A 1400-year multi-proxy record of climate variability from the Northern Gulf of Mexico

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Abstract

A continuous, decadal resolution multi-proxy record of environmental variation in the Northern Gulf of Mexico was constructed from a box core recovered in the Pigmy Basin, in the Northern Gulf of Mexico (fig 1). Proxies include paired analyses of Mg/Ca and $\delta^{18}O$ in closely sized individuals (250-300µm) of the white variety of the planktonic foraminifer *Globigerinoides ruber* and relative abundance variations of *G. sacculifer* in the foraminiferal assemblages. The chronology is based on 7 AMS dates (fig 2).

An abrupt shift recorded in both mean $\delta^{18}O_{calcite}$ and abundance of *Globigerinoides sacculifer* occurs ~600 yrs BP (fig. 3). The shift in the Pigmy Basin record corresponds closely in time with a shift in the sea-salt-sodium (ssNa) record from the GISP2 ice core (Meeker and Mayewski, 2004), which is interpreted as a proxy for an atmospheric circulation change in the North Atlantic. The close correspondence in time between the ssNa record from GISP2 and the Pigmy Basin records links changes in high-latitude atmospheric circulation with the subtropical Atlantic.

Foraminiferal Mg/Ca values in the Pigmy Basin record vary by nearly 2 mmol/mol from the Medieval Warm Period (MWP) maximum to the Little Ice Age (LIA) minimum, equivalent to a temperature range of ~3ºC. Two century-long intervals of sustained high Mg/Ca values between 1000 and 1400 yrs BP indicate GOM SSTs were warmer than near modern SST during portions of the Medieval Warm Period. Northern GOM SSTs during coolest intervals of the Little Ice Age were at least 2ºC below modern SST.

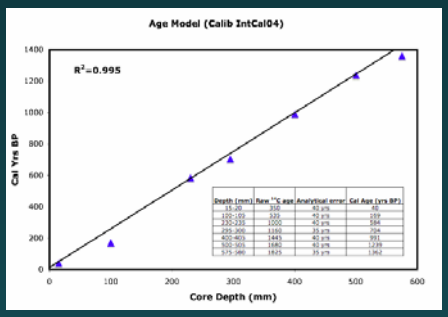

Figure 2. *Age model for core PBBC 1.* The age model is based on 7 AMS ^{14}C dates that were converted to calendar years using the CALIB 5.0 Program with a 400-year reservoir correction (Stuiver et al. 1998). The core-top was set to zero; the most recent ^{14}C date indicates a post-1950 age for the upper 2 cm of PBBC1, thus we infer that the youngest samples in the core record near-modern conditions, or an average of the past 40-50 yrs. Inset shows the actual ^{14}C dates. The age model combined with our sampling interval of 0.5cm results in sample resolution of 12 years over the entire record (sed. rate = 45 cm/1000yrs).

Why the Gulf of Mexico?

- High Sedimentation Rate Basin (35cm/kyr)
- Strongly influenced by North American hydrology via Mississippi River input
- Influenced by tropical and subtropical processes (i.e. Bermuda High and ITCZ)

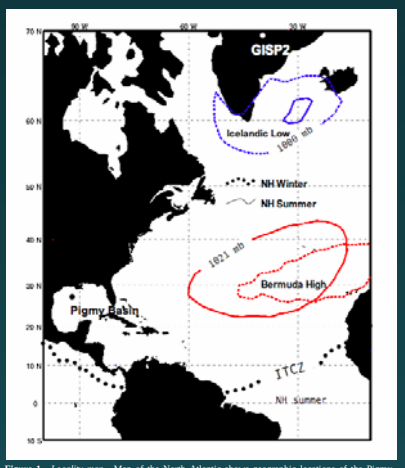

Figure 1. *Locality map.* Map of the North Atlantic shows geographic locations of the Pigmy Basin and GISP2 core sites. The boreal summer (June) and winter (Dec.) positions of the Icelandic Low (IL) and Bermuda High (BH) are shown with the mean summer position of the ITCZ. The 1010 mb and 1021 mb isobars of Sea-level pressure (SLP) are shown in blue (IL) and red (BH), respectively. They are plotted using the NCEP Reanalysis data, representing an average of the past 70 yrs.

