Heinrich Events:

In 1988 a German scientist (Heinrich 1988) discovered six layers in North Atlantic sediments dated approximately 12, 16.5, 23, 29, 37, ?, 75 and 135 Kya., with the following qualities:

1. 20% of sand-sized fragments are detrital limestone
2. Clay sized minerals have higher K-Ar ages (1Byr) than those of surrounding sediments.
3. Devoid of basal-derived clay minerals so abundant in surrounding glacial sediment.
4. Detrital layer thins by more than an order of magnitude from Labrador Sea to European end of 46N iceberg route.

Conclusion: Canadian origin for armada of Heinrich icebergs.

5. Dominant feature not the great abundance of ice-rafted debris, but rather the small amount of foraminiferal shells. Drops from thousands per gram to hundreds per gram.
6. Dilution by ice-rafted sediment cannot be the sole cause, because geographical extent of foram-depleted sediment exceeds that of the Canada-derived detritus. Must reflect a dramatic decrease in ocean productivity.
7. Heinrich events occurred during the coldest times, as evidenced by N. pachyderma down to 45N.
8. Depleted $\delta^{18}O$ content of few forams in Heinrich layers suggests the presence of a low salinity lid.

Conclusion: Heinrich events occurred during a period of extensive sea-ice covers in N. Atlantic similar to today's Arctic Sea.

9. Heinrich events are relatively brief and tend to occur at the boundaries of major climatic transitions as indicated by $\delta^{18}O$. Event number six occurs at the transition between the last interglacial and the following glacial sequence about 130Kya. Heinrich event 1 marks the onset of the termination which brought the last interglacial to a close.

Speculation: Fresh water released during Heinrich events disrupts deep-water formation, thereby permitting switches between glacial and interglacial modes of thermohaline circulation.

10. Heinrich events occur on a roughly 10Kyr interval.

Speculation: Timing is set by shift of insolation associated with Earth's precession on a 20Kyr cycle, perhaps something in the tropical circulation?

11. Ice cores show low CH_4 associated with the cold events during which most H-events take place. This suggests a global imprint of these oscillations, since CH_4 is formed in tropical wetlands by anaerobic bacteria, primarily. There is also lots of other evidence for responses to the cold intervals in the Andes glaciers .

Conclusion: At least for YD event, you can't say that the climatic response was limited to the N.Atlantic regions. Something bigger is involved. Schulz, et al.(1998) find

correlated changes over the Arabian Sea, and Vidal et al. (1999) find connections between the North and South Atlantic.

Heinrich-Continued

Bond and Lotti(1995) looked at a high resolution record of continental material in two ocean cores and compared this with temperature estimates from the GRIP ice core and SST from ocean cores. They found a lot of depositional events that seemed to come from synchronous discharges from the Icelandic ice cap and the Gulf of St. Lawrence. These occurred on intervals of 2-3Kyr and were interspersed between the bigger Heinrich events coming from Hudson Strait, Canada with a slower rythmn. Moreover, these events were well-correlated with air temperature events in the Greenland cores (Dansgaard-Oeschger coolings), but were not as well correlated with changed in SST in the N. Atlantic. These data suggest that:

Conclusion: The ice surges are probably not driven by internal ice sheet time scales, but rather by external atmospheric forcing - the ice surges into the sea when it gets really cold. The reasoning is that widely separated ice sheets are not likely to surge simultaneously unless they are both driven by the same external timing mechanism(atmospheric temperature).

The temperature surges are probably not driven by the N.Atlantic thermohaline circulation changes, because the ice surge events seem better correlated with air temp over Greenland, than SST over the N. Atlantic.

In a related study, Lowell, et al.(1995) showed from ^{14}C dated glacial till material, that southern hemisphere glaciers advance and retreat in synchrony with NH air temperature estimates. Many of the glacier advances in the SH are synchonous with ice-rafting events during cold periods in the N.Atlantic. In particular, there was a wide spread glacial collapse around 14Kya, a full 1,300 yrs before the major north Atlantic thermohaline switch at about 12.7Kya. Paleo people are now looking for an atmospheric mechanism for the rapid global climate changes that occurred during the Pleistocene, perhaps involving water vapor and the tropical climate, which from recent evidence we are beginning to this underwent rather larger changes (5˚C) than was previously thought. This is a big change from a few years ago, when the thermohaline circulation and ice sheets seemed to dominate discussion of climate variability during the last 100Kyr.

Conclusion: Should search for an atmospheric mechanism for climate fluctuations on the 2-3Kyr time scale that does not involve the thermohaline circulation, the ice sheets, or orbital parameters.

The events seem to occur only when the ice volume is relatively large, the temperatures are relatively cold, and the sea level is 40-60 meters below present values (Chapman and Shackleton 1998). One can also argue for changes in the relationship of surface and benthic processes that suggest a thin layer of low salinity water at the surface (Chapman and Shackleton 1999).

One can find additional information on Heinrich Events and even higher frequency oscillations in temperature and ice mass can be found in (Broecker, et al. 1990, Bond, et al. 1992a, Bond, et al. 1992b, Broecker, et al. 1992, Bond, et al. 1993, Dansgaard, et al. 1993, McManus, et al. 1994, Bond, et al. 1997, Chapman and Shackleton 1998,

Elliot, et al. 1998, Stauffer, et al. 1998, Chapman and Shackleton 1999, Chapman, et al. 2000)

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