Ocean & climate: an introduction and paleoceanographic perspective

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The ocean belongs to the climate

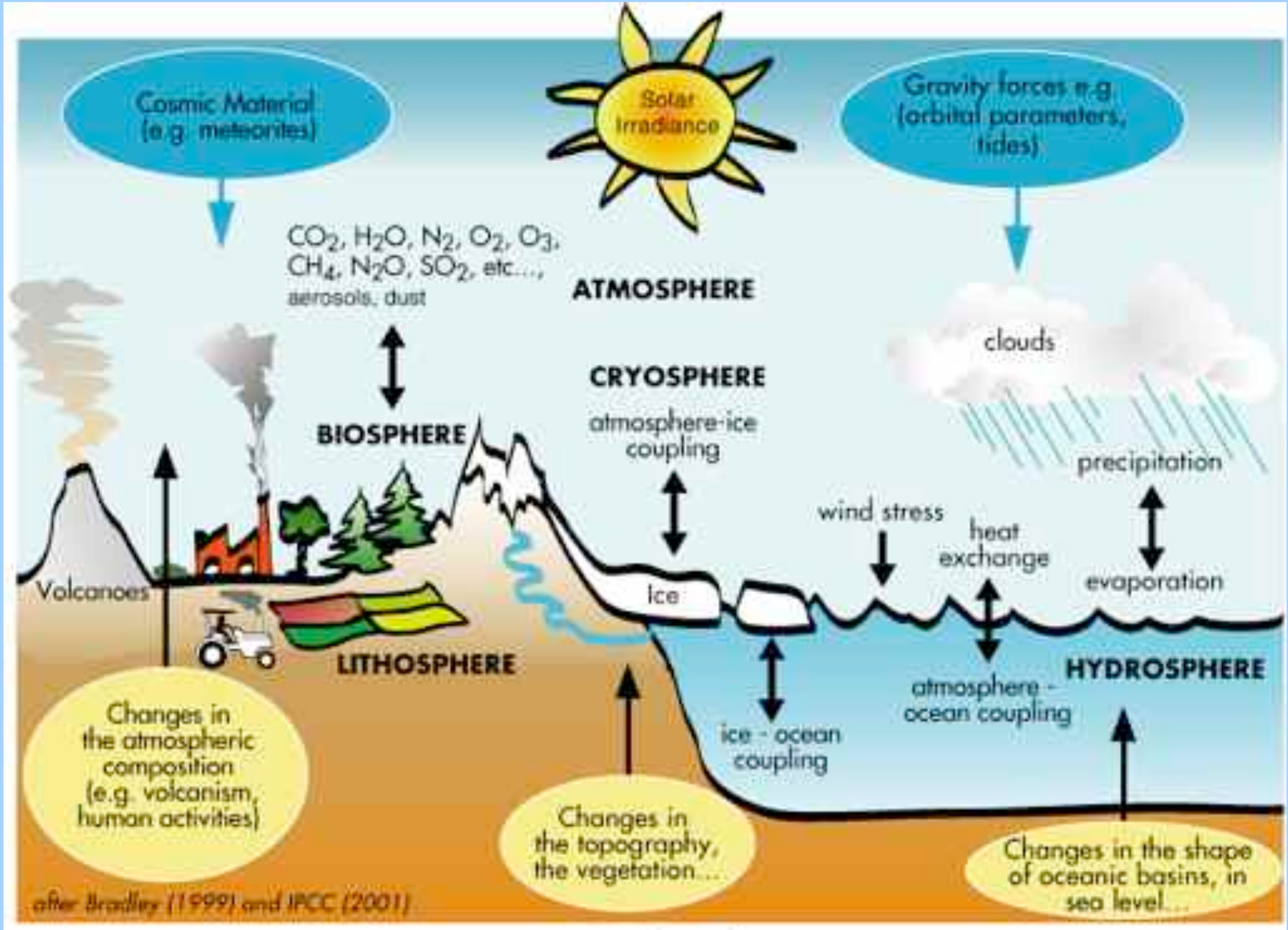
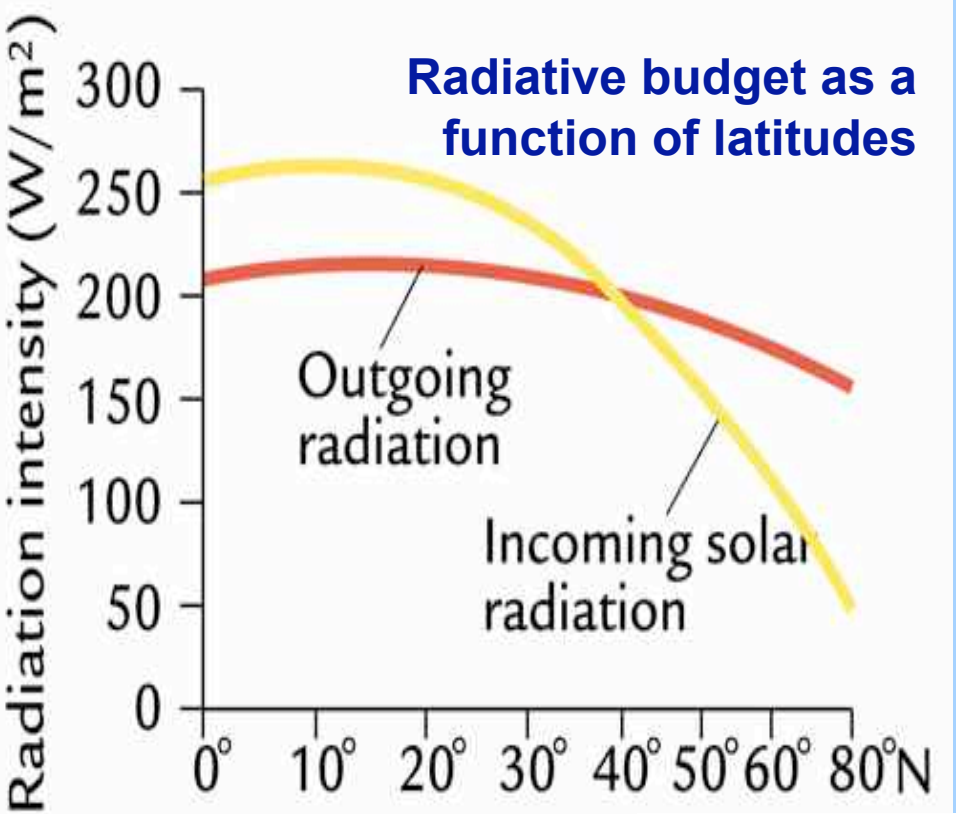
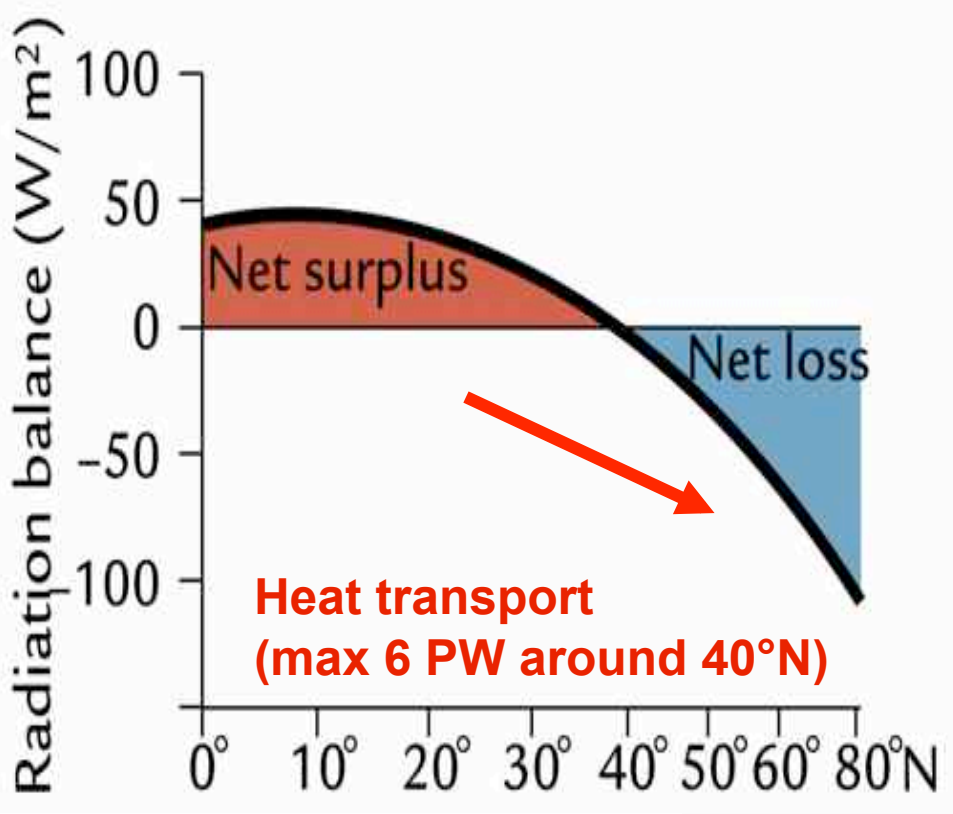
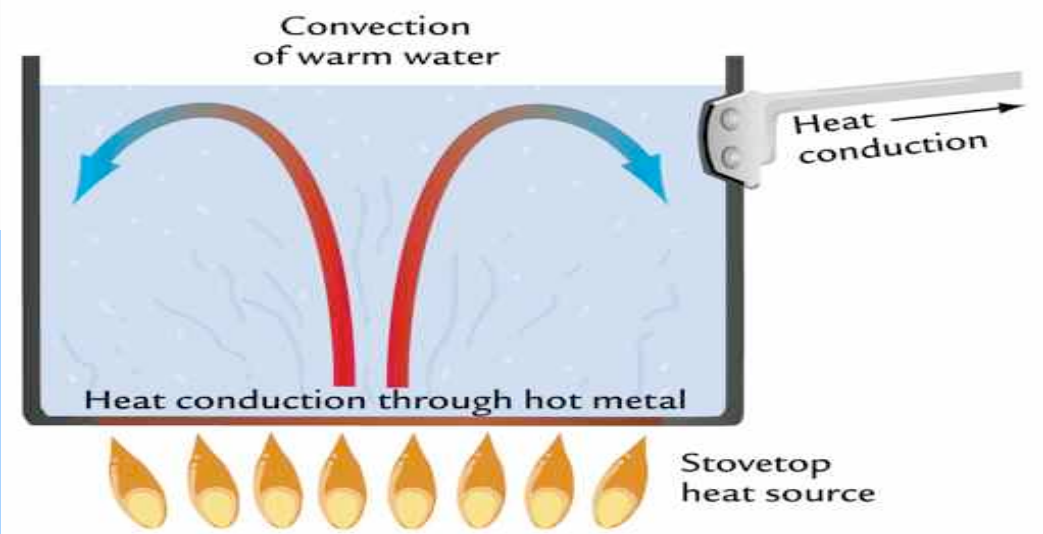


Figure 1

Heat transport is linked to water mass advection

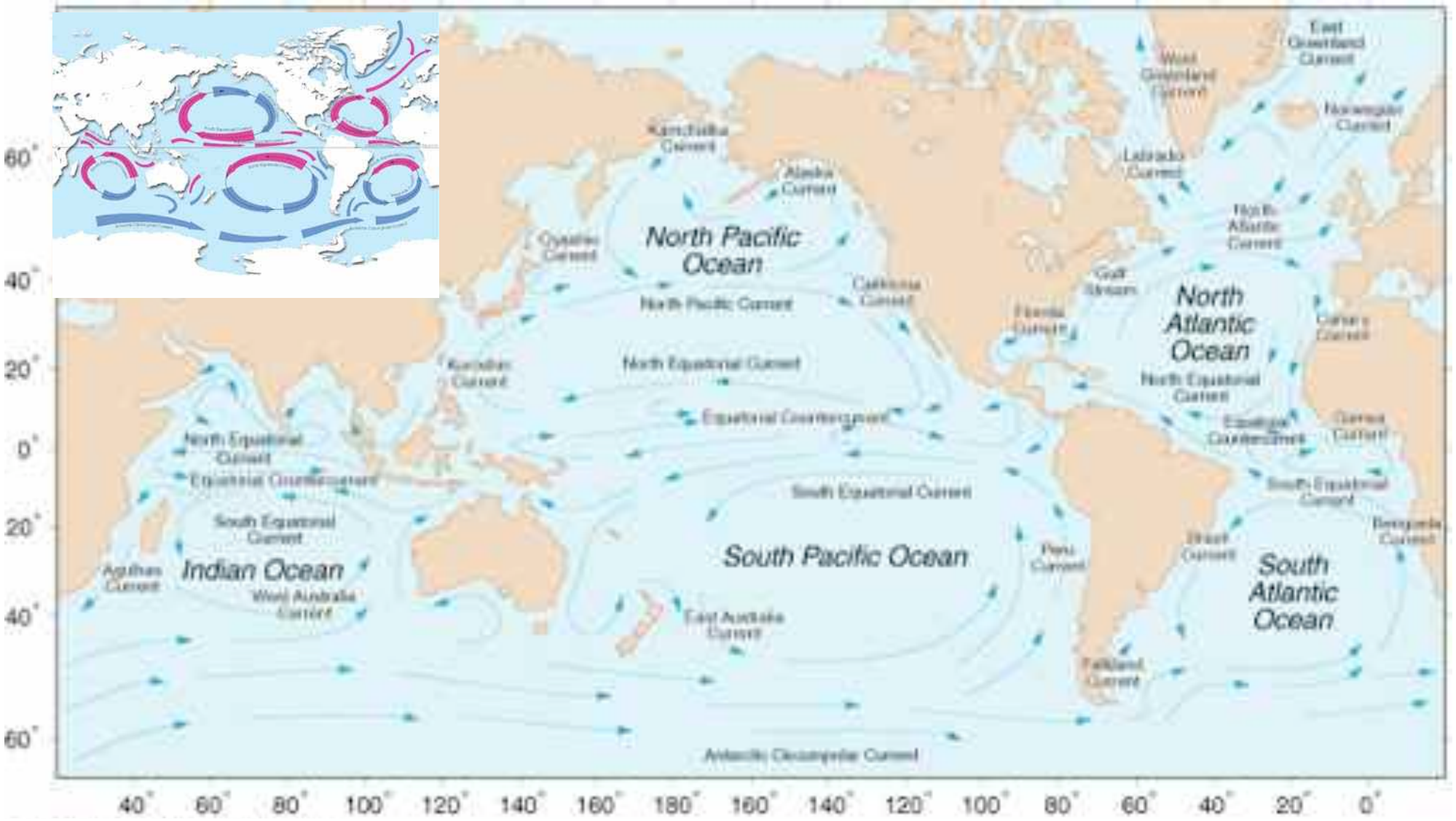






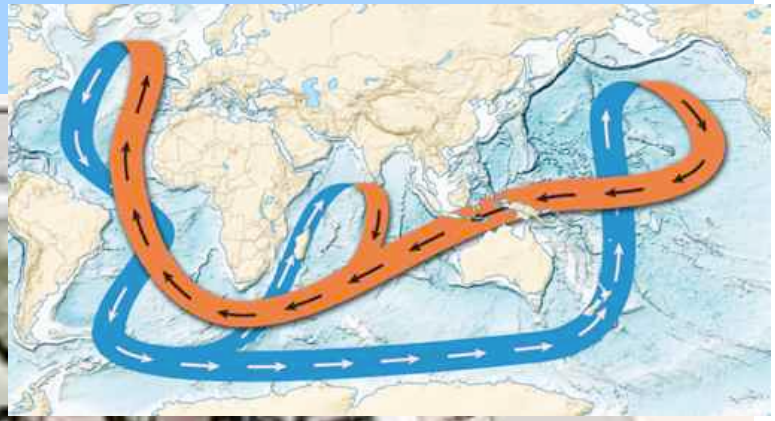
Source: Ruddiman 2002

Surface ocean currents are organized in large gyres linked to wind stress and Coriolis force



