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Research paper

A radiolarian-based modern analogue dataset for palaeoenvironmental reconstructions in the southwest Pacific

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ABSTRACT

Radiolarian species relative abundances have been estimated for a suite of 88 surface sediment samples obtained from a broad area of the southwest Pacific/Southern Ocean bounded by 10°S to 65°S in latitude, and 145°E to 170°W in longitude. This allowed the documentation of a long environmental gradient (28.8 to −1.4 °C for mean annual sea-surface temperature, SST), and covered the most important surface oceanographic features in the area, including the Subtropical (STF), Subantarctic (SAF) and Antarctic Polar (APF) Fronts.

The most abundant species in the dataset show strong relationships to surface hydrography, examples are: *Antarctissa* spp. (5% abundance isoline is a good indicator for the average position of the SAF), Colonials (5% isoline approximates the average location of the Tasman Front, between New Zealand and Australia), *Dictyocoryne profunda* and *Tetrapyle octacantha* (essentially absent in subantarctic/antarctic waters, and documenting warm-water connections to higher latitudes, being present in the Tasmanian retroflection region and/or on the Campbell Plateau).

The Factor Analysis model, with a calibration error of ±1.3 °C, was based on 93 taxa (of the 243 taxa recognised in this study) and 7 factors/assemblages, which explained 87.4% of the total information contained in the dataset. The first five assemblages are readily interpreted in terms of water masses, oceanographic fronts and regions: Subtropical Water/Tasman Front (Factor 1), Circumpolar Surface Water (Factor 2), Equatorial Pacific (Factor 3), Subantarctic Water/Campbell Plateau (Factor 4), and as a subfactor for Subtropical Water (Factor 5). A canonical correspondence analysis identified sea surface temperature as the main environmental explanatory variable for samples with SST 7 °C–28 °C. Due to the elevated nitrate concentrations in high southern latitude surface waters, nitrate concentration is the main explanatory variable when all samples are considered.

In a companion paper, this modern analogue dataset has been applied to relative abundance data from sediment core Y9, in order to reconstruct the SST changes over the last 160 ka at the easternmost boundary of the Campbell Plateau, east of New Zealand.

1. Introduction

Polycystine radiolarians, marine protozoans using biogenic silica to build their tests, are generally well-preserved in surface sediment samples, and are particularly useful for palaeoenvironmental reconstructions in high-latitude, open ocean areas, where most other microfossil groups suffer from dissolution and/or low diversity.

Due to their exclusively planktonic life cycle, their relative abundances are usually well correlated to the main characteristics of the surface water masses in which they live, which makes them useful tracers for water masses, frontal systems, and environmental variables, particularly sea surface temperature (Abelmann and Gowing, 1997; Boltovskoy, 1998).

A large number of regional radiolarian modern analogue datasets to be used for the reconstruction of palaeotemperature is already available for many regions of the World Oceans, including the North Pacific (Kamikuri et al., 2008; Matsuzaki et al., 2014), the equatorial/eastern Pacific (Pisias and Mix, 1997; Pisias et al., 1997), Atlantic (Morley, 1979), Norwegian/Greenland/Iceland Seas (Bjørklund et al., 1998; Cortese et al., 2003; Cortese et al., 2005), Indian Ocean (Morley, 1989; Rogers and De Deckker, 2007) and Southern Ocean (Abelmann et al., 1999; Cortese and Abelmann, 2002).

In the southwest Pacific, one study has addressed the palaeoenvironmental application of radiolarian assemblages to the immediate east of New Zealand, based on cluster analysis (Hollis and Neil, 2005), while several recent studies cover a broader area, use more sophisticated techniques, and are based on diatoms (Cochran and Neil, 2010), palynomorphs and dinoflagellates (Crouch et al., 2010; Prebble et al., 2013), and planktonic foraminifera (Cortese et al., 2013).

This study aims to establish a new modern reference dataset for the southwest Pacific, based on the relative abundance of radiolarian species preserved in surface sediment samples, enabling the reconstruction

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of past sea surface temperature in this area, particularly for those latitudinal provinces (e.g., subantarctic/antarctic) where the application of transfer functions based on other microfosssil groups is problematic.

2. Oceanographic setting

As the study area includes a rather large number of oceanographic features, water masses and frontal systems (Fig. 1), the reader is referred to two recent papers for more detailed oceanographic settings of the two main regions included in this study: the area to the south and east of New Zealand (Panitz et al., 2015), and the western equatorial Pacific/Tasman Sea (Cortese et al., 2013), respectively.

The two main large-scale current systems in the study area are those responsible for the exchange of heat between low and middle latitudes [the South Pacific Gyre (SPG) and the East Australian Current (EAC)], and between middle and high latitudes [the Antarctic Circumpolar Current (ACC), and its associated fronts]. The New Zealand landmass feels the combined influence of these two systems (e.g., in the dominant weather patterns), and the presence itself of a landmass, along with its underwater topography, at these latitudes exert a strong influence on the flow of oceanic currents and frontal positions.

