RECONSTRUCTING THE SOUTH PACIFIC UPPER WATER CONDITIONS DURING THE LATE QUATERNARY

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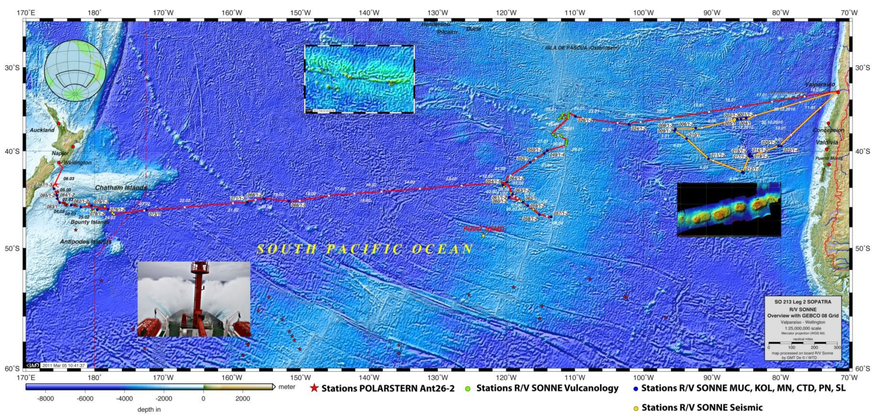
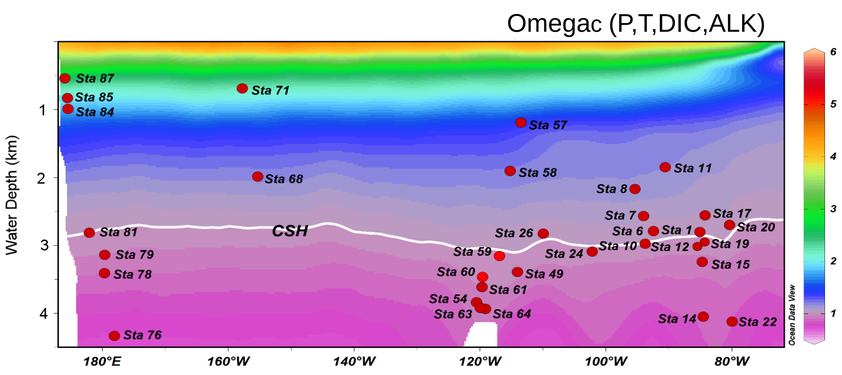
ABSTRACT

The Antarctic Circumpolar Current system (ACC) is the most prominent current system in the Southern Ocean, characterized by strong zonal variations in surface water properties. The variations are used to classify regions, whose edges are defined by fronts. These fronts are characterized by bands of large horizontal density gradients associated with high velocity surface currents. The past changes in the strength and latitudinal position of the ACC frontal system are supposed to play a major role on the global oceanic circulation and thus the Earth's climate. For example, limiting the transfers of CO_2 from the deep ocean to the atmosphere might have been caused by a reduction in the vertical mixing of surface waters. Our study on the variability of surface characteristics of the ACC provides crucial information to understand and to reconstruct the global climate evolution.



Locations of the core top samples retrieved during the **SOPATRA SO-213** cruise (**So**uth Pacific **Pa**leoceanographic **Tra**nsect) from Chile to New Zealand.



Depth position of the core tops in relationship to the Calcite saturation (Ω calcite). The calcite saturation was calculated for the transect P06 2003, calculated from DIC and alkalinity data taken from the CARINA database (Tanhua et al ., 2008). Illustration done with Ocean Data View 4 (Schlitzer, 2009). Ω calcite = 1 countour is highlighted to show the extrapolated depth of the Compensation Saturation Horizon (**CSH**).

