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Climate of the Past Discussions

Interactive comment on "Centennial-scale precipitation anomalies in the southern Altiplano (18° S) suggest an extra-tropical driver for the South American Summer Monsoon during the late Holocene" *by* Ignacio A. Jara et al.

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Referee #1 provided a complete and very constructive review, including some of the most important topic address in our original manuscript. The Referee raised 4 major points. Here are point-by-point responses to these issues:

1.1. Little discussion of the Chungará chronology

Response: According to Referee #1 more information is required to evaluate the chronology of our record. We partially disagree with this suggestion because -as

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indicated in the manuscript (lines 160-162)- the radiocarbon chronology used in our study was explained and discussed in detail in a peer-reviewed publication (Giralt et al., 2008). In fact, this chronology has subsequently been used in multiple peer-reviewed studies from Lago Chungará (e.g. Bao et al., 2015; Hernández et al., 2013) with references to the Giralt et al (2008) article. For that reasons we decided not to include any table or diagram in the main text, although the main features of the chronology are explained throughout lines 202-210. Nonetheless, we agree with Referee #1 that more supporting information might be desirable. Hence, we add the details of the radiocarbon dates, the estimated reservoir correction, and the age-depth curve in the form of a new table and figure in the Supplementary Material (see Figure S1 and Table S1 and attached doc file to this response).

1.2. No reliability in comparing Lago Chungara and Sajama and Huascarán records

Response: Referee #1 comments that a comparison with the Sajama and Huascarán ice records is not appropriated since these records have significant uncertainties in their chronologies. Although we agree with the limitation of these ice records, we note that the Sajama ice cap is the closest paleoclimate site to Lago Chungará, less than 35 km apart from each other (Fig 1 in the original manuscript). Thus, a comparison between these two records is relevant to explore the spatial extent of the climate inferences of our manuscript. In addition, we content that there is reliability in comparing these two records based on stratigraphic evidence. For instance, Giralt et al. (2008) clearly demonstrate that the onset of the Holocene volcanic activity of the Parinacota volcano is recorded at both side at around 7500 cal yr BP (Fig. 8 of that article). Furthermore, there is an excellent correlation between the main eruptions of the Parinacota volcano present in Lago Chungara and the dust peaks recorded in the Sajama ice core for the 4500-1000 cal yr BP period, as it was explained in Sáez et al., (2015). These studies support the idea that both climate reconstructions are perfectly comparable, despite their potential chronological uncertainties. For all these reasons we decided to include a comparison of the δ18O record of the Sajama ice record in the main text and in Fig. 6. On the other hand, we agree with Referee #1 that a comparison with the Huascarán record-located several thousand kilometres away from Chungará- does not represent a real contribution to our discussion, and therefore we have removed that record from the text and from Fig. 6. Additionally, Referee #1 suggests that it might be better to compare our record with reconstructions depicting higher resolutions more accurate chronologies. We have followed this constructive advice, adding a direct comparison with the δ18O record from the Huagapo cave (lines 392-394 and Fig. 6g). As mentioned by Reviewer #1, this record is consistent with our interpretations from the Chungará record, providing additional support for our paleoclimate inferences.

