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Variability in terrigenous sediment supply offshore of the Rio de la Plata (Uruguay) recording the continental climatic history over the past 1200 years

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Abstract

The continental shelf adjacent to the Río de la Plata (RdlP) exhibits extremely complex hydrographic and ecological characteristics which are of great socio-economic importance. Since the long-term environmental variations related to the atmospheric (wind fields), hydrologic (freshwater plume), and oceanographic (currents and fronts) regimes are little known, the aim of this study is to reconstruct the changes in the terrigenous input into the inner continental shelf during the Late Holocene period (associated with the RdlP sediment discharge) and to unravel the climatic forcing mechanisms behind them. To achieve this, we retrieved a 10 m long sediment core from the RdlP mud depocenter at a depth of 57 *m* (GeoB 13813-4). The radiocarbon age control indicated an extremely high sedimentation rate of 0.8 cm per year, encompassing the past 1200 years (750–2000 AD). We used element ratios (Ti / Ca, Fe / Ca, Ti / Al, Fe / K) as regional proxies for the fluvial input signal, and the variations in relative abundance of salinity-indicative diatom groups (freshwater vs. marine-brackish) to assess the variability in terrigenous water and sediment discharge. Ti / Ca, Fe / Ca, Ti / Al, Fe / K and the freshwater diatom group showed the lowest values between 850 and 1300 AD, while the highest values occurred between 1300 and 1850 AD.

The variations in the sedimentary record can be attributed to such regional and global climatic episodes as the Medieval Climatic Anomaly (MCA) and the Little Ice Age (LIA), both of which had a significant impact on rainfall and wind patterns over the region. During the MCA, a northward migration of the Intertropical Confluence Zone (ITCZ) could explain the lowest element ratios (indicative of a lower terrigenous input) and a marine-dominated diatom record, both indicative of a reduced RdlP freshwater plume. In contrast during the LIA, the southward migration of the ITCZ accompanied by El Niño-like state conditions may have led to an expansion of RdlP river plume far to the north, as indicated by higher element ratios and a marked freshwater diatom signal. During the current warm period (i.e., after 1900 AD), the highest values in the element ratios and a pronounced marine to marine-brackish diatom record was found.

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This discordance between diatom record and sediment supply during the last century could be the consequence of an anthropogenic impact on the drainage basin and the RdlP system, expressed by the artificial increase in metal concentrations in the offshore sediments.

1 Introduction

The Río de la Plata (RdlP) estuary is fed by the Paraná and the Uruguay Rivers and drains into the Southwestern Atlantic Ocean (SWAO) forming the second largest estuary system in South America (Bisbal, 1995; Acha et al., 2003). The RdlP is the main source of continental freshwater and sediments entering the SWAO (Piola et al., 2008; Krastel et al., 2011, 2012; Razik et al., 2013; Lantzsch et al., 2014; Nagai et al., 2014). In this sense, the RdlP provides with an average annual suspended sediment load of 79.8×10^6 tons yr^{-1}. Most of this discharge is directed close to the Uruguayan coast towards the inner continental shelf (Depetris et al., 2003; Gilberto et al., 2004).

The RdlP is an extremely dynamic system which exhibits complex hydrodynamic features associated with the climatic pattern that affect the wind and oceanographic systems, as well as the river discharge (Piola et al., 2008). As a consequence, a natural intra-annual variability exists with a higher river discharge during the summer season, related to the southward displacement of the Intertropical Confluence Zone (ITCZ). Under these conditions, the northerly wind pattern leads to a southward and offshore displacement of the low-salinity RdlP freshwater plume (Guerrero et al., 1997; Möller et al., 2008; Piola et al., 2008). In contrast during the winter season, a northward displacement of the ITCZ leads to a lower RdlP discharge, but exists a predominant southerly wind pattern (associated with a northward displacement of the Westerlies). This situation forces a northward displacement of the RdlP plume and thus, considerably diminishes the salinity on the southern Brazilian continental shelf (Guerrero et al., 1997; Camilloni, 2005; Möller et al., 2008; Piola et al., 2008).

The regional climatic system also exhibits an inter-annual and inter-decadal variability, associated with environmental changes (expressed mainly in precipitation patterns) related to the El Niño/La Niña Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), respectively (Depetris and Kempe, 1990; Depetris et al., 2003; Depetris and Pasquini, 2007; Garreaud et al., 2009; Barreiro, 2010). PDO is associated with ENSO as both seem to produce similar climatic effects, though their mechanisms are not yet fully understood (Garreaud et al., 2009). In this sense, it has been suggested that during both the warm El Niño and the positive PDO phases, there is an increasing trend in precipitations over the RdlP drainage basin, which leads to a higher RdlP river discharge, while the opposite trend was observed for the negative phases (Ciotti et al., 1995; Depetris and Pasquini, 2007; Garreaud et al., 2009; Barreiro, 2010; García-Rodríguez et al., 2014).

Regarding the Late Holocene period, a significant number of studies has described the climatic history of South America over the last 1500 cal yr BP (calibrated thousands of years before present), i.e., for the Medieval Climatic Anomaly (MCA, 800–1300 AD) and the Little Ice Age (LIA, 1400–1800 AD), (Cioccale, 1999; Iriondo, 1999; Piovano et al., 2009; del Puerto et al., 2011, 2013; Vuille et al., 2012; Salvatecci et al., 2014). These climatic changes have affected the precipitation pattern over South America with regional differences. For eastern Uruguay, this means a warmer and more humid pulse during the MCA, while in the LIA, a drier and colder climate was recorded (del Puerto et al., 2013). Piovano et al. (2009) have inferred similar climatic conditions for the northeastern region of Argentina. In contrast, the opposite pattern was reported for southern Chile and Argentina, where a dry period occurred during the MCA, and a wetter pulse governed the LIA (Haberzettl et al., 2005).

Nevertheless, little is known about how the natural climatic variability over South America affects sedimentation, salinity and river discharge on the continental shelf in front of the RdlP, during the Late Holocene period (Burone et al., 2012; Perez et al., 2015). The aim of this study therefore, is to determine the variations in the terrigenous sediment input into the ocean over the last 1200 cal yr BP. To determine how the

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continental influence competed with the marine regime, a 10 m long sediment core was taken from a confined mud depocenter on the inner Uruguayan continental shelf (GeoB 13813-4, Fig. 1).

2 Study area

The study area is located on the Uruguayan inner continental shelf hosting the RdlP mud depocenter (50 m water depth, Fig. 1a and b). This silty clay depocenter (Martins and Urien, 2004; Lantzsch et al., 2014) is the result of regional paleogeographic evolution and is associated with deposits of fluvial origin (Urien and Ewing, 1974). The depocenter built up inside the RdlP paleo-valley which was incised by the Paleo-Paraná River during lower sea levels (Masello and Menafra, 1998; Martins et al., 2003; Lantzsch et al., 2014; Hanebuth et al., 2015). The RdlP paleo-valley depression offers an effective protection against the generally strong hydrodynamic conditions on the shelf, thus favoring the deposition and preservation of these muds (Fig. 1b).

