Heat transport and dynamics of past climates

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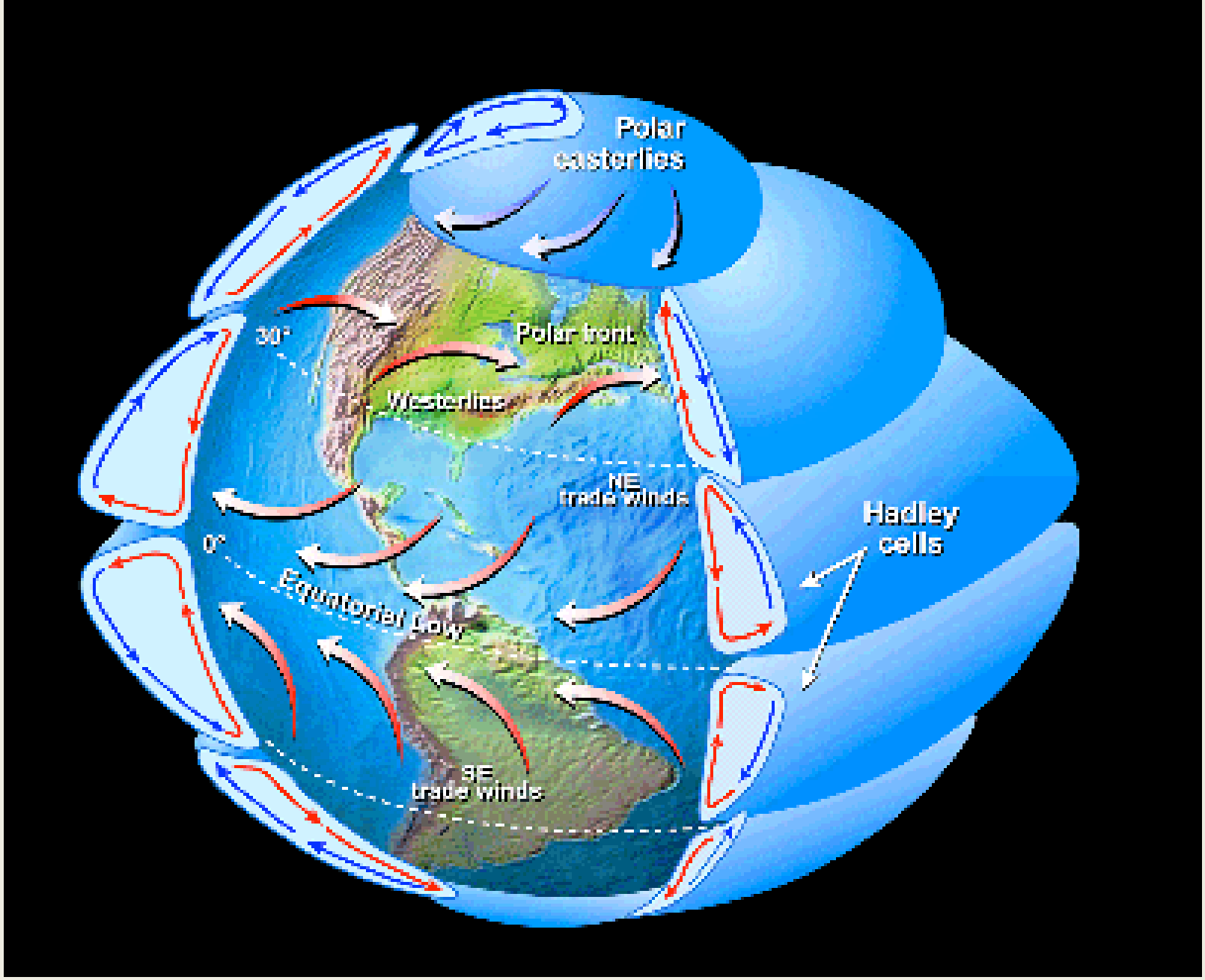
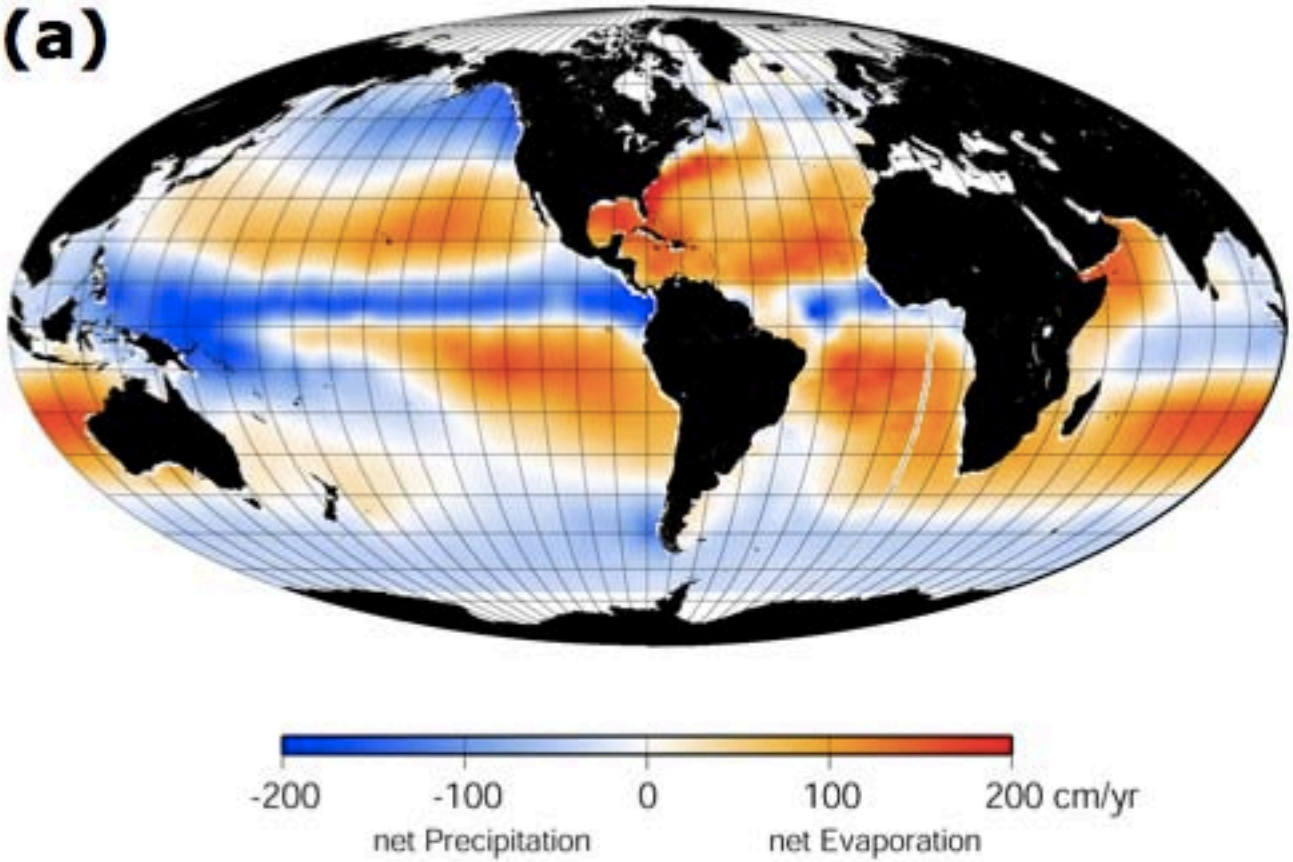
Outline

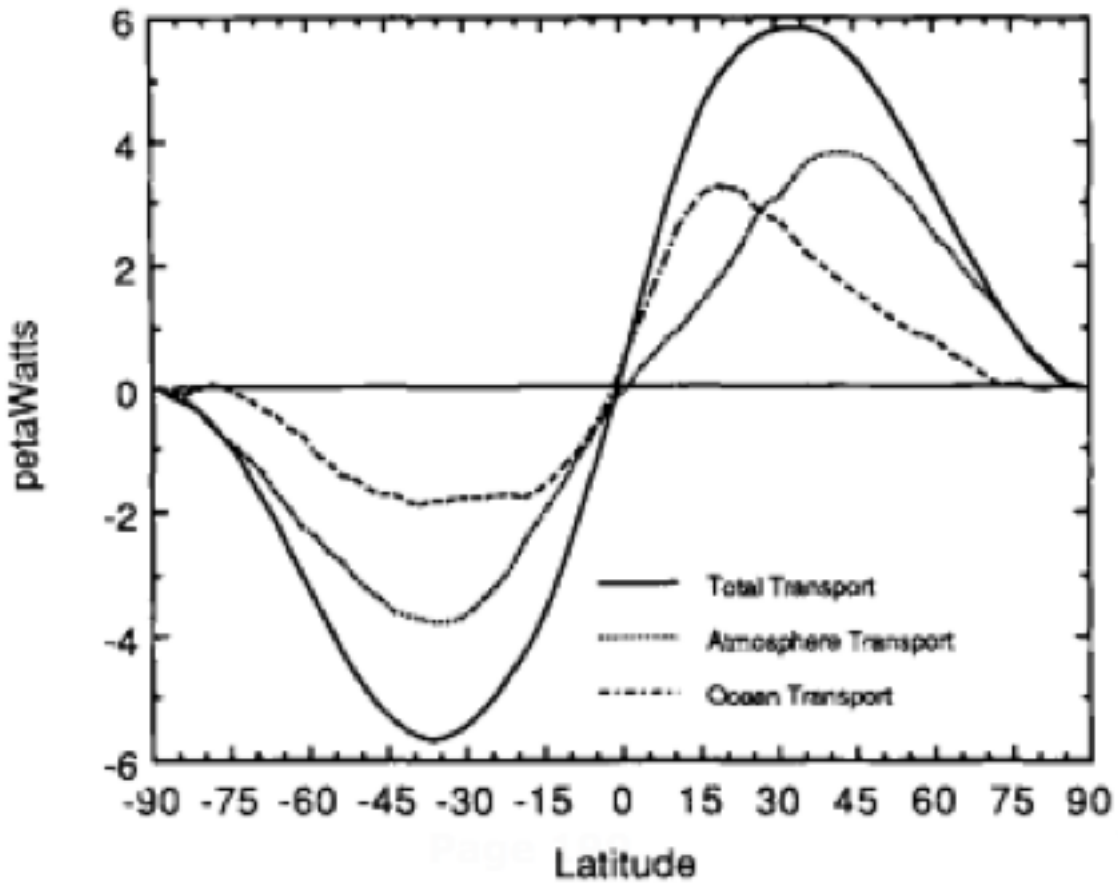
- Atmospheric and ocean circulation
- Past climates
  - The Last Glacial Maximum
  - Heinrich Event 1/the Younger Dryas
- Modeling results and proxy data suggest that a decrease in oceanic heat transport corresponds to an increase in atmospheric heat transport