1.3. Regional temperature variability presented in the manuscript is too low

Response: Referee #1 agrees with us that precipitation is the main driver of the observed pollen changes, although she/he considers that our estimation for the magnitude of Holocene temperature change is too low. We used the values presented in Marcott et al. (2013) for the 4500-1000 cal yr BP period, which are lower than 0.8° C in magnitude for the whole low-latitude band (30° N-30° S). We agree with Referee #1 that this is a broad estimation and that glacier reconstructions from the Tropical Andes provide a more accurate regional constrain that should also be discussed. Consequently, we have added new estimations for the amplitude of Holocene temperature fluctuations in lines 261-266, following the referee's suggested literature. Here we provide a justification of the specific temperature values selected: The Jomelli et al. (2011) article mentioned by Referee #1 uses a climate-glacier model to suggest that temperatures during the Little Ice Age (600-100 cal yr BP) could have been as much as 2.1 $\pm$ 0.8°C lower than pre-industrial means, a value considerably higher than our initial suggestion. However, the application of this estimation to the Chungará record should be taken with caution for two main reasons. First, because our record does not cover the LIA interval, and therefore this climate event and associated temperature decline should only be used as referential values. Secondly, this estimation was made using precipitation values corresponding to the early- and mid-Holocene periods (prior to 4000 cal yr BP), which are considerably lower than late Holocene estimations. Critically, the model does not provide with a unique solution for past temperatures reconstruction, as there are several temperature/precipitation combinations than can reproduce the observed glacial fluctuation. In particular, the magnitude of the LIA cooling declines rapidly if precipitation increases in the model. This is a relevant point because there is evidence from multiple independent records across the Tropical Andes indicating that LIA was a humid interval with precipitation significantly above pre-industrial values (e.g. Vuille et al., 2012). Therefore, we content that -if considering- the value of 2.1 $\pm$ 0.8°C should be taken as a maximum for the magnitude of thermal variability for the Chungará record. Referee #1 also mentioned the more recent review of past glacial fluctuations in the Central Andes presented by Rabatel et al. (2013). Interestingly, the authors of this article also agree that conditions were more likely wetter during the LIA, which could have increased glacier accumulation rates, driving glacial advancement along with colder temperatures. According to these authors, temperature could have drop as much as 3.2 $\pm$ 1.4°C in the Andes of Venezuela (8° N), although this is hardly a local constrain for Lago Chungará. The closest climate-glacial reconstruction cited in Rabatel et al. (2013) corresponds to the records from the Bolivian Andes (Rabatel et al., 2008), which reconstructs a LIA temperature decrease of about 1.1-1.2°C. We consider this could be in fact a better estimation than the one presented in Jomelli et al. (2011), since it assumes a precipitation input 20-30% above the present. Based on all this information, we the range from 1.1 to 2.2° C a reasonable estimation for the magnitude of temperature change during the interval of the Chungará record.

1.4. Inappropriate comparison between well-dated records and ice core

Response: Referee #1 notes that a direct comparison between highly resolved, well-dated records such as Laguna Pumacocha and the less well-dated Sajama and Huascarán ice records is problematic due to the high chronological uncertainties inherent to the ice reconstructions. Refereee #1 further challenge our interpretation that differences between δ18O records from lake and ice cores in the Central Andes could result from the fact that ice-based reconstructions are probably sensing temperature fluctuations instead of SASM variations. We consider this a valid and constructive suggestion. We also acknowledge that discussing the climate sensitivity of ice core records is beyond the scope of our manuscript and clearly very difficult to explain. Therefore, we have removed the discussion that led to the suggestion that the δ18O signal in ice core record could be responding to temperatures from our original manuscript in page 12 (lines 370-394). Instead, we have indicated that these differences are more likely resulting from chronological uncertainties based on: (1) a good agreement between lake, speleothem and ice record during period of strong chronological control, and (2) a trustable SASM signal in δ18O record from ice cores.

Minor edits of Referee #1: Line 43: ‘period of instrumental’ Response: CORRECTED Line 45: ‘makes is difficult’ Response: CORRECTED Line 66: ‘of exploring’, ‘and assessing’ Response: CORRECTED Line 79: ‘have produced’ Response: CORRECTED Line 95: ‘originating’ Response: CORRECTED Line 121: ‘plants’ Response: CORRECTED Line 122: ‘cactus’ Response: CORRECTED Line 123: ‘representative’ = CORRECTED Line 145: ‘has no’ Response: CORRECTED Line 179: ‘superimposed on’ Response: CORRECTED Line 211: ‘based on’ Response: CORRECTED Line 245: ‘values for’ Response: CORRECTED Line 280: ‘vegetation cover’ Response: CORRECTED Line 321: ‘trends indicate’ Response: CORRECTED Line 326: ‘notable rise’ Response: CORRECTED Line 344: ‘notable strengthening’ Response: CORRECTED Line 342: ‘ discussed in Sect. 5.1’ Response: CORRECTED Line 348” replace ‘turns out clear’ with ‘is evident’ Response: REPLACED Line 349” ‘seem at odds’ Response: CORRECTED Line 369: ‘south of’ Response: REMOVED Line 437: ‘Keimig’ Response: CORRECTED Line 446: ‘southeastern’ Response: CORRECTED Line 460: ‘reflecting a’ Response: CORRECTED Line 479: ‘requested from’ Response: NOT CONSIDERED Line 485: ‘they have no’ Response: CORRECTED Line487: ‘was funded by’ Response: CORRECTED Line 689: ‘wind fields’ Response: CORRECTED

REFERENCES

Bao, R., Hernández, A., Sáez, A., Giralt, S., Prego, R., Pueyo, J., Moreno, A., and Valero-Garcés, B. L.: Climatic and lacustrine morphometric controls of diatom paleoproductivity in a tropical Andean lake, Quaternary Science Reviews, 129, 96-110, 2015.