3 Materials and methods

A 1028 cm long sediment core (GeoB 13813-4) was taken from the RdlP mud depocenter (34°44′13′′ S, 53°33′16′′ W) during research cruise M76/3a with the German research vessel "Meteor" in July 2009 (Krastel et al., 2012; Fig. 1a). During this expedition, sub-bottom profiling with the shipboard PARASOUND system (4 kHz) showed an elongated depression on the seafloor corresponding to the RdlP paleo-valley filled with a complex pattern of acoustic facies (Fig. 1b, Krastel et al., 2012; Lantzsch et al., 2014).

This succession was analyzed for major elements (Ca, Ti, Al, Fe, and K) and compared with data from the diatom salinity-indicative groups, i.e. freshwater (F) and marine, marine-brackish (M-B), (Perez et al., 2015).

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3.1 Age-depth model and sedimentation rates

Material from bivalve shells collected from six sediment samples, distributed evenly over the core and preserved in life position, were used for radiocarbon dating (^{14}C), (Table 1). The samples were analyzed using AMS-^{14}C (accelerated mass spectrometry) at the Poznan Radiocarbon Laboratory in Poland. The age depth model was then generated by using the free software Bacon (Blaauw and Christen, 2011, Fig. 2). The raw ^{14}C dates were calibrated using the calibration curve Marine13 (Reimer et al., 2013, cc = 2) integrated into this program.

Bacon software is an approach for developing an age-depth model that uses Bayesian statistics to reconstruct Bayesian accumulation histories for sedimentary deposits. Bacon divides a sediment core into vertical sections (5 cm thick), and estimates the sedimentation rate (years cm^{-1}) for each section through millions of Markov Chain Monte Carlo (MCMC) iterations.

3.2 Paleo-environmental proxies

The two methodological approaches combined in this study were chosen according to previous successful applications for inferring continental vs. marine influences in the Atlantic Ocean (Romero et al., 1999; Mahiques et al., 2009; Govin et al., 2012; Burone et al., 2013).

3.2.1 Runoff-indicative element ratios

The relative concentrations (expressed in counts per second, cps) of the major chemical elements used in this study (Ca, Ti, Fe, K, Al) were obtained by an X-ray fluorescent sediment core scanner AVAATECH at MARUM, University of Bremen. XRF scanning is a fast, non-destructive technique, which allows for the detection of a large number of chemical elements (Löwemark et al., 2011). Core GeoB 13813-4 was scanned in 1 cm steps throughout, and at every 2 mm in the depth interval 340 to 480 cm. This

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method was used to assess the variability in continental sediment input, as suggested by Francus et al. (2009).

The element ratios Ti/Al, Fe/K, Ti/Ca, Fe/Ca and Fe/K are the most common ratios used in paleoclimatic studies (Chiessi et al., 2007; Govin et al., 2012; Nace, 2012). Ti/Ca and Fe/Ca ratios have been highly and successfully used as proxies for reconstructing continental vs. marine influence within the region (Chiessi et al., 2009; Mahiques et al., 2009; Govin et al., 2012; Bender et al., 2013; Burone et al., 2013). Furthermore, The Fe/K and Ti/Al ratio was used in South America to infer the fluvial input of terrigenous material vs. the eolian input, and the eolian input vs. the fluvial, respectively (Garvin et al., 2012).

3.2.2 Salinity-indicative diatom groups

Samples for diatom analyses were first chemically treated (with the aim of cleaning the material from carbonates, organic matter and clay particles). The diatoms were then identified and counted at 10 cm depth intervals throughout the sediment core and in 1 cm steps within the uppermost 100 cm.

Diatom samples were first treated with $Na_2P_2O_7$ to deflocculate the sediment and eliminate clay particles. The samples were then treated with a 35 % HCl to remove inorganic carbonate material. Finally, the samples were boiled in 30 % H_2O_2 for two hours to eliminate organic matter (Metzeltin and García-Rodríguez, 2003). Between each treatment, samples were rinsed at least four times with distilled water. Permanent sediment slides were mounted using the Entellan® mounting medium. A minimum of 400 valves was counted on each slide with a light microscope at 1250 × magnification.

Diatom species were identified and separated into two groups according to their ecological salinity preference, i.e., in groups indicating freshwater (F) and marine/marine-brackish (M-B) conditions, according to Frenguelli (1941, 1945), Müller-Melchers (1945, 1953, 1959), Hasle and Syversten (1996), Witkowski et al. (2000), Metzeltin and García-Rodriguez (2003), Metzeltin et al. (2005), Hassan et al. (2010), Sar et al. (2010) and other standard diatom literature.

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Romero et al. (1999) determined variations in the continental water discharge by using freshwater diatoms (especially from the genus *Aulacoseira*) along a sediment surface transect from the eastern South Atlantic coast to the open ocean.

4 Results

4.1 Age-depth model and sedimentation rates

The core's base was dated to 1200 cal yr BP (750 AD), while a sample at 255 cm was dated to 230 cal yr BP (1700 AD, Table 1). The sedimentation rate varied between 0.68 and 1.0 cm yr^{-1}, with a mean sedimentation rate of 0.8 cm yr^{-1}. Minimum values were observed in the top section (i.e., at 200 to 350 cm) and in the bottom section (i.e., at 705 to 967 cm), while the highest values were observed in the middle of the core (at 500 to 705 cm).

4.2 Paleo-environmental proxies

4.2.1 Runoff-indicative element ratios

All the element ratios (Ti/Al, Fe/K, Ti/Ca and Fe/Ca) showed similar profiles (Fig. 3). The lowest values were recorded between 850–1300 AD (coinciding with the MCA), and remained stable during this interval of time. In contrast, high values occurred from 1300 to 1850 AD (associated with the LIA) and showed a high variability with a number of sharp maxima. In that sense, we recorded for Ti/Al and Fe/K ratios a cyclicity of peaks and low values every 100 years approximately (from 1300 to 1500 AD) and every 50 years (1500 AD up to the present), (Fig. 3). In addition, the interval 340 to 480 cm core depth (1483–1534 AD) was analyzed for Ti/Al and Fe/K ratios in high resolution 2 mm steps (Fig. 4). Besides the large parallelism of the two curves, there was a significant inter-decadal and inter-annual variability. Five Ti/Al and Fe/K major peaks at 470, 440, 390, 370 and 340 cm core depth (corresponding to 1373, 1407.

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1470, 1495, and 1534 AD) were registered (Fig. 4, red arrows). Moreover during the last century, all element ratios showed a rapid increase toward the highest measured values, most pronounced over the last 50 years (Fig. 3). A correlation between sediment grain (Krastel et al., 2012) and Ti/Al ratios (Fig. 4), with coarser sediment grain and highest ratios recorded in the top 500 cm (from 1300 AD up to the present), was also observed.

