*Paleoceanography and Paleoclimatology*

Supporting Information for

# Ventilation and expansion (water column geometry) of the Southeast Pacific water masses during termination I

N.A. Haddam[1, 2], E. Michel[2], G. Siani[1], L. Licari[3], F. Dewilde[2]

[1]GEOPS Géosciences Paris-Sud, CNRS, Université de Paris Sud Paris Saclay, Bâtiment 504, Rue du Belvédère Campus Universitaire d'Orsay 91405 Orsay Cedex, France.

Orcid id : orcid.org/0000-0003-1201-4488

[2]LSCE/IPSL Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS-UVSQ, Orme des Merisiers, 91190 Saint-Aubin, France.

[3]Centre Européen de Recherche de d'Enseignement des Géosciences de l'Environnement, CNRS, Université d'Aix-Marseille, Europôle Méditerranéen de l'Arbois - Avenue Louis Philibert - BP 80 - 13545 AIX EN PROVENCE cedex 04.

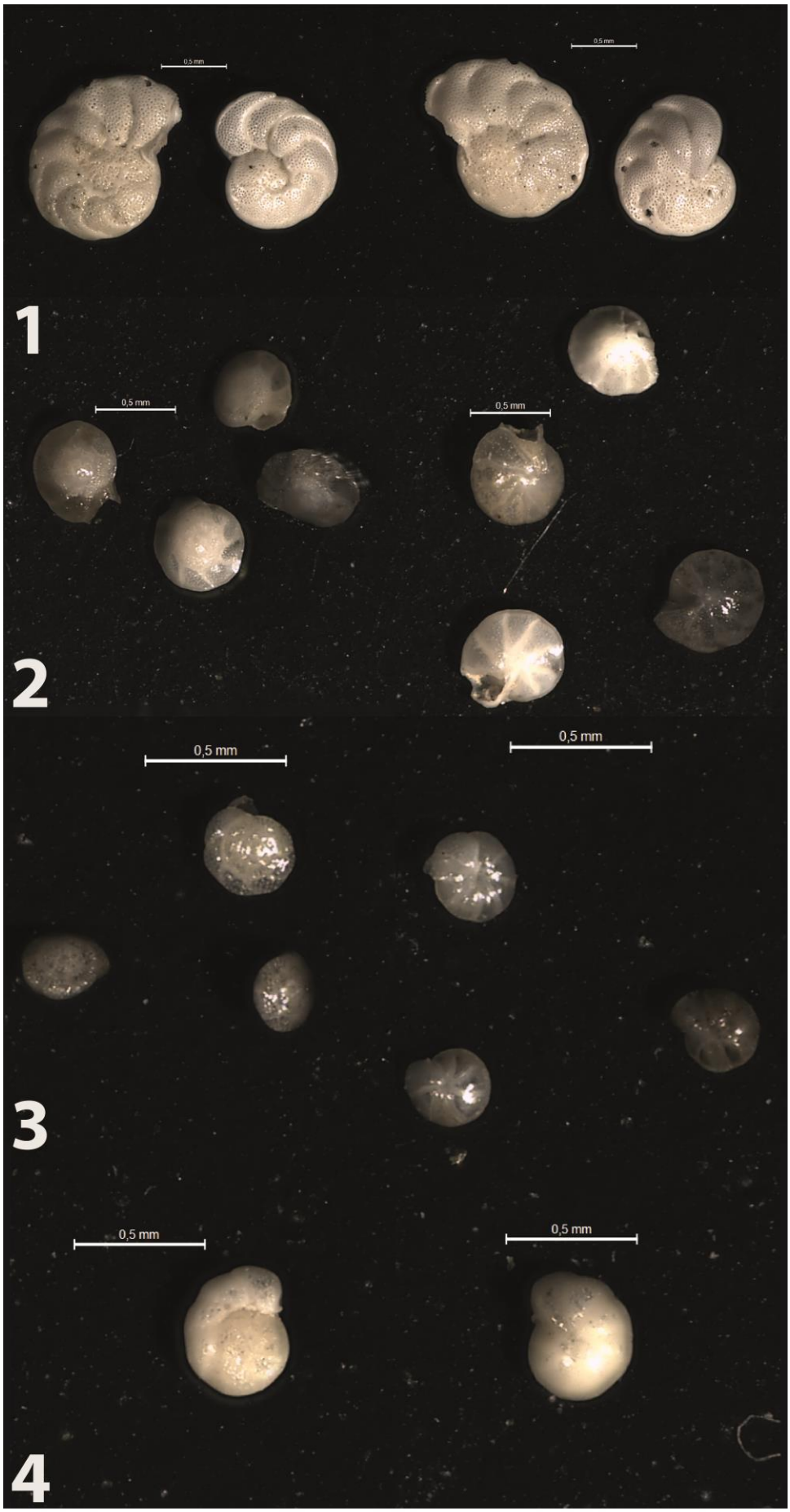
## Contents of this file



## Introduction

In this section we present additional, complementary information on the faunal data, age model, and X-ray fluorescence data, and extended descriptions of the diversity indexes.