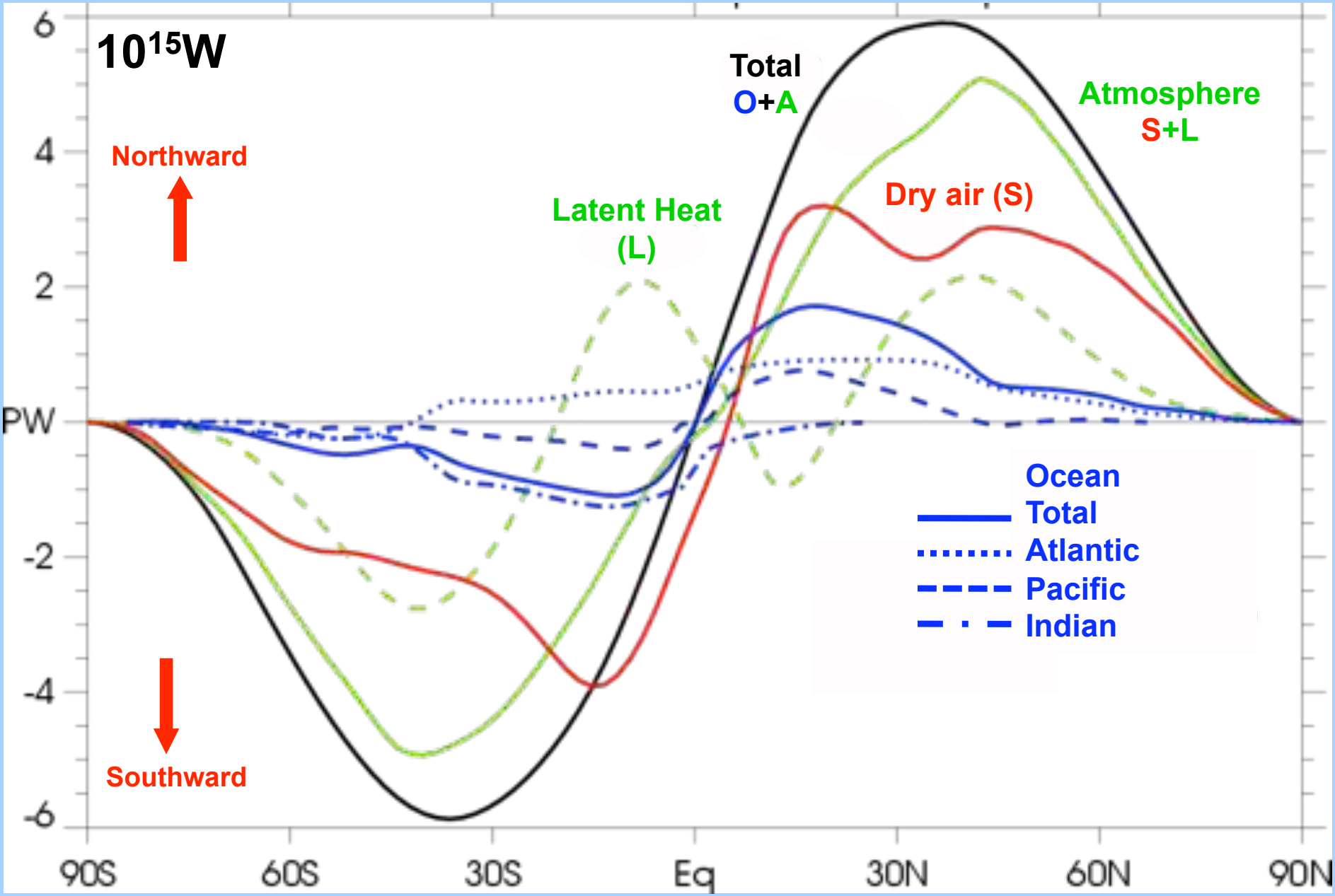
Source: American Meteorological Society

Deep and bottom circulations connecting ocean basins at global scale



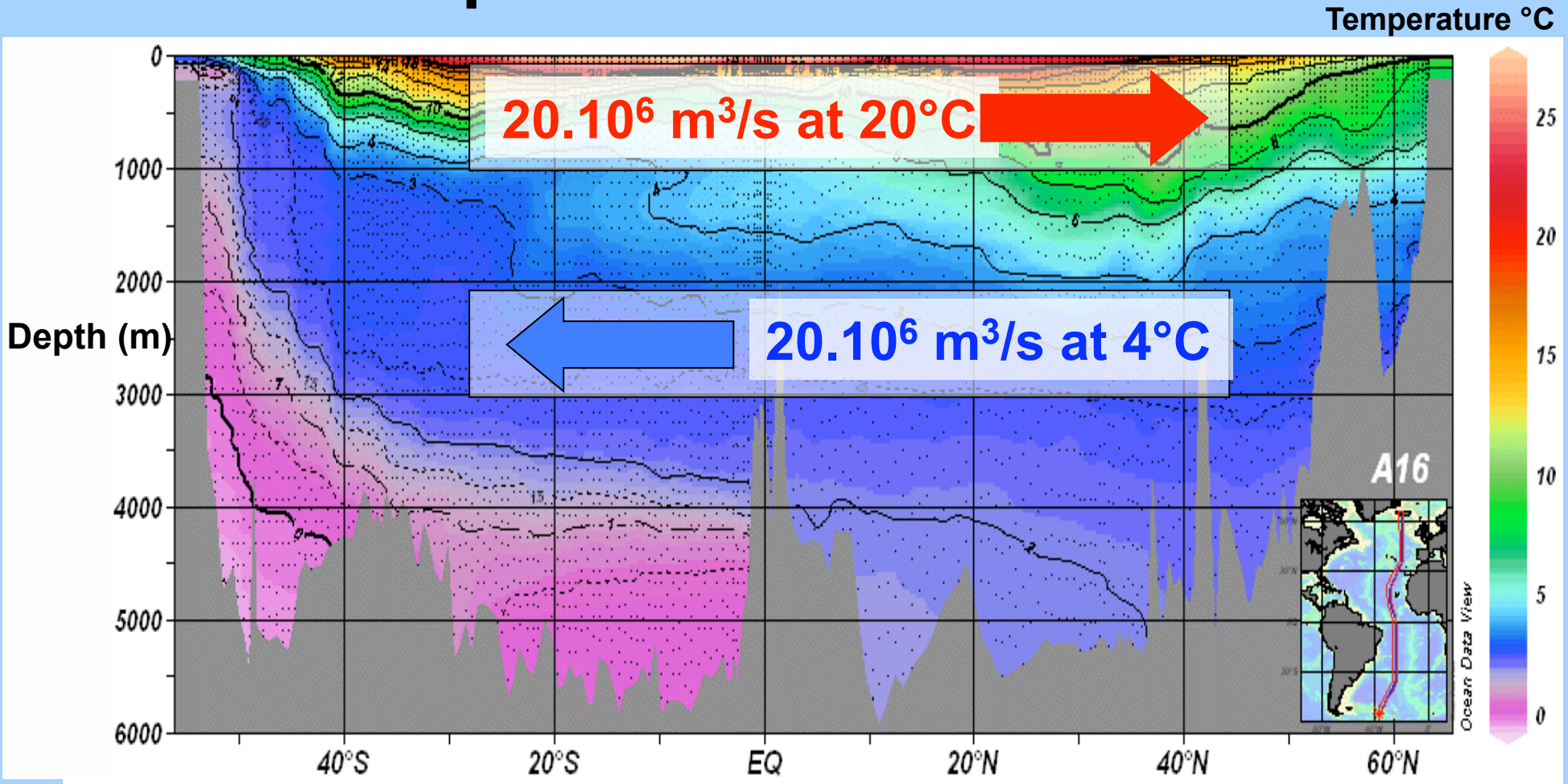
Marshall & Speer 2012 *Nat. Geo.*

Oceans participate to the meridional heat transport



after Fasullo & Trenberth 2008 *J. Clim.*

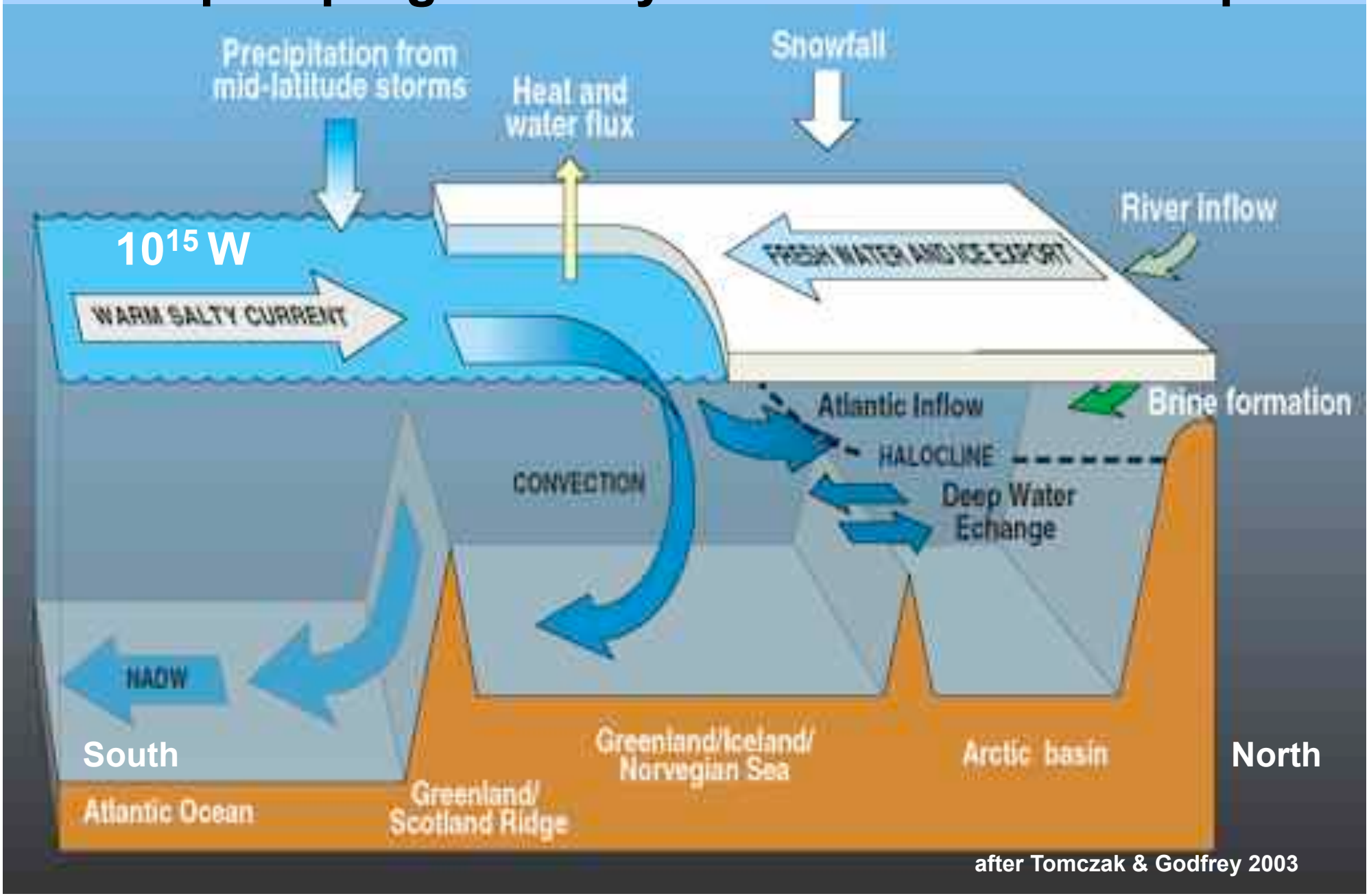
First order approximation of meridional heat transport in the Atlantic Ocean



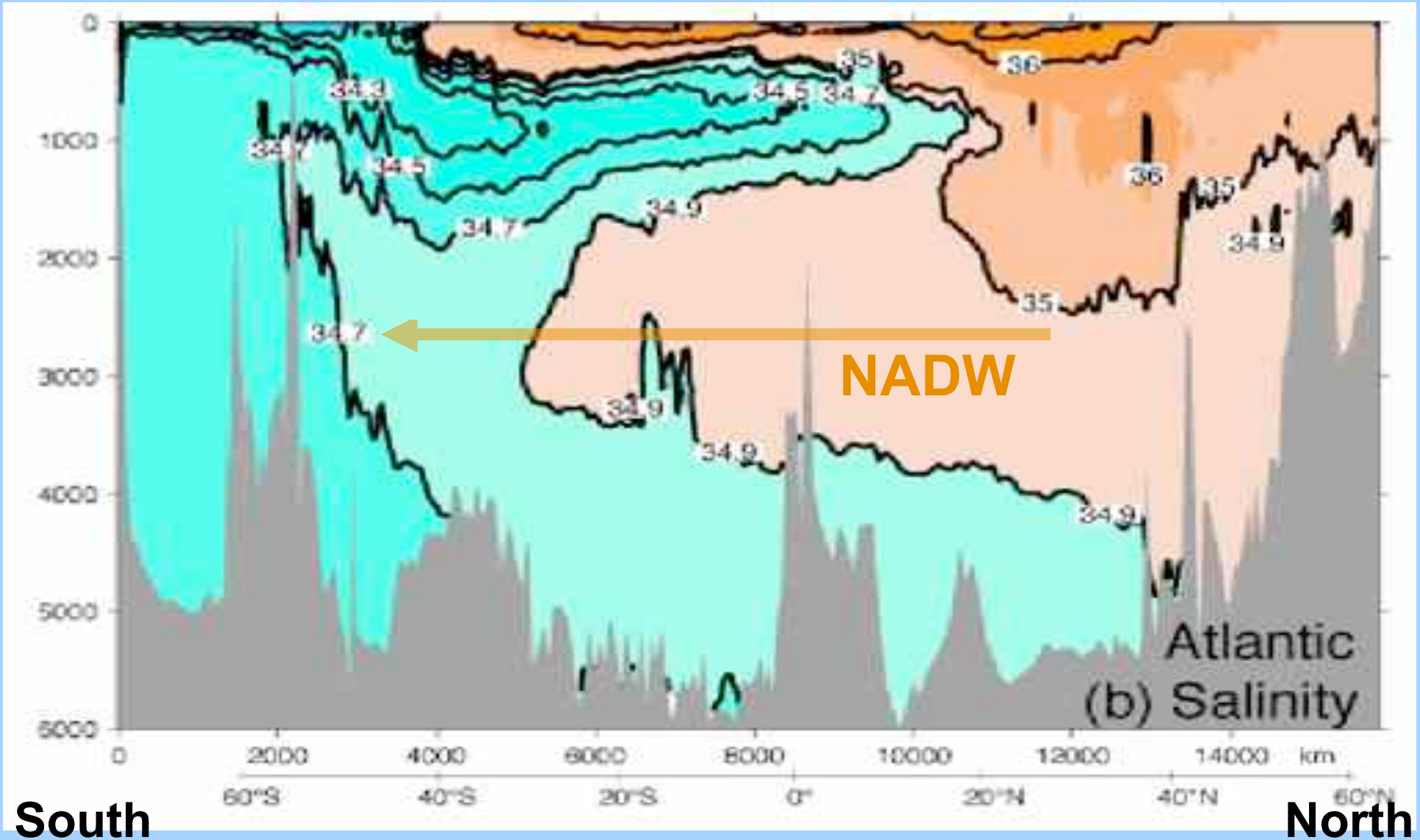
$$F_{heat} = c \cdot \rho \cdot \frac{dV}{dt} \cdot (T_N - T_S) \approx 1.2 \cdot 10^{15}\,W$$