4.2.2 Salinity-indicative diatom groups

Regarding the salinity-indicative diatom groups, the profile of Group *F* seems to generally run parallel to those of the four element ratios with lower percentages around 20 % during the MCA times, and higher up to 60 %, rising and more variable values during the LIA period (Fig. 3). An exception is observed for the last 50 yr BP where the percentages declined rapidly towards the former values counted for the MCA time interval. In contrast, the Group M-B ranged from 30 to 80 % generally describing the expected opposite trend compared to the *F* group (Fig. 3). Over the last 100 yr BP (1900 AD up to the present), an increasing rapid trend coincides with the highest values shown for the element ratios (Fig. 3).

5 Interpretation and Discussion

5.1 Age-depth model and sedimentation rates

The RdlP mud depocenter shows an exceptionally high sedimentation rate (0.8 $cm\,yr^{-1}$ on average) compared with other records from the southern Brazilian continental shelf (Mahiques et al., 2009; Chiessi et al., 2014). This high sedimentation rate is probably a consequence of the enormous amount of sediment transported by the Paraná and Uruguay Rivers into the RdlP watershed and further onto the Uruguayan shelf (Lantzsch et al., 2014). In addition, an amplification of the sedimentation rate could be a consequence of the fact that the RdlP paleo-valley depression offers protection

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against strong hydrodynamic conditions on the shelf, favoring the deposition of sediments (Lantzsch et al., 2014; Hanebuth et al., 2015).

The Bayesian age-depth model calculation (Fig. 2) suggests that here have been significant changes in the sedimentation rate over the last 1200 yr BP (750–2000 AD). The maximum sedimentation rate, registered approximately between 1200 and 1400 AD, indicates a higher sedimentary supply and deposition during this period. This increased accumulation may be the result of less energetic hydrodynamic conditions between the MCA and the LIA.

5.2 Paleo-environmental proxy records

The proxy data used in this study are correlated positively with each other (except for the last century discussed below), and reveal the direct influence of the RdlP as a source of terrigenous sediments within the inner Uruguayan continental shelf.

The element ratios indicate, as do other geochemical and biological proxies (Perez et al., 2015), a mixed fluvio-marine signal on the inner Uruguayan continental shelf, spanning over the last 1200 years. This is possibly associated with the establishment of humidity conditions in the Late Holocene which have resulted in an increasing RdlP river discharge, as well as a significant sedimentation of terrigenous material over the RdlP paleo-valley (Urien et al., 1980; Iriondo, 1999; Mahiques et al., 2009; Lantzsch et al., 2014).

The results of the proxies integral analysis have been linked to general climatic changes that have occurred on a regional to global scale (Fig. 3), and allow us to infer three major time intervals, i.e., the MCA, the LIA and the current warm period (Mann et al., 2009), all of which were characterized by changing continental vs. marine influences in the study area.

The oldest recorded period, from 800 to 1300 AD, is closely associated with the MCA (reported as a positive temperature anomaly in the Northern Hemisphere, Bradley et al., 2008; Mann et al., 2009). During this period, a strong and steady influence of marine conditions governed the inner Uruguayan continental shelf (inferred by low values of Ti/Ca and Fe/Ca, and a dominance of the M-B diatom salinity group), probably as a result of a weakened RdlP water and terrigenous sediment discharge. This situation led to a major sedimentation of marine particulate carbon during the MCA (Perez et al., 2015). Ti and Fe are terrigenous elements which, in this case, come from the RdlP watershed, while Ca is an element associated with calcareous organisms such as forams and coccolithes in the ocean sediment, and therefore related to marine-biogenic productivity (Haug et al., 2001; Salazar et al., 2004; Depetris and Pasquini, 2007; Gonzalez-Mora and Sierro, 2007; Garvin et al., 2012; Razik et al., 2013). In addition, the low Fe/K values registered during the MCA would suggest conditions of reduced RdlP river discharge and dry conditions over the drainage basin (Moy et al., 2009).

Our findings, combined with those reported in other studies, suggest that a northward displacement of the ITCZ during the MCA associated with a weakened South American Monsoon System (SAMS) could have taken place during the MCA (Bird et al., 2011a, b; Vuille et al., 2012; Apaéstegui et al., 2014; Salvatecci et al., 2014). The latitudinal displacement of the ITCZ coincides with temperature anomalies in the Northern Hemisphere, where positive/negative temperature anomalies are linked to the north/south directional migration of the ITCZ (Broccoli et al., 2006; Bird et al., 2011b; Vuille et al., 2012). Such atmospheric conditions would have led to a significant decrease in rainfall over the RdlP watershed. As a consequence of this, there was a reduction in freshwater input in conjunction with an increase in salinity on the Uruguayan continental shelf.

The following period, from 1300 to 1850 AD, coincided with the LIA as reported for the Northern Hemisphere (Bradley et al., 2003; Mann et al., 2009). This period is characterized by higher values of Ti/Al, Fe/K, Ti/Ca and Fe/Ca than those recorded during the preceding period. Furthermore, a dominance of *F* diatoms (Fig. 3) was detected. The *F* diatom group was mainly dominated by *Aulacoseira* spp., especially *A. granulata* (Perez et al., 2015), which is the most common diatom genus from the Paraná River and the inner RdlP (Gomez and Bauer, 2002; Licursi et al., 2006; Devercelli et al., 2014). Moreover, Massaferro et al. (2014) observed that the *F* diatom group recorded

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in the uppermost 55 cm of the sediment core GeoB 13813-4 was associated with the positive anomalies of the Paraná River discharges. Thus, all the proxies indicate wetter conditions over the RdlP drainage basin, and consequently, a major freshwater supply from the RdlP to the inner Uruguayan shelf. Accordingly, we observed the highest rates of terrigenous deposition.

It is important to note that the Ti/Al ratio in this study seems reflect the grain size distribution, and not the eolian input of terrigenous material vs. the fluvial input. In this sense Govin et al. (2012) highlights Ti/Al sensitivity to the input of mafic material (such as in the case of the RdlP). Hence, we recorded higher sediment grain rich in Ti from the RdlP, which is associated with a higher river discharge during the LIA, (Fig. 4).

The LIA was characterized by a southward displacement of the ITCZ and a strengthening of SAMS, which led to both a reduction in rainfall rates over northern South America, Central America and Mexico (Haug et al., 2001; Vazques-Castro et al., 2008), and elevated rainfall rates in the Andes (Sifeddine et al., 2008; Bird et al., 2011a, b; Vuille et al., 2012; Apaéstegui et al., 2014; Salvatecci et al., 2014), and over SESA (Meyer and Wagner, 2009; Vuille et al., 2012). The intensification and northward displacement of the Southern Westerlies during the LIA was also registered (Moy et al., 2009; Koffman et al., 2014), which would have caused a northward shift of the RdlP river plume. Furthermore, the LIA was characterized by stronger El Niño events (associated to El Niño-like state conditions) compared with the MCA (associated with La Niña-like state conditions; Rein et al., 2004, 2005; Sifeddine et al., 2008; Mann et al., 2009; Bird et al., 2011b, Salvatteci et al., 2014). Positive precipitation anomalies in the RdlP drainage basin have been described for El Niño events (Grimm et al., 2003).

