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Last Interglacial End

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ABSTRACT. Last interglacial ended approximately 115 thousand years ago, when the Norwegian warm current was substantially reduced and the dominant near-meridional circulation in Europe turned into near-zonal. Sites in southwestern Europe continued to experience temperate climate. Build-up of the Early Glacial ice was accompanied by the warming of equatorial ocean. Some features of the seasonal and geographic distribution of recent temperature and precipitation anomalies indicate that the cause of the ongoing global warming has a significant natural component.

KEY WORDS: Last Interglacial, Eemian, global warming, El Niño.

There were four interglacials in the last half million years and ours is the fifth one. Past interglacials invariably ended with the increase of solar energy income to low latitudes in boreal spring, compensated by decrease to high latitudes in autumn. The change was caused by orbital shift. A qualitatively similar shift is taking place now (Kukla et al., 1992).

The question is whether the current interglacial will :

1) -last into foreseeable future, maintained by increasing levels of greenhouse gases,
2) -end suddenly with a catastrophic breakdown of thermohaline circulation, or
3) -gradually turn into a colder world following the orbitally driven blueprint of past interglacials, only in part modified by the artificial increase of greenhouse effect.

Seasonal and geographic patterns of the temperature and precipitation departures during the last fifty years point to the third variant as the most likely. Recently observed global warming is marked by a seasonally uniform air surface temperature increase and precipitation decrease in the tropics, opposed by a relatively minor changes of latitudinally averaged temperature in the high latitudes of both hemispheres (Kukla et al., 1998). Two features show that there must be a substantial natural component in the current climate change. It is the lack of preferential Arctic warming expected from the general circulation models of the CO_2 impact, and the cooling experienced between the1940s and the late1970s, when carbon dioxide concentrations were rapidly increasing.

The Eemfest workshop held in October 1999 at Lamont Observatory of Columbia University reviewed currently available information on the ending of the last interglacial. It was concluded that the interglacial climate was very similar to current times, and partly even more temperate and less volatile. The span of relative climatic calm was equally long, if not longer, as the current warm period. During that time, represented by the marine isotope oxygen stage (MIS) 5e, lasting from approximately 130 to 116 ka ago (Martinson et al., 1987), the natural environment over much of the globe resembled the conditions of the last 10 ka. A tall mixed hardwood forest with close canopy covered much of Europe and the warm currents reached far north. Only toward the very end of MIS 5e and only in the northernmost North Atlantic were the pulses of increased ice rafting and cold water detected (Seidenkrantz and Knudsen, 1994). Reports of high climate variability in the last interglacial, based on misinterpretations of Greenland ice cores and on incorrectly dated pollen sites in Europe, are misleading. The glacier in the southern part of Greenland was substantially reduced, reached a lower elevation and was affected by summer melt. The upper parts of the pollen bearing sediments of Eemian biozone in Vosges and in Massif Central in France, considered earlier to be of interglacial age, were deposited in Early Glacial. (Kukla et al., 1997)

At the time of the MIS 5e/5d boundary, some 115 to 116 ka ago, the orbital configuration was closely similar to the current one (Kukla and Gavin, 1992). Since about that time, the climate started to gradually deteriorate. The southern part of Norwegian current, which kept northern Europe warm, was affected by ice rafting pulses. At approximately the same time, the surface temperature in Vostok, (Petit et al., 1999), begun to decline rapidly (Fig. 1). During the next several millennia of the Early Glacial, the hardwood trees in the mixed forests of Lure (Grande Pile) and Ribains interglacials in France were gradually replaced by pine and fir (Woillard, 1978; Beaulieu and Reille, 1992). Open vegetation expanded and retreated in several pulses. Some of these swings toward drier or cooler climate in the second half of the Eemian biozone were assigned earlier erroneously to MIS 5e (Thouveny et al., 1994). The ice build-up during the deposition of the upper part of Eemian biozone in Grande Pile was already well underway and the sea level was dropping. However the central part of North Atlantic remained warm. It might have become even warmer, due to the southward deflection of warm currents from the northernmost North Atlantic. This could explain the pollen record in La Grande Pile which shows maximum expansion of Hedera, Ilex and Buxus in the early MIS 5d. These taxa require a warm wet winter.

