Control of oceanic circulation on sediment distribution in the Southwestern Atlantic margin (23ºS to 55ºS)

Michel Michaelovitch de Mahiques[1,2], Roberto Violante[3], Paula Franco-Fraguas[4], Leticia Burone[4], Cesar Barbedo Rocha[5], Leonardo Ortega[6], Rosangela Felicio dos Santos[1], Bianca Sung Mi Kim[1], Rubens Cesar Lopes Figueira[1], Marcia Caruso Bícego[1]

1 Oceanographic Institute of the University of São Paulo. 05508-120, São Paulo, Brazil

2 Institute of Energy and Environment of the University of São Paulo. 05508-010, São Paulo, Brazil

3 Servicio de Hidrografia Naval. C1270ABV, Buenos Aires, Argentina

4 Facultad de Ciencias, Universidad de La Republica. 11400, Montevideo, Uruguay

5 Department of Marine Sciences, University of Connecticut. 06340, Groton, USA

6 Departamento de Biología Pesquera, Dirección Nacional de Recursos Acuáticos. 11200 Montevideo, Uruguay

Correspondence to: Michel Michaelovitch de Mahiques (mahiques@usp.br)

Abstract. In this study, we interpret the role played by ocean circulation in sediment distribution on the Southwestern Atlantic margin using radiogenic Nd and Pb isotopes. The latitudinal trends for Pb and Nd isotopes reflect the different current systems acting on the margin. The utilization of the sediment fingerprinting method allowed us to associate the isotopic signatures to the main oceanographic features in the area. We recognized differences between Nd and Pb sources to the Argentinean shelf (carried by the flow of Subantarctic Shelf Water) and slopes (transported by deeper flows). Sediments from Antarctica extend up to the Uruguayan margin, carried by the Upper- and Lower Circumpolar Deep Water. Our data confirm that, for shelf and intermediate areas (the upper 1,200 meters), the transfer of sediments from the Argentinean margin to the North of 35ºS is limited by the Subtropical Shelf Front and the basin-wide recirculated Antarctic Intermediate Water. On the southern Brazilian inner and middle shelf, it is possible to recognize the northward influence of the Río de la Plata sediments carried by the Plata Plume Water. Another flow responsible for sediment transport and deposition on the outer shelf and slope is the southward flow of the Brazil Current. Finally, we propose that the Brazil-Malvinas Confluence and the Santos Bifurcation act as boundaries of geochemical provinces in the area. A conceptual model of sediment sources and transport is provided for the Southwestern Atlantic margin.

1 Introduction

Physical and oceanographic processes, ranging from ocean current circulation, river discharge, marine fronts, wind patterns, and climate variability, have a crucial impact on sediment transport variability and fate (Storlazzi and Reid, 2010; Qiao et al., 2020). The Southwest Atlantic margin is located in a key region concerning global ocean circulation and is an excellent example of a complex interaction of physical forcings in the sediment variability. Hydrodynamics is strongly influenced by

35 the Río de la Plata (RdlP) outflow, the second largest river basin in South America (discharge estimated at 23,000 m^3 s $^{-1}$ (Depetris and Griffin, 1968) and by the encounter of subtropical and subantarctic water masses, transported by the Brazil and Malvinas currents, worldwide known as Brazil–Malvinas Confluence (BMC) and its shelf extension, the Subtropical Shelf Front (STSF). At the BMC, water masses are transported eastwards as part of the southern limb of the basin-wide Anticyclonic Atlantic Subtropical Gyre (Boebel et al., 1997; Schmid et al., 2000). Further north, the westward flow of the gyre reaches the

40 South American margin, where it splits into two branches, forming the Santos Bifurcation (SB; Boebel et al., 1999a; Legeais et al., 2013). The southward branch of the bifurcation feeds the Brazil Current (BC), flowing south until its eastward displacement at the BMC (Schmid et al., 2000). The northward branch flows as the Intermediate Western Boundary Current (IWBC) (Legeais et al., 2013), which is an important mechanism for the transport of the Antarctic Intermediate Water towards the northern hemisphere (Boebel et al., 1999b).

45 Even though the distribution of sediments, sources, and transport along the Southwestern Atlantic margin is known since the '50s (Teruggi, 1954; Etchichury and Remiro, 1960, 1963; Berkowsky, 1978; Kowsmann and Costa, 1979; Urien and Martins, 1979; Potter, 1984; Berkowsky, 1986) and recently deepened based on geochemical and mineralogical methods (Campos et al., 2008; de Mahiques et al., 2008; Razik et al., 2013; Nagai et al., 2014a) important issues regarding hydrological controls are still unresolved.

50 Radiogenic Nd and Pb isotopes are efficient tools in studying sediment transport in continental margins (Weldeab et al., 2002; Kessarkar et al., 2003; Maccali et al., 2012; Maccali et al., 2018; Subha Anand et al., 2019). A recent synthesis of potential sources and water masses transport in the South Atlantic was provided by Beny et al. (2020). In that study, the authors combined grain size, clay mineralogy, and Nd, Pb, and Sr isotopes to propose a deep-water mass evolution for the last ca. 30,000 years in the region. The first regional characterization of Nd and Pb isotope signatures of the upper margin surface

55 sediments in the Southwest Atlantic was provided by de Mahiques et al. (2008), filling an extensive area without information about εNd signatures (Jeandel et al., 2007; Blanchet, 2019). In that work the authors: 1) recognize the isotopic signatures of the sediments from the Argentinean, southern and southeastern Brazilian margins and; 2) describe potential source areas of the sediments, such as the Andes, the basalts of the Paraná basin, and the pre-Cambrian rocks of the Brazilian shield.

Notwithstanding, geographic gaps in information preclude a throughout understanding of the role of key hydrological features

60 such as the STSF, BMC, and SB in the sediment distribution and the geochemical boundaries associated, key for paleoceanographic studies. Moreover, in another approach for sediment sources and pathways in the Southwestern Atlantic margin provided by Razik et al. (2015), the authors argued for a mixed Rio de la Plata - Andean origin for the upper slope sediments off southern Brazil.

In this paper, we extend the Nd and Pb dataset along the southwestern Atlantic margin and use the concept of sediment

65 fingerprinting to deepen the role played by hydrodynamic forcing in sediment transport and deposition. The geographical distribution of the new samples presented here, covering the Argentinean margin and the Punta del Este, Pelotas, and Santos basins and covering a bathymetry range between 5 and 4066 meters, allows focusing on the role of the STSF, BMC, and BS

in the distribution of sediments. The results are interpreted with the aid of the output of a state-of-the-art circulation model to understand the role of oceanographic boundaries in the distribution of sediments along the area.

70 **2 Study Area**

The study area comprises a Southwestern Atlantic margin sector, from the parallels 23º00'S to 54º10'S, corresponding to a linear extension of about 3,500 km (Figure 1). Syntheses of the main geological and oceanographic processes can be found in Hernandez-Molina et al. (2009), Franco-Fraguas et al. (2014), Nagai et al. (2014a), Nagai et al. (2014b), Violante et al. (2014), Hernández-Molina et al. (2015), Franco-Fraguas et al. (2016), Violante et al. (2017a), Burone et al. (2018), Piola et al. (2018),
75 and Piola and Matano (2019), among several others.

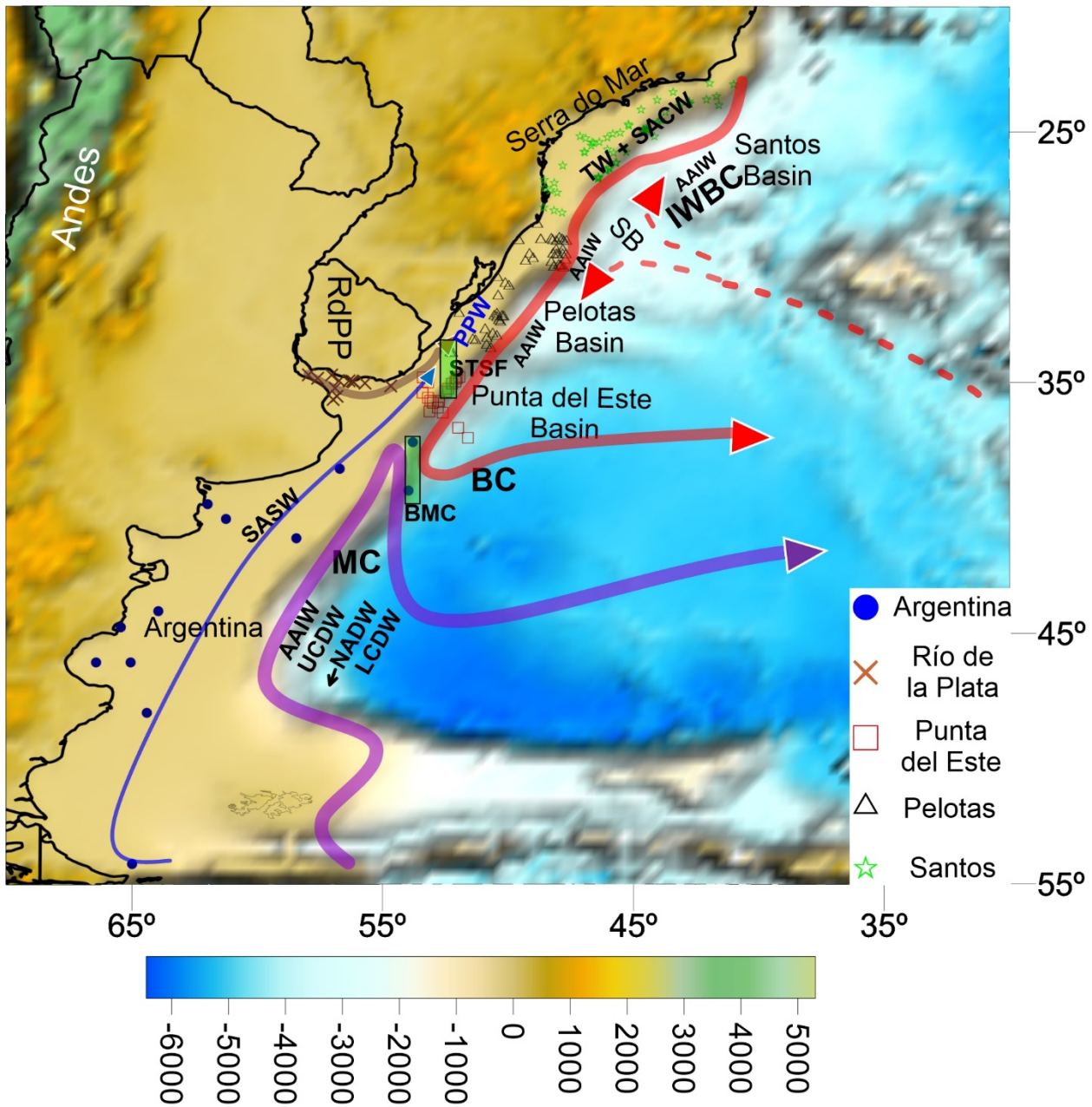



Figure 1. Location of the study area, displaying the main flows, oceanographic boundaries, and sampling stations. Violet thick line: Malvinas Current (MC); thin blue line: Subantarctic Shelf Water (SASW); thin brown line: Río de la Plata Plume (RdlPP); thick red line: Brazil Current (BC); shaded rectangles: Subtropical Shelf Front (STSF) and Brazil – Malvinas Confluence (BMC); dashed red line Santos Bifurcation (SB) and Intermediate Western Boundary Current (IWBC). Other Abbreviations: Antarctic Intermediate Water (AAIW), Upper Circumpolar Deep Water (UCDW), North Atlantic Deep Water (NADW), and Lower Circumpolar Deep Water (LCDW). Bottom scale: topography in meters

2.1 Morphology

The Southwestern Atlantic margin is a typical segmented volcanic-rifted margin, where several transverse basins are recognized (Bassetto et al., 2000; Moulin et al., 2010; Soto et al., 2011). Its origin and evolution are intrinsically related to
90 the opening of the South Atlantic (Nürnberg and Müller, 1991), whose rifting processes first started in the Triassic (Lovecchio et al., 2020) but effectively occurred during the Jurassic and Cretaceous.

There is a general trend of narrowing the margin towards the North (Urien and Ewing, 1974; Zembruscki, 1979; Parker et al., 1996; Violante et al., 2017a). The shelf width varies from 850 km to the south to 70 km in its northernmost limit; the shelf-break depth ranges from 80 m, in southern Brazil, to 200 meters, in Uruguay (Zembruscki, 1979; Muñoz et al., 2010; Lantzsch
95 et al., 2014). The shelf morphology is relatively flat, but sequences of scarps and terraces are recognized along the continental shelf at varying water depths (Corrêa, 1996; Parker et al., 1996; Baptista and Conti, 2009).

The continental slope presents a highly variable morphology, including contouritic terraces, channels, mounds, erosive surfaces, and sediment drifts all along the area (Duarte and Viana, 2007; Hernández-Molina et al., 2010; Preu et al., 2013; Hernández-Molina et al., 2015) as well as canyons (Voigt et al., 2013; Bozzano et al., 2017; Franco-Fraguas et al., 2017;
100 Violante et al., 2017b; Warratz et al., 2019). The contouritic features and submarine canyons actively interact along the margin so that mixed contouritic-gravitational erosive and depositional features are common. Mega-slides (Reis et al., 2016; Franco-Fraguas et al., 2017) and carbonate mounds (Carranza et al., 2012; Maly et al., 2019; Steinmann et al., 2020) are also present along the margin.

2.2 Sedimentary cover

105 The Southwestern Atlantic margin is dominated by a terrigenous, siliciclastic sedimentary cover, with extensive sand sheets (Lonardi and Ewing, 1971; Frenz et al., 2003; Figueiredo and Madureira, 2004). The Argentinean and Uruguayan shelves are capped mainly by a 5 to 15 m thick post-Late Glacial transgressive sandy sheet (with decreasing thickness towards the south) composed of dominant medium to fine sands (sometimes muddy), with varying amounts of shells (more abundant in the Uruguayan shelf) and gravels (more abundant in the Patagonian shelf).
110 Sandy and shelly sediments are mainly relicts of coastal and inner shelf environments that evolved during Pleistocene transgressive-regressive events (Kowsmann and Costa, 1979; Urien et al., 1980; Lantzsch et al., 2014). Therefore, they are considered relict and palimpsest, whereas gravelly-dominated sediments on the southern Argentinean shelf result from glacifluvial origin. More recent works emphasize the existence of mud depocenters as potential fates of modern sediments on the southern Brazilian shelf (Nagai et al., 2014a; de Mahiques et al., 2017; Lourenço et al., 2017; de Mahiques et al., 2020).
115 In the slope and rise, there is a prevalence of very fine sands and silty sands, resulting from exclusively submarine processes occurring across- (gravitational) and along- (contouritic) slope, together with pelagic sedimentation (Violante et al., 2010;

Bozzano et al., 2011; Franco-Fraguas et al., 2016; Schattner et al., 2020). However, coarse sands and gravels occur at or near the head of submarine canyons and in contouritic channels and moats (Lonardi and Ewing, 1971; Bozzano et al., 2011; Reis et al., 2016; Franco-Fraguas et al., 2017). Razik et al. (2015) indicate increasing grain size towards coarse sands due to sediment remobilization and redistribution due to upwelling and downwelling resulting from eddies and vertical water movement generated by the slope off southern Brazil meandering Brazil Current.

