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Recent geographical distribution of organic-walled dinoflagellate cysts in the southeast Pacific (25–53°S) and their relation to the prevailing hydrographical conditions

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ABSTRACT

Forty-eight surface sediment samples from the southeast (SE) Pacific (25–53°S) are investigated for the determination of the spatial distribution of organic-walled dinoflagellate cysts along the western South American continental margin. Fifty-five different taxa are recorded and reflect oceanic or coastal assemblages. The oceanic assemblages are characterised by low cyst concentrations and the dominance of autotrophs, while the coastal assemblages generally contain a higher number of cysts, which are mainly produced by heterotrophic species. Highest cyst concentrations are observed in the active upwelling system offshore Concepción (35–37°S). *Brigantedinium* spp., *Echinidinium aculeatum*, *Echinidinium granulatum/delicatum* and cysts of *Protoperidinium americanum* dominate assemblages related to upwelling. *Echinidinium aculeatum* appears to be the best indicator for the presence of all year round active upwelling cells. Other protoperidinioid cysts may also occur in high relative abundances in coastal regions outside active upwelling systems, if the availability of nutrients, co-responsible for the presence/absence of their main food sources such as diatoms and other protists, is sufficient. The importance of nutrient availability as a determining environmental variable influencing cyst signals on a regional scale (SE Pacific) is demonstrated through statistical analyses of the data. Because of the importance of nutrients, uncertainties about the outcomes of quantitative sea-surface temperature (SST) reconstructions (Modern Analogue Technique) based on dinoflagellate cysts may arise, since no interaction between different hydrographical variables is considered in this approach. The combination of the SE Pacific surface sample dataset with other published cyst data from the Southern Hemisphere resulted in a database which includes 350 samples: the 'SH350 database'. This database is used to test the accuracy of the quantitative reconstructions by calculating and comparing the estimated versus observed values for each site. An attempt to perform quantitative SST reconstructions on the last 25 cal ka of site ODP1233 (41°S; 74°27′W) is made and again stresses the importance of other environmental variables such as nutrient availability in determining the dinoflagellate cyst assemblages.

1. Introduction

Until now, the geographical distribution of dinoflagellate cysts and their controlling environmental factors in the SE Pacific Ocean are poorly understood. Except for the analysis of a few cores offshore Peru (Biebow, 2003; Wall et al., 1977) and a late Quaternary dinoflagellate cyst record offshore Mid-South Chile (Verleye and Louwye, 2010), no marine studies on dinoflagellate cysts are available. The sole study investigating the spatial distribution of cysts in the Chilean Fjord area between 43°S and 54°S is done by Alves-de-Souza et al. (2008). Dinoflagellate cyst studies during the last decennia mainly focused on the middle to high latitudes of the North Atlantic Ocean (e.g. Boessenkool et al., 2001a,b; de Vernal et al., 1994; de Vernal et al., 2001; Harland, 1983; Matthiessen, 1995; Rochon et al., 1999; Turon, 1984; Wall et al., 1977) since changes in the North Atlantic Deep Water production were generally accepted as the primary trigger for climate changes on orbital time scales (e.g. Broecker, 2003; Broecker and Denton, 1989; Clark et al., 2001; Imbrie et al., 1992, 1993; Seidov and Maslin, 2001; Vidal et al., 1999). Recently, new insights in millennial-scale climate change suggested also an active role for the Southern Hemisphere (SH) high latitudes in the initiation of rapid climate variability (Knorr and Lohmann, 2003; Stocker and Wright, 1991; Weaver et al., 2003). However, SH studies dealing with recent and late Quaternary dinoflagellate cysts are still rather rare (Alves-de-Souza et al., 2008; Benderra, 1996; Biebow, 2003; Esper and Zonneveld, 2002; Esper and Zonneveld, 2007; Harland and Pudsey, 1999; Harland et al., 1998; Marret and de Vernal, 1997; Marret et al., 2001; McMinn, 1992, 1995; McMinn and Sun, 1994; McMinn and Wells, 1997; Verleye and Louwye, 2010; Vink et al., 2000; Zonneveld et al., 2001).

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The spatial distribution of dinoflagellate cysts in marine environments is considered to be mainly controlled by SST, sea-surface salinity (SSS) and the availability of nutrients (Dale, 1996; Dale et al., 2002; de Vernal et al., 1997; de Vernal et al., 2001; Devillers and de Vernal, 2000; Rochon et al., 1999). Several studies supported the use of the transfer function method applied to dinoflagellate cysts to quantify palaeo-SST, palaeo-SSS, sea ice cover and more recently nutrient availability (e.g. de Vernal et al., 1997, 2001, 2005; Marret et al., 2001; Rochon et al., 1999; Voronina et al., 2001). Guiot (1990) developed transfer functions based on the best analogue method (MAT; Modern Analogue Technique) for pollen data, later adapted by de Vernal et al. (1993, 1994) for dinoflagellate cyst assemblages of the Northern Hemisphere (NH). However, methodological aspects of the MAT, such as spatial autocorrelation within the training set, were questioned during the last decade (e.g. Dale, 2001; Jackson and Williams, 2004; Telford, 2006; Telford and Birks, 2005, 2009). The ecological basis of the transfer functions have been evaluated for dinoflagellate cysts as well as other microfossil groups such as diatoms and benthic foraminifers (e.g. Anderson, 2000; Murray, 2001). Dale (1983, 1996) demonstrated that cysts in coastal/neritic environments show consistent biogeographical distributions that might differ considerably from those observed in the adjacent deep-sea, notwithstanding a similar SST. Dale and Dale (1992) suggested that the observed differences might be related to large-scale lateral transport of cysts produced in coastal waters to the deep-sea. Furthermore, the species response model underlying the MAT assumes a linear relationship between an environmental gradient and the abundance of a particular species. A species however will often show an unimodal relationship to a specific environmental gradient as demonstrated by a.o. Whittaker (1973a,b).

