Clim. Past Discuss., 9, C3550–C3569, 2014
www.clim-past-discuss.net/9/C3550/2014/

Climate of the Past Discussions
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Interactive comment on “Terrigenous input off northern South America driven by changes in Amazonian climate and the North Brazil Current retroflection during the last 250 ka” *by* A. Govin et al.

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Received and published: 28 February 2014

Comments from Reviewer 1 (P. Baker)

We thank Paul Baker for his constructive review. His comments are in plain text. Our reply is in italic. Text modifications in the manuscript are in blue.

General comments
Using a three-core, south-to-north transect of marine sediments as their archive and

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a detailed analysis of XRF-derived elemental chemistry as their proxy, Govin et al. undertake an orbitally resolved ca. 250 kyr reconstruction of Andes/Amazon and Amazon/Orinoco sedimentary provenance. Theirs is an innovative approach, thoughtfully and carefully undertaken. How well they succeed is a matter of debate. So too is their climatic and oceanographic interpretation of the reconstruction. In any case, the paper is a creative and useful approach that should help to refine the paleoclimate history of tropical South America (TSA).
Thank you.

The only archives of TSA paleoclimate that extend significantly beyond the last glacial are the lacustrine sedimentary record of Lake Titicaca (LT), the pollen records of Sabana de Bogota, and a few speleothem records from the western Amazon/tropical Andes. Baker et al (2001) contended from LT piston core records that both orbital (austral summer insolation) and millennial (north-south Atlantic SST gradient) forcing controlled precipitation variation in the south tropical Andes. LT drill core records (Fritz et al. 2007 and 2010) supported both inferences and extended the record back to nearly 400 Ka. The same inferences have also been largely supported by many well dated and wonderful speleothem records that followed. The LT drill core record also showed that the largest change in water balance (i.e. lake level) occurred on glacial-interglacial (ca. 100 kyr) timescales, thus demonstrating the likely role of global temperature in controlling local water balance.

Offshore, the marine sediment record (von Arz et al., 1998) was paramount in demonstrating the one-to-one correlation between Heinrich events and increased terrigenous input (likely due to increased precipitation) in the northeastern region of Brazil. Combined with LT, the clear implication is that millennial North Atlantic cold events brought about increased precipitation across the entire southern tropics of SA. Cruz et al (2009) on the basis of speleothem records from northeastern Brazil posited that precipitation in the eastern and western tropics of SA was anti-phased on precessional timescales. This was a fundamental and surprising observation and is clearly relevant to the in-

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terpretation of relative Andes vs. Amazon sediment provenance on orbital timescales. Four of these five foundational references were not cited in the original version of the present article. Innovative approaches to science often cause us to forget foundational approaches and papers (for sure, I am equally guilty of this). Speleologists often overlook prior work on lacustrine sediments and very often early papers on geomorphology or pollen are overlooked by those who follow.

We thank the Reviewer for making us aware of these initial studies that we overlooked in the original manuscript. Accordingly, we made several modifications in the text (i.e. Introduction, Discussion, Conclusions) in order to accommodate these relevant aspects.

1. We significantly modified the Introduction and added an extensive paragraph that summarizes the main findings from lacustrine sediment studies (and includes missing references).

Page 3, lines 3-13: "Few lake sediment records go beyond the last glacial period, when dating uncertainties are high (e.g. van der Hammen and Hooghiemstra, 2003; Ledru et al., 2009). Lacustrine sediments from Lake Titicaca (Baker et al., 2001b) and the Salar de Uyuni (Baker et al., 2001a) in the Bolivian Altiplano indicate wet conditions in the south tropical Andes during glacial intervals of high austral summer insolation of the last 50 ka. Over the last 370 ka, Lake Titicaca sediments reveal the largest changes in tropical Andean climate on glacial-interglacial time scales, with warm and dry (cold and wet) conditions during peak interglacial (glacial) periods, which suggest the effect of global temperature changes on regional water balance (Fritz et al., 2007; Hanselman et al., 2011). This site also documents millennial-scale events during the last glacial period, with wet conditions occurring during cold Greenland stadials (Baker et al., 2001a; Fritz et al., 2010)."