Such atmospheric conditions during the LIA would have led to a significant increase in rainfall over the RdlP watershed. Therefore, the outcome was a higher influence of the RdlP river plume within the inner Uruguayan continental shelf as recorded in this study. Furthermore, highly marked oscillations in the element ratios from 1300 AD up to the present were observed, most likely associated with strong El Niño conditions (Fig. 4, Rein et al., 2005).

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Finally, the latest period started around 1850 AD, and is characterized by a sharp global increase in temperature due to significant human impact (Crutzen, 2006; Halpern et al., 2008; Hoegh-Guldberg and Bruno, 2010; Mauelshagen, 2014). Our sediment record for the last century bears witness to a higher river discharge, whilst the diatom record shows a dominance of the M-B species, typical of marine-estuarine conditions. We make the assumption that such a unique incongruence, compared with a good positive correlation for the preceding time intervals, is a consequence of the regional anthropogenic impact (Bonachea et al., 2010). Human activity, including shipping and harbor industries, have probably increased the contamination of the environment with various heavy metals, such as Fe, Al, Pb, Ti, among others (Salazar et al., 2004; Bonachea et al., 2010; García-Rodríguez et al., 2010). In addition, the RdlP drainage basin itself has been modified through human activity (i.e., river damming, deforestation, agricultural modifications), which have changed the natural hydrological variability and conditions of remote sedimentation, i.e. by increasing the erosion rates and retaining diatom species and sediments in dams.

6 Conclusions

The observed changes in the presented proxy records indicate variations in both the continental runoff and the marine influence, related to regional climatic variability. Therefore, we put forward the suggestion that global atmospheric changes (mainly the latitudinal shifts of the ITCZ and the ENSO events) have made an impact on the hydrodynamics and consequently, on the local sedimentation regime, on the inner Uruguayan continental shelf over the past 1200 cal yr BP (750–2000 AD).

During the MCA (800–1300 AD) a northward shift of the ITCZ would have caused a decrease in the rainfall rate over the RdlP drainage basin, resulting in more estuarine-marine conditions predominating over a freshwater plume signal. During the LIA (1400–1800 AD) in contrast, a southward shift of the ITCZ would have led to an increased

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precipitation over the RdlP drainage basin, reflected by stronger terrigenous influences in terms of freshwater supply on the inner Uruguayan shelf.

It is important to note that the human industrial impact has modified heavy metal concentrations in the offshore sediments over the past century in such a drastic manner that proxies tracing the terrigenous lithic supply from element concentrations, can no longer be applied to the anthropogenic time period.

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References

Acha, E., Mianzan, H., Iribarne, O., Gagliardini, D., Lasta, C., and Daleo, P.: The role of the Río de la Plata bottom salinity front in accumulating debris, Mar. Pollut. Bull., 46, 197–202, 2003.

Apaéstegui, J., Cruz, F. W., Sifeddine, A., Vuille, M., Espinoza, J. C., Guyot, J. L., Khodri, M., Strikis, N., Santos, R. V., Cheng, H., Edwards, L., Carvalho, E., and Santini, W.: Hydroclimate variability of the northwestern Amazon Basin near the Andean foothills of Peru related to the South American Monsoon System during the last 1600 years, Clim. Past., 10, 1967–1981, 2014.

Barreiro, M.: Influence of ENSO and the South Atlantic Ocean on climate predictability over Southeastern South America, Clim. Dynam., 35, 1493–1508, doi:10.1007/S00382-009-0666-9, 2010.

Bender, V. B., Hanebuth, T. J. J., and Chiessi, C. M.: Holocene shifts of the subtropical shelf front off Southeastern South America controlled by high and low latitude atmospheric forcings, Paleoceanography, 28, 1–10, doi:10.1002/palo.20044, 2013.

Bird, B. W., Abbott, M. B., Rodbell, D. T., and Vuille, M.: Holocene tropical South American hydroclimate revealed from a decadally resolved lake sediment δ^{18}O record, Earth Planet. Sc. Lett., 310, 192–202, 2011a.
Bird, B. W., Abbott, M. B., Vuille, M., Rodbell, D. T., Stansella, N. D., and Rosenmeiera, M. F.: 2300-year-long annually resolved record of the South American summer monsoon from the Peruvian Andes, P. Natl. Acad. Sci. USA, 108, 8583–8588, 2011b.
Bisbal, G. A.: The southeast South American shelf large marine ecosystem: evolution and components, Mar. Policy, 19, 21–38, 1995.
Blaauw, M. and Christen, J. A.: Flexible paleoclimate age-depth models using an autoregressive gamma process, Bay. Anal., 6, 457–474, 2011.
Bonachea, J., Bruschi, V. M., Hurtado, M. A., Forte, L. M., da Silva, R., Etcheverry, M., Cavallotto, J. L., Dantas, M. F., Pejon, O. J., Zuquette, L. Z., Bezerra. M. A. O., Remondo, J., Rivas, V., Gómez-Arozamena, J., Fernández, G., and Cendrero, A.: Natural and human forcing in recent geomorphic change; case studies in the Rio de la Plata basin, Sci. Total Environ., 408, 2674–2695, doi:10.1016/J.SCITOTEN.V.2010.03.00, 2010.
Bradley, R. S., Hughes, M. K., and Diaz, H. F.: Climate in medieval time, Science, 302, 404–405, 2008.
Broccoli, A. J., Dahl, K. A., and Stouffer, R. J.: Response of the ITCZ to Northern Hemisphere cooling, Geophys. Res. Lett., 33, L01702, doi:10.1029/2005GL024546, 2006.
Burone, L., Centurión, V., Cibils, L., Franco-Fraguas, P., García-Rodríguez, F., García, G., and Pérez, L.: Sedimentología y paleoceanografía, in: Programa Oceanográfico de Caracterización del Margen Continental Uruguayo-ZEE, edited by: Burone, L., Montevideo, Uruguay, Facultad de Ciencias, 240–295, 2012.
Burone, L., Ortega, L., Franco-Fraguas, P., Mahiques, M., García-Rodríguez, F., Venturini, N., Marin, Y., Brugnoli, E., Nagai, R., Muniz, P., Bicego, M., Figueira, R., and Salaroli, A.: A multiproxy study between the Río de la Plata and the adjacent South-weastern Atlantic inner shelf to asses the sediment footprint of river vs. marine influence, Cont. Shelf Res., 55, 141–154, 2013.
Camilloni, I.: Variabilidad y tendencias hidrológicas en la cuenca del Plata, in: El Cambio Climático en el Río de la Plata, edited by: Barros, V., Menendez, A., and Nagy, G., CIMA, Buenos Aires, 20–31, 2005.

Chiessi, C. M., Mulitza, S., Patzold, J., Wefer, G., and Marengo, J. A.: Possible impact of the Atlantic Multidecadal Oscillation on the South American summer monsoon, Geophys. Res. Lett., 36, L21707, doi:10.1029/2009GL039914, 2009.

Chiessi, C. M., Mulitza, S. G., Jeroen, S. J. B., Campos, M. C., and Gurgel, M. H. C.: Variability of the Brazil current during the late holocene, Palaeogeogr. Palaeocl., 415, 28–36, doi:10.1016/j.palaeo.2013.12.005, 2014.