Barnes, J., and Ehlers, T.: End member models for Andean Plateau uplift, Earth-Science Reviews, 97, 105-132, 2009.

Barr, C., Tibby, J., Leng, M., Tyler, J., Henderson, A., Overpeck, J., Simpson, G., Cole, J., Phipps, S., and Marshall, J.: Holocene el Niño–southern Oscillation variability reflected in subtropical Australian precipitation, Scientific reports, 9, 1627, 2019.

Conroy, J. L., Overpeck, J. T., Cole, J. E., Shanahan, T. M., and Steinitz-Kannan, M.: Holocene changes in eastern tropical Pacific climate inferred from a Galápagos lake sediment record, Quaternary Science Reviews, 27, 1166-1180, http://dx.doi.org/10.1016/j.quascirev.2008.02.015, 2008.

Giralt, S., Moreno, A., Bao, R., Sáez, A., Prego, R., Valero-Garcés, B. L., Pueyo, J. J., González-Sampériz, P., and Taberner, C.: A statistical approach to disentangle environmental forcings in a lacustrine record: the Lago Chungará case (Chilean Altiplano), Journal of Paleolimnology, 40, 195-215, 2008.

Haug, G. H., Hughen, K. A., Sigman, D. M., Peterson, L. C., and Röhl, U.: Southward migration of the intertropical convergence zone through the Holocene, Science, 293, 1304-1308, 2001.

Hernández, A., Bao, R., Giralt, S., Sáez, A., Leng, M. J., Barker, P. A., Kendrick, C. P., and Sloane, H. J.: Climate, catchment runoff and limnological drivers of carbon and oxygen isotope composition of diatom frustules from the central Andean Altiplano during the Lateglacial and Early Holocene, Quaternary Science Reviews, 66, 64-73, 2013.

Jomelli, V., Khodri, M., Favier, V., Brunstein, D., Ledru, M.-P., Wagnon, P., Blard, P.-H., Sicart, J.-E., Braucher, R., and Grancher, D.: Irregular tropical glacier retreat over the Holocene epoch driven by progressive warming, Nature, 474, 196, 2011.

Jordan, T. E., Nester, P. L., Blanco, N., Hoke, G. D., Dávila, F., and Tomlinson, A.: Uplift of the AltiplanoâĂŘPuna plateau: A view from the west, Tectonics, 29, 2010.

Marcott, S. A., Shakun, J. D., Clark, P. U., and Mix, A. C.: A reconstruction of regional and global temperature for the past 11,300 years, science, 339, 1198-1201, 2013.

Ortega, C., Vargas, G., Rojas, M., Rutllant, J. A., Muñoz, P., Lange, C. B., Pantoja, S., Dezileau, L., and Ortlieb, L.: Extreme ENSO-driven torrential rainfalls at the southern edge of the Atacama Desert during the Late Holocene and their projection into the 21th century, Global and Planetary Change, 175, 226-237, 2019.

Rabatel, A., Francou, B., Jomelli, V., Naveau, P., and Grancher, D.: A chronology of the Little Ice Age in the tropical Andes of Bolivia (16 S) and its implications for climate reconstruction, Quaternary Research, 70, 198-212, 2008.

Rabatel, A., Francou, B., Soruco, A., Gomez, J., Cáceres, B., Ceballos, J. L., Basantes, R., Vuille, M., Sicart, J. E., Huggel, C., Scheel, M., Lejeune, Y., Arnaud, Y., Collet, M., Condom, T., Consoli, G., Favier, V., Jomelli,

V., Galarraga, R., Ginot, P., Maisincho, L., Mendoza, J., Ménégoz, M., Ramirez, E., Ribstein, P., Suarez, W., Villacis, M., and Wagnon, P.: Current state of glaciers in the tropical Andes: a multi-century perspective on glacier evolution and climate change, The Cryosphere, 7, 81-102, 10.5194/tc-7-81-2013, 2013.

