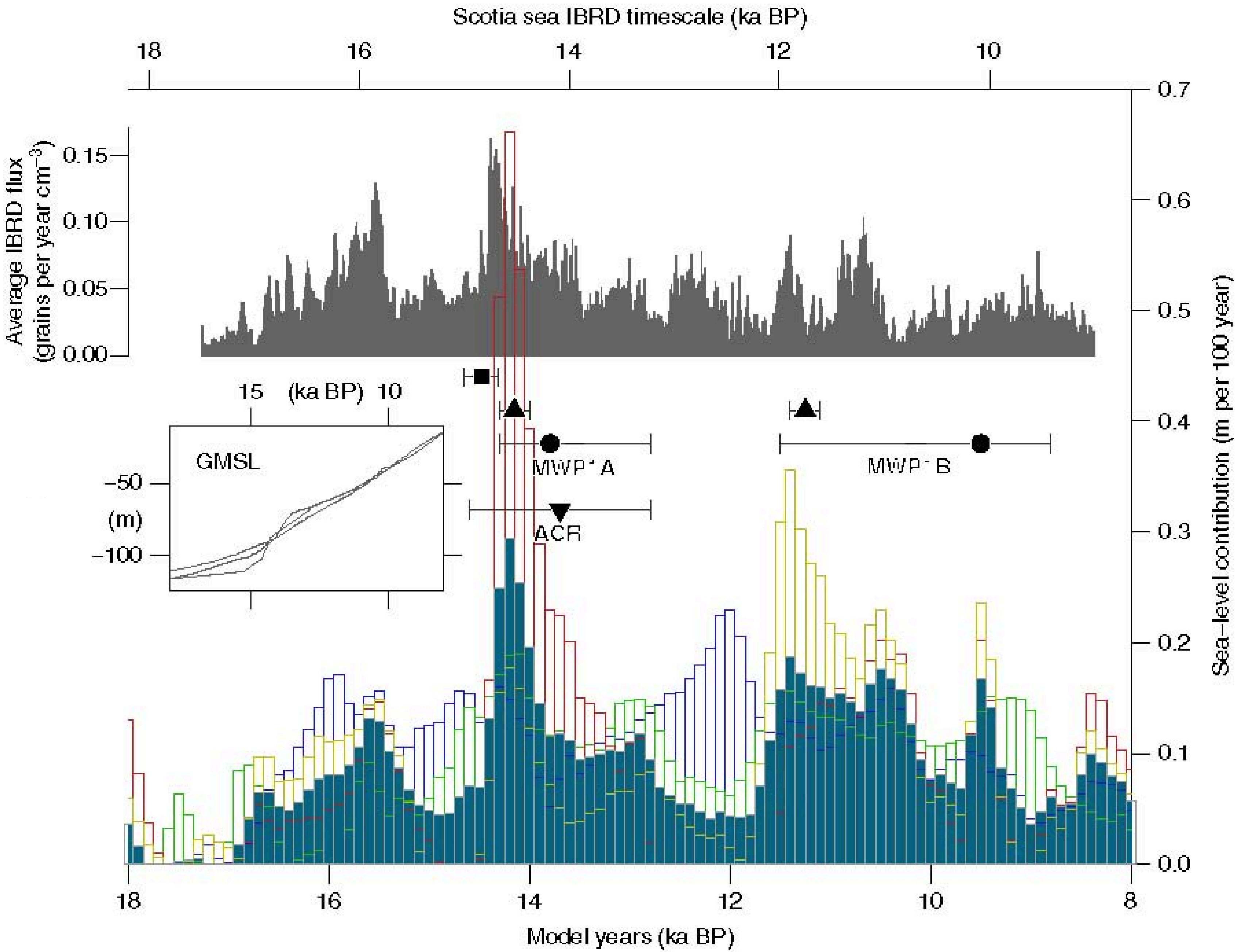


Probability of presence of small icebergs (0.1 to 3 km)