Cioccale, M.: Climatic conditions in the central region of Argentina in the last 1000 years, Quatern. Int., 62, 35–47, 1999.

Ciotti, A. M., Odebrecht, C., Fillmann, G., and Moller, O. O.: Freshwater outflow and subtropical convergence influence on phytoplankton biomass on the southern Brazilian continental shelf, Cont. Shelf Res., 15, 1737–1756, 1995.

Crutzen, P. J.: The "Anthropocene", in: Earth System Science in the Anthropocene, edited by: Ehlers, E. and Krafft, T., Springer, Berlin, Heidelberg, 13–18, doi:10.1007/3-540-26590-2_3, 2006.

del Puerto, L., García-Rodríguez, F., Bracco, R., Castiñeira, C., Blasi, A., Inda, H., Mazzeo, N., and Rodríguez, A.: Evolución climática holocénica para el sudeste de Uruguay, Analisis multi-proxy en testigos de lagunas costeras, in: El Holoceno en la zona costera de Uruguay, edited by: García-Rodríguez, F., Universidad de la Republica (UdelaR), Montevideo, Uruguay, 117–154, 2011.

del Puerto, L., Bracco, R., Inda, H., Gutierrez, O., Panario, D., and García-Rodríguez, F.: Assessing links between late Holocene climate change and paleolimnological development of Peñ a Lagoon using opal phytoliths, physical, and geochemical proxies, Quatern Int., 287, 89–100, doi:10.1016/j.quaint.2011.11.026, 2013.

Depetris, P. J. and Kempe, S.: The impact of the E1 Niño 1982 event on the Paraná River, its discharge and carbon transport, Palaeogeogr. Palaeocl., 89, 239–244, 1990.

Depetris, P. J. and Pasquini, A. I.: Discharge trends and flow dynamics of southern southamerican rivers draining the southern Atlantic seabord: an overview, J. Hydrol., 333, 385–399, 2007.

Depetris, P. J., Probst, J. L., Pasquini, A. I., and Gaiero, D. M.: The geochemical characteristics of the Paraná River suspended sediment load: an initial assessment, Hydrol. Process., 17, 1267–1277, doi:10.1002/hyp.1283, 2003.

CPD
11, 1343–1369, 2015

Devercelli, M., Zalocar de Domitrovic, Y., Forastier, M. E., and Meichtry de Zaburlín, N.: Phytoplankton of the Paraná River Basin, Advanc. Limnol., 65, 39–65, doi:10.1127/1612-166X/2014/0065-0033, 2014.

Francus, P., Lamb, H., Nakawaga, T., Marshall, M., and Brown, E.: The potential of high resolution X-ray fluorescense core scanning: aplications in paleolimnology, PAGES news, 17, 93–95, 2009.

Frenguelli, J.: Diatomeas del Río de la Plata, Revista Museo Nacional La Plata, 3, 213–334, 1941.

Frenguelli, J.: Diatomeas del Platense, Revista Museo Nacional La Plata, 3, 77–221, 1945.

FREPLATA: Análisis Diagnóstico Transfronterizo del Río de la Plata y su Frente Marítimo, Documento Técnico, Proyecto “Protección Ambiental del Río de la Plata y su Frente Marítimo: prevención y Control de la Contaminación y Restauración de Hábitats”, Proyecto PNUD/GEF/RLA/99/G31, Montevideo, Uruguay, 2004.

García-Rodríguez, F., Hutton, M., Brugnoli, E., Venturini, N., del Puerto, L., Inda, H., Bracco, R., Burone, L., and Muniz, P.: Assessing the effect of natural variability and human impacts on the environmental quality of a coastal metropolitan area (Montevideo Bay, Uruguay), PANAMJAS, 5, 90–99, 2010.

García-Rodríguez, F., Brugnoli, E., Muniz, P., Venturini, N., Burone, L., Hutton, M., Rodríguez, M., Pita, A., Kandratavicius, N., Perez, L., and Verocai, J.: Warm-phase ENSO events modulate the continental freshwater input and the trophic state of sediments in a large South American estuary, Mar. Freshwater Res., 65, 1–11, 2014.

Garreaud, R. D., Vuille, M., Compagnucci, R., and Marengo, J.: Present-day South American climate, Palaeogeogr. Palaeocl., 281, 180–195, 2009.

Giberto, D. A., Bremec, C. S., Acha, E. M., and Mianzan, H.: Large-scale spatial patterns of benthic assemblages in the SW Atlantic: the Río de la Plata, Estuar. Coast. Shelf S., 61, 1–13, 2004.

Gómez, N. and Bauer, D. E.: Diversidad fitoplanctónica en la franja costera Sur del Río de la Plata, Biol. Acuát., 19, 7–26, 2000.

González-Mora, B. and Sierro, F. J.: Caracterización geoquímica de las capas ricas en materia orgánica registradas durante el estadio isotópico marino 7 en el Mar de Alborán (Mediterráneo occidental), GEOGACETA, 43, 111–114, 2007.

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): im-

CPD
11, 1343–1369, 2015

print of terrigenous input and continental weathering, Geochem. Geophy. Geosy., 13, 1525–2027, 2012.
Grimm, A. M.: The el niño impact on the summer monsoon in Brazil: regional processes versus remote influences, J. Climate, 16, 263–280, 2003.
Guerrero, R., Acha, E., Framiñan, M., and Lasta, C.: Physical oceanography of the Rio de la Plata Estuary, Argentina, Cont. Shelf Res., 17, 727–742, 1997.
Haberzettl, T., Fey, M., Lucke, A., Maidana, N., Mayr, C., Ohlendorf, C., Schabitz, F., Schleser, G. H., Wille, M., and Zolitschka, B.: Climatically induced lake level changes during the last two millennia as reflected in sediments of Laguna Potrok Aike, southern Patagonia (Santa Cruz, Argentina), J. Paleolimnol., 33, 283–302, 2005.
Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H., Madin, E. M., Perry, M. T., Selig, E., Spalding, M., Steneck, R., and Watson, R.: A global map of human impact on marine ecosystems, Science, 319, 948–951, 2008.
Hanebuth, T. J. J., Lantzsch, H., García-Rodríguez, F., and Perez Becoña, L.: Currents controlling sedimentation: paleo-hydrodynamic variability inferred from the continental-shelf system off SE South America (Uruguay), in: Ciencias Marino Costeras en el Umbral del Siglo XXI: Desafíos en Latinoamérica y el Caribe (XV COLACMAR), edited by: Muniz, P., Conde, D., Venturini, N., and Brugnoli, E., in press, 2015.
Hasle, G. R. and Syvertsen, E. E.: Marine diatoms, in: Identifying Marine Phytoplankton, edited by: Tomas, C. R., Academic Press, San Diego, California, 5–361, 1996.
Hassan, G.: Paleoecological significance of diatoms in argentinean estuaries, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina, 2010.
Haug, G. H., Hughen, K. A., Sigman, D. M., Peterson, L. C., and Rohl, U.: Southward Migration of the Intertropical Convergence Zone Through the Holocene, Science, 293, 1304–1307, doi:10.1126/science.1059725, 2001.
Hoegh-Guldberg, O. and Bruno, J. F.: The Impact of Climate Change on the World′ s Marine Ecosystems, Science, 328, 1523–1528, doi:10.1126/science.1189930, 2010.
Iriondo, M.: Climatic changes in the South American plains: records of a continent-scale oscillation, Quatern. Int., 57/58, 93–112, 1999.
Koffman, B. G., Kreutz, K. J., Breton, D. J., Kane, E. J., Winski, D. A., Birkel, S. D., Kurbatov, A. V., and Handley, M. J.: Centennial-scale variability of the Southern Hemisphere west-

erly wind belt in the eastern Pacific over the past two millennia, Clim. Past, 10, 1125–1144, doi:10.5194/cp-10-1125-2014, 2014.

