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Interactive comment on "Marine terraces of the last interglacial period along the Pacific coast of South America (1° N–40° S)" *by* Roland Freisleben et al.

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The manuscript entitled "Marine terraces of the last interglacial period along the Pacific coast of South America (1âŮę N–40âŮę S)" by Roland Freisleben and co-authors presents an enormous amount of research and work, putting forward an exhaustive compilation of data regarding the Last Interglacial Marine Terraces for a significant part of the Western South American coastline. Therefore, I believe this to be an interesting manuscript to be published and I congratulate the authors for this effort. The application of the TerraceM methodology is most useful for this area and will provide relevant information that has not yet been fully characterized.

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However, there is room for improvement and I strongly encourage the authors to submit a revised final manuscript. I present a list of comments and minor corrections/ suggestions, and there are two main aspects that I would like to see properly addressed, especially in a manuscript dedicated to the last interglacial.

The authors only provide the example of Chala Bay (southern Peru) to illustrate their methodology. Chala Bay is probably a good example, since it exhibits clear morphology and has geochronology information. The authors identified the two terraces as MIS 5e and MIS 5c, and based their interpretation in Saillard (2008) data. Taking in consideration the inner edges elevations for the two terraces, and assuming them as MIS 5e and MIS 5c, the calculation of the uplift rates for each is different, implying uplift rates changes (using Sidall et al., 2007 and Creveling et al., 2017 for example). However, if we consider that the lower terrace is not MIS 5c but instead MIS 5a, then the uplift rate for both marine terraces is very similar, which is a plausible configuration. In fact, when looking at Figure 2A, it is possible to note that between the paleo-shorelines inferred for the two terraces illustrated, a third paleo-shoreline is easily visible between the swath profile in 74°16W and 74°17W and in close to the profile immediately south from the larger drainage in the Bay area. This other possible inner edge is thus located between the two paleo-shorelines presented. This immediately suggests that the less preserved morphology between the terraces can correspond to the MIS 5c and that the inner-edges at $\sim$70$\pm$2 m and $\sim$37$\pm$2 may instead be respectively MIS 5e and MIS 5a. A MIS 5c evidence, is only present when there were conditions to promote its preservation, since in most cases worldwide was indeed re-occupied by MIS 5a. Testing if possible less preserved feature is evidence of MIS 5c, can be performed for example, by estimating uplift rates and look for consistency with MIS 5e and 5a uplift rates. This is a relevant question for most MIS 5 users and needs to be clarified.

Saillard (2008) in fact suggests the same, that the morphology could be a mix of MIS 5c and/or MIS 5a and ultimately favoring a MIS 5a interpretation: - “Dans la zone de ChalaâĂŘTanakaâĂŘChaviña, la terrasse marine à +60 m, dans la baie de Chala, a un âge supérieur à 100 ka, et correspond vraisemblablement au SI 5 et au SSI 5c ou a (Figure 84). La terrasse marine à +94 m, dans la baie de Chala, a un âge minimum de 220 ka et correspond au SI 7 et au SSI 7c. De même, la terrasse marine à +154 m dans la baie de Chala, a un âge minimum de 250 ka et correspondrait donc au SI 9 et au SSI 9a. La terrasse d'abrasion marine à +90 m, au niveau du Cap de Tanaka, a un âge de 171 ka $\pm$ 21 ka et correspond au SI 7 et au SSI 7a (page 202, Saillard 2008)" - "Nous avons corrélé la terrasse +60 m au SSI 5e (122 $\pm$ 7 ka), conformément à Goy et al. (1992) et à nos âges 10Be obtenus sur un cône alluvial déposé sur la terrasse, indiquant un âge supérieur à 100 ka. En effet, la terrasse +60 m est le premier niveau étendu et séparé de la terrasse supérieure par un grand escarpement qui mesure $\sim$30 m. . . . A partir des corrélations de Goy et al. (1992), nous avons corrélé les terrasses marines inférieures +2 m, +11 m et +31 m, à l'Holocène moyen (SI 1 ; 6000 $\pm$ 1000 ans), au SSI 3 et au SSI 5a (Table 8)." (page 208, Saillard, 2008).

Note that the elevations of Saillard are not the same presented in this manuscript, which I think is a consequence of presenting TerraceM data (and maybe orthometric elevation), and this difference should in fact be checked. The MIS 5c or MIS 5a is a most relevant question. Why have the authors chosen to consider the morphology as MIS 5c? Is there any other evidence that supports it? As geochronology data? This also raises questions about the other locations where the authors also interpret MIS 5c landforms. If MIS 5c was recognized (and generally less preserved worldwide) why was it not possible to identify MIS 5a? If that was the case, what mechanisms differ from 112ka to 80 ka? And why is the Quality Rating for this location rated as high confidence?