The mainly wind-driven ACC is the world's largest current, with an average 125 Sv flow. Its northernmost boundary is represented by the Subantarctic Front (SAF), which flows along, and is bathymetrically bounded by the eastern flank of the Campbell Plateau, to the east of New Zealand (Morris et al., 2001). Further to the northeast, another submarine feature, Chatham Rise, plays a large role (Uddstrom and Oien, 1999) in controlling the position of the Subtropical Front (STF). Bottom topography is not however the only control on the STF, as its position is also dynamically steered by two eastwards flows: the East Auckland/East Cape currents advecting subtropical water along its northern flank, and the Southland Current, advecting a ca. 90% subantarctic surface water mixture along its southern flank (Sutton, 2003).

The STF is the most marked oceanic front in the southwest Pacific, as it is characterised by a steep temperature gradient (4–5 °C) (Heath, 1985), which separates two very distinct biogeographic areas/water masses: Subtropical Surface Water (STW) to the north, and Subantarctic Surface Water (SAW) to the south. These two watermasses have contrasting, and somewhat complementary, characteristics, with STW being warm (annual mean SST > 13 °C), saline (ca. 35.8), micronutrient-rich/macronutrient-poor, while SAW is colder (6–12 °C), less saline (34.5–34.8), micronutrient-poor/macronutrient-rich (Heath, 1985; Carter et al., 2008).

The SST gradient at the SAF is ca. 2 °C, and this feature represents the boundary between SAW to the north and Circumpolar Surface Water (CSW) to the south, with the latter being recognised thanks to its cooler temperatures (0–5 °C), and lower salinity (34.0–34.4).

The southernmost oceanic front of interest for this study is the Antarctic Polar Front (APF), separating CSW from Antarctic Surface Water (ASW), a watermass whose temperature can be lower than 0 °C (Carter et al., 2008).

As for the lower latitude portion of the study area (from the subtropics into the Tasman Sea), the main large-scale system is the South Pacific Gyre, whose western limb is represented by the South Equatorial Current (SEC). The southward-flowing branch of the SEC follows the eastern coast of Australia, as an eddy-rich system named the East

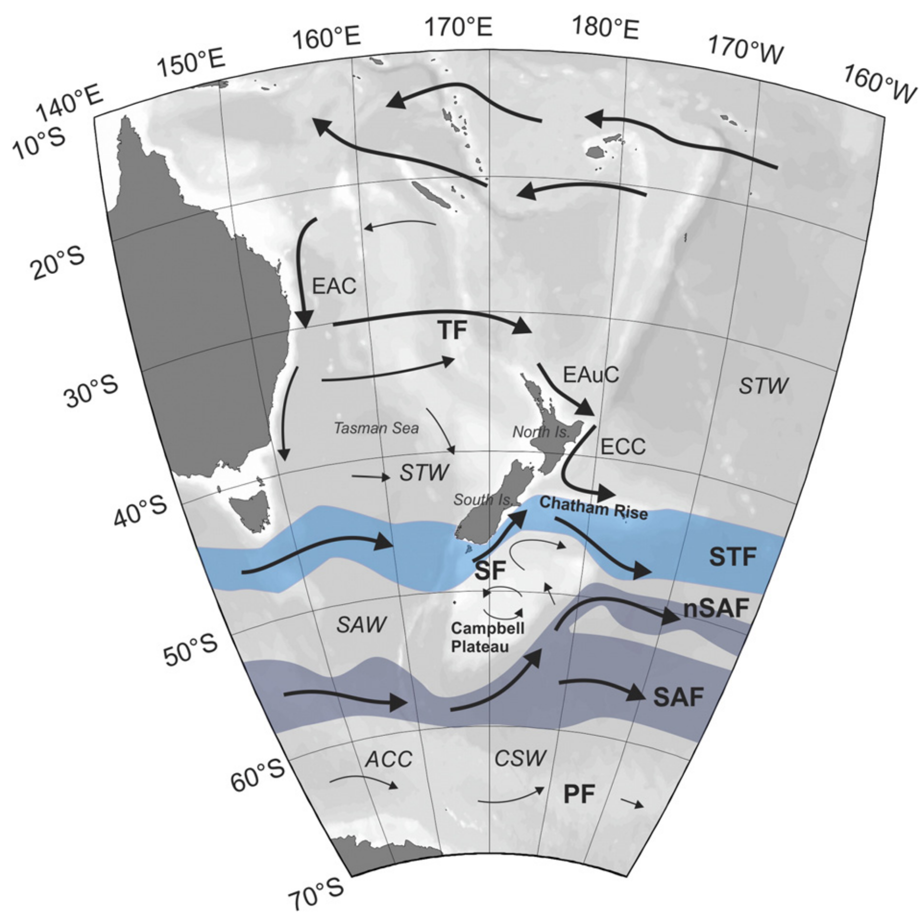

Fig. 1. Simplified oceanography and major currents and fronts in the study area. Frontal locations from Orsi et al. (1995), Carter et al. (1998), and Orsi and Harris (2001). Abbreviations are as follows: Frontal systems (bold): TF = Tasman Front; STF = Subtropical Front; SF = Southland Front; nSAF = northern Subantarctic Front; SAF = Subantarctic Front; PF = Polar Front; Currents (plain text): EAC = East Australian Current; EAuC = East Auckland Current; ECC = East Cape Current; Water-masses (italics): STW = Subtropical Water; SAW = Subantarctic Water; CSW = Circumpolar Surface Water; ACC = Antarctic Circumpolar Current.