Krastel, S., Wefer, G., Hanebuth, T. J. J., Antobreh, A. A., Freudenthal, T., Preu, B., Schwenk, T., Strasser, M., Violante, R., and Winkelmann, D.: Sediment dynamics and geohazards off Uruguay and the de la Plata River region (northern Argentina and Uruguay), Geo-Mar. Lett., 31, 271–283, doi:10.1007/s00367-011-0232-4, 2011.

Krastel, S., Wefer, G., and cruise participants: Sediment transport off Uruguay and Argentina: from the shelf to the deep sea. 19.05.2009–06.07.2009, Montevideo (Uruguay) – Montevideo (Uruguay), Report and preliminary results of RV *METEOR* Cruise M78/3, Berichte, Fachbereich Geowissenschaften, Universität Bremen, 285, Bremen, Germany, 2012.

Lantzsch, H., Hanebuth, T. J. J., Chiessi, C. M., Schwenk, T., and Violante, R.: The high-supply, current-dominated continental margin of southeastern South America during the late Quaternary, Quaternary Res., 81, 339–354, 2014.

Licursi, M., Sierra, M. V., and Gómez, N.: Diatom assemblages from a turbid coastal plain estuary: Río de la Plata (South America), J. Marine Syst., 62, 33–45, 2006.

Löwemark, C., Chen, H., Yang, T.-N., Kylander, M., Yu, E.-F., Hsu, Y.-W., Lee, T.-Q., Song, S.-R., and Jarvis, S.: Normalizing XRF scanner data: a cautionary note on the interpretation of high-resolution records from organic-rich lakes, J. Assia Earth Sci., 40, 1250–1256, 2011.

Mahiques, M. M., Wainer, I. K. C., Burone, L., Nagai, R., Sousa, S. H. M., Lopes Figueira, R. C., da Silveira, I. C. A., Bicego, M. C., Alves, D. P. V., and Hammer, O.: A high-resolution Holocene record on the Southern Brazilian shelf: paleoenvironmental implications, Quatern. Int., 206, 52–61, 2009.

Mann, M. E., Zhang, Z., Rutherford, S., Bradley, R. S., Hughes, M., Shindell, D., Ammann, D., Faluvegi, G., and Ni, F.: Global signatures and dynamical origins of the little ice age and medieval climate anomaly, Science, 326, 1256–1259, 2009.

Martins, L. R., Martins, I. R., and Urien, C. M.: Aspectos sedimentares da plataforma continental na área de influencia de Rio de La Plata, Gravel, 1, 68–80, 2003.

Martins, L. R. and Urien, C. R.: Areias da plataforma e a erosao costeira, Gravel, 2, 4–24, 2004.

Masello, A. and Menafra, R.: Macrobenthic comunities of the Uruguayan coastal zona and adjacent areas, in: Río de la Plata una revisión ambiental, edited by: Wells, P. G. and Daborn, G. R., University of Dalhousie, Canada, 140–186, 1998.

CPD
11, 1343–1369, 2015

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L. Perez et al.

Massaferro, J., Perez, L., de Porras, M. E., Pérez Becoña, L., Tonello, M., and Juggins, S.: Paleoecological data analysis with R, course for Latin American researchers, Pages Magazine, Workshop reports, San Carlos de Bariloche, Argentina, 31 March–6 April, 105, 2014.

Mauelshagen, F.: Redefining historical climatology in the Anthropocene, The Anthropocene Review, 1, 171–204, doi:10.1177/2053019614536145, 2014.

Metzeltin, D. and García-Rodríguez, F. (Eds): Las Diatomeas Uruguayas, Facultad de Ciencias, Montevideo, Uruguay, 2003.

Metzeltin, D., Lange-Bertalot, H., and García-Rodríguez, F.: Diatoms of Uruguay – taxonomy, Biogeography, Diversity, in: Iconographia Diatomologica (15), edited by: Lange-Bertalot, H., and Gantner Verlag, A. R. G., Koenigstein, Germany, 736 pp., 2005.

Meyer, I. and Wagner, I.: The Little Ice Age in Southern South America: proxy and model based evidence, in: Past Climate Variability in South America and Surrounding Regions, from the Last Glacial Maximum to the Holocene, edited by: Vimeux, F., Sylvestre, F., and Khodri, M., Springer, 395–412, Netherlands, 2009.

Möller Jr., O. O., Piola, A. R., Freitas, A. C., and Campos, E.: The effects of river discharge and seasonal winds on the shelf off southeastern South America, Cont. Shelf Res., 28, 1603–1624, 2008.

Moy, C. M., Moreno, P. I., Dunbar, R. B., Kaplan, M. R., Francois, J.-P., Villalba, R., and Haberzettl, T.: Climate change in Southern South America during the last two millennia, in: Past Climate Variability in South America and Surrounding Regions, edited by: Vimeux, F., Sylvestre, F., and Khodri, M., Developments in Paleo, Environ. Res., 14, 353–393, 2009.

Müller-Melchers, P.: Diatomeas procedentes de algunas muestras de turba del Uruguay, Comunicaciones Botánicas del Museo de Historia Natural de Montevideo, 1, 1–25, 1945.

Müller-Melchers, P.: Sobre algunas diatomeas planctónicas de Atlántida (Uruguay), Physis, 20, 459–466, 1953.

Müller-Melchers, P.: Plankton diatoms of the Southern Atlantic of Argentina and Uruguay coast, Comunicaciones Botánicas del Museo de Historia Natural de Montevideo, 3, 1–53, 1959.

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

Perez, L., García-Rodríguez, F., and Hanebuth, T.: Paleosalinity changes in the Río de la Plata estuary and on the adjacent Uruguayan continental shelf over the past 1200 cal ka BP: an

CPD
11, 1343–1369, 2015

approach using diatoms as proxy, in: Applications of Paleoenvironmental Techniques in Estuarine Studies, Developments in Paleo, Environ. Res., edited by: Weckström, K., Saunders, P., and Skilbeck, G., Springer, in press, 2015.

Piola, A. R., Moller, 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, Cont. Shelf Res., 28, 1639–1648, doi:10.1016/j.csr.2008.03.013, 2008.

