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The potential of organic-walled dinoflagellate cysts for the reconstruction of past sea-surface conditions in the Southern Ocean

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Abstract

In this study we investigate the potential of organic-walled dinoflagellate cysts (dinocysts) as tools for quantifying past sea-surface temperatures (SST) in the Southern Ocean. For this purpose, a dinocyst reference dataset has been formed, based on 138 surface sediment samples from different circum-Antarctic environments. The dinocyst assemblages of these samples are composed of phototrophic (gonyaulacoid) and heterotrophic (protoperidinioid) species that provide a broad spectrum of palaeoenvironmental information. The relationship between the environmental parameters in the upper water column and the dinocyst distribution patterns of individual species has been established using the statistical method of Canonical Correspondence Analysis (CCA). Among the variables tested, summer SST appeared to correspond to the maximum variance represented in the dataset.

To establish quantitative summer SST reconstructions, a Modern Analogue Technique (MAT) has been performed on data from three Late Quaternary dinocyst records recovered from locations adjacent to prominent oceanic fronts in the Atlantic sector of the Southern Ocean. These dinocyst time series exhibit periodic changes in the dinocyst assemblage during the last two glacial/interglacial-cycles. During glacial conditions the relative abundance of protoperidinioid cysts was highest, whereas interglacial conditions are characterised by generally lower cyst concentrations and increased relative abundance of gonyaulacoid cysts. The MAT palaeotemperature estimates show trends in summer SST changes following the global oxygen isotope signal and a strong correlation with past temperatures of the last 140 000 years based on other proxies. However, by comparing the dinocyst results to quantitative estimates of summer SSTs based on diatoms, radiolarians and foraminifer-derived stable isotope records it can be shown that in several core intervals the dinocyst-based summer SSTs appeared to be extremely high. In these intervals the dinocyst record seems to be highly influenced by selective degradation, leading to unusual temperature ranges and to unrealistic palaeotemperatures. We used the selective degradation index (kt-index) to determine those intervals that have been biased by selective degradation in order to correct the palaeotemperature estimates. We show that after correction the dinocyst based SSTs correspond reasonably well with other palaeotemperature estimates for this region, supporting the great potential of dinoflagellate cysts as a basis for quantitative palaeoenvironmental studies.

Keywords: Southern Ocean; Modern Analogue Technique; Palaeotemperatures; Late Quaternary; Dinoflagellates

1. Introduction

Changes in the oceanographic setting of the Antarctic Circumpolar Current (ACC) can affect the global thermohaline circulation system via changes in the volume

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and type of endemic water generated in the ACC frontal system (e.g. Saenko et al., 2003; Sijp and England, 2006). Furthermore, the Southern Ocean contributes significantly to the biogenic primary production of the world´s oceans with major impact on the global carbon dioxide budget (e.g. Bakker et al., 1997). Recent studies suggest that productivity variations and/or changes in the circulation and alkalinity of the Southern Ocean water masses might be important factors in influencing global changes in atmospheric carbon dioxide concentrations during glacial/interglacial cycles (e.g. Broecker and Henderson, 1998; Sigman and Boyle, 2000). Thus, an enhanced knowledge of the driving forces behind deep and surface water circulation in the Southern Ocean is of great importance. To gain such knowledge, it is essential to apply methods that can provide quantitative estimates of past changes in the Southern Ocean, such as shifts in the frontal positions and changes in the surface water palaeoenvironment.

In recent years, transfer function-based methods, such as the Imbrie and Kipp Method (IKM) and the Modern Analogue Technique (MAT) based on foraminifera (Niebler and Gersonde, 1998), diatoms (Crosta et al., 1998; Zielinski et al., 1998; Gersonde and Zielinski, 2000; Crosta et al., 2004; Gersonde et al., 2005) and radiolarians (Brathauer and Abelmann, 1999) have allowed the reconstruction of past sea-surface temperature (SST) and sea-ice extent in the Atlantic and Indian sectors of the Southern Ocean. However, these approaches are limited by the distribution range and preservation potential of each microfossil group, constraining the use of siliceous and calcareous fossil groups to areas lacking opal or carbonate dissolution (Zielinski and Gersonde, 1997; Niebler and Gersonde, 1998). In areas of high opal and carbonate dissolution, however, the sediments may contain abundant organic-walled microfossils, such as dinoflagellate cysts (dinocysts). The Modern Analogue Technique based on organic-walled dinocysts has previously been applied only in the southwest Pacific sector of the Southern Ocean (Marret et al., 2001), a region influenced not only by the northern branch of the ACC but also by local environmental gradients. In our study, we

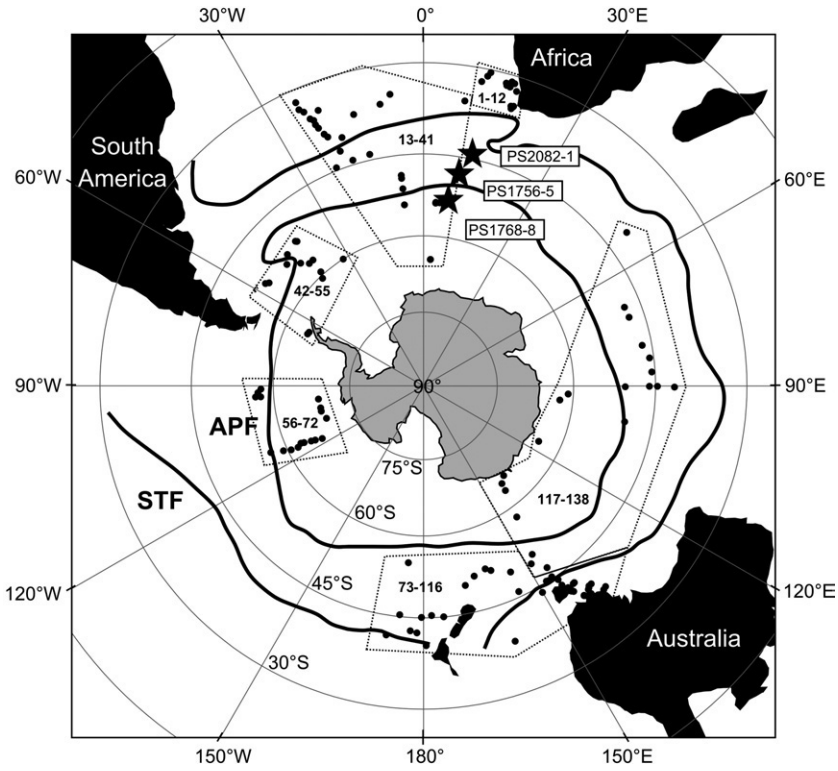

Fig. 1. Geographic positions of the 138 reference samples used in the Modern Analogue Technique-based reconstruction of palaeotemperatures for sediment cores PS1768-8, PS1756-5 and PS2082-1. The three coring sites cover different surface water regimes within the Subantarctic, Polar Front and Antarctic zones. The thick lines indicate the modern average positions of the Subtropical Front (STF) and the Antarctic Polar Front (APF; front positions after Peterson and Stramma, 1991; Orsi et al., 1995; Lutjeharms, 1996). See Appendix B for detailed information on the origin of the reference samples from the 5 different areas (dashed lines).