https://mynasadata.larc.nasa.gov/glossary.php?&word=Hadley%20Cell



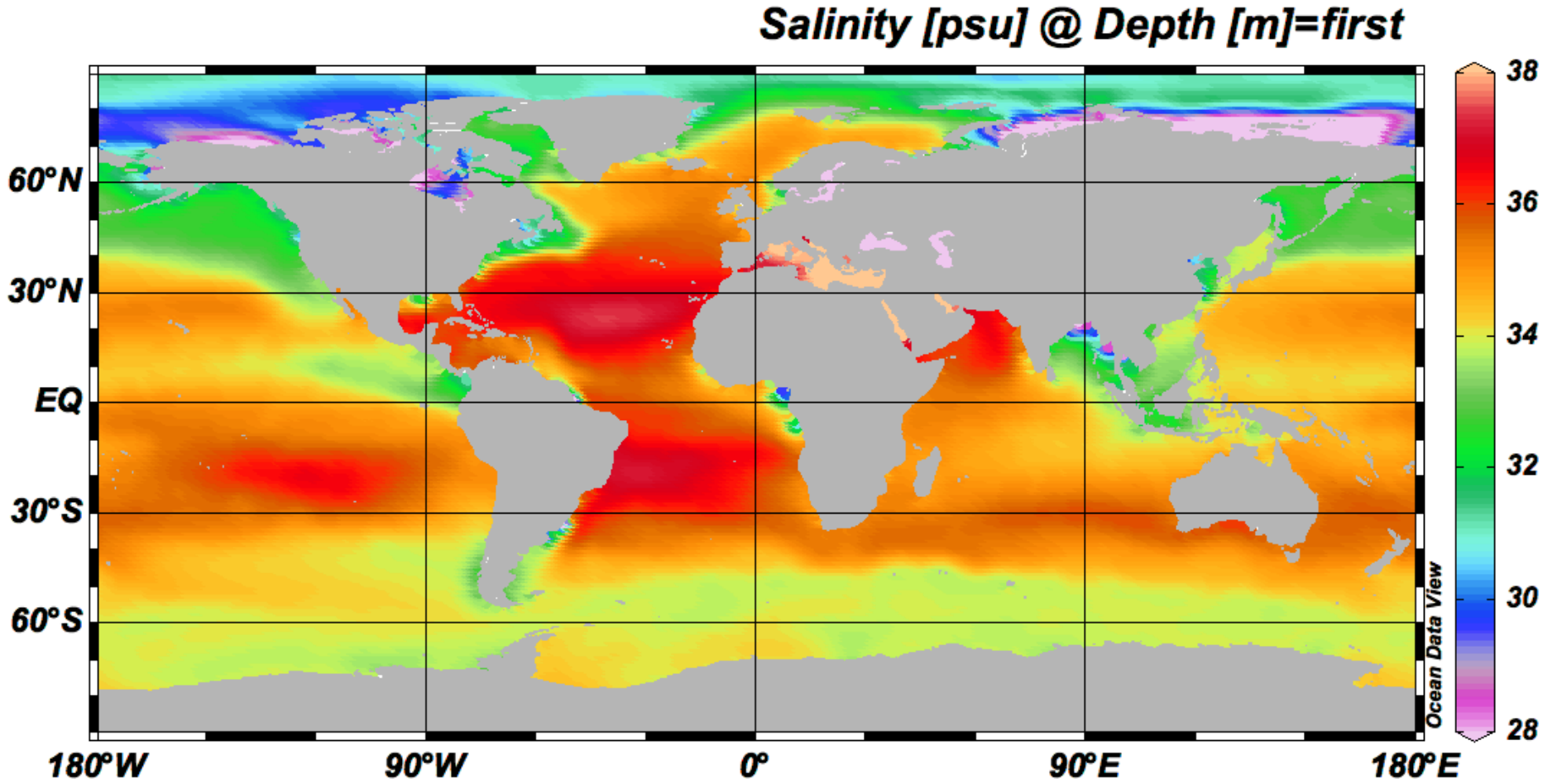
Oppo and Curry, 2012



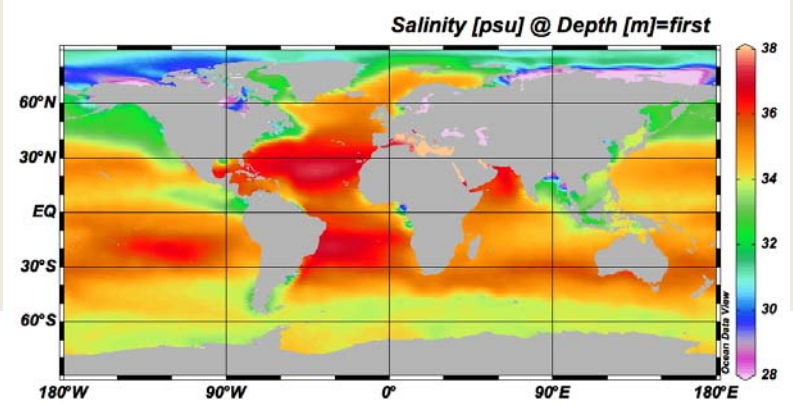
Hartman, 1994

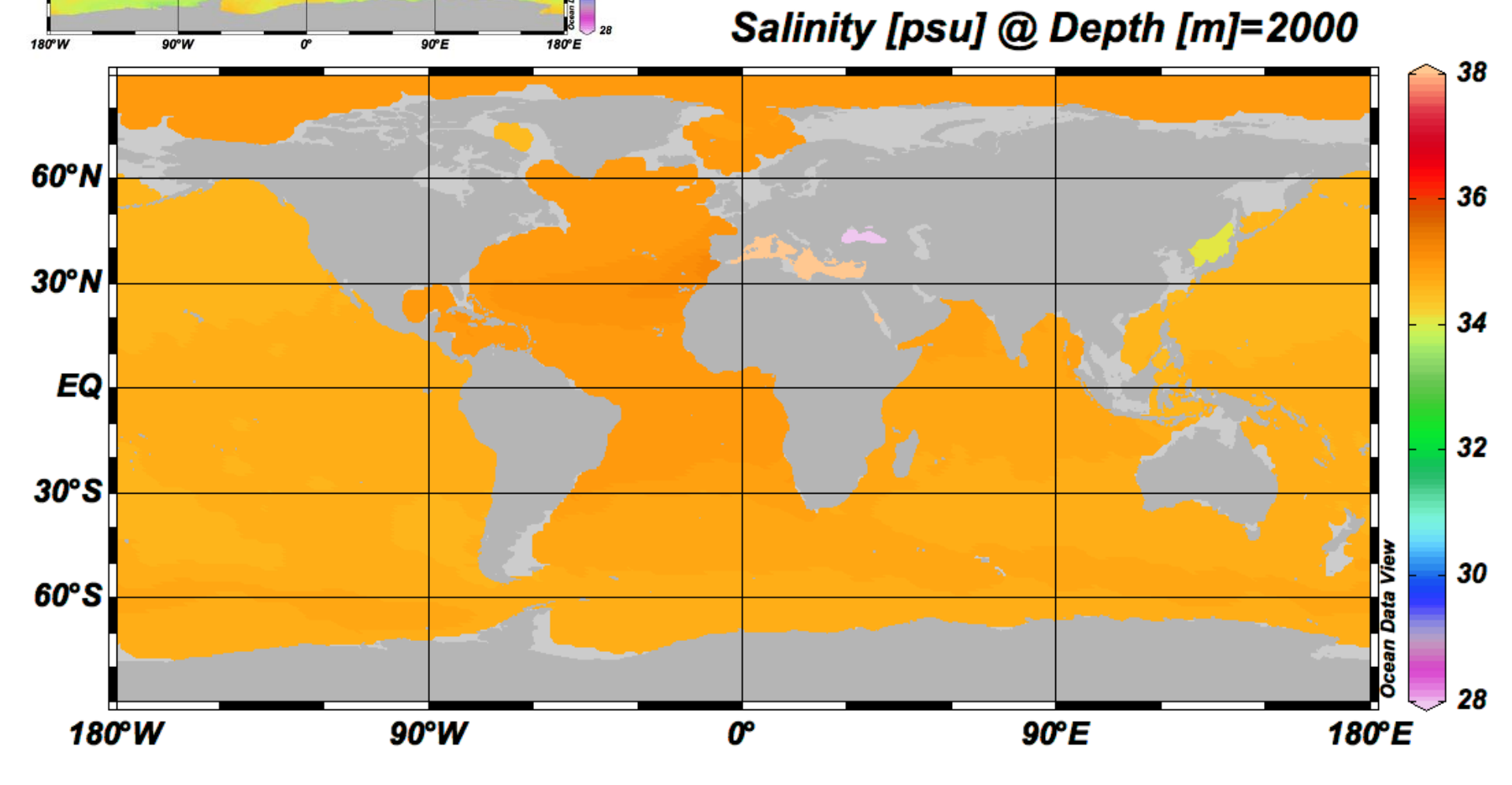
Oceanic circulation and heat transport

- Warm surface currents transport heat from equator towards poles
- Temperature and salinity for deepwater are set at the surface
- Deepwater is only formed in select regions