2. In the Introduction we also modified the presentation of speleothem records. We highlight in our formulation that high-resolution and well-dated speleothem records confirm original findings from lake sediments. We also mention the east-west rain-

fall antiphase documented by Cruz et al. 2009 over the last 25 ka (see our reply to the 1st specific comment below for discussion on the influence of this antiphase on our records).
Page 3, lines 13-29: "Such orbital and millennial-scale changes in South American tropical climate are supported by recent high-resolution and well-dated speleothem records. Few speleothem records documenting South American tropical climate on orbital time scales indicate strong precessional variations with increased rainfall during intervals of high austral summer insolation (Cruz et al., 2005; Cheng et al., 2013). NE Brazilian speleothems suggest an east-west antiphase in precipitation over the last 25 ka, with humid conditions prevailing over NE Brazil and dry conditions over other South American tropical regions during the mid-Holocene period of low austral summer insolation (Cruz et al., 2009; Prado et al., 2013a; Prado et al., 2013b). Finally, a growing number of speleothems document positive precipitation anomalies over most of Brazil and the Amazon Basin during Heinrich stadials due to increased moisture advection and southward migration of the Intertropical Convergence Zone (ITCZ) induced by strong North Atlantic cooling (Wang et al., 2004; Kanner et al., 2012; Mosblech et al., 2012). Because factors other than rainfall intensity (e.g. source of moisture) can influence the oxygen isotopic composition (δ18O) of speleothems, the interpretation of these records in terms of past South American tropical precipitation changes is, however, not straightforward (e.g. Cruz et al., 2005; Mosblech et al., 2012)."

3. We also modified the Discussion section 5.3 (formerly 5.2) and the Conclusions.
- We added missing references on lake sediment studies in page 17, lines 11-15: "Lake sediments from the Bolivian Andes, which show alternating wet and dry phases over the last 370 ka, with wet phases occurring during periods of high austral summer insolation (Baker et al., 2001a; Baker et al., 2001b; Fritz et al., 2007; Gosling et al., 2008; Hanselman et al., 2011) further support our assumption."
- We added the reference to Bolivian Altiplano lake sediment studies in page 18, lines 27-33: "Large Andean precipitation changes indicated by Bolivian Altiplano lake sedi-

ments (Baker et al., 2001a; Baker et al., 2001b; Fritz et al., 2007; Gosling et al., 2008; Hanselman et al., 2011) and western Amazonian speleothems (Figure 8) (Mosblech et al., 2012; Cheng et al., 2013), as well as altitudinal shifts in the Andean forest belt (Colinvaux et al., 1997; Wille et al., 2001) suggest large past variations in sediment delivery by Andean tributaries (where most of modern terrigenous material originates, e.g. Meade et al., 1985; Guyot et al., 2007)."

- We added missing references to lake sediment studies in page 19, lines 7-8: "lake sediments (Baker et al., 2001a; Baker et al., 2001b; Fritz et al., 2007; Gosling et al., 2008; Hanselman et al., 2011)"
- We added the mention of Bolivian Altiplano lake sediment studies in the Conclusions on page 23, lines 8-9: "Observations from Bolivian Altiplano lake sediments and western Amazonian speleothems fully support our hypothesis."

Likewise it seems that seductive technological advances, such as scanning XRF, cause us to neglect more classical, tedious, yet powerful approaches. In the present case, mineralogical analysis by heavy mineral separation or powder X-ray diffractometry could have greatly advanced any conclusions regarding sediment provenance and paleoclimate based solely upon the bulk chemistry. Perhaps the authors will undertake such studies in the future to bolster their claims and to demonstrate the correlation between cation chemistry and mineralogy.

