Avancées scientifiques : Exp. anciennes IODP 306

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North Atlantic Mid-latitude Surface-Circulation Changes Through the Plio-Pleistocene Intensification of Northern Hemisphere Glaciation

E Knowledge of surface- and deep-ocean current pathways and strength ("ocean circulation") is critically important to improve our understanding of what drives and amplifies climate change on planet Earth, on both short (tens to hundreds of years) and long (thousands to millions of years) timescales. The North Atlantic Ocean is a key region in the global picture, because surface ocean currents here (namely the Gulf Stream and the North Atlantic Current, NAC) play a major role in transporting heat and moisture from the tropics to the polar northern latitudes, providing western Europe with a much milder climate than it would otherwise experience (Figure 1). The presence of warm, salty water at high latitudes creates conditions that favour density-driven overturning and sinking of water parcels, leading to the creation of "North Atlantic Deep Water" that in turn drives the global thermohaline circulation conveyor belt (Figure 2). The NAC (which sits today between 45°N and 55°N) forms a boundary between cool, polar waters to the north and warm, tropical waters to the south, and its latitudinal position determines the extent of this northward heat transport (Fig. 1). In a recent study, we focused on understanding the history of the NAC during the last great climate transition on Earth ~2.6 million years ago (Ma), when the relative global warmth during the Pliocene (~5.3 to 2.6 million years ago) gave way to generally cooler conditions with progressively bigger glaciations during the latest Pliocene and Pleistocene (since 2.6 Ma). This climate transition is often referred to as the "intensification of

