ABRUPT CLIMATE CHANGE: AN ALTERNATIVE VIEW

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As far as “abrupt” millennial time-scale climate change is concerned, there are several issues worth raising---even where no definitive answer is possible at the present time.

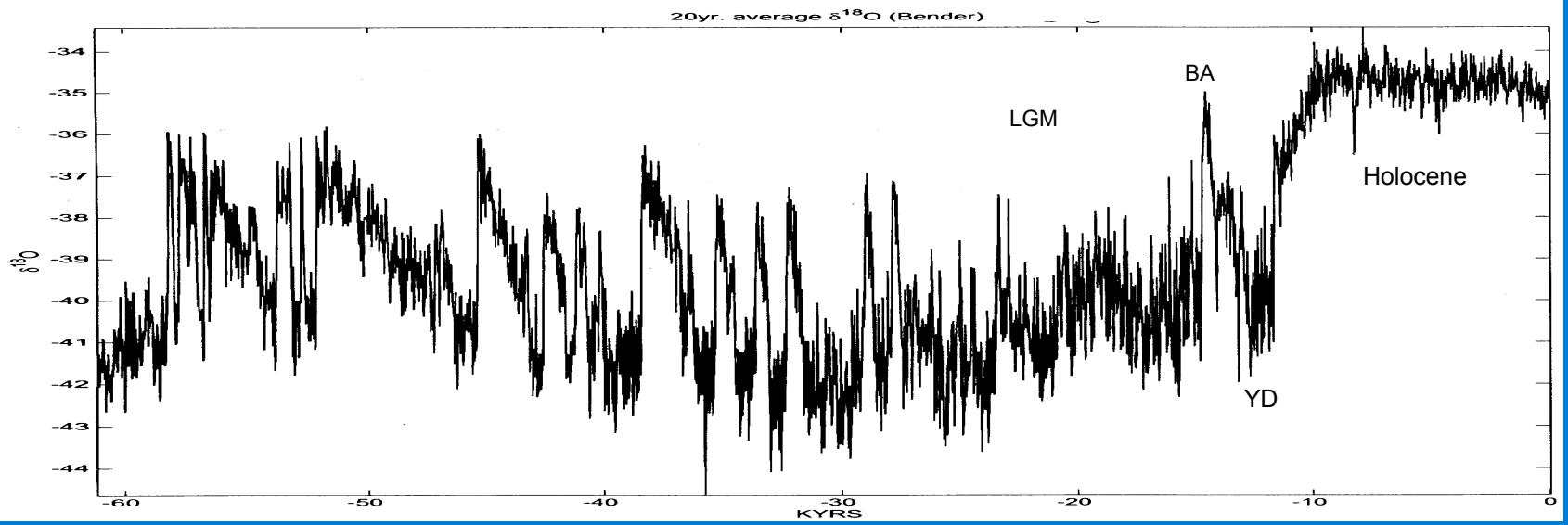
What are the proxies describing? Is an abrupt proxy change the same as an abrupt climate change?

Is abrupt climate change a regional, or hemispheric, or global phenomenon? Or is there a mixture of all of those things?

To the extent that abrupt change is real (and some is quite convincing) what is the simplest (as opposed to the most dramatic) explanation?

Temperature Proxies

M. Bender, GISP2 core



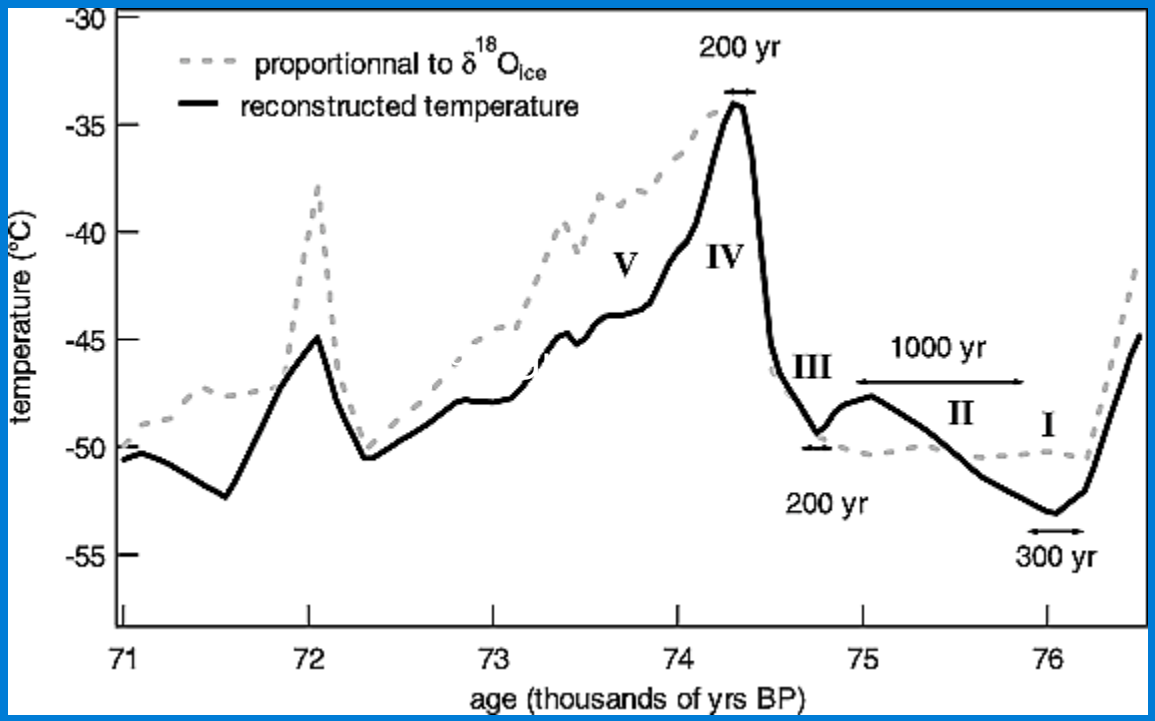
Not temperature, but clearly coherent with temperature.

Dominant features:
(1) Glacial/interglacial---a separate story, not today.
(2) Holocene stability
(3) Glacial period instability (rapid fluctuations, the `Dansgaard-Oeschger,' D-O, events)

Although not seen in the Greenland core, Heinrich events appear abruptly in some records.

Landais et al., GRL, 2004

$^{40}Ar/^{15}N$ in ice, temperatures



TIME

The generally accepted explanation of the abrupt shifts appears to be that the North Atlantic circulation shifted, thus generating a large-scale (even global) climate change.

Focuses on the ‘global conveyor’.

Fluctuations in the North Atlantic mass flux (or even, more likely) its heat flux, are not the most obvious place to look for the cause of global climate change. (Not the same as saying it isn't ultimately the cause.) Ocean has normally been considered something of a fly-wheel of the system, not the engine.

Has the tail been wagging the dog?

Question: Are the D-O events global?