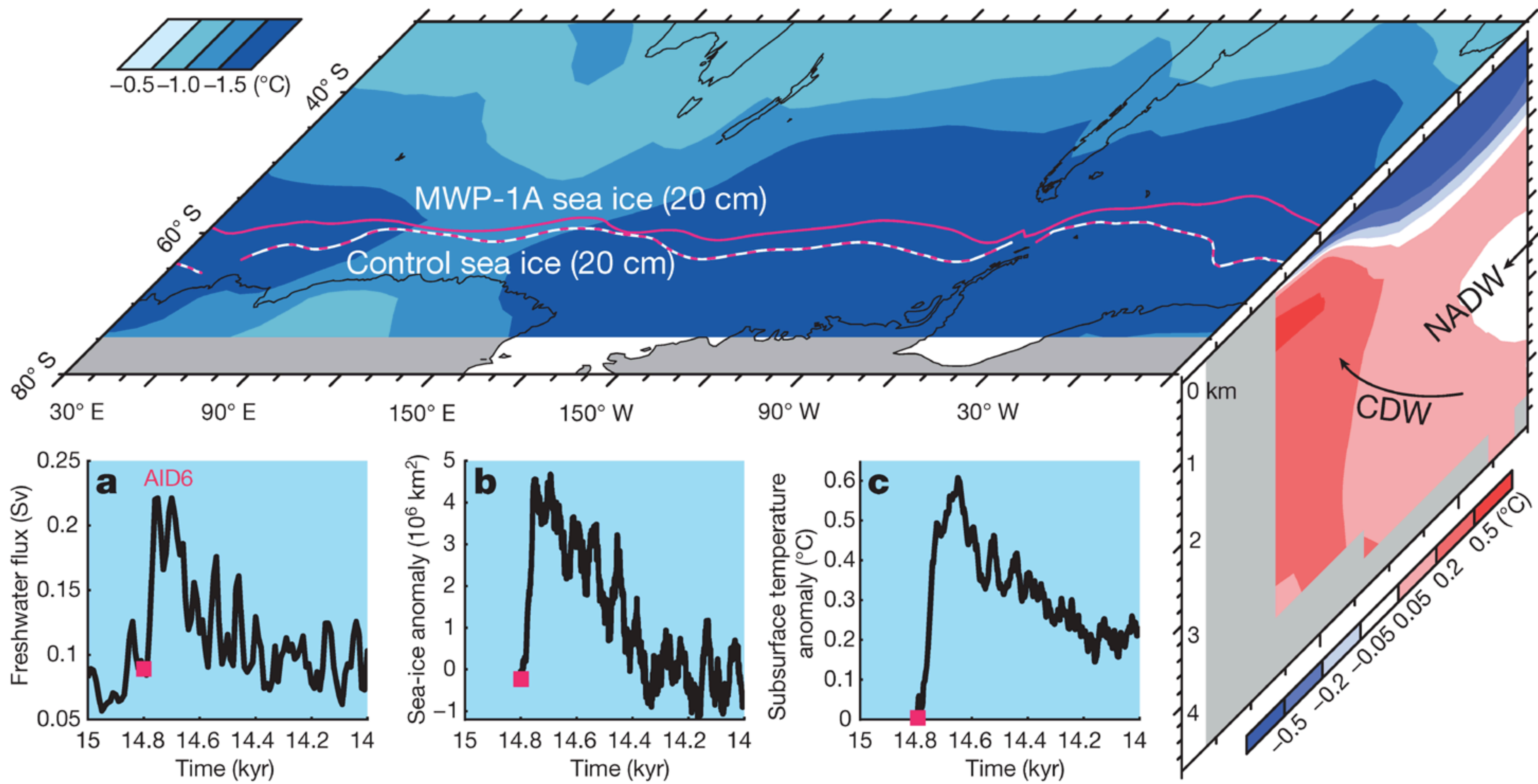


Weber et al. (2014)