Piovano, E. L., Ariztegui, D., Cordoba, F., Cioccale, J., and Sylvestre, F.: Hydrological variability in South America below the tropic of Capricorn (Pampas and Patagonia, Argentina) during the Last 13.0 Ka, in: Past Climate Variability in South America and Surrounding Regions, from the Last Glacial Maximum to the Holocene, edited by: Vimeux, F., Sylvestre, F., and Khodri, M., Springer, 323–352, Netherlands, 2009.

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 14 kyr, Palaeogeogr. Palaeocl., 374, 28–40, 2013.

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Buck, C. E., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T. J., Hoffmann, D. L., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., Manning, S. W., Niu, M., Reimer, R. W., Richards, D. A., Scott, M. E., Southon, J. R., Turney, C. S. M., and van der Plicht, J.: IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 yrcalBP, Radiocarbon, 55, 1869–1887, 2013.

Rein, B., Luckage, A., and Frank, S.: A major holocene ENSO anomaly during the medieval period, Geophys. Res. Lett., 31, L17211, doi:10.1029/2004GL020161, 2004.

Rein, B., Luckge, A., Reinhardt, L., Sirocko, F., Wolf, A., and Dullo, W.-C.: El Niño variability off Peru during the last 20,000 years, Paleoceanography, 20, PA400, doi:10.1029/2004PA001099, 2005.

Romero, O. E., Lange, C. B., Fischer, G., Treppke, U. F., and Wefer, G.: Variability in export production documented by downward fluxes and species composition of marine panctonic diatoms: observations from the tropical and ecuatorial Atlantic, in: Use of proxies in paleoceanography: Examples from the South Atlantic, edited by: Fischer, G., and Wefer, G., Universitat Bremen, Springer, Germany, 365–392, 1999.

Salazar, A., Lizano, O. G., and Alfaro, E. J.: Composición de sedimentos en las zonas costeras de Costa Rica utilizando Fluorescencia de Rayos-X (FRX), Rev. biol. Trop., 52, 61–75, 2004.

Salvatteci, R., Gutiérrez, D., Field, D., Sifeddine, A., Ortlieb, L., Bouloubassi, I., Boussafir, M., Boucher, H., and Cetin, F.: The response of the Peruvian Upwelling Ecosystem to centennial-scale global change during the last two millennia, Clim. Past, 10, 715–731, doi:10.5194/cp-10-715-2014, 2014.

Sar, E. A., Sunesen, I., and Lavigne, A. S.: Cymatotheca, Tryblioptychus, Skeletonema and Cyclotella (Thalassiosirales) from Argentinian coastal waters, Description of Cyclotella cubiculata sp. nov., Vie milieu, 60, 135–156, 2010.

Siffedine, A., Gutiérrez, D., Ortlieb, L., Boucher, H., Velazco, F., Field, D., Vargas, G., Boussafire, M., Salvatteci, R., Ferreira, V., García, M., Valdés, J., Caquineau, S., Mandeng Yogo, M., Cetin, F., Solis, J., Soler, P., and Baumgartner, T.: Laminated sediments from the central Peruvian continental slope: a 500 year record of upwelling system productivity, terrestrial runoff and redox conditions, Prog. Oceanogr., 79, 190–197, 2008.

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, New York, 157–177, 1974.

Urien, C. M., Martins, L. R., and Martins, I. R.: Evolução geológica do Quaternário do litoral atlântico uruguaio, plataforma continental e regiões vizinhas, Notas Técnicas, CECO/URFGS, 3, 7–43, 1980.

Vázquez-Castro, G., Ortega-Guerrero, B., Rodríguez, A., Caballero, M., and Lozano-García, S.: Mineralogí a magnética como indicador de sequía en los sedimentos lacustres de los últimos ca. 2600 años de Santa María del Oro, occidente de México, Rev. Mex. Cienc. Geol., 25, 21–38, 2008.

Vuille, M., Burns, S. J., Taylor, B. L., Cruz, F. W., Bird, B. W., Abbott, M. B., Kanner, L. C., Cheng, H., and Novello, V. F.: A review of the South American monsoon history as recorded in stable isotopic proxies over the past two millennia, Clim. Past., 8, 1309–1321, doi:10.5194/cp-8-1309-2012, 2012.

Witkowski, A., Lange-Bertalot, H., and Metzeltin, D.: Diatom flora of marine coasts 1, in: Iconographia Diatomologica, edited by: Lange-Bertalot, H., A.R.G. Gantner Verlag, 7, 925 pp., 2000.

CPD
11, 1343–1369, 2015

Table 1. Radiocarbon dates as obtained from the Bacon modeling.

Lab # (Poz-)	Depth in core (cm)	Raw ^{14}C age (yr BP)	Bacon weighted average age (cal yr BP)	Bacon weighted average age (cal yr AD)	Sedimentation rate ($cm\,yr^{-1}$)
35198	255	640 ± 30	230	1688	0.72
47935	305	775 ± 35	371	1494	0.68
42428	447	1000 ± 40	552	1293	0.78
35199	560	1090 ± 30	665	1167	1.00
47937	705	1220 ± 40	830	994	0.88
42429	964	1600 ± 30	1197	753	0.70

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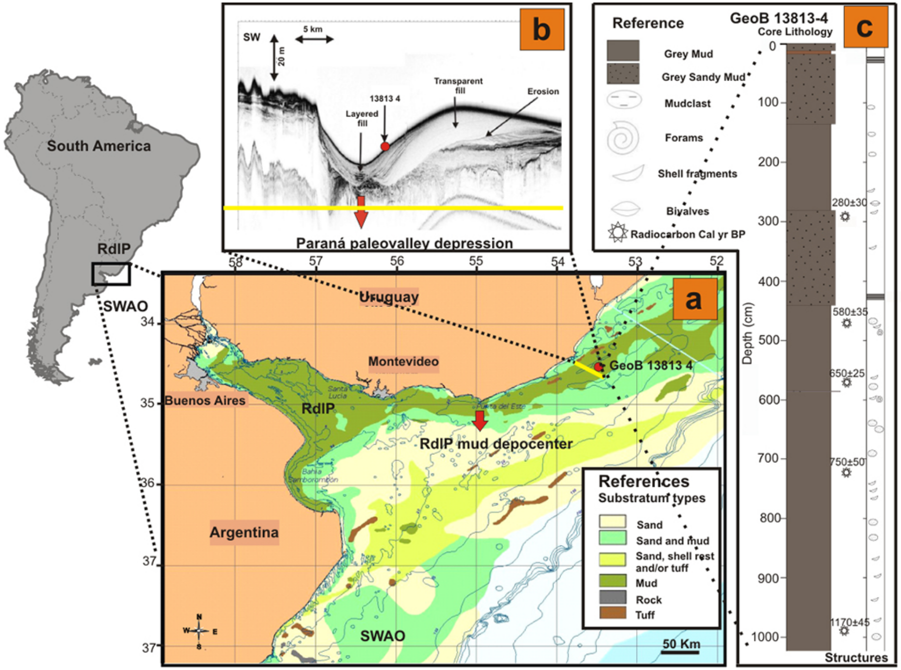

Figure 1. (a) Study area: the red circle indicates the location of Core GeoB 13813-4 retrieved from the inner-shelf mud depocenter off the Uruguayan coast (modified from FREPLATA, 2004). **(b)** Rio de la Plata (RdlP) mud depocenter PARASOUND sub-bottom profile), which represents the RdlP paleo-valley and its sedimentary multi-story filling succession. **(c)** GeoB 13813-4 core lithology. (**b** and **c** modified from Krastel et al., 2012 and Lantzsch et al., 2014.)