Our study is based on elemental intensities obtained from the relatively new XRF core scanning that we combined to major element concentrations measured on bulk sediment samples by EDP-XRF (a more classical method) in order to derive calibrated proportions of six major elements. It is of course always possible to add more measurements from complementary methods. However, every study requires finding the best balance between costs (e.g. measurements) and benefits (e.g. outcomes). We think we found the best one in our study from the analyses we performed, from the comparison of obtained results to the modern mineralogical compositions of Orinoco and Amazon sediments and to the modern depositional environment in western equatorial

Atlantic, as well as from the careful discussion of processes and hypotheses that could influence or drive our results. In particular, the link between elemental composition and mineralogy has already been discussed in many studies investigating e.g. Amazon suspended sediments (Bouchez et al., 2011), Atlantic surface sediments (Govin et al., 2012), South American paleoclimate (e.g. Yarincik et al., 2000; Chiessi et al., 2010; Siani et al., 2010) or African paleoclimate (e.g. Zabel et al., 2001; Mulitza et al., 2008; Zhao et al., 2012; Collins et al., 2013). We explain this link and cite most of these references at the beginning of section 3.5 (i.e. Endmember unmixing analysis). Therefore, we think that heavy mineral separation (usually applied to the sand fraction, hence very complicated in our fine-grained sediments) and powder X-ray diffractometry, as proposed by the Reviewer, would push our manuscript beyond the best cost vs. benefit balance, bringing few benefits to our study. It is worthy of note that performing these analyses in our four cores would generate large amounts of data that would require a separate manuscript to be appropriately discussed.

Specific comments

In every core analyzed, the variations that they reconstruct in end-member proportions (e.g., %Andes, %Amazon, %Orinoco, %marine; see Figure 5) are surprisingly small. Values of %Andes in their time series from 5N and 9N are always ca. 70+/-5%. If the Cruz et al (2009) antiphasing is present throughout the entire record, then I would expect that Andes/Amazon ratios should also change strongly with precessional pacing. However, the only proportion that changes more than a few percent is the marine sediment end member; this has much higher values during periods of high sea level, which also tend to be periods of much lower sedimentation rate (Figure 3). In fact, combining the variations of total sedimentation rates (Fig. 3) and %marine (Fig. 5), there appears to be about a 7X increase of Amazon-derived sediment flux during glacial versus interglacial periods in both cores. Why the variations of %Andes are so small despite the large change of Amazon sediment flux, is a big conundrum.

We agree with the Reviewer that the amplitude of %-Andes changes is relatively small *at 5° N and 9° N: values range between 62 and 80 % (72 % on average) at 5° N and between 68 and 85 % (77 % on average) at 9° N (Figure 6). However, we do not think that this result is "a big conundrum" for several reasons, as described below.*

(1) Relatively small %-Andes variations reflect the stability of the Amazon sedimentary system, where the amount of suspended sediments is an important criteria to classify Amazon tributaries into the three traditional categories (white, clear or black waters, Meade, 1994). The small amplitude of %-Andes variations is hence in line with the large modern dominance of terrigenous material (> 90 %) delivered by Andean tributaries (vs. lowland tributaries) at the Amazon mouth (Meade et al., 1985; Guyot et al., 2007). High precipitation, steep topographic gradient and lithology are responsible for intensive physical erosion in the Andes and the very large amounts of sediments delivered by Andean tributaries to the Amazon (Masek et al., 1994; Aalto et al., 2006). Therefore, steep topography and intense erosion make Andean tributaries the main source of Amazon suspended material over the last 250 ka, whereas past Amazonian precipitation changes are likely responsible for the relatively small amplitude of observed %-Andes variations. Storage of suspended sediments in Amazonian floodplains (Meade et al., 1985) could also minimize the amplitude of changes in suspended load driven by precipitation variations.

(2) We agree with the Reviewer that changes in marine vs. terrigenous material (ranging between 7 and 65 % at 5° N and between 1 and 30% at 9° N, Fig. 6) exhibit a larger amplitude than %-Andes records. However, this observation is not in contradiction with the preceding result (i.e. stable Amazon sedimentary sources). Large input of Amazon terrigenous material during glacial intervals is a robust feature of western tropical Atlantic sedimentation (e.g. Milliman et al., 1975; Mikkelsen et al., 1997; Maslin et al., 2006) and is driven by global sea level changes (see also our reply to Reviewer 1's penultimate comment below and the new section 5.1 in the Discussion). Sea-level changes have limited effect on the provenance (i.e. Andean vs. lowland) of Amazon sediments (see discussion in section 5.2, formerly 5.1), hence on our %-Andes records.

Therefore, large terrigenous vs. marine biogenic changes driven by sea level changes do not contradict and are independent from the relatively small amplitude of %-Andes changes which reflect relatively stable Amazon sedimentary sources over time.

