Holocene Antarctic seasonality reconstructions from barnacle shells

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A limitation of many paleoclimate records is that they only provide temperature information with annual or decadal scale resolution. Higher resolution, seasonal paleoclimate reconstructions are important to determine the role of particular seasons in climate change. Many seasonal resolution records come from corals, where the high growth rates enable monthly to weekly sampling, but these are generally restricted to tropical regions. Mid and high latitudes have larger seasonal ranges, making them of particular interest for paleoclimate reconstructions.

This study evaluates the potential of the Antarctic barnacle *Bathylasma corolliforme* to reconstruct seasonality during the Holocene. The barnacle secretes a robust low-Mg calcite shell with distinct growth increments on the external surface with estimated life spans of 30-50 years. *Bathylasma* grows in the Ross Sea and becomes entrained near the grounding line of coastal ice shelves, suggesting they should be a sensitive archive not only to changes in ice shelf dynamics, but also to changes in temperature and salinity related to oceanic conditions, sea-ice and West and East Antarctic ice sheet behaviour.

Barnacle samples as old as 7000 years B.P. were collected from the McMurdo Ice Shelf. High resolution stable isotope ($\delta^{18}O$ and $\delta^{13}C$) and trace element analyses were obtained from eight shells by micro-milling. Average $\delta^{18}O$ values indicate that *Bathylasma* calcifies close to equilibrium with ambient seawater. Cycles of $\delta^{18}O$ are observed which broadly correlate with annual growth bands. The amplitude of this seasonal $\delta^{18}O$ signal is slightly larger than the local seawater temperature range (~ 1°C) indicating an additional salinity effect. Changes in the mean $\delta^{18}O$ value occur between 6 ka and 3 ka suggesting fluctuations in salinity and/or local ice balance during this period. These data indicate that *Bathylasma* can provide valuable paleoclimate information at seasonal resolution for regions around Antarctica that play an important role in the climate system.

Application of an inverse method to interpret $^{231}Pa/^{230}Th$ observations from marine sediments

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Sedimentary $^{231}Pa/^{230}Th$ ratios have been used to infer information about elements of the ocean circulation in the geological past. For instance, high $^{231}Pa/^{230}Th$ ratios in Atlantic sediments have been interpreted as a reduction in the export of ^{231}Pa to the Southern Ocean owing to a slowdown of the meridional overturning circulation [1, 2]. Such an interpretation can and should be quantitatively tested, giving due regard to the uncertainties both in the sedimentary data (chronological errors, limited data coverage, etc.) and in our current understanding of the removal of both radionuclides from the water column (particle scavenging). Here we use an inverse method in order to evaluate the information contained in an updated compilation of $^{231}Pa/^{230}Th$ observations for Atlantic sediments of the Last Glacial Maximum (LGM) and Heinrich event 1 (H1). First, an estimate of the modern circulation is obtained by combining (i) a climatology of temperature and salinity, (ii) observational estimates of volume transport of deep water masses at specific locations, and (iii) the statements of a model of the abyssal circulation. Second, $^{231}Pa/^{230}Th$ observations for the LGM or H1 are combined with this circulation estimate in order to determine the adjustment in these observations that is necessary to bring them into consistency with the modern flow in the presence of particle scavenging. The amplitude of the adjustment provides a test of the null hypothesis that these observations *are* consistent with the modern flow. Likewise, the null hypothesis that the $^{231}Pa/^{230}Th$ observations for LGM or H1 are consistent with a state of no flow is assessed. The assumptions about the uncertainties in the $^{231}Pa/^{230}Th$ data and in the scavenging model [3] which are required to test both hypotheses are determined.

[1] McManus *et al*. (2004) *Nature* **428**, 834-837. [2] Gherardi *et al*. (2005) *EPSL* **240**, 710-723. [3] Marchal *et al.* (2007) *Deep-Sea Research* I **54**, 557-585.