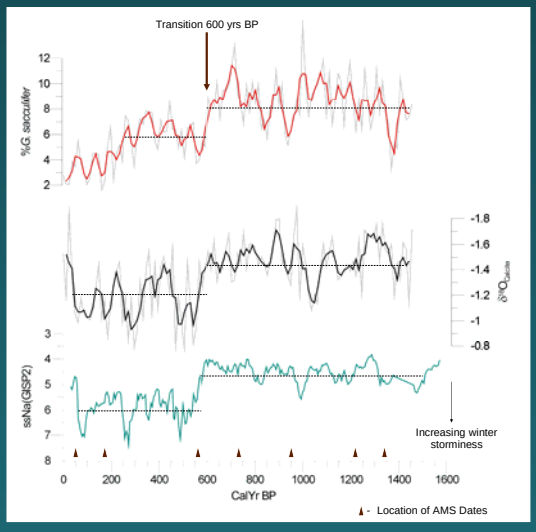

Figure 3. Relative abundance variations of the planktic foraminifer *Globigerinoides sacculifer* and $\delta^{18}O$ measured *G. ruber* (white variety) in core PBBC1 plotted against calibrated years. Solid line is a 3-point running average. Bottom panel shows sea-salt-sodium (ssNa) record from GISP 2 ice core. The ssNa record is a 20-year smoothed version, resampled at 6-yr resolution, and is plotted against the time scale for GISP 2 (from Meeker and Mayewski, 2004).

Proxies

- The relative abundance of *G. sacculifer* in Pigmy Basin Basin sediments indicates the influence of Caribbean waters in the GOM, and is related to the average position of the intertropical convergence zone (ITCZ), with increased abundances indicating a more northward position of the ITCZ (Poore et al. 2005).
- The $\delta^{18}O_{G.ruber}$ record is influenced by changes in both temperature and $\delta^{18}O$ of seawater.
- The sea-salt sodium (ssNa) record is related to the intensity of the Icelandic Low (IL). A more pronounced (deeper) IL results in increased winter winds blowing from the North Atlantic onto Greenland, increasing the ssNa content of the ice.

Findings (Fig.3)

- A distinct and synchronous shift in the mean values of 3 independent proxies at 600 yrs BP indicates a close linkage between atmospheric circulation in the N. Atlantic and subtropical Atlantic.
- The decrease in *G. sacculifer* abundance suggests that a southward shift in the mean position of the ITCZ coincided with the intensification of the IL.

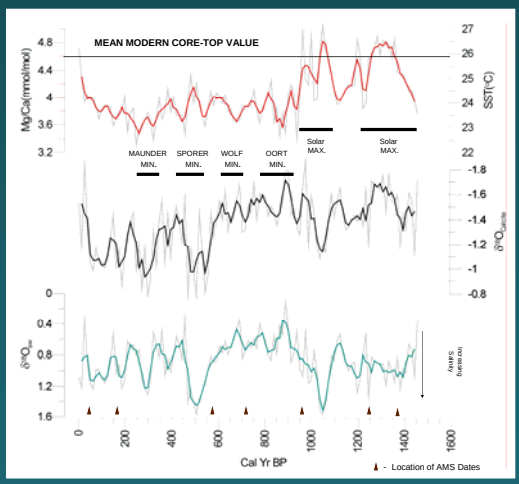

Figure 4. Mg/Ca, $\delta^{18}O_{calcite}$ for *G. ruber* (white variety), and calculated $\delta^{18}O_{seawater}$ in PBBC 1. The Mg/Ca record is plotted with the corresponding SST values on the secondary axis, calculated using the equation Mg/Ca=0.449exp(0.09T) (Anand et al. 2003). Using both the $\delta^{18}O_{calcite}$ and derived SST values, we calculated $\delta^{18}O_{seawater}$ using the equation SST(°C)=14.9-4.8*($\delta^{18}O_{calcite}$-$\delta^{18}O_{sw}$)+.27 (Bemis et al. 1998).

Findings (Fig.4)

- The high Mg/Ca values between 1000 and 1400 yrs BP indicate that SST in the northern GOM during portions of the MWP were warmer than near-modern SST.
- Minimum Mg/Ca values between 300 and 200 yrs BP indicate that SST in the northern GOM during portions of the LIA were at least 2 to 2.5ºC cooler than modern SST.
- The Mg/Ca record does not show a significant feature at 600 yrs BP when major shifts are seen in mean values of the $\delta^{18}O$ and *G. sacculifer* records. Thus the intensification of the IL and southward shift of the ITCZ at 600 yrs BP did not have a significant effect on SST in the northern GOM.
- In general the Pigmy Basin record does not show a systematic relationship between temperature and salinity on multi-decadal to centennial timescales.

Conclusions

A multi-proxy record from the Pigmy Basin, northern Gulf of Mexico provides evidence for rapid and significant changes in SST and atmospheric circulation over the last 1400 years. Major features include:

- Warmer than near-modern SST during parts of the Medieval Warm Period (1000-1400 yrs BP)
- SSTs colder than modern by 2-2.5ºC during Little Ice Age minima (200-300 yrs BP)
- Correspondence of SST record with sunspot minima and maxima in the insolation record
- Strong links between the Icelandic Low and changes in GOM oceanography at 600 yrs BP

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