**TextS1 Supplementary information on foraminifera accumulation rates and diversity index**

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**Picture S1 Benthic foraminifera used for the isotopic measurements.1) *C. wuellerstorfi*; 2) *C. pachyderma*; 3) *H. bradyi*; 4) *C. kullenbergi*. The dorsal (left) and umbilical (right) views are displayed for each species. These foraminifera were sampled in core MD07-3100.**

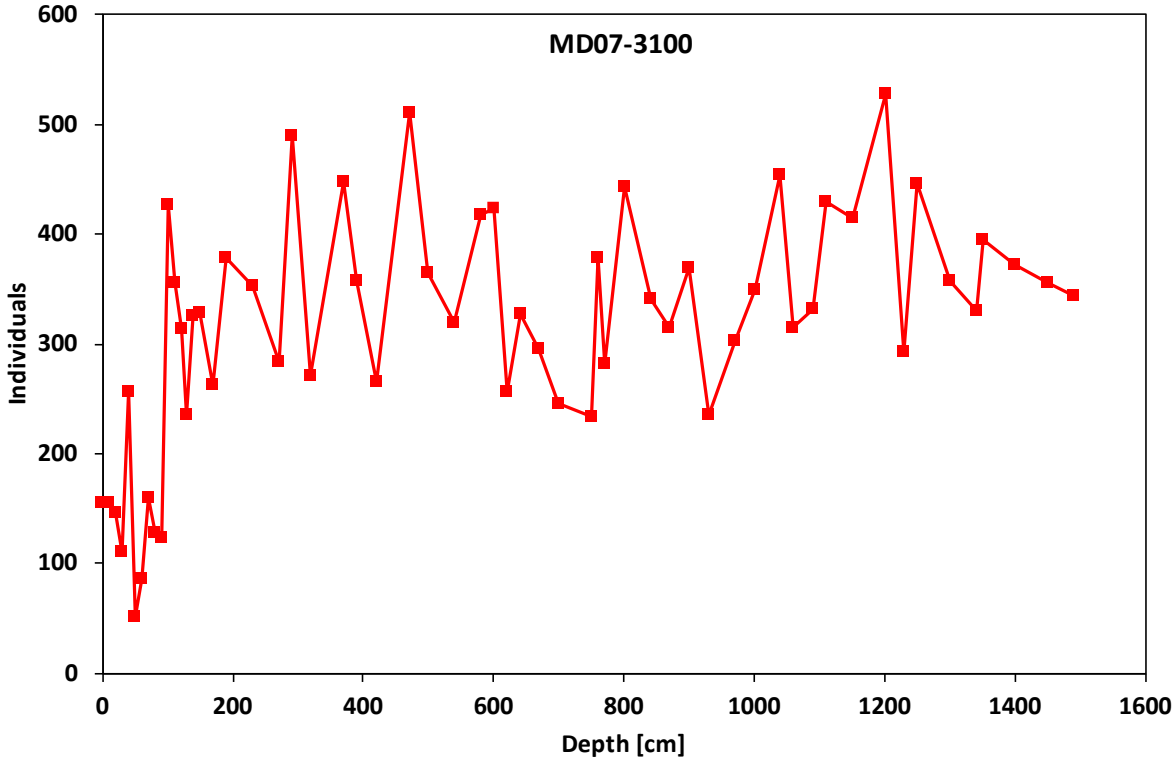


Figure S1 Total individuals counted in core MD07-3100.