Sáez, A., Giralt Romeu, S., Hernández Hernández, A., Bao Casal, R., Pueyo Mur, J. J., Moreno Caballud, A., and Valero Garcés, B. L.: Comment on" Climate in the Western Cordillera of the Central Andes over the last 4300 years", by Engel et al.(2014), Quaternary Science Reviews, 2015, vol. 109, p. 126-130, 2015.

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, Climate of the Past, 10, 715-731, 2014.

Vargas, G., Rutllant, J., and Ortlieb, L.: ENSO tropical–extratropical climate teleconnections and mechanisms for Holocene debris flows along the hyperarid coast of western South America (17–24 S), Earth and Planetary Science Letters, 249, 467-483, 2006.

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

Zhang, Z., Leduc, G., and Sachs, J. P.: El Niño evolution during the Holocene revealed by a biomarker rain gauge in the Galápagos Islands, Earth and Planetary Science Letters, 404, 420-434, 2014.

Please also note the supplement to this comment:
https://www.clim-past-discuss.net/cp-2019-13/cp-2019-13-AC1-supplement.pdf

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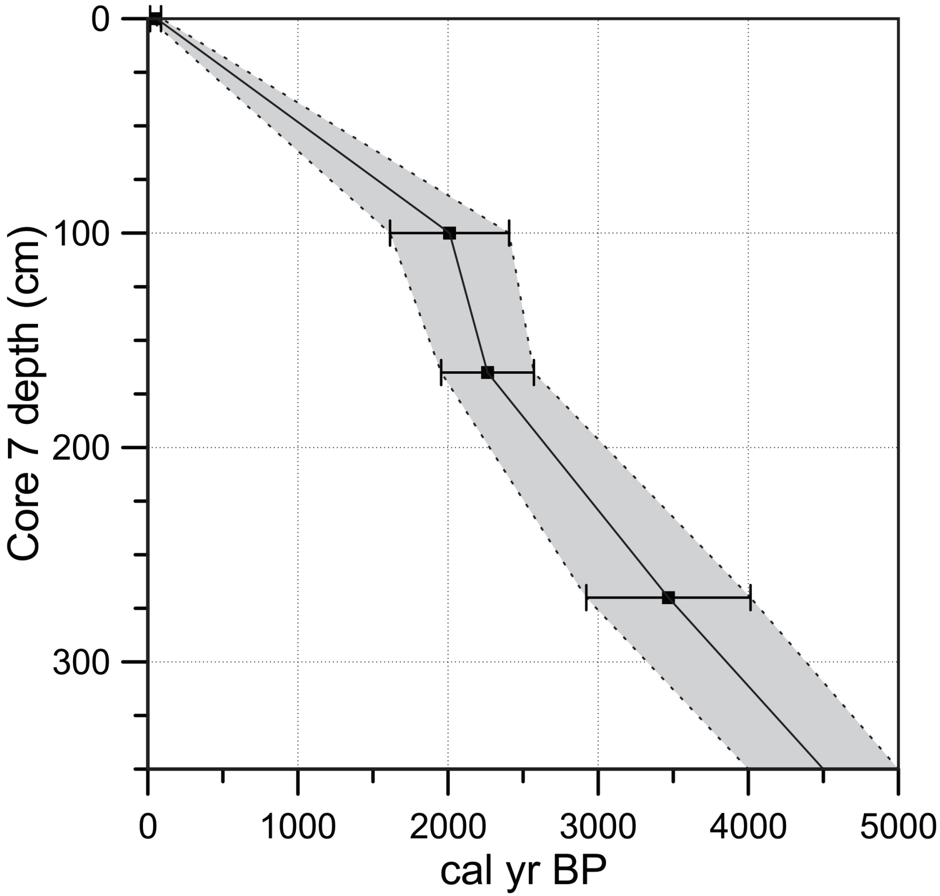

Fig. 1. Figure S1

Laboratory code	core	depth (cm)	^{14}C age	1σ	Median probability (cal yr BP)	youngest 2σ intercept (cal yr BP)	oldest 2σ intercept (cal yr BP)	Calibration curve
Poz-8726	14 A-1	100	4620	40	2010	1791	2188	SHCal13
Poz-8720	11 A-2	165	4850	40	2263	2073	2382	SHCal13
Poz-8721	11 A-2	270	7290	50	3468	2658	4263	SHCal13

Fig. 2. Table S1

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