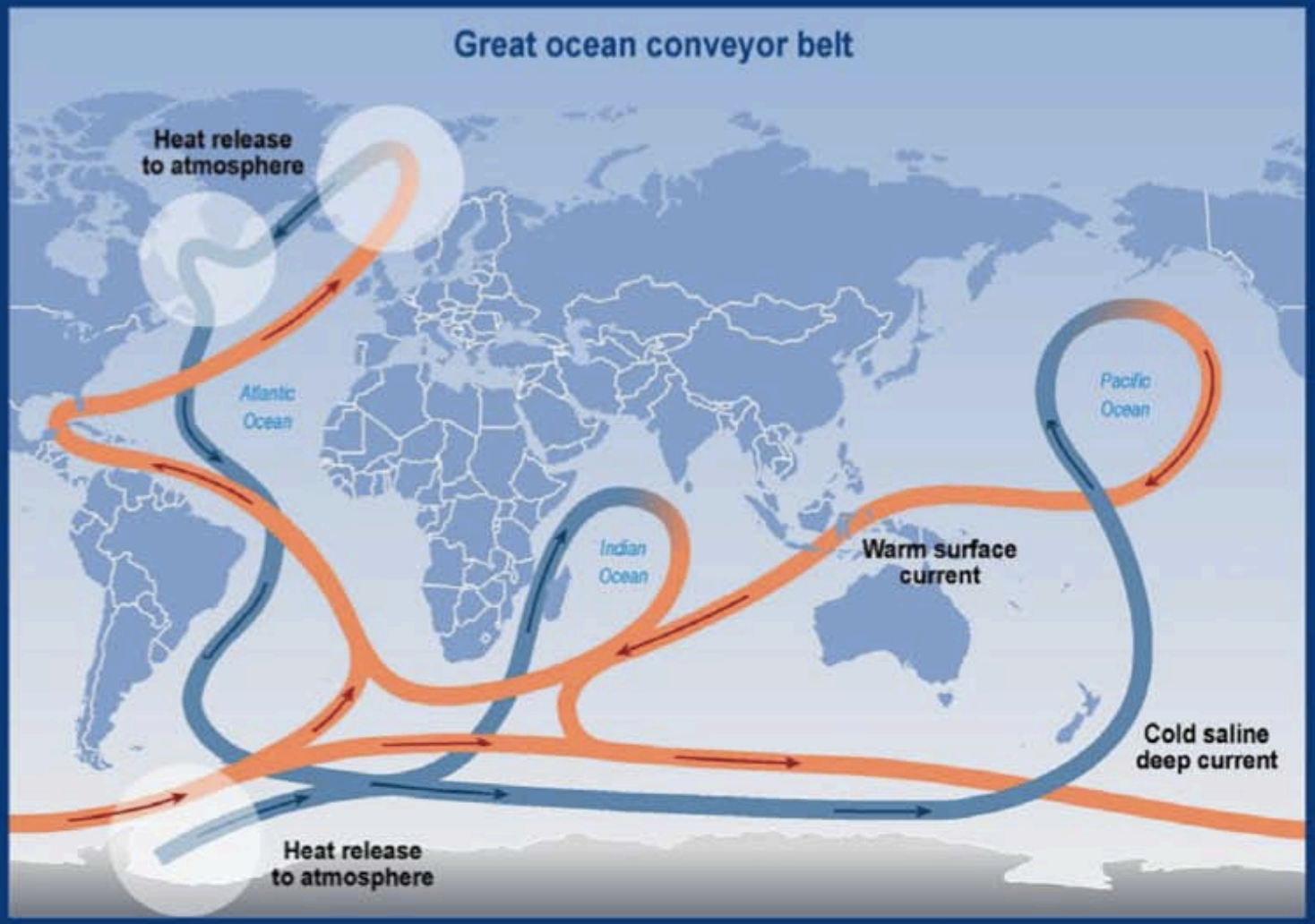


World Ocean Atlas 2005 data

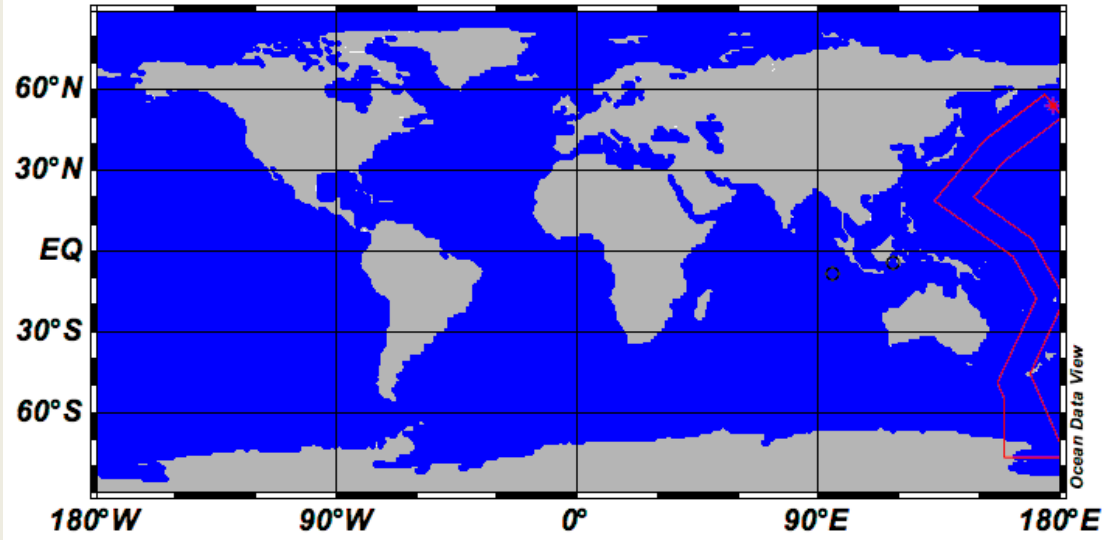




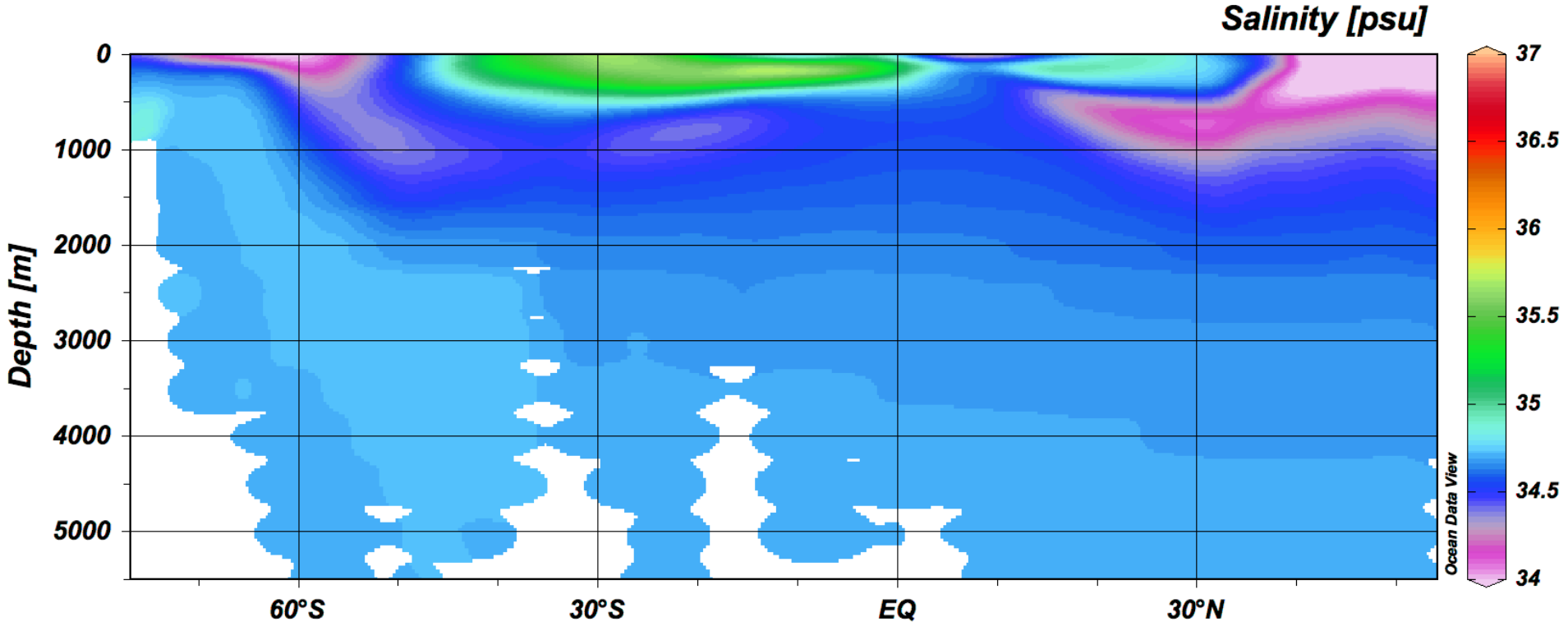
World Ocean Atlas 2005 data



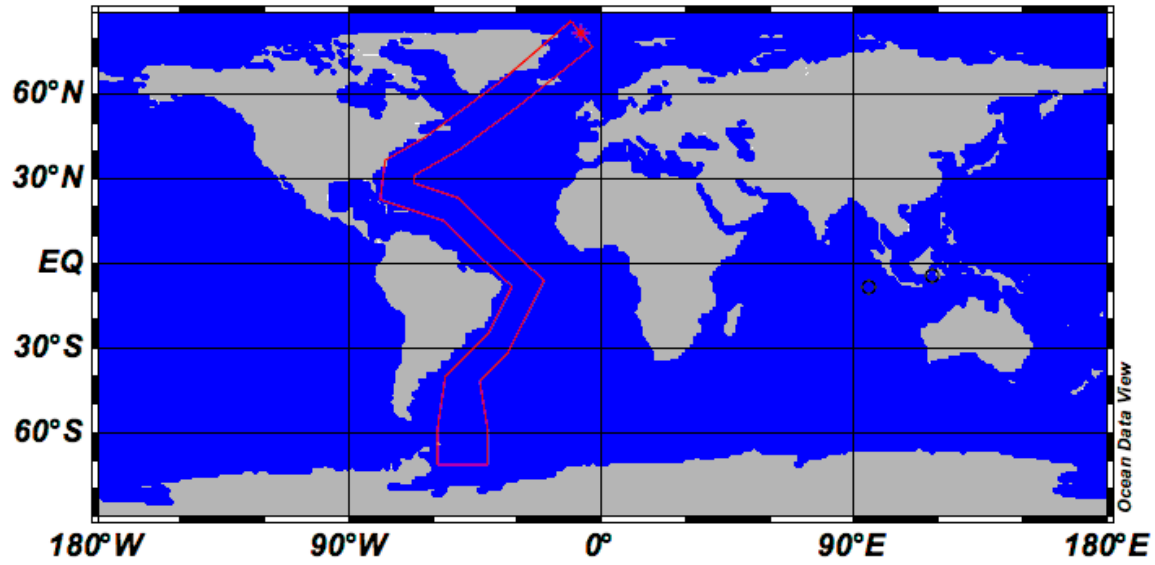
Circles are key areas for deepwater formation



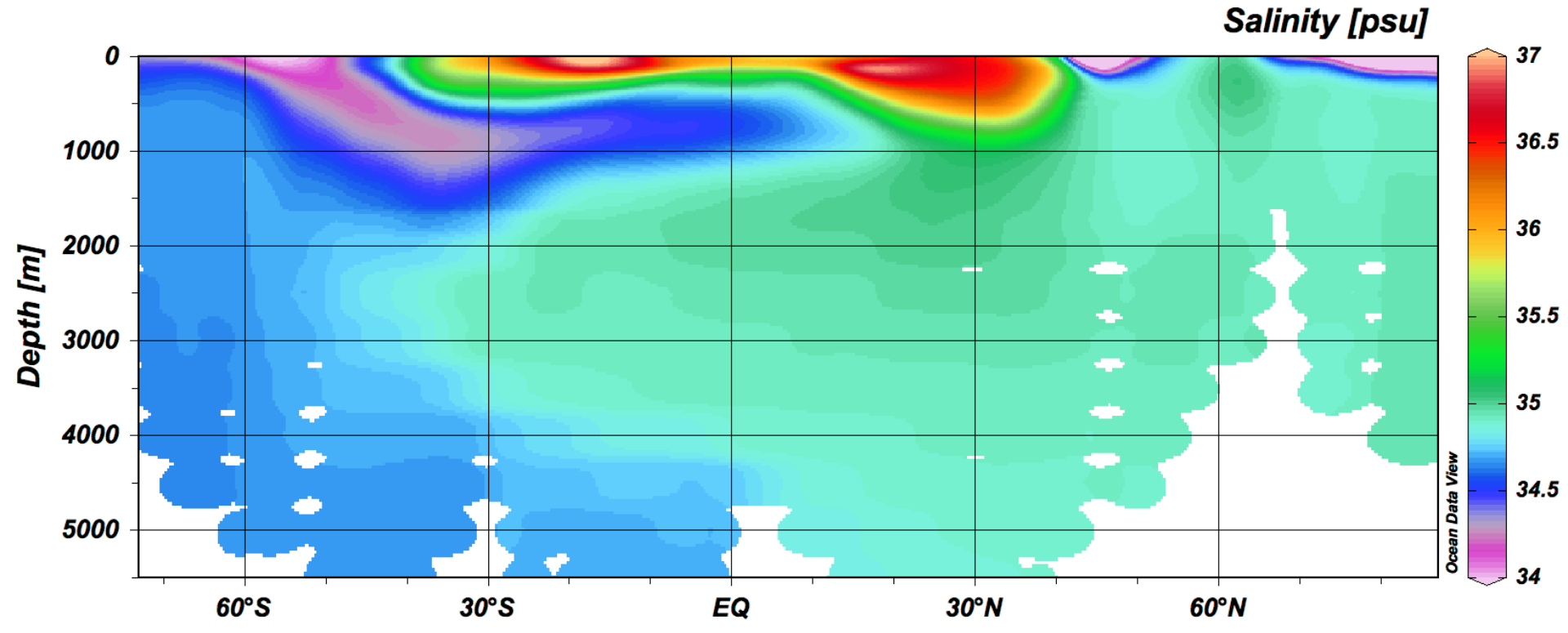
Abyssal Pacific Ocean has only one source of deep water



From WOA05 data



Abyssal Atlantic Ocean has two sources of deep water



From WOA05 data

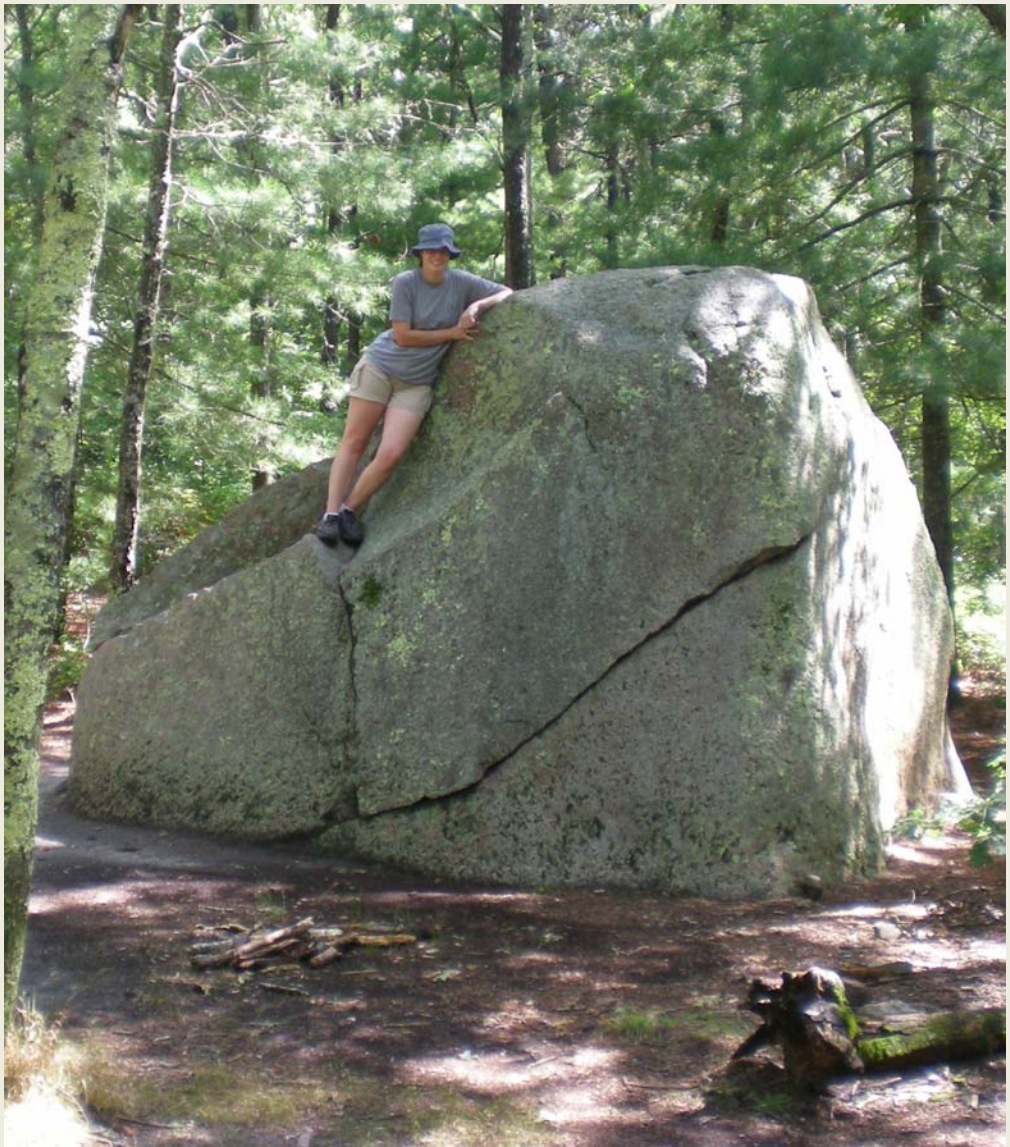
But past climate (and ocean circulations) were different

