Orbital and atmospheric forcing of western Antarctic Peninsula climate in the Holocene: The TEX_{86} paleotemperature record of Palmer Deep

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Summary A detailed TEX_{86} sea surface temperature record is presented from a well-dated hemipelagic sedimentary sequence drilled in Palmer Deep, on the western Antarctic Peninsula continental margin (ODP Hole 1098B; 1010 m). To test the regional utility of the TEX_{86} proxy, surface sediment samples with paired CTD casts were acquired and results show the promise of TEX_{86} in this region. Down core TEX_{86}-derived temperatures at Site 1098 range between 0 and 6°C during the Holocene (0-12 ky). A long-term Holocene cooling of ~3°C is suggested and is punctuated by millennial scale temperature variability. The TEX_{86} temperature record from Palmer Deep is consistent with temperature trends recorded in west Antarctic ice cores and southeast Pacific marine sediments. This observation is consistent with hypotheses that favor atmospheric (via the Southern Hemisphere westerly winds), not thermohaline, control over the hydrography of Palmer Deep.

Citation: Shevenell, A. E., A. Ingalls, and E. Domack (2007), Orbital and atmospheric forcing of western Antarctic Peninsula climate in the Holocene: The TEX_{86} paleotemperature record of Palmer Deep, in Antarctica: A Keystone in a Changing World – Online Proceedings of the 10th ISAES X, edited by A. K. Cooper and C. R. Raymond et al., USGS Open-File Report 2007-1047, Extended Abstract 131, 4 p.

Introduction

Warming of the atmosphere and oceans has been implicated in the recent disintegration of massive ice shelves, reduced sea ice extent, and shifting ecologic zones observed along the Antarctic Peninsula. To place this environmental variability within the context of long-term deglacial to Holocene (0-13,000 years) change, researchers have reconstructed the past climate state of the Antarctic Peninsula using proxy records from ice and sediment cores. While ice cores provide a detailed record of regional Holocene atmospheric temperature change, obtaining similar quality records of past ocean temperatures has proven difficult due to a dearth of calcium carbonate in Antarctic continental margin marine sediments. Because ocean temperatures likely play a significant role in Antarctic ice shelf/ice sheet stability and sea ice extent, robust geochemical records of past sea surface temperatures (SST) are critically required to more fully resolve mechanisms of Holocene climate and cryosphere variability.

Discussion

The TEX_{86} sea surface temperature proxy

Here we present a detailed TEX_{86} sea surface temperature (SST) record extracted from a well-dated hemipelagic sedimentary sequence drilled in Palmer Deep, on the western Antarctic Peninsula continental margin (ODP Hole 1098B; 1010 meters water depth). The recently developed TEX_{86} (TetraEther indeX of lipids with 86 carbon atoms) proxy is based on the distribution of sedimentary lipids originally produced by surface dwelling planktonic archaea and has been calibrated using core-top sediments from waters with temperatures between 0 and 30°C (current error estimate: ±2°C) (Schouten et al., 2002). To our knowledge, our Palmer Deep record is the first downcore TEX_{86} record produced in the Antarctic region and due to the small number of existing measurements at these cold temperatures, estimates of the error at this end of the calibration may continue to evolve. However, the appeal of employing TEX_{86} paleothermometry in Palmer Deep sediments is that TEX_{86} can be measured in carbonate-poor sediments and the ratio is not influenced by oxic decomposition.

Regional calibration of the TEX_{86} proxy

To test the utility of the TEX_{86} proxy in Palmer Deep, seven surface sediment samples with paired CTD casts and two surface and mid depth sediment trap samples from the vicinity of Palmer Deep and the Gerlache Strait were acquired. Initial results show the promise of the TEX_{86} paleotemperature proxy in this region. TEX_{86} derived temperatures in Palmer Deep and the Gerlache Strait are coolest and correspond well with measured sea surface temperatures. TEX_{86} derived temperatures in Paradise Harbor are generally warmer than both the outer shelf samples and the measured temperatures, but close to the standard error of the calibration. These observed trends are supported by regional hydrographic studies. Several sediment trap samples from Andvord Bay were analyzed and appear quite warm (7-9°C) in two samples spaced six months apart. Currently, we do not have a very good explanation for these warm temperatures. But, the result is not unexpected as previous studies suggest that water column TEX_{86} derived temperatures are routinely warmer than measured temperatures.

The seven core top samples with paired CTD data from the Palmer Deep and Gerlache Strait region were plotted with the core top data of Schouten et al (2002) and from these data, we generated an improved calibration equation

between 0 and 20 degrees centigrade. The new equation resulted in temperatures that are 0.5°C cooler and within the standard error of the Schouten et al (2002) equation. It is clear from the addition of this new Antarctic core top data that the TEX_{86} temperature calibration will continue to evolve with the addition of core top data from cold temperatures. However, if the calibration remains linear, the absolute temperatures will change but the overall temperature trends will remain the same.

