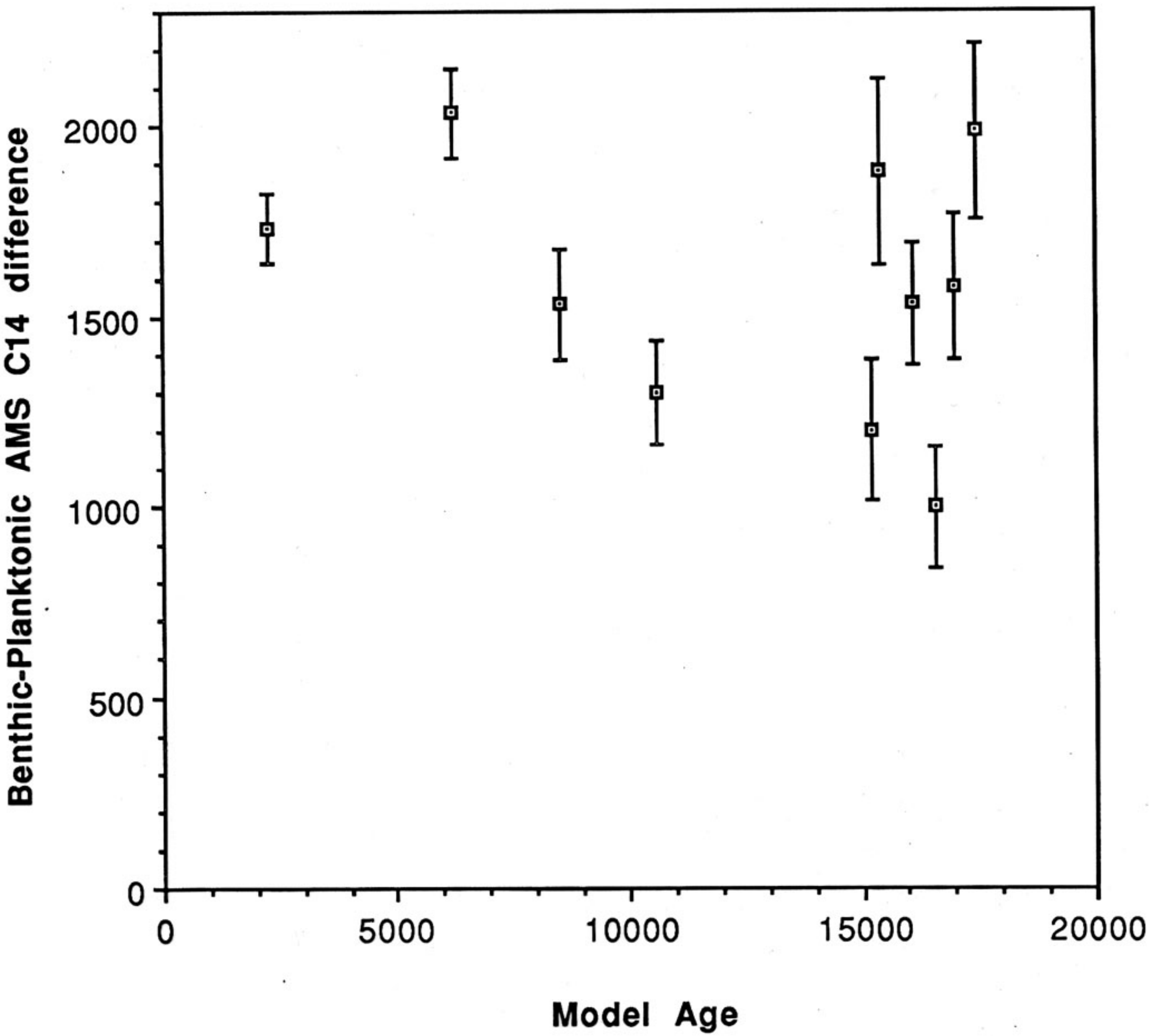
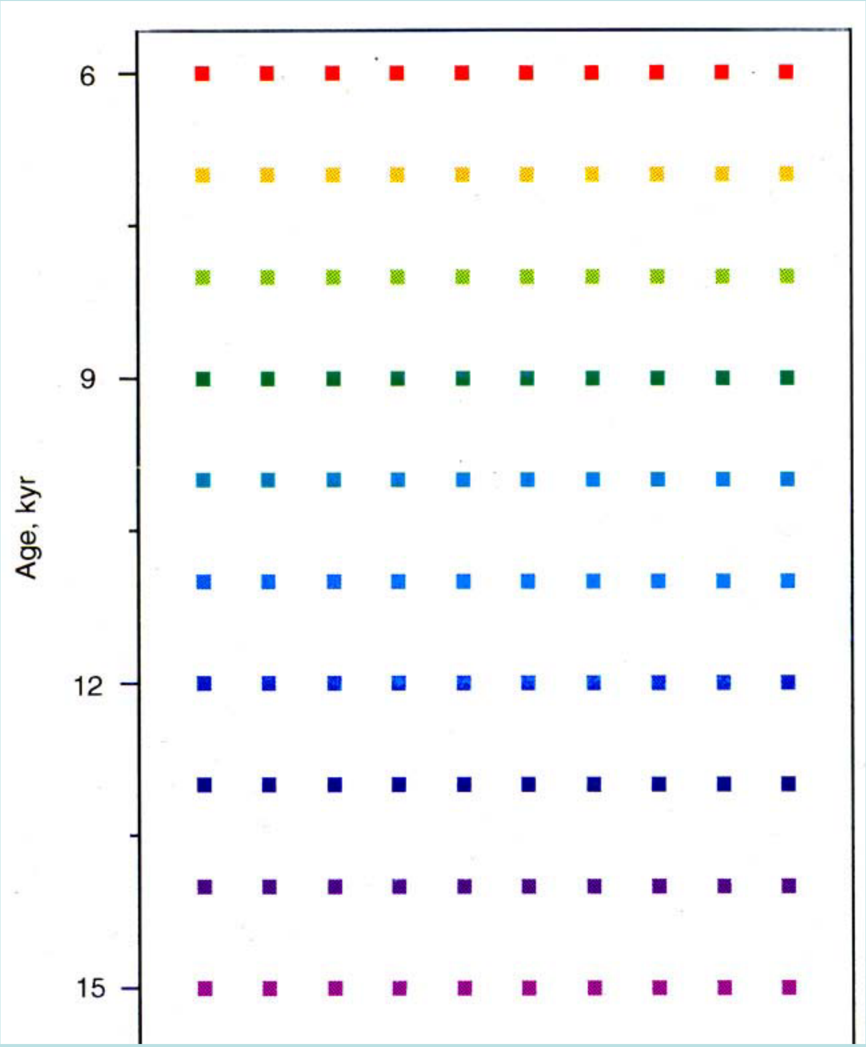
12.740 Paleoceanography
Spring 2008