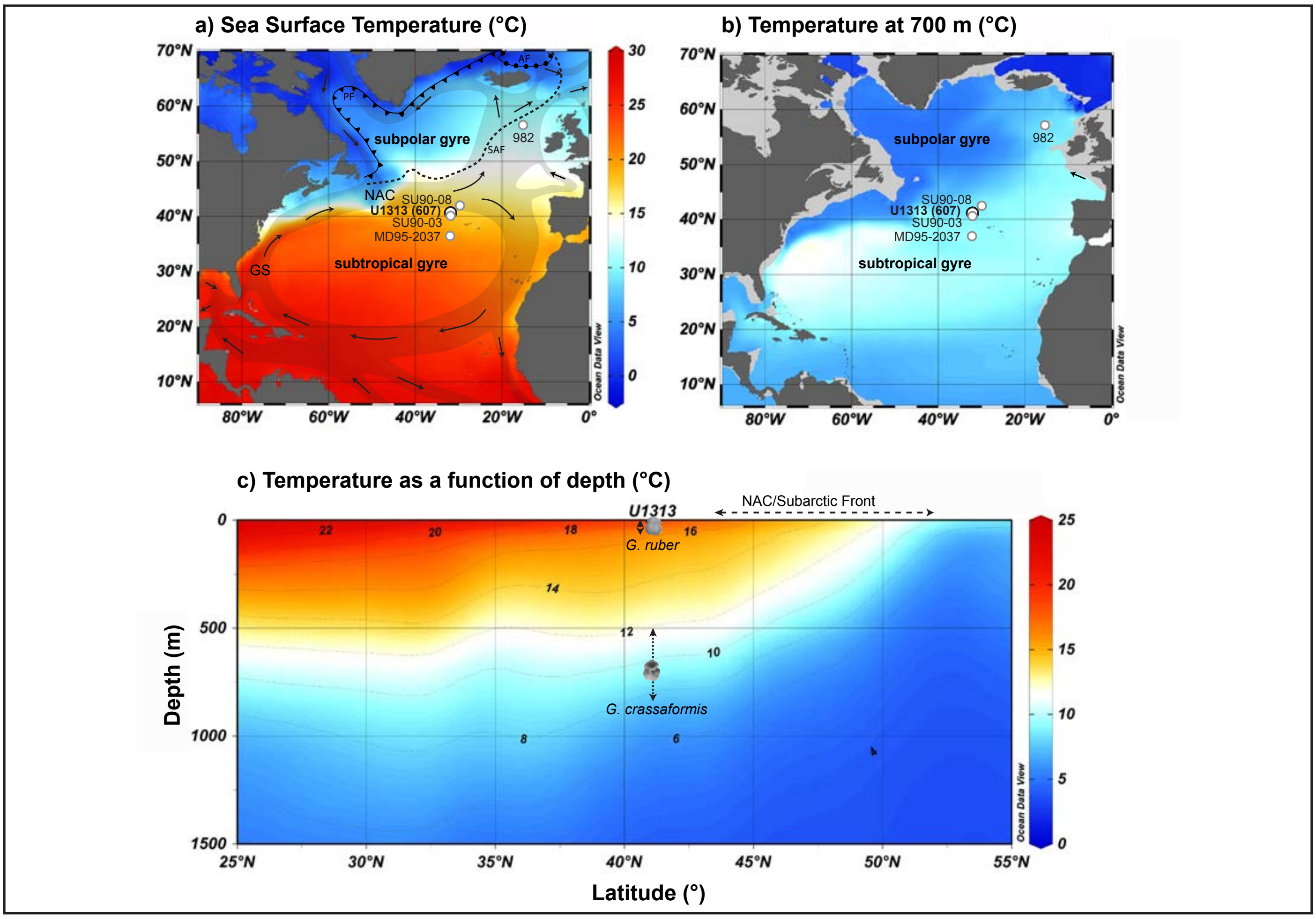

Figure 1 – Modern North Atlantic sea surface temperatures (colour scale), and the location of Integrated Ocean Drilling Program Site U1313 and other nearby sites discussed in the paper. Black arrows show simplified surface ocean currents. GS = Gulf Stream, NAC = North Atlantic Current. Black lines show approximate front positions according to Dickson et al. (1988): PF (triangles) = Polar Front, AF (dots) = Arctic Front, SAF (dash) = Subarctic Front. Map made in Ocean Data View (Schlitzer, 2015) using World Ocean Atlas 2013 temperature data (Locarnini et al., 2013).