(3) We disagree with the Reviewer that the east-west antiphase highlighted by Cruz et al. (2009) will strongly affect our records. Cruz et al. (2009) document humid conditions in NE Brazil and dry conditions in other southern tropical regions of South America during periods of low austral summer insolation (e.g. during the mid-Holocene). This antiphase derives from interactions between the Walker and Hadley atmospheric circulations that govern modern large-scale subsidence and aridity in NE Brazil and intense convection and precipitation in other tropical South American regions during austral summer. However, most of the Amazon Basin is placed to the west of the area influenced by the tropical South American east-west precipitation dipole (Cruz et al., 2009; Prado et al., 2013a; Prado et al., 2013b). Only the easternmost tributaries (Tapajós and Xingu Rivers) may be slightly influenced by contrasting eastern rainfall patterns. However, because these tributaries supply very little sediment material to the Amazon River (Meade et al., 1985; Guyot et al., 2007), east-west antiphasing rainfall changes will have negligible influence on our %-Andes records.

To clarify these points, we made the following modifications to the text.
1. We completed the comparison on %-Andes values to the modern mineralogical composition of Amazon sediments in the Discussion section 5.2 (formerly 5.1).
From page 13, line 22 to page 14, line 8: “Nevertheless, although slightly too low, such high proportions of Andean material in marine sediments reflect the large delivery (> 90 %) of suspended sediments by Andean tributaries within the Amazon Basin (Meade et al., 1985; Guyot et al., 2007). The endmember unmixing approach hence produces %-Andes values that agree with the modern provenance of Amazon terrigenous sediments. High precipitation, steep topography and lithology are responsible for intense erosion in the Andes and very large amounts of sediments delivered by Andean tributaries to the Amazon under modern times (Masek et al., 1994; Aalto et al., 2006).

The amount of transported suspended sediments is an important criteria used to classify Amazon tributaries into the three traditional categories (Sioli, 1984; Meade, 1994): white waters (very high suspended load, e.g. Madeira, Solimões Rivers), clear waters (relatively low suspended load, e.g. Tapajós River) and black waters (very low suspended load, e.g. Negro River). The small amplitude of %-Andes variations recorded at 5°N and 9°N (± 10 % around averaged values, Figure 6) hence reflects the stability of this Amazon sedimentary system over the last 250 ka. Due to steep topography and intense erosion in the Andes, Andean tributaries remained the main source of Amazon sediments over the last 250 ka, while past Amazonian precipitation changes are likely responsible for the small amplitude of %-Andes variations (see section 5.3). Storage of suspended sediments in Amazonian floodplains (Meade et al., 1985) could also minimize the amplitude of suspended load variations driven by precipitation changes."

2. Processes controlling the relative proportions in terrigenous vs. marine biogenic components are now specifically discussed in the new section 5.1 (entitled "Factors controlling terrigenous vs. marine biogenic proportions"). Please see our reply to the penultimate comment of Reviewer 1 for details.

3. We discuss the effect of east-west contrasting rainfall patterns on our %-Andes records in section 5.3 of the discussion (page 18, lines 3-8):
"East-west antiphasing precipitation changes documented during the mid Holocene are mostly restricted to NE Brazil and have a small influence on easternmost Amazon (Tapajós and Xingu) tributaries only (Cruz et al., 2009; Prado et al., 2013a; Prado et al., 2013b). Because these tributaries supply very little sediment material to the Amazon River (Meade et al., 1985; Guyot et al., 2007), east-west antiphasing rainfall changes will have negligible influence on our %-Andes records."

Also, if these reconstructions are correct then time series from both cores (5N and 9N) should be identical, yet this is not the case (Figures 6C and 6D), a discrepancy that is not sufficiently explained.

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Marine sediment cores rarely exhibit identical records, also when classical methods (e.g. foraminiferal stable isotopes) are used. This reflects inter-core variability that is intrinsically linked to local effects over proxy variables and to the limitation of proxies to represent complex environmental properties. Although not identical, the %-Andes records from cores at 5°N and 9°N exhibit high similarities: relatively high and stable %-Andes values throughout the cores (Fig. 6), and significant variations on precessional and sub-millennial time scales (Fig. 7). Two main differences characterize both %-Andes records:

(1) %-Andes values are slightly higher at 9°N (∼77 % on average) than 5°N (∼72 % on average, Fig. 6). Reasons for this feature are unfortunately unknown.