2.3 Ocean Circulation

The Southwestern Atlantic margin is characterized by complex hydrography (Matano et al., 2010). It presents two main oceanographic boundaries, the Subtropical Shelf Front (STSF), as the shelf extension of the Brazil – Malvinas Confluence (BMC) (Piola et al., 2000; Severov et al., 2012), and the less-studied Santos Bifurcation (SB) (Boebel et al., 1997; Boebel et al., 1999a). The region is also influenced by the Rio de la Plata (RdlP), the second-largest hydrographic basin in South America, whose average discharge is 22,000 m^3 s^{-1} (Framiñan and Brown, 1996). This regional circulation system experiences seasonal latitudinal shifts in response to wind regimes (Schmid et al., 2000; Piola and Matano, 2001; Piola et al., 2018).

At the BMC, centered at 37-39°S (Maamaatuaiahutapu et al., 1992), the southward-flowing Brazil Current (BC) encounters the northward-flowing Malvinas Current (MC) (Schmid and Garzoli, 2009), transporting and mixing water masses with contrasting thermohaline characteristics. The BC is a baroclinic boundary current that concentrates its main flow in the upper 500 m water-depth upstream of 28°S, carrying the Tropical Water (TW) at the surface (Emilsson, 1961; Palma et al., 2008), and the South Atlantic Central Water (SACW) at pycnoclinic levels (Emilsson, 1961; Signorini, 1978). Near the BMC, a significant fraction of the BC transport is below 500m. The MC is a strong barotropic boundary current that advects the Subantarctic Water (SAW) near the surface (Spadone and Provost, 2009), and the Antarctic Intermediate Water (AAIW) at intermediate levels (Tomczak and Godfrey, 1994a, b).

At the BMC, water masses are transported eastwards as part of the southern limb of the basin-wide Anticyclonic Atlantic Subtropical Gyre (Boebel et al., 1997; Boebel et al., 1999a; Schmid et al., 2000; Núñez-Riboni et al., 2005; Legeais et al., 2013). At the intermediate levels of the westward flow of the gyre, the water reaches the South American margin near 28°S, where it splits into two branches, forming the Santos Bifurcation (Boebel et al., 1999a; Legeais et al., 2013). From the bifurcation, one-quarter of the transport at 40°W flows northward along the continental slope (mainly between the 800 and 1,200 m isobaths), forming the Intermediate Western Boundary Current (IWBC) (Fernandes et al., 2009; Biló et al., 2014). About three-quarters feed the BC, flowing south until its separation from the coast at the BMC (Schmid et al., 2000; Piola and Matano, 2019). This configuration leads to an overall southward flow on the outer shelf and the outer to middle slope, from 28°S up to the BMC.

Concerning deep circulation, the North Atlantic Deep Water (NADW) (Sverdrup et al., 1942), transported from the northern hemisphere high latitudes by the Deep Western Boundary Current, occupies the region between the 2,000 and 3,000 m isobaths. The NADW flows between two northward-flowing branches of the Circumpolar Water (i.e., Upper and Lower Circumpolar

Deep Water). The abyssal circulation (> 3,500 m) is dominated by the Antarctic Bottom Water (AABW), which is partially trapped in the Argentine Basin (Tarakanov and Morozov, 2015).

Over the shelf, the extension of the BMC, known as the Subtropical Shelf Front (STSF), separates Subtropical Shelf Waters (STSW, formed by the mixture of the TW and SACW) and Subantarctic Shelf Waters (SASW) (Piola et al., 2000). This narrow and sharp front extends between 32°S at 50 m of water column depth and 36°S over the shelf break, and its position appears stable throughout the year (Piola et al., 2000; Berden et al., 2020). The main branch of the STSF is mixed with waters transported by the BC and exported offshore along with the BMC. A secondary branch is diluted with the PPW and TW and returns along the shelf (Berden et al., 2020).

At the surface, the low-salinity RdlP plume flows northward along the inner Uruguayan continental shelf during the austral winter. In the summer and during El Niño events, the plume remains off the RdlP mouth and extends along the entire upper continental margin (Piola et al., 2000; Piola et al., 2005; Möller et al., 2008).

3 Materials and Methods

3.1 Geochemical Analyses

The samples were organized in five distinct sectors in this study, corresponding to the Santos, Pelotas, and Punta del Este marginal basins, RdlP estuary, and the Argentinean margin. Due to the small number of samples, the sediments from Argentina were not divided into the corresponding sedimentary basins (Figure 1). Geographic coordinates and water depth of the samples are presented in the Supplementary Material file.

The results of one hundred and fifty-six sediment samples were used as a dataset, including eighty-three new samples, fifty-three samples published in de Mahiques et al. (2008), six samples published in Basile et al. (1997), eight samples published in Franco-Fraguas et al. (2016), and three coretop samples published in Lantzsch et al. (2014). The analytical methods used in those ancillary papers are described in the original references. The new samples were collected with box-corers and multiple-corers in distinct surveys onboard the research vessels Alpha Crucis (Brazilian margin), Miguel Oliver, Capitán Saldaña, and Sarmiento de Gamboa (Uruguayan margin). Only the superficial samples (the upper one centimeter) of each core were used in this work.

The Nd and Pb isotopic analyses of the lithogenic fraction were conducted at the Geochronological Research Centre of the University of São Paulo, Brazil.

All chemical procedures were performed in class 10,000 cleanroom equipped with laminar flow hoods class 100. All reagents were purified before use. Water was distilled and then purified on a Milli-Q System (®Millipore Corporation) ('ultrapure' water - "Type 1"). The acids were purified in sub boiling distillers (DST-1000, ®Savillex) and sub boiling stills (®Savillex) at low temperatures.

All of the samples were previously decarbonated with HCl. Sediment powder (70 mg) was dissolved with HF, HNO3, and HCl acids. Dissolution was done on a MARS-5 microwave oven. Both Pb and Nd were purified by the ion-exchange

technique. The first stage of ion-exchange chromatography involves separating Pb from the other matrix elements using columns packed with anion exchange AG1-X8, 200-400 mesh (Biorad) resin. After Pb collection, the remaining solution is dried out, and the residue is retaken to separate the Rare Earth Elements using RE resin (EIChroM Industries Inc.) from the bulk solution. Nd was then separated using Ln resin (EIChroM Industries Inc.).

185 Pb isotopic compositions were measured on a Finnigan MAT 262 Mass Spectrometer. Samples were loaded on Re filaments with H_3PO_4 and silica gel. Every single analysis consisted of 60 ratio measurements. The Pb ratios were corrected for mass fractionation of 0.13%/amu based on repeated analysis of the NBS-981 standard ($^{206}Pb/^{204}Pb = 16.893 \pm 0.003$; $^{207}Pb/^{204}Pb = 15.432 \pm 0.004$, and $^{208}Pb/^{204}Pb = 36.512 \pm 0.014$; n = 11), which yielded mass discrimination and fractionation corrections of 1.0024 ($^{206}Pb/^{204}Pb$), 1.0038 ($^{207}Pb/^{204}Pb$) and 1.0051 ($^{208}Pb/^{204}Pb$). The combination of these uncertainties and within-run

190 uncertainties are typically 0.15%–0.48% for $^{206}Pb/^{204}Pb$, 0.13%–1.07% for $^{207}Pb/^{204}Pb$ and 0.10%–0.45% for $^{208}Pb/^{204}Pb$, all at the 2σ (95%) confidence level. The total Pb blank contribution, <1 ng, is negligible.

The Nd analyses, here reported as εNd, values, were prepared by standard methods by the analytical procedures described by Sato et al. (1995) and Magdaleno et al. (2017), involving $HF–HNO_3$ dissolution plus HCl cation exchange using a Teflon Powder column to separate REEs. No visible solid residues were observed after dissolution. Samples with incomplete

195 dissolution were discarded.

Nd determinations were performed on a Thermo Neptune Plus ICP-MS. Nd isotopic ratios ($^{143}Nd/^{144}Nd$) were normalized to the value of $^{146}Nd/^{144}Nd = 0.7219$ (DePaolo, 1981) and $^{143}Nd/^{144}Nd = 0.512103$ of the JNDi-1 standard (laboratory average of the last 12 months). Usually, a single analysis consisted of 60 measurements of Nd. The $^{143}Nd/^{144}Nd$ mean average of the JNDi standard during the analyses was 0.512095 ± 0.000007 (n = 3) and 0.512096 ± 0.000005 between July and November

200 2013 (n = 56). The daily average of $^{143}Nd/^{144}Nd$ of the JNDi-1 standard was 0.512101 ± 0.000002 (n=18). The analytical blank during the analyses varied from 51 and 53 pg.

The parameter εNd was calculated as follows:

εNd = (($^{143}Nd/^{144}Nd_{sample}/^{143}Nd/^{144}Nd_{CHUR}$)-1) * 10^4, where $^{143}Nd/^{144}Nd_{CHUR} = 0.512638$ (Jacobsen and Wasserburg, 1980).

Reproducibility analysis was made for both Pb and Nd isotopes, using Buffalo River Sediment (NIST-RM8704) (n = 7), with

205 the following results:

$^{143}Nd/^{144}Nd = 0.51203 \pm 0.00001$ (SD)

$^{206}Pb/^{204}Pb = 18.846 \pm 0.018$ (SD)

$^{207}Pb/^{204}Pb = 15.646 \pm 0.005$ (SD)

$^{208}Pb/^{204}Pb = 38.503 \pm 0.016$ (SD)

210 Statistical analyses were performed using the software PAST (Palaeontological Statistics), version 4.05 (Hammer et al., 2001). To recognize the distinct isotopic domains over the study area, we applied the Geochemical Fingerprinting procedure, similar to the approaches proposed by Walling (2013), Miller et al. (2015), and Palazon and Navas (2017). First, a Kruskal-Wallis non-parametric analysis of variance was applied for each variable, followed by a Mann-Whitney pairwise post-hoc test to

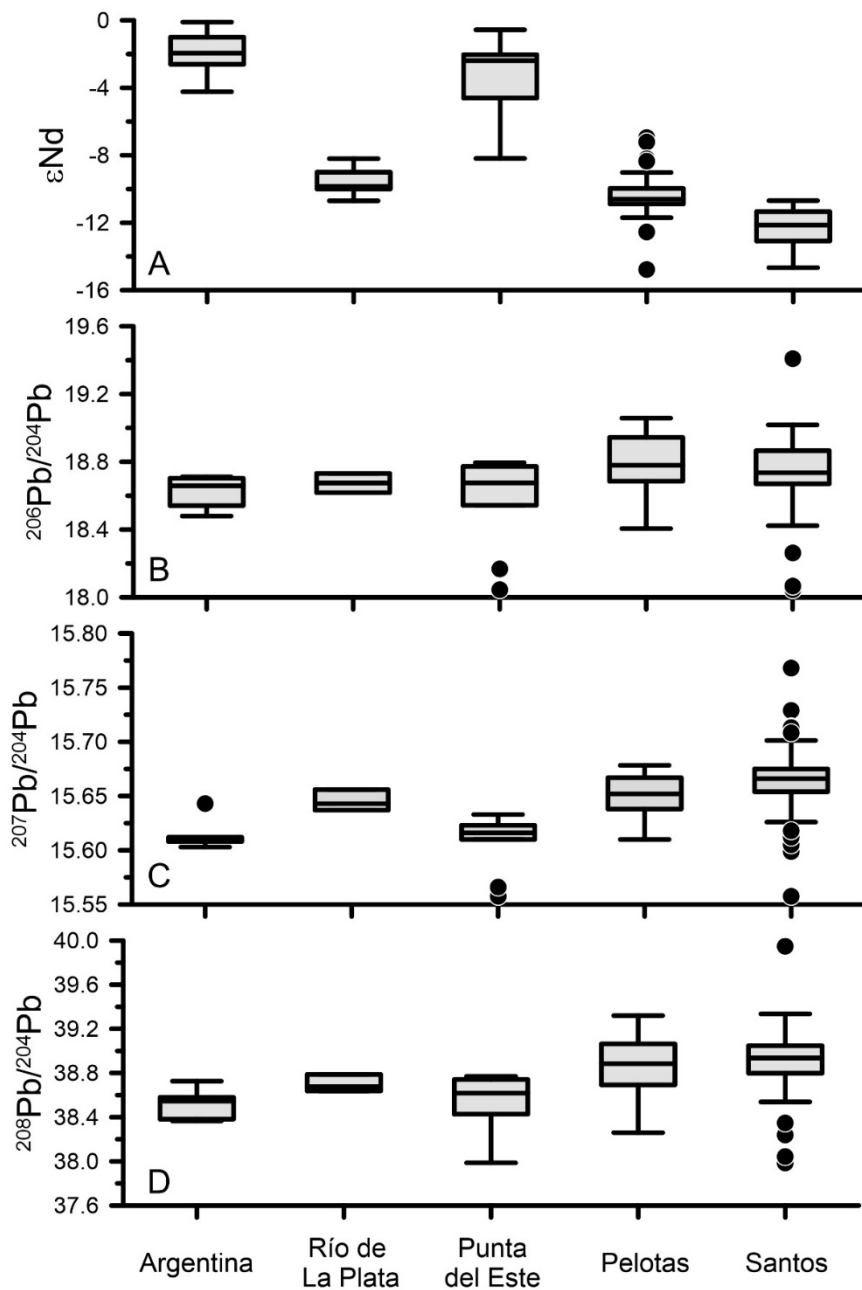
identify which variables presented statistically significant differences. Finally, a Discriminant Analysis with standardized values was used to determine the correct classification for the previously assigned groups.

3.2. The LLC2160 Circulation Model

To support the geochemical data distribution interpretation, we analyzed the output of the LLC2160 simulation, a global 1/24º forward run of the Massachusetts Institute of Technology General Circulation Model (MITGCM) that was spun up from Estimating from Circulation and Climate of the Ocean (ECCO). The ECCO state estimate is similar to an ocean reanalysis and assimilates millions of observations, starting in 1992. With 90 vertical levels and a horizontal resolution of about 4 km in the South American margin, the LLC2160 simulation resolves the main ocean circulation features on the continental slope and shelf of the Southwestern Atlantic. Our analysis focuses on a 12-month average spanning September 2011 through August 2012. Details of the simulation, including a description of the spin-up hierarchy and forcing, are available in Chen et al. (2018). We used annual-mean fields of LLC2160 simulation to identify two key features: the Santos Bifurcation (SB) and the Subtropical Shelf Front (STSF). The SB is recognized as the region on the continental slope where the flow within the AAIW depth range (550-1400 m) is negligible. Specifically, we search on different isobaths ranging from 500 m to 1500 m for the region where the AAIW flow is weaker than 0.01 m/s. We emphasize that the SB is not a stagnation point where the flow is zero but a shadow zone that spans nearly 100 km, wherein the intermediate flow is feeble (see the schematic SB in Figure 1). In our discussion below, we present the mean position and the latitudinal extension of the SB as a function depth.

