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# Late Pleistocene Sea Surface Temperature Variations in the Peru-Chile Current


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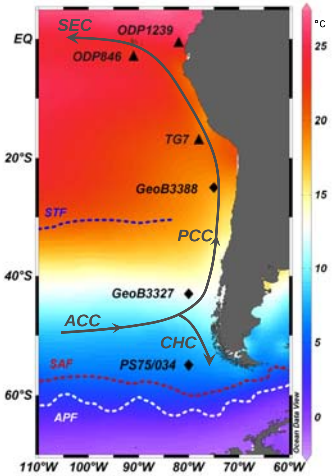


## 1. Background of study

The southeast Pacific mid- to low-latitudes are an important area of heat transfer from the southern high latitudes to the tropics via the vigorous Peru-Chile Current (PCC). The changes in PCC advection account for about half of the total variability in equatorial SSTs (Feldberg and Mix, 2003). However, currently available mid-latitudes sea surface temperature (SST) records are mostly from the continental margin and do not reach back beyond the last glacial (e.g. Kaiser et al., 2005), neither do they extend more southerly that 45°S. Therefore, this study was carried out as an attempt to improve our understanding on the SST variations in southern mid- and high-latitudes on orbital time scale and its implication on the PCC and global climate.

**Figure 1**: Location of study sites along the latitudinal range of the PCC. Black diamonds indicate cores studied in this work, black triangles indicate sites with published alkenone based SST records; TG7 Calvo et al. (2001), ODP846 Lawrence et al. (2006), ODP1239 from Rincón-Martínez et al. (2010). Grey line denotes the major surface currents; dotted lines denote oceanic fronts based on Orsi et al. (1995). Abbreviations: APF = Antarctic Front; SAF = Subantarctic Front; STF = Subtropical Front; ACC = Antarctic Circumpolar Current; CHC = Cape Horn Current; PCC = Peru-Chile Current; SEC = South Equatorial Current.

## 2. Material, methods and stratigraphy

- 3 piston cores (GeoB3388, GeoB3327 and PS75/034) were used to complete the north-south transect along the PCC.
- Sea surface temperature was estimated using $U^{k'}_{37}$ index with the global core top calibration of Müller et al. (1998)
- Age models were based on visual alignment of benthic benthic d18O record to reference record: core GeoB3388 was tuned to ODP Site 677 as reported in Mohtadi et al. (2006) while GeoB3327 was tuned to LR04 stack (Lisiecki and Raymo, 2005). (Figure 2)
- Preliminary stratigraphy of core PS75/034 was achieved by tuning its SST record to that of GeoB3327 up till MIS12 and linear extrapolation for interval before MIS12.
- The reconstruction of paleo SST gradient is done based only on visual assessment due to the difficulty in quantitative reconstruction caused by very different sampling interval in the records.
- Due to the preliminary nature of the results, the discussions remain highly speculative.

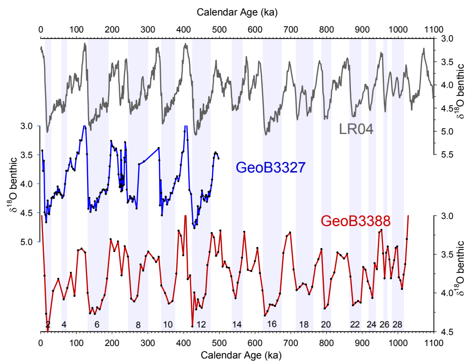


**Figure 2**: Benthic $\delta^{18}O$ records of GeoB3388 and GeoB3327, global benthic $\delta^{18}O$ stack LR04 (Lisiecki and Raymo, 2005) as reference.

## 3. Results

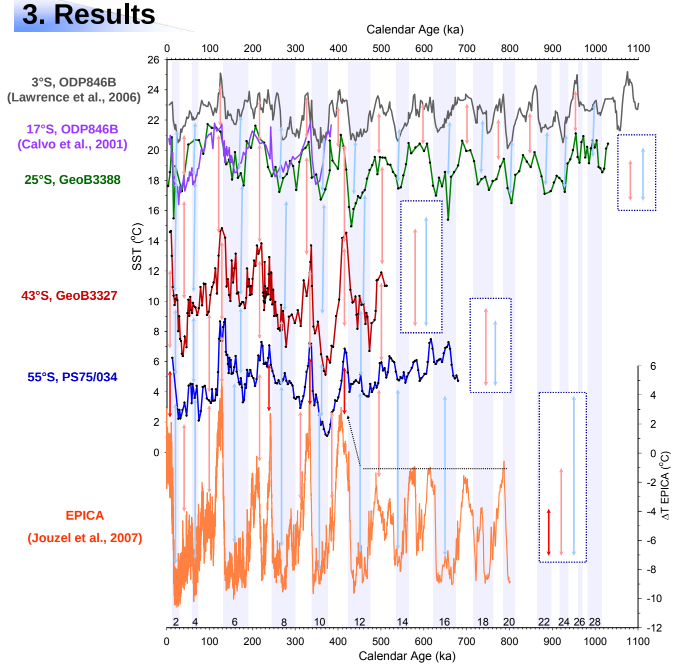


**Figure 3**: SST records along the latitudinal range of the PCC and the ΔT record from Dome C on EDC age scale. Blue bars denote glacial interval, the numbers in the bars denote marine isotope stage. The arrows illustrate the temperature difference between the records; blue arrows (glacials), pink arrows (interglacials); red arrows (interglacial maxima between core PS75/034 and ΔT in ice core). Black dotted lines depict the shift in interglacial baseline in EPICA ΔT records.