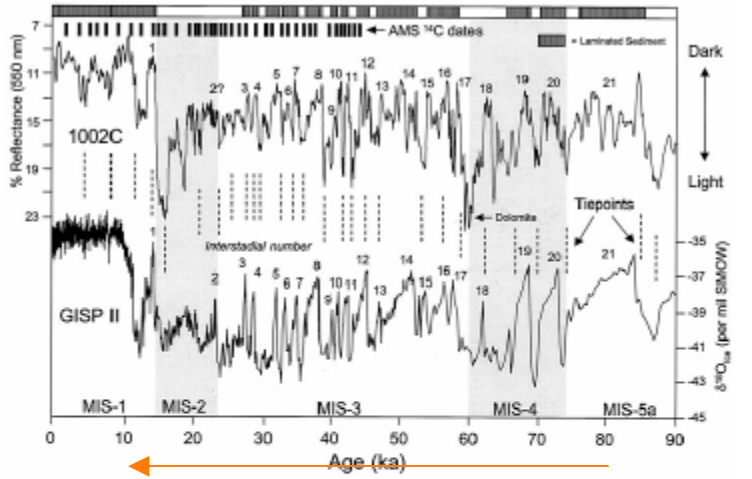


Fig. 1. Comparison of measured color reflectance (550 nm) (five-point moving average) of Cariaco Basin sediments from ODP Hole 1002C to $\delta^{18}O$ from the GISP II ice core (9). MIS boundaries in Hole 1002C are from (7), and detailed age control over the upper 22 m is based on AMS ^{14}C dating of the planktic foraminifer *G. bulloides* (10). Additional visual tie points between the color reflectance and GISP $\delta^{18}O$ records are shown. The distribution of laminated intervals is indicated across the top. The presence of a semi-indurated dolomite layer in Hole 1002C at 28.3 m below the sea floor resulted in minor core disturbance at this level. Deposition of dark, generally laminated sediments preferentially occurs during warm interglacial or interstadial times (numbered events), whereas deposition of light-colored bioturbated sediments was restricted to colder stadial intervals of the last glacial. Sediment color variations in the Cariaco Basin are driven by changing surface productivity, with increased organic rain leading to darker sediments and, through remineralization reactions, periods of anoxic or near-anoxic conditions in the deep basin. SMOW, standard mean ocean water.

Cariaco Basin reflectance & GISP2
Peterson et al., 2000, Science.

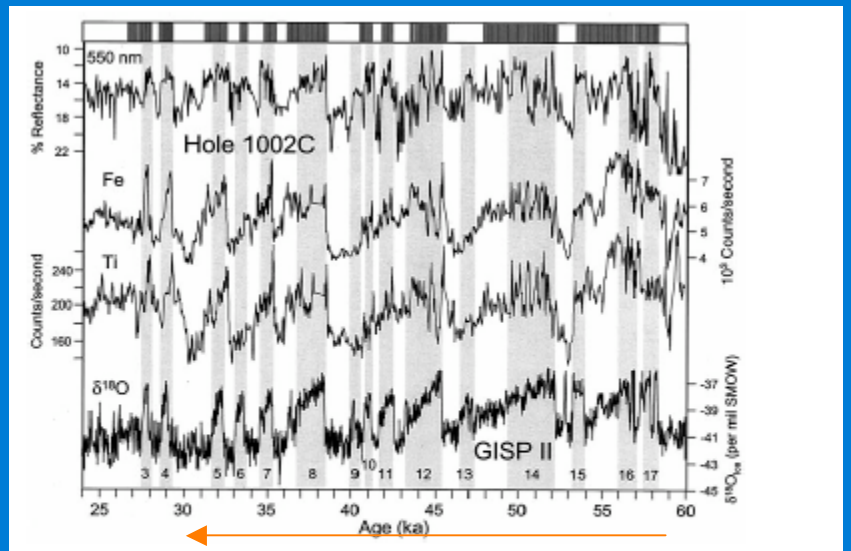
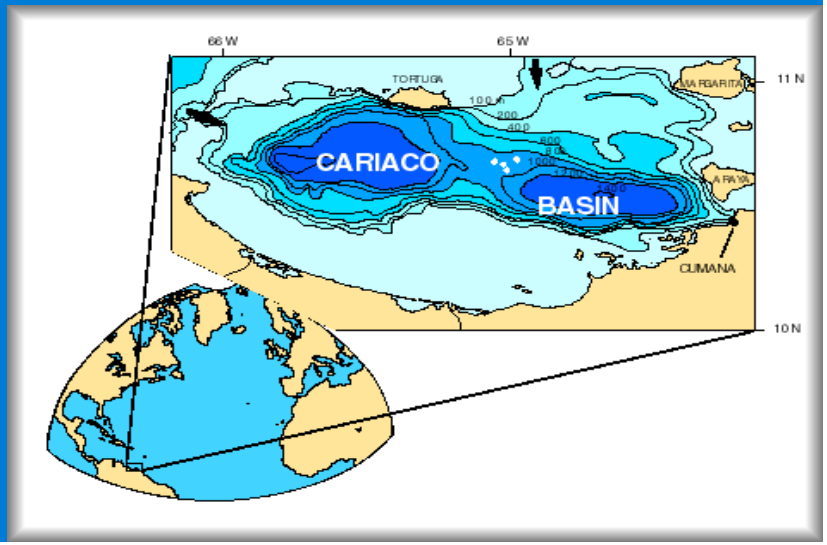


Fig. 2. Detailed comparison of sediment reflectance and Fe and Ti (counts/s) (three-point moving average) from MIS 3 sediments of ODP Hole 1002C with measured $\delta^{18}O$ in the GISP II ice core (9). The distribution of laminated sediment intervals in MIS 3 is shown across the top of the figure. Warm interstadials in the GISP II record were marked by the deposition of Fe- and Ti-rich, dark, and generally laminated (anoxic) sediments in the Cariaco Basin. High Fe and Ti values indicate periods of greater terrigenous input to the basin and reflect increased precipitation and input from rivers draining the northern coast of tropical South America.

Hughen et al. NGDC website:



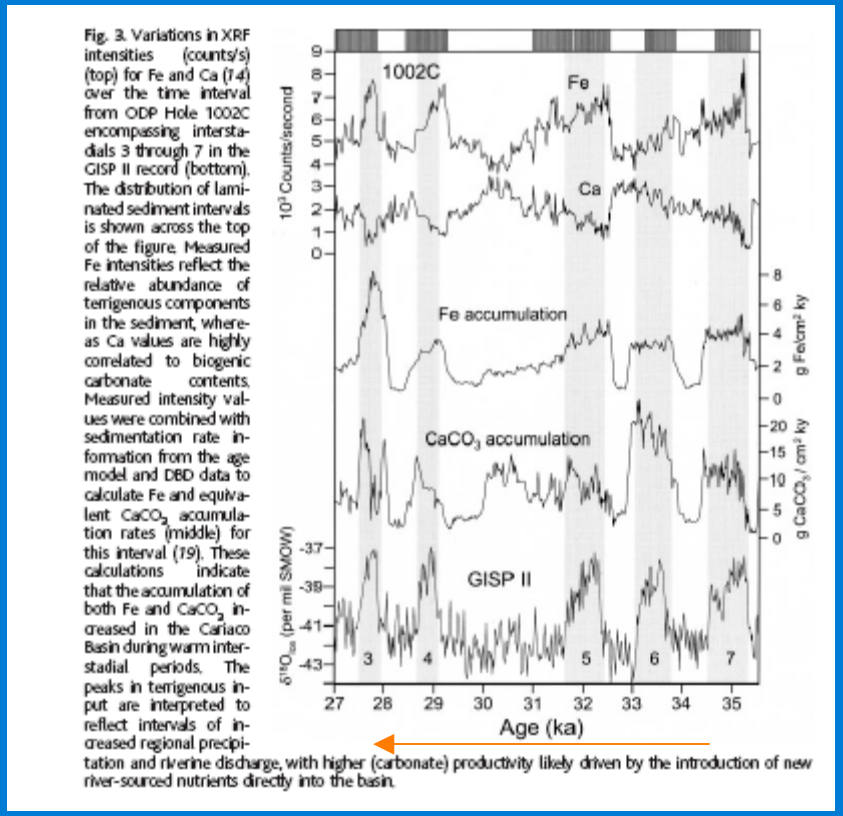


Fig. 3. Variations in XRF intensities (counts/s) (top) for Fe and Ca (14) over the time interval from ODP Hole 1002C encompassing interstadials 3 through 7 in the GISP II record (bottom). The distribution of laminated sediment intervals is shown across the top of the figure. Measured Fe intensities reflect the relative abundance of terrigenous components in the sediment, whereas Ca values are highly correlated to biogenic carbonate contents. Measured intensity values were combined with sedimentation rate information from the age model and DBD data to calculate Fe and equivalent $CaCO_3$ accumulation rates (middle) for this interval (19). These calculations indicate that the accumulation of both Fe and $CaCO_3$ increased in the Cariaco Basin during warm interstadial periods. The peaks in terrigenous input are interpreted to reflect intervals of increased regional precipitation and riverine discharge, with higher (carbonate) productivity likely driven by the introduction of new river-sourced nutrients directly into the basin.