Using past insolation values in the predictive model of El Niño events, Clement and Cane (1999) have shown that the frequency of warm events in equatorial Pacific during MIS 5d was twice as high as in the MIS 5e. Thus it is not only impossible, but highly probable that the early stage of the last glacial was marked by warming of low latitude oceans. At the same time major circulation shifts and sea ice advances in the northernmost North Atlantic accompanied sea ice growth on surrounding lands (Mangerud and Svendsen, 1992).

A rapid cooling occurred in France at about 110 ka BP. At this time the broadleaf trees perished, replaced by pine and spruce. This abrupt event in the late Eemian biozone took only few decades (Woillard, 1989). Final end of the closed Eemian forests in France came in the late MIS 5d, simultaneously with the cold water and iceberg surge in central North Atlantic at about 107 ka ago (McManus et al., 1994; Kukla et al., 1997). It is unclear at what time were the woodlands in northwestern Europe replaced by open vegetation. Varve counts in Bispingen (Müller, 1974) and in Quakenbruck, Germany (Hahne et al., 1995), indicate that it happened substantially earlier than in France (Kukla, 2000).

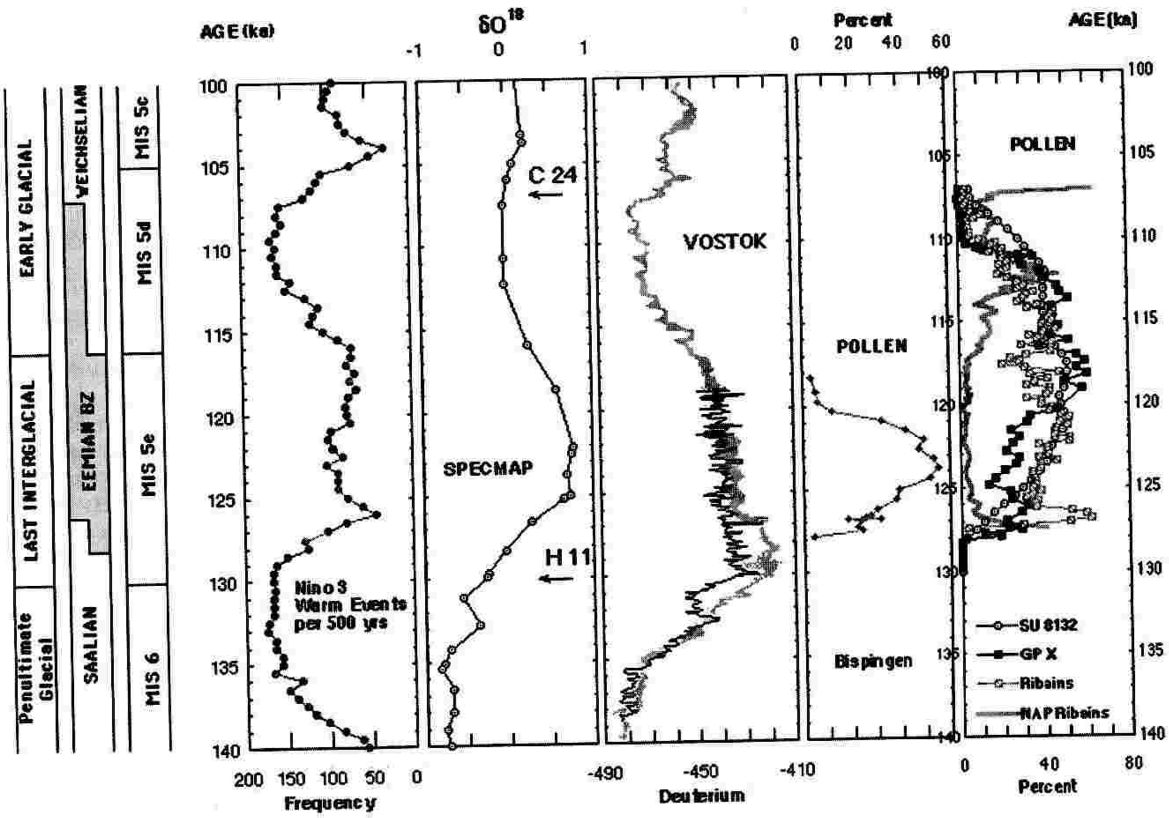

Fig. 1. Tentative correlation of stratigraphy and selected paleoclimate indicators of the last interglacial and early glacial. From left to right: Eemian biozone in France and northern Germany after Kukla (2000) and Shackleton (in press); marine oxygen-isotope stages from Martinson et al. (1987); frequency of El Niño events per 500 years after Clement and Cane (1999); SPECMAP benthic oxygen isotope curve of Martinson et al. (1987) and ice rafted detritus events C24 and H11 from McManus et al. (1994); local temperature proxy in the Vostok ice core in grey, overlain by the Late Glacial and Holocene record of the same core in black, from data of Petit et al. (1999); Carpinus pollen in Bispingen after Müller (1974) and the combined percentage of Carpinus and Quercus in the tree pollen count of the Atlantic core SU 8132 after Turon (1984), in Grande Pile GPX core from Woillard (1978) and in Ribains after Beaulieu and Reille (1992). Also shown percentage of non arboreal pollen (NAP) in the total count.

Conclusion