PROXY CALIBRATION

Seasurface temperature calculation

Paleo seasurface temperatures ($SST_{Mg/Ca}$) were calculated from the Mg/Ca ratios of the planktonic foraminifer *Globigerina bulloides. G. bulloides is a* transitional to subpolar species, with a vertical distribution of ~50-150 m water depth and a wide temperature range with optimum temperatures between 10ºC and 20ºC (Wang *et al*., 1995).

Specimens of *G. bulloides* were selected from the 355–400 µm size fraction of cores SO213-59-2 and SO213-60-1. The conversion of foraminiferal Mg/Ca ratios into $SST_{Mg/Ca}$ was according to the equation of Mashiotta *et al*. (1999):

$$Mg/Ca = 0.474\ e0.107\ SST \qquad R^2 = 0.98$$

The error in terms of $SST_{Mg/Ca}$ is ±0.8ºC. The calibration of Mashiotta *et al*. (1999) is based on Mg/Ca from cultured and Subantarctic Southern Ocean core-top foraminifers related to laboratory and sea surface temperatures. At temperatures <17ºC, it is equivalent to the Elderfield and Ganssen (2000) calibration, which related foraminiferal Mg/Ca to subsurface foraminiferal calcification depths.

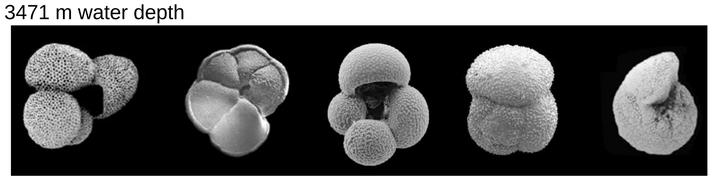
MATERIAL

Core-Top Foraminiferal Mg/Ca

Here we present Mg/Ca of shallow-living (*G. bulloides, G. sacculifer*) and deeper-living planktonic foraminifers (*G. inflata, G. menardii, G. truncatulinoides*) preserved in core top samples from the South Pacific (36º to 45ºS). Sediments were retrieved during the **SOPATRA SO-213** cruise (**So**uth Pacific **Pa**leoceanographic **Tra**nsect) from Chile to New Zealand in 2010/2011.

Downcore records

We provide $SST_{Mg/Ca}$ records for two cores from the East Pacific Rise:Core SO213-59-2 is at 45.8ºS / 116ºW and was recovered from 3164 m water depth. Core SO213-60-1 is located at 44.9ºS / 119ºW and was retrieved from 3471 m water depth