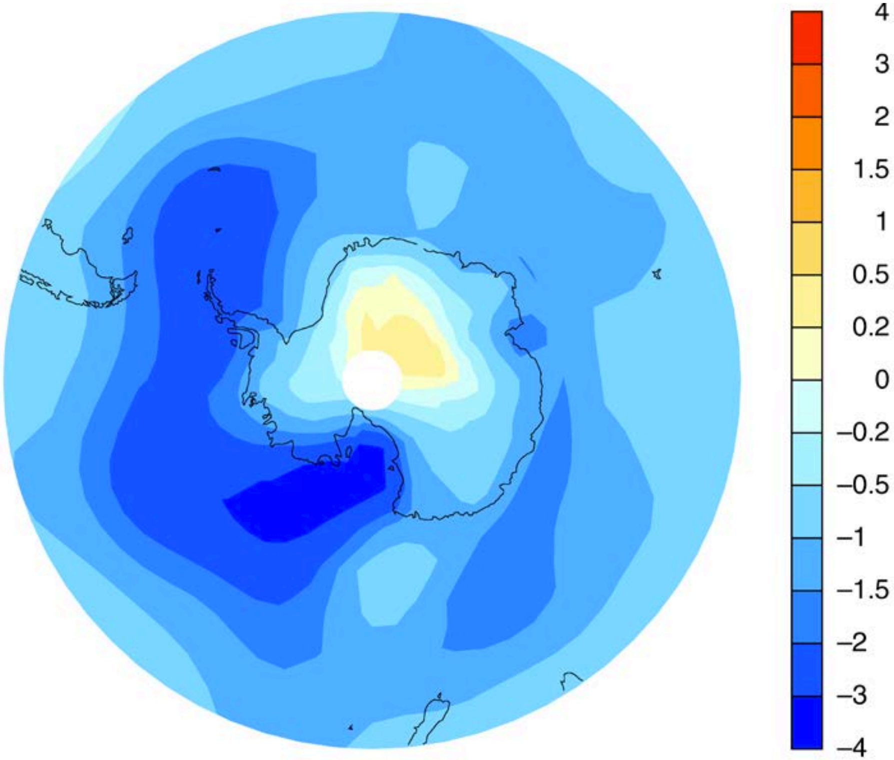
Golledge et al. (2014)

Responses to FW forcing: surface cooling, sea-ice expansion, halocline formation, reduced AABW, poleward migration of CDW, subsurface warming.

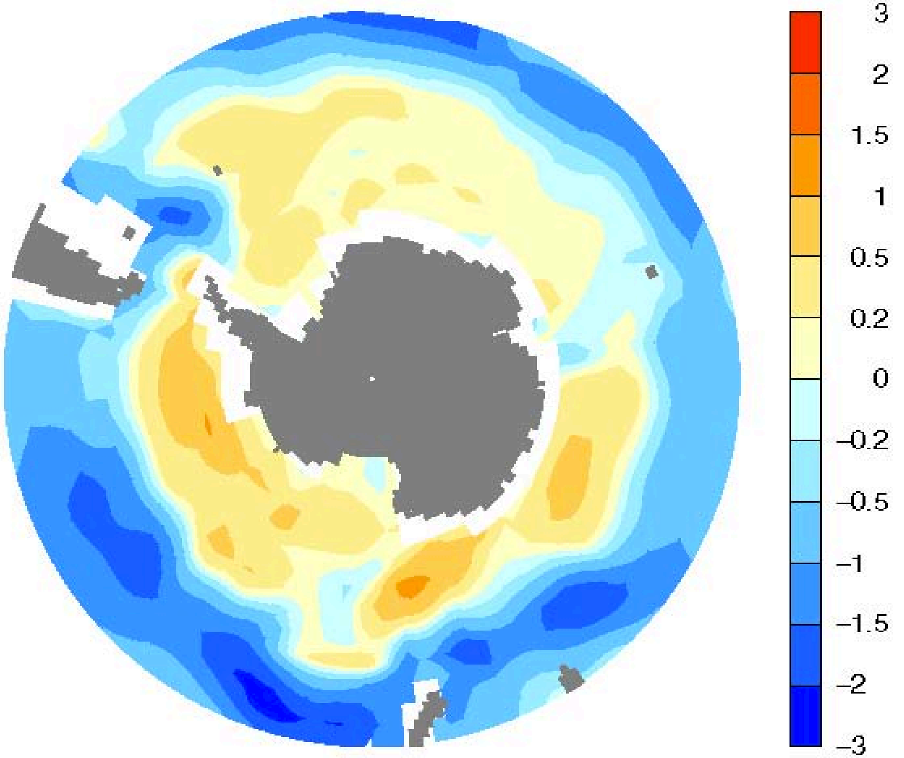


Weber et al. (2014)