Courtesy from Thomas Stocker

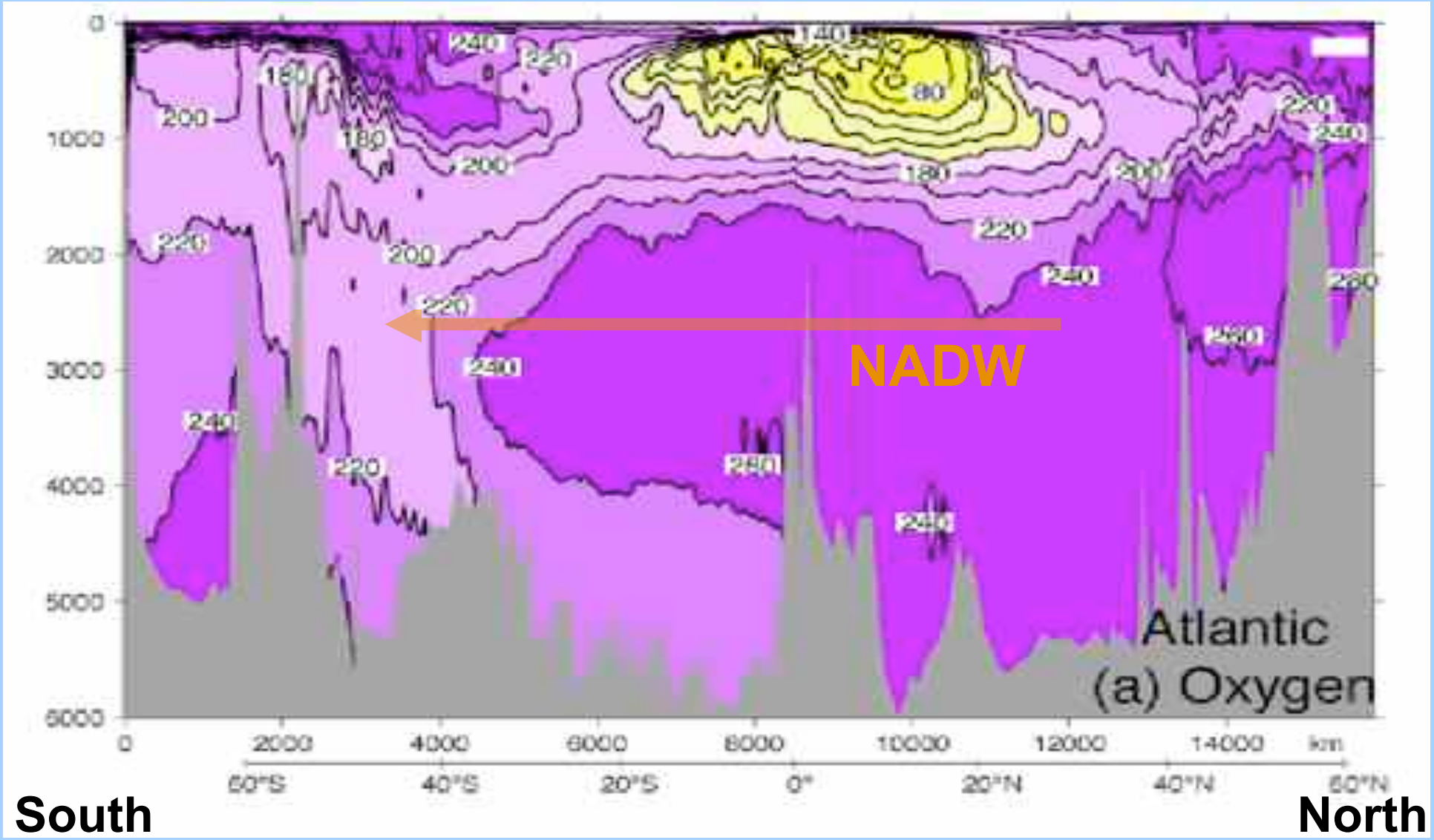
In the North Atlantic, salty surface water from the subtropics progressively cools and sinks to depth



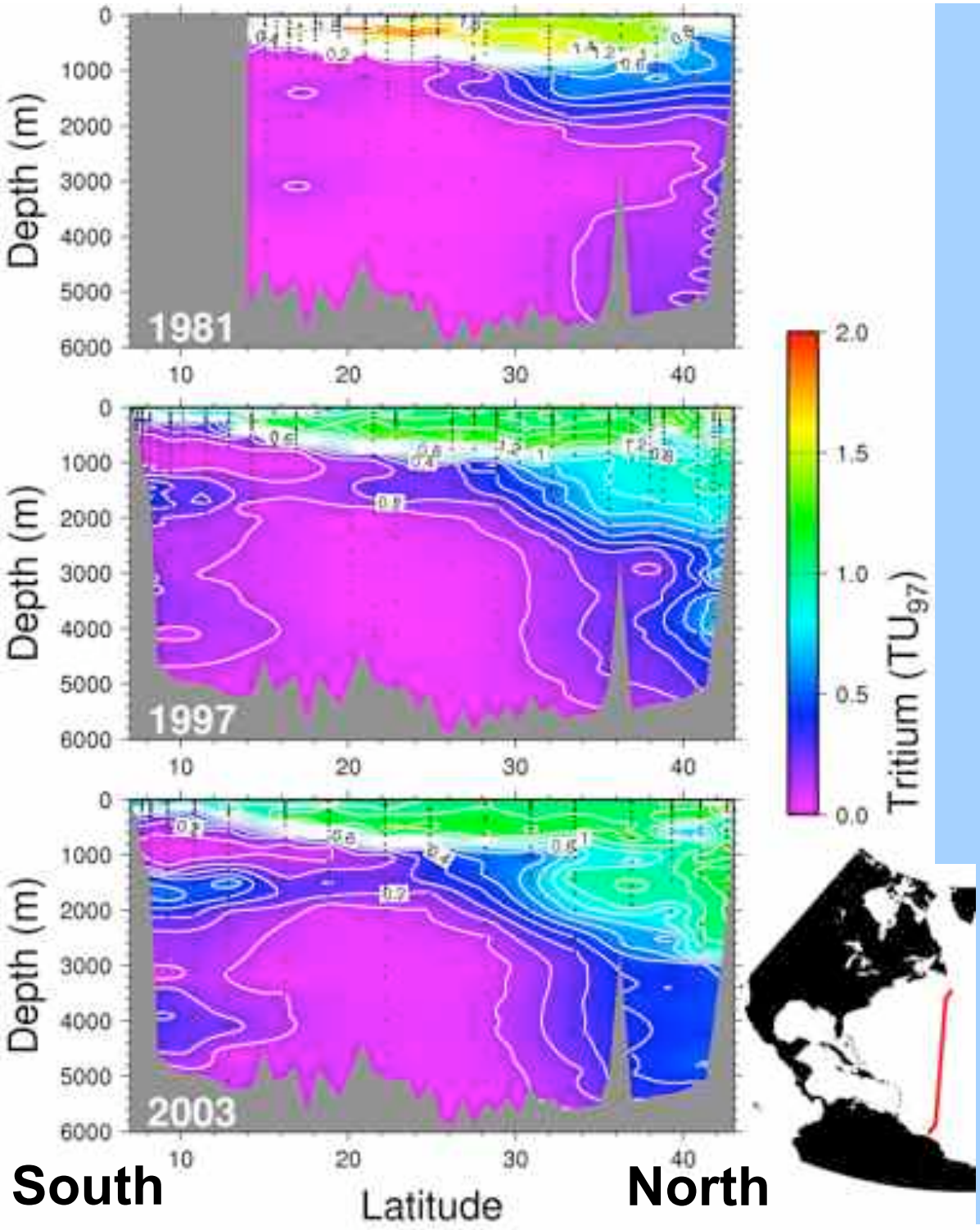
The salinity distribution allows the identification of water masses such as North Atlantic Deep Water



Dissolved oxygen is consumed by biological respiration during transport



Source: WOCE

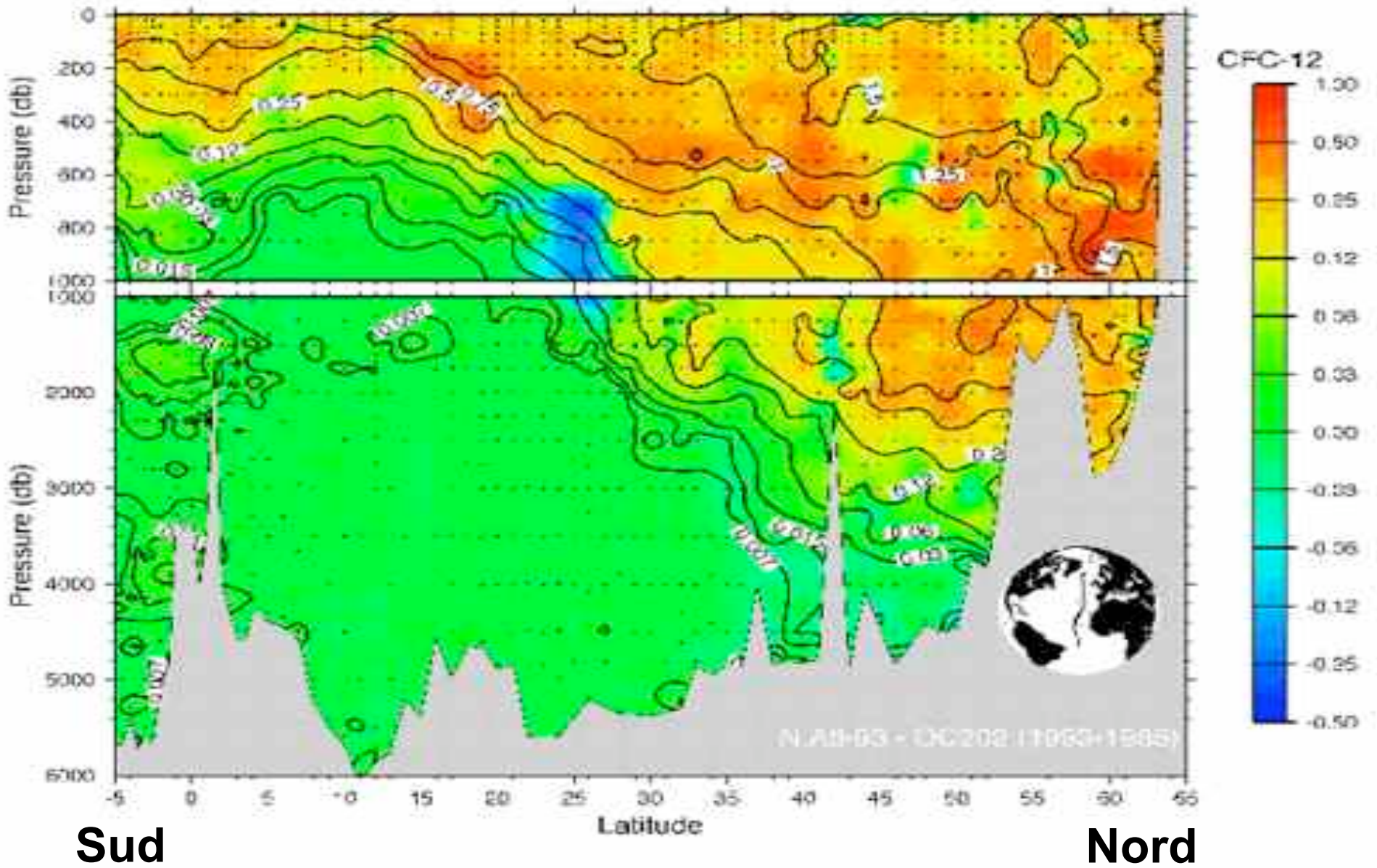


The propagation of transient tracers allows to follow the sinking and advection of NADW

ex. Tritium and ^{14}C produced during nuclear bomb tests in the atmosphere during the early 60s

Source: WHOI

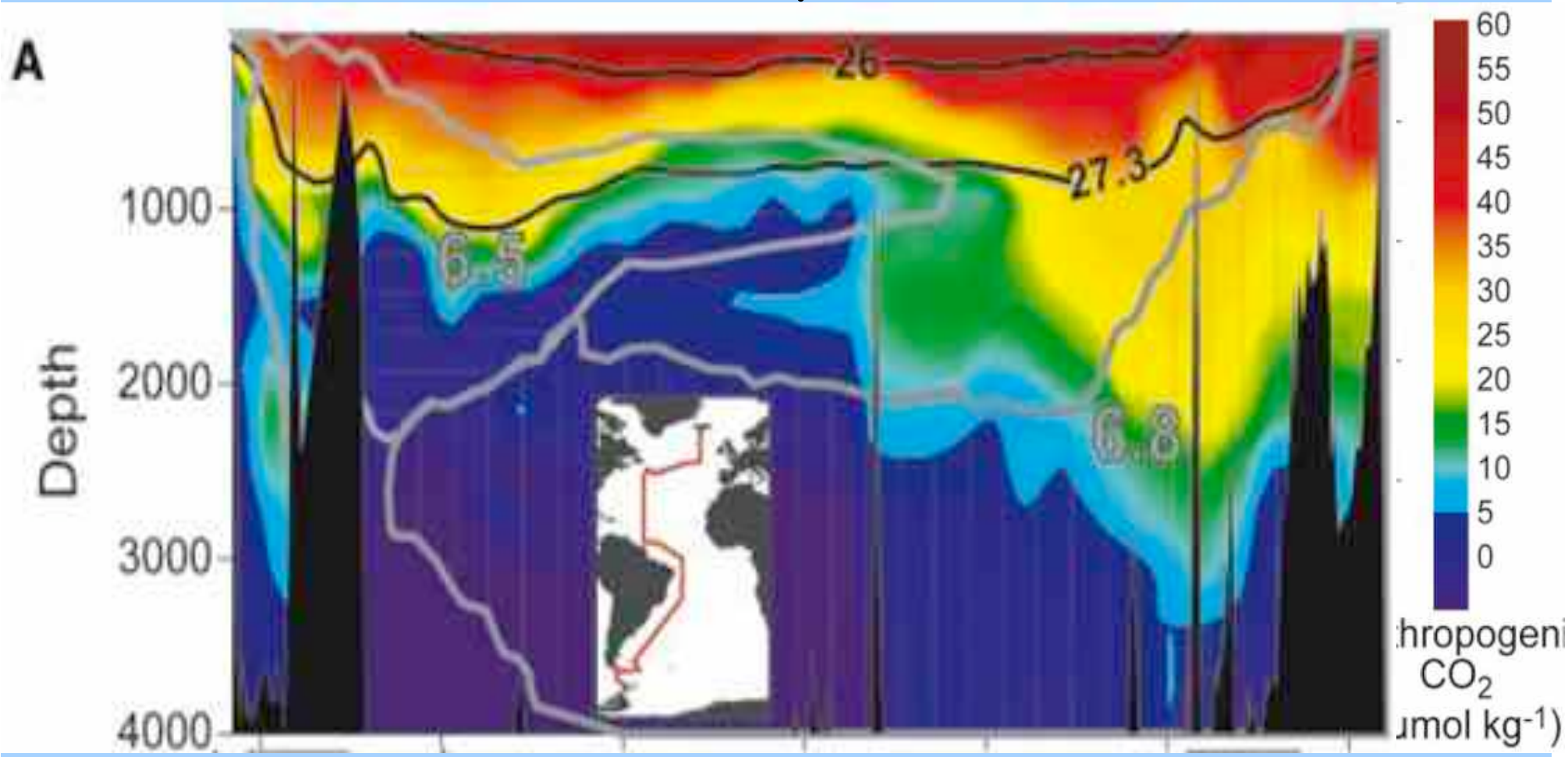
Diffusion and advection of anthropogenic freons (evolution from 1988 to 1993)



Source: NOAA

The Atlantic Meridional Overturning Circulation plays a major role in the sequestration of anthropogenic CO_2 in the deep Ocean (1/3 since the 19th century)