This study provides the first extensive database of the geographical distribution of organic-walled dinoflagellate cysts from surface sediment samples in the SE Pacific. In order to compile a database which includes the spatial distribution of recent dinoflagellate cysts in the SH, the SE Pacific core-top samples were combined with surface sediment samples from earlier studies; this resulted in a database including 350 sites. This so called SH350 database was further used to gain insight into the underlying mechanisms and reliability of the MAT as a method for quantitative palaeoenvironmental reconstructions. This allows us to test if SSS and SST can be used as independent determining parameters, apart from other hydrographical variables and their mutual interactions, in order to make accurate quantitative palaeohydrographical reconstructions.

2. Regional settings

The eastward flowing Antarctic Circumpolar Current (ACC) dominates the surface water circulation of the SH high latitudes,

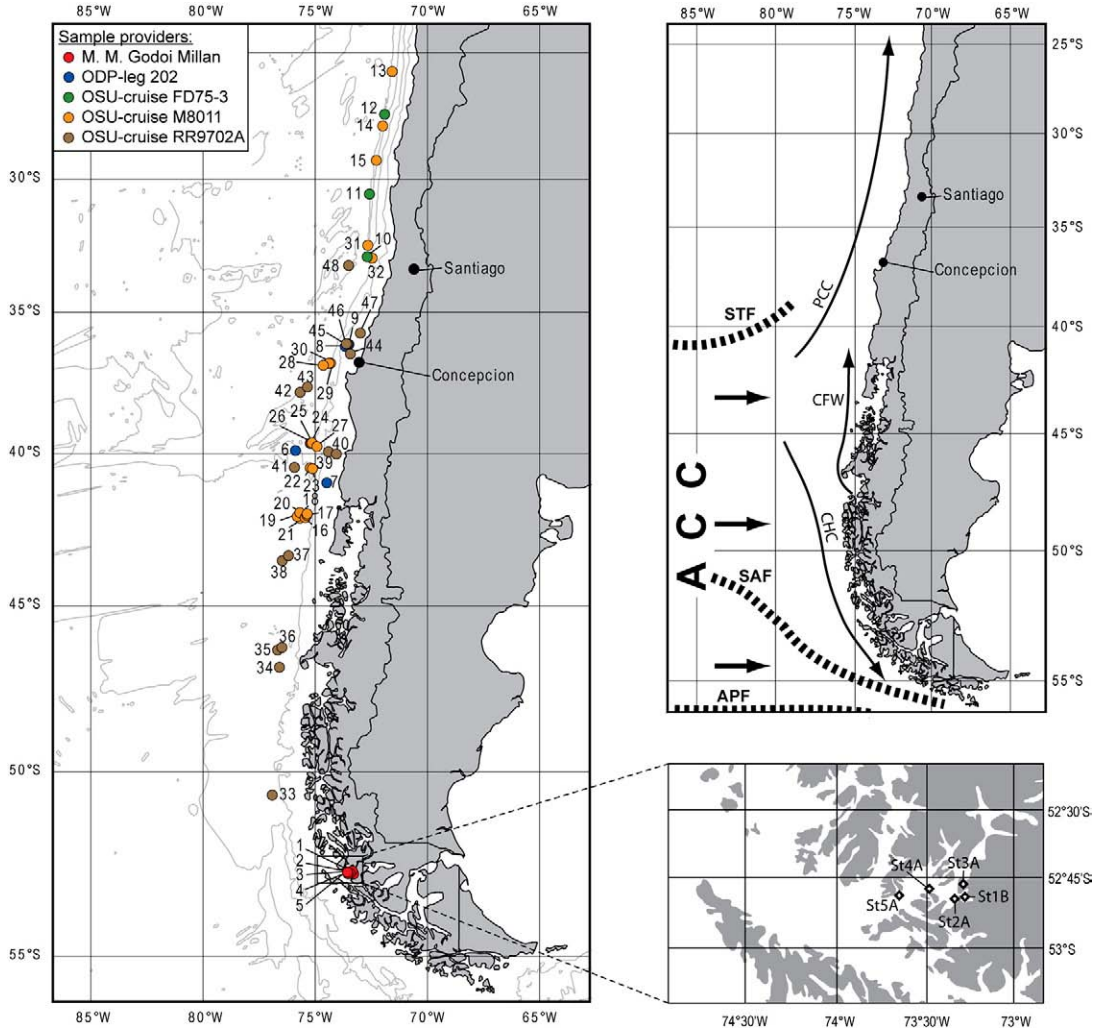

Fig. 1. Location of the 48 studied sites along the Chilean coast. Inset map of the fjord area in South Chile. The material derived from several institutions and cruises as indicated by the coloured dots. The upper right map visualises the main sea-surface oceanographic currents and circumpolar frontal systems. Abbreviations: ACC, Antarctic Circumpolar Current; CFW, Chilean Fjord Water; CHC, Cape Horn Current; PCC, Peru–Chile Current; APF, Antarctic Polar Front; SAF, Subantarctic Front; STF, Subtropical Front. Position of the circumpolar frontal systems after Belkin and Gordon (1996).