Sonne 50 37 KL

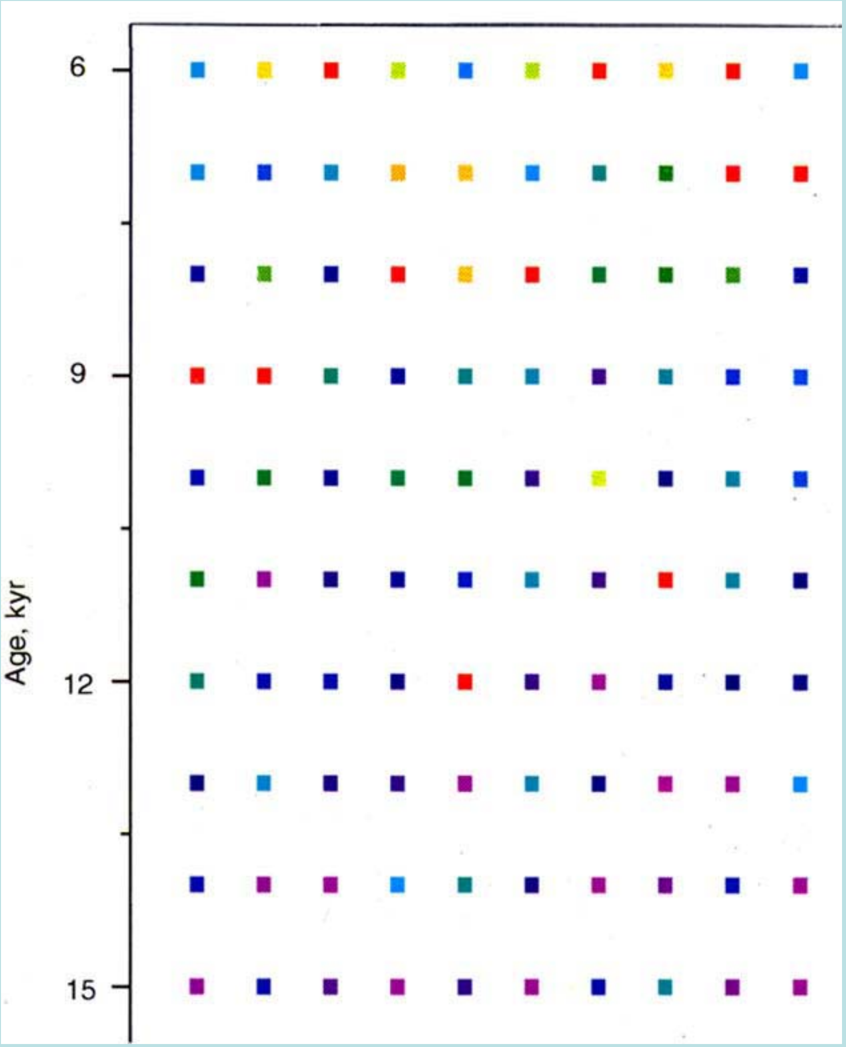


Effect of bioturbation on sedimentary ^{14}C

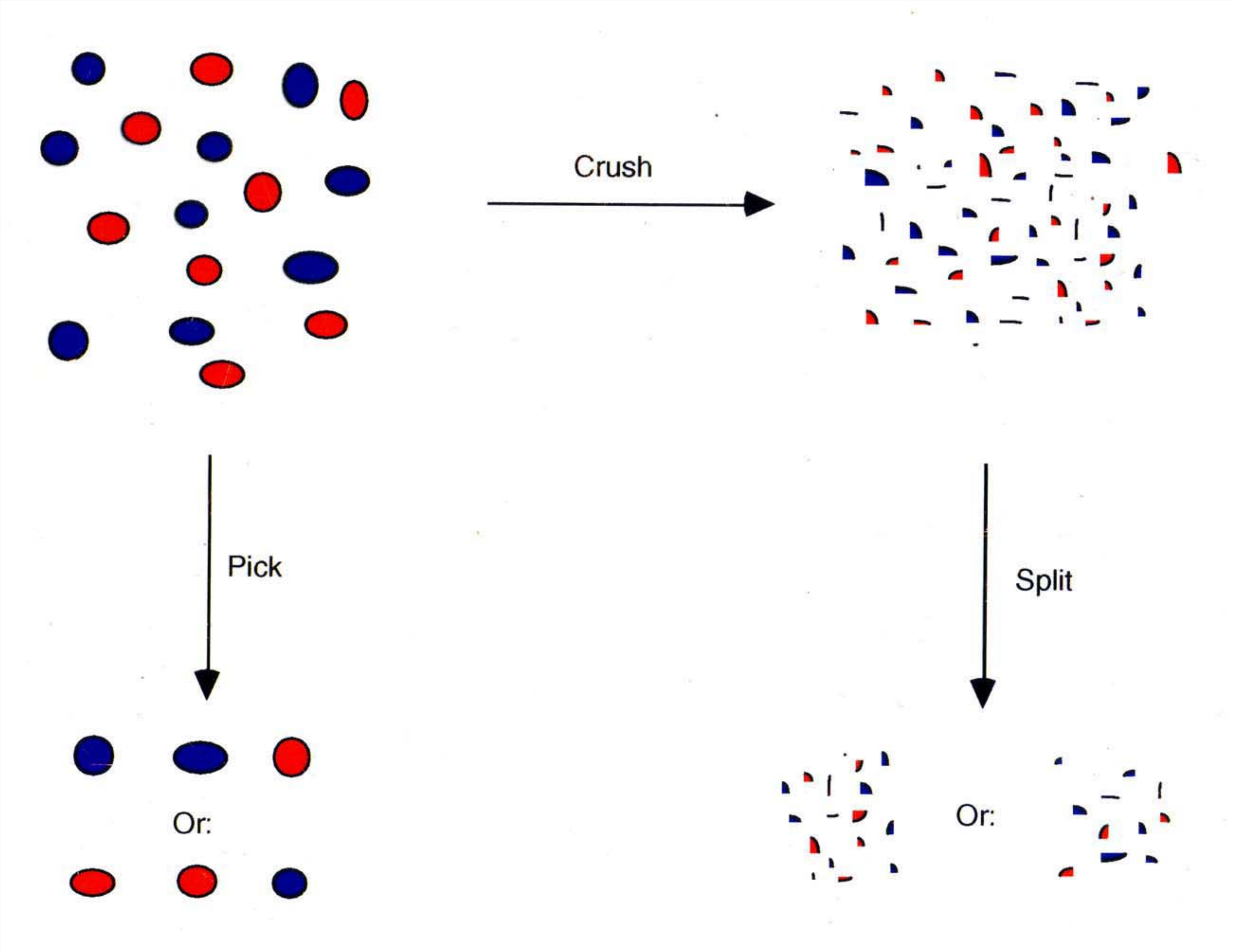
Laminated sediment



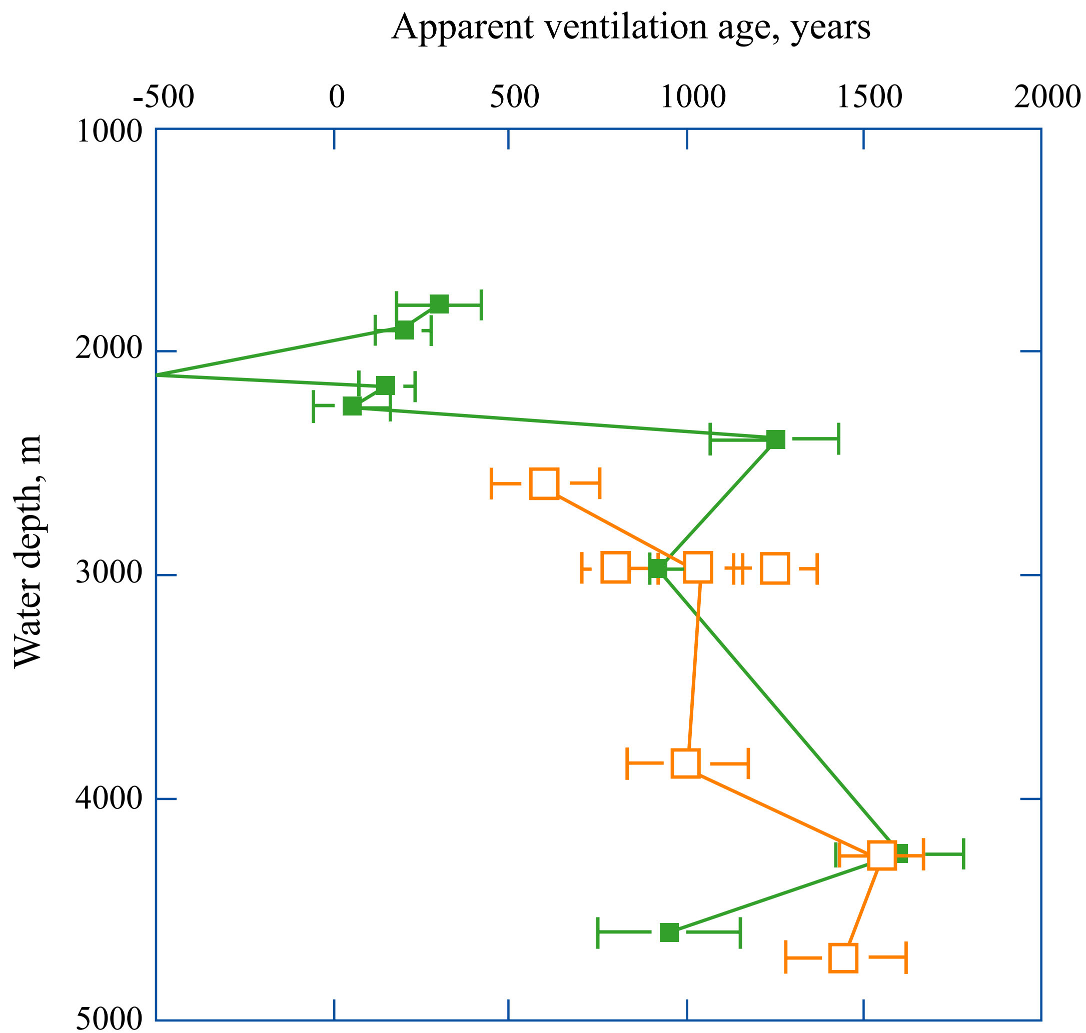
Bioturbated sediment



The role of sampling statistics in foraminiferal property analysis



Keigwin Atlantic LGM vertical ^{14}C profile



Summary of apparent ventilation ages for (a) the YD and LGM time slices, and (b) benthic foram dates during the YD and planktonic dates on the LGM benthic peaks. For each panel, YD data are solid squares, and LGM data are open squares.

KEIGWIN: VENTILATION IN THE WESTERN NORTH ATLANTIC Paleoc. 19:PA4012 (2004)

