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# *Interactive comment on* "Early Pliocene vegetation and hydrology changes in western equatorial South America" *by* Friederike Grimmer et al.

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HOORN Summary The purpose of the paper is to establish the direction of shift of the ITCZ following the closure of the Central American Seaway (CAS) and uplift of the northern Andes. The paper comprises a palynological study of sediments from the interval between 4.7 and 4.2 Ma of the appropriately situated ODP core 1239A. The specific aims are to reconstruct vegetation, climate and topography in this region throughout this time interval. The conclusion is that an (already) high Andean landscape existed at the time, and that both vegetation and landscape during this interval match with a scenario corresponding to a southward shift of the ITCZ. Fluctuations of the ENSO are also considered. The results are in accordance with other paleoceanographic data in the region.



Main comments: There is a shortage of continuous records from the Pliocene in the eastern Pacific that reflect hydrological and climatic change in the region. This paper aims to fill this gap. However, the dataset makes it hard to see the big changes that one would expect from the text. If possible the dataset should be extended with additional data to which are referred in the text.

RESPONSE We emphasize in the text that the changes within the analyzed time window are rather small (e.g. line 20 "stable, permanently humid conditions"; line 271 "During the early Pliocene, no profound changes in the vegetation occur"). We prepare an extra figure (Fig 4A in supplementary file) showing both the data discussed in the manuscript and the data of a pilot study to show the long-term trends. It should be kept in mind that the age model for the period between 5 and 6 Ma is based on shipboard data and less detailed. We will adapt the text accordingly and include: "Percentages of humidity indicators hint to slightly drier conditions at the beginning of the Pliocene. A trend towards higher palynomorph concentrations is found for the period from 6 to 2 Ma. Grass pollen percentages remain low indicating mainly closed forest at altitudes below the Páramo. Representation of lowland rainforest was low around 4.7 Ma, increased by 4.5 Ma, declined again to low levels around 3.5 Ma, and rose to remain at higher levels during the Pleistocene. Continuous presence of pollen and spores from the Páramo indicates that the northern Andes had reached high altitudes in Ecuador before the Pliocene."

HOORN The interaction of Andean uplift, closure of the CAS, shifting ITCZ and ENSO altogether make it quite a daunting task to interpret the palynological diagram an assign changes to specific causes. The case is clearly made and looked at from all angles. Question: Is there a chance that some of the subtle changes in the diagram can be related to the Pliocene uplift pulses in the Andes and related atmospheric changes? Such pulses are postulated in tectonic reconstructions (e.g. Anderson et al., 2015, Geosphere) and are mentioned by authors in the paragraph starting at line 464.

RESPONSE We do not understand this question. We cannot find a paper of Anderson et al. in Geosphere, vol. 11 (2015). We therefore assume that meant is the paper of Anderson et al. in GSA Bulletin that we cite on line 422. However, this paper does not discuss pulses of uplift but that the uplift since 7.6 Ma was more gradual than hypothesized by, for instance, Hooghiemstra et al. (2006).

HOORN The new dataset further confirm that a high topography (Anderson et al., 2015) and paramo (Bermudez et al., 2015 in Basin Research; Hoorn et al., 2017 in Global & Planetary Change) was in place at least since the early Pliocene. It might be worthwhile highlighting the regional character of this condition?

RESPONSE To highlight the regional character, we'll specify Ecuadorean Andes at line 425: "that the Ecuadorean Andes must have already reached close to modern elevations by the early Pliocene": "in line with inferences of Hoorn et al. (2017) and Bermúdez et al. (2015)." (line 425-6). We'll add the reference of Berúmdez et al. to the list. At line 420 we'll add: "Moreover, phases of major uplift might have strongly differed regionally." We'll also specify Ecuadorean Andes at lines 22 and 357.

HOORN Note that modern type precipitation patterns are likely to have been in place already from middle Miocene onwards (see Kaandorp et al., 2006; Hoorn et al., 2010; Barnes et al., 2012) and this would have required a significant orographic barrier. A high Andes might go as far back as the mid-Miocene, however, first evidence for a paramo is now set as latest Miocene to early Pliocene. Lines 406-407 could be reconsidered in this context.

RESPONSE We'll insert "which probably were more or less in place (Kaandorp et al., 2006; Hoorn et al., 2010)," in line 407 after "Possibly these oceanic reorganizations did not directly trigger modifications of the atmospheric circulation," and add the extra reference to the list.

HOORN The elemental concentrations analysis needs to be better introduced and is currently rather hidden and makes a surprise first appearance in the methods section. In methods also explain why this is a useful additional technique. Part of the text in



section 4.3 (line 360 onwards) could be moved to the introduction to explain approach.

RESPONSE We are reluctant to shift section 4.3 to the Introduction as it discusses the interpretation of the elemental ratio results. Instead, we'll shift the section to the beginning of the discussion (new section 4.1 see at next point). To satisfy the valid objection, we'll mention the use of elemental ratios at the end of the Introduction (line 75) inserting: "We also use elemental ratios to estimate variations in fluvial terrestrial input (Ríncon-Martínez et al. 2010)."

HOORN The discussion of the Holocene samples in relation to the Pliocene seems a bit ambivalent and does not form a very good guideline to better understand the new results.