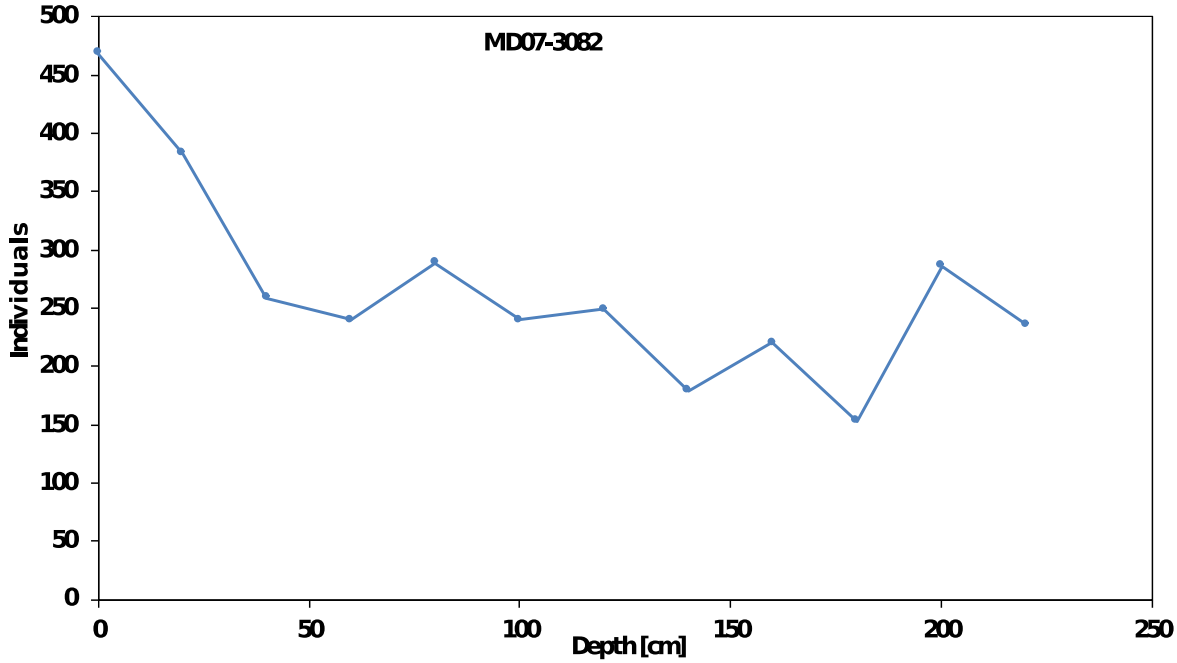


Figure S2 Total individuals counted in core MD07-3082.