Figure by MIT OpenCourseWare.

Deep-sea Corals

- solitary: generally don't build reefs (some exceptions, however)
- live for 100-1000 years, but submersibles and dredge hauls can bring in specimens >100,000 yrs old
- reveal banding that is reminiscent of surface corals - although these may or may not be annual, they at least give a sense of the direction of time
- contain U, so can be ^{230}Th/U dated
- can be carbon dated to calculate initial ^{14}C
- can measure δ^{18}O, δ^{13}C, Cd, Ba, Sr, U etc., but none of these at present appear to be reliable indicators

$^{231}Pa/^{230}Th$ as a deep sea circulation tracer

^{235}U ^{238}U dissolved in seawater

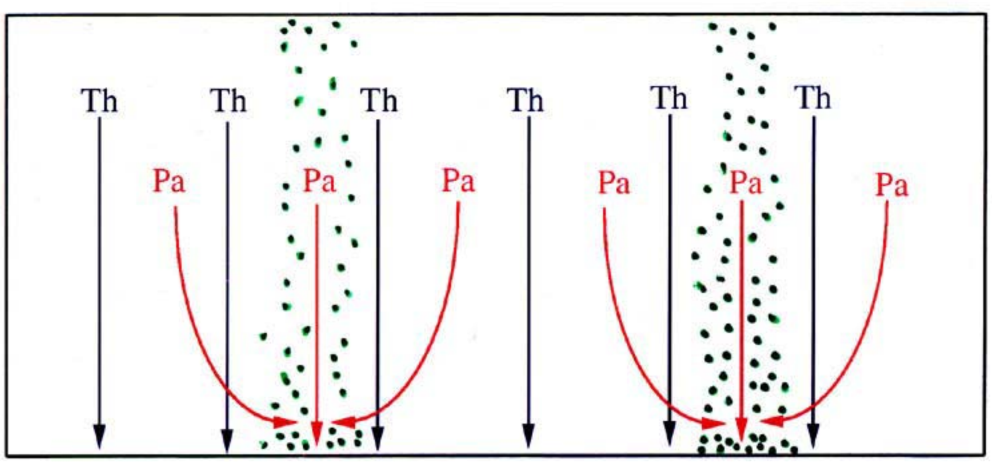
↓ ↓

^{231}Pa ^{230}Th scavenged onto sinking particles

$^{231}Pa/^{230}Th$
production ratio
= 0.093

If we were to scoop up all of the sediment deposited in the ocean for the past 500 years from the seafloor and analyze it for $^{231}Pa/^{230}Th$, it MUST equal the production ratio - because all of the Pa and Th produced in seawater ends up in the ocean sediments

Most of the Th falls to the bottom immediately below, but Pa can move laterally some distance before deposition, concentrating beneath areas of higher productivity.