Difficulties in characterizing MIS 5 and younger landforms bring me to the second major question. GIA causes a known impact to crustal vertical deformation that needs to be taken into account to infer paleo sea level positioning and decode tectonic imprint (e.g. Creveling et al., 2015, Simms et al., 2016). Comments regarding possible Glacio-Isostatic-Adjustments effects in the elevation of last interglacial and paleo sea-levels are absent from this manuscript. It is likely that theses effects along the Western South America coast may vary from null or very little to a certain amount, however, this has not been introduced and discussed and the reader is not aware if it was considered or excluded and if the annexed dataset took those effects in consideration.

List of comments:

Line 38 – is there any difference between abrasion platforms and marine terraces? If so, can you explain what abrasion platforms are? Are marine terraces depositional landforms and abrasion platforms erosional? Line 60 – again what is the difference between marine terrace sequences and abrasion platforms? Clarifying may be useful for the reader. Maybe add definition of rasas, as well. Clarify what are the chosen nomenclatures for this manuscript. Lines 63-65 – "The marine terrace morphology comprises a gently inclined marine abrasion platform or depositional surface that terminates landward at a steeply sloping paleo-cliff surface. The intersection point between both surfaces represents the sea-level position during the formation of the marine terrace also known as shoreline angle" Please consider that it represents the higher sea-level associated to this landform and that it there may be a discrepancy between the timing of the shoreline angle trimming and the length of the MIS

Line 65 – please introduce the terminology Inner Edge, since it will be used in the later part of the manuscript and never explained.

Line 112 – "Several bathymetric anomalies have been recognized on the subducting Nazca plate." The bathymetric anomalies are landforms at the bathymetric surface, rather than on the plate. Please rephrase, explaining the landform, and if the landforms are in the continental shelf, abyssal plain? Why are they anomalies? Are they reliefs standing it out from a background? Are they seamounts or depressions, since both cases can be bathymetric anomalies? Since you will debate later that these features when subducted may cause an impact, consider describing their sizes, how high and wide are they (elevation from the ocean floor). Maybe include lithologies if you know

(are they volcanoes, structural reliefs?)

112-113 – “most prominent anomalies being subducted beneath South America are the Carnegie and Nazca” the anomalies are not subducted per se, but rather the morphologies “

Line 114 – “The Carnegie Ridge subducts roughly parallel with the convergence direction and its position should have remained relatively stable beneath the continent” please rephrase the word position and continent. The position is relative and it changes through time, consider using geometry, shape and for continent, consider renaming it with the concept of plate.

Line 119-120 “these bathymetric anomalies are thought to influence the characteristics of interplate coupling and seismic rupture” please consider rephrasing to something like these larger reliefs (seamounts etc? explain what they are) previously present at the surface of the now subducted plates are thought to . . ..

Line 124 and 126 – “amount of sediments” please consider rephrasing to volume of sediments, since amount could refer of number of different type of sediments, number of clasts. . . etc.

Line 127-128 –“thick trench sediments” consider rephrasing to thick trench sediment sequences. Is not sufficiently clear.

Line 141 – consider replacing dominates with is dominant or is prevalent.

Line 152 – “Smaller coastal fault systems” how small? You gave one order of magnitude for one example (2000 km) and now the reader doesn’t know if small can be 800, 400, 50 km. . .

Line 139-157 – These paragraphs describe a lot of places that are not mentioned in figure 1 and the reader doesn’t really know their location. In addition, although not the scope per se of this manuscript, consider adding a sentence of two, stating that the different kinematics reflect the deformation (different areas/ segments) associated

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to the subduction. Also, can you add reference to a figure? For someone who is unfamiliar with the Geography, this is hard to follow.

Line 169-185 – These paragraphs describe a lot of places that are not mentioned in figure 1 and the reader doesn't really know their location, as for example Gulf of Guayaquil (3°S) and the Dolores-Guayaquil megashear, San Juan de Marcona area.

Based on comments for lines 139-157 and 169-185, would it be possible to add another map to Fig 1 with more information regarding sites and in land structures kinematics (suggestion, different colors for different kinematics)? It is very hard to read the small numbers referring to the location names.

Line 188 – what is rasa in comparison with abrasion platforms? Clarifying the different nomenclatures is very positive.

Line 222 – can you define what the Maule segment is? This nomenclature is not included in the map, and it has not been introduced earlier.

Line 228 – "extensive uplift rate of 0.31 to 0.42 m/ka", Can you add information for the period of time corresponding to this uplift rate, since MIS 5, since before? Add a time period.