(2) During the last glacial period, precessional %-Andes variations are stronger at 5°N than at 9°N (Fig. 6). Such weak precessional variability (with relatively high %-Andes values indicating increased Amazonian rainfall) is also shown by western Amazonian (Mosblech et al., 2012; Cheng et al., 2013) and southern Brazilian (Cruz et al., 2007) speleothems. It has been attributed to glacial boundary conditions in the northern hemisphere whose effect on South American tropical rainfall overlaps precessional variations (Cruz et al., 2007). The reason why the 9°N core does not reproduce this feature is not clear. Differences between the 5°N and 9°N %-Andes records may be related to differences in sedimentation. The better resolution of millennial-scale events due to higher sedimentation rates at 9°N (around twice higher than at 5°N, Fig. 3) may contribute to weak precessional variations recorded at 5°N. Although, we may not be able to understand all differences between both %-Andes records, the main results of our paper are based on their strong similarities: Andean provenance of Amazon sediments and increased %-Andes related to wetter conditions during periods of high DJF insolation.

We now highlight the difference between 5°N and 9°N %-Andes values at the beginning of the Discussion section 5.2 (formerly 5.1).
Page 13, lines 20-21: “The reason why %-Andes values are slightly higher at 9°N than

at 5°N (Figure 6) is unknown."

The difference in the magnitude of precessional variability between 5°N and 9°N cores during the last glacial period is already addressed at the end of section 5.3 (formerly 5.2). Page 20, lines 1-4: "The record at 9°N exhibits relatively high %-Andes values and weak precessional variations between ∼15 and 60 ka (Figure 6D). The reason why precessional changes are weak at 9°N but strong at 5°N during the last glacial period is not clear. Better resolved millennial-scale events due to higher sedimentation rates at 9°N (Figure 3) could explain this feature."

In the tropical Andes (Lake Titicaca sediment record, e.g., Fritz et al., 2007), glacial-age sedimentation rates are many times higher than interglacial rates and sediment compositions are also totally different. This is likely due to increased erosion rates by greatly expanded glaciers of the high Andes. I would expect to see a much higher ratio of Andes/Amazon sediment during glacial times, yet this is not reconstructed in the present study nor is the possibility discussed.

We thank the reviewer for drawing our attention on the strong glacial-interglacial variability indicated by Lake Titicaca sediments. As highlighted by the Reviewer, specific sediment composition and enhanced sedimentation rates observed in these records during glacial times likely reflect cold and wet conditions and increased erosion rates due to enhanced Andean precipitation and strong glacier expansions in the surrounding cordillera (Fritz et al., 2007; Gosling et al., 2008). These mechanisms could contribute to the relatively high %-Andes values and weak precessional variability observed at 9°N during the last glacial period (15-60 ka).

In the revised manuscript, we completed the discussion on the drivers of relatively weak glacial precessional variability at the end of section 5.3 (formerly section 5.2).

From page 20, lines 5-18: "Nevertheless, Bolivian Altiplano lake sediments (e.g. Fritz et al., 2007; Gosling et al., 2008) and western Amazonian and southern Brazilian speleothems (Cruz et al., 2007; Mosblech et al., 2012; Cheng et al., 2013) also suggest weak precessional variability during past glacial intervals. Lake Titicaca sediment

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records exhibit strong glacial – interglacial variability over the last 370 ka. Specific sediment composition (e.g. high magnetic susceptibility, low total carbon, no carbonate) and increased sedimentation rates recorded during glacial periods likely reflect cold and wet conditions and increased erosion rates due to enhanced Andean precipitation and strong glacier expansions in the surrounding cordillera (Fritz et al., 2007; Gosling et al., 2008). Such increased erosion induced by glacier advances in the Andes could contribute to the relatively high %-Andes values observed at 9°N throughout the last glacial period (Figure 6D). Weak glacial precessional variability indicated by speleothems is associated with relatively wet South American tropical conditions (Cruz et al., 2007; Mosblech et al., 2012; Cheng et al., 2013), which could also contribute to the relatively high glacial %-Andes values (Figure 6D)."