Concentration in µmol/kg in 1994

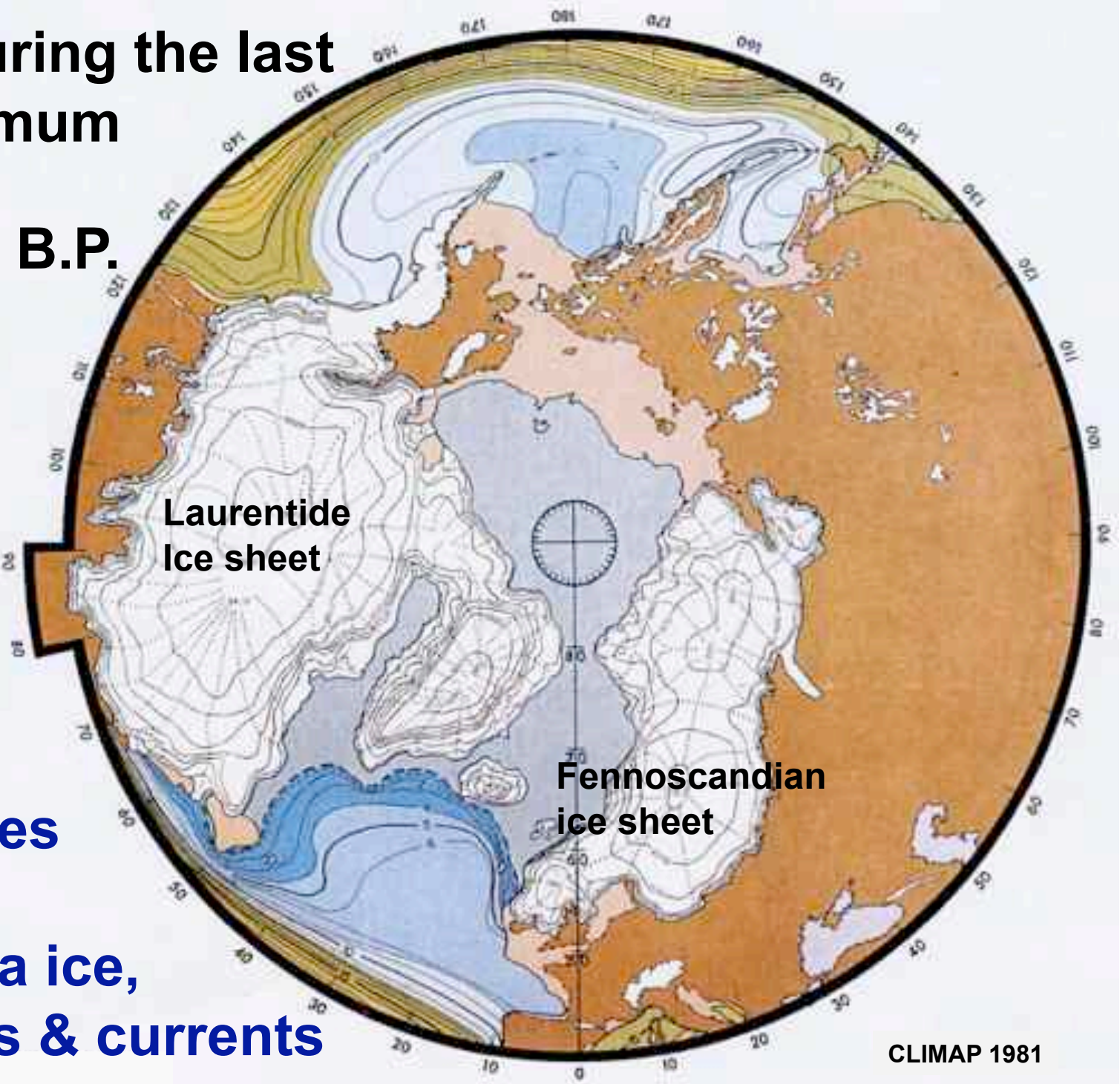


Sabine et al. 2004 *Science*

Looking at the past to illustrate large changes of ocean & climate

The Earth during the last glacial maximum

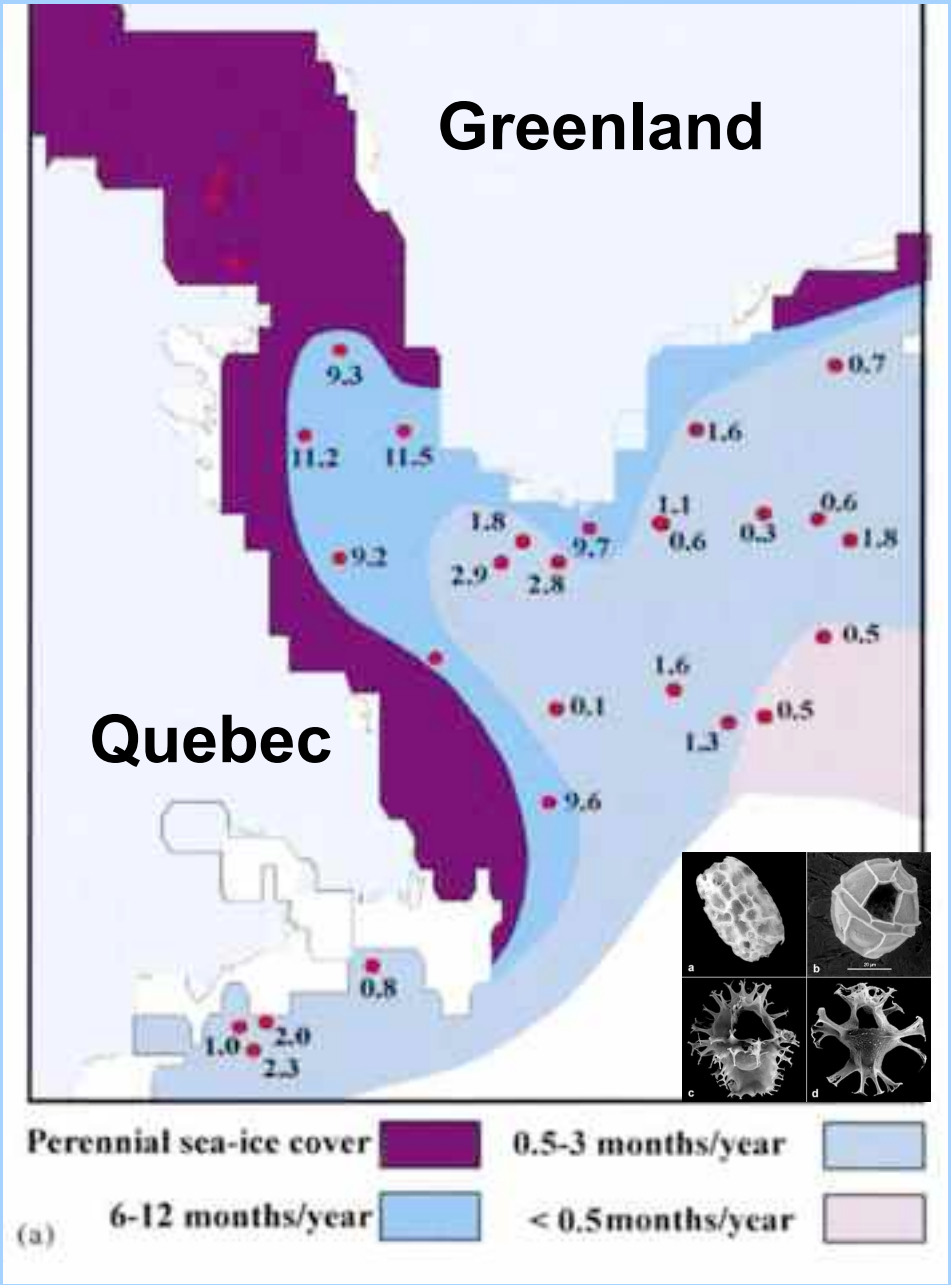
21,000 years B.P. (21 kyr BP)

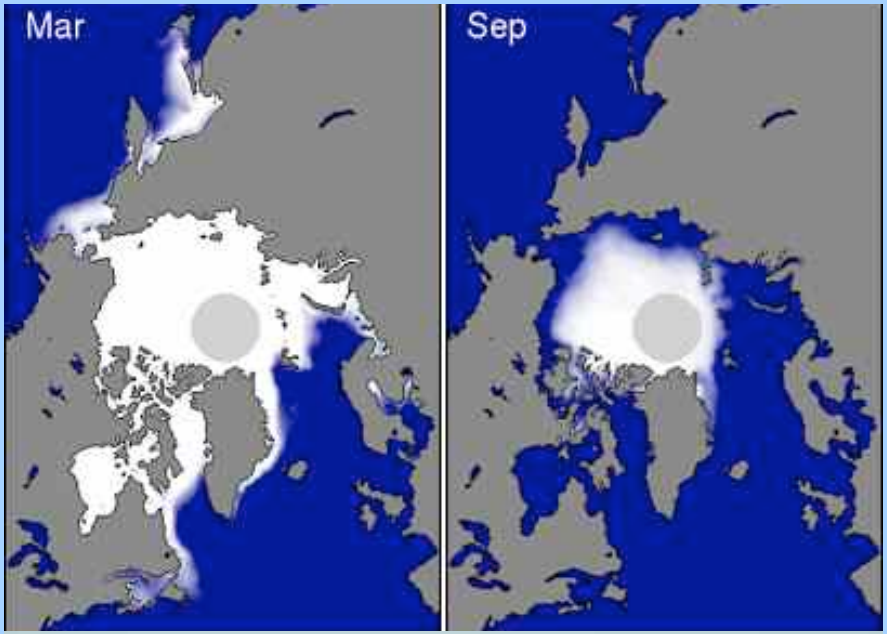


Major changes in climate, sea-level, sea ice, temperatures & currents

CLIMAP 1981

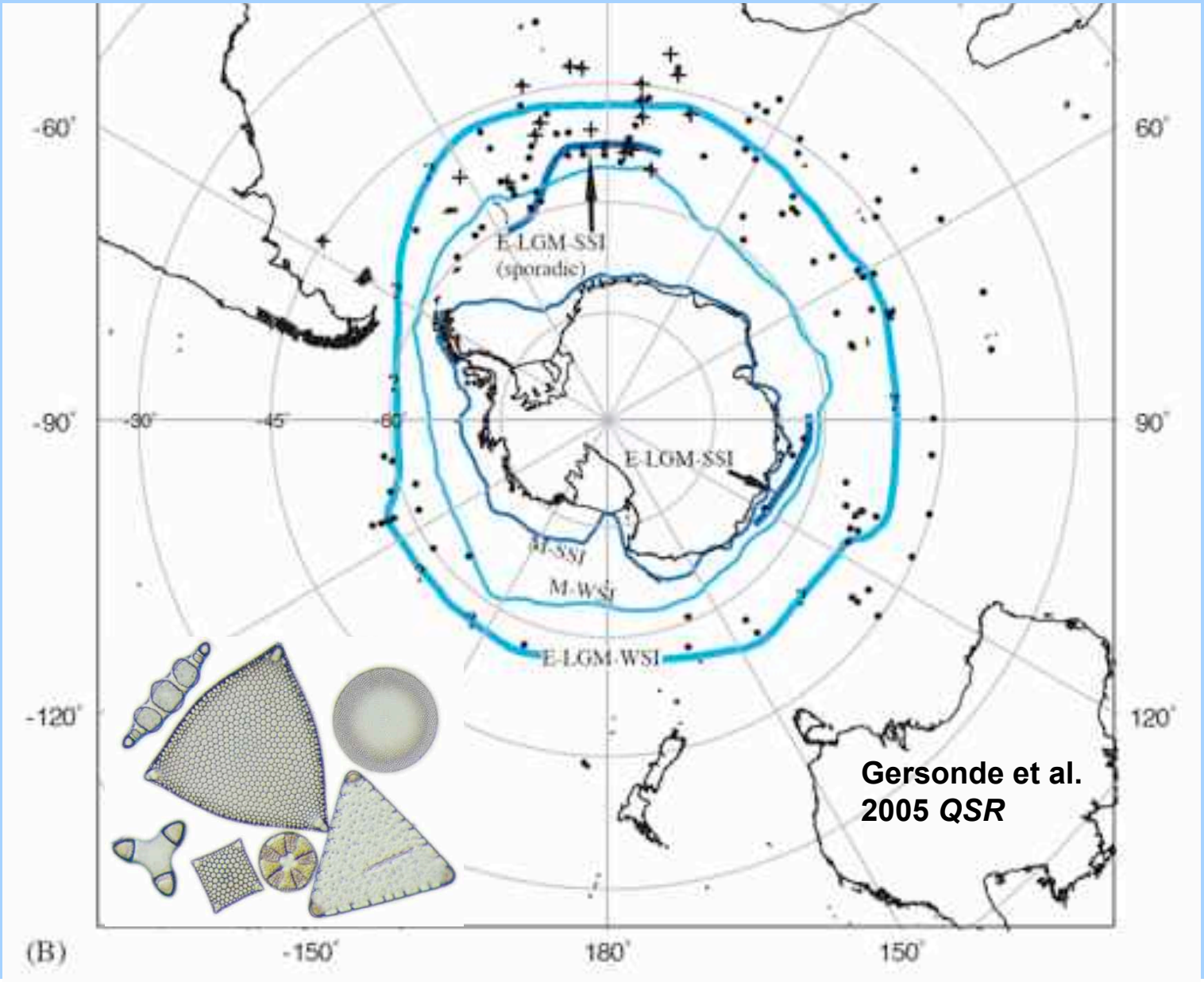
Attempt to reconstruct sea ice during the LGM based on the distribution of planktonic dinocysts