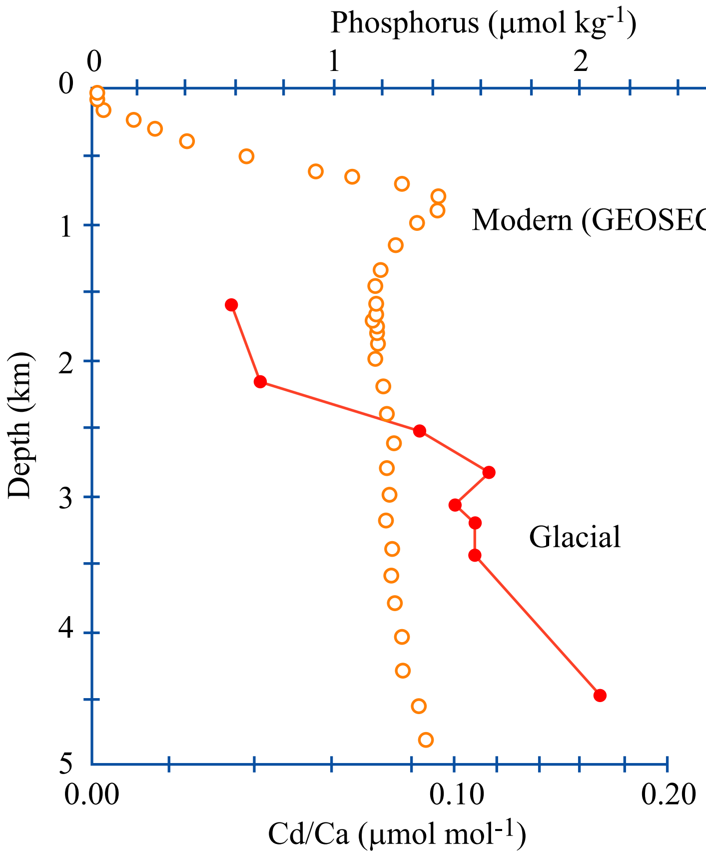


Western North Atlantic $\Delta^{14}C$, 26-10 ka

(from deep corals and abundance maxima benthic-planktonic pairs)

Images removed due to copyright restrictions.

Boyle and Keigwin (1987): North Atlantic LGM nutrient profile shows reductions in upper waters, enrichments in deeper waters



Glacial depth profile of phosphorus in the modern western North Atlantic (GEOSECS station 120) compared to glacial profile.

Figure by MIT OpenCourseWare.

Boyle and Keigwin (1987): deep N. Atlantic nutrient enrichment occurred during Younger Dryas

Images removed due to copyright restrictions.

Journal of Marine Research, 41, 327-347, 1983

Why is no deep water formed in the North Pacific?

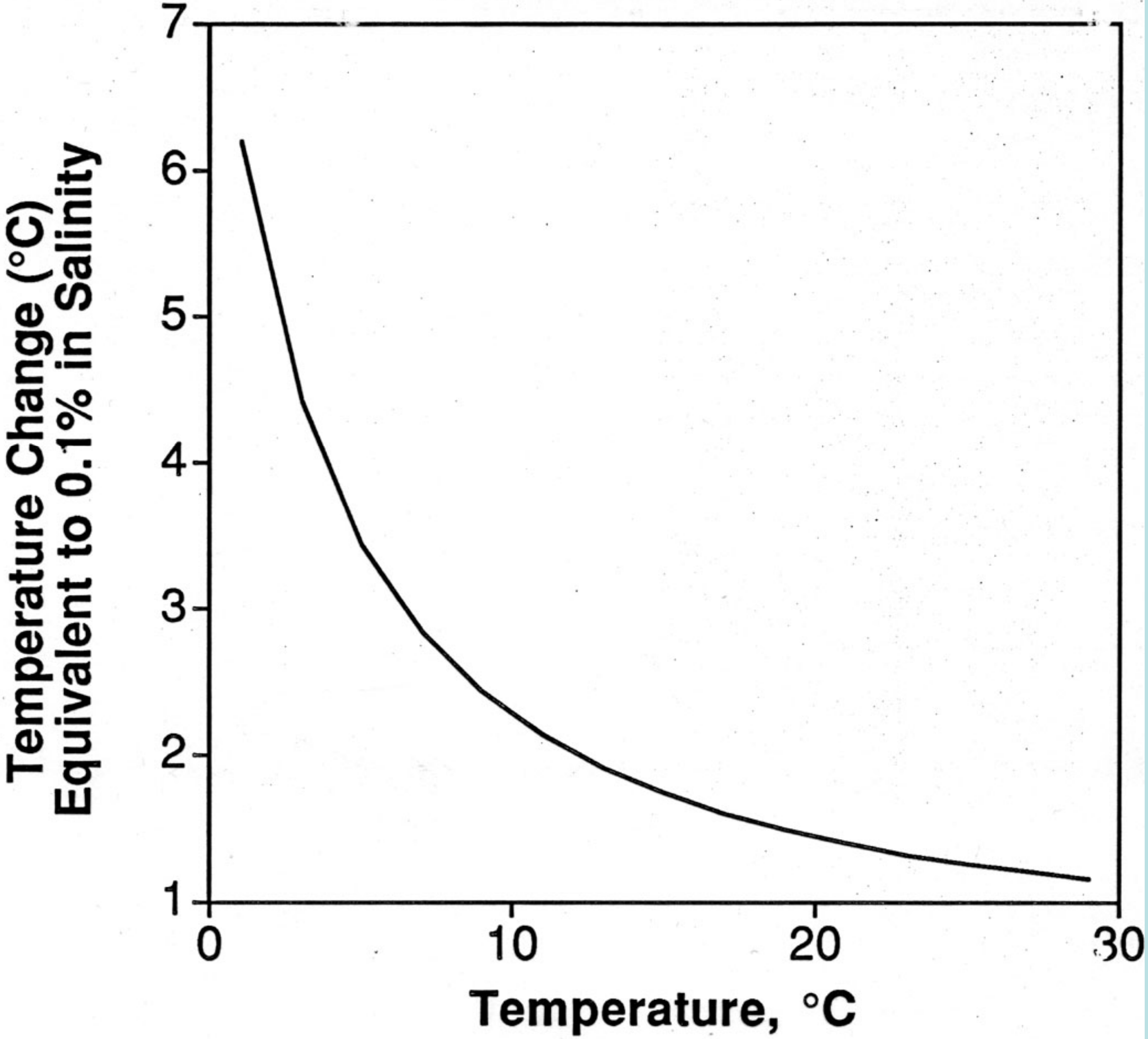
by Bruce A. Warren[1]