To identify the mean position of the STSF, we searched for the local maximum of the potential temperature gradient, which is a very distinct feature on the northern Argentina/southern Brazil shelf. We compute the potential temperature gradients at 40 m to avoid contamination by RdlP water (e.g., Piola et al., 2008). When applied to the LLC2160 output using seasonal averages, our method yielded frontal locations consistent with those identified by applying the isothermal criteria at 40 m proposed by Piola et al. (2008). In the yearly fields, the front follows approximately the 14 ºC isotherm.

4 Results

The results of isotopic analyses are presented in the Supplementary Material and summarized in the box plots shown in Figure 2. We also present the latitudinal variation of each isotope (Figure 3).

240   **Figure 2. Box-plots of the distributions of (A) εNd, (B) ^{206}Pb/^{204}Pb, (C) ^{207}Pb/^{204}Pb, and ^{208}Pb/^{204}Pb. Outliers are shown as dots**

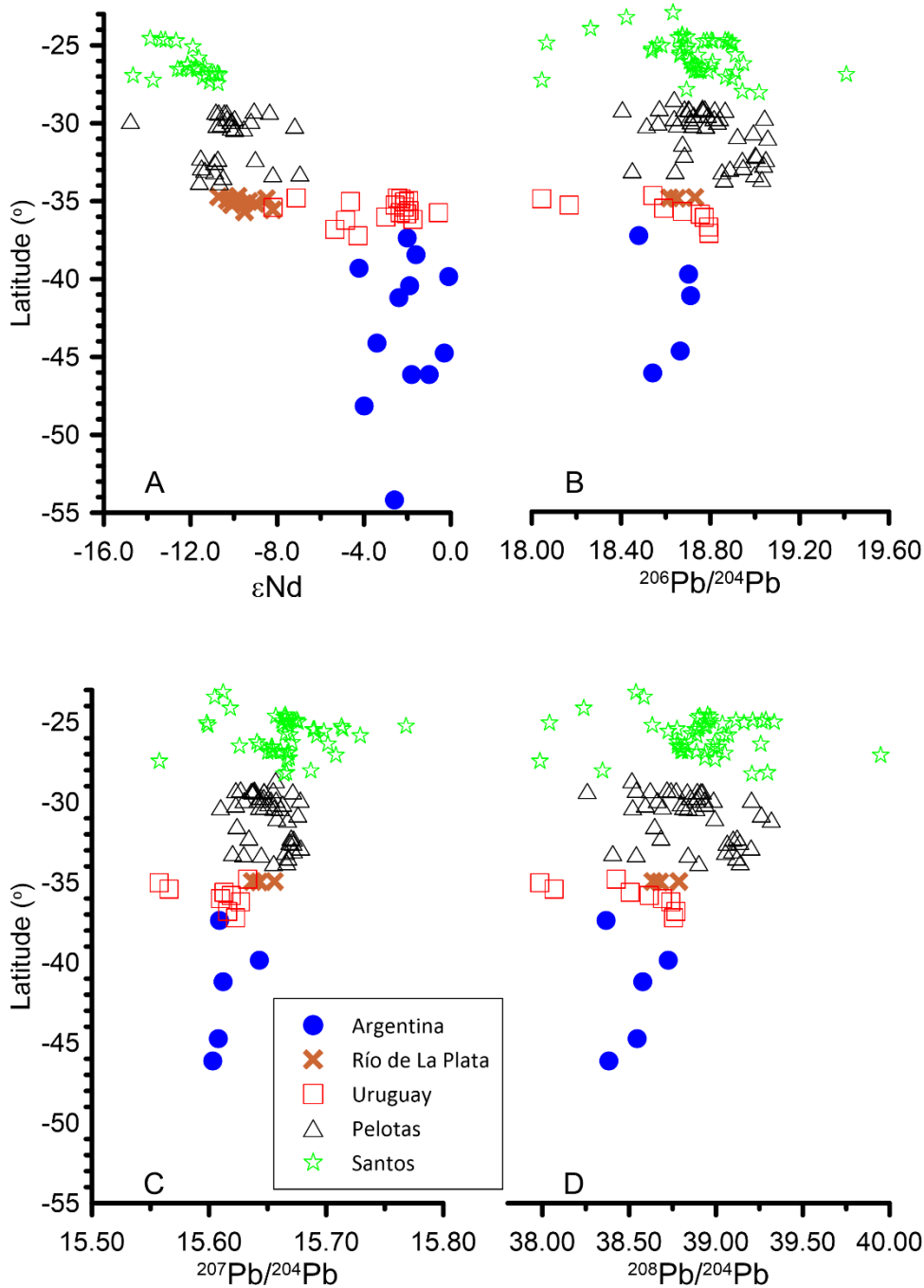



Figure 03. Latitudinal variations of (A) εNd, (B) ^{206}Pb/^{204}Pb, (C) ^{207}Pb/^{204}Pb, and ^{208}Pb/^{204}Pb.

245   εNd values show a northward trend to less radiogenic values, varying from -0.1 (Argentina) to -17.1 (Santos Basin) (Figure 3a). The latitudinal variation of the Pb isotopes is less clear but still visible for ^{207}Pb/^{204}Pb and ^{208}Pb/^{204}Pb (Figures 3c and 3d).

On average, the Argentina sector presents the highest εNd average values (-2.1±1.3), and lowest ^{206}Pb/^{204}Pb, ^{207}Pb/^{204}Pb, and ^{208}Pb/^{204}Pb average values (18.620±0.104, 15.615±0.016, and 38.520±0.149, respectively). On the other hand, the Santos sector shows the lowest εNd (-12.0±1.1) and highest ^{207}Pb/^{204}Pb and ^{208}Pb/^{204}Pb average values (15.664±0.008 and

250   38.909±0.016, respectively). Values of ^{206}Pb/^{204}Pb did not show any evident latitudinal trend. For ^{206}Pb/^{204}Pb, the values range from 18.045, on the Punta del Este sector, to 19.409, on the Santos Basin shelf. ^{207}Pb/^{204}Pb values range from 15.558 to 15.768 in the same areas. Finally, ^{208}Pb/^{204}Pb values vary from 37.986 to 39.949, also in the same sectors.

From the Kruskal-Wallis analysis, we observe that except for ^{206}Pb/^{204}Pb, the variables show significant differences among the compartments, thus allowing us to proceed with the Discriminant Analysis. Furthermore, the Mann-Whitney analysis allowed

255   us to recognize the pairwise differences among the other variables (Table 1). Finally, it is to be noted that sediments from Argentina showed statistically significant differences with all of the variables analyzed, suggesting that they are distinct from those located towards the North. On the other hand, sediments from the Rio de la Plata are statistically similar to those from the Pelotas sector for all of the variables.

Table 1. p values of the Mann-Whitney pairwise test. Statistically significant differences are underlined

εNd	Argentina	Rio de la Plata	Punta del Este	Pelotas
Argentina				
Rio de la Plata	0.00			
Uruguay	0.09	0.00		
Pelotas	0.00	0.32	0.00	
Santos	0.00	0.00	0.00	0.00
^{206}Pb/^{204}Pb	Argentina	Rio de la Plata	Punta del Este	Pelotas
Argentina				
Rio de la Plata	0.21			
Uruguay	0.59	0.59		
Pelotas	0.02	0.31	0.08	
Santos	0.08	0.69	0.37	0.08
^{207}Pb/^{206}Pb	Argentina	Rio de la Plata	Punta del Este	Pelotas
Argentina				
Rio de la Plata	0.07			
Uruguay	0.42	0.29		
Pelotas	0.00	0.06	0.00	
Santos	0.00	0.02	0.00	0.01
^{208}Pb/^{204}Pb	Argentina	Rio de la Plata	Punta del Este	Pelotas
Argentina				
Rio de la Plata	0.04			
Uruguay	0.59	0.29		
Pelotas	0.01	0.11	0.02	
Santos	0.00	0.02	0.01	0.47

The two first axes of the Discriminant Analysis account for 99.72% (99.09% for axis 1) of the total variance considering the standardized values of εNd, ^{207}Pb/^{204}Pb, and ^{208}Pb/^{204}Pb (Figure 4). It is possible to recognize that samples from Argentina are

detached from the other sectors. On the other hand, samples from Pelotas Basin show a transitional character between Santos Basin, on one side, and on the other side, Río de La Plata and Punta del Este Basin.

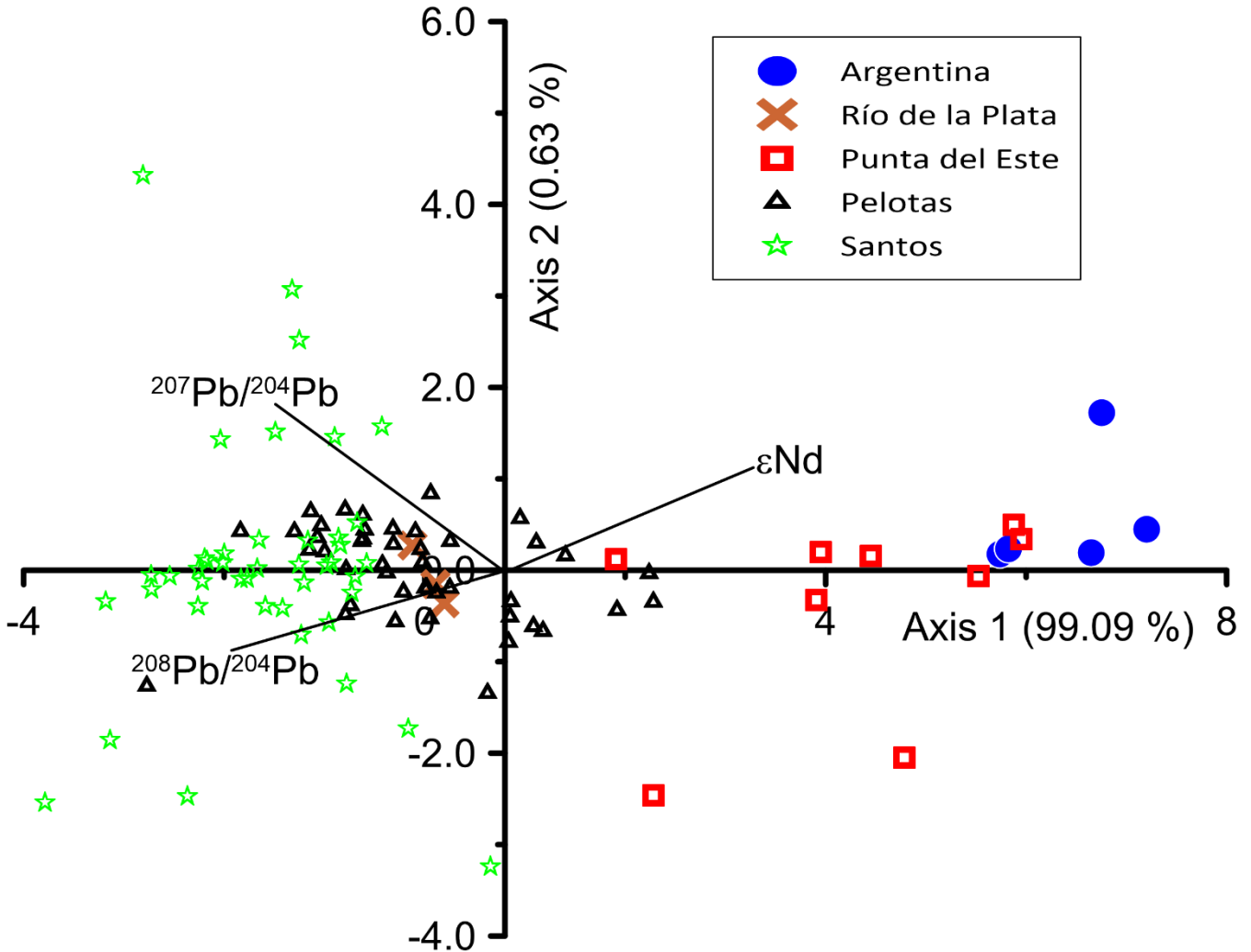



Figure 4. Scatter plot of the samples according to the two first axes generated from the Discriminant Analysis.

270

Graphical representations of the LLC2160 output are presented for both the Santos Bifurcation (Figure 5) and Subtropical Shelf Front (Figure 6). The Santos Bifurcation is identified as the maximum horizontal velocity divergence region at the AAIW level, identified in Figure 5A close to 26ºS. The visualization based on the horizontal fields is more complicated but still visible as the sector with velocities close to 0 m/s (Figure 5B). The Subtropical Shelf Front (Figure 6A) is identified as a

275 maximum subsurface temperature gradient (Figure 6B). Vertically it is well marked below the 30 m isobath (Figure 6C).

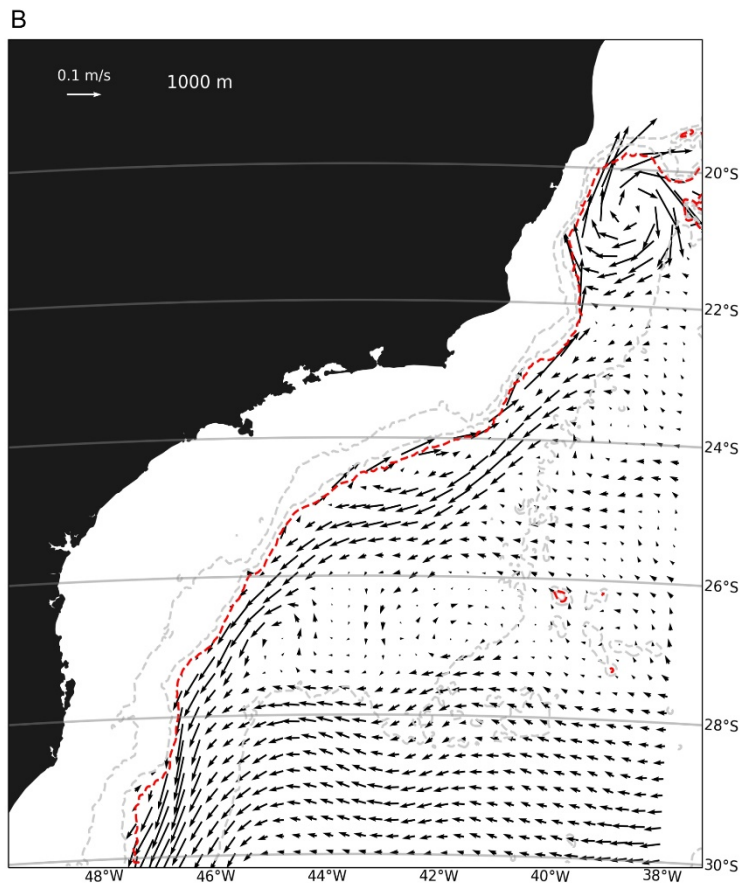
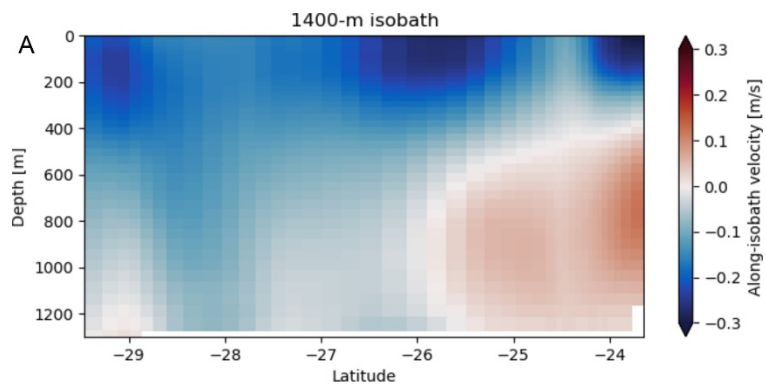



Figure 5. Graphical outputs of the LLC2160 focused on the Santos Bifurcation. A: the bifurcation is identified as the white zone located around 26ºS between the 800 and the 1200 isobath. B: the bifurcation is recognized as the zone of velocities tending to 0 cm/s at 26ºS – 44ºW.

