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Supporting Online Material for

Enhanced Modern Heat Transfer to the Arctic by Warm Atlantic Water

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METHODS

Sediment sampling, preparation, and CTD measurements

The 46 cm long sediment core MSM5/5-712-1 was obtained by a giant box corer (50x50x60 cm) from RV *Maria S. Merian* on August 4, 2007. A surface sample was taken with a spoon by skimming off the uppermost ~0.5 cm and preserved in ethanol with Rose Bengal to stain living microorganisms. A plastic archive box was pressed horizontally into the core, thereby avoiding vertical compression. Slices of 0.5 cm thickness (~25 cm^3) were taken manually from this box, freeze-dried, washed in deionized water through a 63 µm mesh and split into several size fractions. Dry bulk density was determined every 5 cm from defined 10 cm^3 samples. Temperature and conductivity measurements at the position of site MSM5/5-712 were performed with calibrated Seabird 911 Plus CTDs from RV *Jan Mayen* (October 12, 2006; site JM06-WP-02) and RV *Maria S. Merian* (August 4, 2007; site MSM5/5-713-1). Uncertainties are <0.005°C and <0.005 practical salinity units.

Radiocarbon dating

Five accelerator mass spectrometry ^{14}C datings (Table S1) were performed at the Leibniz Laboratory of Kiel University on ~2000 specimens of the planktic foraminifer *Neogloboquadrina pachyderma* (sin.) per sample. Dated material from the surface sample contained additional planktic foraminiferal species. The surface sample contained many Rose Bengal stained foraminifers and yielded ^{14}C from nuclear bomb tests (103.47 pMC). We therefore assigned a Zero age (year of core sampling) to the sediment-water interface. ^{14}C results of the other samples were calibrated to calendar years by the CALIB 6.0 programme (*S1*) with the Marine09 data set (*S2*) and a standard reservoir correction of 402 years. A stratigraphic model of calendar year ages was established by linear interpolation between the calibrated AMS ^{14}C ages.

SIMMAX paleotemperature reconstruction

Planktic foraminiferal counts were performed on representative splits (~500 specimens per sample) of the 100-250 µm fraction on all samples to register also small subpolar species which have an abundance maximum in the 100-150 µm fraction (*S3*) (Fig. S1). The 150-250 size fraction was counted every 1 cm for the interval before AD 1835 and every 0.5 cm thereafter (uppermost 5 cm) to calculate summer paleotemperatures (July-September) at 50 m water depth using the SIMMAX technique (*S4*) and the 2003 core-top reference data set (*S5*). SIMMAX normally uses the >150 µm fraction but we checked the >250 µm fraction and found that it contains only negligible numbers of planktic foraminifers. The method proved to reach a better accuracy than other classical modern analog and transfer function techniques, especially in high latitudes (*S4, S5*). The reconstructed SSTs are calculated as mean SSTs of the ten best analogs weighted by the similarity indices which estimate the degree of analogy of foraminiferal assemblages between the core samples and modern core top samples from the data base in Ref. *S5*. Our similarity indices are >0.99 for all analyzed samples except 0.25 and 0.5 cm (0.97). All these values fall within the "very good" similarity range (*S4*). Below 3°C SIMMAX tends to overestimate temperatures (*S5*). Thus, the reconstructed temperature increase from the Little Ice Age to the Modern (Industrial) Period probably represents a minimum value.

Mg/Ca paleotemperature reconstruction

For Mg/Ca analysis ~50 tests of *N. pachyderma* (sin.) per sample were picked from the 100-150 µm fraction. The size interval was kept narrow in order to avoid a possible size-dependent bias (*S6*). In preparation of Mg/Ca measurements, foraminifers were gently crushed between glass slides. Subsequently each sample underwent the trace metal cleaning procedures described elsewhere (*S7, S8*). Samples were analyzed for Mg/Ca by magnetic sector single-collector ICP-MS on a Thermo-Finnigan Element2, using methods adapted from Rosenthal et al. (*S9*) with a long-term 1σ precision of Mg/Ca for of 0.5% (*S10*). Four samples were rejected due to low post-cleaning mass recovery (< 5µg $CaCO_3$) (*S10*), leaving a total of 26 reliable Mg/Ca data (including two replicates). Elemental ratios of Fe/Ca and Al/Ca (detrital material) and Mn/Ca (secondary diagenetic coatings) were analyzed coincidental with Mg/Ca. No values of Mn/Ca exceeded 24 µmol mol^{-1}, which is well below the threshold for likely trace metal contamination (*S11*). One sample (0.25 cm) had Fe/Ca and Al/Ca values exceeding 100 µmol mol^{-1}. However, this single sample was not omitted as its Mn/Ca ratio did not show signs of contamination and its Mg/Ca value was similar to surrounding samples.