RESPONSE To better explain what guidelines we use to interpret the Pliocene record, we'll make the following changes. We change Fig. 2 (supplementary file) and add to Section 1.1.2 two paragraphs replacing lines 139-143:

"Ríncon-Martínez et al. (2010) showed that the terrigenous sediment supply at ODP Site 1239 during Pleistocene interglacials is mainly fluvial and input of terrestrial material drop to low amounts during the drier glacial stages. Also transport of pollen and spores to the ocean is mainly fluvial (González et al., 2010). High rates of orographic precipitation characterize the western part of equatorial South America. These heavy rains quickly wash out any pollen that might be in the air and result in large discharge by the Ecuadoran Rivers (Fig. 2). Esmeraldas and Santiago Rivers mainly drain the northern coastal plain of Ecuador, and the southern coastal plain is drained by several smaller rivers, which end in the Guayas River. Moreover, the predominantly westerly winds (Fig. 2) are not favorable for eolian pollen dispersal to the ocean. Nevertheless, some transport by SE trade winds is possible and should be taken into account.

"After reaching the ocean pollen and spores might pass the Peru-Chile Trench, which is quite narrow along the Carnegie Ridge, by means of nepheloid layers at subsurface depths. Some northward transport from the Bay of Guayaquil by the Coastal Current

(Fig. 2) is likely. However, the Peru-Chile Current flows too far from the coast to have strong influence on pollen and spore dispersal. We consider western Ecuador, northernmost Peru and southwestern Colombia the main source areas of pollen and spores in sediments of ODP Site 1239."

We'll switch sections 3.1 and 3.2 to emphasize the function of the Holocene analysis as a tool for interpretation. We add values for Podocarpus to Figure 3 (see supplementary file). We'll replace "whereof the... Alnus" (line 197) with "During the Holocene Podocarpus is replaced by Alnus as the most abundant upper montane forest tree, although Podocarpus was still abundant during the glacial (González et al. 2010)."

We'll rewrite section 4.1 and put it behind the discussion about the elemental ratios consequently becoming section 4.2. We'll open the rewritten section as follows: "In order to better understand the source areas and transport ways of pollen grains to the sediments, we make a comparison of the results of our two Holocene samples with that of another pollen record retrieved from the Carnegie Ridge southeast of Site 1239 (Figure 2) reflecting rainfall and humidity variation of the late Pleistocene (González et al. 2006). Holocene samples of Site 1239 gave similar results showing extensive open vegetation (indicated by pollen of Poaceae, Cyperaceae, Asteraceae) and maximum relative abundance of fern spores although concentration is low (González et al., 2006). As also indicated by the elemental ratios, fluvial transport of pollen predominates in this area (González et al., 2006; Ríncon-Martínez, 2013). This is understandable as both ocean currents and wind field do not favor transport from Ecuador to Site 1239 (Figure 2)."

HOORN Lines from 313: A rather crucial line comes up here and reads as follows: "unpublished data from the earliest Pliocene show that the percentage of lowland rainforest before 4.7 Ma was very low". The evidence that is presented seems rather subtle and perhaps not iconic for an important vegetation & climate change. The authors allude to data of the earliest Pliocene, which they say strengthen their case. However, they are not visible. If these data belong to the authors it might be timely to include



them here (or a selection of them) and make a more compelling case.

RESPONSE We'll introduce a new figure (Fig 4A in supplementary file) with the selected results of the pilot study (see also response above) illustrating the low rainforest pollen percentages prior to 4.7 Ma and, more importantly, the continuously higher values after 3 Ma. We'll correct and precise the description accordingly.

HOORN A map with the scenarios for the changing ITCZ would be welcome. Instead this could also be added to figure 1.

RESPONSE We'll change Figure 2 (which we assume is referred to) to show the windfield together with the resulting precipitation during boreal summer (July), because this is the rainy season in the region. This should illustrate the correspondence of the summer rains in northern South America with the present northern limit of the ITCZ. Furthermore, we'll include a panel with summer SST combined with main ocean currents. The adapted figure is shown separately in the supplementary file. This, together with the revision of Section 1.1.2, should also illustrate the ineffectiveness of transport mechanisms other than fluvial discharge by the Guayas and Esmeraldas Rivers.

HOORN Minor comments: In line 465 Hoorn et al. 2010 are listed as backing up a rapid rise of the region since 4–6 Ma, However we suggest in the mid-Miocene the Andes must have already been high with further uplift at a later stage.

RESPONSE Sorry about that. We'll delete Hoorn et al. (2010) from the list and add it later in the paragraph in the altered sentence: "Possibly these oceanic reorganizations did not directly trigger modifications of the atmospheric circulation, which probably were more or less in place (Kaandorp et al., 2006; Hoorn et al., 2010), but critical periods of uplift influencing atmospheric circulation might have occurred earlier." (see also above).

HOORN The writing style at places can be somewhat convolute and could do with rephrasing. A suggestion for the opening sentence would be: "The progressive closure of the Central American Seaway (CAS) and the uplift of the northern Andes profoundly reorganized early Pliocene ocean and atmospheric circulation in the Eastern Equatorial Pacific (EEP).“

RESPONSE We’ll do our best and adopt your suggestion for the opening sentence.

ADDITIONAL REFERENCES

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