The downcore TEX_{86} record from Palmer Deep: Site 1098

Palmer Deep TEX_{86}-derived SSTs range between 0 and 6°C (pooled SD of replicates: ±0.5°C) during the Holocene (0-12 ky). The TEX_{86} record suggests a long-term cooling of ~3°C between 12 and 0 ky, consistent with temperature trends recorded in the Taylor Dome ice core and southeast Pacific marine sediments. In general, SSTs are warmest (5-6°C) in the early Holocene (12-10.5 ky) and shift towards cooler temperatures (~1°C) after 5 kyr. Preliminary results indicate that the long-term Holocene climate trend is punctuated by millennial scale SST variability, the timing of which appears consistent with regional ice core temperature records and sedimentary evidence for ice shelf breakup and retreat in West Antarctica. The Palmer Deep SST record exhibits millennial scale variations that suggest changes in the location and strength of westerly wind field and the Antarctic circumpolar current, which may influence the both the regional stratification and the amount of warm upper circumpolar deep water that upwells in Palmer Deep and around Antarctica.

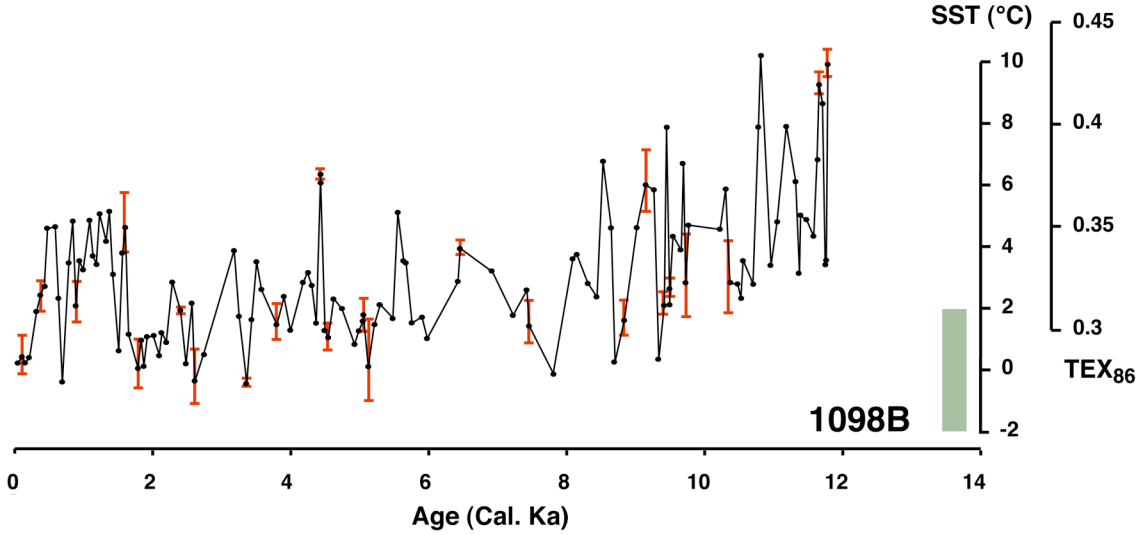

Figure 1. TEX86 SST record from ODP Site 1098 (Palmer Deep) on the western Antarctic Peninsula continental margin. The 1s temperature error bars are shown in red for replicated data;20% of the data has been replicated (SDp: ±0.5°C). The green bar represents the range of average Austral Spring-Fall sea surface temperatures observed in Palmer Deep.

Comparison with regional and global Holocene temperature records

Interestingly, the Palmer Deep SST record is remarkably similar to many Antarctic ice core duterium records, including Taylor Dome (Steig et al., 1998), and the alkenone record from the Chilean margin (Lamy et al., 2001), which indicate maximum regional temperatures between 12 and 9 ka, and a cooling trend through the Holocene that reflects changes in Earth's obliquity on local insolation. After ~6000 years, the millennial scale variations in Palmer Deep are similar in timing to those observed at Taylor Dome, supporting an inferred shift towards a more local oceanic moisture source. The increase in similarity between the Taylor Dome record and that of Palmer deep after 6000 years ago coincides with the establishment of the modern El Nino/Southern Oscillation (ENSO) frequencies. Support for a present day teleconnection between these two regions and the low latitude tropical pacific, comes from the strong relationship between ENSO and sea ice extent. We argue the teleconnection may have evolved in the mid Holocene. This observation is consistent with hypotheses that favor atmospheric (via the Southern Hemisphere westerly winds), not thermohaline, control over the hydrography of Palmer Deep. Further development and calibration of the TEX_{86} proxy in Palmer Deep and the Southern Ocean region is required.

Summary

This contribution presents a the first Antarctic TEX_{86} sea surface temperature record from a well-dated hemipelagic sedimentary sequence drilled in Palmer Deep, on the western Antarctic Peninsula continental margin (ODP Hole 1098B; 1010 m). Long-term and millennial scale Holocene SST trends are similar to regional and global Holocene paleotemperature records.

Acknowledgements. The authors thank A. Cooper for handling this extend abstract, R. Murray and K. Kryc for providing us with the Palmer Deep samples, the Ocean Drilling Program, and C. Kelly for assistance with TEX_{86} sample preparation. This research was funded by the University of Washington Program on Climate Change and NSF OPP award #0620099.

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