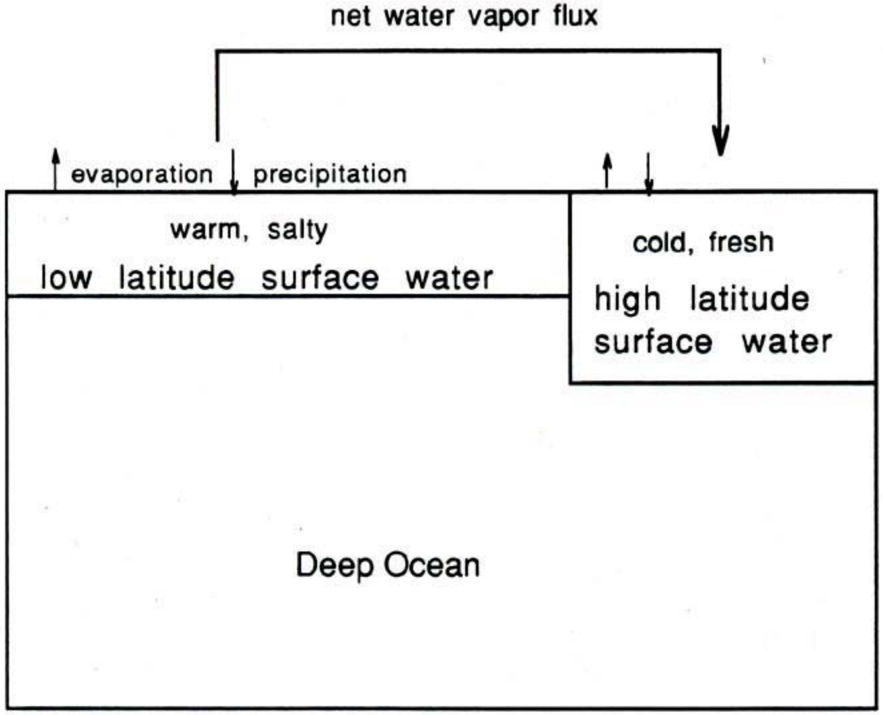
ABSTRACT

According to climatological data, the low salinity of near-surface water in the northern North Pacific, which reduces its density so much as to prevent sinking to great depth there, is due to the small regional evaporation rate (which allows a substantial net freshwater input to the surface layer from precipitation and runoff), in combination with the small rate of flow through the surface layer (which amplifies the effect of the freshwater flux on the salinity). The low evaporation rate is due in turn to the relatively low surface temperature (decreasing the specific humidity of the air at the air-sea interface), which seems to be caused mainly by the relatively large proportion of cold upwelling water in the inflow to the surface layer, contrasting with that in the northern North Atlantic where warm surface water to the south is the principal component of inflow. The reduction in southern inflow—and thereby in through-flow as well—results somewhat from the absence of a sink for surface water in any analogue to the Norwegian Sea, but probably in greater part from the more southerly extent of the subpolar gyre in the North Pacific than in the North Atlantic, whereby little water from the subtropical gyre passes through the northern North Pacific. The latter feature indicates a linkage between deep-water formation in the northern hemisphere and the distribution of wind-stress curl. Some aspects of this process by which lowering the temperature of seawater can reduce its density—by decreasing its salinity through diminished evaporation—are illustrated in a simple model.

At Cold Temperatures, Salt controls density more than heat

(surface water density)





1. If the high latitude box becomes too fresh, the density even at the freezing point is less than the density of average deep ocean water, so deep water formation shuts down.

2. Because the evaporation/precipitation cycle doesn't know about this change, it continues as before. Polar waters become ever fresher and low-latitude waters become ever saltier.

3. If this process continues, the low-latitude waters become more dense than average deep ocean water (despite being warmer), and deep water begins to form at low latitudes!

4. Did this ever happen? Are there other feedbacks which prevent this "catastrophe"?

Pore water chlorinity and oxygen isotopes

Images removed due to copyright restrictions.

Adkins, Schrag, and McIntyre (2002)

Temperature and salinity for LGM as estimated from foram $\delta^{18}O$ and pore water $\delta^{18}O$ and salinity

TEMPERATURE AND SALINITY OF OCEAN DEEP WATERS

	Present[1]		Last glacial maximum[2.,3]	
	T (°C)	S (‰)	T (°C)	S (‰)
Atlantic	~2.0	~34.9	–1.5 ± 0.5	36.0 ± 0.2
Antarctic	~0.0	~34.7	–1.2 ± 0.5	37.2 ± 0.5
Pacific	~1.0	~34.6	–1.3 ± 1.0	36.2 ± 0.1

[1]Although temperature and salinity are measured extremely precisely in the modern ocean, the deep sea contains a range of values; these numbers are chosen as a "mode" in the volumetric distribution.

[2] Errors include the best estimate of propagation of uncertainties in data and curve fits; Altantic errors include the difference between two sites.

[3] The average LGM salinity is ~3% higher because of the withdrawal of water into massive continental ice sheets.