Summarizing, the last interglacial ended at the MIS 5e/5d boundary some115 or 116 ka ago. Norwegian warm current was substantially reduced at that time and the dominant meridional circulation in Europe shifted to a dominant zonal. Meridional gradient in the ocean and over land increased greatly. Dropped sea level joined Britain with the rest of Europe. Central North Atlantic and the southwestern Europe remained warm for several more millennia. A mixed temperate Eemian forest remained in France during the Early Glacial until about 110 ka BP. Boreal phase of the Eemian biozone in France terminated in the second half of MIS 5d, well within the glacial, at about 107 ka ago. The rapid shift to open vegetation occurred in sync with major expansion of cold water and icebergs in central North Atlantic. The shift from peak interglacial environments into the early glacial ones in MIS 5d advanced gradually from the high into the low latitudes. The paleoclimate proxies in MIS 5d, both in the ocean as well as on land, show a stepwise sequence of relatively rapid deteriorations followed by slower partial recoveries that lasted several centuries each. Such behavior is consistent with the expected impact of iceberg surges and flip-flops of thermohaline circulation (Bond and Lotti, 1995; Broecker, 1994).

Several features of the last interglacial/glacial transition resemble the recent temperature and precipitation trends They are:

1) Preferential warming of the low latitudes.

2) Increasing meridional temperature gradient.

3) Increasing precipitation in cold season in the high northern latitudes (which supposedly also accompanied the ice build-up in MIS 5d).

4) Cooling of the northern North Atlantic with simultaneous warming of the equatorial one.

While some of the above features may be due to the increase of man-made greenhouse gases, they may also indicate that the natural redistribution of shortwave radiation is already affecting the ongoing climate change (Kukla et al., 1992). However no increase of ice volume, nor a decrease of mean sea level have yet been observed. So even if not completely counter balanced by future impact of man-made greenhouse gases, the natural shift toward cooler climates in the middle latitudes of the Northern Hemisphere would be still many millennia ahead. Another point to consider is that the orbitally caused seasonal insolation changes, although qualitatively similar, are less expressed than in the last interglacial. Their amplitude is closer to the exceptionally long Holsteinian interglacial (MIS 11).

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