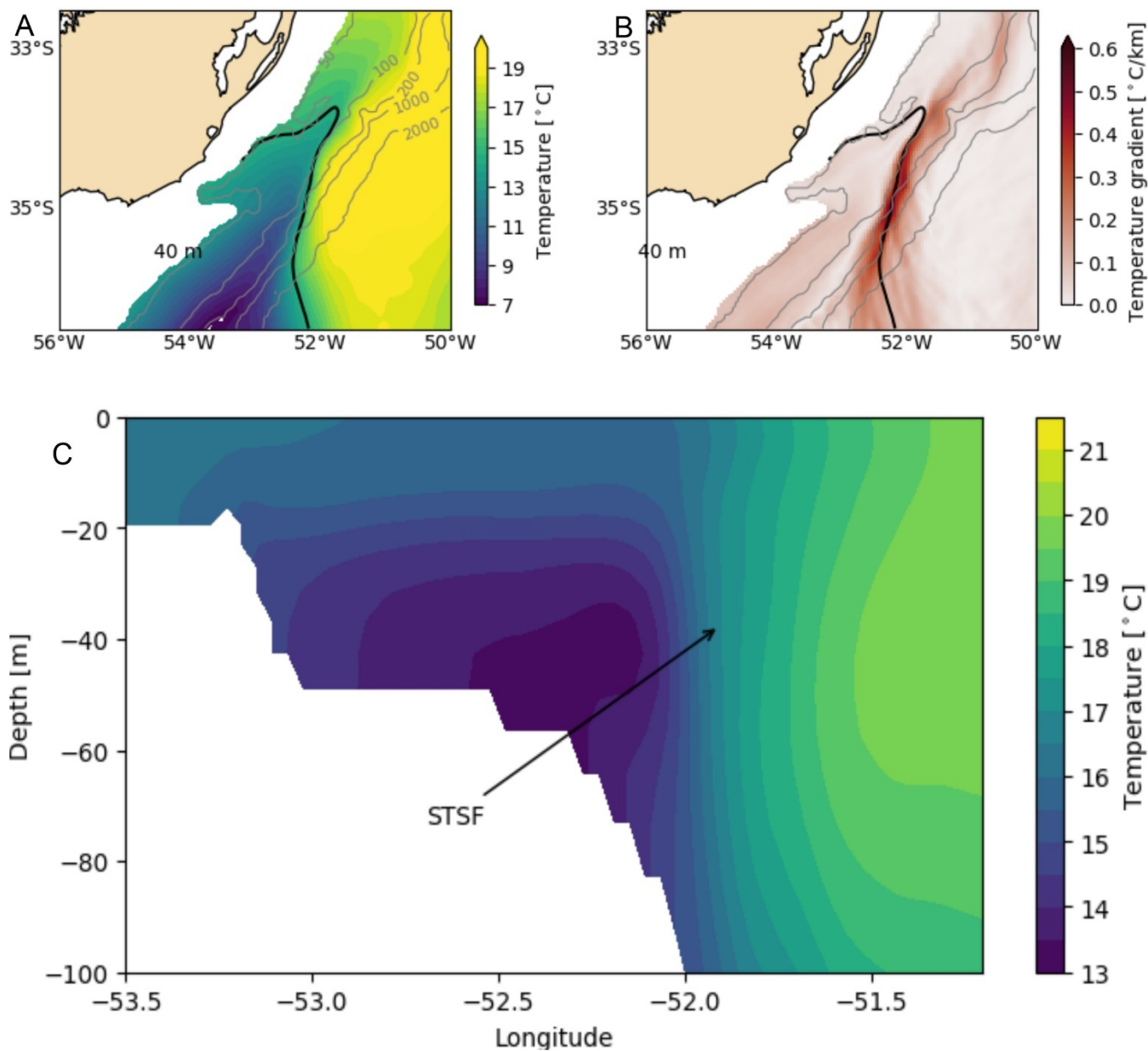



Figure 6. Graphical outputs of the LLC2160 focused on the Subtropical Shelf Front. A: Variations of temperature in the zone of the front. B: Temperature gradient; the front is recognized as the zone of maximum gradient (darker colors). C: Vertical transect at 35ºS showing the location of the Subtropical Shelf Front (STSF) as the gradient of the Subantarctic Shelf Water (deep blue) and the Subtropical Shelf Water (light green)

285

5 Discussion

The integration of both isotopic signatures (εNd, ^{207}Pb/^{204}Pb, and ^{208}Pb/^{204}Pb) and hydrographic (water masses) and hydrodynamic (currents) information is presented in figures 7 to 9, respectively. This information is essential to infer both sediment sources and the role played by ocean circulation in the distribution of sediments in the study area.

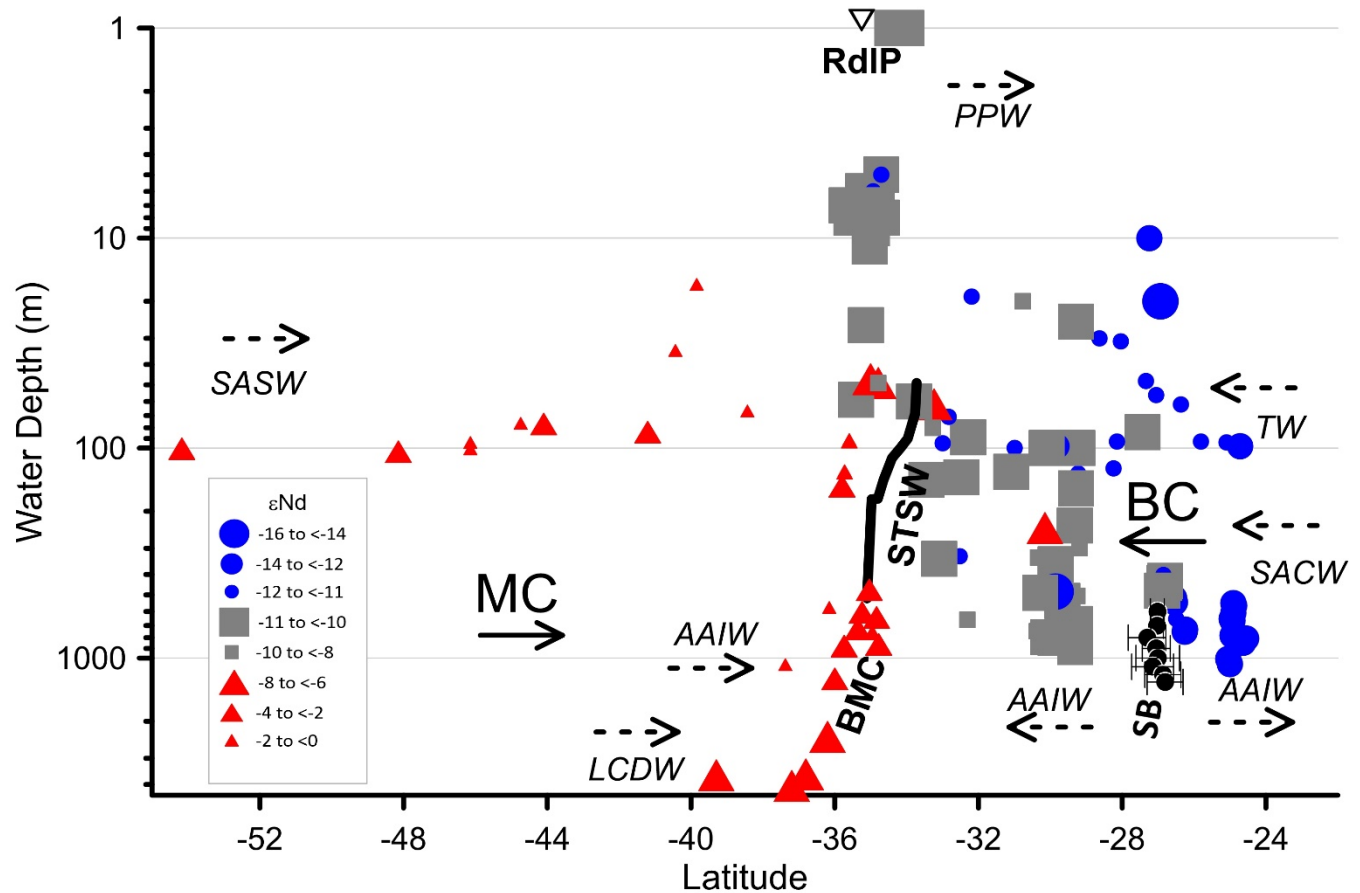



Figure 7. Latitudinal and bathymetric variability of εNd in the sector between 23°S and 55°S. Water masses: Plata Plume Water (PPW), Subantarctic Shelf Water (SASW), Tropical Water (TW), South Atlantic Central Water (SACW), Antarctic Intermediate Water (AAIW), and Lower Circumpolar Deep Water (LCDW). Currents: Malvinas Current (MC) and Brazil Current (BC). Fronts: Subtropical Shelf Front (STSW), Brazil-Malvinas Confluence (BMC), and Santos Bifurcation (SB). Vertical axis in Log$_{(10)}$ scale.

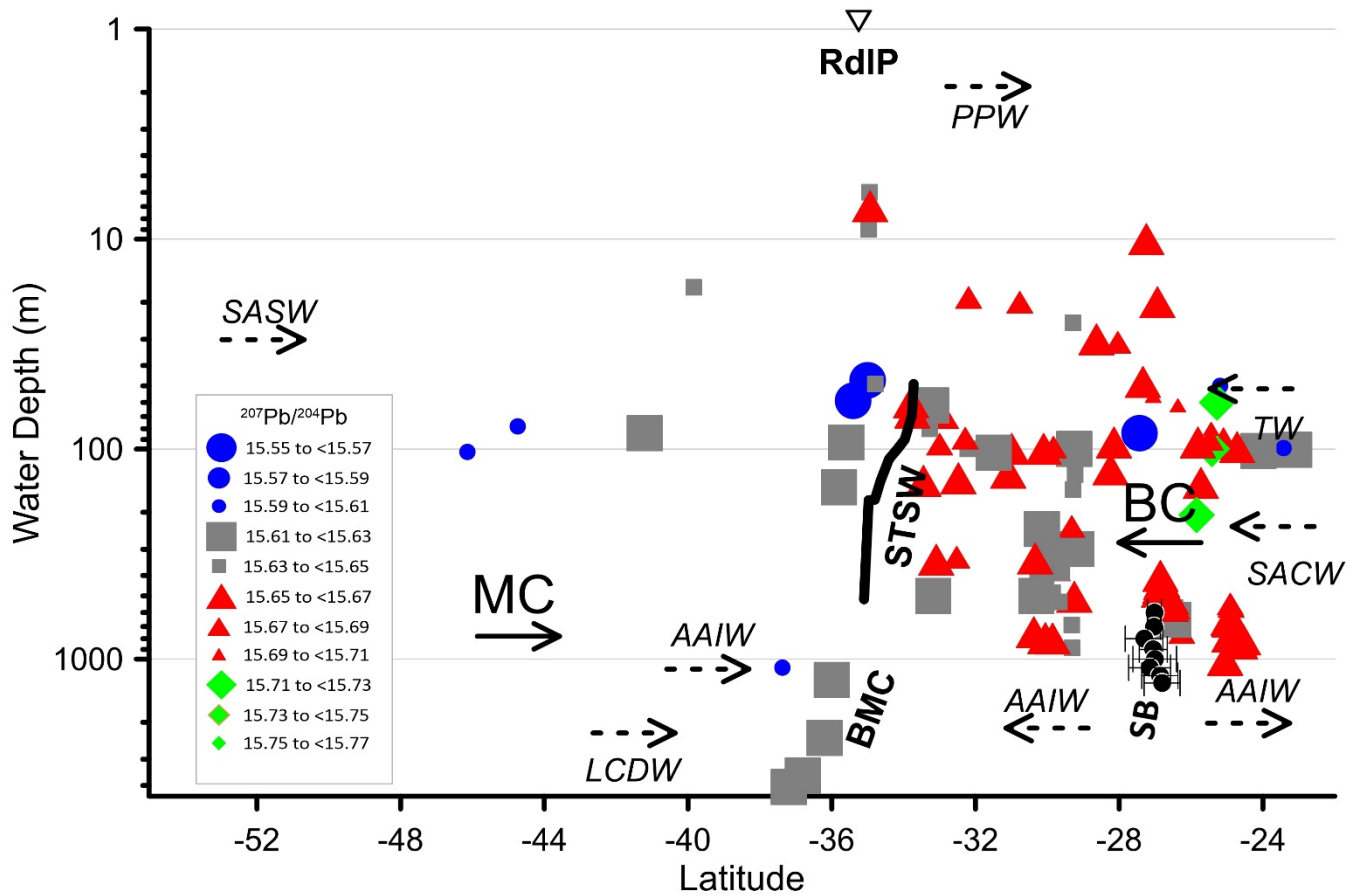



Figure 8. Latitudinal and bathymetric variability of ^{207}Pb/^{204}Pb in the sector between 23ºS and 55ºS. Rio de la Plata (RdlP). Water masses: Plata Plume Water (PPW), Subantarctic Shelf Water (SASW), Tropical Water (TW), South Atlantic Central Water (SACW), Antarctic Intermediate Water (AAIW), and Lower Circumpolar Deep Water (LCDW). Currents: Malvinas Current (MC) and Brazil Current (BC). Fronts: Subtropical Shelf Front (STSW), Brazil-Malvinas Confluence (BMC), and Santos Bifurcation (SB). Vertical axis in Log$_{(10)}$ scale.