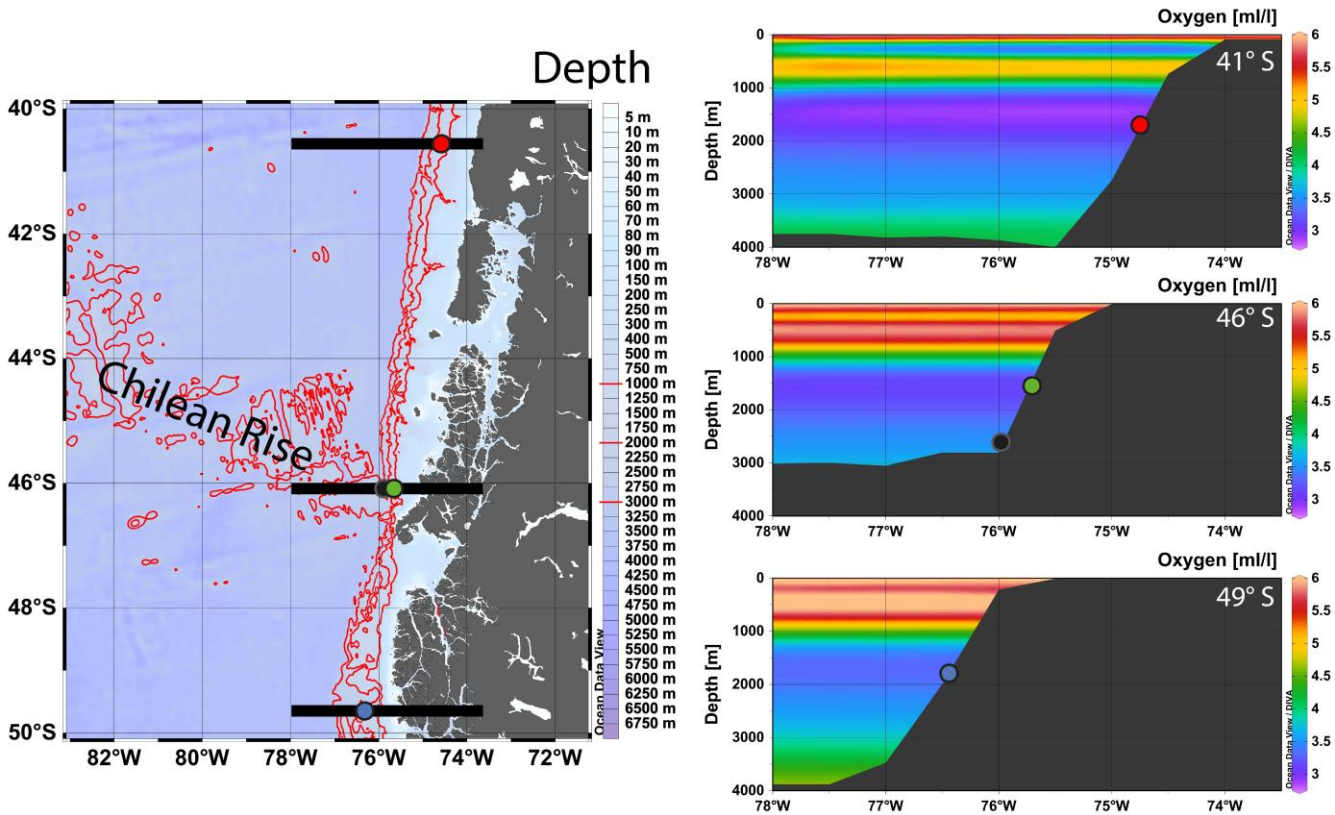


Figure S3 East-West transects showing the slope and seafloor architecture at each site. Red isolines indicate depths 1000, 2000, and 3000 m to emphasize the slope and the Chilean rise.

We measured X-ray Fluorescence (XRF) each centimeter in the sediment of core MD07-3082, using an Avaatech core scanner at the Alfred Wegener Institute in Bremerhaven, Germany (Figure S4). Both Barium and Barium Titanium ratio show highest values during the Holocene (Figure S4).

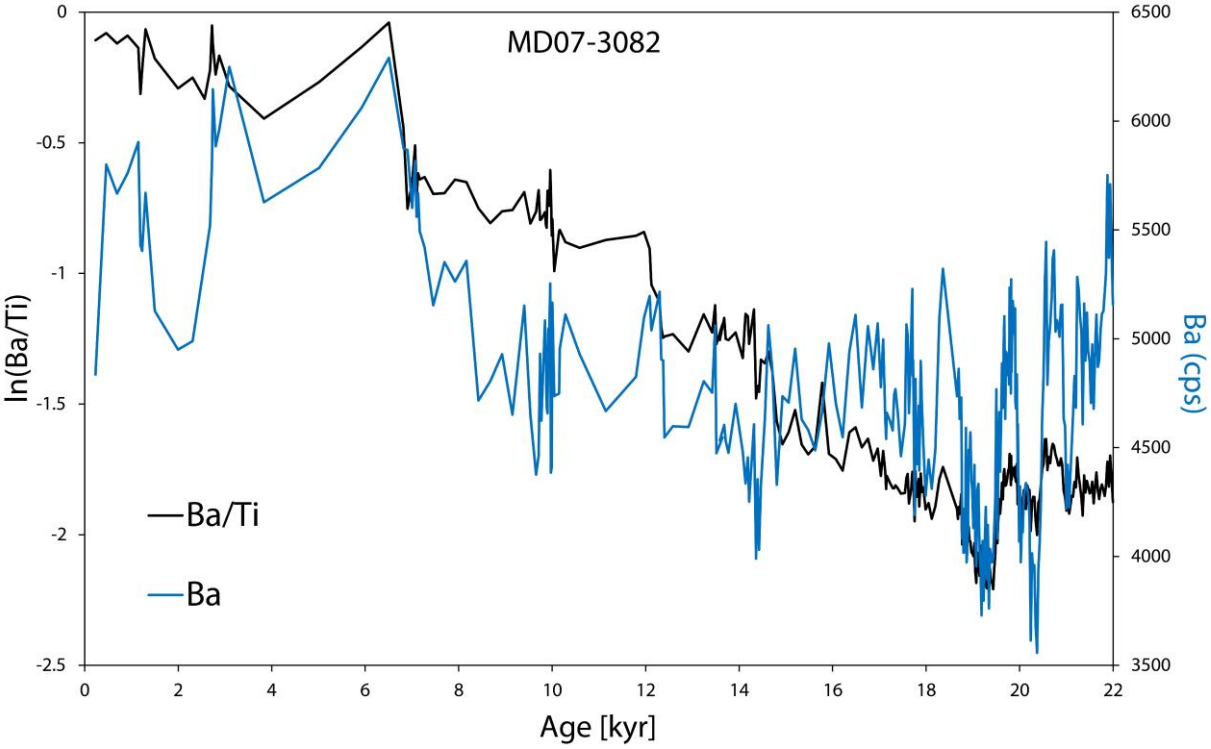


Figure S4 Barium and Titanium measured in the sediment of core MD07-3082 using X-Ray fluorescence. The Barium is expressed in counts per second.