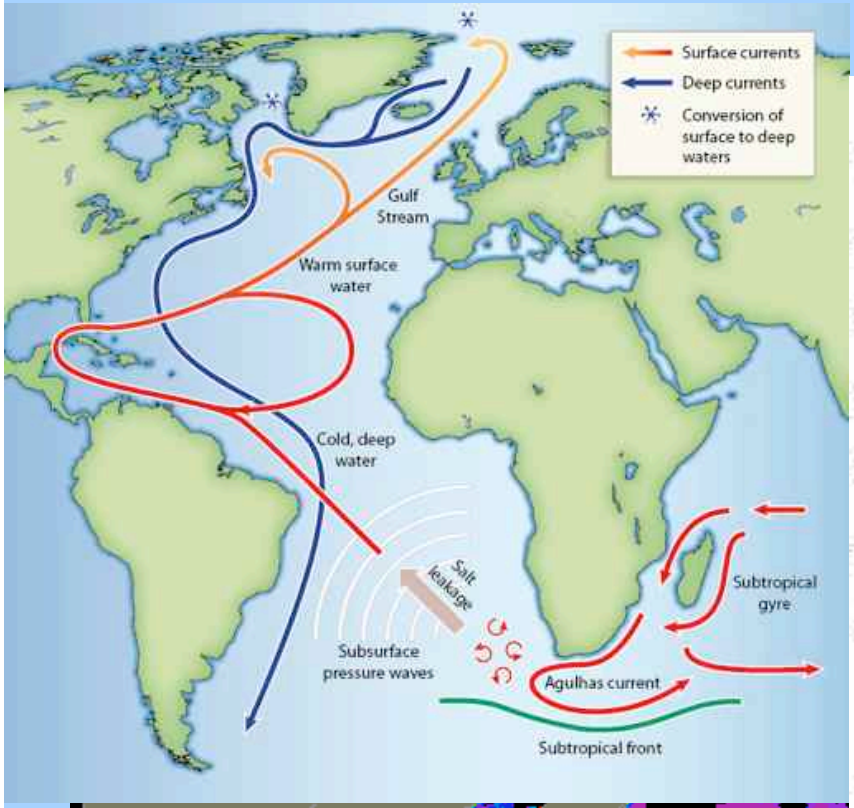


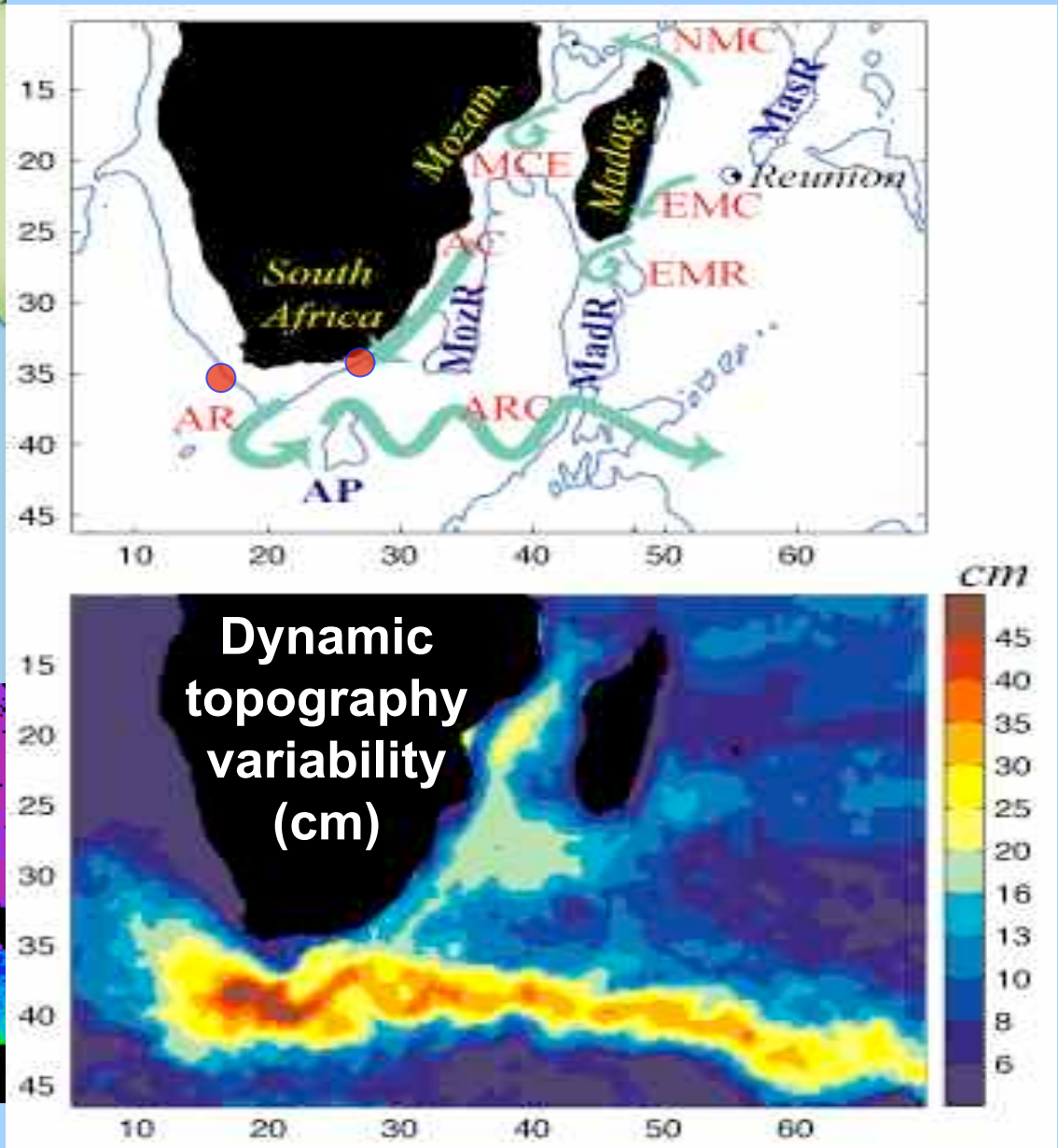
De Vernal & Hillaire-Marcel 2000 *QSR*

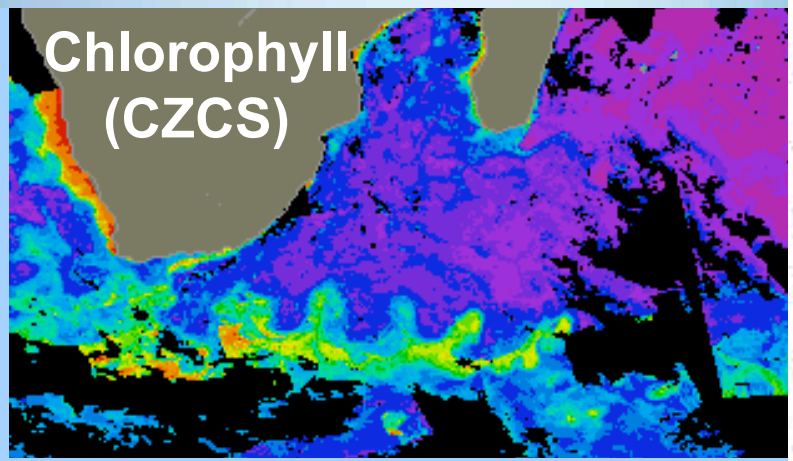
The distribution of fossil diatoms and radiolaria is also used to map the LGM sea ice around Antarctica : doubling of sea ice extent



South of Africa, a zone of confrontation between the Agulhas Current, the Benguela Current et the Antarctic Circumpolar Current: retroflexion & Indian-Atlantic exchanges

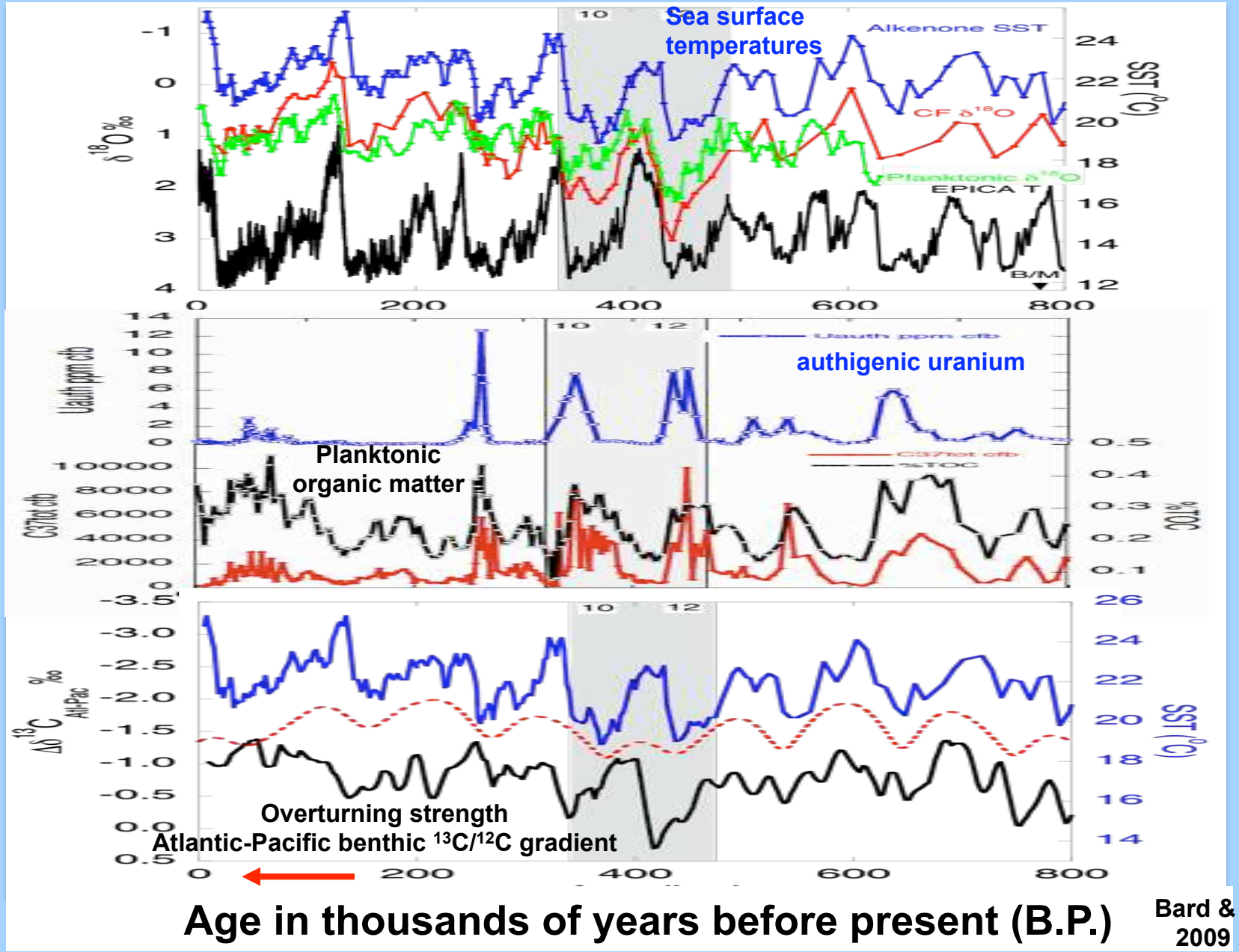






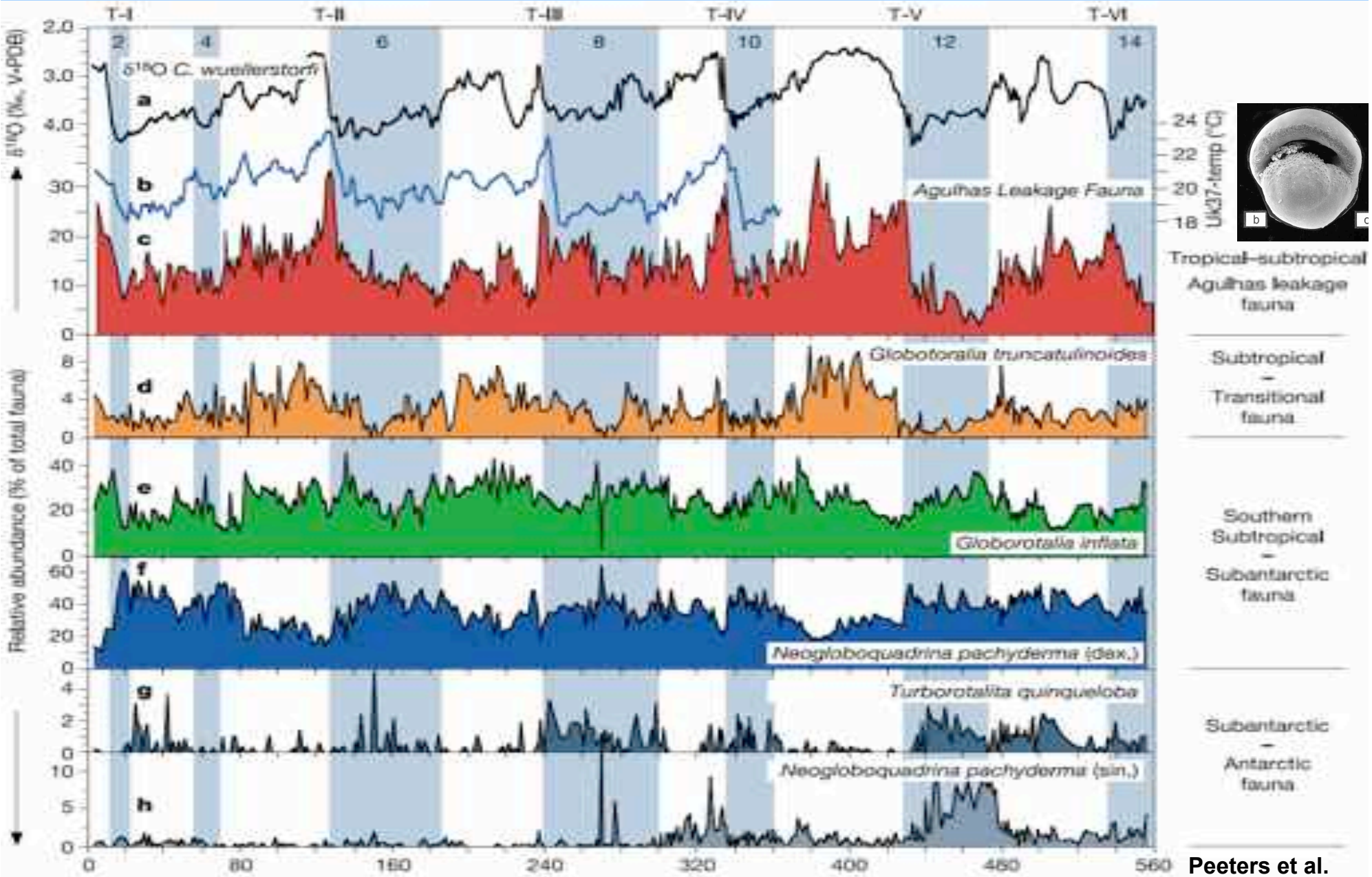
Source: NOC, Southampton

Variations of the Agulhas current and of Indian-Atlantic exchanges



Bard & Rickaby 2009 *Nature*

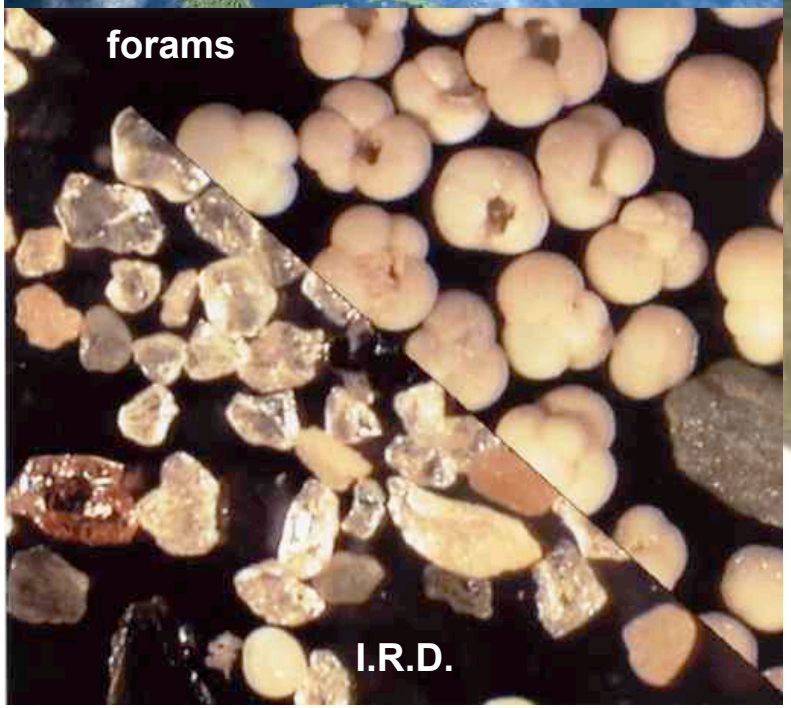
Agulhas leakage glacial-interglacial modulation