- The Last Glacial Maximum
  - Approximately 20,000 years ago
- Warming from Last Glacial Maximum to today was not continuous
  - Heinrich Event 1
  - Younger Dryas

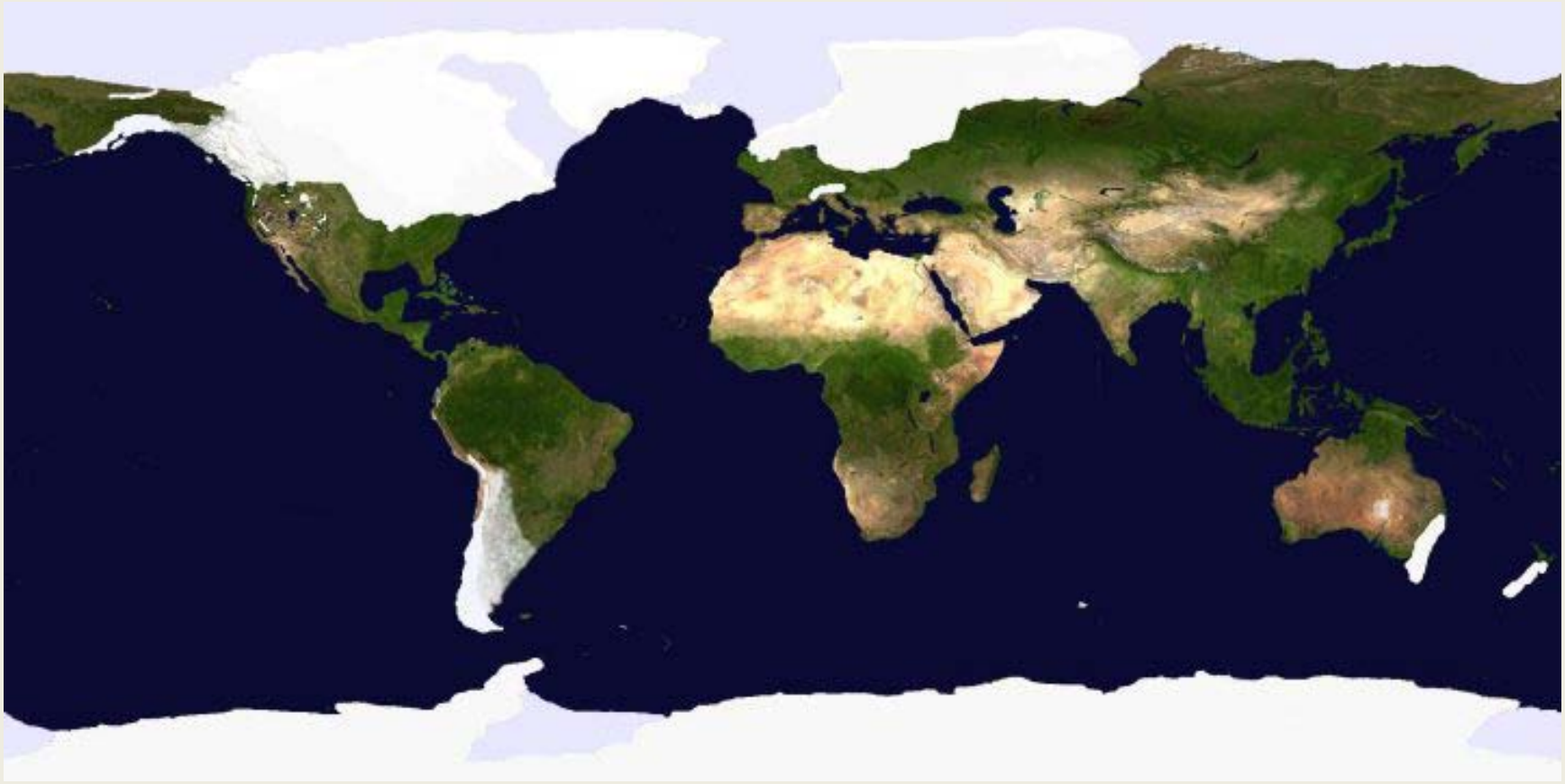
How do we explore past climates and ocean circulation?

- Physical evidence of past glaciers
- Ice cores
  - Oxygen and hydrogen isotopes
  - Trapped gas bubbles (CO_2, for example)
- Sediment cores
  - Fossils assemblages
  - Molecular biomarkers
  - Oxygen and carbon carbon isotopes

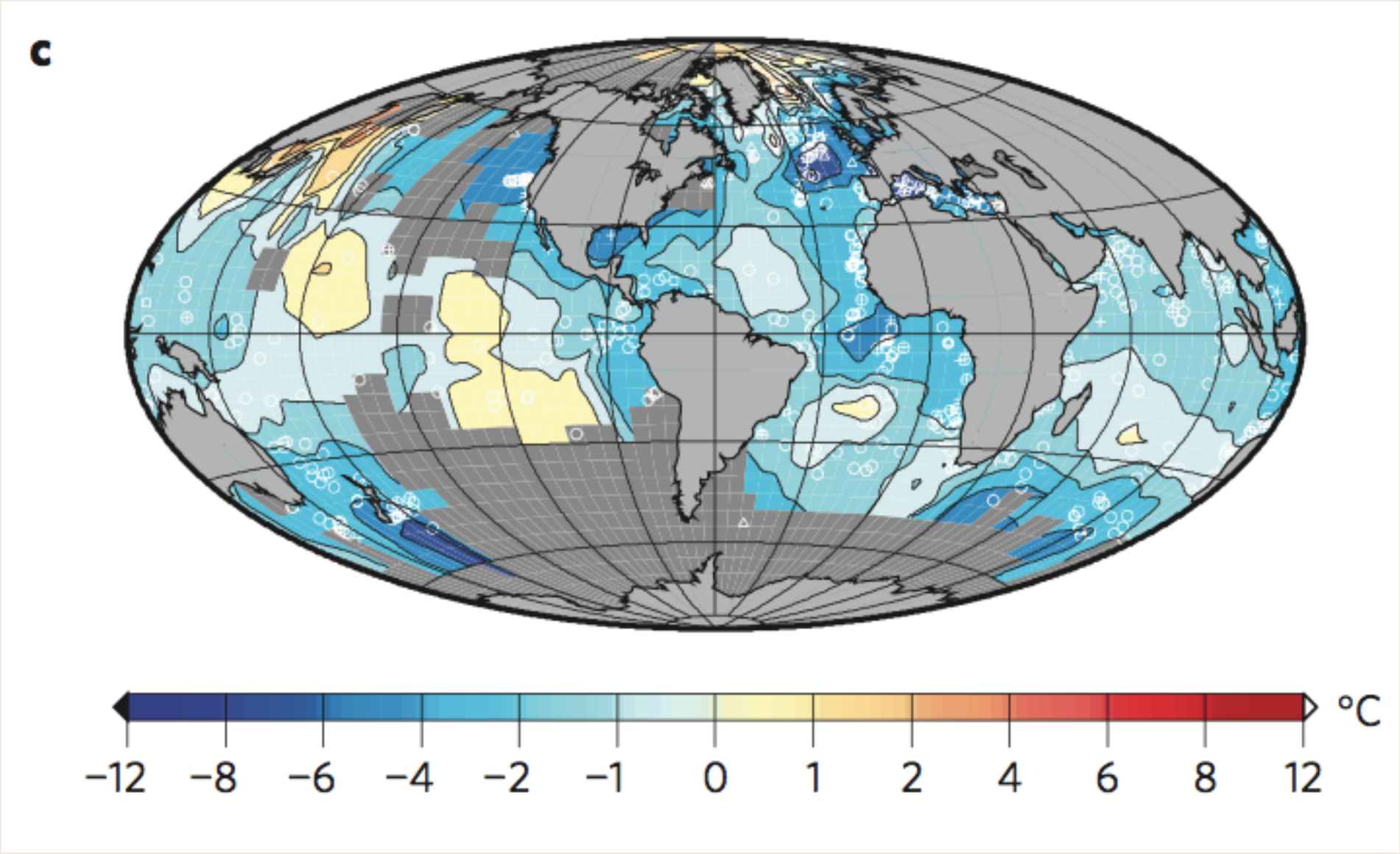
Rock solid evidence of past glaciers



Last Glacial Maximum



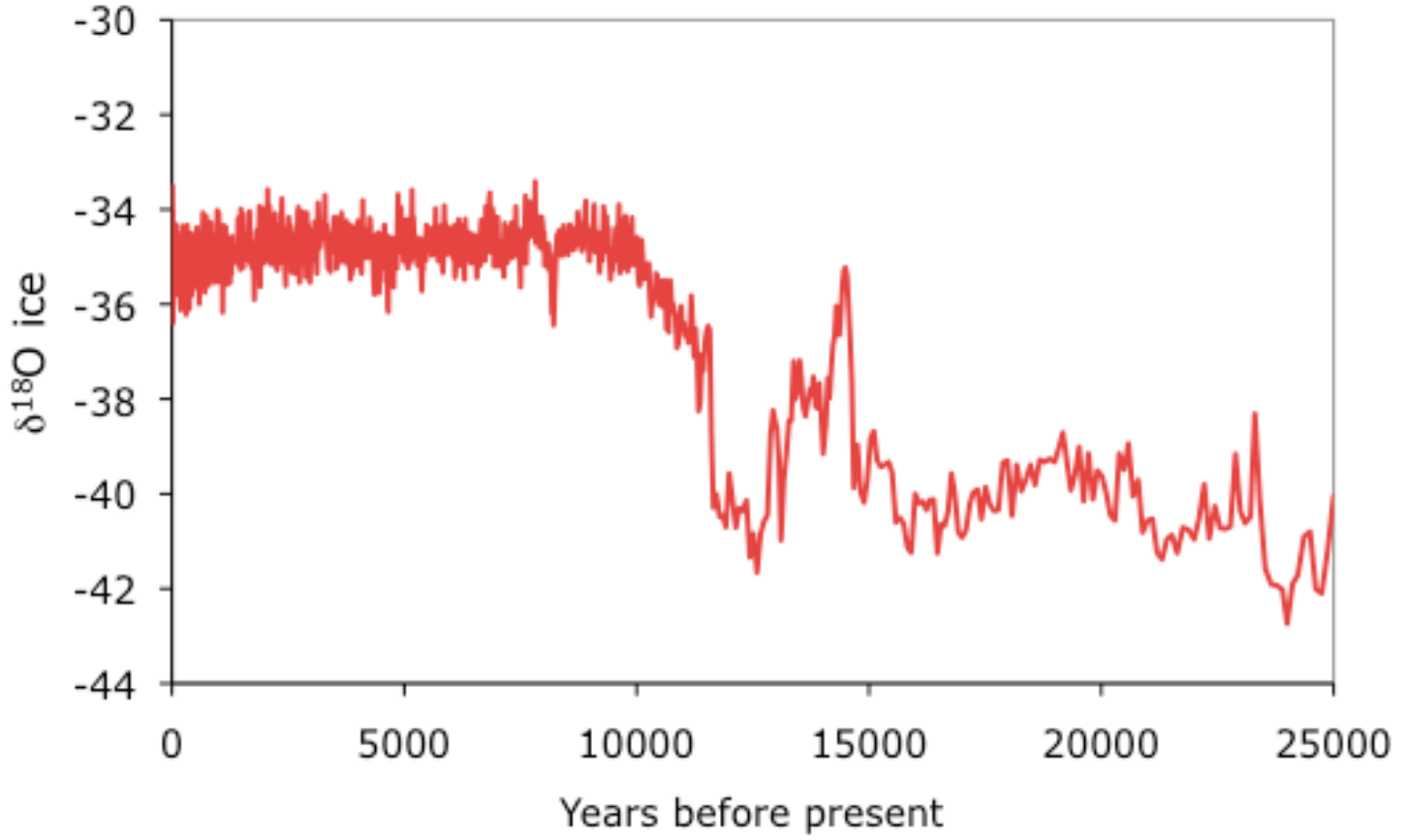
From http://www.johnstonsarchive.net/spaceart/cylmaps.html