Line 229 – 0.34 m/ka is not lower than 0.31 to 0.42 m/ka, is actually within the range. Can you rephrase, please?

Line 230 – 0.17– 0.21 m/ka for what time period?

Line 231-235 – "Marine Terraces above . . . last 125 ka according to.." this sentence is confusing, maybe rewrite to clarify. Consider adding the word between to help differentiate.

Line 243 – "oldest Pleistocene shore platforms" can you provide information regarding the age?

Line 243- 246 – "The Central Andean rasa (15°–33°S) and the oldest Pleistocene shore platforms – which are also generally wider – indicate accelerated and spatially continuous uplift after a period of tectonic stability or subsidence. According to Melnick (2016), the Central Andean rasa has experienced slow and steady long-term uplift at 0.13 ± 0.04 m/ka during the Quaternary," It is my understanding from what is written that the Central Andean rasa were subjected to a low uplift rate, favoring their development. Is this long-term uplift at 0.13 ± 0.04 m/ka still the same? Was the period of tectonic stability or subsidence prior to the Central Andean rasa? Or the uplift initiated already during the Quaternary, and if yes, when? This sentence can be improved for clarification. Remember that today and yesterday are Quaternary as well.

Comment to the entire section 2.2.2 – Would greatly benefit if supported by an additional figure with geographic and some structural as suggested earlier. The reader is not aware of what is the Maule segment for example. It is very hard to follow locations.

Line 299 – Please verify if the provided link is correct

Line 299 – "placed swath profiles of variable width perpendicular to the previously mapped inner edge" It has not been given sufficient explanation regarding the selection of sites to study and where to place the swath profiles. How many for region, etc. . I understand their spacing being also controlled by drainage density, but maybe a sentence here to add further information is helpful.

Line 304 – "show only minimal deviations of less than 0.5 m" is this deviation regarding vertical or horizontal? Please clarify.

Line 308 – "we measured 1843 and 110 shoreline-angle elevations" in a total of 1953? It seems that a word is missing after 1843. What is the difference between 1843 and 110?

Line 309 – "5e and MIS-5c terrace levels". How do you know that it is MIS 5c and not MIS 5a? As far as I understand, there is not a direct numerical dating for it. Please discuss this identification as MIS 5c.

Figure 2 – This figure is extremely important, by being taken as an example of the methodology for the entire area. Due to its relevance, I have some comments. The shaded relief is not very visible, and the color scheme is not necessary, also because you have information for the inner edges elevations along the swath profiles. Slope information is barely noticeable and probably not necessary.

It lacks relevant information, most needed to validate your MIS interpretations. One can observe several other terraces higher and older that the one with the inner-edge at ∼70±2 m elevation. Those terraces are in fact the ones that were dated with Terrestrial Cosmogenic Nuclides by Saillard (2008) and providing a time constrain for the marine terrace interpretation. I was unable to find in the thesis a direct TCN numerical dating for MIS 5e in Chala Bay, but rather for MIS 7 and older, and I think the authors need to clarify this information in the manuscript.

I strongly advise to add to this image the inner edges from previous terraces (as dashed lines for instances) and add locations of TCN samples with numerical ages (X± x ka) . I also question the sudden change elevation of the lower inner edge in the western most and southern most profiles. Is it a steep section of the cliff? Why in one drives the inner edge up and in the other lowers it? Why was not possible to measure the upper terrace one? Since the confidence level given to these coastal landforms as MIs 5e and MIS 5c is 5 (high confidence), a proper justification supported in evidences is required.

Figure 3D – is n= 1953 referring to what? terrace-elevation measurements ? What is the 1843 referred earlier?

Line 342- 343 – "The following equation illustrates how we calculated the individual parameters and the overall quality rating:" Besides identifying variables, the authors do not provide any explanation for the equation per se, and it would be most adequate to do so. Can you please provide the basis for this equation? Maybe including references as well.

Line 397-398 – Only now is explained what 1843 and 110 are. Please consider explaining this earlier. (line 308).

Figures 5 to 8 – should probably be organized together, similar to what was done with figure 4. It would be easier to compare the different regions and then it will be easier to compare that figure with figure 4. Consider including location of the ridges previously mentioned as anomalies.

Line 542 "Our statistical analysis of mapped shoreline-angle elevations" for the entire area? Does it make sense, when there are so many tide and wave height variations, not to mention changes imposed by tectonics?

