Online Supplementary Material

1. Stable isotope size fraction analyses

To determine the most representative size fraction for this specific study location, stable isotopes were analyzed from *Uvigerina sp., Cibicidoides sp., Globigerina bulloides, Neoglobigerina pachyderma,* and *Neoglobigerina incompta* (formerly *Neoglobigerina pachyderma dextral*) in different size fractions on a Thermo Delta V Plus equipped with a Kiel IV individual acid bath device at LDEO. Three samples were selected for the Holocene (0cm), deglaciation (16cm), and last glacial period (39cm) from the shallowest multicore (53MC), which has the best carbonate preservation and thus the greatest volume of coarse fraction. Each sample was sieved into the following size fractions: 150-180um, 180-200um, 200-250um, 250-300um, 300-355um, and >355um. Foraminiferal tests were picked from each size fraction and analyzed for stable isotopes in triplicate. Note that each foraminiferal species was not available in every size fraction from each of the three samples.

The average 18O for each sample depth was calculated by averaging (mean) the values for each size fraction for each species (e.g., the 18O for all the size fractions of *G. bulloides* in 53MC-16cm). The deviation from this mean value could then be determined by dividing the size fraction 18O by the sample mean 18O, so that a value of 1.2 indicates a size fraction 18O that is 20% greater than the mean value for that species (Supplementary Figure 1). On average, there is no apparent size fractionation of oxygen isotopes in *N. pachyderma*, *G. bulloides*, or *Cibicidoides sp*, while *Uvigerina sp.* demonstrates a positive size relationship, in which 18O increases with increasing size fraction, and *N. incompta* exhibits the opposite size relationship, with 18O decreasing with increasing size fraction. The more stable environment and longer life cycle of benthic species makes them less sensitive to size fractionation effects [*Schmiedl et al.*, 2004], and the size-independent 18O of *Cibicidoides sp.* is consistent with previous results from the South Atlantic [*Franco-Fraguas et al.*, 2011], Equatorial Pacific [*Dunbar and Wefer*, 1984], and the Mediterranean [*Schmiedl et al.*, 2004]. The positive trend in *Uvigerina sp.* may be attributed to ontogenetic calcite precipitation [*Schmiedl et al.*, 2004] and it is consistent with results from the Equatorial Pacific [*Dunbar and Wefer*, 1984], and the Mediterranean [*Schmiedl et al.*, 2004]. Amongst the planktic species, previous studies have found a similar size-dependent negative trend in both *N. incompta* and *N. pachyderma* [*Hillaire-Marcel et al.*, 2004], but the presence of size-dependent 18O in just *N. incompta* on the JdFR may indicate separate ecological niches for *N. incompta* and *N. pachyderma* in this region.



**Supplementary Figure 1. Size fraction 18O for each of the five foraminifera species analyzed**. Samples are from 53MC and cover the Holocene (0cm, orange), deglaciation (16cm, gray), and the last glacial period (39cm, blue). All 18O have been normalized to the specific mean for each sediment interval in order to plot the data on the same y-axis. Dashed lines at 1 indicate values equivalent to the mean. Data are plotted at the lower sieve bounds, so that the size fraction 150-180m is shown at 150m. Black lines indicate the average (mean) deviation within each size bin.



**Supplementary Figure 2.** **Alignment of individual core depths to the composite depth scale.** Core 13MC *Uvigerina sp.* 18O data were used as the reference to which the other cores were aligned. Dashed lines represent 1:1 relationships.



**Supplementary Figure 3.** **Average shell weights for *G. bulloides* and *N. incompta* within the 250-300m size fraction.** Samples were weighed in triplicate to assess reproducibility. Error bars show the average reproducibility for each species: 1.04g for *G. bulloides* and 1.13g for *N. incompta.*

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**Supplementary Figure 4.** **Model output results using a deep (30cm) mixed layer.** Model outputs were calculated by employing the variation in mixing depth shown in the bottom panel. Shaded envelopes define 1 of 1000 bootstrap sampling runs for the model output, and they are much wider for 18O due to the smaller foraminiferal sample in the average (*n*=10) compared to age (*n*=300). Red dots indicate the actual data. Even this very deep (30cm) mixed layer fails to prolong a young *N. incompta* age plateau down to 27cm depth.

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**Supplementary Figure 5.** **Model output with increased coretop *N. incompta* abundance.** Model outputs were calculated by employing 1) the variation in mixing depth shown in the bottom panel and 2) 500x abundance of *N. incompta* in the top 5cm. Shaded envelopes define 1 of 1000 bootstrap sampling runs for the model output, and they are much wider for 18O due to the smaller foraminiferal sample in the average (*n*=10) compared to age (*n*=300). Red dots indicate the actual data. The combination of increased coretop abundance and deep mixing (35cm) is able to reconstruct the *N. incompta* age plateau, although it fails to reconstruct the *G. bulloides* results.

Supplementary References

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