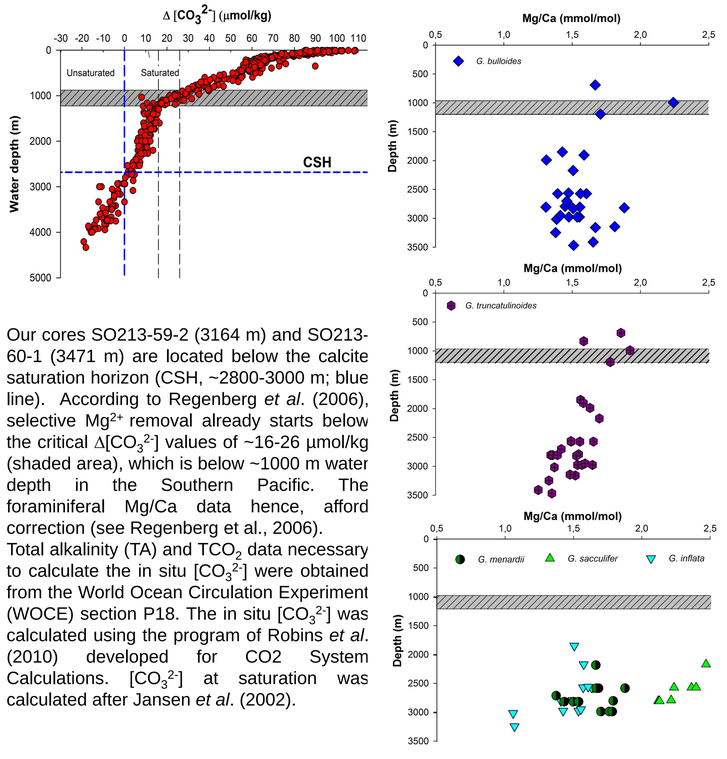


G. sacculifer ***G. menardii*** ***G. bulloides*** ***G. inflata*** ***G. truncatulinoides***

PROXY ASSESSMENT

Calcite dissolution affecting foraminiferal Mg/Ca

The foraminiferal Mg/Ca signal is definitely affected by calcite dissolution, which causes the selective removal of Mg^{2+} from the biotic calcite, lowers Mg/Ca, and decreases $SST_{Mg/Ca}$ (Regenberg *et al*., 2006; Dekens *et al*., 2002). In order to evaluate the reliability of the South Pacific Mg/Ca signal for paleotemperature reconstructions, we defined the effect of the calcite saturation state (CSH, $\Delta[CO_3^{2-}] = 0$) on foraminiferal Mg/Ca for selected planktonic species. The total Mg/Ca values preserved in the foraminiferal calcite from the core top samples ranged from ~2 to 1.3 mmol/mol. Notably, only *G. truncatulinoides* and *G. sacculifer* show an evident reduction in their Mg/Ca ratios with increasing water depth.

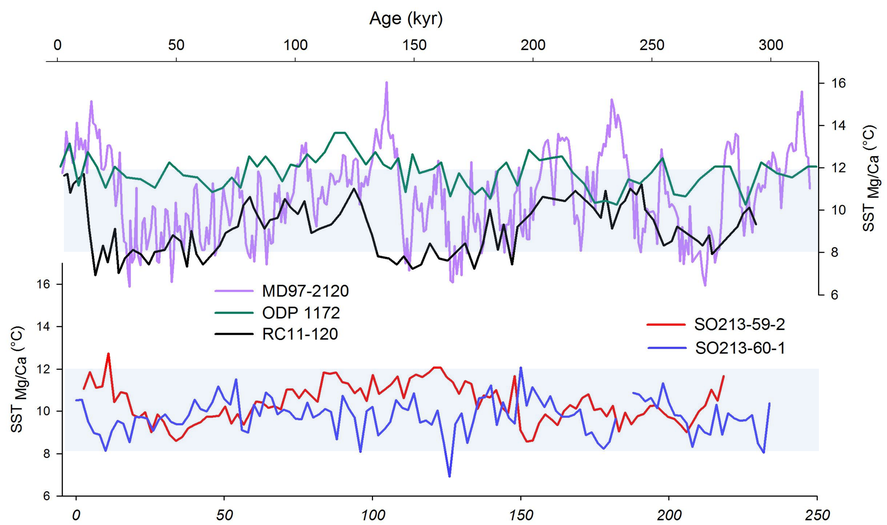


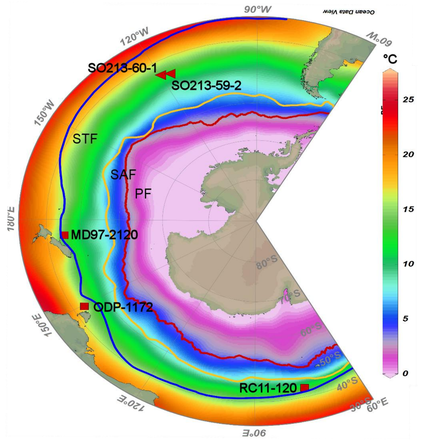
Our cores SO213-59-2 (3164 m) and SO213-60-1 (3471 m) are located below the calcite saturation horizon (CSH, ~2800-3000 m; blue line). According to Regenberg *et al*. (2006), selective Mg^{2+} removal already starts below the critical $\Delta[CO_3^{2-}]$ values of ~16-26 µmol/kg (shaded area), which is below ~1000 m water depth in the Southern Pacific. The foraminiferal Mg/Ca data hence, afford correction (see Regenberg et al., 2006).
Total alkalinity (TA) and TCO_2 data necessary to calculate the in situ $[CO_3^{2-}]$ were obtained from the World Ocean Circulation Experiment (WOCE) section P18. The in situ $[CO_3^{2-}]$ was calculated using the program of Robins *et al*. (2010) developed for CO2 System Calculations. $[CO_3^{2-}]$ at saturation was calculated after Jansen *et al*. (2002).

