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Surface and deep water variations and their impact on the Meridional Overturning Circulation during the mid-Brunhes as revealed at IODP Sites U1313 and U1305

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Climate records from IODP Site U1313 (41°N, 33°W; 3412 m w.d.) from the mid-latitude North Atlantic are used to reconstruct surface and deep-water changes during the mid-Brunhes glacial – interglacial cycles of Marine Isotope Stages (MIS) 10 to 16 (340 – 640 ka), the interval encompassing the mid-Brunhes event at the end of MIS 12 with colder interglacials prior to the event and warmer ones afterwards. G. inflata stable isotope and trace element records are combined with lithic fragment concentrations to trace surface water variations and the presence of melting icebergs. Deep water conditions are revealed by benthic foraminifer stable isotope date and the mean grain size <63μm.

Site U1313 surface water records reflect conditions in the North Atlantic Current and its southward displacement by incursions of iceberg-laden subpolar waters. Major Heinrich-type ice-rafting events were associated with terminations V and VII, but also occurred within MIS 10 and 12. During the MIS 10.4 Heinrich-type event winter mixed layer temperatures, as recorded by G. inflata Mg/ Ca data, dropped as low as 2°C. MIS 14, often called the "failed" glacial, stands out as a period of minor ice-rafting at Site U1313, but was associated with three major events off southern Greenland at IODP Site U1305 indicating that the Polar Front was positioned further to the north than during the more pronounced glacial MIS 10, 12 and 16. Nevertheless, the meridional overturning circulation (MOC) was weakened during all glacials as indicated by the lower benthic 13C values and thus the presence of Antarctic Bottom Water (AABW).

Interglacial surface water conditions were in general more stable during MIS 11.3 and 13.1 than during MIS 15 with winter mixed layer temperatures between 9 and 12°C. For MIS 11.3 the data, however, shows that cooling in the winter mixed layer started already at 405 ka, i.e. > 5 ka prior to the end of interglacial warmth as recorded in the alkenone temperatures at Site U1313 (Stein et al., 2009; Paleoceanogr.) and to the weakening of the MOC as revealed by declining benthic 13C values. MOC was strong with North Atlantic Deep Water (NADW) bathing Site U1313 during all the interglacials. Deep water ventilation was, however, reduced during MIS 15 and the mean grain size data furthermore shows that bottom current strength was stronger than during the younger interglacials. Thus the records of Site U1313 reveal that MIS 15 is the "outsider" in the suite of mid-Brunhes interglacials studied.

The glacial inceptions were marked by frontal movements inducing centennial-scale cooling/ warming cycles in the surface water and oscillations in the depth of the NADW/ AABW interface. Stadials led to cooling in the surface waters and MOC weakening. Interstadials, on the other hand, were associated with relative warm and stable surface water conditions and a strong MOC. During interstadial MIS 11.23 mixed layer temperatures reached 11°C, i.e. interglacial levels, while the subsequent interstadials were 3°C colder. Outstanding Mg/ Ca analyses for the older stages will show if this pattern of winter mixed layer temperatures during the first interstadial of a glacial inception being close to interglacial level will hold up and if these variations are linked to insolation.

One recurring pattern is already seen for all glacial inceptions and that is that with increasing ice volume the length of the interstadial periods become shorter with the last one only lasting about 600 years.