Peterson et al., 2000, Science.

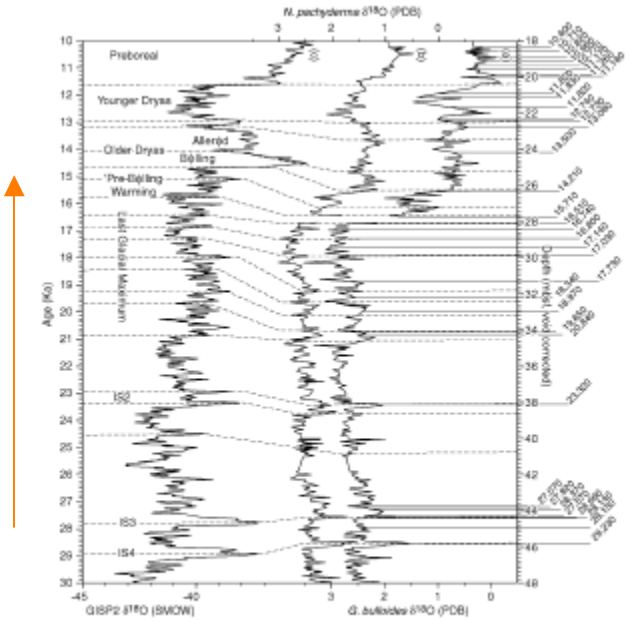


Fig. 3. The $\delta^{18}O$ record of: (a) GISP2 versus time, compared to the $\delta^{18}O$ record of (b) *N. pachyderma*; and (c) *G. bulloides* from ODP Hole 893A versus depth (void corrected meters below sea floor) for the time interval 10–30ka. Dotted lines match climate events recorded in both records, while solid lines match calibrated ^{14}C dates (Roark et al, in prep.). Major climatic events are identified.

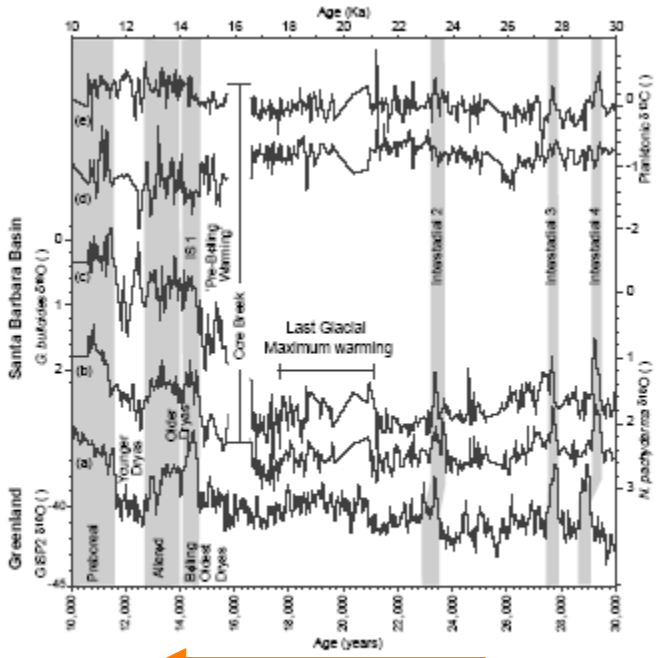


Fig. 4. Comparison of (a) the $\delta^{18}O$ record from GISP2 with ODP Hole 893A for the time interval 10–25ka. Records from Santa Barbara Basin include (b) *N. pachyderma* $\delta^{18}O$, (c) *G. bulloides* $\delta^{18}O$, (d) *G. bulloides* $\delta^{13}C$ and (e) *N. pachyderma* $\delta^{13}C$. Shaded areas represent warm climate events. Major climate events are identified.

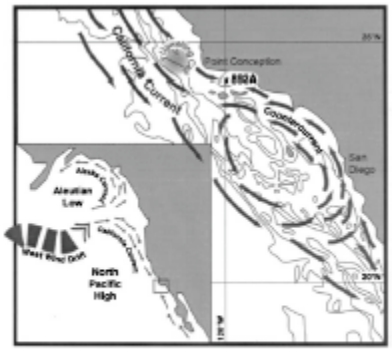


Fig. 1. Maps showing both the location of ODP Hole 893A, Santa Barbara Basin, and the relationship between surface ocean currents on the Southern California continental margin which influence Santa Barbara and broad atmospheric circulation over the North Pacific.

