Time Series Foraminiferal Fluxes from the Iceland Sea: 1986 to Present

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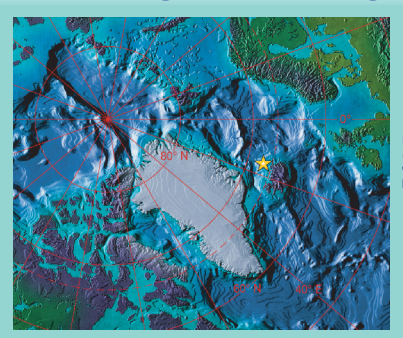
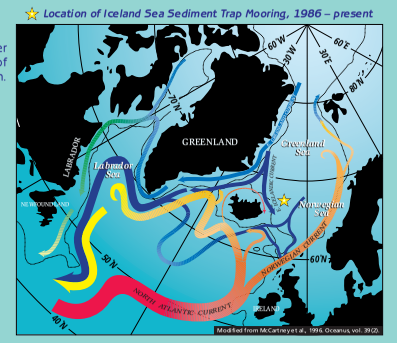
Regional Hydrography



Location of sediment trap mooring (68°N, 12.6°W) indicated by yellow star, showing basin and bottom topography.



Current diagram showing water masses affecting the mixture of water at trap location.

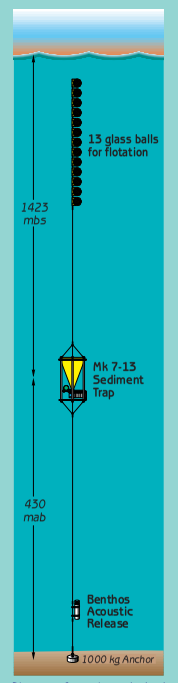
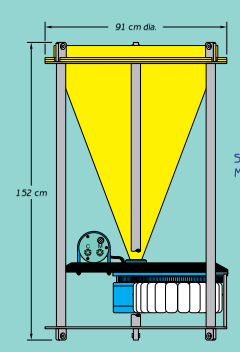
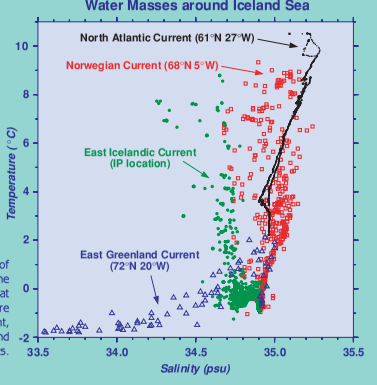


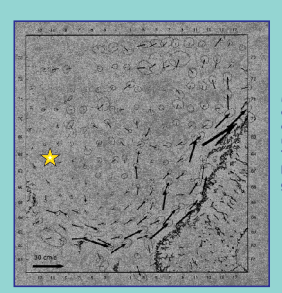
Diagram of mooring at Iceland



Side View detail of Mk 7-13 Sediment trap



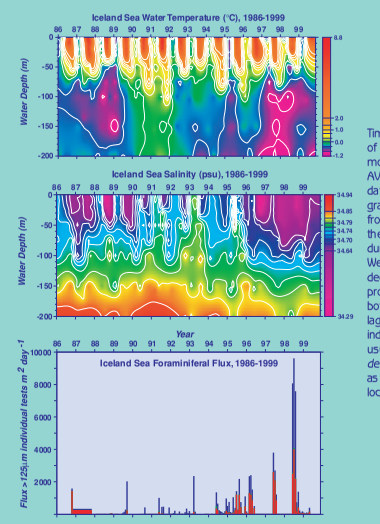
Temperature/Salinity diagrams of water masses at and near the mooring location showing that the mooring site water is a mixture of North Atlantic Current, Norwegian Current and East Greenland Current waters.



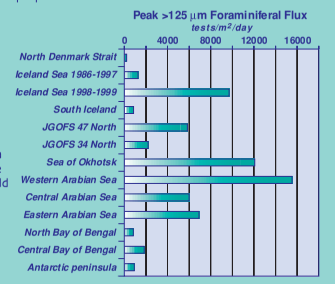
Mean velocity vectors corrected (open arrows) and not corrected (solid arrows) for the "array" bias. Statistics are computed from combined drogued and wind corrected undrogued drifter observations (Aug. 1991–Dec. 1994). The mooring location (yellow star) straddles the boundaries between the Polar and Arctic Fronts within a weak cyclonic gyre of low near-surface current velocities (Poulain et al., 1996).