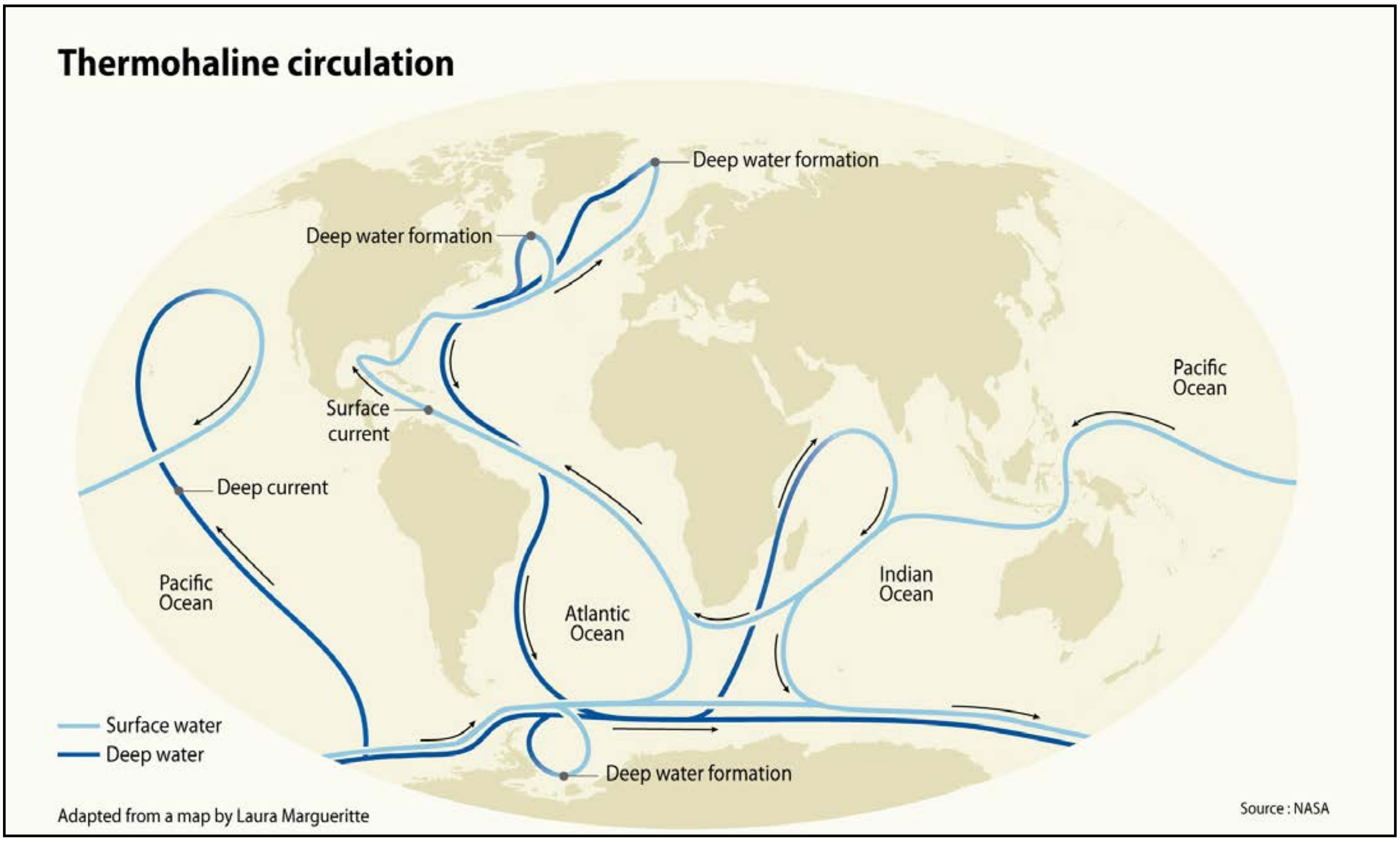

Figure 2 – A simplified schematic of global ocean thermohaline circulation (graphic credit: NASA).

northern hemisphere glaciation" (iNHG), because it was at this time that the first large, land-based ice sheets became established in high northern latitudes (Greenland, Scandinavia, and northern North America).

In our study (published in Bolton et al., 2018, *Paleoceanography and Paleoclimatology* and completed thanks to funding from *IODP-France*), we looked at a number of different indicators of past conditions during iNHG in the mid-latitude North Atlantic, using deep-sea samples taken from a sediment core (IODP Site U1313) drilled by the RV *JOIDES Resolution* in 2005 during IODP Expedition 306 (North Atlantic Climate 2). Indicators, or "climate proxies", applied include ocean surface temperature and oxygen isotopic composition (δ18O), the abundance of cold-water-favoring plankton, and the presence of sand dropped to the seafloor by melting icebergs as they floated south ("ice-rafted detritus", IRD). Our new data allow us to determine: (1) the exact timing of the first major southward migrations of the NAC and subpolar surface water masses into the mid-latitudes during iNHG (which is unclear from existing work in the region) and (2) whether these circulation changes were similar to the major changes thought to have occurred during the last glacial period (~ 20 000 years ago), as suggested by some authors and, (3) the role that North Atlantic circulation played in driving or amplifying the growth of northern hemisphere ice sheets at this time.

Planktic foraminifera are single-celled organisms that float in the surface layers of the ocean and produce a chalk ($CaCO_3$) shell using raw materials that are dissolved in seawater (calcium and carbonate) (Figure 3). The carbon and oxygen isotopic make-up of these shells reflects conditions in the ocean during their lifetime (lifespan = weeks to months), and upon their death, foraminifera shells sink slowly to the bottom of the ocean where they are buried in sediments if conditions allow. From our Site U1313 samples, we reconstructed surface and subsurface (~700 m) temperature and the oxygen isotope composition (δ18O) of seawater using paired Mg/Ca-δ18O measurements on the planktic foraminifers *Globigerinoides ruber* and *Globorotalia crassaformis* (which live at different depths) and determined abundances of the surface-dwelling subpolar foraminifer *Neogloboquadrina atlantica* (Figures 4 and 5).

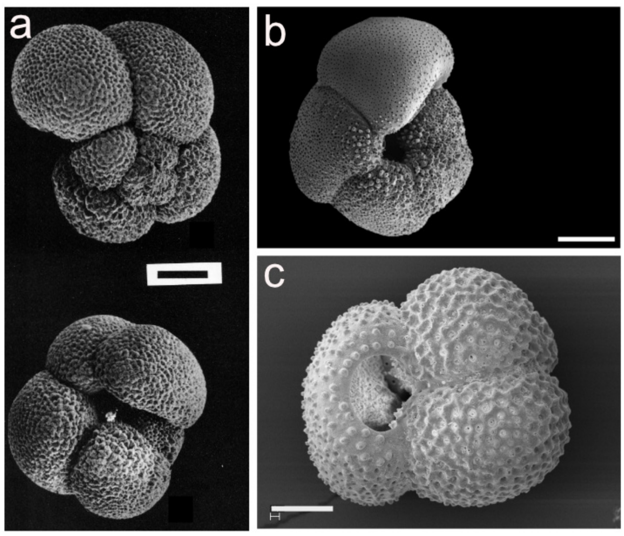

Figure 3 – Scanning Electron Micrographs of fossil planktic foraminifera shells studied belonging to the species studied here (a) N. atlantica (from Poore and Berggren, 1975, scale bar = 140 µm), (b) G. crassaformis (from Norris et al 1998, scale bar = 100 µm), (c) G. ruber (photo credit: O. Friedrich, specimen from Site U1313, scale bar = 100 µm).