To convert the measured Mg/Ca ratios into temperatures we used the *N. pachyderma* equation of Elderfield and Ganssen (*S12*): Mg/Ca (mmol mol^{-1}) = 0.5 exp 0.10 T. This equation is indistinguishable from the Norwegian Sea *N. pachyderma* (sin.) calibration of Nürnberg (*S13*) and the cultured *N. pachyderma* (dex.) calibration of von Langen et al. (*S14*). Application of an alternative equation of Kozdon et al. (*S15*) results in consistently lower temperatures throughout the core which are also lower than the SIMMAX results.

Tests from the upper 10 cm of the core showed some signs of dissolution and were fragile. Generally, partly dissolved tests should be avoided as they may give too low Mg/Ca ratios and the reconstructed temperatures may be underestimated (*S16*). With respect to core MSM5/5-712-1, however, we regard the close similarity between temperatures reconstructed from independent SIMMAX and Mg/Ca results as evidence of a minor effect of dissolution. Were dissolution of importance, it would affect also the planktic foraminifer associations used for SIMMAX. Fragile subpolar species would be more easily dissolved than the only polar, robust species *N. pachyderma* (sin.), eventually leading to lower calculated SIMMAX temperatures especially for the youngest time interval. Thus, carbonate dissolution within the uppermost part of the core would result in an underestimation (by both methods) of the Atlantic Water temperature difference between the Modern (Industrial) Period and, e.g., the Medieval Climate Anomaly.

Replicate Mg/Ca analysis on separate picks at 0 cm and 28 cm core depth revealed differences of 0.01 mmol mol^{-1} and 0.12 mmol mol^{-1}, respectively. Although this is insufficient to provide a robust estimate of reproducibility, a pooled standard deviation of order 0.05-0.1 mmol mol^{-1} is typical for foraminifera (e.g., Refs. *S17, S18*). The standard deviation for each interval before and after AD 1850 was 0.1 mmol mol^{-1}, which translates to relatively large temperature ranges at the cold end of the Elderfield and Ganssen (*S12*) exponential calibration: +1.3/-1.5°C pre-industrial and +1.1/-1.2°C post-industrial. Since this is close to our estimated reproducibility, we cannot interpret the temperature variability *within* each interval, which we suggest is dominated by random error. However the *mean* within each interval is well constrained, with standard errors (stdev/sqrt[n]) of ±0.3°C pre-industrial and ±0.5°C post-industrial.

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Table S1. Results of radiocarbon datings

Depth (cm)	Interval (cm)	Laboratory Code	^{14}C age[a] (yr B.P.)	Standard deviation (^{14}C yr)	Calendar age (CALIB 6.0) using Marine09 data set and 402 yr reservoir correction		
					Mean (yr B.P.)	Standard deviation (yr)	Year AD
0.25	0.0-0.5	KIA39656	Bomb age[b]				2007[c]
14.75	14.5-15.0	KIA39262	820	25	476	23	1486
21.50	21.0-22.0	KIA39041	1290	30	838	45	1112
30.75	30.5-31.0	KIA39263	1760	25	1303	25	647
42.00	41.5-42.5	KIA38079	2270	25	1878	39	72

[a] Results are ^{13}C-corrected. [b] Sample contained 103.47 pMC. [c] Assumed age for 0 cm core depth, based on considerations described in Methods.