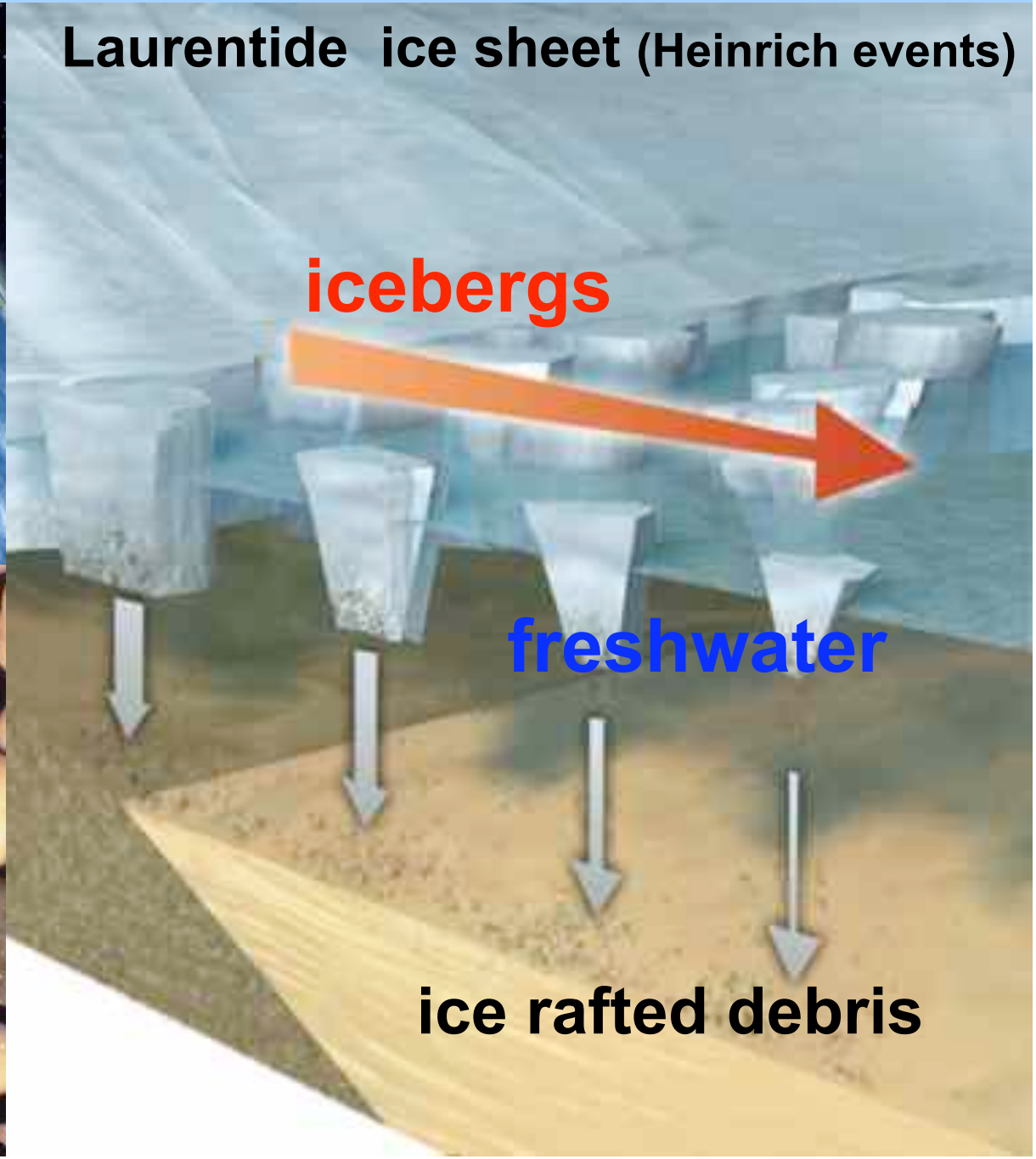


Peeters et al. 2004 *Nature*

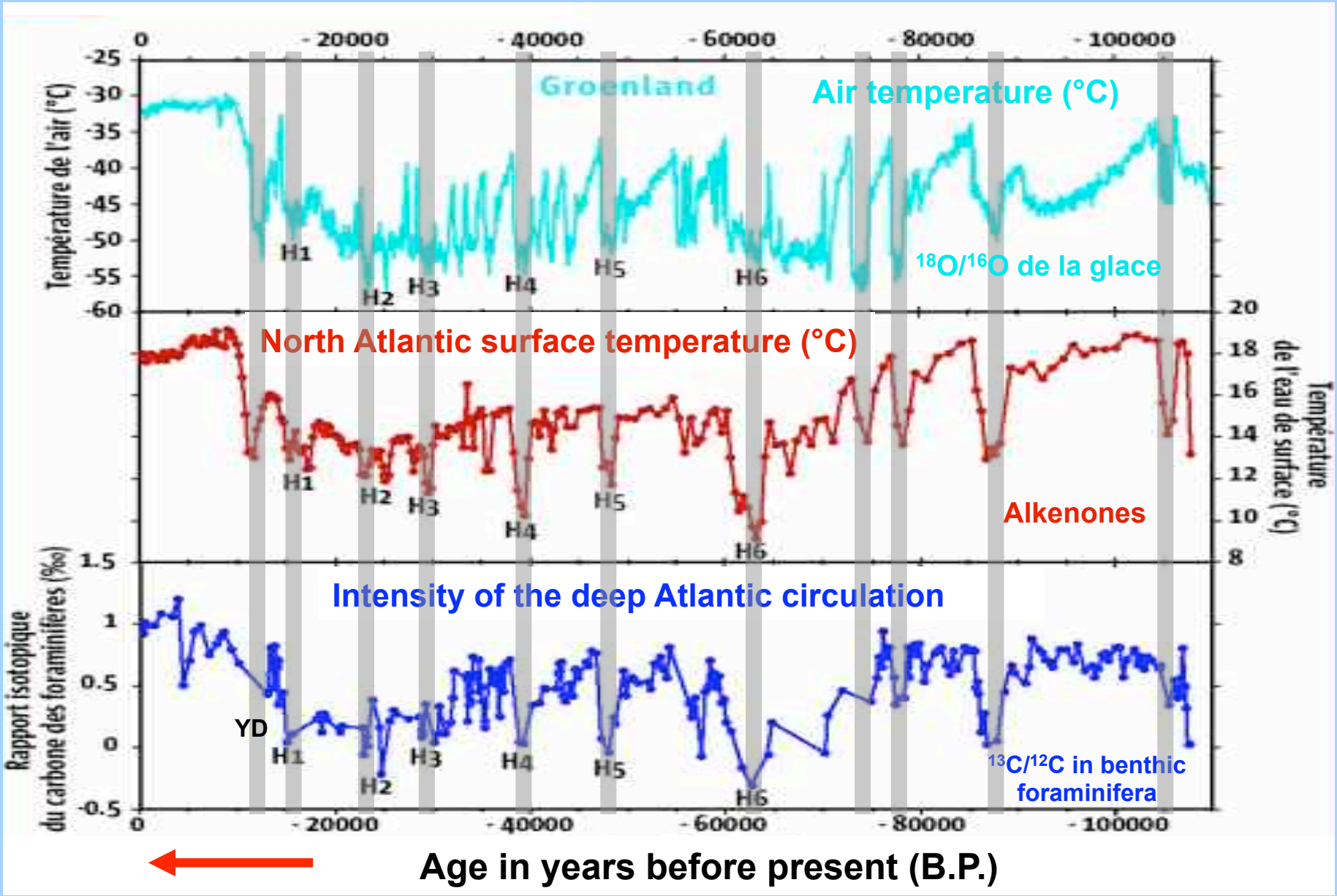
Age in thousands of years before present (B.P.)

Hydrological perturbations linked to transient collapses of the Laurentide ice sheet (Heinrich events)



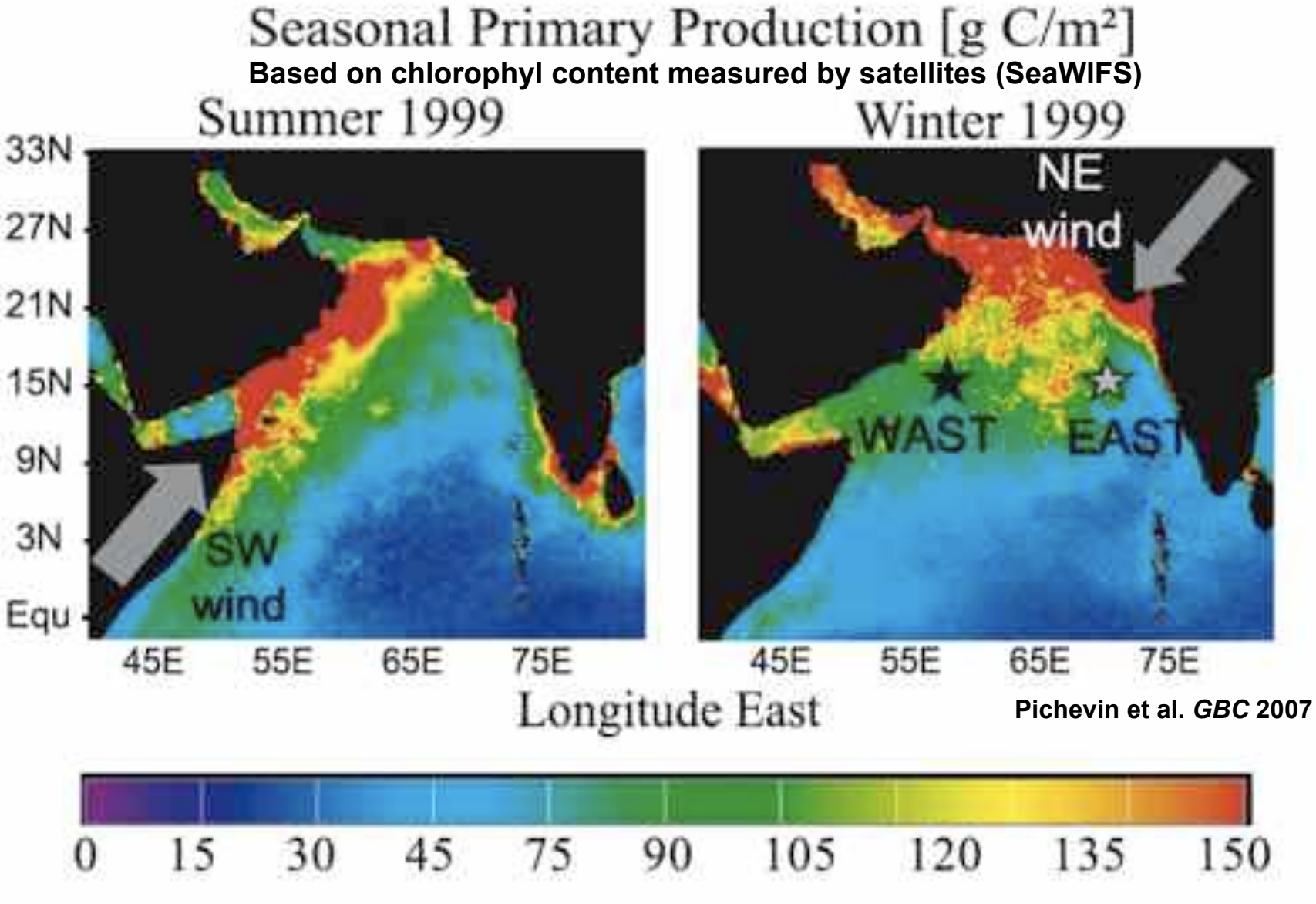


Many instabilities of the deep circulation over the last 100,000 years affecting air and ocean temperatures



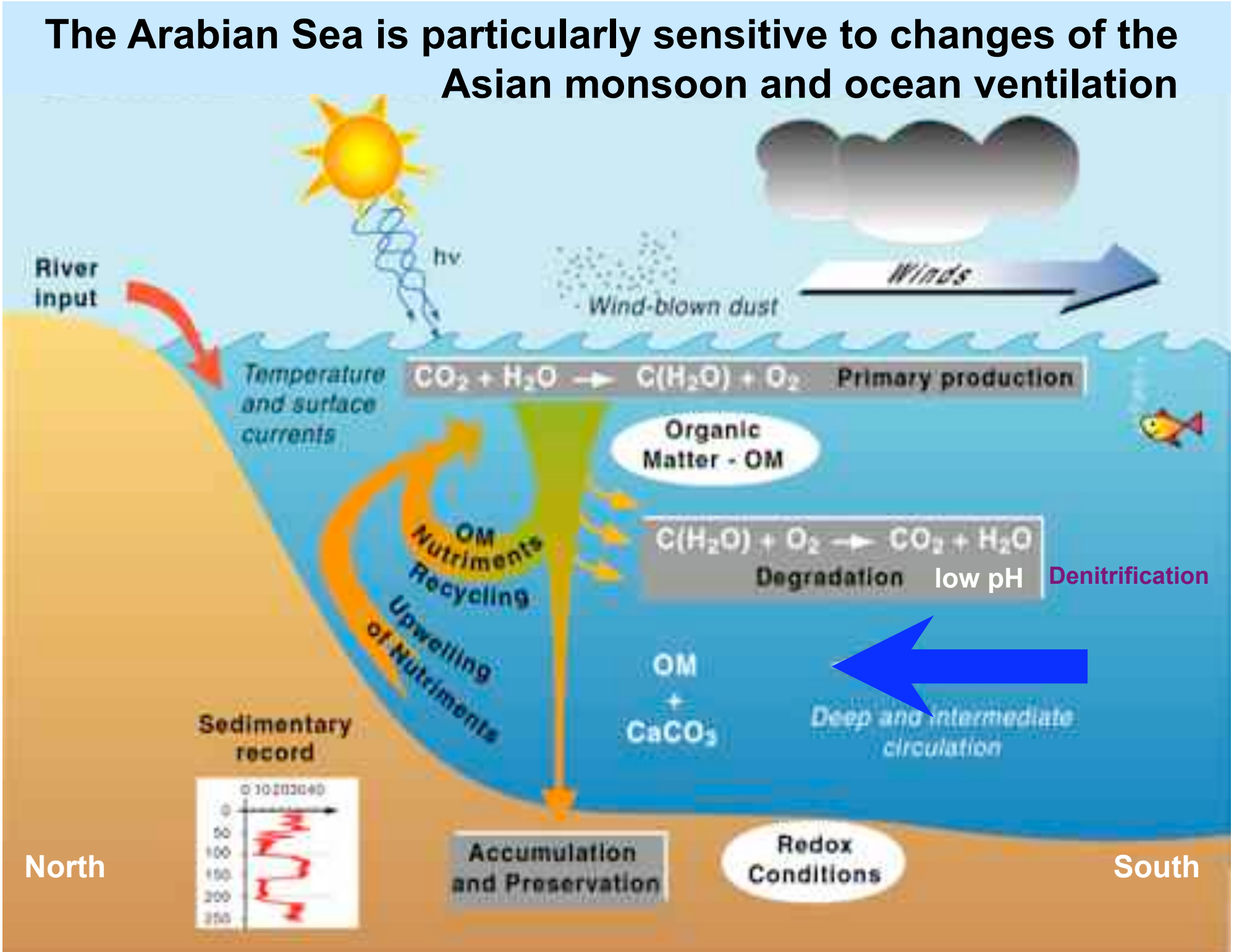
Johnsen et al. 2001 *JQS*, Bard et al. 2000 *Science*, 2002 *Phys. Today*, Shackleton et al. 2000 *Paleoceanography*

Marine biological productivity favored by upwelling and surface mixing due to monsoon winds in the Arabian Sea