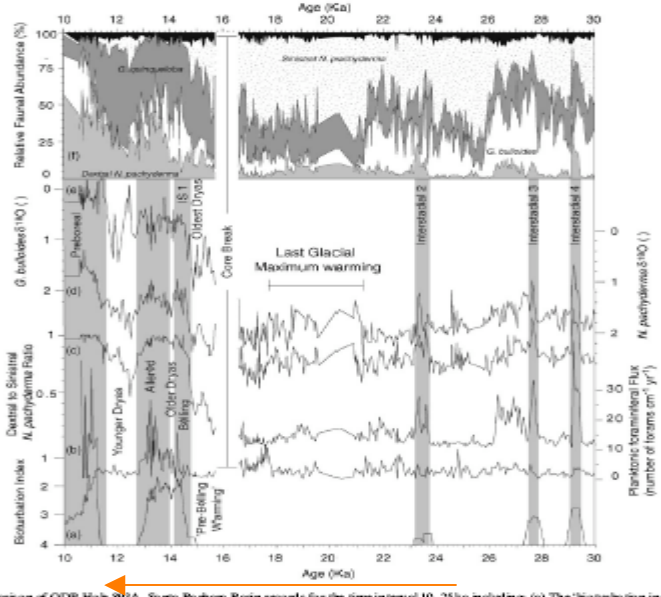
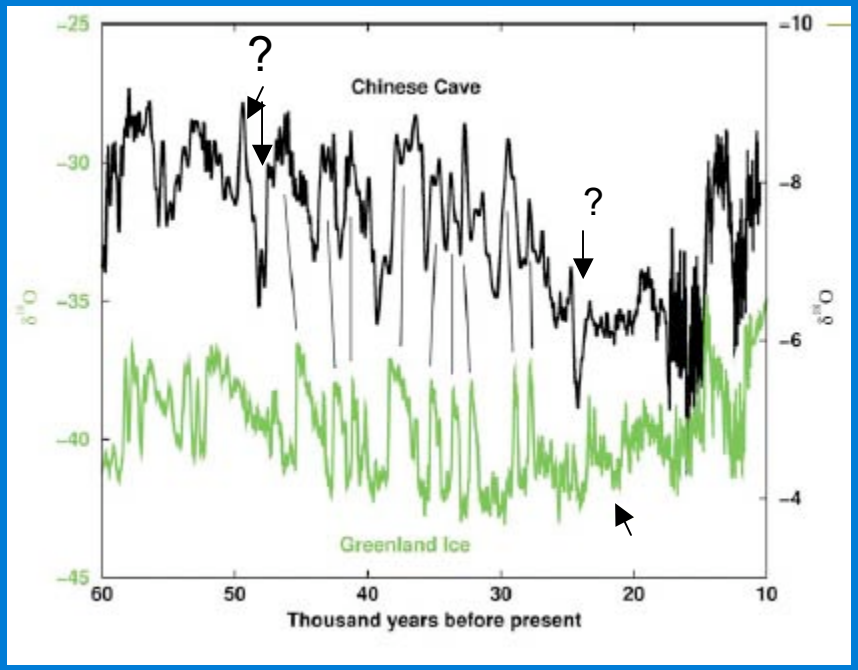
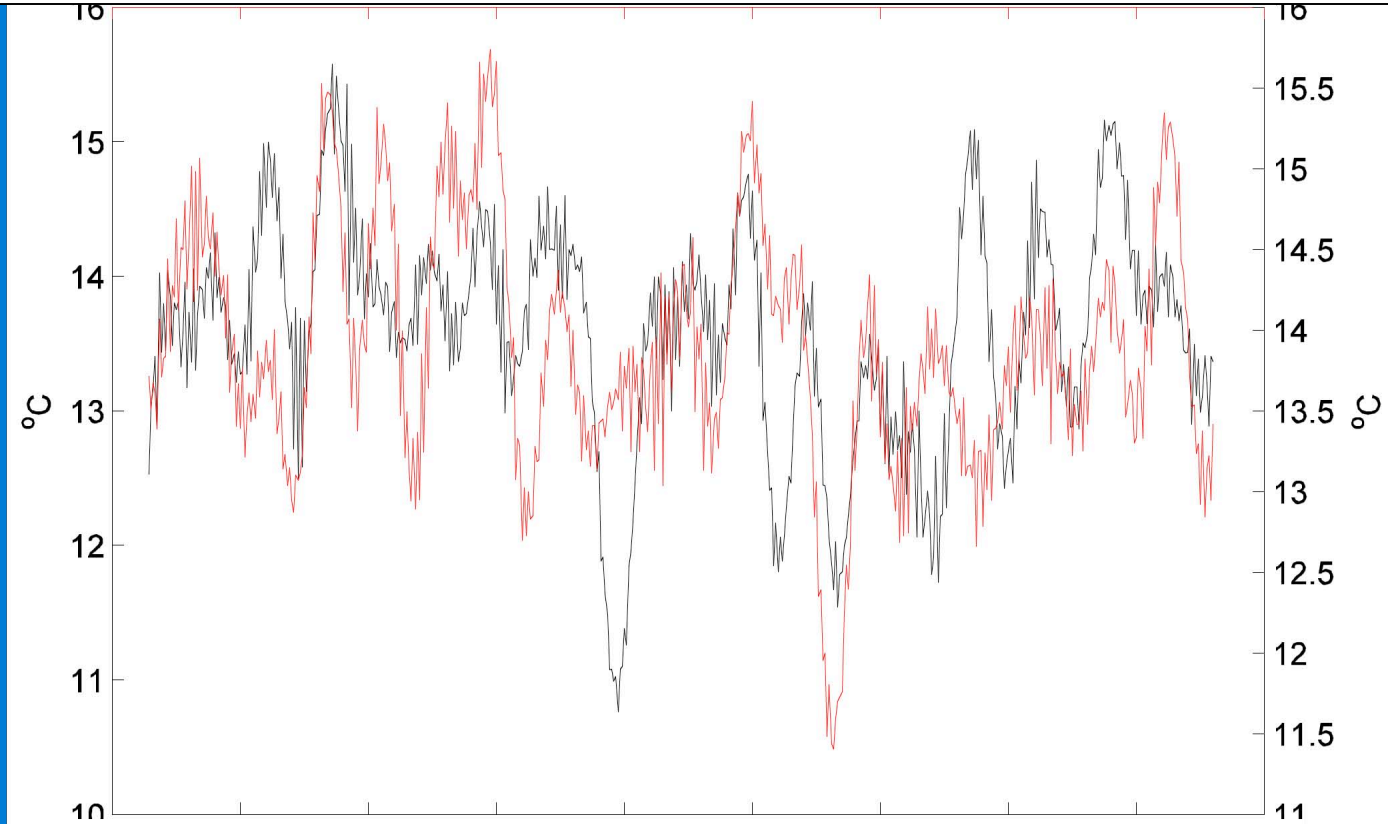


Fig. 5. Comparison of ODP Hole 893A, Santa Barbara Basin records for the time interval 10–25ka including: (a) The 'bioturbation index' (Behl and Kennett, 1996); (b) Planktonic foraminiferal flux; (c) The ratio of dextral to sinistral-coiled *N. pachyderma*; (d) *N. pachyderma* $\delta^{18}O$; (e) *G. bulloides* $\delta^{18}O$; and (f) the percent composition of the total planktonic foraminiferal assemblage, species from left to right, *N. pachyderma* (dextral), *G. bulloides*, *G. quinqueloba*, *N. pachyderma* (sinistral) and other species. Shaded areas represent warm climate events. Major climate events have been named.