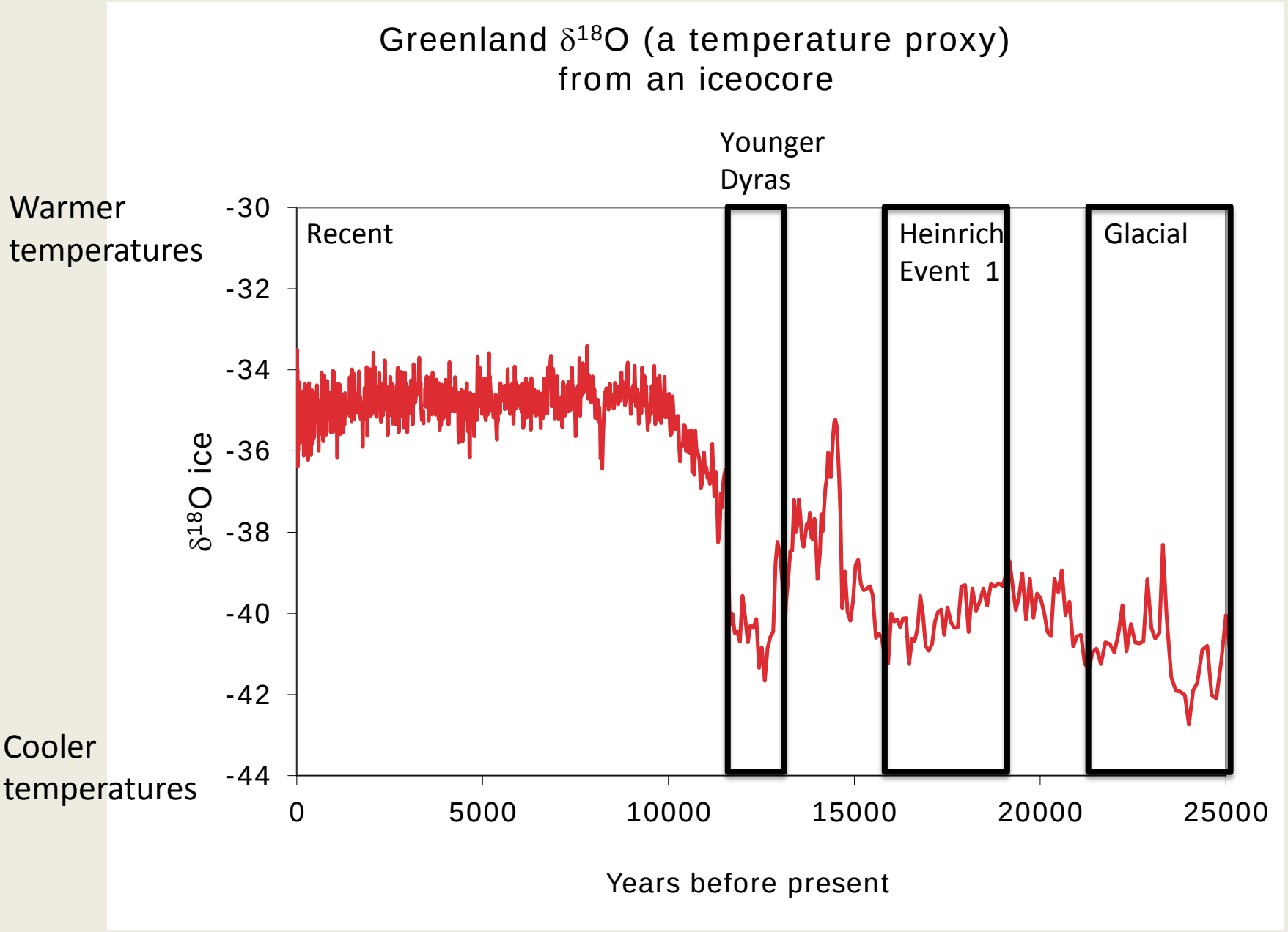
Using all available proxy data, the mean global ocean was 1.9˚C (+/- 1.8) cooler