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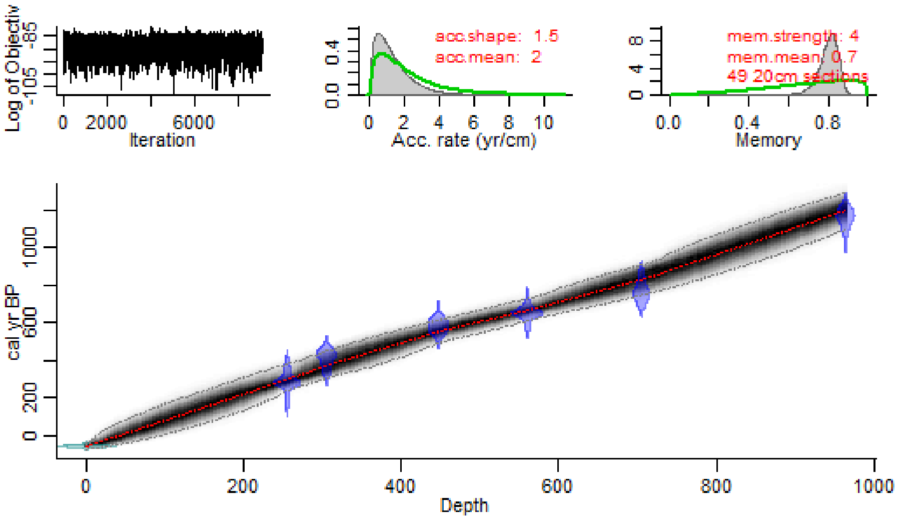

Figure 2. The age-depth model for core GeoB 13813-4 using the program Bacon. Upper panels depict the Markov Chain Monte Carlo (MCMC) iterations (left), the prior (green curves) and posterior (grey histograms) distributions for the sedimentation rate (middle panel) and memory (right panel). The bottom panel shows the calibrated ^{14}C dates (transparent blue), extraction year of the core (−59 yr BP, 2009 AD, transparent blue light) and the age-depth model (grey stippled lines indicate the 95 % confidence intervals; the red curve shows the "best" fit based on the weighted mean age for each depth).

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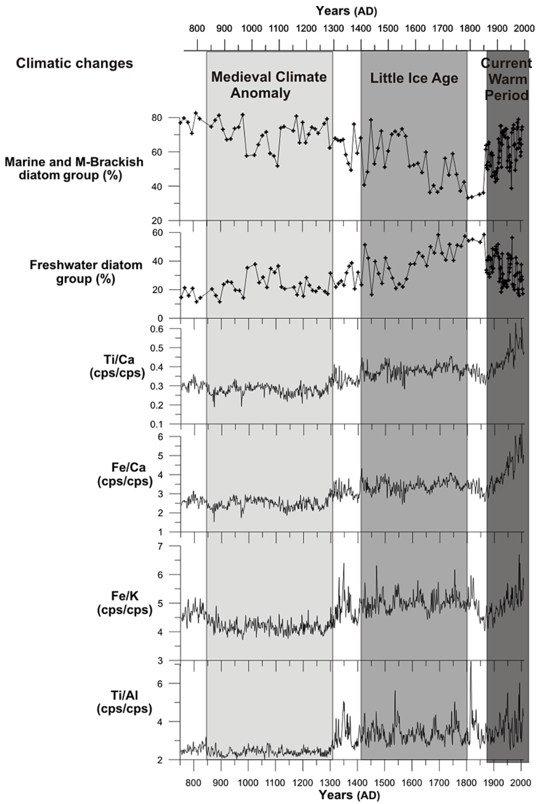

Figure 3. Centennial variation of Ti/Al, Fe/K, Ti/Ca, Fe/Ca ratios, and the freshwater and marine, marine-brackish salinity-indicative diatom groups from the sediment core GeoB 13813-4 (from bottom to top, respectively), during the last 1200 yr BP (750–2000 cal yr AD). The major climatic changes during this period of time were the Medieval Climatic Anomaly and the Little Ice Age.

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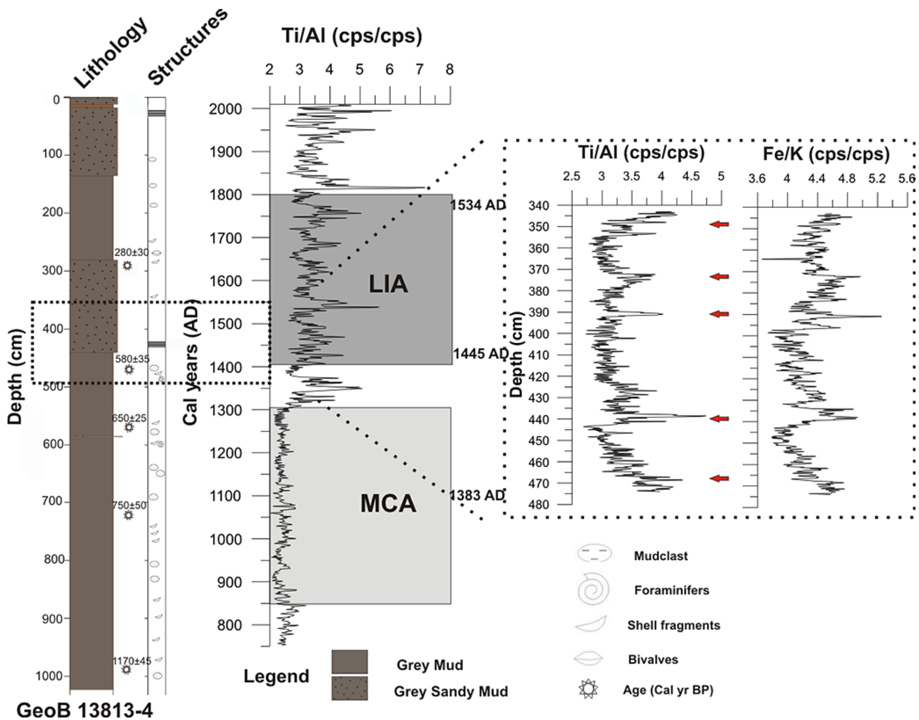

Figure 4. Lithology of Core GeoB 13813-4 and the variations within the Ti/Al ratios throughout all the sediment core every 1 cm (left) and the variations within the Ti/Al and Fe/K ratios from 340 to 470 cm every 2 mm (right).

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