305

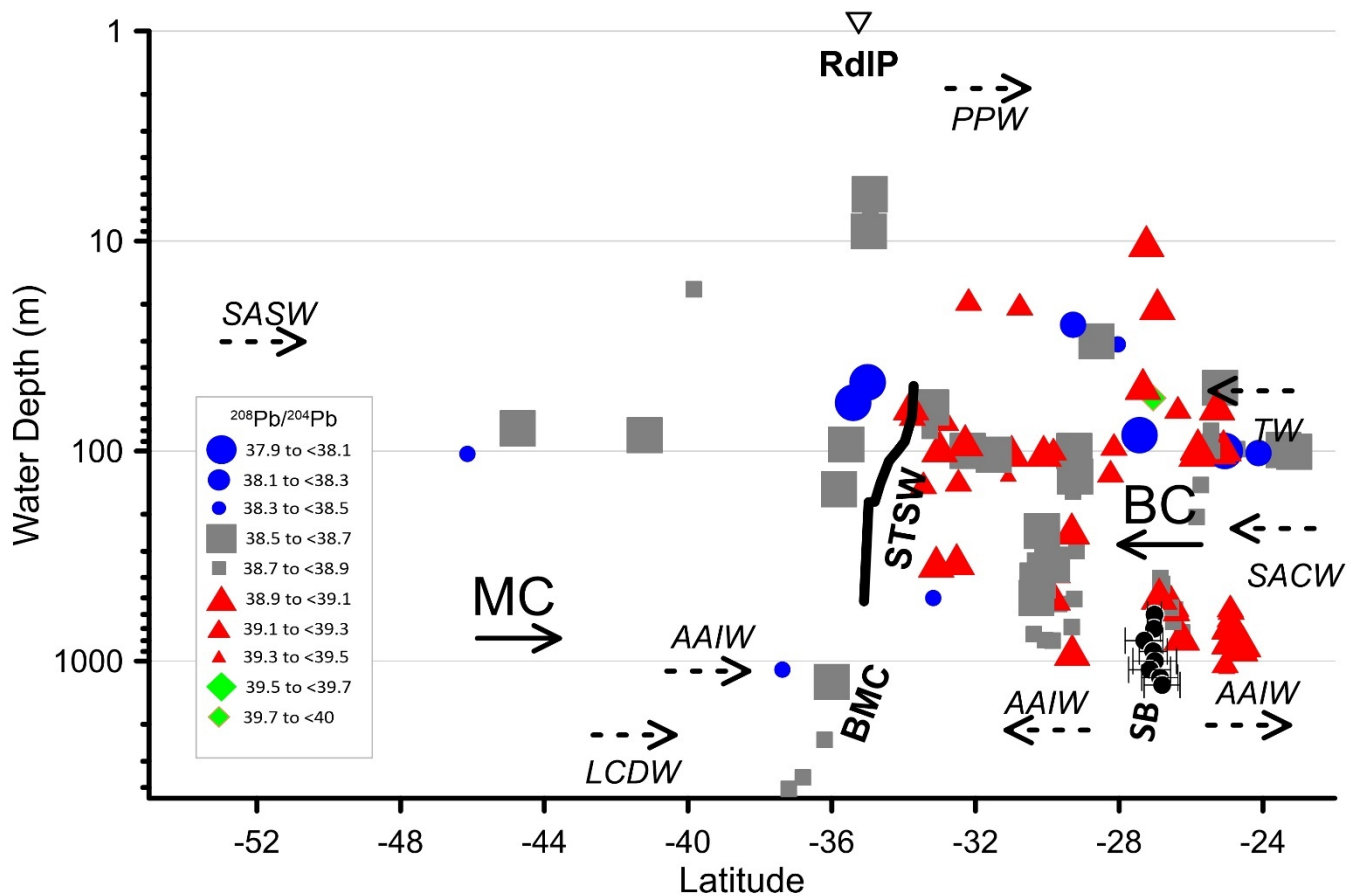



Figure 9. Latitudinal and bathymetric variability of [208]Pb/[204]Pb in the sector between 23°S and 55°S. Rio de la Plata (RdlP). Water masses: Plata Plume Water (PPW), Subantarctic Shelf Water (SASW), Tropical Water (TW), South Atlantic Central Water (SACW), Antarctic Intermediate Water (AAIW), and Lower Circumpolar Deep Water (LCDW). Currents: Malvinas Current (MC) and Brazil Current (BC). Fronts: Subtropical Shelf Front (STSW), Brazil-Malvinas Confluence (BMC), and Santos Bifurcation (SB). Vertical axis in Log(10) scale.

5.1. Sediment sources

Recognizing the role of circulation on the deposition of sediments requires an association of the sedimentary provinces with potential source areas. Indeed, radiogenic isotopes are considered good sediment source fingerprints (Owens et al., 2016). Two seminal papers, by Goldstein et al. (1984) and Bayon et al. (2015), used Nd isotopes and other proxies from the world´s rivers and provided the basis for comprehending distribution detrital Nd in the world´s oceans. Beny et al. (2020) provided the summary of Nd, Pb, and Sr signatures in the South Atlantic, looking for the potential sources and circulation in the area. More recently, a work by Höppner et al. (2021) provided new data on the isotopic signatures of the river sediments that feed the RdlP basin. Worth noting that the RdlP-Paraná-Uruguay riverine system drains several types of terranes, such as pre-Cambrian rocks of the Brazilian shield, Paleozoic sediments, and tholeiitic basalts from the Paraná Basin, and Cenozoic Andean rocks.

Table 2 provides a list of Nd and Pb isotopic signatures of potential continental materials (rocks and sediments) for the study area. It is possible to recognize a trend of decreasing values of εNd towards the north, as already observed in our samples. Concerning Pb isotopes, the small number of data hampers the recognition of a trend.

Table 2. Nd and Pb isotopic values of distinct continental materials from Antarctica and Southeastern South America

Material	εNd	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	Source
Sediments from the Antarctic Peninsula and Western Antarctica	-4.3±1.0	n.a.	n.a.	Roy et al. (2007)
River bed sediments from Patagonia	-2.0±0.7	n.a.	n.a.	Gaiero et al. (2007)
Topsoils and river bed sediments from Southern Patagonia	-1.7±1.6	15.63±0.01	38.61±0.12	Khondoker et al. (2018)
Clay and silt fractions from the Chubut River (Patagonia)	-0.4 -1.6	n.a.	n.a.	Bayon et al. (2015)
Bulk sediment from Paraná River	-10.3	n.a.	n.a.	Goldstein et al. (1984)
Suspended sediments from Paraná River	-10.8±0.5	n.a.	n.a.	Henry et al. (1996)
Low-Ti basalts from the southern Paraná Igneous Province	-8.0±1.2	15.68±0.02	38.97±0.24	Barreto et al. (2016); Melankholina and Sushchevskaya (2018)
Ribeira River sediments. The river drains Proterozoic low- to middle-rank metamorphic rocks from southeastern Brazil (river mouth located at 24.68ºS – 047.42ºW)	n.a.	15.55±0.02	37.67±0.4	Moraes et al. (2004)
Neoarchean and Proterozoic metasediments from the coastal region of southeastern Brazil	-21.5±5.6	n.a.	n.a.	Ragatky et al. (2000)
Proterozoic granites from the coastal region of southeastern Brazil	-18.7±1.4	n.a.	n.a.	Mendes et al. (2011)
Paraíba do Sul River sediments. The river drains middle-rank to high-rank metamorphic rocks from southeastern Brazil (river mouth located at 21.61ºS – 41.02ºW)	-19.3±1.4	n.a.	n.a.	Roig et al. (2005)
Proterozoic metasediments from southeastern Brazil	-8.8±1.9	n.a.	n.a.	Mantovanelli et al. (2018)
Proterozoic granites from southeastern Brazil	-18.2±1.2	n.a.	n.a.	Mantovanelli et al. (2018)

330

Isotopic distinctions and similarities among the sectors are recognized from the interpretation of the results of the Discriminant Analysis (Figure 4). Sediments from Argentina and part of the Punta del Este Basin present isotopic signatures similar to the values obtained for Patagonia (Gaiero et al., 2007; Bayon et al., 2015; Khondoker et al., 2018). The deepest samples of the dataset, located in the Punta del Este basin, at water depths between 3579 and 4066 meters, present εNd values of -5.33 and -4.26, respectively. These values are consistent with those from the Antarctic Peninsula and West Antarctica (Roy et al., 2007). They can indicate a provenance of sediments via the flow of the Upper- and Lower- Circumpolar Deep-water masses (UCDW and LCDW, respectively) (Beny et al., 2020) or even from ice-rafted debris (Bozzano et al., 2021). Another sample, located at 2378 meters, presents an εNd value of -4.80 but is presently under the influence of the NADW southward flow (Figure 7). The distinct character of these samples also resides in the fact that they are lower $^{207}Pb/^{204}Pb$ and higher $^{208}Pb/^{204}Pb$ radiogenic than those located in shallower areas (Figures 8 and 9). The remainder of the Punta del Este basin samples, situated on the shelf, might represent a mixture of Patagonian and Río de la Plata sediments.

Most of the samples from the Pelotas Basin are under the influence of the RdlP. Apart from Nd and Pb isotope values, other independent proxies confirm the Plata Plume Water (PPW) as a source of the sediments to the southern Brazilian margin (Pelotas Basin) and part of the southeastern margin (Santos Basin). Campos et al. (2008) and Nagai et al. (2014a) used clay mineralogy to indicate sediments from the Río de la Plata to the North. Also, the maps presented by Govin et al. (2012) show similarities in the ln(Ti/Al) and ln(Fe/K) between the Uruguayan and southern Brazilian upper margin. Finally, Mathias et al. (2014) used magnetic properties of sediments in a core located at the latitude of 25°30'S to recognize the influence of the Río de la Plata on the southern Brazilian shelf since 2 cal kyr BP. Finally, in a study that included the analysis of potential source rocks from the continent, Mantovanelli et al. (2018) confirmed the contribution of the Paraná Basin basalts along the Holocene off the southern Brazilian shelf (27°S). The authors observed a remarkable change to less radiogenic Nd in the sedimentary column further North (23°S).

The samples from Santos Basin present lower radiogenic Nd and higher radiogenic Pb values, thus indicating a Pre-Cambrian source, as Mantovanelli et al. (2018) stated. Nevertheless, the values obtained for Pb isotopes differ significantly from those reported by the literature for the Precambrian metasediments and granites of the southeastern Brazilian coast (Ragatky et al., 2000; Moraes et al., 2004; Mendes et al., 2011). A possible explanation for this discrepancy is that the input of sediments from the adjacent coast is hampered by the Serra do Mar mountain chain, limiting the development of expressive drainage basins in the area (Riccomini et al., 2010; Cogné et al., 2011). In this sense, we cannot rule out the possibility that a significant part of sediments that presently cover the shelf and upper slope of the Santos basin is originated further north and transported by the Brazil Current and derived shelf dynamics (Castro and Miranda, 1998; Silveira et al., 2017).

5.2. Isotope fingerprinting and ocean circulation

365 The geochemical fingerprinting approach confirmed the suitability of using Nd and Pb isotopes (except $^{206}Pb/^{204}Pb$) as reliable proxies for the discrimination among the distinct sectors of the Southwestern Atlantic margin. Indeed, the first axis provided more than 99% of explained variance (Figure 4). The distribution of the samples and, together with the recognition of the potential sources (Table 2), allows tracing a correlation among isotopic signatures, sediment sources, and ocean circulation. Figures 7 to 9 present the bathymetrical variations of the isotopes and positions of the STSF (continuous line) and SB

370 (continuous line with horizontal bars) identified in the LLC2160 output. The positions of both oceanographic features in the LLC2160 simulation are broadly consistent with previous studies (e.g., Boebel et al., 1999a; Boebel et al., 1999b; Piola et al., 2008). The LLC2160 output, together with the isotopic values, allows us to present the bathymetrical variations of those features. As observed, there are clear distinctions in the signature corresponding to both fronts. The STSF presents only minor seasonal variations, and its control is probably related to the interaction between the RdlP plume and the subsurface water

375 masses distribution. During austral summer, the strong stratification (Möller et al., 2008) inhibits RdlP sedimentation southward of the STSF. During austral winter, the northeastward RdlP plume promotes the offshore displacement of subtropical waters (Möller et al., 2008), enabling the deposition of fine sediments on the shelf north of the STSF. On the upper and middle slope, the southward displacement of the thickened Brazil Current, carrying the recirculated AAIW, likely limits RdlP sedimentation (Schmid et al., 2000). There are apparent differences in the Nd and Pb signatures in the intermediate zone,

380 at about 34ºS – 35ºS; this boundary might represent the northernmost limit of the BMC (Benthien and Müller, 2000; Pezzi et al., 2009).

This integrated analysis suggests no transport of sediments from the Argentinean sector to the southern Brazilian margin. On the other hand, based on the same analysis, we can confirm that sediments from the Rio de la Plata reach, at least partially, the Santos sector, i.e., to the north of 28ºS. Concerning the SB, there is a clear distinction in isotopic signatures below the 500 m

385 isobath, less radiogenic Nd prevailing to the north of the bifurcation. We thus argue that both STSF and SB also separate distinct geochemical provinces on the Southwestern Atlantic margin.

The Argentinean and part of the Uruguayan upper margins are covered by Andean-Patagonian sediments, redistributed by the shelf circulation and Malvinas Currents. The STSF and BMC block the transport of these sediments to the north. This finding corroborates Hernández-Molina et al. (2016) and Franco-Fraguas et al. (2016), who defined the northernmost limit of a mega-

390 contouritic feature on the Uruguayan slope. Sediments located more profound than the 2,000 m isobath present an Antarctic signature, transported either by the bottom circulation (UCDW and LCDW) or ice-rafted debris.

Sediments from the Río de la Plata estuary advance along the inner shelf towards southern Brazil and a mixture of Pelotas and Santos signatures are observed between 28ºS and 30ºS. This mixture is visible in the scatter plot presented in Figure 4, in which sediments of Pelotas Basin constitute a mixture of distinct populations, i.e., Santos Basin and Río de la Plata. It is

395 essential to highlight that, on interannual time scales, the influence of El Niño-Southern Oscillation (ENSO) in the precipitation regime determines changes in the freshwater outflow of the RdlP. Cold and warm episodes of ENSO cause drought and

abundant rainfall in Uruguay, southern Brazil, and north-eastern Argentina (Pisciottano et al., 1994; Cazes-Boezio et al., 2003). In addition, changes in the wind patterns during the warm phase of ENSO determine the influence of the PPW towards higher latitudes. In conjunction with the Coriolis force, this phenomenon determines that the PPW follows a NE direction close to the
400   shelf break, explaining the distribution up to 28ºS and, in anomalous years, 25ºS (Piola et al., 2005).