### 3.1. SST Variations

#### (a) Subantarctic (Figure 3)

- Gradual warming or warming event (e.g. MIS 6 at 43°S) during the glacials prior to terminations – this feature is not observed in the ΔT EPICA, nor the benthic oxygen isotope.
- Coldest glacial – MIS 10; warmest interglacial – MIS 5e.
- Most drastic SST change across the glacial-interglacial (G-I) cycles occurred during the transition from MIS 11 maximum to MIS 9 maximum.
- G-I SST amplitude: ~9°C at 43°S; ~6°C at 55°S but ~3°C before MIS12.

#### (b) Subtropics (Figure 3)

- The trend and absolute values of SST (low resolution, GeoB3388) is similar to the published record TG7 (Calvo et al., 2001) except MIS 4.
- Interglacial intervals are prolonged relative to those from the mid- and high-latitudes.
- "Gradual warming" as found in the higher latitudes (GeoB3327 and PS75/034) is also observed in MIS 6 and MIS 16.

### 3.2. Severity of glacials

- There is a decoupling between benthic $\delta^{18}O$ and SST at subtropical (GeoB3388) and subantarctic (GeoB3327) sites during MIS 6 and MIS 12 – warm SSTs in spite of large global ice volume. (Figure 2 and Figure 3)
- Warm MIS 6 is present in all the sites along the latitudinal range of the PCC.
- At 55°S: Glacial baseline before MIS 10 was warmer than the later glacials.

### 3.3. Meridional thermal gradients

- Steeper gradient between tropics and subtropics during glacial – could imply northward shift in subtropical front to the north of 25°S.(Figure 3)
- Smaller gradient between 43°S and 55°S during glacial – might be due to a northward shift of ACC to the north of 43°S.
- Before MIS11: Large gradient between 55°S and the Antarctica due to contrasting shift, i.e. colder interglacial baseline in ΔT EPICA and warmer glacial baseline in SST at 55°S. (Black dotted lines in Figure 3 and Figure 4)

## 4. Discussions

### 4.1. Potential Causes of "glacial warming"

- Not observed in EPICA ΔT record – probably not caused by the ice sheet
- Retreat of sea ice - triggered by austral high-latitudes glacial spring/summer insolation if it passes a certain "threshold" (Figure 4)
- Remarkable synchrony with T residual of EPICA, which might have a coupling mechanism with the low latitudes (Masson-Delmotte et al., 2010)
- Severity of glacial SSTs correlates with the eccentricity – low latitude signals? Monsoon?

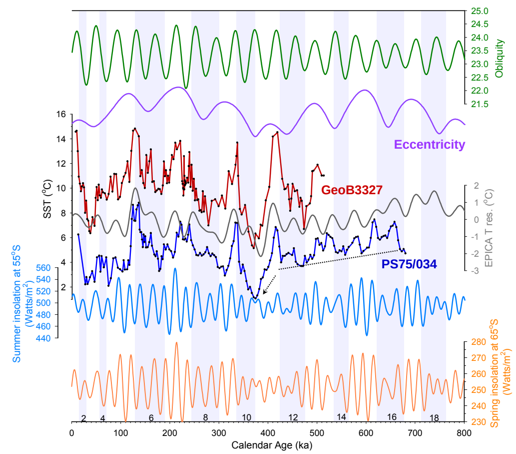


**Figure 4**: A comparison of orbital parameters, insolation, SST at the subantarctic and the residual part of EDC temperature than cannot be explained by a multiple linear model considering greenhouse radiative forcing and obliquity. Blue bars denote glacial intervals, the numbers in the bars denote marine isotope stages. Black dotted line indicates the shift in glacial baseline in PS75/034.

### 4.2. PCC variations over G-I cycles

- Glacial equatorward shift of Subtropical front and ACC, coupled with a glacial northward shift of the Equatorial front and Intertropical convergence zone (Rincón-Martínez et al., 2010) – could imply an equatorward shift of the subtropical gyre circulation during the glacials in the past 500ka.
- Judging by the steep glacial SST gradients between mid-latitude and the tropics due to substantial cooling at site GeoB3327, it is possible that the wind-driven gyre circulation is strengthened and the PCC became more vigorous during the glacials.

## 5. Conclusions

- Warming across the glacials in the subantarctic, especially MIS 6, 8, and 12 probably caused by high austral spring insolation.
- Mismatch between SST and benthic $\delta^{18}O$ regarding the severity of glacial along the latitudinal range of the PCC (MIS 6)


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