We calculated the Benthic Foraminifera Accumulation Rate (BFAR) for core MD07-3100 and MD07-3082 (figure S6). The BFAR is obtained from the product of the number of foraminifera per gram of dry sediment, dry bulk density (g/cm$^3$), and the sedimentation rate (cm/kyr). For each core, we used the bulk density measurements from the shipboard physical properties dataset (*Kissel*, 2007). Although the BFAR is intrinsically corrected from sedimentation rates variations, we cannot discard any sedimentary influence on this signal. A correction of the fluxes using $^{230}$Thorium in excess as proposed by *Bacon*, (1984) would have helped to improve the correction of the accumulation rates, but unfortunately the Chilean margin geographical setting, with high continental terrigenous inputs to our study area, prevent us to performing this exercise.

Using the benthic foraminifera assemblages we calculated the Shannon diversity index 'H' (Hayek & Buzas, 1997; Shannon, 1948) with the PAST 3.01 software (Hammer et al., 2001) on the benthic foraminifera from core MD07-3100 and MD07-3082 (figure S6). This diversity index is useful when comparing samples of different totals of counted individuals. The H index in natural environments ranges between 1 and 3.5, with high values corresponding to stable ecosystems and low ones indicating environmentally stressed environments (Magurran, 1988). The H index reaches a maximum value if all the species of the sample are equally abundant.

BFAR calculated from the faunal content of cores MD07-3100 and 3082 are displayed in figure S5a and S5b.

The BFAR in core MD07-3100 (Figure S3b) varies from ~160 to ~34 000 f/cm²/kyr. Maximal values are found between ~10.7 and ~19.6 kyr, with several BFAR maxima (e.g. ~19.6, 16 and between ~14.6 and ~12.2 kyr). The last ~9 kyr are characterized by the lowest BFAR values, with little variability, compared to the previous time interval.

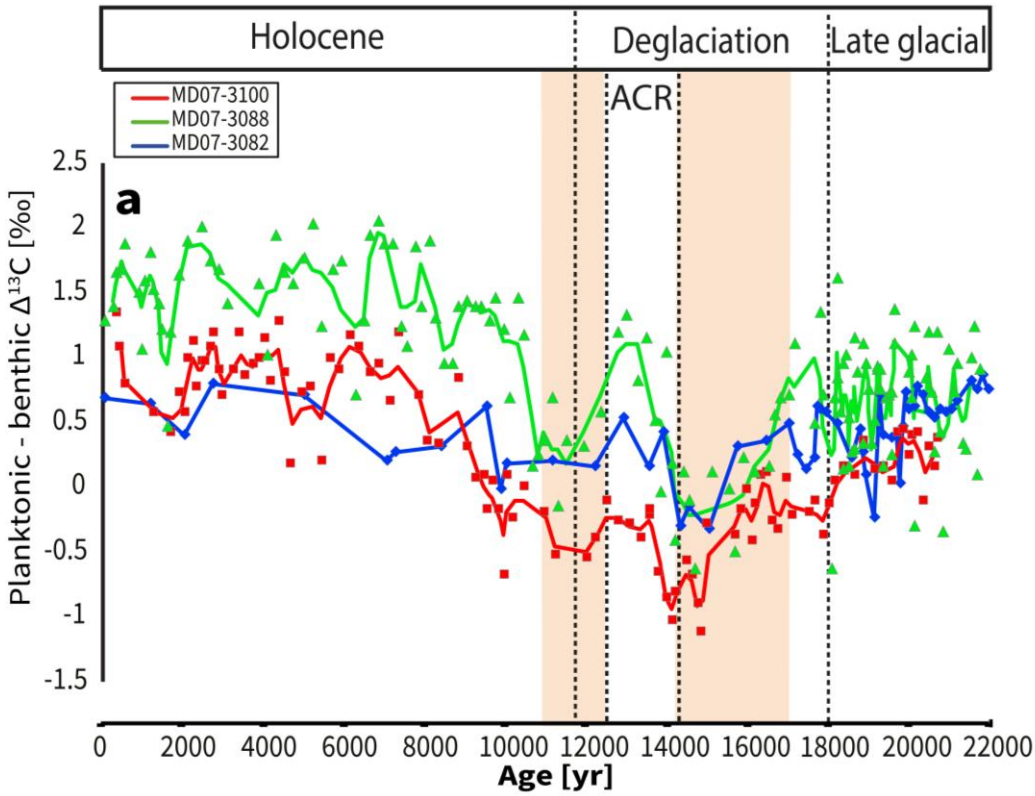


Figure S5 Planktonic – Benthic foraminifera ∂$^{13}$C difference. Pink shaded area are the periods of Southern Ocean upwelling increase.