MARGO Project Members, 2009

Greenland temperature from the last glacial maximum to modern

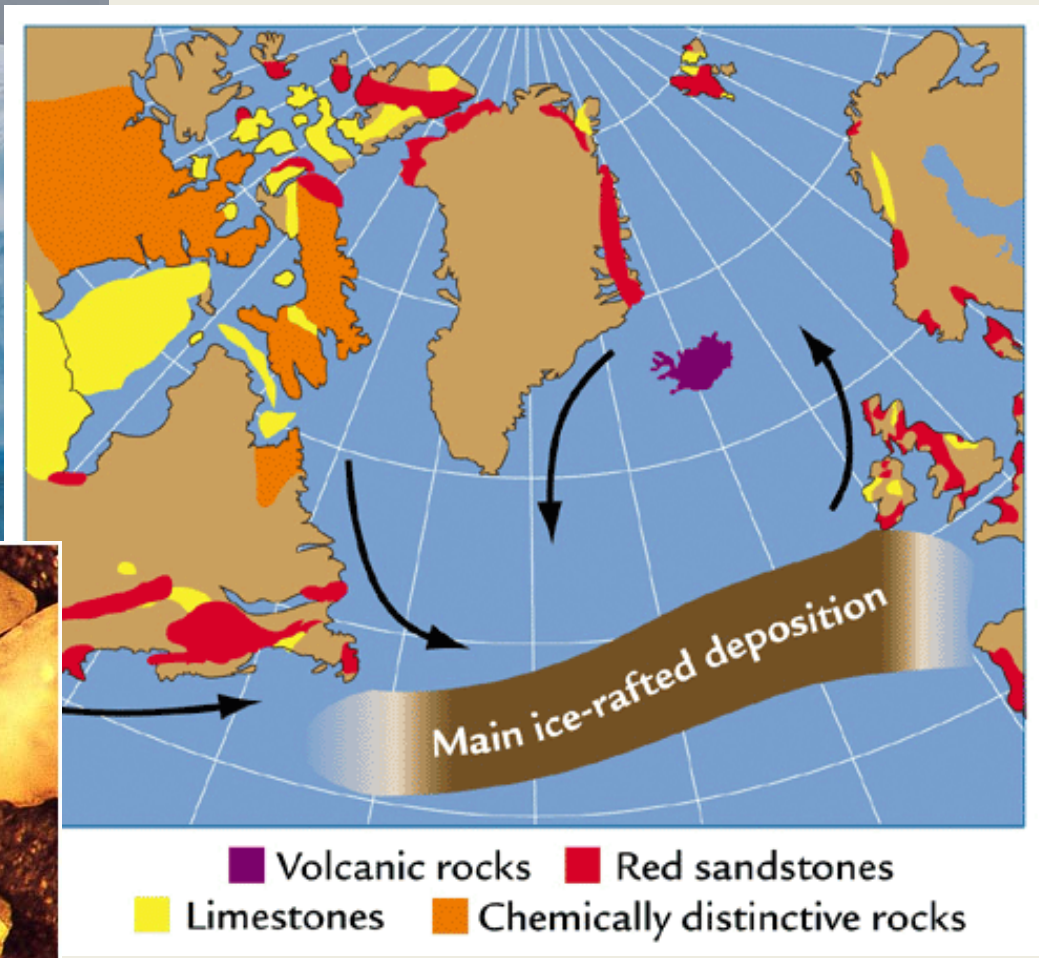


Grootes *et al., 1*997



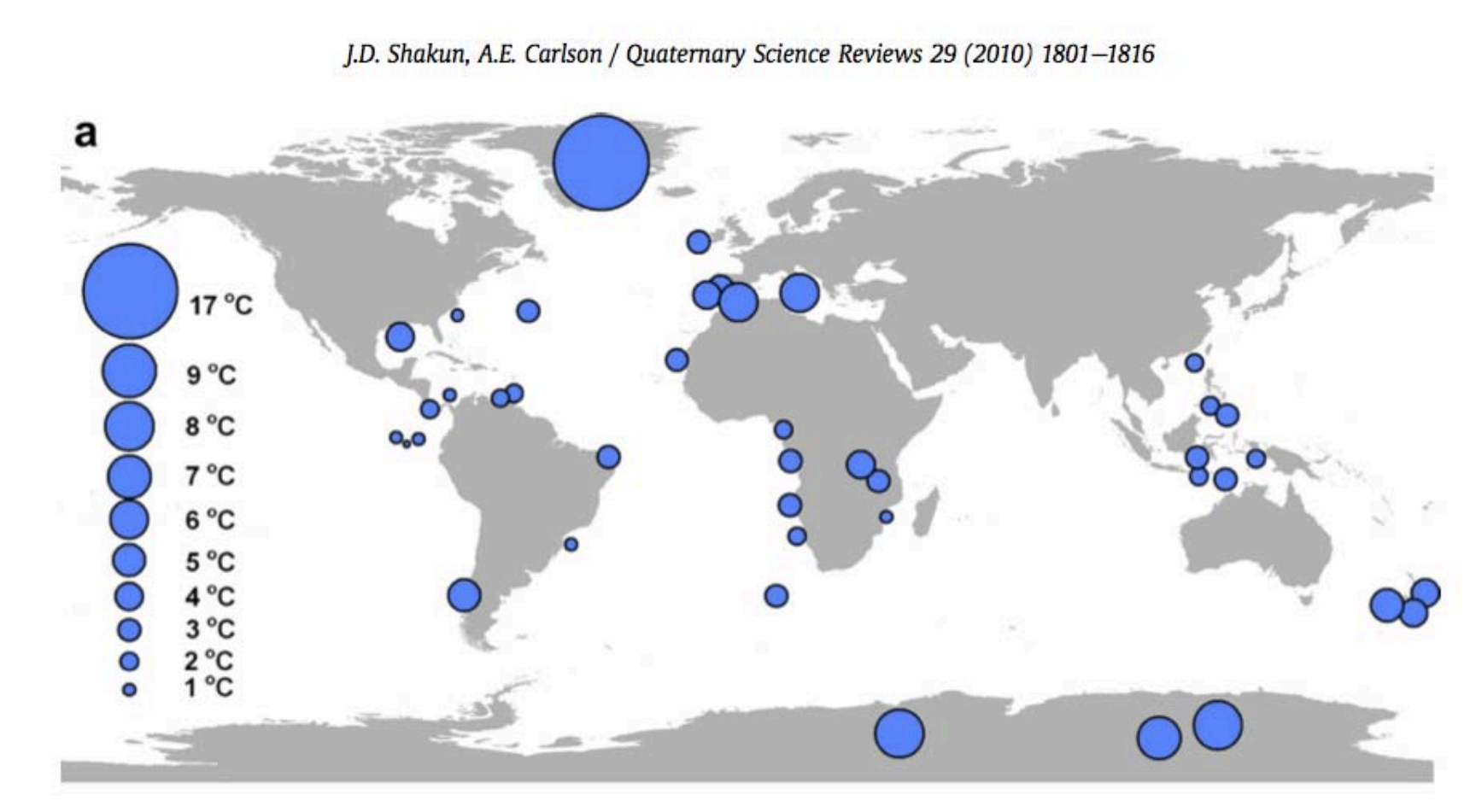
Grootes *et al., 1*997

Heinrich Events

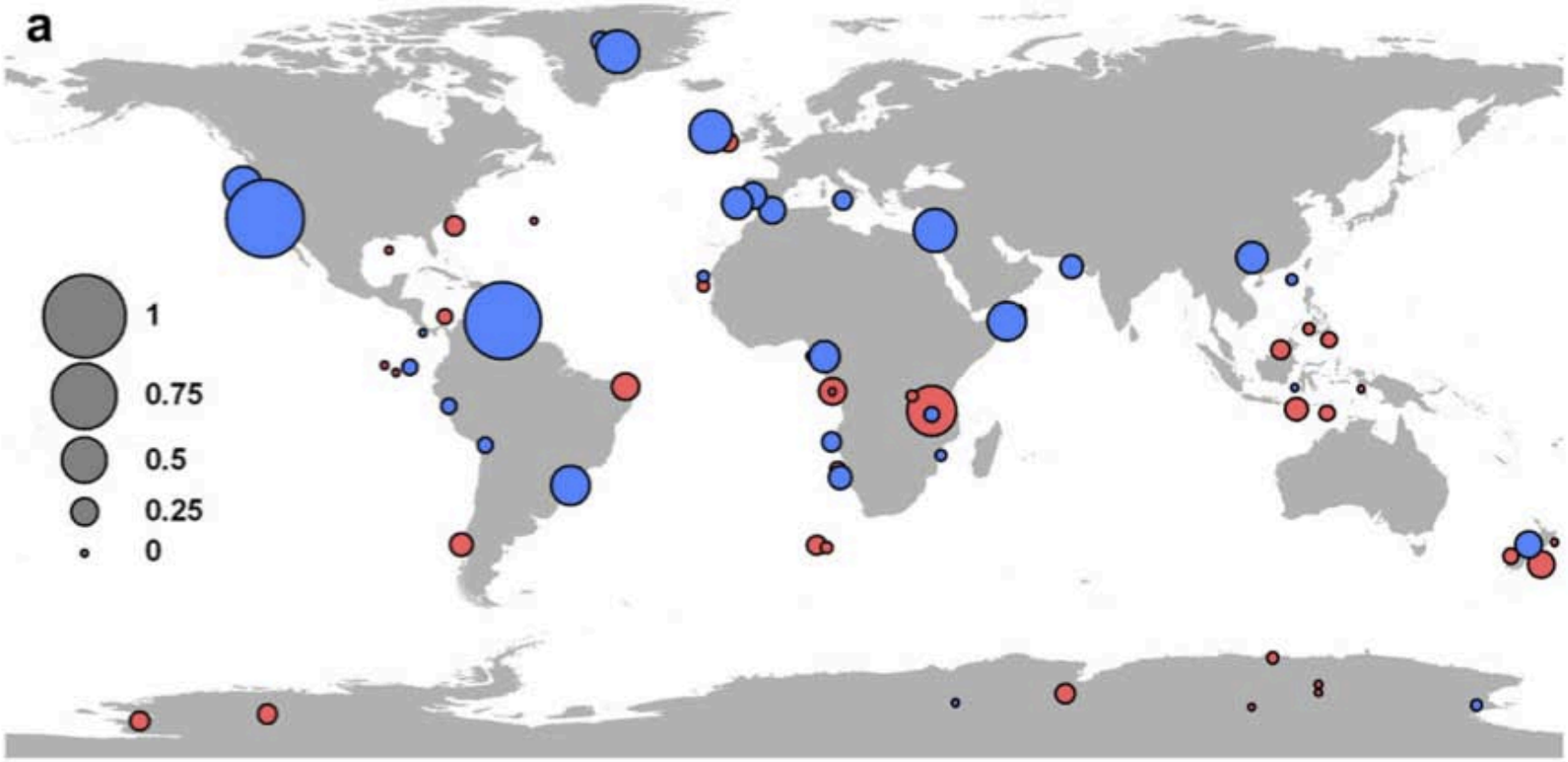


Ruddiman, 2001

Cooling at the Last Glacial Maximum – both north and south high latitudes have more cooling than tropics

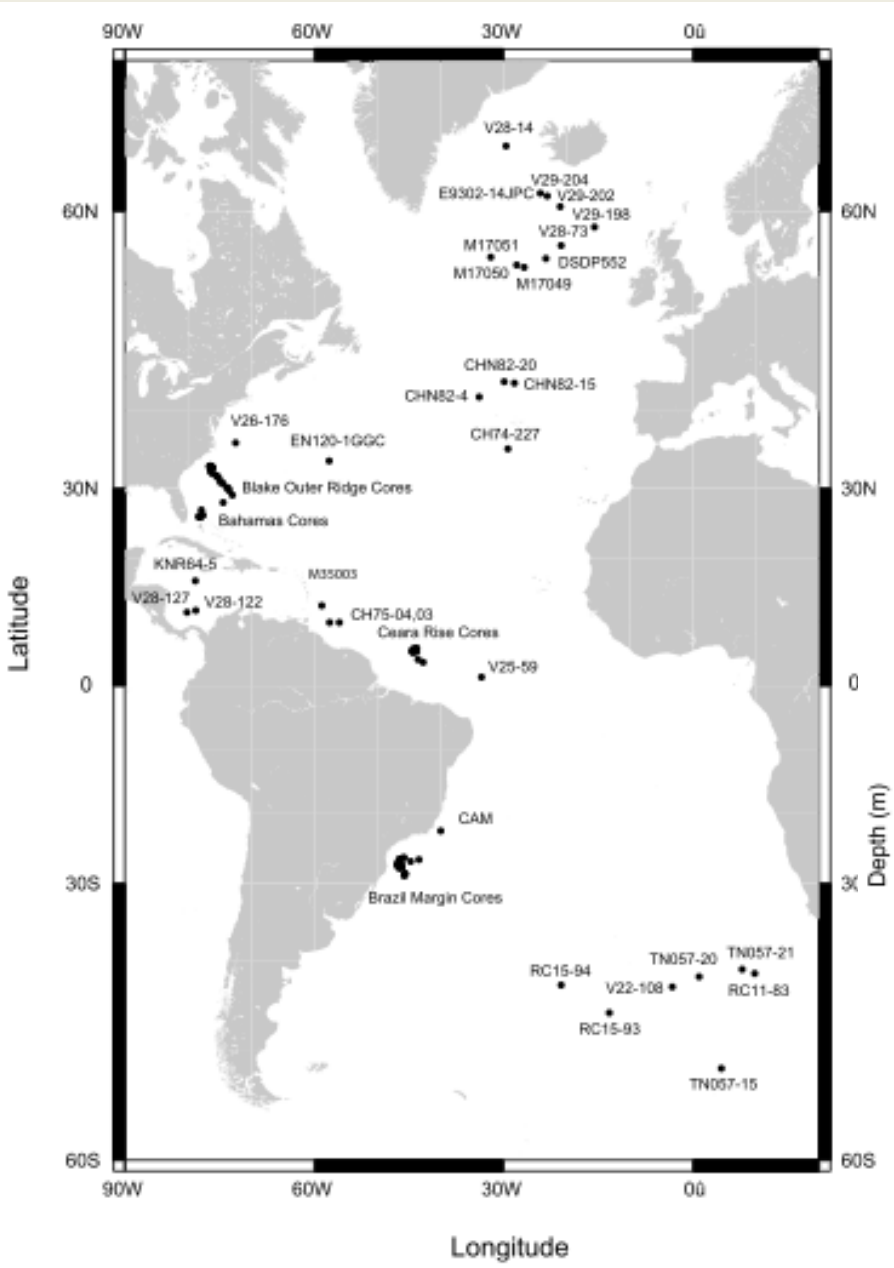


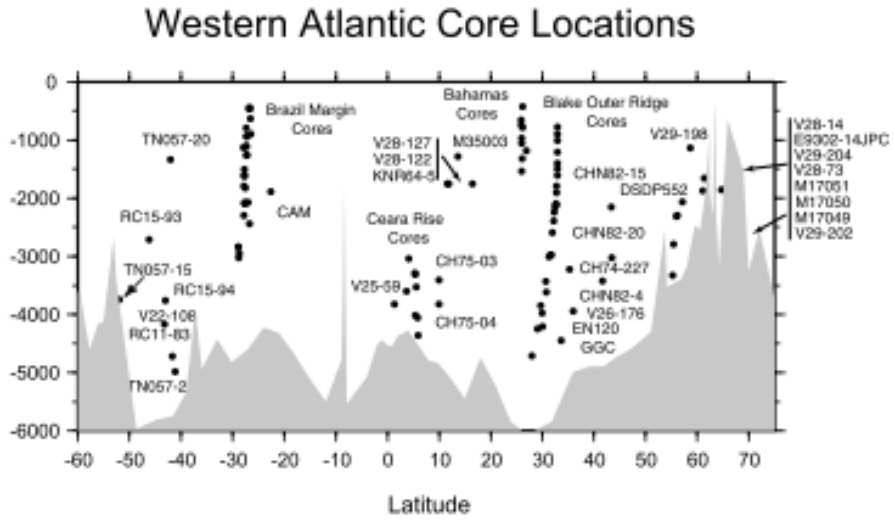
Heinrich Event 1 temperature anomalies – cold pattern is not the same as the glacial



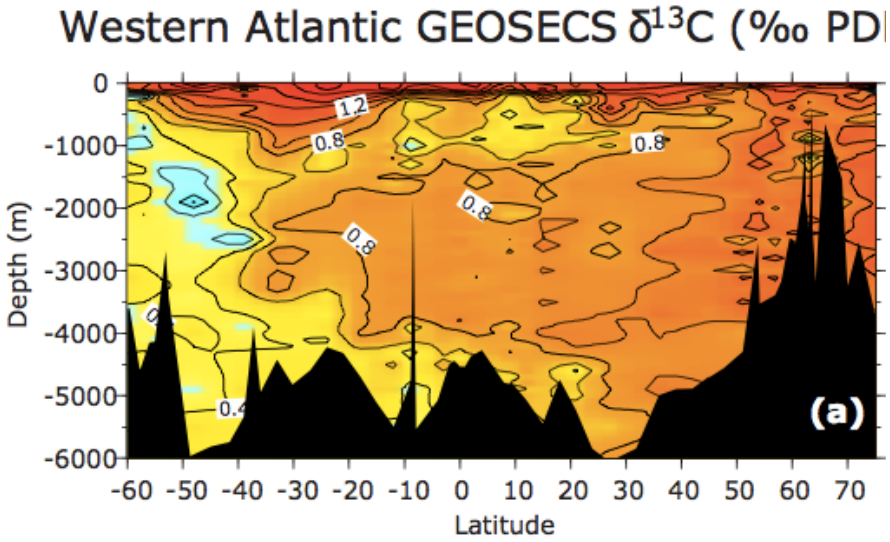
Shakun and Carlson, 2010

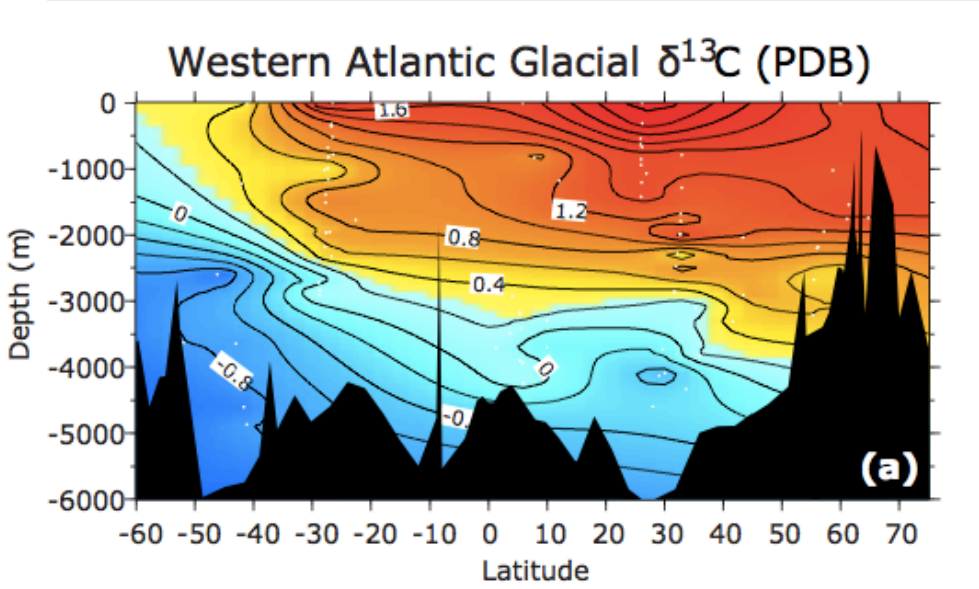
Benthic foraminifera from a variety of core depths can help us understand the deep ocean