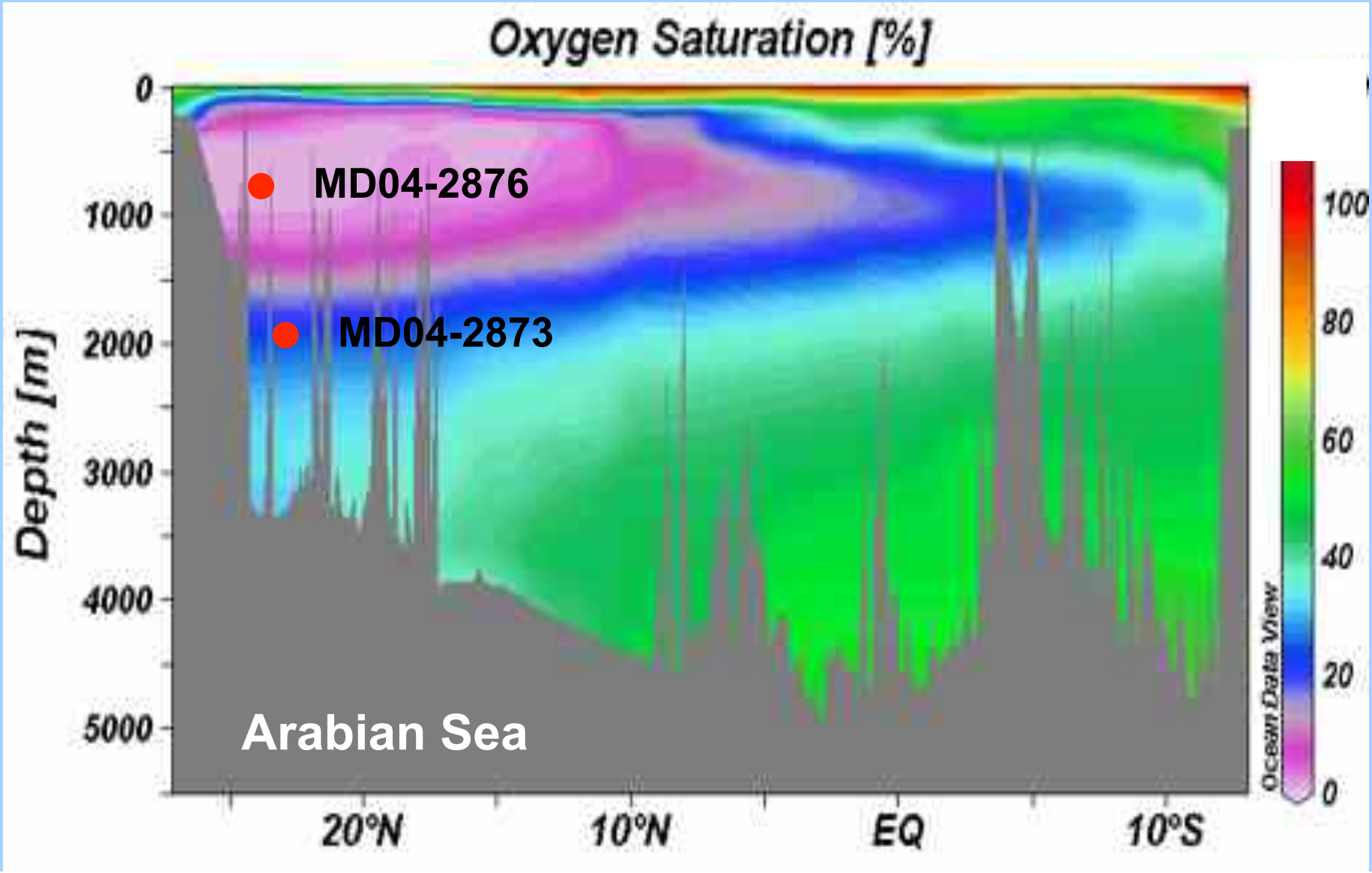


Pichevin et al. *GBC* 2007

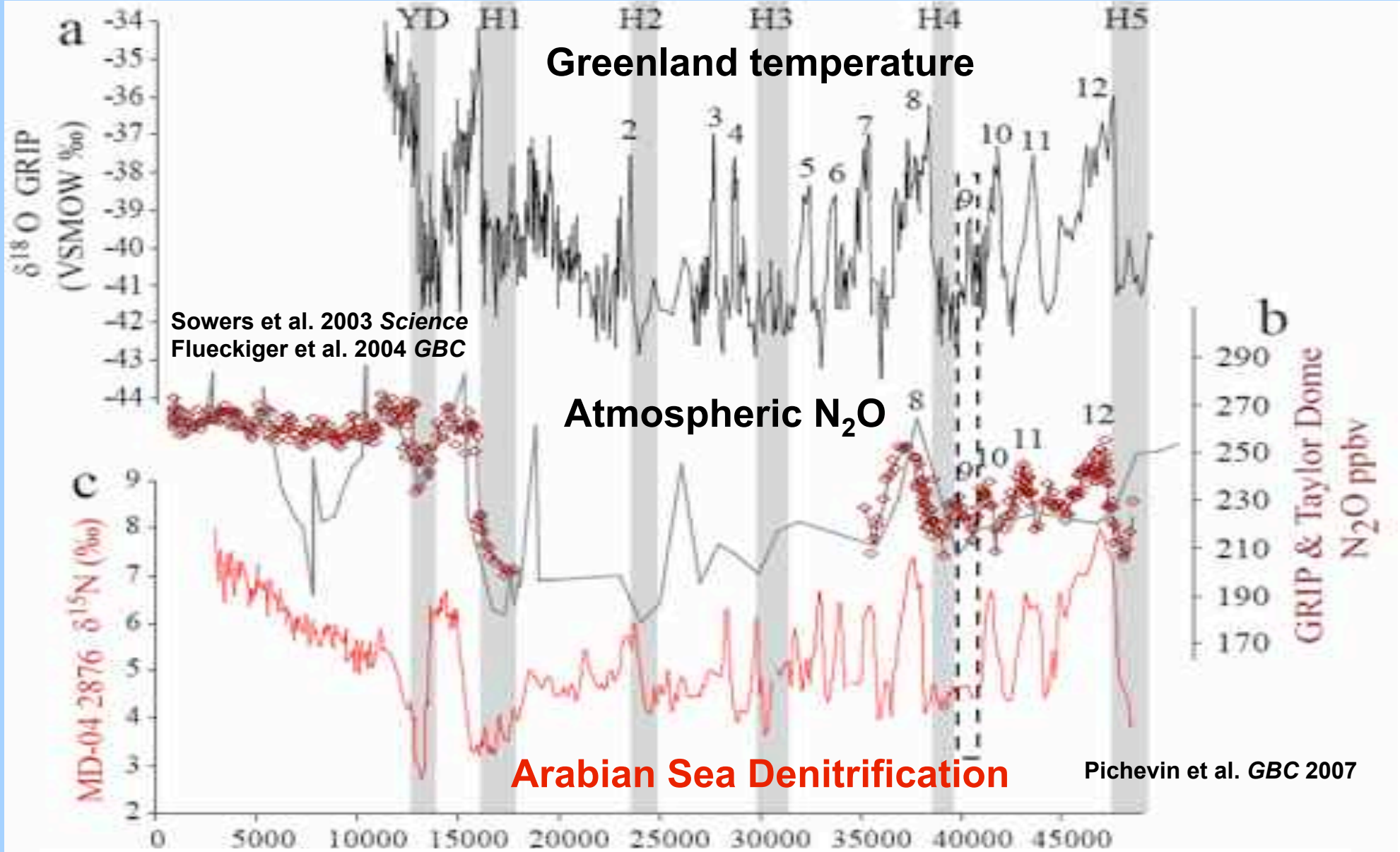
The Arabian Sea is particularly sensitive to changes of the Asian monsoon and ocean ventilation



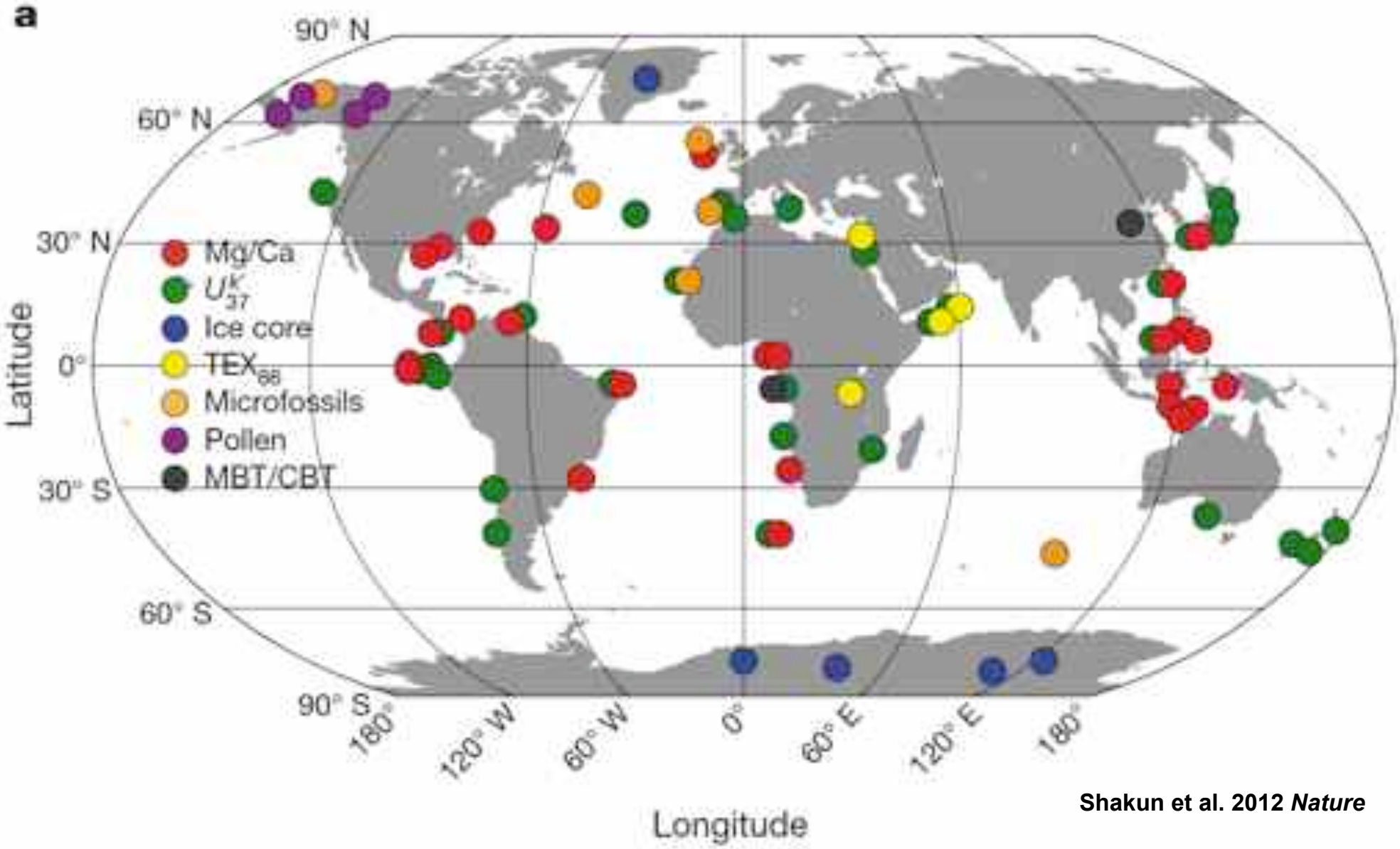
Study of sediment cores recovered within and below the oxygen minimum zone (OMZ) of the Arabian Sea



Probable contribution of the Arabian Sea in the atmospheric variations of nitrous oxide (N_2O)

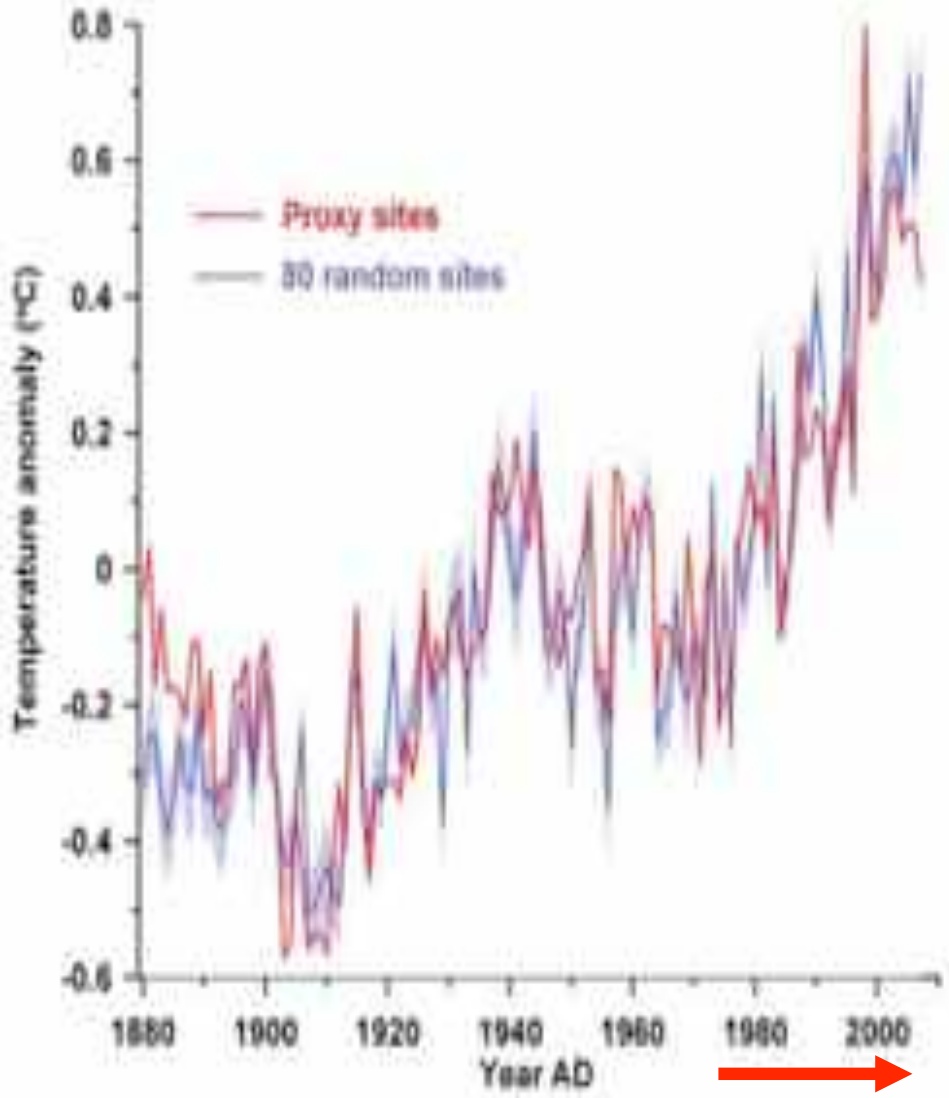


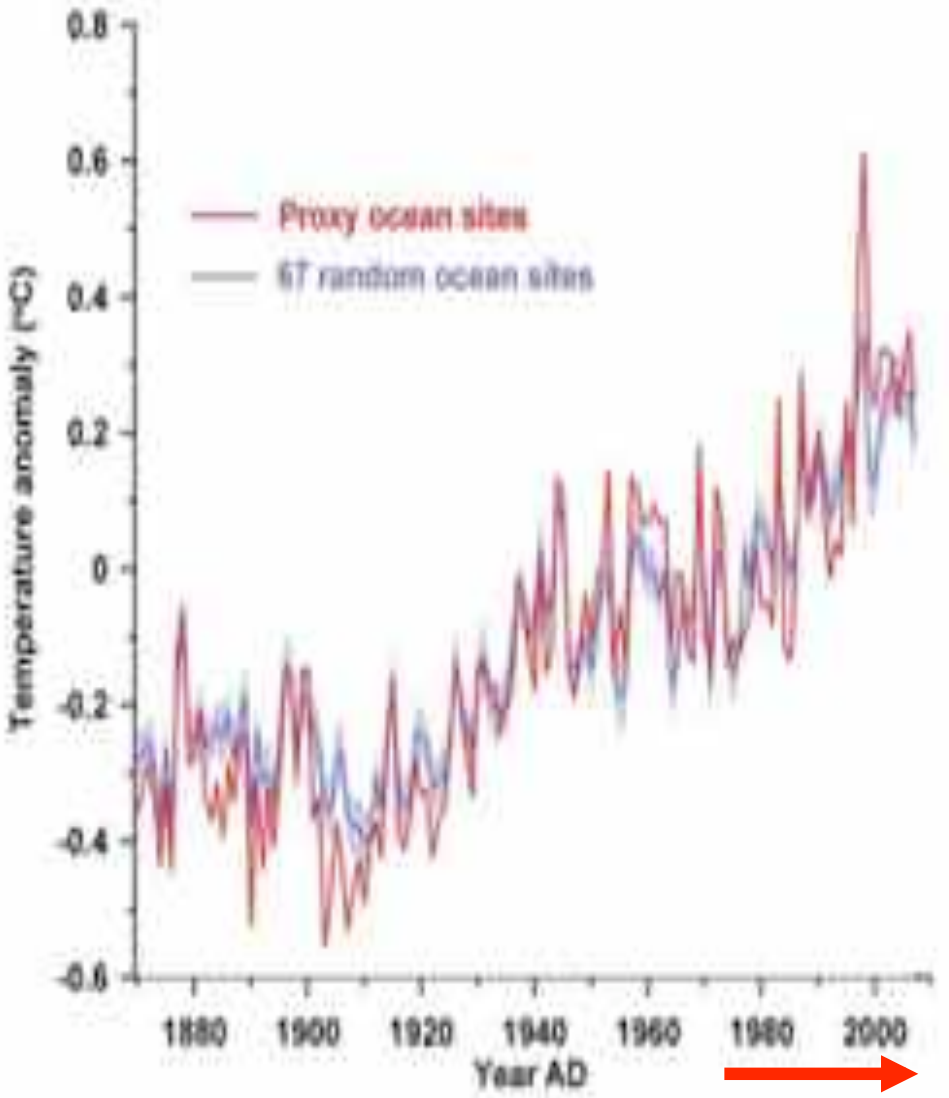
Compiling 80 well-dated temperature records over the last deglaciation (21-6 kyr B.P.)



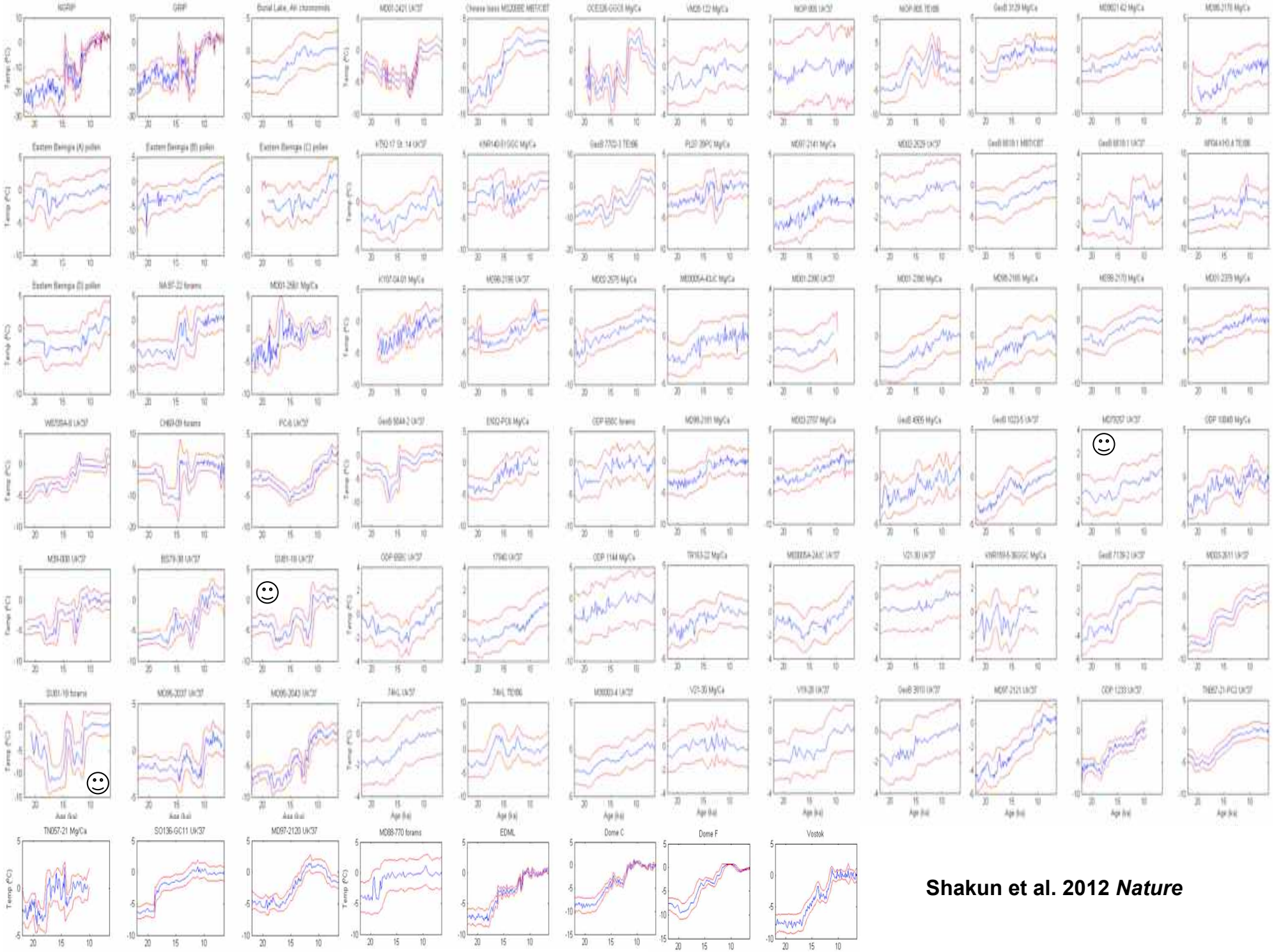
Shakun et al. 2012 *Nature*

How well do the proxy sites represent the globe ?