Surface air temperature



485-700 m water depth



Golledge et al. (2014)

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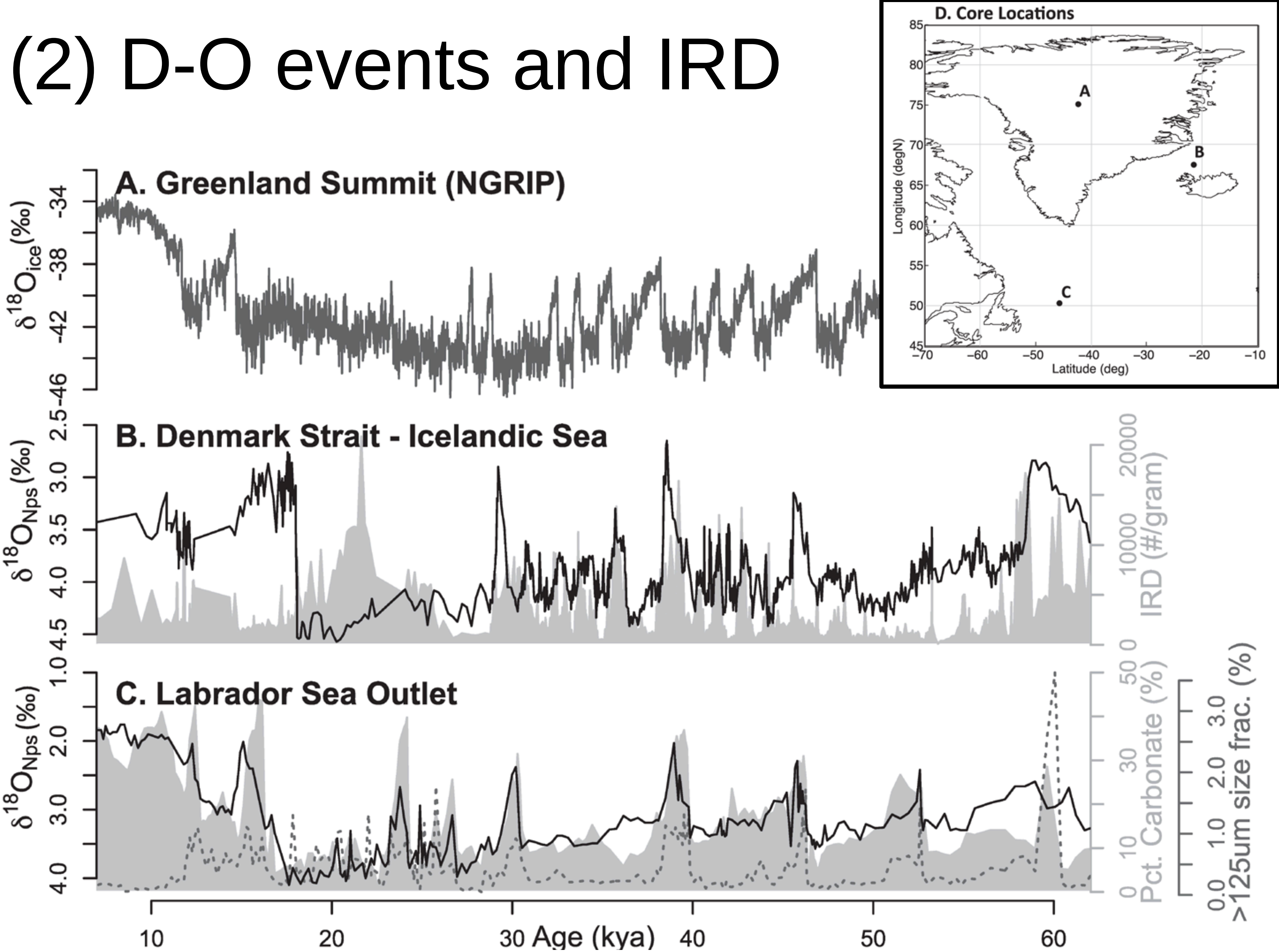
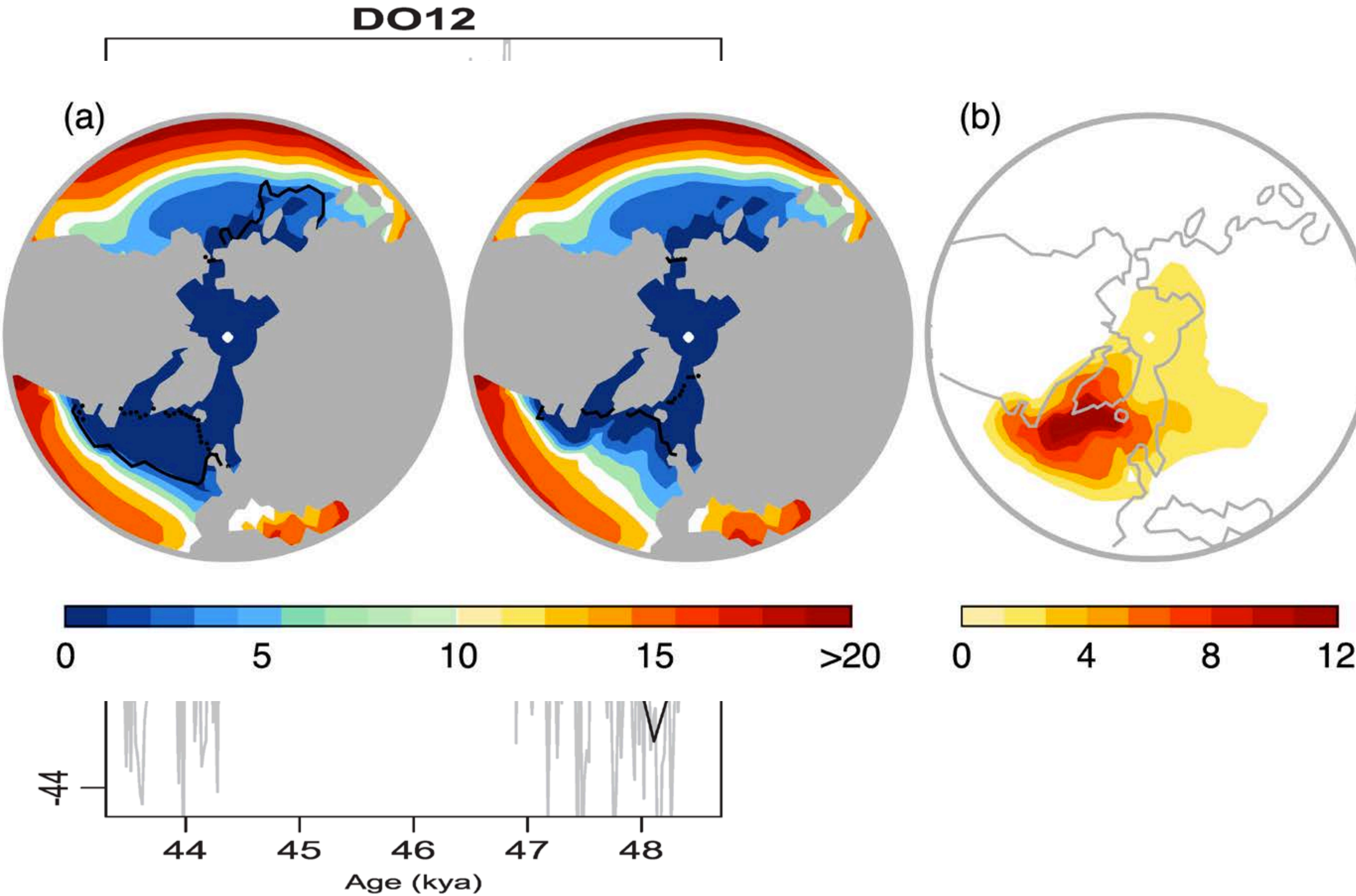
(2) D-O events and IRD