Santa Barbara Basin/GISP2,
Hendy, Kennett, Roark, Ingram, QSR, 2002

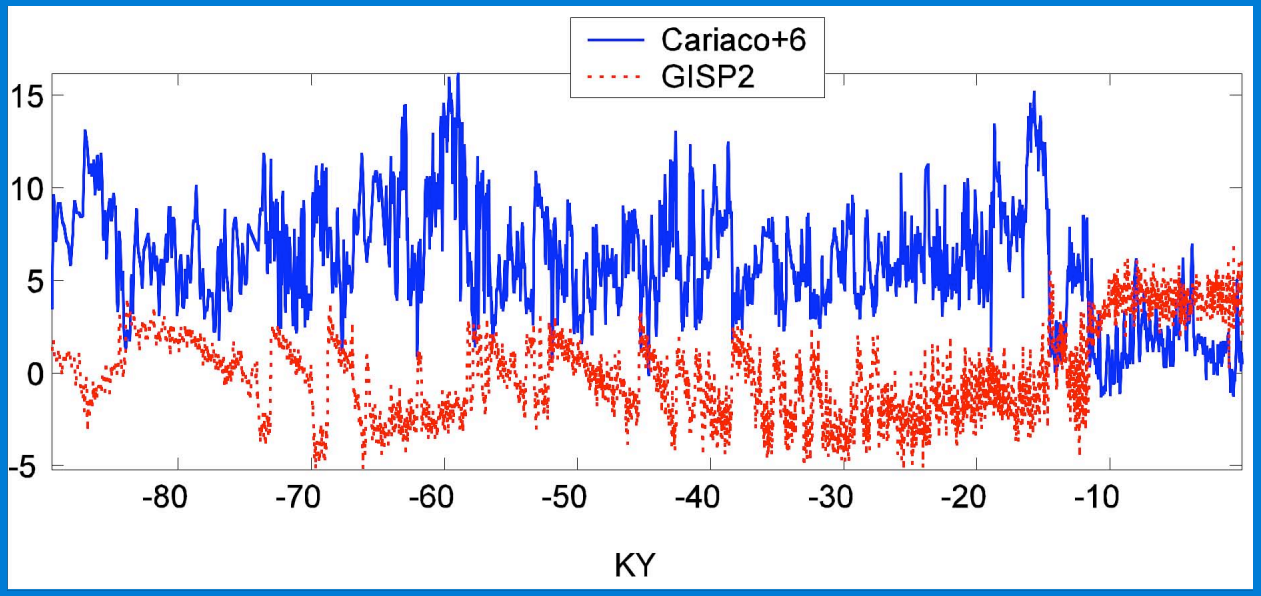


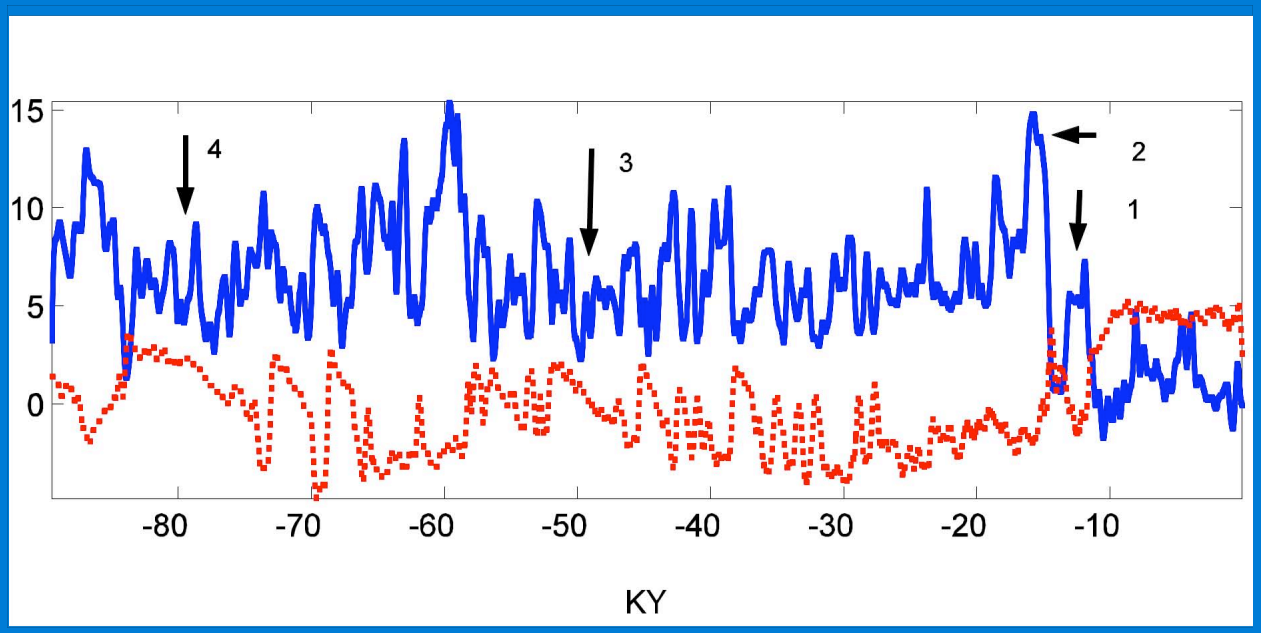
Hulu Cave (eastern China)/GISP2
R. Alley, Oceanography, 2005



Two real records

A closer look at the Cariaco Basin records:





Rapid events exist in many records with a character somewhat similar to the D-O events. It is plausible that they *are* D-O events, but there is little evidence demonstrating it. The contrary assumption, that spatially uncorrelated shifts occur having similar spectral character is also unproven.

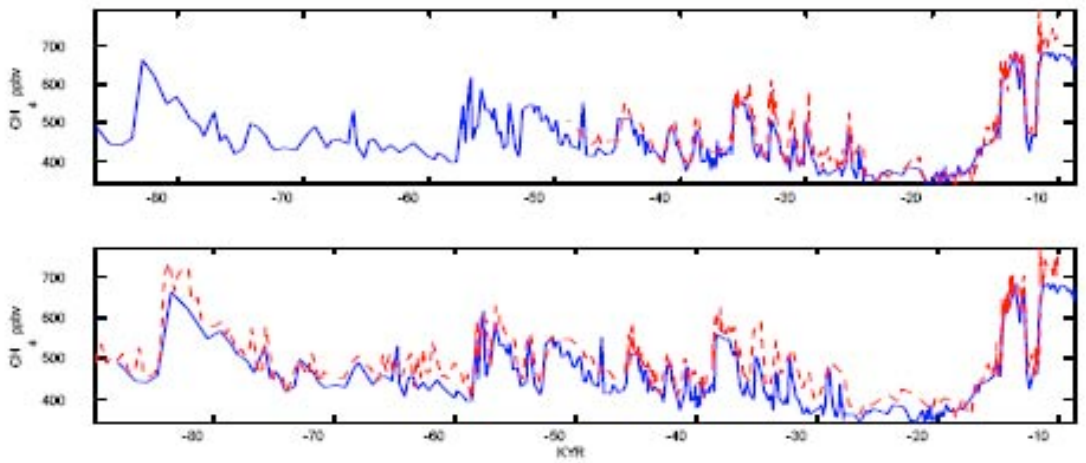
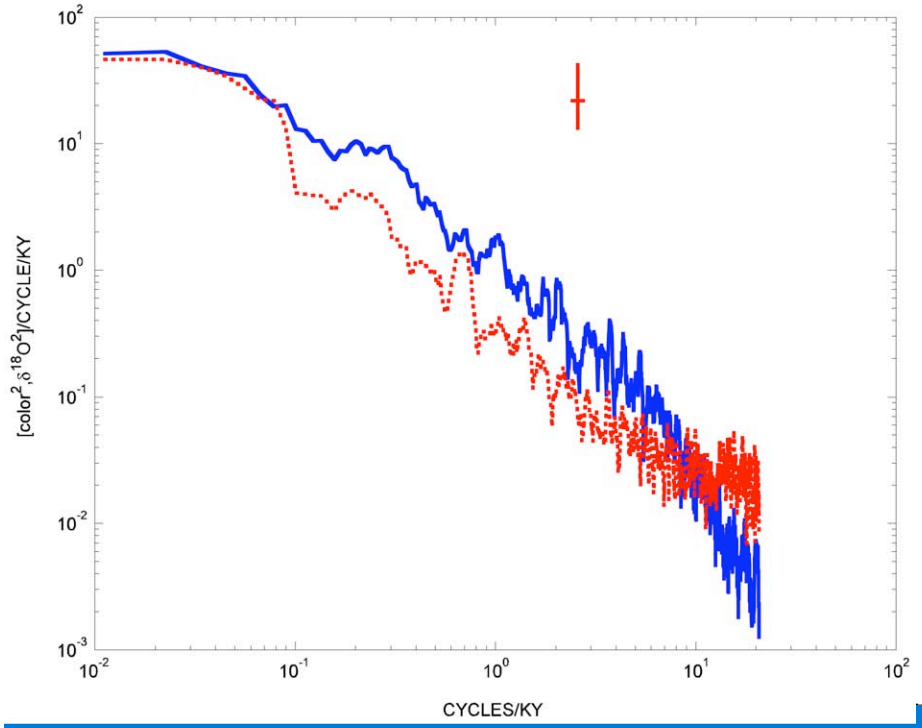
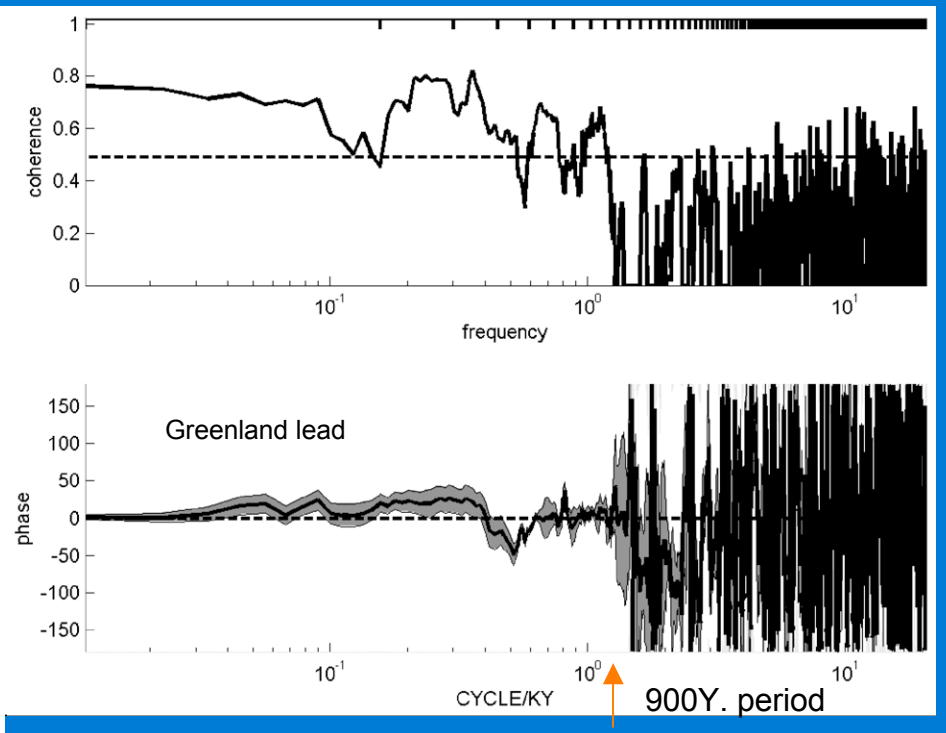