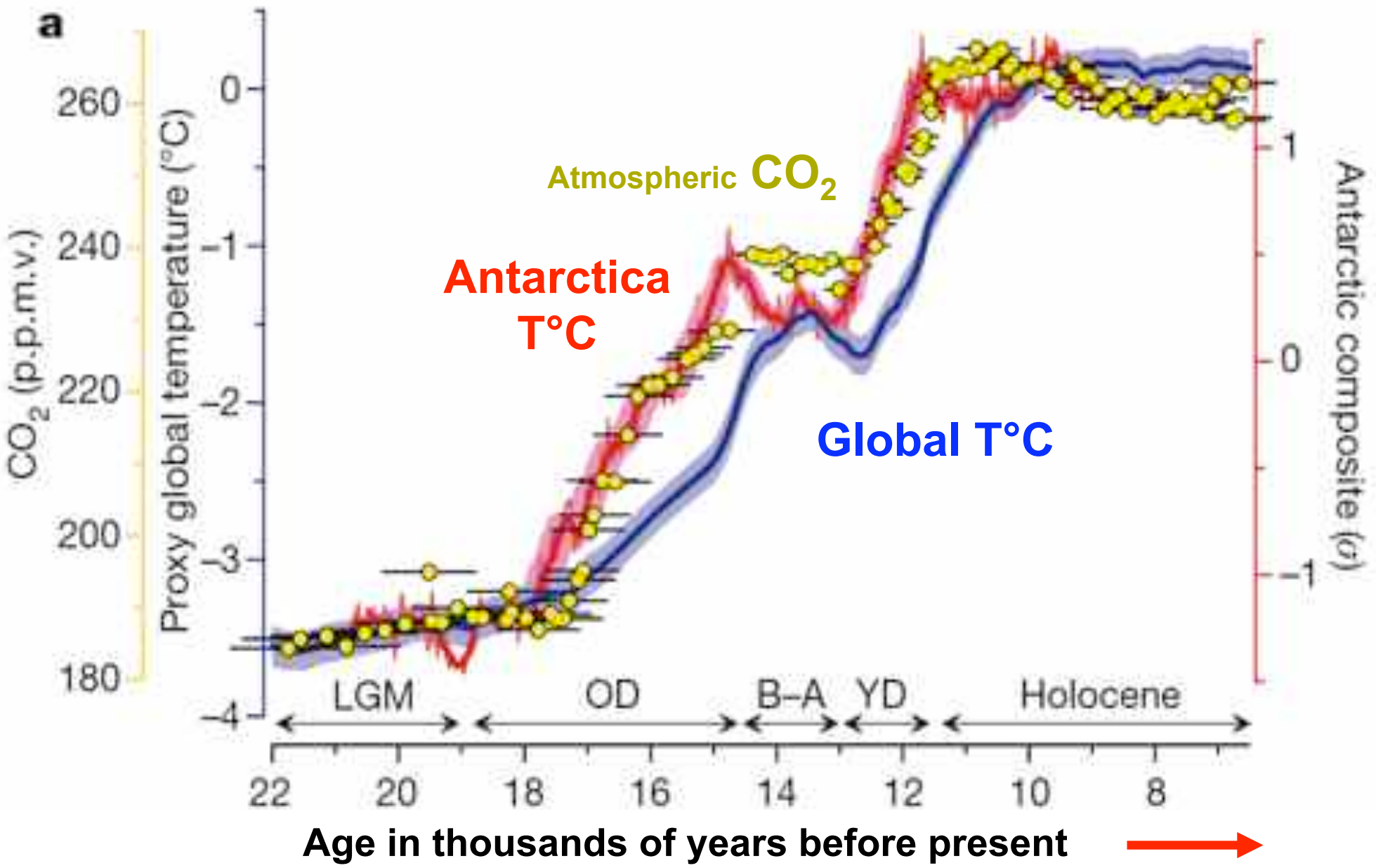


Shakun et al. 2012 *Nature*



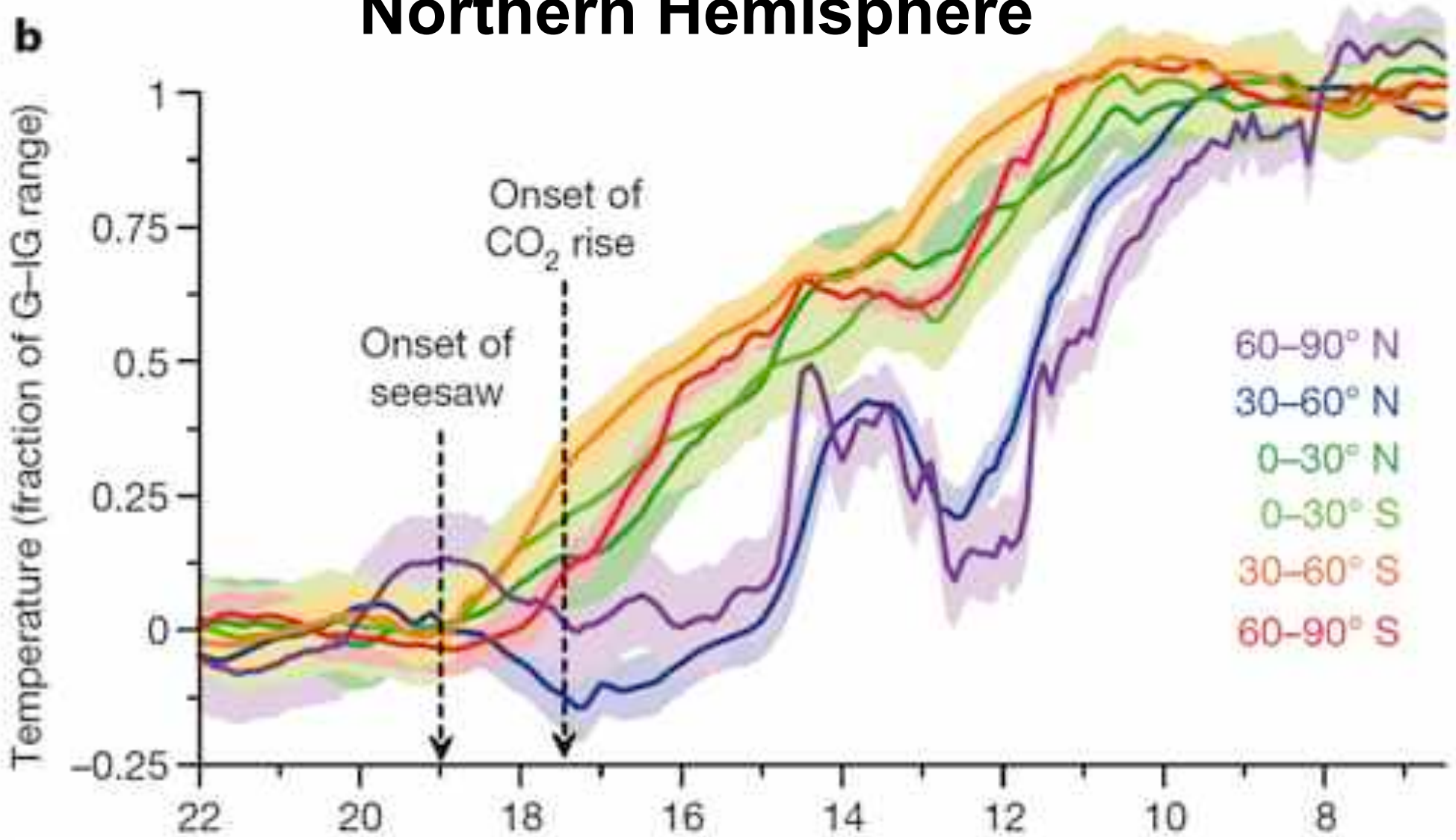
Shakun et al. 2012 *Nature*

The global deglacial warming lags the CO_2 rise



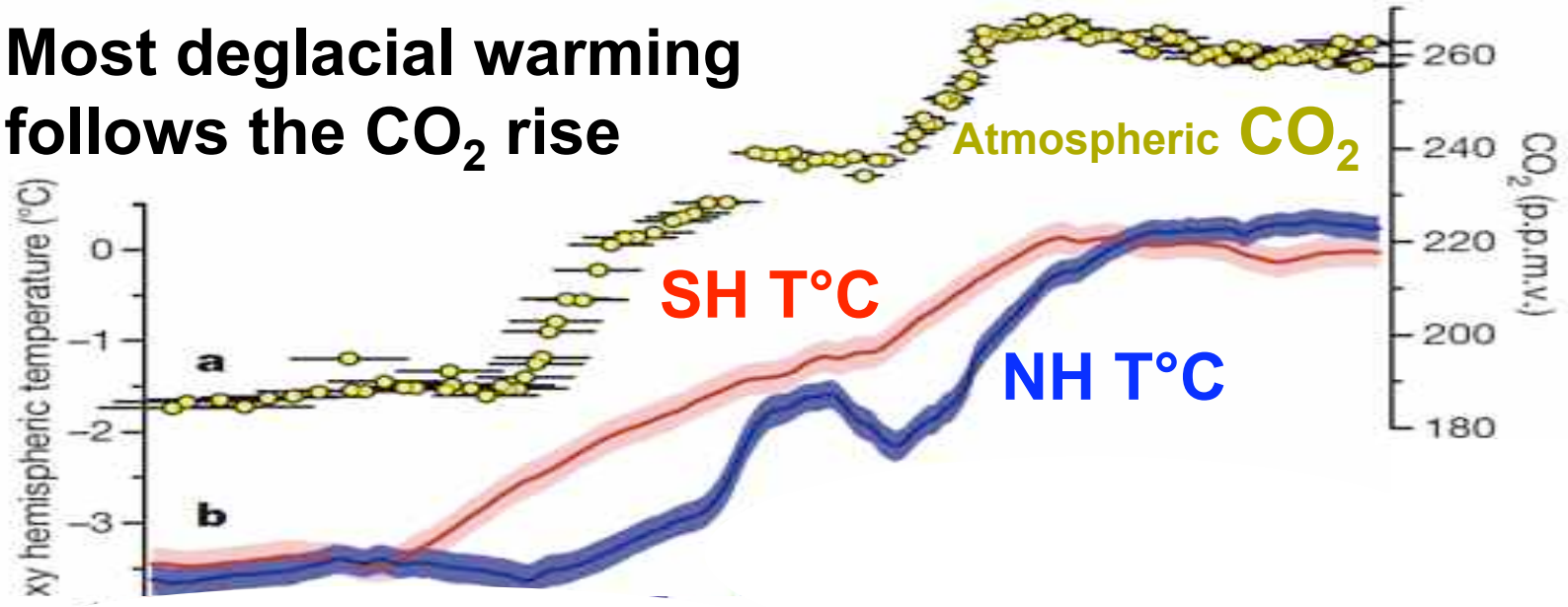
Shakun et al. 2012 *Nature*

The deglacial warming is delayed in the Northern Hemisphere

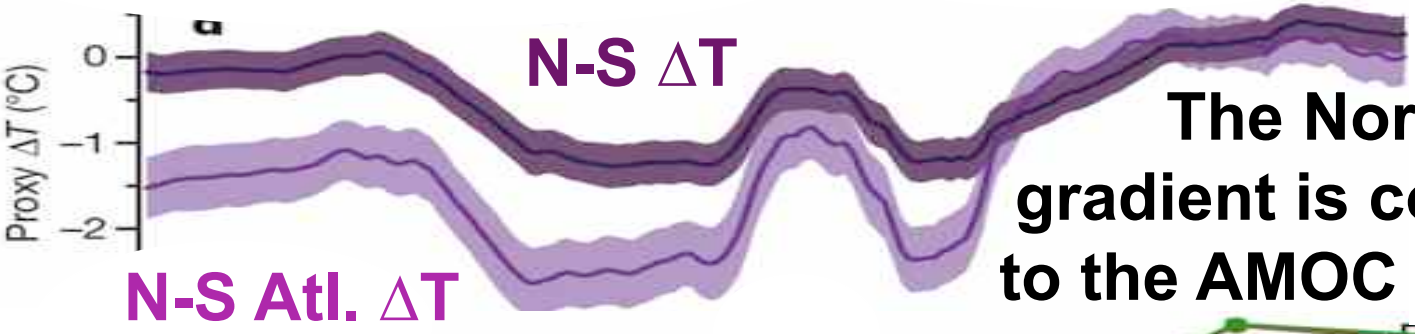


Shakun et al. 2012 *Nature*

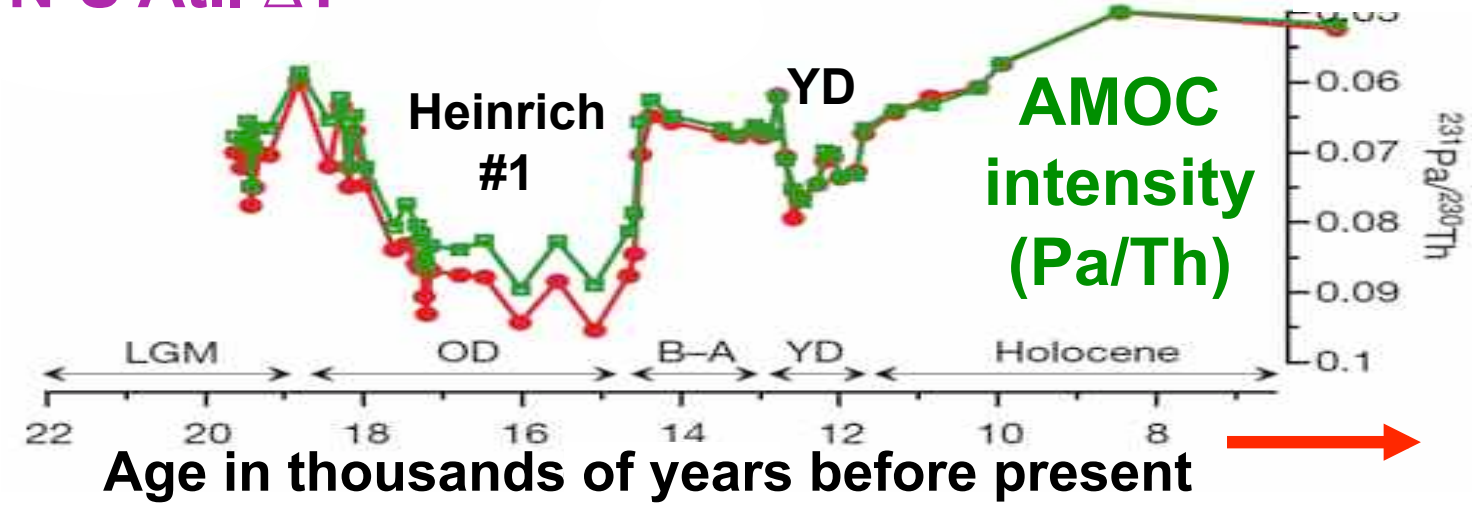
Most deglacial warming follows the CO_2 rise



Shakun et al. 2012 *Nature*



The North-South gradient is correlated to the AMOC intensity



McManus et al. 2004 *Nature*

Paleoceanography tells us that the Ocean is a key player in the climate system, which moderates (smoothes and delays) but can also amplify or curb large climatic changes (i.e. positive or negative feedbacks)


Thank you for your patience and attention