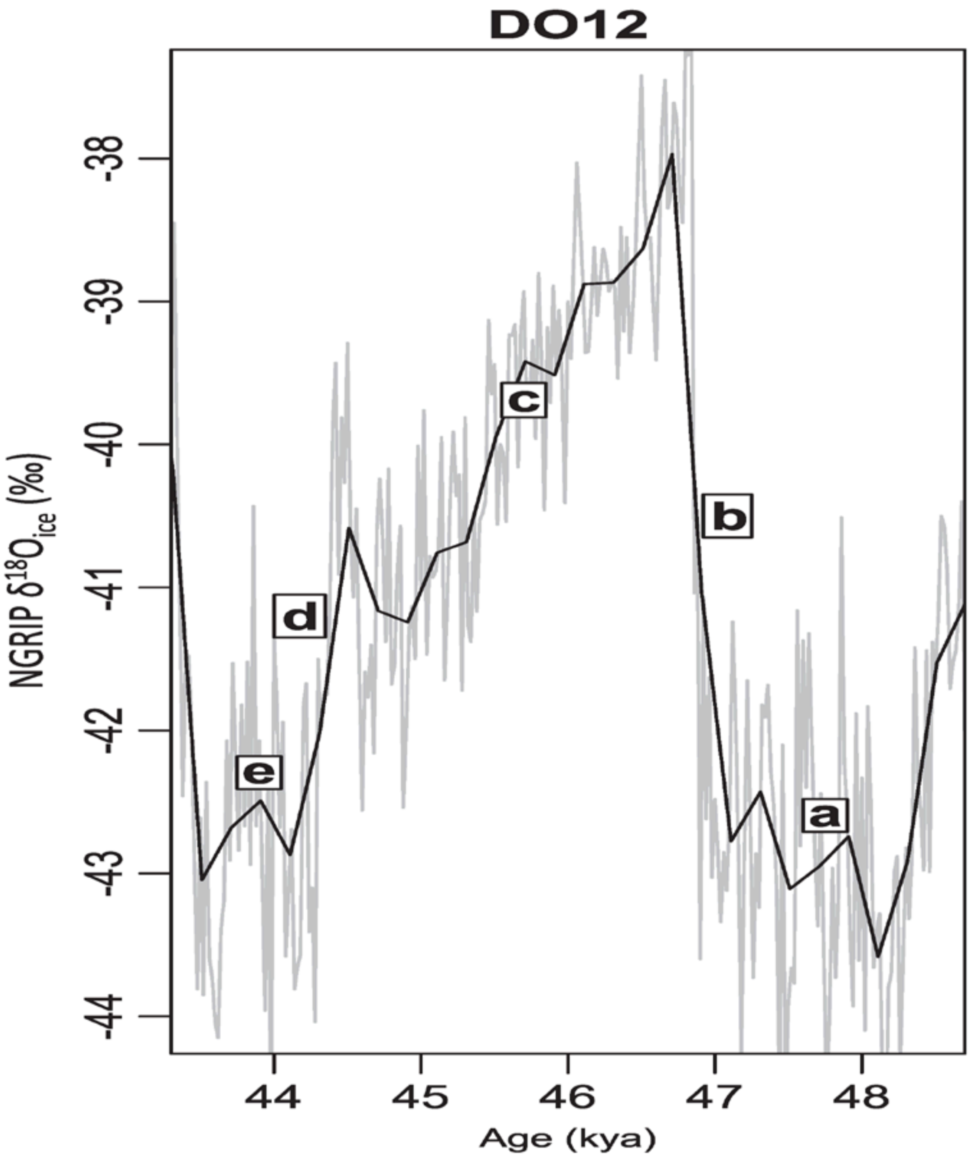
Petersen et al. (2013)

Canonical D-O event



Li et al. (2005, 2010)

Canonical D-O event – two timescales



Conceptual model

(a) Cold climate, reduced AMOC

(b) Shelf collapse, sea-ice retreat

(c) Shelf growth

(d) Sea-ice advance

(e) Cold climate, reduced AMOC

Petersen et al. (2013)

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(3) Meltwater pulse 1A (MWP-1A)

Primary geological archive: Iceberg-rafted debris (IRD)