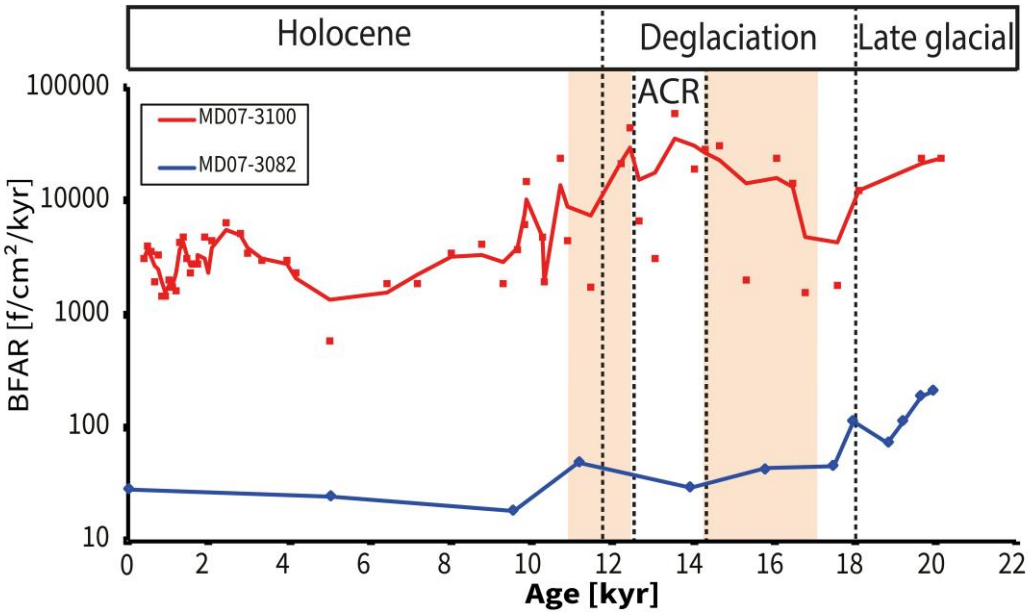


Figure S6 Benthic Foraminifera Accumulation Rates (BFAR) of cores MD07-3100 and MD07-3082. Pink shaded area are the periods of Southern Ocean upwelling increase. A 3 points smoothing average was applied for the MD07-3100 curve.

The foraminifera accumulation rates indicate a difference in surface productivity between the northernmost and the southernmost cores, as the BFAR in the latter is several orders of magnitude

lower than MD07-3100 (figure S3). We also note highest BFAR values in core MD07-3082 during the late glacial.

- Diversity Indexes

Shannon index H was calculated from the assemblages of core MD07-3100 and core MD07-3082 (Figure 3c). In core MD07-3100, it shows a mean value of ~2.3. We note 3 events of increasing values reaching a maximum of ~2.7, from 8.7 to 10.2 kyr, from 11.5 to 14.2 kyr where the highest values are found, and older than 16.4 kyr. The last ~2 kyr are marked by the lowest Shannon index H values. In core MD07-3082, all values are between ~2.8 and ~2.6, except between 17.5 and 19.5 kyr, with H values ranging between ~2.2 and ~2.4 (Figure 4c). Interestingly the Holocene (especially >9 kyr) seems to be a period of less diversity in core MD07-3100 compared to the ACR (figure S4). In the uppermost Holocene, the low H values are due to the low number of counted foraminifera (<250) highlighting poor benthic foraminifera production at this time.