Figure 4: Byrd (solid-blue) and GRIP (dashed-red) aligned CH_4 records (upper panel), and for the GISP2 core in the lower panel. Note that time here and subsequently, increases to the right—in the conventional physics/time series convention.

To the extent that Greenland methane changes are correlated with with Greenland temperature, and to the extent that the methane changes arise because of low latitude warming, one has a strong argument of at least a latitudinal reach of the D-O events.





Blue, Cariaco Basin reflectance, power density. Red, GISP2 _ ^{18}O

coherence amplitude/phase manually aligned by Peterson et al.

Some things are clearly correlated, others clearly not, and some ambiguous because of age-model problems.

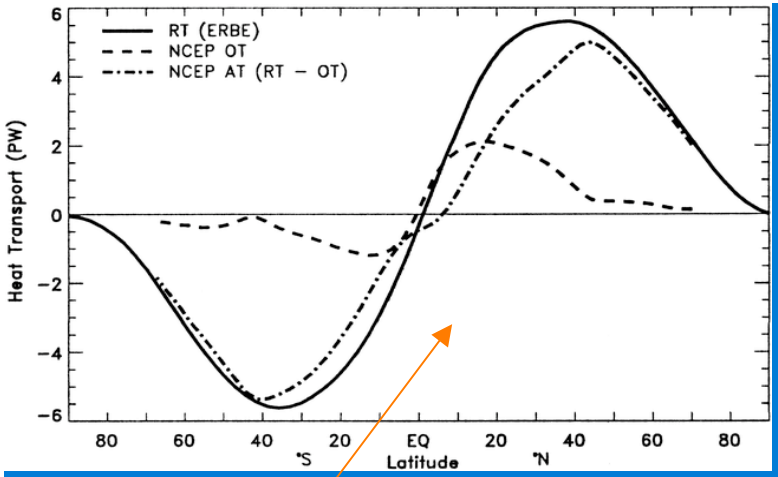
What is the minimalist explanation of what we see?

Why is the North Atlantic Ocean the focus of so much attention as the primal cause of abrupt climate change?

Some things to consider:

What matters to the atmosphere is not the oceanic mass flux--- it is the heat transport and, even more directly, oceanic seasurface temperatures. These are rarely discussed.

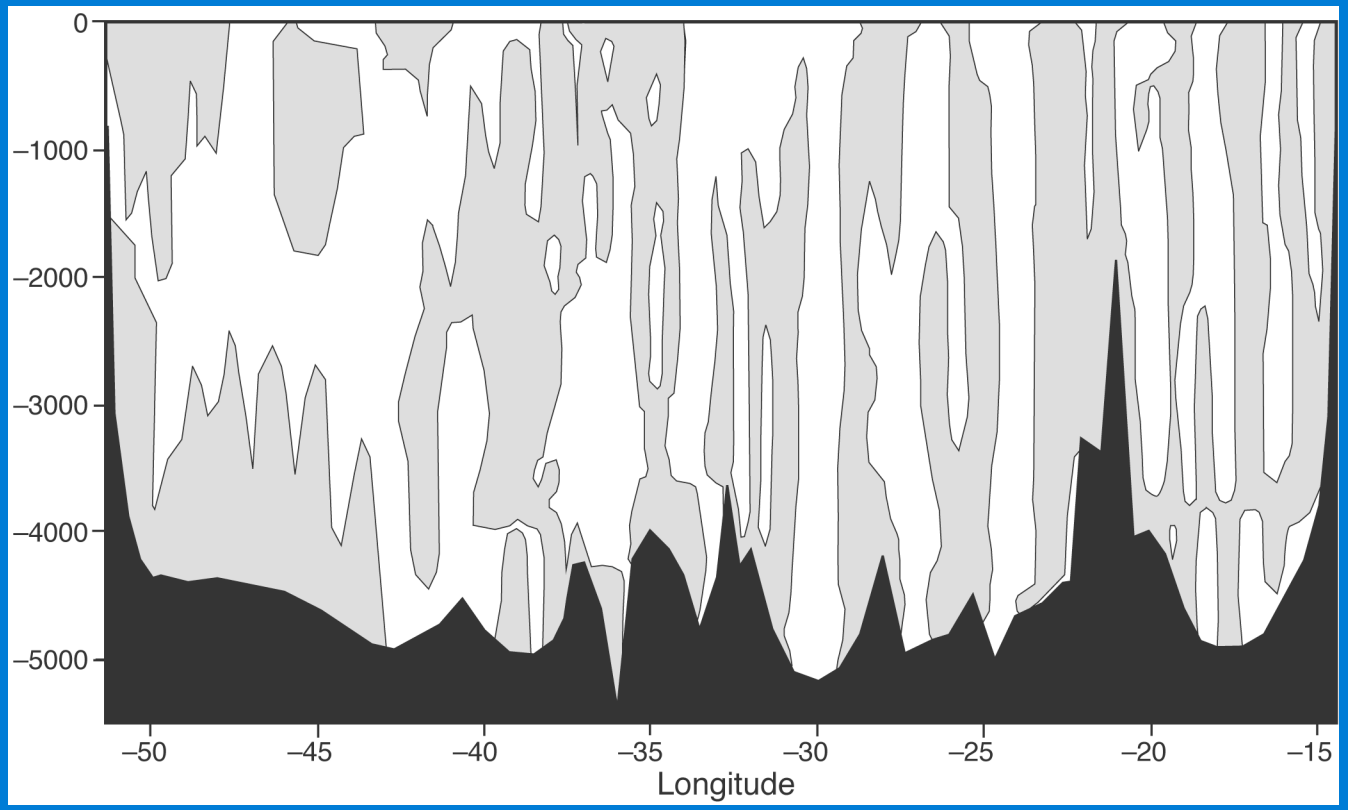
Property transports in the ocean are the product of the flow field integrated times the property concentrations. These are not the simple fields that ‘conveyor belt’ cartoons would imply.



Total ocean+atmosphere heat transport (solid). Ocean (dashed).

Trenberth and Caron, 2001. Ocean as a residual of ERBE & atmospheric estimate.