Foraminiferal Species & Weight Flux

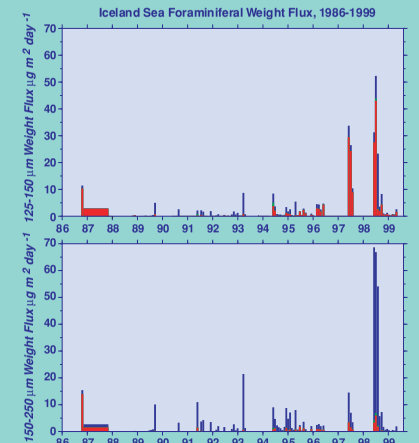
G. quinqueloba *N. pachyderma* dextral (R) *N. pachyderma* sinistral (L)



Time series temperature and salinity profiles of the upper 200 meters of water at the mooring location. This figure is based upon AVHRR satellite sea surface temperature data and data from at least four hydrographic bottle casts during each year (data from the M.R.I., Reykjavik, Iceland). Note the deepening of the fresher water lens during the years beginning in 1996. We speculate that this may indicate a deepening of the surface mixed layer providing greater nutrient availability. The bottom figure shows the foraminiferal flux lagged by 14 days. The width of each bar indicates the sampling interval which was usually ~27 days. Although rare, *N. pachyderma* dextral (R) occurs at the same time as *N. pachyderma* sinistral (L) at this location.



A compilation of foraminiferal fluxes from sediment traps deployed around the world. Iceland Sea peak fluxes were averaged from 1986-1997 and presented separately from the 1998-1999 deployment interval. The 1998-1999 Iceland Sea peak foraminiferal fluxes are similar in magnitude to some of the most productive areas of the world (eg. Arabian Sea, Curry et al., 1992 & Sea of Okhotsk, Alderman, 1996).

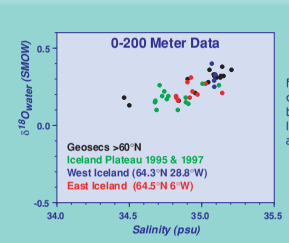


Foraminiferal weight flux lagged by 14 days. Note that the 125-150 *G. quinqueloba* weight flux is approximately equal to the 150-250 weight flux of *N. pachyderma* sinistral (L), and that all weight fluxes dramatically increase during the 1998 collection interval.

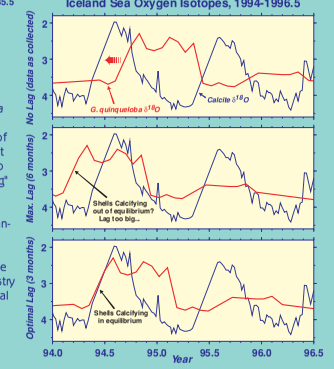
Summary:

Temperature and salinity data alone do not uniquely constrain the large species and weight flux variability of planktonic foraminifera at the Iceland Sea mooring location. Quarterly hydrographic data may also bias the records by missing unique, short lived hydrographic phenomena. It is clear that the foraminiferal assemblage, although constant in species composition, shows dramatic changes over decadal time scales in numbers and weight. These changes will certainly affect the number of shells preserved in the sediment during unique production pulses such as the 1998 collection interval.

Isotopic Signature

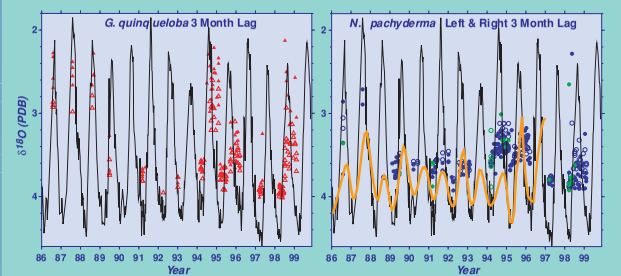


Relationship between salinity (psu) and the $\delta^{18}O$ (SMOW) content of the upper 200 meters of water around Iceland based upon Geosecs (>60°N) and water collected around Iceland by D.R. Ostermann and extracted and measured at Harvard University by D. Schrag.



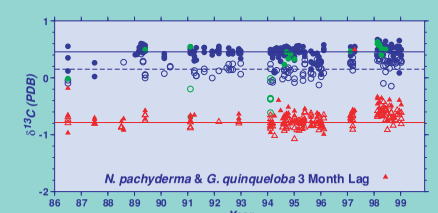
The blue line in each panel at right shows the average equilibrium calcite $\delta^{18}O$ of the surface temperature data and measured $\delta^{18}O$ (SMOW) data from the panel above. The red line in each panel is the average 150-250 µm *G. quinqueloba* isotopic measurements. The upper panel shows that foraminiferans are almost 180 degrees out of phase with the equilibrium $\delta^{18}O$. This means that the shells were calcified almost 6 months prior to deposition into the sediment trap. A 6 month "lag" shows foraminifers calcifying in enriched waters well before the temperature actually begins to warm up, not likely to happen under normal oceanographic conditions. With a "lag" of 5 months, *G. quinqueloba* data are brought into phase with the surface $\delta^{18}O$. *G. quinqueloba* was used to set the lag because as a surface dweller, its shell chemistry exhibits a strong seasonal sea surface $\delta^{18}O$ signal (see panel below).