Finally, sediments located northward of 27ºS originate from the Precambrian rocks that dominate the coastal domains off SE and E Brazil, being mainly transported by the intense flow of the BC on the outer shelf and upper slope. Limited input comes from the small rivers that drain the mountainous areas of the Serra do Mar, as previously reported by Lourenço et al. (2017) and de Mahiques et al. (2017)

405

Conclusions

In this paper, we use Nd and Pb radiogenic isotopes to recognize the role of ocean circulation in the sediment distribution of
410   the Southwestern Atlantic margin.

Andean and continental Patagonian sediments are the primary source for the deposits of the Argentinean and Uruguayan shelves, while the lower slope is more influenced by more distant sources, such as the Antarctic Peninsula. Nevertheless, sediments on the shelf and upper slope are carried by the flows of the SASW and AAIW, while the UCDW and LCDW transport sediments from the lower slope.

415   The Río de la Plata is the primary influencer of the sediments off southern Brazil up to the 27ºS parallel. The sediments are transported northwards by the PPW, which is transported by a wind-driven current. A mixture of sediments from the PPW and the north is transported towards the slope between 34ºS and 28ºS.

Finally, Pre-Cambrian terrains are the primary sources of the sediments deposited further north. They are originated from rivers located northward of the area of study and, on a smaller scale, by the small drainages that face the ocean in the Serra do
420   Mar region.

We propose that the main oceanographic boundaries of the southwestern South Atlantic margin, i.e., the Subtropical Shelf Front and the Santos Bifurcation, separate distinct geochemical provinces.

Data availability

All of the data used in this paper is presented as Supplementary Material

Acknowledgments

The authors acknowledge the crew of R.V. Alpha Crucis and participants of research cruises Mudbelts I and II and Talude I and II for helping during the sampling surveys. This work is a contribution to the Grupo de Investigación en Ciencia y Tecnología Marina (CINCYTEMA) as well as to the MOU between the Oceanographic Institute of University of São Paulo (Brazil) and the Facultad de Ciencias of the Universidad de La Republica (Uruguay), institutions to whom the authors are indebted.

Funding

This work was financially supported by the São Paulo Science Foundation (FAPESP) for grants 2010/06147-5, 2014/08266-2, 2015/17763-2, 2016/22194-0, and 2019/00256-1. In addition, MM de M acknowledges the Brazilian Council of Scientific Research (CNPq) for the Research Grant 300962/2018-5.

References

Baptista, M. S., and Conti, L. A.: The Staircase Structure of the Southern Brazilian Continental Shelf, Mathematical Problems in Engineering, 2009, 1-17, 10.1155/2009/624861, 2009.

Barreto, C. J. S., Lafon, J. M., de Lima, E. F., and Sommer, C. A.: Geochemical and Sr–Nd–Pb isotopic insight into the low-Ti basalts from southern Paraná Igneous Province, Brazil: the role of crustal contamination, International Geology Review, 58, 1324-1349, 10.1080/00206814.2016.1147988, 2016.

Basile, I., Grousset, F. E., Revel, M., Petit, J. R., Biscaye, P. E., and Barkov, N. I.: Patagonian origin of glacial dust deposited in East Antarctica (Vostok and Dome C), during glacial stages 2, 4 and 6, Earth and Planetary Science Letters, 146, 573-589, 1997.

Bassetto, M., Alkmim, F. F., Szatmari, P., and Mohriak, W. U.: The oceanic segment of the southern Brazilian margin: Morpho-structural domains and their tectonic significance, in: Atlantic Rifts and Continental Margins, Geophysical Monograph Series, 235-259, 2000.

Bayon, G., Toucanne, S., Skonieczny, C., André, L., Bermell, S., Cheron, S., Dennielou, B., Etoubleau, J., Freslon, N., Gauchery, T., Germain, Y., Jorry, S. J., Ménot, G., Monin, L., Ponzevera, E., Rouget, M. L., Tachikawa, K., and Barrat, J. A.: Rare earth elements and neodymium isotopes in world river sediments revisited, Geochimica et Cosmochimica Acta, 170, 17-38, 10.1016/j.gca.2015.08.001, 2015.

Benthien, A., and Müller, P. J.: Anomalously low alkenone temperatures caused by lateral particle and sediment transport in the Malvinas Current region, western Argentine Basin, Deep Sea Research Part I: Oceanographic Research Papers, 47, 2369-2393, 10.1016/s0967-0637(00)00030-3, 2000.

Beny, F., Bout-Roumazeilles, V., Davies, G. R., Waelbroeck, C., Bory, A., Tribovillard, N., Delattre, M., and Abraham, R.: Radiogenic isotopic and clay mineralogical signatures of terrigenous particles as water-mass tracers: New insights into South Atlantic deep circulation during the last termination, Quaternary Science Reviews, 228, 106089, 10.1016/j.quascirev.2019.106089, 2020.

Berden, G., Charo, M., Möller, O. O., and Piola, A. R.: Circulation and Hydrography in the Western South Atlantic Shelf and Export to the Deep Adjacent Ocean: 30°S to 40°S, Journal of Geophysical Research: Oceans, 125, 10.1029/2020jc016500, 2020.

Berkowsky, F.: Variaciones mineralógicas en sedimentos del Río de la Plata, VII Congreso Geológico Argentino, Neuquén, 1978, 649-658,

Berkowsky, F.: Arenas del Río de la Plata: una excepción a la relación entre composición de areniscas y la tectónica de placas, Primera Reunión Argentina de Sedimentología, La Plata, 1986, 263-266,

Biló, T. C., da Silveira, I. C. A., Belo, W. C., de Castro, B. M., and Piola, A. R.: Methods for estimating the velocities of the Brazil Current in the pre-salt reservoir area off southeast Brazil (23∘ S–26∘ S), Ocean Dynamics, 64, 1431-1446, 10.1007/s10236-014-0761-2, 2014.

Blanchet, C. L.: A database of marine and terrestrial radiogenic Nd and Sr isotopes for tracing earth-surface processes, Earth System Science Data, 11, 741-759, 10.5194/essd-11-741-2019, 2019.

Boebel, O., Schmid, C., and Zenk, W.: Flow and recirculation of Antarctic Intermediate Water across the Rio Grande Rise, Journal of
465   Geophysical Research: Oceans, 102, 20967-20986, 10.1029/97jc00977, 1997.

Boebel, O., Davis, R. E., Ollitrault, M., Peterson, R. G., Richardson, P. L., Schmid, C., and Zenk, W.: The intermediate depth circulation of
the western South Atlantic, Geophysical Research Letters, 26, 3329-3332, 10.1029/1999gl002355, 1999a.

Boebel, O., Schmid, C., and Zenk, W.: Kinematic elements of Antarctic Intermediate Water in the western South Atlantic, Deep Sea Research
Part II: Topical Studies in Oceanography, 46, 355-392, 10.1016/s0967-0645(98)00104-0, 1999b.

470   Bozzano, G., Violante, R. A., and Cerredo, M. E.: Middle slope contourite deposits and associated sedimentary facies off NE Argentina,
Geo-Marine Letters, 31, 495-507, 10.1007/s00367-011-0239-x, 2011.

Bozzano, G., Martín, J., Spoltore, D. V., and Violante, R. A.: Los cañones submarinos del margen continental Argentino: una síntesis sobre
su génesis y dinámica sedimentaria, Latin American Journal of Sedimentology and Basin Analysis, 24, 85-101, 2017.

Bozzano, G., Cerredo, M. E., Remesal, M., Steinmann, L., Hanebuth, T. J. J., Schwenk, T., Baqués, M., Hebbeln, D., Spoltore, D., Silvestri,
475   O., Acevedo, R. D., Spiess, V., Violante, R. A., and Kasten, S.: Dropstones in the Mar del Plata Canyon Area (SW Atlantic): Evidence for
Provenance, Transport, Distribution, and Oceanographic Implications, Geochemistry, Geophysics, Geosystems, 22, 10.1029/2020gc009333,
2021.

Burone, L., Franco-Fraguas, P., de Mahiques, M. M., and Ortega, L.: Geomorphological and Sedimentological Characterization of the
Uruguayan Continental Margin: A Review and State of Art, Journal of Sedimentary Environments, 3, 253-264, 10.12957/jse.2018.39150,
480   2018.

Campos, E. J. D., Mulkherjee, S., Piola, A. R., and de Carvalho, F. M. S.: A note on a mineralogical analysis of the sediments associated
with the Plata River and Patos Lagoon outflows, Continental Shelf Research, 28, 1687-1691, 10.1016/j.csr.2008.03.014, 2008.

Carranza, A., Recio, A. M., Kitahara, M., Scarabino, F., Ortega, L., López, G., Franco-Fraguas, P., De Mello, C., Acosta, J., and Fontan, A.:
Deep-water coral reefs from the Uruguayan outer shelf and slope, Marine Biodiversity, 42, 411-414, 10.1007/s12526-012-0115-6, 2012.

485   Castro, B. M., and Miranda, L. B.: Physical Oceanography of the Western Atlantic continental shelf located between 4N and 34S, in: The
Sea, edited by: Robinson, A. R., and Brink, K. H., John Wiley & Sons, New York, 210-251, 1998.

Cazes-Boezio, G., Robertson, A. W., and Mechoso, C. R.: Seasonal Dependence of ENSO Teleconnections over South America and
Relationships with Precipitation in Uruguay, Journal of Climate, 16, 1159-1176, 10.1175/1520-0442(2003)16<1159:Sdoeto>2.0.Co;2, 2003.

Chen, S., Qiu, B., Klein, P., Wang, J., Torres, H., Fu, L.-L., and Menemenlis, D.: Seasonality in Transition Scale from Balanced to
490   Unbalanced Motions in the World Ocean, Journal of Physical Oceanography, 48, 591-605, 10.1175/jpo-d-17-0169.1, 2018.

Cogné, N., Gallagher, K., and Cobbold, P. R.: Post-rift reactivation of the onshore margin of southeast Brazil: Evidence from apatite (U–
Th)/He and fission-track data, Earth and Planetary Science Letters, 309, 118-130, 10.1016/j.epsl.2011.06.025, 2011.

Corrêa, I. C. S.: Les variations du niveau de la mer durant les derniers 17.500 ans BP: l'exemple de la plate-forme continentale du Rio Grande
do Sul-Brésil, Marine Geology, 130, 163-178, 10.1016/0025-3227(95)00126-3, 1996.

495   de Mahiques, M. M., Tassinari, C. C. G., Marcolini, S., Violante, R. A., Figueira, R. C. L., Silveira, I. C. A., Burone, L., and Sousa, S. H.
M.: Nd and Pb isotope signatures on the Southeastern South American upper margin: Implications for sediment transport and source rocks,
Marine Geology, 250, 51-63, 10.1016/j.margeo.2007.11.007, 2008.

de Mahiques, M. M., Hanebuth, T. J. J., Nagai, R. H., Bícego, M. C., Figueira, R. C. L., Sousa, S. H. M., Burone, L., Franco-Fraguas, P.,
Taniguchi, S., Salaroli, A. B., Dias, G. P., Prates, D. M., and Freitas, M. E. F.: Inorganic and organic geochemical fingerprinting of sediment
500   sources and ocean circulation on a complex continental margin (São Paulo Bight, Brazil), Ocean Science, 13, 209-222, 10.5194/os-13-209-
2017, 2017.

de Mahiques, M. M., Figueira, R. C. L., Sousa, S. H. d. M., Santos, R. F. d., Ferreira, P. A. d. L., Kim, B. S. M., Cazzoli y Goya, S., de
Matos, M. C. S. N., and Bícego, M. C.: Sedimentation on the southern Brazilian shelf mud depocenters: Insights on potential source areas,
Journal of South American Earth Sciences, 100, 10.1016/j.jsames.2020.102577, 2020.

505   DePaolo, D. J.: Neodymium isotopes in the Colorado Front Range and crust–mantle evolution in the Proterozoic, Nature, 291, 193-196,
10.1038/291193a0, 1981.

Depetris, P. J., and Griffin, J. J.: Suspended Load in the Rio De La Plata Drainage Basin, Sedimentology, 11, 53-60, 10.1111/j.1365-
3091.1968.tb00840.x, 1968.

Duarte, C. S. L., and Viana, A. R.: Santos Drift System: stratigraphic organization and implications for late Cenozoic palaeocirculation in
510   the Santos Basin, SW Atlantic Ocean, Geological Society, London, Special Publications, 276, 171-198, 10.1144/gsl.sp.2007.276.01.09,
2007.

Emilsson, I.: The shelf and coastal waters off southern Brazil, Boletim do Instituto Oceanográfico, 11, 101-112, 10.1590/S0373-
55241961000100004 1961.

Etchichury, M. C., and Remiro, J. R.: Muestras de fondo de la plataforma continental comprendida entre los paralelos 34° y 36°30 de latitud
515   sur y los meridianos 53°10 y 56°30 de longitud oeste, Revista del Museo Argentino de Ciencias Naturales Bernardino Rivadavia, VI, 1-70,
1960.

Etchichury, M. C., and Remiro, J. R.: La corriente de Malvinas y los sedimentos pampeanopatagónicos, Revista del Museo Argentino de
Ciencias Naturales Bernardino Rivadavia, 1, 1-11, 1963.

Fernandes, A. M., da Silveira, I. C. A., Calado, L., Campos, E. J. D., and Paiva, A. M.: A two-layer approximation to the Brazil Current–
Intermediate Western Boundary Current System between 20°S and 28°S, Ocean Modelling, 29, 154-158, 10.1016/j.ocemod.2009.03.008,
2009.

Figueiredo, A. G., and Madureira, L. S. P.: Topografia, composição, refletividade do substrato marinho e identificação de províncias
sedimentares na Regiao Sudeste-Sul do Brasil, Série Documentos Técnicos do Programa REVIZEE Score Sul, Instituto Oceanográfico -
USP, São Paulo, 64 pp., 2004.

Framiñan, M. B., and Brown, O. B.: Study of the Río de la Plata turbidity front, Part 1: spatial and temporal distribution, Continental Shelf
Research, 16, 1259-1282, 10.1016/0278-4343(95)00071-2, 1996.

Franco-Fraguas, P., Burone, L., Mahiques, M., Ortega, L., Urien, C., Muñoz, A., López, G., Marin, Y., Carranza, A., Lahuerta, N., and de
Mello, C.: Hydrodynamic and geomorphological controls on surface sedimentation at the Subtropical Shelf Front / Brazil–Malvinas
Confluence transition off Uruguay (Southwestern Atlantic Continental Margin), Marine Geology, 349, 24-36,
10.1016/j.margeo.2013.12.010, 2014.

Franco-Fraguas, P., Burone, L., Mahiques, M., Ortega, L., and Carranza, A.: Modern sedimentary dynamics in the Southwestern Atlantic
Contouritic Depositional System: New insights from the Uruguayan margin based on a geochemical approach, Marine Geology, 376, 15-
25, 10.1016/j.margeo.2016.03.008, 2016.

Franco-Fraguas, P., Burone, L., Goso, C., Scarabino, F., Muzio, R., Carranza, A., Ortega, L., Muñoz, A., and Mahiques, M.: Sedimentary
processes in the head of the Cabo Polonio mega slide canyon (Southwestern Atlantic margin off Uruguay), Latin American Journal of
Sedimentology and Basin Analysis, 24, 31-44, 2017.