Estimated absolute velocity, 7.5degreesN, North Atlantic

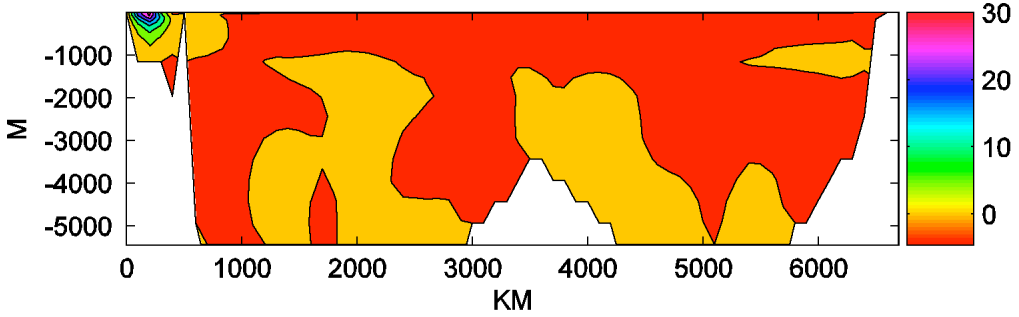


Ganachaud (1999)

$$H_C = \int_0^L \int_{z_b(x)}^0 \rho(z,x)v(z,x)C(z,x)dzdx$$

$$\approx \sum_j \sum_k \rho(z_j,x_k)v(z_j,x_k)C(z_k,x_j)\Delta a_{jk}$$

$$= cov[\rho(z_j,x_k)v(z_j,x_k)\Delta a_{jk}, C(z_k,x_j)]$$



Absolute velocity, 26^{o}N, North Atlantic. 12 year mean from a constrained GCM (ECCO Consortium)

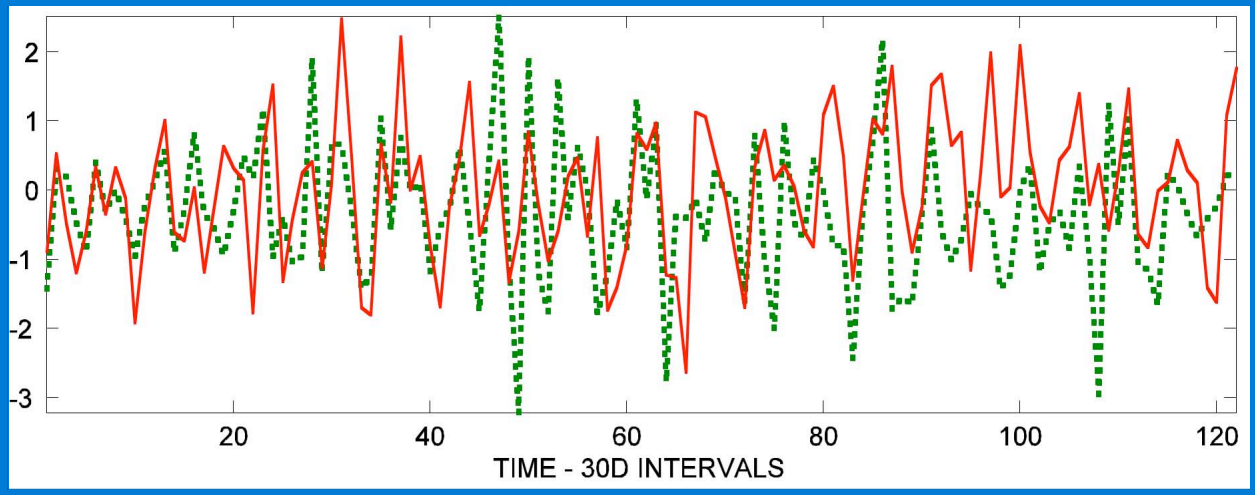
If one seeks to most efficiently and rapidly to change air temperatures, the nature of dust laid down in a core, the ocean circulation, and sea ice distribution, there is an attractive, single mechanism:

Example of tracer transport volatility:

Louisiana

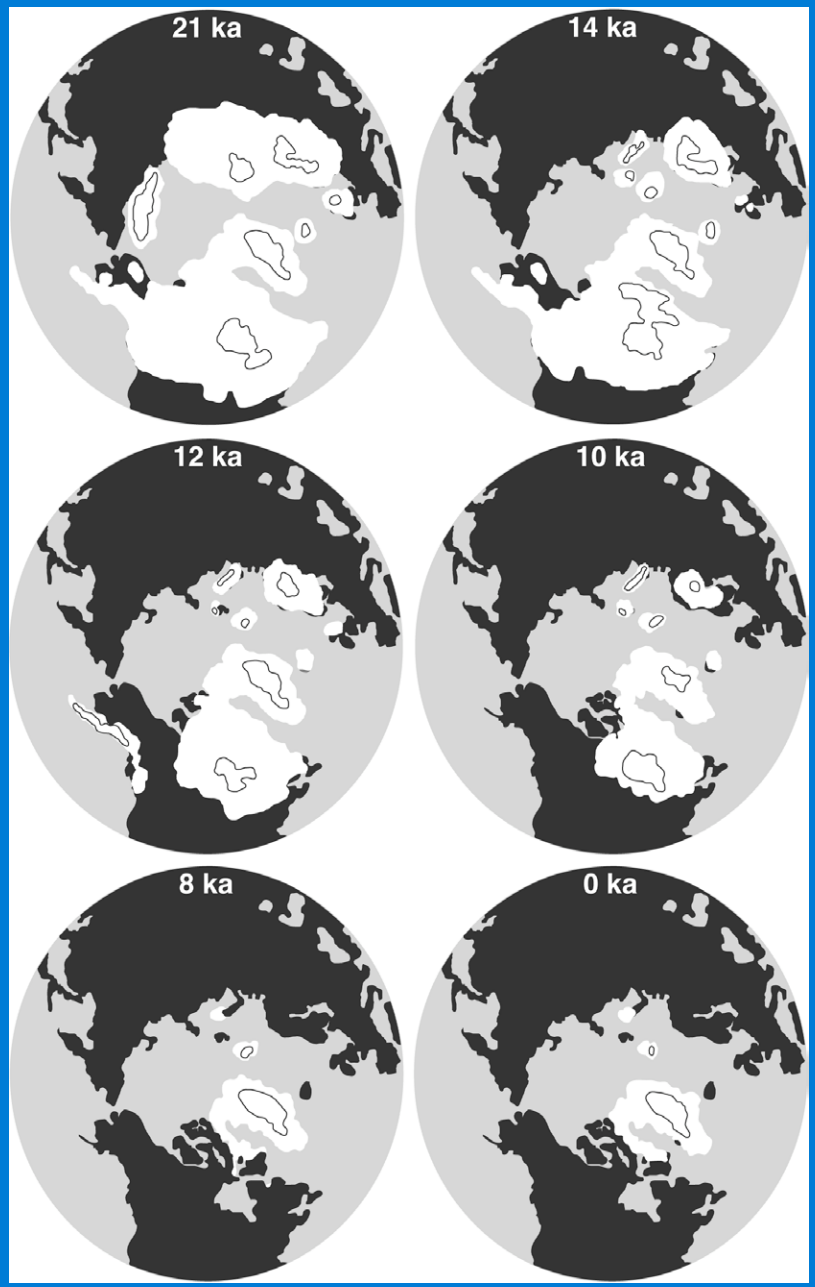
New York Times, Science Section, 27 July 2004.
Smoke from Alaskan fires seen over Louisiana.

(See Newell and Zhu, GRL, 1994, for a more technical discussion.)