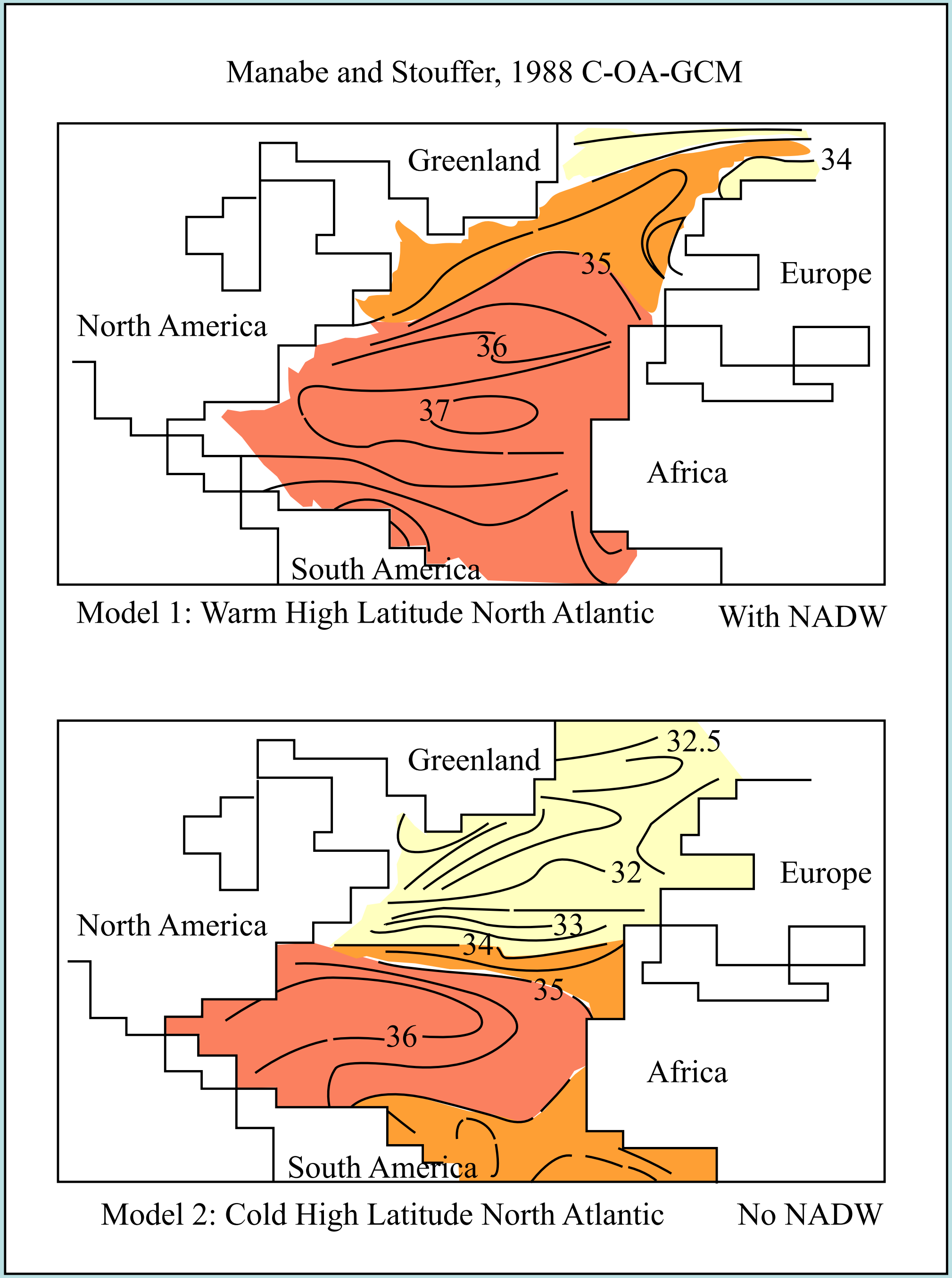
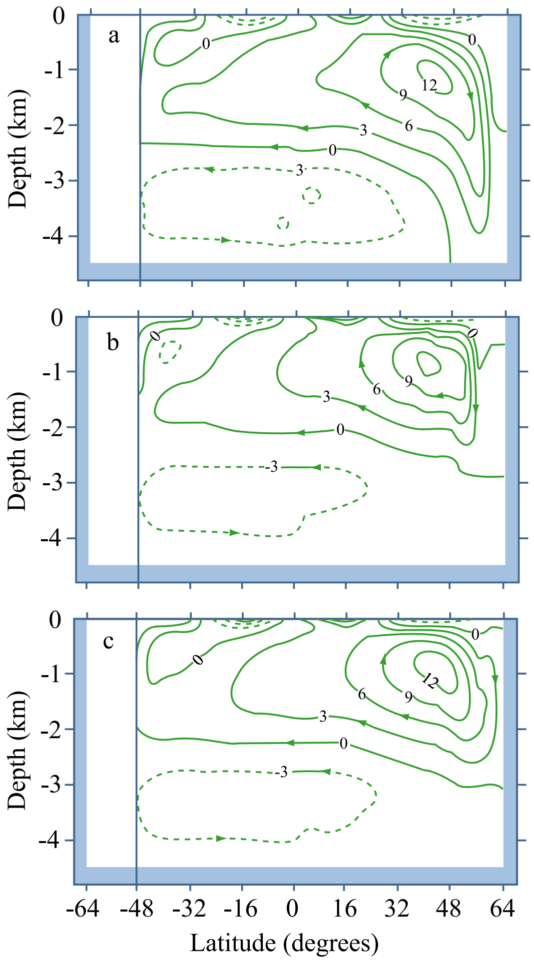


Figure by MIT OpenCourseWare.



