Variability of Foraminiferal Flux and Isotopic Composition at Sites Around Iceland and the Sea of Okhotsk, with a Special Focus on *N. pachyderma* (sinistral and dextral), *G. quinqueloba* and *G. bulloides*

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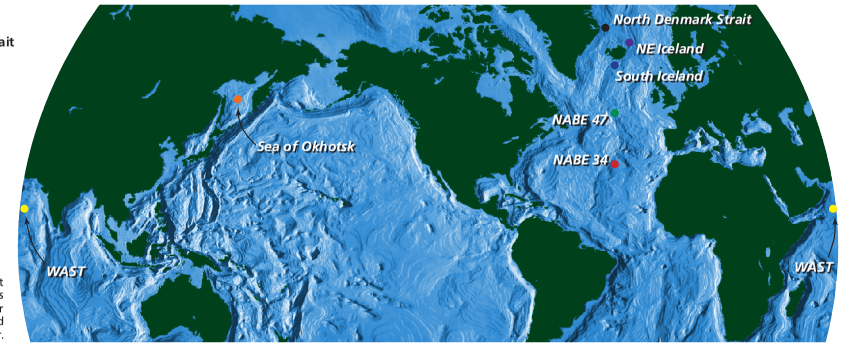
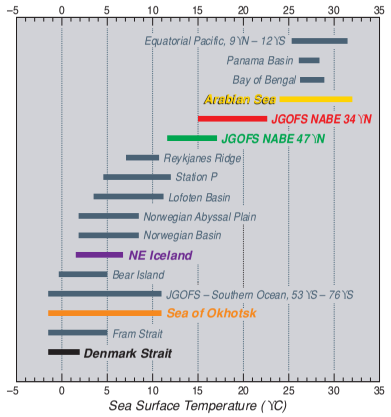
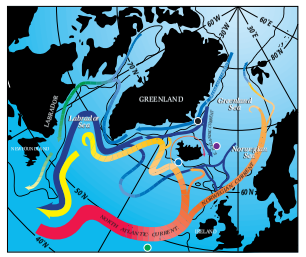
North Denmark Strait
NE Iceland
South Iceland
JGOFS NABE 47
JGOFS NABE 34
Sea of Okhotsk
West Arabian Sea



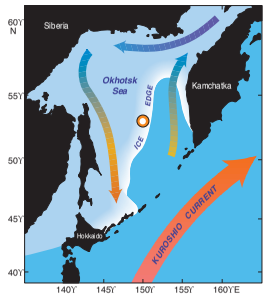
The location of sediment trap moorings used in this study. The color coding for each location will be used throughout the poster.



Seasonal sea surface temperature variation for the sediment traps used in this study cover the entire temperature range found in the world's oceans today.



Representative surface circulation scheme for the North Atlantic with the trap locations marked with color coded circles (modified from McCarthey et al.,1996). The North Denmark Strait trap was ice-covered for approximately 5 months during the deployment. All other traps in the Atlantic and Indian Oceans were ice free during the deployment duration.



Representative surface circulation scheme for the Sea of Okhotsk with the trap location noted by the orange circle. The March maximum sea-ice edge is indicated by the white shading (after Watanabe, 1968). The trap was covered with annual sea ice for approximately 5 months during the deployment duration.

North Denmark Strait - Because of seasonal ice cover at the location, very few *N. pachyderma* sinistral measurements were made. The four datapoints allow us to set the lag and show that at the very lowest temperature ranges, *N. pachyderma* sinistral lives at or near the surface in the summer.

NE Iceland - see the text for figures at lower left. In addition, it is clear that the lag of 4.3 months while appropriate for data from 1994-1996, may be too long for 1986-1988 and we don't have enough *G. quinqueloba* analyses from 1989-1994 to be more quantative about the lag.

South Iceland - This location is the northern-most extent of *G. bulloides* analyzed from this study. At this location we found that *G.quinqueloba*, *G. bulloides* and *N. pachyderma* dextral are calcifying at or near the surface and that only *N. pachyderma* sinistral continues to live deeper in the water column.