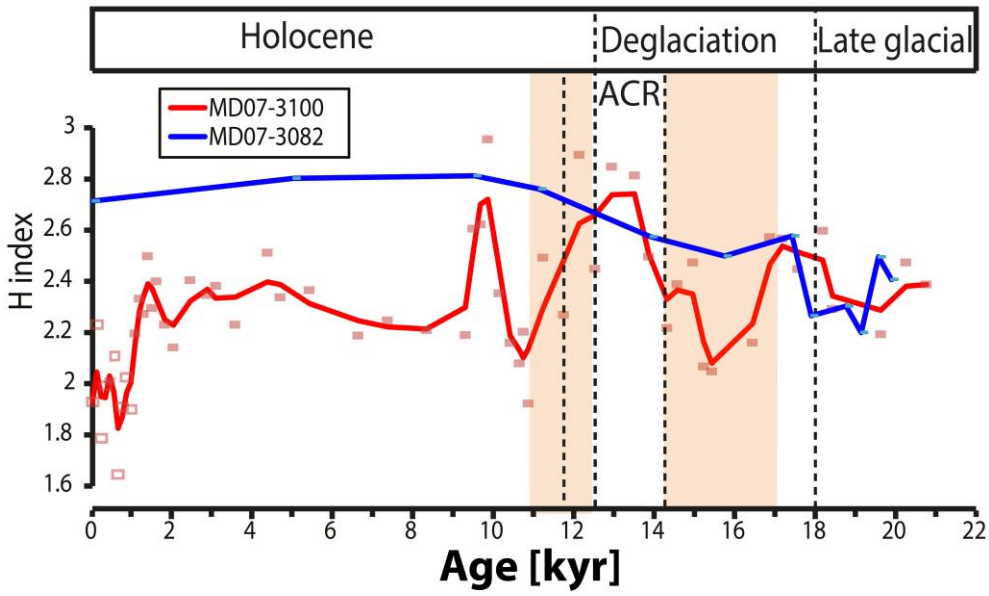


Figure S7 Shannon H index calculated from the assemblage of cores MD07-3100 and MD07-3082. Pink shaded area are the periods of Southern Ocean upwelling increase.

The deglacial upwelling events and the PIS meltwater fluxes probably induce an increase in primary productivity generating BFAR increase (figure 3). Nevertheless, this enhanced BFAR events during the deglaciation may traduce more fertilized surface water. This labile source of food is then transferred to the bottom water enhancing the total benthic foraminifera stock production as indicated by the BFAR record. However, the intervention of external parameters such as: i) changes in primary producers, ii) varying hydrodynamic conditions in the bottom water, or iii) changes in [$O_2$] cannot be excluded. At the deglaciation onset, the surface and bottom water $\delta^{13}C$ gradient decreases (Supplementary information figure S5), while the [$O_2$] increases (Figure 2c) suggesting increased vertical mixing masses during this time. The BFAR seems to be at their maximal values at the onset of the ACR and during the first half of the ACR for core MD07-3100 (Supplementary information figure S3), while the H index of core MD07-3100 indicates optimal benthic foraminifera diversity during this period compared to the first upwelling event and the end of the deglaciation (figure S4).

## TextS2 Supplementary information on age models

On figure S5 the difference between benthic and planktonic foraminifera δ13C (noted Δ13C) is presented for the three shallow cores.

| Depth [cm] | Age [yrs] | Error [yrs] | Dating method / Laboratory Code |
|---|---|---|---|
| **2** | 1420 | 30 | $^{14}C$ age / SacA35728 |
| **165** | 7590 | 50 | $^{14}C$ age / SacA35729 |
| **265** | 9560 | 45 | $^{14}C$ age / SacA35730 |
| **292** | 9930 | 50 | $^{14}C$ age / SacA35731 |
| **361** | 11300 | 50 | $^{14}C$ age / SacA35732 |
| **401** | 12105 | 50 | $^{14}C$ age / SacA35733 |
| **431** | 12450 | 50 | $^{14}C$ age / SacA35734 |
| **461** | 13000 | 60 | $^{14}C$ age / SacA35735 |
| **491** | 14080 | 60 | $^{14}C$ age / SacA35736 |
| **531** | 14640 | 60 | $^{14}C$ age / SacA35737 |
| **561** | 15170 | 60 | $^{14}C$ age / SacA35738 |
| **591** | 15490 | 60 | $^{14}C$ age / SacA35739 |
| **641** | 15690 | 70 | $^{14}C$ age / SacA35740 |
| **682** | 16060 | 80 | $^{14}C$ age / SacA35741 |
| **712** | 16040 | 60 | $^{14}C$ age / SacA35742 |
| **2000** | 24000 | 1000 | Isotopic tuning / - |

Table S1 Radiocarbon dating of core MD07-3119. The $^{14}C$ ages were measured on *Globigerina bulloides*.