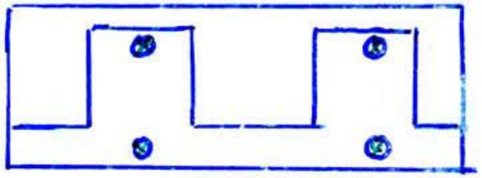
Zonally integrated meridional mass transport in 10^6 m^3 s^{-1} in the Atlantic model basin: (a) for the spin-up conveyor state; (b) for the equilibrium reached after the first freshwater perturbation; (c) for the equilibrium after the second perturbation. These three coupled equilibria exit under the same forcing. Note that in b and c the North Atlantic Deep Water (NADW) cell does not reach down to the bottom of the North Atlantic.

Figure by MIT OpenCourseWare.

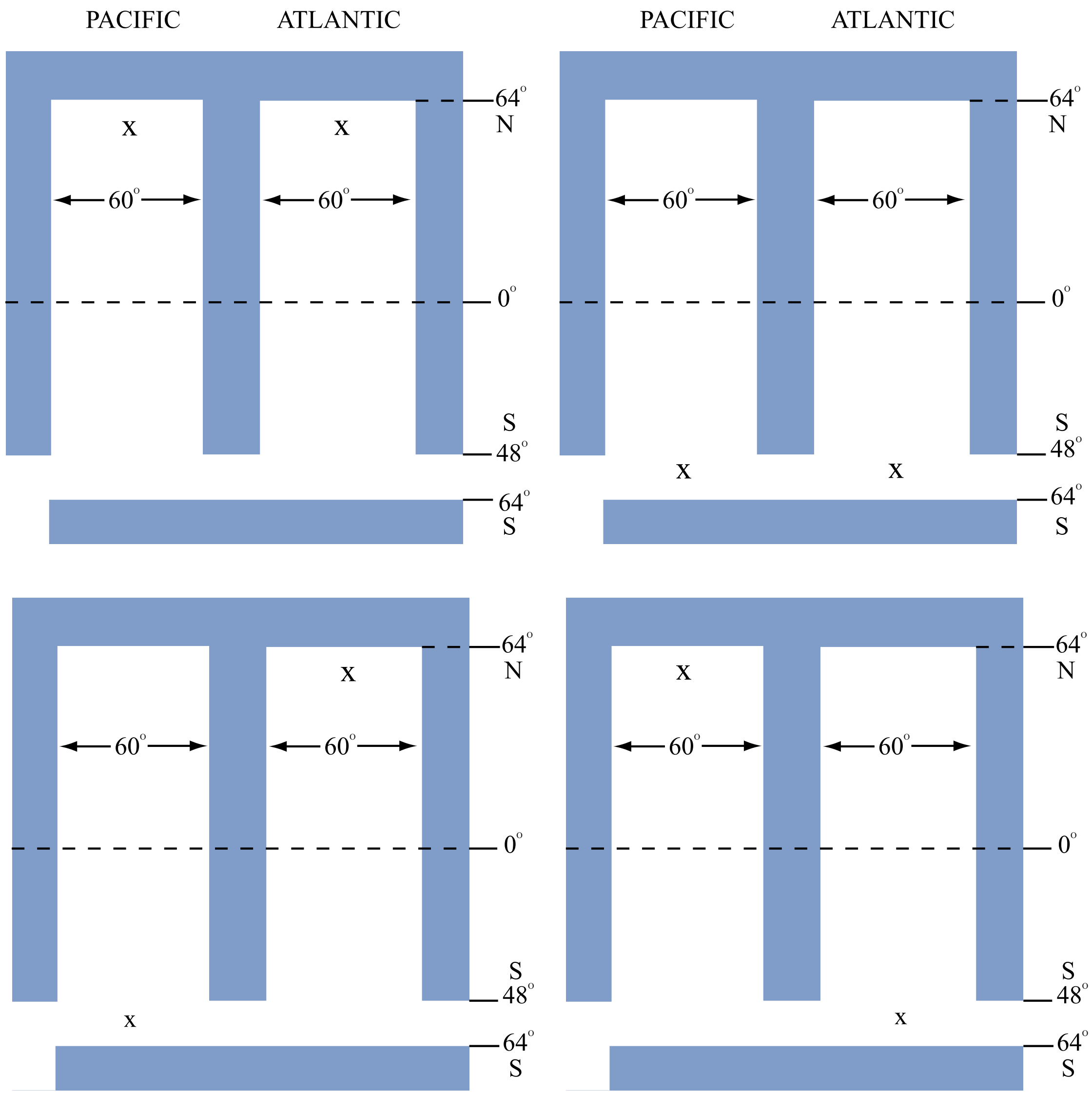
DOES THE OCEAN-ATMOSPHERE SYSTEM HAVE MORE THAN ONE STABLE "MODE" OF OPERATION?

1. Manabe & Stouffer: Coupled OA-GCM has two stable modes, one with NADW, another without

2. Marotzke et. al. : Highly idealized O-GCM has multiple stable states:



3. Broecker, Birchfield et. al : NADW salt oscillator model - can it account for Dansgaard-Oeschger climate fluctuations?



x denotes sinking; larger is stronger.

Model domain of the global GFDL model.

Figure by MIT OpenCourseWare.

Marotzke and Willebrande

Events that may be related to fresh water pulses

- Younger Dryas? - diversion of outflow from Mississippi drainage to St. Lawrence but no evidence for freshwater signal in the North Atlantic at this time

- 8200 year cold event - possibly due to disintegration of ice-dammed glacial Lake Aggasiz