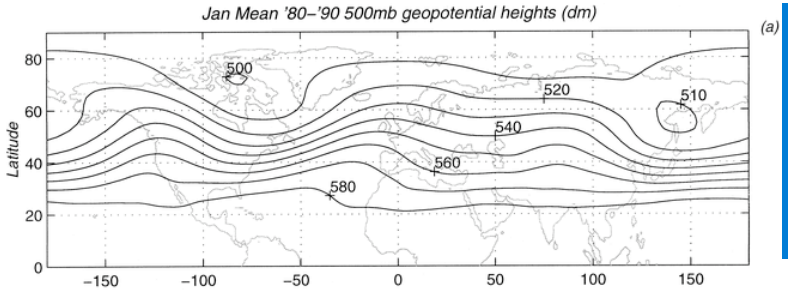


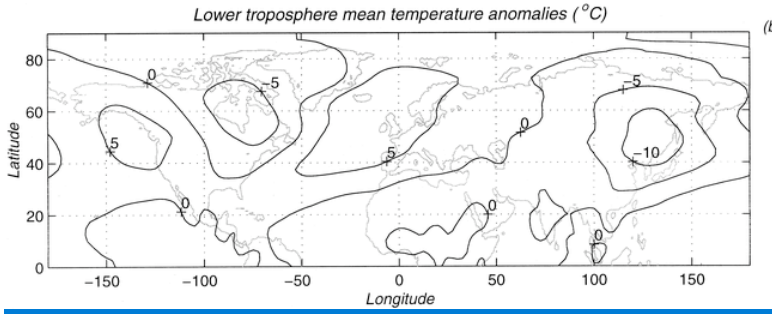
30-day mean meridional windfield and air temperature at Boston (normalized by their standard deviations). Red is temperature.

If step back and inquire as to the difference between the Holocene, with its stability, and the glacial period, with its instability, (D-O, Heinrich events) what is the most obvious change?

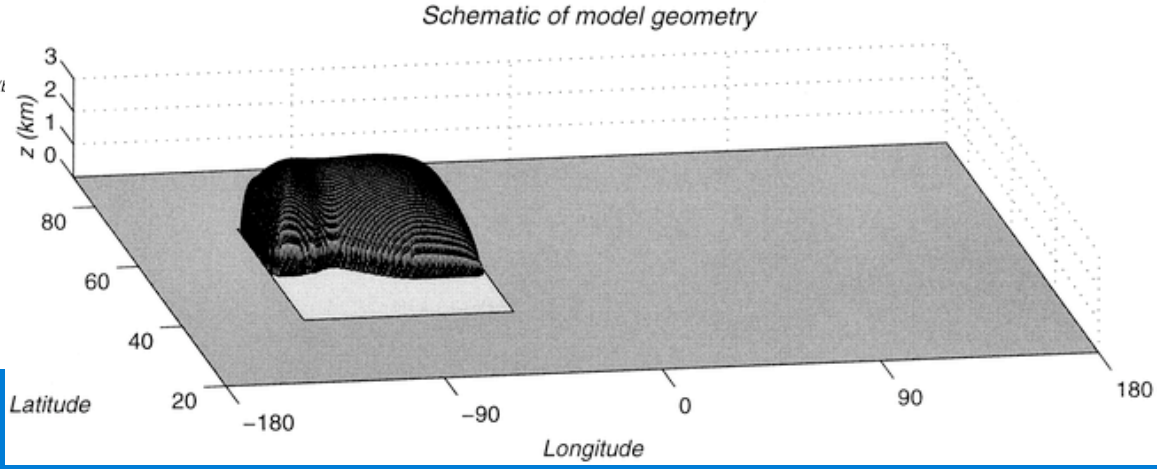


Adapted from
Peltier (1994), *Science*

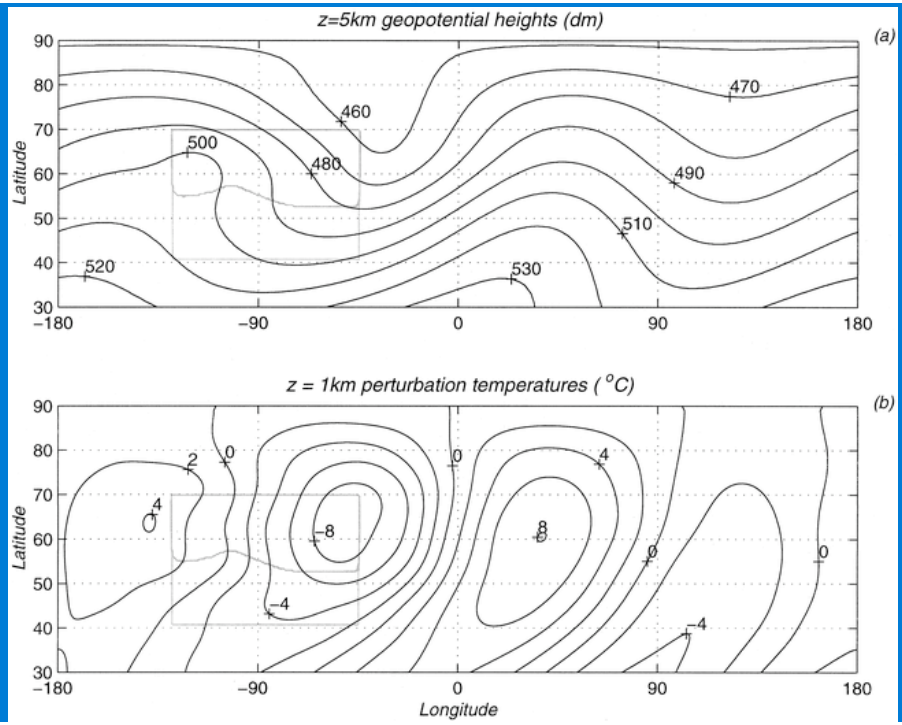




The most obvious abrupt climate events (D-O) disappear with the great continental ice sheets. Is this an accident?



Roe and Lindzen, 2001, J. Clim.
Also see C. Jackson, 2000, JGR



Is it a coincidence that apparent abrupt climate change only occurs during the presence of the continental ice sheets?

What controls the ocean circulation? There exist a few ways to answer the question. The simplest theories, going back over 50+ years, suggest that if one wants to change the circulation, quickly and efficiently, one should change the wind stress. Signal velocities can be as fast as the rate at which the atmosphere propagates disturbances, or as fast as the ocean itself can propagate signals---the barotropic response time – days.

In energy terms, fluid dynamics and thermodynamics both strongly imply (not rigorously proven) that only the wind and tides can matter.

Any serious discussion of how the ocean circulation varied through time requires a quantitative knowledge of the wind field. As there is no proxy for wind (dust concentration is a partial proxy for wind speed, but not direction) it has been widely ignored. If such a proxy existed, probably the entire history of the subject would have been different! For mid- and high- latitude oceanic regions, the curl of the windstress is extremely important. One need not reverse the sign of the windstress to induce a major change---merely shift the derivatives.

Wind field, and its interaction with the continental ice sheets, is the 800 pound (kilogram?) gorilla of the climate system.

It seems premature to conclude that:

(1) Abrupt climate change in Greenland extends much beyond Greenland except for what large-scale wind changes would induce elsewhere, or that abrupt tracer change necessarily implies significant abrupt climate change.

(2) The North Atlantic Ocean is the trigger rather than, primarily, a responder with feedbacks.

(3) A weakening of the North Atlantic circulation necessarily causes a change in the global-scale atmospheric climate (regional is a different matter).

(4) Greenland abrupt climate change during glacial conditions has direct relevance for possible abrupt climate change in the present world.

(5) The models being used to depict abrupt climate change have any skill on such timescales (have not discussed today).

Not the same as a disproof---but an open mind seems important, as the standard story is now in all the textbooks as ‘fact’.

Thank you.