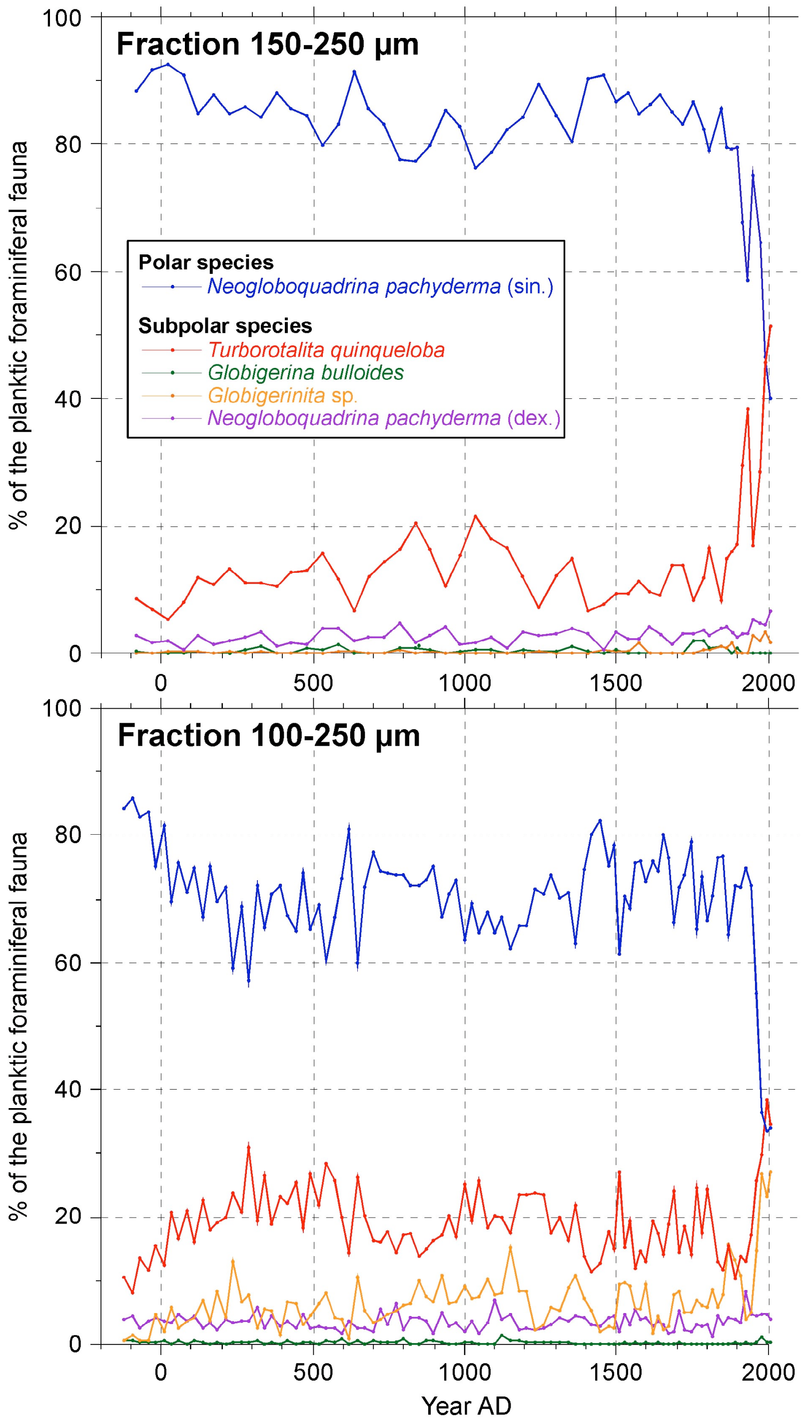

Fig. S1. Results of planktic foraminifer counts for the 150-250 µm (top) and 100-250 µm (bottom) fractions of sediment core MSM5/5-712-1. Data are given as relative abundance. Sample spacing is 0.5 cm (1 cm for samples older than AD 1844 in the 150-250 µm fraction). *Globigerinita* sp. accounts for *G. uvula* and *G. glutinata* which cannot always be distinguished when smaller than 150 µm. As a rule, the relative abundance of subpolar species appears higher when small specimens (size 100-150 µm) are included in the counting procedure. In particular, *Globigerinita* sp. are almost neglected when small specimens are not counted.