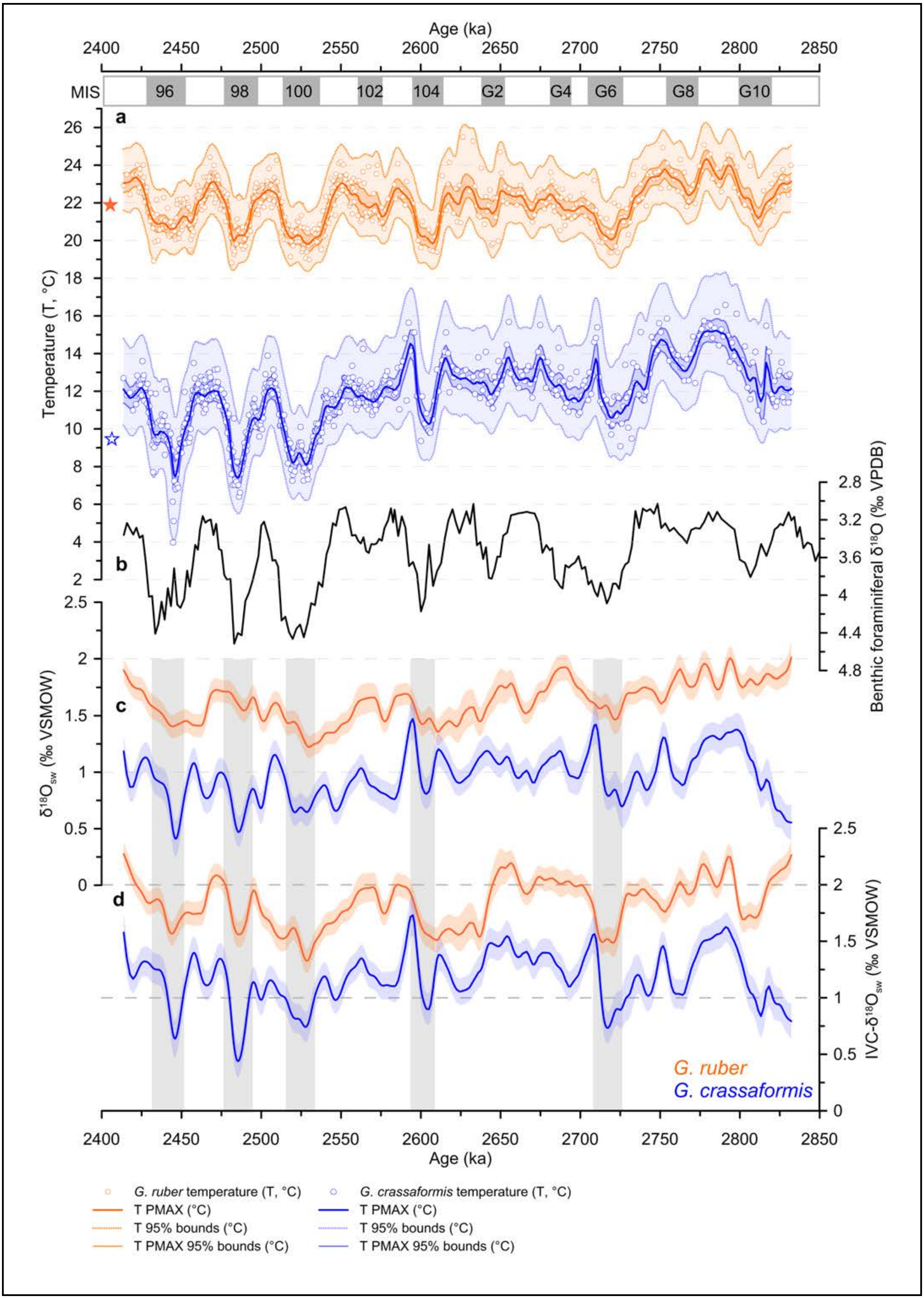

Figure 4 – Temperature and seawater δ18O records from Site U1313 over iNHG for two species of foraminifera (see publication for full detailed caption).