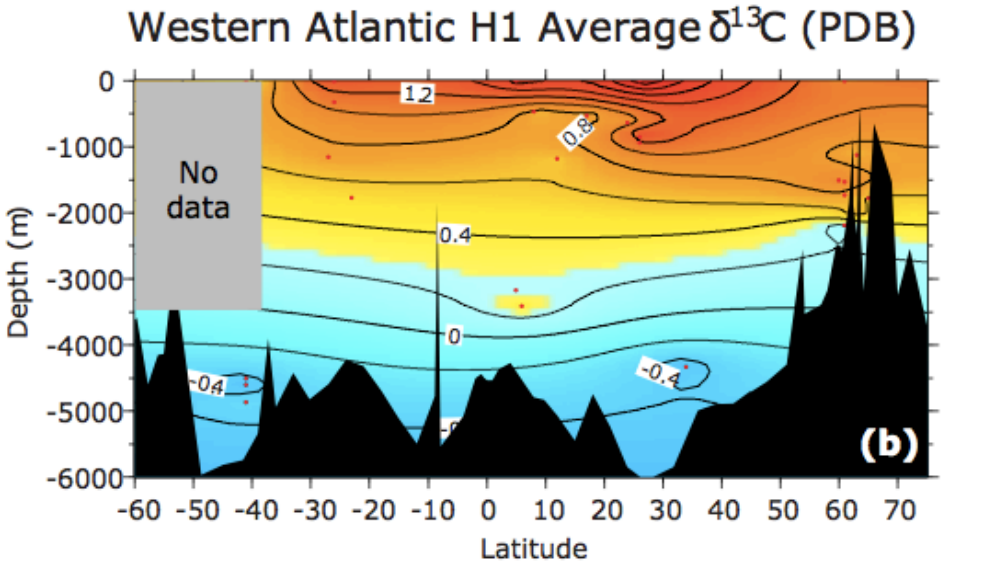




Curry and Oppo 2005







Data suggest different water mass geometries at during the glacial, Heinrich Event 1, and today

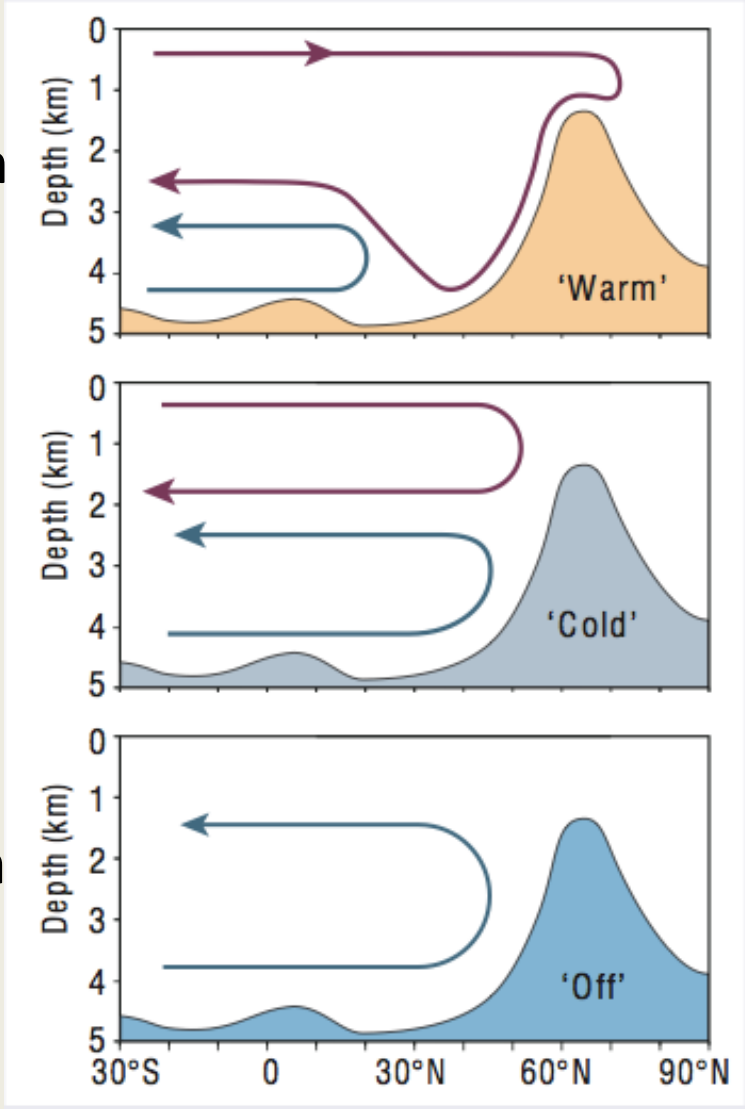
Oppo and Curry 2012

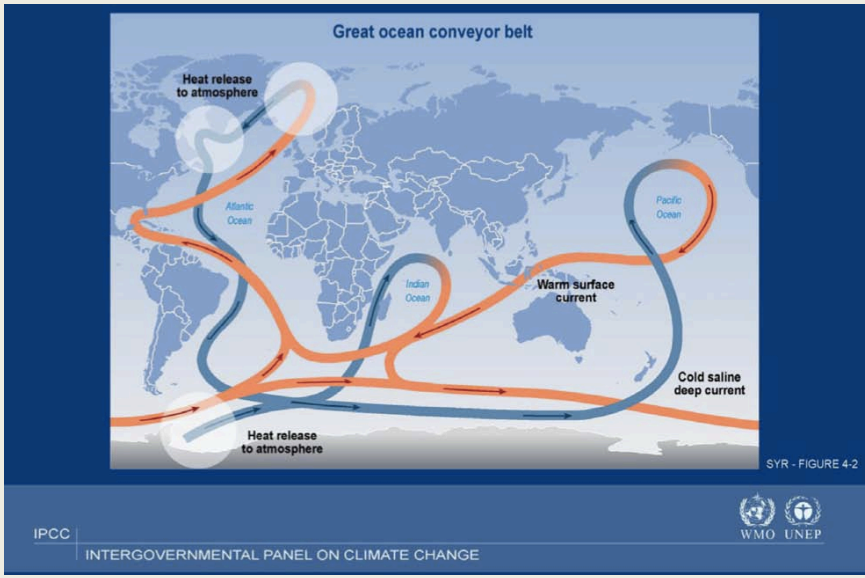
Hypothetical schematic of North Atlantic Ocean circulation modes