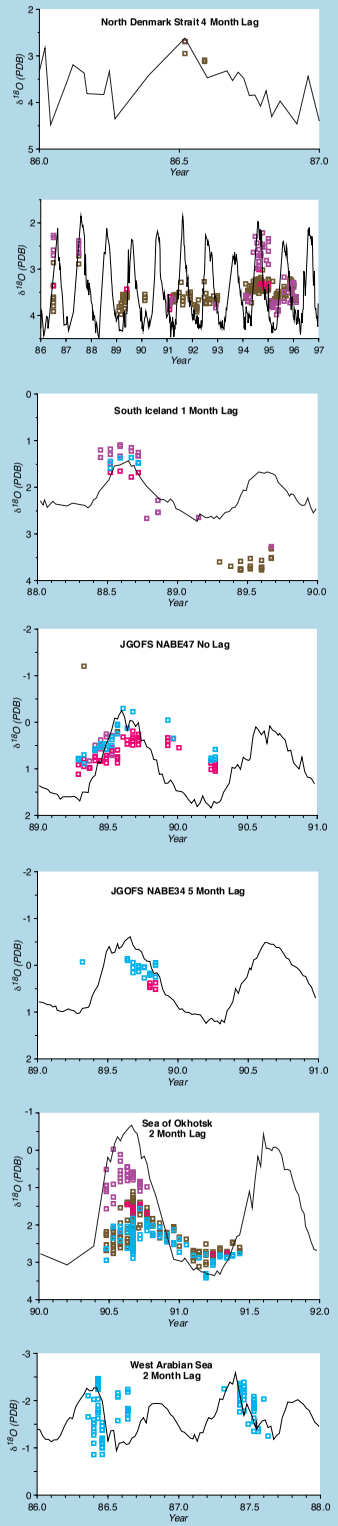
JGOFS NABE 47 - Because of elevated surface temperatures, *N. pachyerma* sinistral is rarely found at this location. *G. quinqueloba*, *G. bulloides* and *N. pachyderma* dextral are calcifying at or near the surface with a continued depth stratification as found South of Iceland. We can't explain why no lag was necessary to align isotopic values to the surface equilibrium calcite values or why the isotopic anlayses in 1990 are so heavy compared to the equilibrium calcite profile.

JGOFS NABE 34 - The surface waters are too warm at this location for *G. quinqueloba* and only *G. bulloides* and *N. pachyderma* dextral remain and appear to be calcifying at or near surface. The 5 month lag imposed for this trap is the longest of this study.

Sea of Okhotsk - Hydrographically, the Sea of Okhotsk is much different than all the other trap locations discussed here because of the seasonal ice cover and the subsurface low temperature layer (dichothermal) which persists year-round in the Sea of Okhotsk. The 1.0 per mil lighter $\delta^{18}O$ values in the Sea of Okhotsk are due to an average salinity which is fresher by 2 psu compared to NE Iceland. It is clear that *G. quinqueloba* lives very close to the surface for only a few months. *N. pachyderma* (sinistral & dextral) live at the same time and subsurface depth. *G. bulloides*, absent from NE Iceland, is very abundant, making up over 50% of the foraminifera flux >150 ×m.

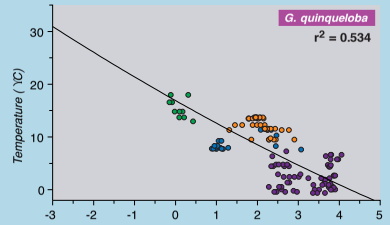
West Arabian Sea - *G. bulloides* is the only species of foraminifer anlayzed from the Arabian Sea which is also found in the other traps of this study. *G. bulloides* only occurs during southwest monsoonal upwelling events.

N. pachyderma (sinistral)
N. pachyderma (dextral)
G. bulloides
G. quinqueloba

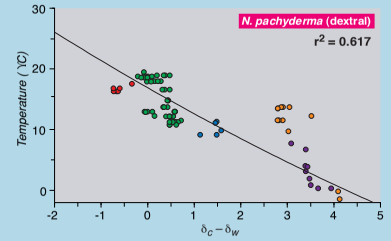


Paleotemperature Reconstruction Implications

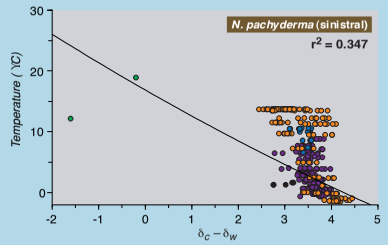
Stable isotopic analyses of foraminifers from seven trap locations are shown in the figures to the left using the previously described square color coded symbols. The black line in each figure is the calculated time-series equilibrium calcite $\delta^{18}O$ value for the surface water based upon satellite SST data and measured or calculated $\delta^{18}O$. In the figures below we present the calibration of each species $\delta^{18}O$ to the O'Neil paleotemperature equation (plotted as the black line) with trap locations as color coded circles.



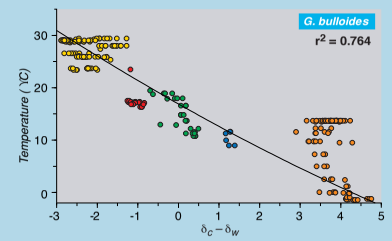
G. quinqueloba - Being the most surface calcifying of the foraminifer species studied here, we find that it has a good fit to the paleo-temperature equation, even at the lowest temperatures. This is especially important for reconstructions of the glacial ocean where the Iceland Plateau and Sea of Okhotsk could be viewed as modern day analogs for the glacial North Atlantic.



N. pachyderma (dextral) - Could be used in the absence of *G. quinqueloba* for paleoceanographic reconstructions. We have shown that this species lives at the same time and depth as the sinistral variety and is a better recorder of the near surface hydrography.