Frenz, M., Höppner, R., Stuut, J.-B., Wagner, T., and Henrich, R.: Surface sediment bulk geochemistry and grain-size composition related
to the oceanic circulation along the South American continental margin in the Southwest Atlantic, in: The South Atlantic in the Late
Quaternary: Reconstruction of material budgets and current Systems, edited by: Wefer, G., Mulitza, S., and Ratmeyer, V., Springer-Verlag,
Berlin, 347-373, 2003.

Gaiero, D. M., Brunet, F., Probst, J.-L., and Depetris, P. J.: A uniform isotopic and chemical signature of dust exported from Patagonia:
Rock sources and occurrence in southern environments, Chemical Geology, 238, 107-120, 10.1016/j.chemgeo.2006.11.003, 2007.

Goldstein, S. L., O'Nions, R. K., and Hamilton, P. J.: A Sm-Nd isotopic study of atmospheric dusts and particulates from major river systems,
Earth and Planetary Science Letters, 70, 221-236, 10.1016/0012-821x(84)90007-4, 1984.

Govin, A., Holzwarth, U., Heslop, D., Ford Keeling, L., Zabel, M., Mulitza, S., Collins, J. A., and Chiessi, C. M.: Distribution of major
elements in Atlantic surface sediments (36°N-49°S): Imprint of terrigenous input and continental weathering, Geochemistry, Geophysics,
Geosystems, 13, n/a-n/a, 10.1029/2011gc003785, 2012.

Henry, F., Probst, J. L., Thouron, D., Depetris, P., and Garçon, V.: Nd-Sr isotopic compositions of dissolved and particulate material
transported by the Parana and Uruguay rivers during high (December 1993) and low (September 1994) water periods. / Compositions
isotopiques de Nd et Sr des matières en suspension et dissoutes transportées par les fleuves Parana et Uruguay en périodes de hautes
(décembre 1993) et basses (septembre 1994) eaux, Sciences Géologiques. Bulletin, 49, 89-100, 10.3406/sgeol.1996.1937, 1996.

Hernandez-Molina, F. J., Paterlini, M., Violante, R., Marshall, P., de Isasi, M., Somoza, L., and Rebesco, M.: Contourite depositional system
on the Argentine Slope: An exceptional record of the influence of Antarctic water masses, Geology, 37, 507-510, 10.1130/g25578a.1, 2009.

Hernández-Molina, F. J., Paterlini, M., Somoza, L., Violante, R., Arecco, M. A., de Isasi, M., Rebesco, M., Uenzelmann-Neben, G., Neben,
S., and Marshall, P.: Giant mounded drifts in the Argentine Continental Margin: Origins, and global implications for the history of
thermohaline circulation, Marine and Petroleum Geology, 27, 1508-1530, 10.1016/j.marpetgeo.2010.04.003, 2010.

Hernández-Molina, F. J., Soto, M., Piola, A. R., Tomasini, J., Preu, B., Thompson, P., Badalini, G., Creaser, A., Violante, R. A., Morales,
E., Paterlini, M., and De Santa Ana, H.: A contourite depositional system along the Uruguayan continental margin: Sedimentary,
oceanographic and paleoceanographic implications, Marine Geology, 10.1016/j.margeo.2015.10.008, 2015.

Hernández-Molina, F. J., Soto, M., Piola, A. R., Tomasini, J., Preu, B., Thompson, P., Badalini, G., Creaser, A., Violante, R. A., Morales,
E., Paterlini, M., and De Santa Ana, H.: A contourite depositional system along the Uruguayan continental margin: Sedimentary,
oceanographic and paleoceanographic implications, Marine Geology, 378, 333-349, 10.1016/j.margeo.2015.10.008, 2016.

Höppner, N., Chiessi, C. M., Lucassen, F., Zavala, K., Becchio, R. A., and Kasemann, S. A.: Modern isotopic signatures of Plata River
sediments and changes in sediment supply to the western subtropical South Atlantic during the last 30 kyr, Quaternary Science Reviews,
259, 106910, 10.1016/j.quascirev.2021.106910, 2021.

Jacobsen, S. B., and Wasserburg, G. J.: Sm-Nd isotopic evolution of chondrites, Earth and Planetary Science Letters, 50, 139-155,
10.1016/0012-821x(80)90125-9, 1980.

Jeandel, C., Arsouze, T., Lacan, F., Téchiné, P., and Dutay, J. C.: Isotopic Nd compositions and concentrations of the lithogenic inputs into
the ocean: A compilation, with an emphasis on the margins, Chemical Geology, 239, 156-164, 10.1016/j.chemgeo.2006.11.013, 2007.

Kessarkar, P. M., Rao, V. P., Ahmad, S. M., and Babu, G. A.: Clay minerals and Sr–Nd isotopes of the sediments along the western margin
of India and their implication for sediment provenance, Marine Geology, 202, 55-69, 10.1016/s0025-3227(03)00240-8, 2003.

Khondoker, R., Weiss, D., van de Flierdt, T., Rehkämper, M., Kreissig, K., Coles, B. J., Strekopytov, S., Humphreys-Williams, E., Dong,
S., Bory, A., Bout-Roumazeilles, V., Smichowski, P., Cid-Agüero, P., Babinski, M., Losno, R., and Monna, F.: New constraints on elemental

and Pb and Nd isotope compositions of South American and Southern African aerosol sources to the South Atlantic Ocean, Geochemistry, 78, 372-384, 10.1016/j.chemer.2018.05.001, 2018.

Kowsmann, R. O., and Costa, M. P. A.: Sedimentação quaternária da margem continental brasileira e das áreas adjacentes, REMAC, Petrobrás (*In Portuguese*), Rio de Janeiro, 55 pp., 1979.

Lantzsch, H., Hanebuth, T. J. J., Chiessi, C. M., Schwenk, T., and Violante, R. A.: The high-supply, current-dominated continental margin of southeastern South America during the late Quaternary, Quaternary Research, 81, 339-354, 10.1016/j.yqres.2014.01.003, 2014.

Legeais, J.-F., Ollitrault, M., and Arhan, M.: Lagrangian observations in the Intermediate Western Boundary Current of the South Atlantic, Deep Sea Research Part II: Topical Studies in Oceanography, 85, 109-126, 10.1016/j.dsr2.2012.07.028, 2013.

Lonardi, A. G., and Ewing, M.: Sediment transport and distribution in the Argentine Basin. 4. Bathymetry of the continental margin, Argentine Basin and other related provinces. Canyons and sources of sediments, in: Physics and Chemistry of the Earth, edited by: Ahrens, L. H., Press, F., Runcorn,, and S.K., U., H.C. , Pergamon Press, New York, 79-121, 1971.

Lourenço, R. A., Magalhães, C. A., de Mahiques, M. M., Taniguchi, S., and Bícego, M. C.: Distribution of terrigenous and marine material along the Southeastern Brazilian continental margin, Regional Studies in Marine Science, 14, 118-125, 10.1016/j.rsma.2017.05.012, 2017.

Lovecchio, J. P., Rohais, S., Joseph, P., Bolatti, N. D., and Ramos, V. A.: Mesozoic rifting evolution of SW Gondwana: A poly-phased, subduction-related, extensional history responsible for basin formation along the Argentinean Atlantic margin, Earth-Science Reviews, 203, 10.1016/j.earscirev.2020.103138, 2020.

Maamaatuaiahutapu, K., Garçon, V. C., Provost, C., Boulahdid, M., and Osiroff, A. P.: Brazil-Malvinas Confluence: Water mass composition, Journal of Geophysical Research, 97, 10.1029/92jc00484, 1992.

Maccali, J., Hillaire-Marcel, C., Carignan, J., and Reisberg, L. C.: Pb isotopes and geochemical monitoring of Arctic sedimentary supplies and water mass export through Fram Strait since the Last Glacial Maximum, Paleoceanography, 27, n/a-n/a, 10.1029/2011pa002152, 2012.

Maccali, J., Hillaire-Marcel, C., and Not, C.: Radiogenic isotope (Nd, Pb, Sr) signatures of surface and sea ice-transported sediments from the Arctic Ocean under the present interglacial conditions, Polar Research, 37, 10.1080/17518369.2018.1442982, 2018.

Magdaleno, G. B., Petronilho, L. A., Ruiz, I. R., Babinski, M., Hollanda, M. H. B. M., and Martins, V. T. S.: Pb-Sr-Nd isotopoic characterization of USGS reference materials by TIMS at CPGeo-USP, II Workshop of inorganic mass spectrometry, São Paulo, 2017, http://wims.igc.usp.br/wp-content/uploads/2017/2007/Giselle-Magdaleno.pdf,

Maly, M., Schattner, U., Lobo, F., Ramos, R. B., Dias, R. J., Couto, D. M., Sumida, P. Y., and de Mahiques, M. M.: The Alpha Crucis Carbonate Ridge (ACCR): Discovery of a giant ring-shaped carbonate complex on the SW Atlantic margin, Scientific Reports, 9, 18697, 10.1038/s41598-019-55226-3, 2019.

Mantovanelli, S. S., Tassinari, C. C. G., de Mahiques, M. M., Jovane, L., and Bongiolo, E.: Characterization of Nd radiogenic isotope signatures in sediments from the southwestern Atlantic Margin, Frontiers in Earth Science, 6, 74, 10.3389/feart.2018.00074, 2018.

Matano, R. P., Palma, E. D., and Piola, A. R.: The influence of the Brazil and Malvinas Currents on the Southwestern Atlantic Shelf circulation, Ocean Science, 6, 983-995, 10.5194/os-6-983-2010, 2010.

Mathias, G. L., Nagai, R. H., Trindade, R. I. F., and de Mahiques, M. M.: Magnetic fingerprint of the late Holocene inception of the Río de la Plata plume onto the southeast Brazilian shelf, Palaeogeography, Palaeoclimatology, Palaeoecology, 415, 183-196, 10.1016/j.palaeo.2014.03.034, 2014.

Melankholina, E. N., and Sushchevskaya, N. M.: Tectono-Magmatic Evolution of the South Atlantic Continental Margins with Respect to Opening of the Ocean, Geotectonics, 52, 173-193, 10.1134/s0016852118020061, 2018.

Mendes, J. C., Medeiros, S. R. d., and Chaves, E. A.: Assinatura isotópica de Sr e Nd do magmatismo cálcio-alcalino de alto-K na Faixa Ribeira central: o exemplo do Granito São Pedro em Lumiar, RJ, Revista Brasileira de Geociências, 41, 408-419, 10.25249/0375-7536.2011413408419, 2011.

Miller, J. R., Mackin, G., and Orbock Miller, S. M.: Geochemical Fingerprinting, in: Application of Geochemical Tracers to Fluvial Sediment, edited by: Miller, J. R., Mackin, G., and Miller, S. M. O., SpringerBriefs in Earth Sciences, Springer, Cham, 11-51, 2015.

Möller, O. O., Piola, A. R., Freitas, A. C., and Campos, E. J. D.: The effects of river discharge and seasonal winds on the shelf off southeastern South America, Continental Shelf Research, 28, 1607-1624, 10.1016/j.csr.2008.03.012, 2008.

Moraes, R. P., Figueiredo, B. R., and Lafon, J. M.: Pb-Isotopic tracing of metal-pollution sources in the Ribeira Valley, Southeastern Brazil, Terrae, 1, 26-33, 2004.

Moulin, M., Aslanian, D., and Unternehr, P.: A new starting point for the South and Equatorial Atlantic Ocean, Earth-Science Reviews, 98, 1-37, 10.1016/j.earscirev.2009.08.001, 2010.

Muñoz, A., Fontan, A., Marin, Y., Carranza, A., Franco-Fraguas, P., and Rubio, L.: Informe de Campaña Uruguay 0110. Buque de Investigacion Oceanografica y Pesquera Miguel Oliver (SGM). Dinara, Montevideo, 67, 2010.

Nagai, R. H., Ferreira, P. A. L., Mulkherjee, S., Martins, M. V., Figueira, R. C. L., Sousa, S. H. M., and de Mahiques, M. M.: Hydrodynamic controls on the distribution of surface sediments from the southeast South American continental shelf between 23°S and 38°S, Continental Shelf Research, 89, 51-60, 10.1016/j.csr.2013.09.016, 2014a.

Nagai, R. H., Sousa, S. H. M., and de Mahiques, M. M.: The southern Brazilian shelf, Geological Society, London, Memoirs, 41, 47-54, 10.1144/m41.5, 2014b.

Núñez-Riboni, I., Boebel, O., Ollitrault, M., You, Y., Richardson, P. L., and Davis, R.: Lagrangian circulation of Antarctic Intermediate Water in the subtropical South Atlantic, Deep Sea Research Part II: Topical Studies in Oceanography, 52, 545-564, 10.1016/j.dsr2.2004.12.006, 2005.

Nürnberg, D., and Müller, R. D.: The tectonic evolution of the South Atlantic from Late Jurassic to present, Tectonophysics, 191, 27-53, 10.1016/0040-1951(91)90231-g, 1991.

Owens, P. N., Blake, W. H., Gaspar, L., Gateuille, D., Koiter, A. J., Lobb, D. A., Petticrew, E. L., Reiffarth, D. G., Smith, H. G., and Woodward, J. C.: Fingerprinting and tracing the sources of soils and sediments: Earth and ocean science, geoarchaeological, forensic, and human health applications, Earth-Science Reviews, 162, 1-23, 10.1016/j.earscirev.2016.08.012, 2016.

Palazon, L., and Navas, A.: Variability in source sediment contributions by applying different statistic test for a Pyrenean catchment, J Environ Manage, 194, 42-53, 10.1016/j.jenvman.2016.07.058, 2017.

Palma, E. D., Matano, R. P., and Piola, A. R.: A numerical study of the Southwestern Atlantic Shelf circulation: Stratified ocean response to local and offshore forcing, Journal of Geophysical Research: Oceans, 113, n/a-n/a, 10.1029/2007JC004720, 2008.

Parker, G., Violante, R., and Paterlini, C. M.: Fisiografía de la Plataforma Continental, in: Relatorio, 13o Congreso Geologico Argentino, edited by: Ramos, V. A., and Turic, M. A., Asociación Geológica Argentina, Buenos Aires, 1-16, 1996.

Pezzi, L. P., de Souza, R. B., Acevedo, O., Wainer, I., Mata, M. M., Garcia, C. A. E., and de Camargo, R.: Multiyear measurements of the oceanic and atmospheric boundary layers at the Brazil-Malvinas confluence region, Journal of Geophysical Research, 114, 10.1029/2008jd011379, 2009.

Piola, A. R., Campos, E. J. D., Möller, O. O., Charo, M., and Martinez, C.: Subtropical Shelf Front off eastern South America, Journal of Geophysical Research: Oceans, 105, 6565-6578, 10.1029/1999jc000300, 2000.