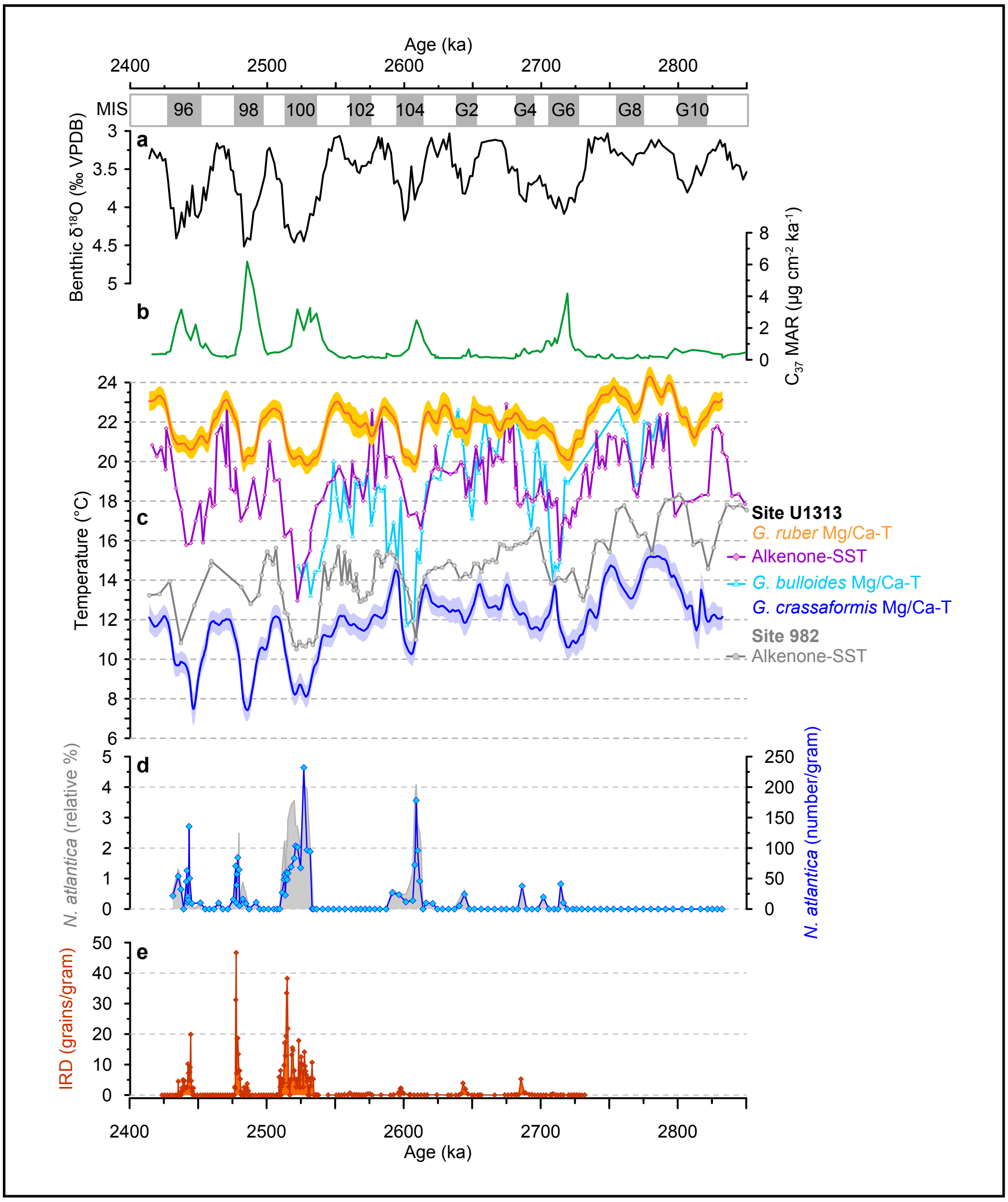

Figure 5 – New and previously published temperature, productivity, N. atlantica abundance, and ice-rafted detritus (IRD) records from Site U1313 (see publication for full detailed caption).

Considered alongside existing records (Fig. 5), our new data allow us to infer that the first significant glacial incursions of Subarctic waters above Site U1313 did not occur until ~2.6 Ma, later than previously suggested, and that the NAC did not adopt a position as far south as during the last glacial at any point during iNHG. At Site U1313, glacial surface ocean cooling during iNHG was modest (~50 %) compared to the 8–9 °C warming observed between the last glacial maximum and the Holocene (the current interglacial period) at the same location. The fact that the first significant influence of nutrient-rich subpolar surface waters at Site U1313 post-dates the onset of major glacial productivity peaks at our site by ~120 thousand years implies that changes in surface circulation at this time were not the sole driver of primary productivity in the midlatitude North Atlantic during iNHG. We propose that additional factors, namely, a significant increase in dust delivery from North America to the midlatitude North Atlantic during glacial periods from ~2.7 Ma onward and the influence of cold-core eddies (giant rings of subpolar water that break off from the front and travel south into tropical waters) originating from a closer NAC, helped promote an increase in productivity at this time.

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Références

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