N. pachyderma (sinistral) - This foraminifer should only be used in reconstructions in the coldest water (-2 to 0°C) where there is an absence of any other species. When surface temperatures exceed ~5°C, this species calcifies in the thermocline.

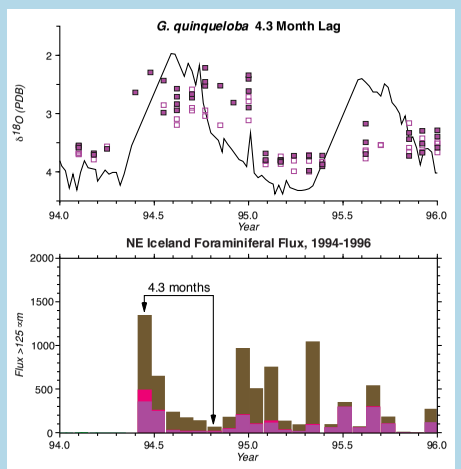


G. bulloides - This species has the widest temperature range in this study and closely follows the paleotemperature equation and could be considered a good species to use in the middle to warmer temperature regimes to monitor the near surface paleocean.

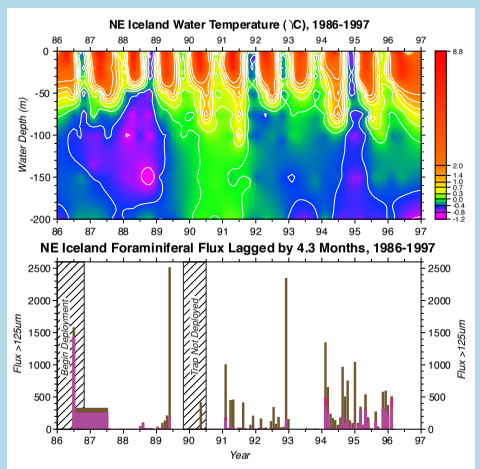
N. pachyderma (sinistral)
N. pachyderma (dextral)
G. bulloides
G. quinqueloba

NE Iceland Foraminiferal Flux & Isotopic Signature

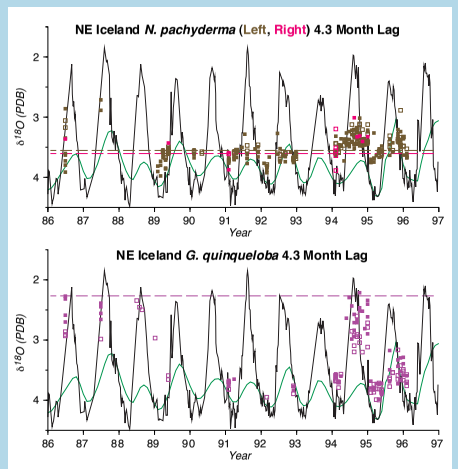
Based upon sediment trap material from the NE of Iceland, we have learned that temperature alone does not uniquely constrain foraminiferal flux. We show that *G. quinqueloba* may be a better indicator of summer sea surface paleotemperatures than the normally used *N. pachyderma* (sinistral) which appears to calcify between 30-40 meters in waters about 0-6°C. *G. quinqueloba* $\delta^{18}O$ showed a marked seasonal signal with 0.85 per mil heavier values during winter compared to summer, consistent with the 4°C SST difference between those seasons.



Using data from the bottom figure we have quantified the lag between foraminifer calcification and deposition in the sediment trap based on stable isotopic analyses shown in the upper figure. A 4.3 month lag has implications for comparisons between foraminiferal flux and other measured flux components which may have shorter or longer lags than the relatively dense foraminifers.



The top figure shows a time-series temperature profile for the upper 200m of the water column at the NE Iceland location. This data is based upon the satellite SST data and at least three hydrographic bottle casts during each year (data from the Marine Research Institute, Reykjavik, Iceland). The bottom figure shows the NE Iceland >125 ×m foraminiferal flux. The width of each bar indicates the sampling interval which was usually ~27 days. *N. pachyderma* sinsitral and dextral cohabit in time and depth at this location. *G. quinqueloba* flux, which can be as much as 60% of the total flux, seems to increase as the subsurface cools. When the sub-surface warms, the *G. quinqueloba* flux drops dramatically.



In both figures the black line is the equilibrium calcite $\delta^{18}O$ value of the surface water and the green line is the value for water at 40 meters. The open squares are analyses of the 125-150 ×m size fraction and the closed squares are the 150-250 ×m size fraction. The dashed line is the average oxygen isotopic value for each species from core-top sediment sampes taken at the trap location (C14 age =1600ybp). Stable isotopes from the top figure show that both varieties of *N. pachyderma* live at or near 40 meters. *G. quinqueloba* stable isotopes in the bottom figure show a marked seasonal signal indicating that they live very close to the surface.