Two assumptions made in the end member analysis (p. 5863) deserve further consideration. Although calcite dissolution may not be an important factor, can the same be said for pteropod dissolution?
Calcite or aragonite dissolution has no influence on the definition of our three endmembers (terrigenous endmembers are defined from the modern composition of fluvial material and the biogenic endmember from the relative Ca and Si proportions estimated from nearby surface sediments). However, in principle carbonate dissolution can contribute to the increases in terrigenous vs. marine biogenic endmember proportions observed during past cold substages (MIS 2, 4. 5.2, 5.4 and 6, Fig. 5). But because all sites are located above the modern and glacial calcite lysocline, calcite dissolution has very limited effect on the sediment's composition (as already explained p. 5863).
What about aragonite dissolution? Two aragonite lysocline levels are detected in surface sediments from Central and South Atlantic (20° N-40° S): an upper aragonite lysocline at ∼750 m (presence of Antarctic Intermediate Waters) and a lower lysocline at ∼2500 m (influence of Lower North Atlantic Deep Waters) (Gerhardt and Henrich, 2001). Among the four cores included in this study:

- Cores GeoB7011-1 (1910 m, 9° N) and 3938-1 (1972 m, 12° N) are located above the modern lower aragonite lysocline. We use the results from core GeoB2204-2 from the NE Brazilian slope (8° S) and a similar water-depth (2072 m) to estimate past variations in aragonite contents (Gerhardt et al., 2000). In this site, the aragonite content accounts for ∼15 % of the total weight content (and ∼25 % of the carbonate content). Lower pteropod contents and increased aragonite dissolution during past cold substages (e.g. MIS 2, 4, 5.4) due to increased bottom-water corrosiveness related to glacial deep-water changes (Gerhardt et al., 2000). We expect similar patterns at our two shallowest core sites.
- Core GeoB7010-2 (2549 m, 9° N) is located close to the modern lower aragonite lysocline. Similar to the shallowest sites, we expect low pteropod content (< 15 % of total weight) during warm substages and increased aragonite dissolution during cold substages.
- Core GeoB4411-2 (3295 m, 5° N) is located well below the modern lower aragonite lysocline. We expect negligible pteropod content in this core and negligible influence of aragonite dissolution on the sediment geochemistry.
Therefore, increased aragonite dissolution during past cold substages may affect the geochemical composition of three sediment cores of our study. Decreased aragonite content during these periods acts to increase the relative terrigenous content, as observed in our study (fig. 5). Past changes in aragonite dissolution may hence contribute to the relative variations of reconstructed marine vs. terrigenous endmembers (Fig. 5). However, we believe that changes in carbonate vs. terrigenous contents are strongly dominated by global sea level changes (Milliman et al., 1975; Maslin et al., 2006). During interglacial highstands, sediments delivered by northern South American rivers are deposited by longshore currents along the continental shelf. When during glacial times sea level falls 80-100 m below the present level, sediments are directly channelled down the continental slope (Milliman et al., 1975; Maslin et al., 2006). Sedimentation rates in the Amazon Fan about 20 to 1000 times higher during glacial times than during the Holocene reflect the extremely large amounts of

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sediments delivered to the deep sea (Mikkelsen et al., 1997). Such amounts cannot solely derive from changes in carbonate (calcite and aragonite) dissolution.

To address this point, we performed the following modifications in the manuscript.
1. We now specify the location of all cores relative to the position of the modern aragonite lysocline at the end of Material and Methods section 3.1. Page 6, lines 11-15: "Past changes in aragonite dissolution may have an influence on cores GeoB7011-1 (1910 m), GeoB3938-1 (1972 m) and GeoB7010-2 (2549 m) that are located above or close to the modern lower aragonite lysocline (∼2500m, Gerhardt and Henrich, 2001) (see Discussion section 5.1). Negligible aragonite content is expected in core GeoB4411-2 (3295 m) located well below the modern aragonite lysocline."