| | | *Cibicides spp.* | *Globobulimina spp.* | Estimated $[O_2]$ error |
|---|---|---|---|---|
| **MD07-3100** | $\delta^{18}O$ | 0.07 | 0.17 | |
| | $\delta^{13}C$ | 0.10 | 0.22 | 31.09 |
| **MD07-3119** | $\delta^{18}O$ | 0.11 | 0.13 / n=43 | |
| | $\delta^{13}C$ | 0.12 | 0.07 / n=43 | 18.47 |
| **MD07-3088** | $\delta^{18}O$ | 0.06 | 0.08 | |
| | $\delta^{13}C$ | 0.12 | 0.22 | 32.73 |
| **MD07-3082** | $\delta^{18}O$ | 0.06 | - | |
| | $\delta^{13}C$ | 0.18 | - | |

Table S2 Reproducibility of the measurements on each species group for the considered cores. The "n" represents the number of replicates. The $\delta^{13}C$ and $\delta^{18}O$ values are expressed in ‰ and the $[O_2]$ values in µmol/kg.

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Table S3 Foraminifera census from core MD07-3100

*Uploaded separately due to its length*
Table S4 Foraminifera census from core MD07-3082

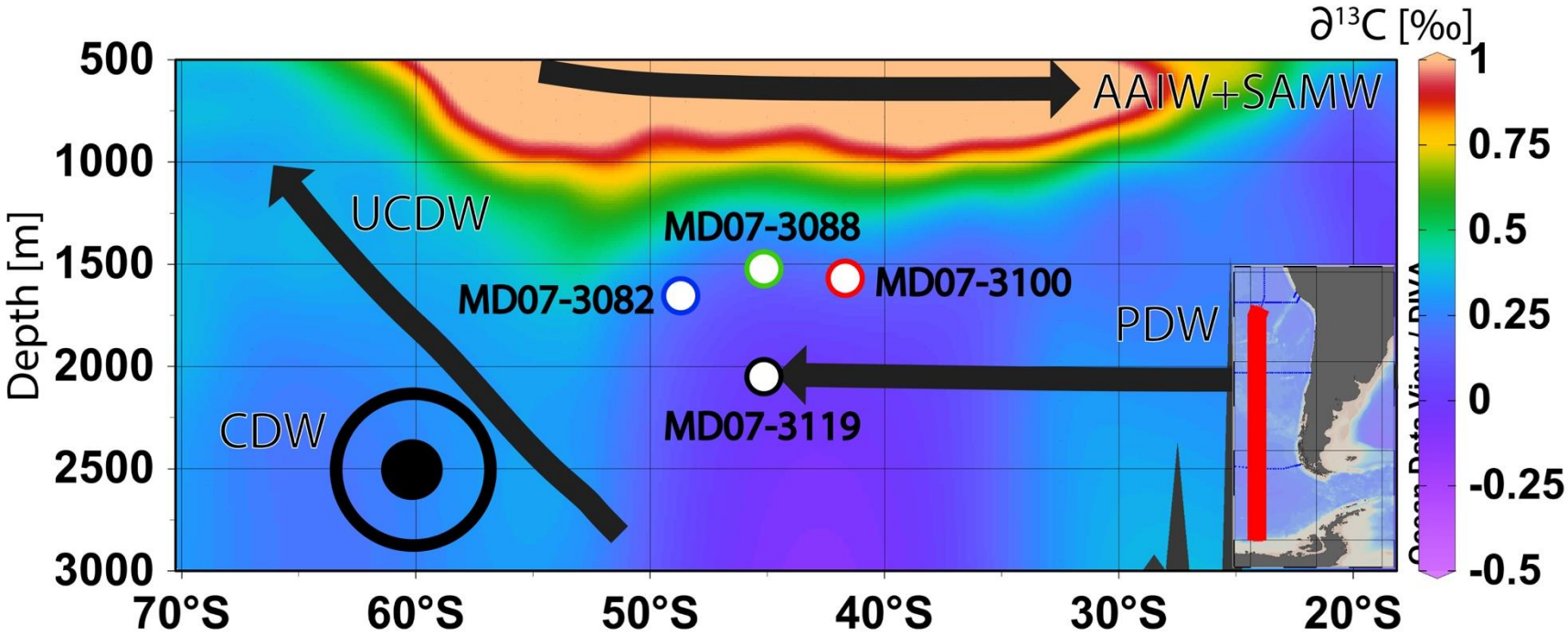


Figure S8 Latitudinal transects showing the ∂$^{13}$C values of the different water masses in the SEP according to the PACIFICA database (Suzuki et al., 2013)