Piola, A. R., and Matano, R. P.: Brazil and Falklands (Malvinas) currents, in: Encyclopedia of Ocean Sciences, edited by: Steele, J. H., Thorpe, S. A., and Turekian, K. K., Academic Press, London, 340-349, 2001.

Piola, A. R., Matano, R. P., Palma, E. D., Möller, O. O., and Campos, E. J. D.: The influence of the Plata River discharge on the western South Atlantic shelf, Geophysical Research Letters, 32, 10.1029/2004GL021638, 2005.

Piola, A. R., Möller, O. O., Guerrero, R. A., and Campos, E. J. D.: Variability of the subtropical shelf front off eastern South America: Winter 2003 and summer 2004, Continental Shelf Research, 28, 1639-1648, 10.1016/j.csr.2008.03.013, 2008.

Piola, A. R., Palma, E. D., Bianchi, A. A., Castro, B. M., Dottori, M., Guerrero, R. A., Marrari, M., Matano, R. P., Möller Jr, O. O., and Saraceno, M.: Physical oceanography of the SW Atlantic Shelf: A review, in: Plankton ecology of the southwestern Atlantic, edited by: Hoffmeyer, M. S., Sabatini, M. E., Brandini, F. P., Calliari, D. L., and Santinelli, N. H., Springer, Cham, 37-56, 2018.

Piola, A. R., and Matano, R. P.: Ocean Currents: Atlantic Western Boundary—Brazil Current/Falkland (Malvinas) Current, in: Encyclopedia of Ocean Sciences, edited by: Cochran, J. K., Bokuniewicz, H. J., and P.L., Y., Elsevier, Amsterdam, 414-420, 2019.

Pisciottano, G., Díaz, A., Cazess, G., and Mechoso, C. R.: El Niño-Southern Oscillation Impact on Rainfall in Uruguay, Journal of Climate, 7, 1286-1302, 10.1175/1520-0442(1994)007<1286:Ensoio>2.0.Co;2, 1994.

Potter, P. E.: South American modern beach sand and plate tectonics, Nature, 311, 645-648, 1984.

Preu, B., Hernández-Molina, F. J., Violante, R., Piola, A. R., Paterlini, C. M., Schwenk, T., Voigt, I., Krastel, S., and Spiess, V.: Morphosedimentary and hydrographic features of the northern Argentine margin: The interplay between erosive, depositional and gravitational processes and its conceptual implications, Deep Sea Research Part I: Oceanographic Research Papers, 75, 157-174, 10.1016/j.dsr.2012.12.013, 2013.

Qiao, L., Liu, S., Xue, W., Liu, P., Hu, R., Sun, H., and Zhong, Y.: Spatiotemporal variations in suspended sediments over the inner shelf of the East China Sea with the effect of oceanic fronts, Estuarine, Coastal and Shelf Science, 234, 106600, 10.1016/j.ecss.2020.106600, 2020.

Ragatky, D., Tupinambá, M., and Duarte, B. P.: Sm/Nd data of metasedimentary rocks from the central segment of Ribeira Belt, southeastern Brazil, Revista Brasileira de Geociências, 30, 165-168, 2000.

Razik, S., Chiessi, C. M., Romero, O. E., and von Dobeneck, T.: Interaction of the South American Monsoon System and the Southern Westerly Wind Belt during the last 14kyr, Palaeogeography, Palaeoclimatology, Palaeoecology, 374, 28-40, 10.1016/j.palaeo.2012.12.022, 2013.

Razik, S., Govin, A., Chiessi, C. M., and von Dobeneck, T.: Depositional provinces, dispersal, and origin of terrigenous sediments along the SE South American continental margin, Marine Geology, 363, 261-272, 10.1016/j.margeo.2015.03.001, 2015.

Reis, A. T., Silva, C. G., Gorini, M. A., Leão, R., Pinto, N., Perovano, R., Santos, M. V. M., Guerra, J. V., Jeck, I. K., and Tavares, A. A. A.: The Chuí Megaslide Complex: Regional-Scale Submarine Landslides on the Southern Brazilian Margin, in: Submarine Mass Movements and their Consequences, edited by: Lamarche, G., Mountjoy, J., Bull, S., Hubble, T., Krastel, S., Lane, E., Micallef, A., Moscardelli, L., Mueller, C., Pecher, I., and Woelz, S., Advances in Natural and Technological Hazards Research, 41, Springer, Cham, 115-123, 2016.

Riccomini, C., Grohmann, C. H., Sant'Anna, L. G., and Hiruma, S. T.: A captura das cabeceiras do Rio Tietê pelo Rio Paraíba do Sul, in: A Obra de Aziz Nacib Ab'Sáber, edited by: Modenesi-Gauttieri, M. C., Bartorelli, A., Mantesso-Neto, V., Carneiro, C. D. R., and Lisboa, M. B. A. L., BecaBALL (*In Portuguese*), São Paulo, 157-169, 2010.

Roig, H. L., Moraes Rego, A. P., Dantas, E. L., Meneses, P. R., Walde, D. H. G., and Goia, S. M. L. C.: Assinatura isotópica Sm-Nd de sedimentos em suspensão: implicações na caracterização da proveniência dos sedimentos do Rio Paraíba do Sul - SP, Revista Brasileira de Geociências, 35, 503-514, 2005.

685 Roy, M., van de Flierdt, T., Hemming, S. R., and Goldstein, S. L.: 40Ar/39Ar ages of hornblende grains and bulk Sm/Nd isotopes of circum-Antarctic glacio-marine sediments: Implications for sediment provenance in the southern ocean, Chemical Geology, 244, 507-519, 10.1016/j.chemgeo.2007.07.017, 2007.

Sato, K., Tassinari, C. C. G., Kawashita, K., and Petronilho, L.: A metodologia Sm–Nd no IGc-USP e suas aplicações, Anais da Academia Brasileira de Ciências, 67, 313-336, 1995.

690 Schattner, U., José Lobo, F., López-Quirós, A., Passos Nascimento, J. L., and Mahiques, M. M.: What feeds shelf-edge clinoforms over margins deprived of adjacent land sources? An example from southeastern Brazil, Basin Research, 32, 293-301, 10.1111/bre.12397, 2020.

Schmid, C., Siedler, G., and Zenk, W.: Dynamics of Intermediate Water Circulation in the Subtropical South Atlantic, Journal of Physical Oceanography, 30, 3191-3211, 10.1175/1520-0485(2000)030<3191:doiwci>2.0.co;2, 2000.

Schmid, C., and Garzoli, S. L.: New observations of the spreading and variability of the Antarctic Intermediate Water in the Atlantic, Journal 695 of Marine Research, 67, 815-843, 10.1357/002224009792006151, 2009.

Severov, D. N., Pshennikov, V., and Remeslo, A. V.: Fronts and thermohaline structure of the Brazil–Malvinas Confluence System, Advances in Space Research, 49, 1373-1387, 10.1016/j.asr.2012.01.024, 2012.

Signorini, S. R.: On the circulation and the volume transport of the Brazil Current between the Cape of São Tomé and Guanabara Bay, Deep Sea Research, 25, 481-490, 10.1016/0146-6291(78)90556-8, 1978.

700 Silveira, I. C. A., Foloni Neto, H., Costa, T. P., Schmidt, A. C. K., Pereira, A. F., Castro Filho, B. M., Soutelino, R. G., and Grossmann-Matheson, G. S.: Physical oceanography of Campos Basin continental slope and ocean region, in: Meteorology and Oceanography: regional environmental characterization of the Campos Basin, Southwest Atlantic. Habitats, edited by: Martins, R. P., and Grossman-Matheson, G. S., Elsevier, Rio de Janeiro, 135-190, 2017.

Soto, M., Morales, E., Veroslavsky, G., de Santa Ana, H., Ucha, N., and Rodríguez, P.: The continental margin of Uruguay: Crustal 705 architecture and segmentation, Marine and Petroleum Geology, 28, 1676-1689, 10.1016/j.marpetgeo.2011.07.001, 2011.

Spadone, A., and Provost, C.: Variations in the Malvinas Current volume transport since October 1992, Journal of Geophysical Research, 114, 10.1029/2008jc004882, 2009.

Steinmann, L., Baques, M., Wenau, S., Schwenk, T., Spiess, V., Piola, A. R., Bozzano, G., Violante, R., and Kasten, S.: Discovery of a giant cold-water coral mound province along the northern Argentine margin and its link to the regional Contourite Depositional System and 710 oceanographic setting, Marine Geology, 427, 106223, 10.1016/j.margeo.2020.106223, 2020.

Storlazzi, C. D., and Reid, J. A.: The influence of El Niño-Southern Oscillation (ENSO) cycles on wave-driven sea-floor sediment mobility along the central California continental margin, Continental Shelf Research, 30, 1582-1599, 10.1016/j.csr.2010.06.004, 2010.

Subha Anand, S., Rahaman, W., Lathika, N., Thamban, M., Patil, S., and Mohan, R.: Trace Elements and Sr, Nd Isotope Compositions of Surface Sediments in the Indian Ocean: An Evaluation of Sources and Processes for Sediment Transport and Dispersal, Geochemistry, 715 Geophysics, Geosystems, 20, 3090-3112, 10.1029/2019gc008332, 2019.

Sverdrup, H. U., Johnson, M. W., and Fleming, R. H.: The Oceans, Their Physics, Chemistry, and General Biology, Prentice-Hall, New York, 1065 pp., 1942.

Tarakanov, R. Y., and Morozov, E. G.: Flow of Antarctic Bottom Water at the output of the Vema Channel, Oceanology, 55, 153-161, 10.1134/s0001437015010166, 2015.

720 Teruggi, M. E.: El material volcánico-piroclástico en la sedimentación pampeana, Revista de la Asociación Geológica de Argentina, 9, 184-191, 1954.

Tomczak, M., and Godfrey, J. S.: CHAPTER 14 - The Atlantic Ocean, in: Regional Oceanography, Pergamon, Amsterdam, 253-278, 1994a.

Tomczak, M., and Godfrey, J. S.: CHAPTER 15 - Hydrology of the Atlantic Ocean, in: Regional Oceanography, Pergamon, Amsterdam, 279-296, 1994b.

725 Urien, C. M., and Ewing, M.: Recent Sediments and Environment of Southern Brazil, Uruguay, Buenos Aires, and Rio Negro Continental Shelf, in: The Geology of Continental Margins, edited by: Burk, C. A., and Drake, C. L., Springer Berlin Heidelberg, Berlin, Heidelberg, 157-177, 1974.

Urien, C. M., and Martins, L. R.: Sedimentación marina en América del Sur Oriental, Memorias del seminario sobre ecología bentónica y sedimentación de la plataforma continental del Atlántico Sur, Montevideo, 1979,

730 Urien, C. M., Martins, L. R., and Martins, I.: Modelos deposicionais na plataforma continental do Rio Grande do Sul (Brasil), Uruguai e Buenos Aires (Argentina), Notas Técnicas, 2, 13-25, 1980.

Violante, R. A., Paterlini, C. M., Costa, I. C., Hernandez-Molina, J., Segovia, L. M., Cavallotto, J. L., Marcolini, S., Bozzano, G., Laprida, C., García Chapori, N., Bickert, T., and Spieß, V.: Sismoestratigrafia y evolucion geomorfologica del talud continental adyacente al litoral del este bonaerense, Argentina, Latin American Journal of Sedimentology and Basin Analysis, 17, 33-62, 2010.

735 Violante, R. A., Paterlini, C. M., Marcolini, S. I., Costa, I. P., Cavallotto, J. L., Laprida, C., Dragani, W., Garcia Chapori, N., Watanabe, S., Totah, V., Rovere, E. I., and Osterrieth, M. L.: Argentine continental shelf: morphology, sediments, processes and evolution since the Last Glacial Maximum, Geological Society, London, Memoirs, 41, 55-68, 10.1144/m41.6, 2014.

Violante, R. A., Burone, L., Mahiques, M., and Cavallotto, J. L.: The Southwestern Atlantic Ocean: present and past marine sedimentation, Latin American Journal of Sedimentology and Basin Analysis, 24, 1-5, 2017a.

740   Violante, R. A., Cavallotto, J. L., Bozzano, G., and Spoltore, D. V.: Deep marine sedimentation in the Argentine continental margin: Revision and state-of-the-art, Latin American Journal of Sedimentology and Basin Analysis, 24, 7-29, 2017b.

Voigt, I., Henrich, R., Preu, B. M., Piola, A. R., Hanebuth, T. J. J., Schwenk, T., and Chiessi, C. M.: A submarine canyon as a climate archive — Interaction of the Antarctic Intermediate Water with the Mar del Plata Canyon (Southwest Atlantic), Marine Geology, 341, 46-57, 10.1016/j.margeo.2013.05.002, 2013.

745   Walling, D. E.: The evolution of sediment source fingerprinting investigations in fluvial systems, Journal of Soils and Sediments, 13, 1658-1675, 10.1007/s11368-013-0767-2, 2013.

Warratz, G., Schwenk, T., Voigt, I., Bozzano, G., Henrich, R., Violante, R., and Lantzsch, H.: Interaction of a deep-sea current with a blind submarine canyon (Mar del Plata Canyon, Argentina), Marine Geology, 417, 10.1016/j.margeo.2019.106002, 2019.

Weldeab, S., Emeis, K.-C., Hemleben, C., and Siebel, W.: Provenance of lithogenic surface sediments and pathways of riverine suspended
750   matter in the Eastern Mediterranean Sea: evidence from 143Nd/144Nd and 87Sr/86Sr ratios, Chemical Geology, 186, 139-149, 10.1016/s0009-2541(01)00415-6, 2002.

Zembruscki, S. G.: Geomorfologia da margem continental sul brasileira e das bacias oceânicas adjacentes, in: Geomorfologia da margem continental Brasileira e áreas oceânicas adjacentes, edited by: Chaves, H. A. F., REMAC, 7, Petrobrás (*In Portuguese*), Rio de Janeiro, 129-177, 1979.

755

Author contributions

Michel Michaelovitch de Mahiques: Conceptualization, Investigation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision

Paula Franco-Fraguas: Conceptualization, Investigation, Writing - Original Draft, Writing - Review & Editing,

Leticia Burone: Conceptualization, Investigation, Writing - Original Draft, Writing - Review & Editing,

Roberto Antonio Violante: Conceptualization, Investigation, Writing - Original Draft, Writing - Review & Editing,

Leonardo Ortega: Writing - Original Draft, Visualization, Writing - Review & Editing,

Cesar Barbedo Rocha: Investigation, Writing - Original Draft, Visualization, Writing - Review & Editing,

Rosangela Felicio dos Santos: Investigation, Writing - Original Draft, Writing - Review & Editing,

Bianca Sung Mi Kim: Investigation, Writing - Original Draft, Writing - Review & Editing,

Rubens Cesar Lopes Figueira: Supervision, Project Administration, Funding Acquisition, Writing - Original Draft, Writing - Review & Editing

Marcia Caruso Bícego: Supervision, Project Administration, Funding Acquisition, Writing - Original Draft, Writing - Review & Editing

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data availability

All of the data used are available as a Supplementary file