G. quinqueloba 125-150 △ 150-250 ▲ | *N. pachyderma* (R) 125-150 ○ 150-250 ● | *N. pachyderma* (L) 125-150 ○ 150-250 ●



G. quinqueloba oxygen isotopic data plotted with surface water equilibrium calcite (black line). This species is a surface dweller and show a strong seasonal signal, with the 125-150 µm individuals living slightly deeper than the individuals in the 150-250 µm fraction.

N. pachyderma oxygen isotopic data plotted with surface (black line) and 40 meter (orange line) equilibrium calcite $\delta^{18}O$. This species is a subsurface dweller, living at or near 40 meters during the entire year.



G. quinqueloba and *N. pachyderma* carbon isotopic data. The lines indicate the average values for each species and size fraction. The *N. pachyderma* sinistral and dextral $\delta^{13}C$ indicate that these deeper dwelling foraminifers are living in depleted water compared to the more surface dwelling *G. quinqueloba* where there is a 0.28 per mil difference between the average 125-150 µm $\delta^{13}C$ and the average 150-250 µm $\delta^{13}C$. The *G. quinqueloba* $\delta^{13}C$ has shown a small but detectable change over the collection interval as well. These changes don't account for the large species and weight flux changes over the same intervals.

Summary:

Given the trap depth and typical foraminifer settling velocities of about 100 m day-1, individual tests would be expected to settle into the sediment trap within 14 days. Based on comparisons to water temperature and chemistry, we found that the date of deposition into the sediment trap was significantly delayed up to 3-6 months from the probable date of shell calicification. Stable isotopic analyses of near-surface dwelling *G. quinqueloba* allow us to shift or lag the deposition dates to the calicification dates by 3 months and align isotopically depleted values of *G. quinqueloba* to the warmest SST's and chemistries and enriched values to the coldest SST's and chemistries. *G. quinqueloba* $\delta^{13}C$ depletion in 1998-1999 maybe be a response to the stripping of nutrients following the elevated production during these years.

Discussion

The Greenland, Iceland and Norwegian Seas (GIN) together form a high latitude region with waters of both Arctic and North Atlantic origin mix. The GIN Seas have also been recognized as critical to the formation of North Atlantic Deep water (NADW) whose production has been linked to the heat balance associated with the Global Conveyor circulation system. The Iceland Sea sediment trap was deployed to monitor the particle flux response to decadal changes in local and regional hydrographic conditions and to interpret downcore *N. pachyderma* and *G. quinqueloba* flux and stable isotope records on glacial to interglacial time scales.

At the Iceland Sea mooring location, in-situ and satellite derived sea surface temperature (SST) data show clear interannual oscillations between cold and warm periods which have affected the planktonic foraminiferal faunal assemblage and stable isotopic data. These dramatic temperature oscillations do not directly affect the timing and magnitude of the peak foraminiferal flux (> 125 µm individual foraminiferal tests m^2 day^{-1}) which have been documented to occur in almost any month at this location.

The 1998-1999 collection interval clearly shows an earlier and greatly intensified spring bloom, more typical of the North Atlantic than the summer and fall blooms of the Iceland Sea. Although the foraminiferal faunal assemblages contain similar species during the entire 1986-1999 collection interval, the foraminiferal flux collected during 1998-1999 is more indicative of a North Atlantic bloom signature. Olafsson et al. (see poster to the left) document a greatly increased total particulate flux for this interval. These particle fluxes may correlate with a westerly inflow of warmer nutrient-rich Atlantic water north of Iceland.

Stable isotopic data indicate that the foraminiferans at the Iceland Sea mooring location are living for 3-6 months. They make their shells in isotopically enriched waters and reproduce, die and settle into the sediment trap 3-6 months later. Poulain et al. (1996) show the mooring location to be in an area of low near-surface current velocities and we believe that the oxygen isotopic signature of *G. quinqueloba* indicates in-situ calcification and not calcification in waters to the south or north with subsequent transport to the mooring location, and deposition into the sediment trap. The use of stable isotopic analyses allows us to correctly identify the timing of foraminiferal calcification.

References:

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