2. We reorganized the Discussion to include detailed information on the potential effect of carbonate dissolution on terrigenous vs. marine biogenic proportions: we added a new section 5.1 entitled "Factors controlling terrigenous vs. marine biogenic proportions". This section successively addresses the role played by global sea level changes, marine biological productivity and carbonate dissolution. The effect of carbonate dissolution is addressed in page 12, lines 18-30: "Because all core sites are located above the modern and glacial calcite lysocline (Volbers and Henrich, 2004), calcite dissolution will have a very limited effect on the sediment's composition. In contrast, aragonite dissolution could affect the geochemical composition of three cores (1900-2550 m, section 3.1) located above or close to the modern lower aragonite lysocline (∼2500 m, Gerhardt and Henrich, 2001). Results from a NE Brazilian core from a similar water-depth range (2070 m) indicate aragonite contents ranging between 10 and 30 % of the total weight (∼15 % on average) with increased bottom-water corrosiveness and aragonite dissolution during past cold substages (in response to deep-water changes, Gerhardt et al., 2000). Similarly, increased aragonite dissolution during glacial intervals could contribute to increases in terrigenous vs. marine biogenic proportions, as described here (Figure 5). However, we suggest that large changes in

sediment delivery induced by global sea level variations dominate the effect of carbonate dissolution and are the main driver of terrigenous vs. biogenic changes recorded in deep sediments."

3. In order to make this new section 5.1 even more comprehensive, we also added a short paragraph on the influence of changes in carbonate productivity. From page 12, lines 10-17: "Reconstructions of paleoproductivity on Ceara Rise (close to our 5°N site) indicate low carbonate productivity over the 300 ka (as expected for this oligotrophic region), with slightly enhanced productivity values during past warm substages if compared to glacial intervals (Rühlemann et al., 1999). This result suggests that changes in carbonate productivity could contribute to the decreases in terrigenous vs. marine biogenic proportions observed during warm substages (Figure 5). However, such small productivity variations are probably overprinted by the large deep-sea input of terrigenous material induced by lower glacial sea levels (Rühlemann et al., 2001)."

Also, is it true that Si (diatom) productivity rates are "very small" despite large changes in Amazon sediment flux and the known influence of Amazon outflow on modern diatom productivity?
The Reviewer raises an interesting point that requires clarification. What matters in the endmember unmixing analysis is the amount of biogenic opal accumulating in sediments. We agree that nutrient-rich waters delivered by the Amazon River stimulate the siliceous productivity in surface shelf waters off the Amazon mouth. This feature is illustrated by high diatom abundance and diversity in surface waters and high biogenic silica values (up to 40 %) measured in surface-water suspended solids (DeMaster et al., 1983). However, very low biogenic silica values (< 0.5 %) characterize surface shelf sediments off the Amazon mouth (DeMaster et al., 1983). This result indicates that most of the biogenic silica dissolves in the water column or at the sediment interface prior to accumulation. In the end, only 4 % of riverine silica accumulates in shelf sediments (DeMaster et al., 1983).
We now detail this issue in a new footnote to Supplementary Figure 4 (that summa-

rizes the composition of endmembers in all cores): “Nutrient-rich freshwater from the Amazon River stimulate siliceous productivity in surface shelf waters off the Amazon mouth, as illustrated by high diatom abundance and high biogenic silica (up to 40 %) in surface waters (DeMaster et al., 1983). However, very low biogenic silica values (< 0.5 %) measured in surface shelf sediments off the Amazon mouth indicate that most biogenic silica dissolves in the water column or at the sediment interface prior to accumulation (DeMaster et al., 1983). These results support the low biogenic silica content (< 1.5 %) of surface sediments used to define the marine endmember (see footnote 1) and the low Si proportion in the endmember's composition. In addition, the error on respective Ca and Si proportions that we used during the Monte-Carlo analysis accounts for small variations in biogenic opal content.”

We also slightly modified the main text to incite readers to check the footnote in Supplementary Table 4. Page 9, lines 15-18: “This assumption is supported by very small changes in western tropical Atlantic paleoproductivity (Höll et al., 1999; Rühlemann et al., 1999) and low accumulation of biogenic opal in sediments (also on the Amazon continental shelf, DeMaster et al., 1983) (see footnote of Supplementary Table 4 for details).”

Aline Govin, on behalf of all authors)

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