Mg/Ca ratios (355-400 µm size fraction) versus water depth for each planktonic foraminiferal species (*G. bulloides, G. truncatulinoides, G. inflata, G sacculifer, G., menardii*). The shaded area marks the critical depths below which Mg^{2+} is selectively removed from the foraminiferal calcite.

SEA SURFACE RECONSTRUCTION

Comparison of $SST_{Mg/Ca}$ downcore records of G. *bulloides* from the East Pacific Rise: SO213-59-2 (red) and SO213-60-1 (blue) (data plotted versus core depth due to a still missing stratigraphy). For comparison, we show three Southern Ocean sites from comparable southern latitudes: ODP Site 1172A from East Tasman Rise (green, Nürnberg & Groeneveld, 2006), RC11-120 from the subantarctic Indian Ocean (black, Mashiotta *et al*., 1999), and MD97-2120 from Chatham Rise (purple, Pahnke *et al*., 2003) (all plotted versus age).
The coretop $SST_{Mg/Ca}$ of ~11ºC at our core locations is close to the modern austral summer temperature, reflecting conditions south of the Subtropical Front.





Ocean seasurface temperature chart (austral summer) showing the locations of our cores SO213-59-2 and SO213-60-1 and reference sites of interest to this study. All sites are located at comparable southern latitudes. The positions of the Subtropical Front (STF, blue line), the Subantarctic Front (SAF, orange line), and the Polar Front (PF, red line) are indicated.

The $SST_{Mg/Ca}$ are quite similar at both core locations, although core location SO213-60-1 is deeper by ~300 m and should have been more strongly affected by calcite dissolution. The $SST_{Mg/Ca}$ of our cores range from ~12.6º to ~8.4ºC (SO213-59-2) and ~11.2º to ~7ºC (SO213-60-1). The preliminary comparison with records from similar southern latitudes show that our records are similar in absolute temperature and amplitude to the temperature record Mashiotta *et al*., (1999) from the Indian Ocean.

REFERENCES

Deckens *et al*., 2002. Geochem. Geophys. Geosyst., 3(4), 1022, doi:10.1029/2001GC000200
Elderfield & Ganssen. 2000. Nature, 405, 442–445.
Jansen, H., *et al*., 2002.Global Biogeochem. Cycles, 16(2), 1027, doi:10.1029/2000GB001279.
Mashiotta *et al*., 1999. Earth and Planetary Science Letters 170 417–432
Nürnberg & Groeneveld, 2006. Geochem. Geophys. Geosyst., 7, Q04P11,doi:10.1029/2005GC000984.
Regenberg et al., 2006. Geochem.Geophys. Geosyst., 7, Q07P15, doi:10.1029/2005GC001019
Pahnke *et al*., 2003. Science *301, 948;* doi: 10.1126/science.1084451
Robbins, ***et al*.**,2010. U.S. Geological Survey Open-File Report 2010–1280.
Schlitzer, 2009. Ocean Data View software. /http://odv.awi.de/S.
Tanhua *et al*., 2008. CARINA Data Synthesis Project, ORNL/CDIAC-157, NDP-091. Carbon Dioxide Information Analysis Center. Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee. doi:10.3334/CDIAC/otg.ndp091.
Wang, L., *et al*.1995. Paleoceanography, 10(4),749–761.