Line 551-556 – "We observe the lowest errors from the 30 m TanDEM-X, slightly higher errors from the 1-5 m LiDAR data, and the highest errors from the 12 m TanDEM-X. This observation is counterintuitive as we would expect lower errors for topographic data sets with higher resolution. The reason for these errors is probably related to the higher number of measurements using the 12 m TanDEM-X (1564) in comparison with the measurements using 30 m TanDEM-X (50), which result in a higher dispersion (Fig. 9B)." These sentences will greatly benefit from a better explanation or rewriting. It is unclear if the authors are stating that 30 m TAnDEM-X is a better topographic dataset for this type of analysis, or if their results of error analysis result from their own sampling.

Line 627-629 "This emphasizes also the importance of last interglacial marine terraces with respect to currently active faults, which might be compared in the future with short-term deformation estimates from GPS or the earthquake catalog." Short term estimates from GPS are really very short in time and may not reflect long term rates expressed by the faults, and active structures may even be seismic silent for Holocene times. Maybe focus in discuss their validity as a Late Pleistocene marker for crustal vertical deformation.

Line 651-652 – "An increase of wave height and tidal range may lead to enhanced erosion and morphologically well-expressed marine terraces, which is consequently reflected in a higher number of measurements" This statement probably needs further evidence.

Line 664- 669 – has the lithology effect been considered? Some lithologies are easier to trim that others and other are more easily eroded. Has structural control (bedding, etc) taken into account in this analysis? Has the cliff erosion and in particular the Holocene retreat been compared? Obviously a higher cliff retreat will erode terraces which don't necessarily mean that they were never formed.

Line 693-694 "The marine terrace elevations display a median value of 30.1 m for the MIS-5e level and a median uplift rate of 0.22 m/ka for MIS-5e and 5c." Why presenting median values in such a dynamic and variable tectonic setting along 5000 km? Is it relevant as a conclusion?

References added:

Creveling, J. R., Mitrovica, J. X., Hay, C. C., Austermann, J., and Kopp, R. E., 2015, Revisiting tectonic corrections applied to Pleistocene sea-level highstands: Quaternary Science Reviews, v. 111, p. 72-80.

Creveling, J.R., Mitrovica, J.X., Clark, P.U., Waelbroeck, C., Pico, T., 2017. Predicted bounds on peak global mean sea level during marine isotope stages 5a and 5c, Quaternary Science Reviews, V. 163, 193-208, https://doi.org/10.1016/j.quascirev.2017.03.003.

Simms, A. R., Rouby, H., and Lambeck, K., 2016, Marine terraces and rates of vertical tectonic motion: The importance of glacio-isostatic adjustment along the Pacific coast of central North America: Geological Society of America Bulletin, v. 128, p. 81-93.

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Cerro El Huevo

Terrasses	Hsu (1988a et b)		Ortlieb et Macharé (1990)		Ce travail		
	SI	Age SI (ka)	SI	Age SI (ka)	Age ^{10}Be (ka)	SI	Age SI (ka)
+41 m	3	60	3	60		5a	85
+56 m			5a	85			
+72 m	5e	125	5c	105		5c	105
+105 m	7a	200	5e	125		5e	122
+150 m	9	300	7a	195	228 ± 28	7e	232,5
+170 m	11	400	7c	220		9a	280
+190 m	13	500	9c	330	318 ± 37	9c	321
+220 m					400 ± 49	11	405

Cerro Tres Hermanas

Terrasses	Ortlieb et Macharé (1990)		Ce travail		
	SI	Age SI (ka)	Age ^{10}Be (ka)	SI	Age SI (ka)
+41 m	5a	85		5a	85
+55 m	5c	105		5c	105
+80 m	5e	125		5e	122
+131 m	7a	195		7e	232,5
+145 m	7c	220		9a	280
+162 m	9c	330	353 ± 10	9c	321
+177 m				11	405

Chala

Terrasses	Goy et al. (1992)		Ce travail		
	SI	Age SI (ka)	Age ^{10}Be (ka)	SI	Age SI (ka)
+2 m	1	0,5		1	0,5
+11 m	3	60		3	60
+ 31 m	5a	85		5a	85
+60 m	5e	125	<100	5e	122
+94 m	7	~215	>220	7a	197
+109 m				7e	232,5
+154 m	9	~300	>250	9c	321
+160 m					
Entre +178 m et +212 m	11	400			

Ilo

Terrasses	Ortlieb et al. (1996)		Ce travail		
	SI	Age SI (ka)	Age ^{10}Be (ka)	SI	Age SI (ka)
+25 m	5e	125		5e	122
+40 m	7	~215		7e	232,5
+80 m	9	~300	300 ± 30	9c	321
+120 m				11	405

Table 8 : Table récapitulative des corrélations des différents niveaux de terrasses proposées dans les études antérieures et dans ce travail, pour les zones de San Juan de Marcona (Cerros El Huevo et Tres Hermanas), Chala et Ilo. SI : Stade isotopique.

Fig. 1.

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