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Sea surface temperature evolution of the North Atlantic Ocean across the Eocene-Oligocene Transition

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When a permanent ice cap developed on Antarctica during the Eocene–Oligocene transition (EOT; ~34.44 to 33.65 million years ago (Ma)), Earth witnessed a transition from a greenhouse towards a glacially driven climate. Evidence of high-latitude cooling and increased latitudinal temperature gradients across the EOT has been found in both marine and terrestrial environments. However, the timing and magnitude of temperature change in the North Atlantic remains poorly constrained.

Here, we used two independent organic geochemical palaeothermometers derived from (i) alkenones and (ii) Glycerol Dialkyl Glycerol Tetraether (GDGT) lipids, to reconstruct sea surface temperature (SST) evolution across the EOT from the southern Labrador Sea (Sites: ODP 647 and DSDP 112). In the Labrador Sea alkenones do not appear until the earliest Oligocene (both sites) while GDGT lipids (analysed in Site 647 only) provides a well-constrained temperature record across the EOT.

Our SST records provide the most detailed record for the northern North Atlantic through the 1 Myr leading up to the EOT onset, and reveals a distinctive cooling step of ~3 °C (from 27 to 24 °C), between 34.9 and 34.3 Ma, ~500 kyr prior to Antarctic glaciation. This cooling step, when compared visually to other SST records, is asynchronous across North and South Atlantic sites. This illustrates a considerable spatiotemporal variability in SST evolution in the northern sector of the North Atlantic and the Norwegian-Greenland Sea. Overall, the cooling step fits within a phase of general SST cooling recorded across sites in the North Atlantic in the 5 Myr interval bracketing the EOT.

We used a modelling study (GFDL CM2.1) to try and reconcile the observation of pre-EOT cooling

with the hypothesis that Atlantic Meridional Overturning Circulation (AMOC) switched on or intensified on the lead up to the EOT, which would be expected to have warmed the North Atlantic region. Results suggest that a reduction in atmospheric CO_2 from 800 to 400 ppm may be sufficient to counter warming from an AMOC start-up. In the model, the AMOC start-up is initiated during closure of the Arctic–Atlantic gateway.

While the model simulations applied here are not yet in full equilibrium, and the experiments are idealized, the results, together with the proxy data, highlight the heterogeneity of basin-scale surface ocean responses to the EOT thermohaline changes, with sharp temperature contrasts expected across the northern North Atlantic as positions of the subtropical and subpolar gyre systems shift in response to climatic and oceanic adjustments.