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The last interglacial warm period record of the Arctic Ocean: proxy-data support a major reduction of sea ice

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Rapid changes of the Arctic environment seen over the last decades are considered to be a likely consequence of global warming and polar amplification. One of the most conspicuous changes observed is the large areal reduction and thinning of the perennial sea ice cover. A large body of instrumental and modelling data suggests that modern Arctic sea-ice is extremely dynamic and sensitive to wind and thermal forcing over decades to centuries. In order to understand the long-term variability and magnitude of natural changes in the Arctic Ocean environment, we focus on Arctic Ocean records from the Last Interglacial (LIG) warm period (Eemian), at about 115-125 thousand years ago. Many paleo-data from the circum-Arctic region indicate that this period was even warmer than today, thereby serving as a possible analogue for future climate trends (CAPE Last Interglacial Project Members, 2006, Quat. Sci. Rev., 25(13–14), p. 1552–1569). However, very few high–arctic oceanic records of this period are available. This study presents intriguing new paleoceanographic data supporting a considerable reduction of Arctic summer sea ice during some part of LIG. Calcium carbonate-shelled planktic foraminifers preserved in sediment cores are used as proxies of former sea ice conditions and properties of surface-near water masses. Studies of planktic foraminifera distribution and isotope signals in present day subpolar-polar regions are used to valid proxy reconstructions and to better understand the messages of the past. At present, subpolar Turborotalita quinqueloba (hereafter named Tq) shows maximum abundance in the Nordic Seas along oceanic fronts, in particular the Arctic Front that separates Atlantic and Arctic Water masses. The Fram Strait and Barents Sea Margin, currently characterized by strong subsurface advection of Atlantic water below colder and lower-salinity polar surface water, contain abundant living subpolar Tq in the upper 200-300 m of the water column. The abundance of Tq declines rapidly further to the north and to the east (permanently ice-covered regions), where the species assemblage is totally dominated by polar Neogloboquadrina pachyderma (sinistral). Sediment cores retrieved from the Lomonosov Ridge close to the North Greenland margin reveal two sediment units with an exceptionally high abundance of small subpolar foraminifera. Detailed stratigraphic investigations confirm that the layer with the highest Tq percentage represents the last interglacial period. The Tq specimens are typically in the size range 63-125 µm, and as planktic foraminifera assemblages below 125 µm have only rarely been studied, we have re-analysed key sediment cores with a well-defined LIG section from the interior Arctic Ocean (Morris Jesup Rise, central Lomonosov Ridge, Alpha Ridge). Almost ubiquitously we find large numbers of small Tq specimens in the LIG section. This assemblage is in stark contrast to species data of Holocene sections representing the last ca. 11.000 years, all showing a clear dominance of polar specimens and very rare subpolar Tq. Oxygen isotope values of the LIG subpolar specimens from the interior Arctic are much lower than LIG values preserved in the Fram Strait region. This is further supportive evidence for an in-situ interior Arctic Ocean production of the subpolar specimens. At present, the North Greenland margin and Alpha Ridge adjacent to the Canadian margin are characterised by the toughest sea-ice conditions of the Arctic Ocean and most climate models of future summer sea-ice reduction predict that this region may be the last sea-ice stronghold. As the major arctic circulation systems of the LIG and the present may have been quite identical, we conclude that summer sea ice during (at least) parts of LIG was much reduced over large parts of the Arctic Ocean. Due to a low time-resolution of the interior Arctic records we are not, at this stage, able to pin-point in more detail the exact timing of the events and possible linkages to North Atlantic/Nordic Seas reconstructions. Recent high-resolution studies of foraminifera assemblages and dinocyst content from the Nordic Seas indicate that the most pronounced advection of warm Atlantic water culminated in the late part of LIG, but also that a significant regional variability prevailed (Van Nieuwenhove et al., 2008, Mar. Micropal., 66, p. 247-263). A seasonally sea ice-free Arctic hypothesis, however, is supported by recent studies of the last interglacial in high Northern Hemisphere showing evidence that some part of the last interglacial was warmer than the Holocene interglacial (CAPE, 2006). Sea-level and climate modelling studies also support extreme Arctic warming with a reduced Greenland ice sheet as a response to a higher Northern hemisphere summer insolation (Overpeck et al., 2006, Science 311, 1747-1750; Otto-Bliesner et al., 2006, Science 311, 1751-1753).