Modern

Glacial

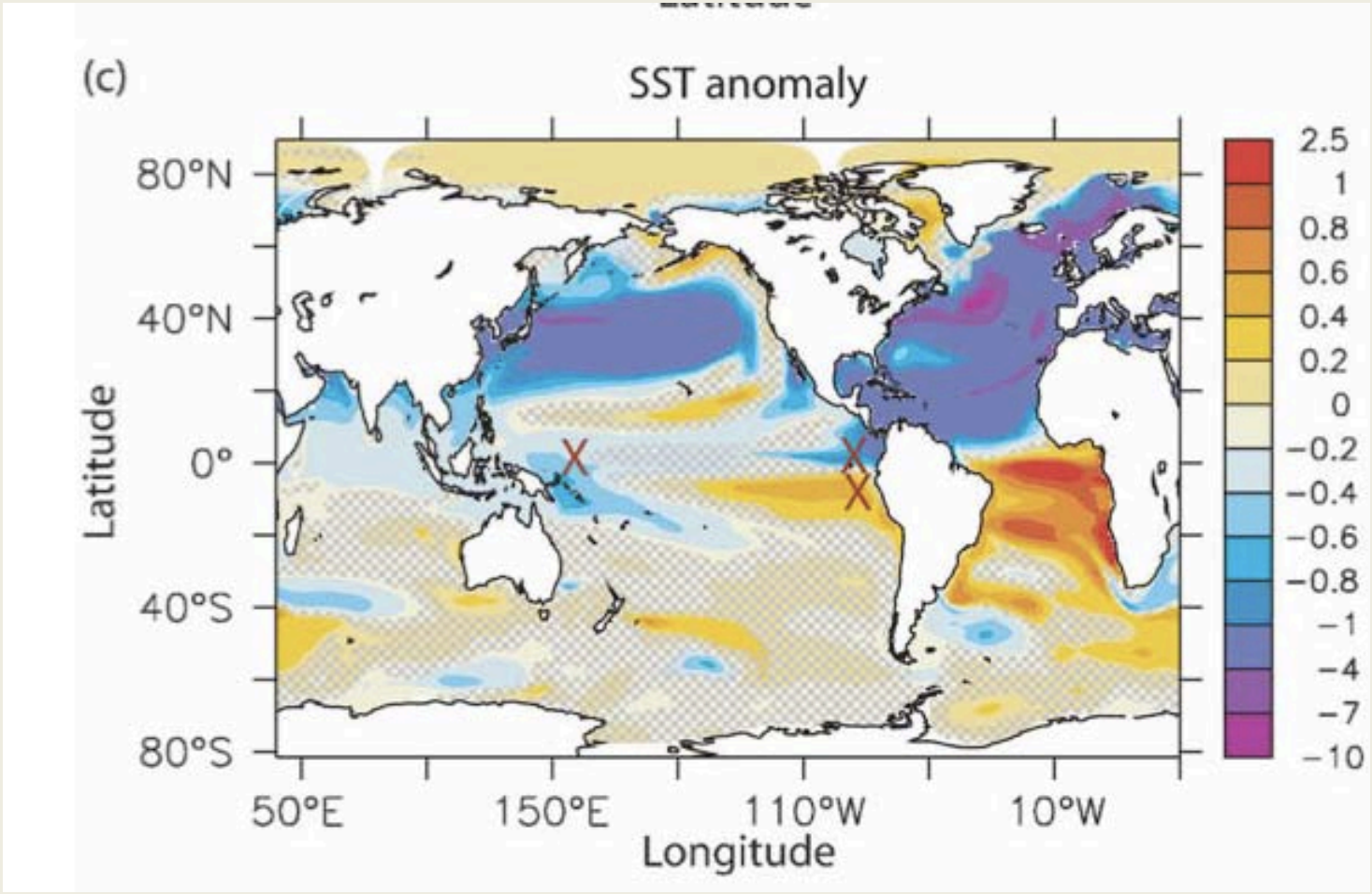
Heinrich





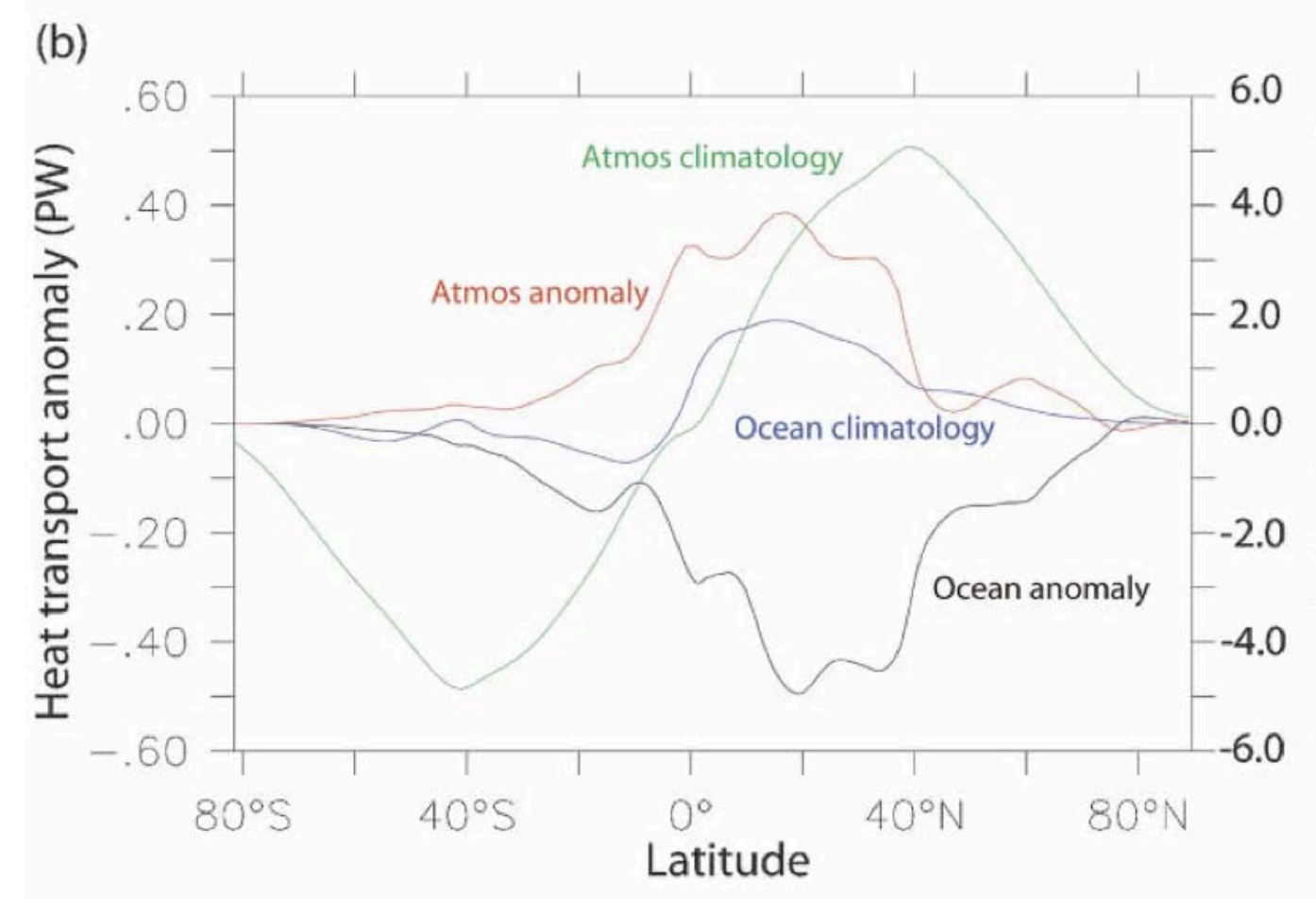
Rahmstorf 2002

Modeled Heinrich Events produce asymmetric cooling pattern



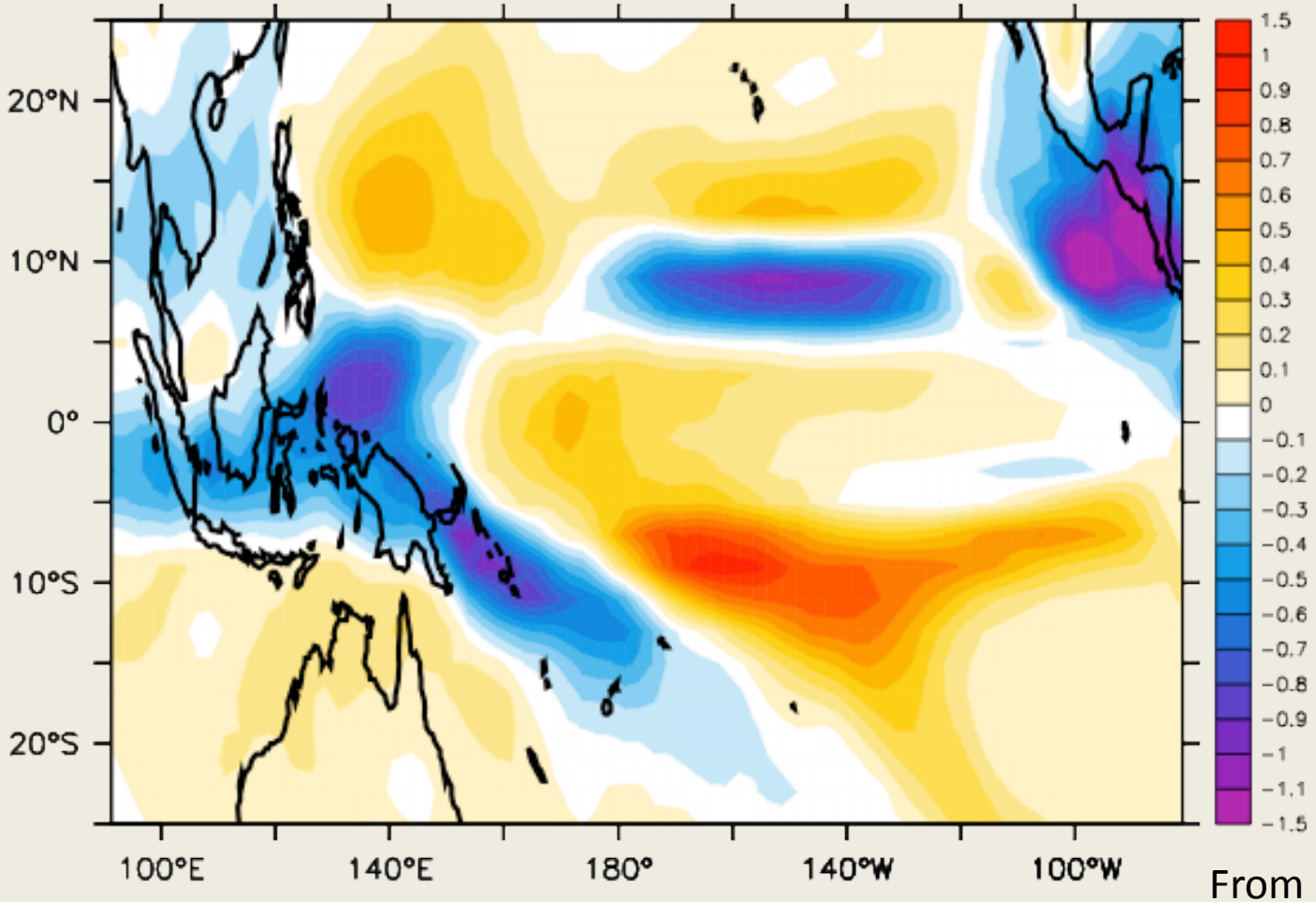
Zhang and Delworth, 2005

In model, northward oceanic heat transport is reduced and atmospheric heat transport is increased



Zhang and Delworth 2005

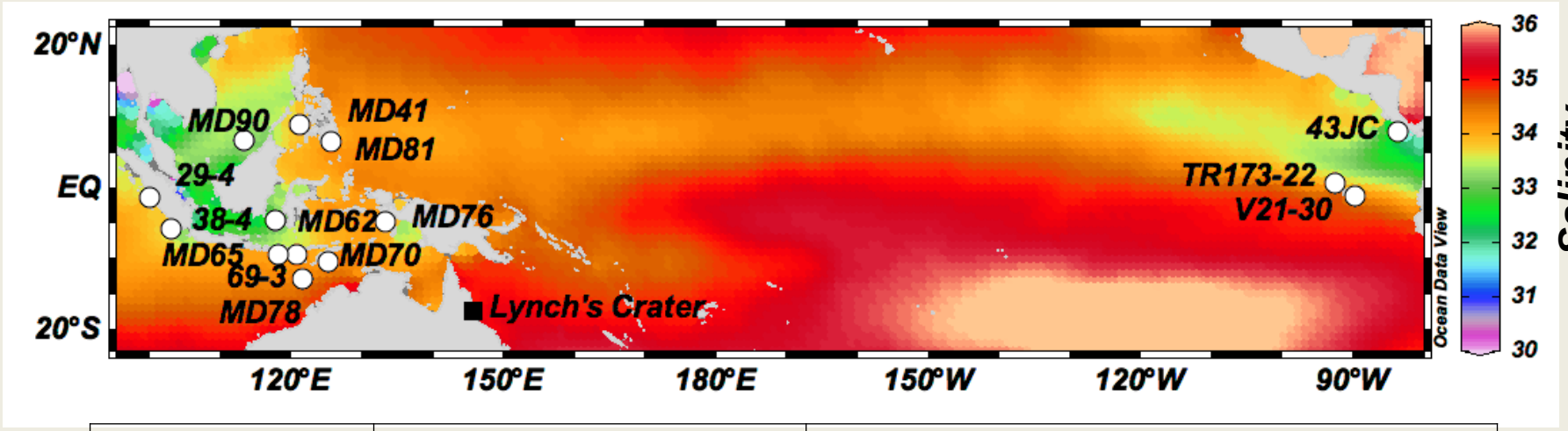
There are also large changes in tropical hydrology (cool colors indicate drier conditions)



wetter

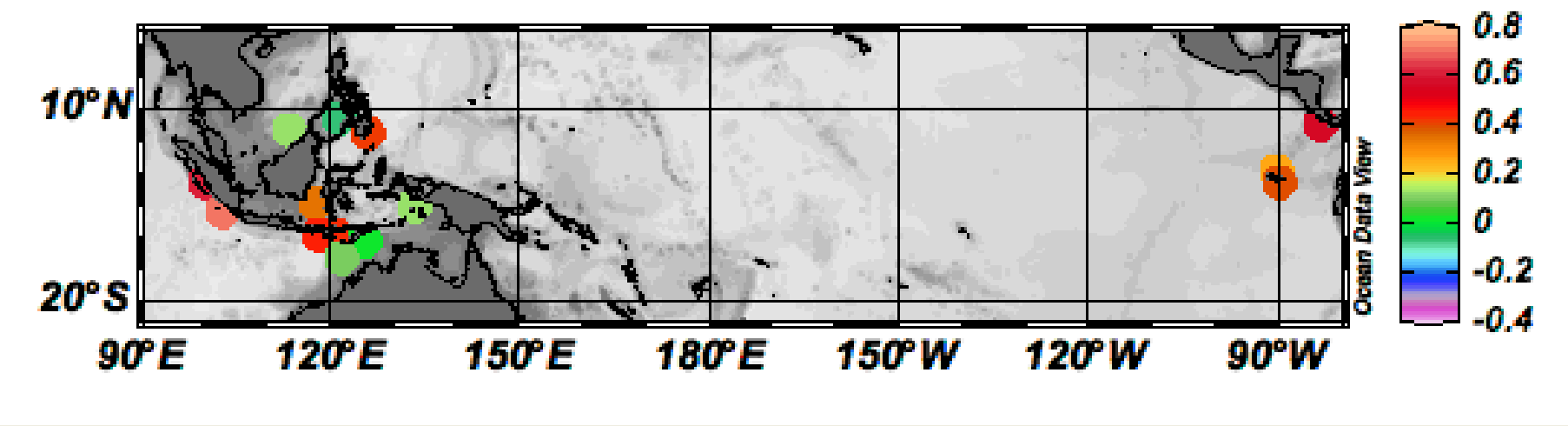
drier

From Rong Zhang



Core ID	Ave. Sample interval (yr)	Reference
GeoB10029-4	600	Mohtadi *et al.*, 2010
GeoB10038-4	560	Mohtadi *et al.*, 2010
GeoB10069-3	190	this study
MD97-2141	90	Rosenthal *et al.*, 2003
MD98-2162	415	Visser *et al.*, 2003
MD98-2165	200	Levi et al., 2007
MD98-2170	300	Stott *et al.*, 2007
MD98-2176	75	Stott *et al.*, 2007
MD98-2181	50	Stott *et al.*, 2007
MD01-2378	125	Xu *et al.*, 2008; Sarnthein *et al.*, 2011
MD01-2390	200	Steinke et al., 2008
ME0005A-43JC	240	Benway *et al.*, 2006
TR163-22	270	Lea et al., 2006
V21-30	430	Koutavas *et al.*, 2002

Heinrich Event 1 reconstruction of tropical hydrology (warm colors are drier) is consistent with modeled changes



Gibbons *et al.* submitted

Conclusions

- Ocean circulation and sea surface temperature patterns were different in the past
- A modeled Heinrich Event suggests
  - A reduction in deepwater formation in the North Atlantic
    - reduced northward ocean heat transport
    - Increased northward atmospheric heat transport
- Hydrologic data from the tropics is consistent with modeled changes in atmospheric circulation
- Tropical hydrology may respond very strongly to temperature changes