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Climate of the Past
Discussions
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Interactive comment on "Volcanism and climate change as drivers in Holocene depositional dynamic of Laguna del Maule (Andes of central Chile – 36° S)" *by* Matías Frugone-Álvarez et al.

Matías Frugone-Álvarez et al.

matutefrugone@gmail.com

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Response to referee #3

I write this reply on my behalf of my coauthors. We appreciate the work carried out by referee #3 to review our manuscript and for his/her helpful comments that have improved our work. We believe we have addressed all comments and concerns of the reviewer and we have agreed with them. In this document we explained how we have changed the manuscript accordingly.

1. General Comments referee #3:

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I can recognize only one major issue in this study, which is related to the interpretation of the pollen data.

1.1 General Comments referee #3:

Interpretation of the pollen data In Line 383 the authors mention that the pollen data reveals “sparse vegetation and relatively high Ephedra/Poaceae ratio would suggest relatively humid conditions facilitating an upward shift of lower vegetation belts.” How can humid conditions facilitate an upward expansion of lowland vegetation? In most mountain regions humid conditions tend to promote downslope invasions of high-altitude taxa. This should be the case in the Laguna del Maule area, as rainfall increases with elevation (Supplementary Figure S4). In my opinion the authors should reconsider their vegetation climate interpretations or, alternatively, provide supporting information.

Reply general comments 1.1 :

The sentence was not well written, and we agree with the reviewer that it was a source of confusion. Modern pollen rain studies in northward and southward sites of LdM show a clear altitudinal relationship between Poaceae and Ephedra (Fernández Murillo et al 2019; Páez et al 1997). The first taxa are abundant in the Mediterranean Andean Shrubland dominated by Laretia acaulis and Berberis empetrifolia and it is correspondent to a vegetation belt where LdM is located; Ephedra is present in the Mediterranean Andean shrubland dominated by Chuquiraga oppositifolia and Discaria articulata, and this vegetation belt locates just below the altitude of the belt described above (Luebert & Pliscoff 2006; Figure S5). In both cases, Poaceae and Ephedra are not the main component of the vegetation, however, they are ones of few taxa in the Andean flora with anemophilous pollen dispersion syndrome (high production and dispersal of pollen). In this work, we postulate that these taxa are good indicators of each vegetation belt. So, high values of the pollen ratio, would suggest expansion of the high altitude belt and retraction of the low elevation vegetation belt and it would be associated to humid conditions. The pollen ratios have an editing problem in the manuscript

as this should be Poaceae/Ephedra instead of Ephedra/Poaceae. We have removed ratio Amaranthaceae/Poaceae and will only analyze ratio Poaceae/Ephedra. All data will be available online.

Thus, we have changed the sentence to: “Pollen samples indicate sparse vegetation and relatively high Poaceae/Ephedra ratio, suggesting expansion of high altitude belt and retraction of low elevation vegetation belt is associated to humid conditions during this period.”

Páez, M.M, C. Villagrán, S. Stutz, F. Hinojosa & R. Villa. 1997. Vegetation and pollen dispersal in thesubtropical-temperate climatic transition of Chile and Argentina. Review of Palaeobotany and Palynology 96(1-2): 169-181.

Fernández Murillo, M.P., J.G. Cuevas & A. Maldonado. 2019. Análisis de la lluvia polínica actual enun gradiente altitudinal en los Andes de Chile Central (33° S). Gayana Botánica vol. 76, No. 2, 103- 119

1.2 General Comments referee #3:

In addition, is hard to understand how an upward expansion of lowland vegetation can be expressed by a rise in the Ephedra/Poaceae index of Figure 7. To my (rather limited) understanding of the flora of Chile, several species of the Poaceae family are commonly found in the high Andes, with their altitudinal distribution being, on average, higher than Ephedra. Can the authors state which are the relative climate affinities of Poaceae and Ephedra? I think this would clarify the interpretation of the index. There might be also a methodological problem in the actual index calculation. The pollen ratio in Figure 7 was calculated from the formula (a-b)/(a+b); where “a” corresponds to Ephedra and “b” corresponds to Poaceae. Yet, in Figure S12 Poaceae shows higher abundance than Ephedra in almost all samples (b>a). If so, shouldn 0 t the ratio be dominated by negative values? This issue makes the understanding of this index a bit confusing. For instance, the high values seen at the beginning of Phase 3 and during Phase 6 (Figure 7) are hard to reconcile considering that these phases are actually

associated with rises in Poaceae and a drop in Ephedra (supplementary Figure S12). It would be great if the authors address this issue and ensure that the index is well calculated.

Reply general comments 1.2 :

We greatly appreciate the reviewer's comments regarding the pollen aspects. As we have commented above, we have decided to change the pollen ratio only to Poaceae/Ephedra. This change does not generate any modification in the interpretation or the results of the manuscript. So, the Poaceae/Ephedra ratio was calculated using the formula (a−b)/(a+b) where "a" is Poaceae and "b" is Ephedra. In this way, values near 1 in the pollen relationship are interpreted as an increase of humidity, while values near to -1 suggest drier conditions.

1.3 General Comments referee #3:

Finally, although I am not sure how was the index calculated; from my understanding of the regional vegetation and the pollen data of Figure S12, the index in Figure 7 could be directly proportional to regional humidity. In this case, high index values during pre-Holocene and the late Holocene time would indicate relative high precipitation, whilst low values during the early to mid-Holocene would reveal a drop in regional precipitation.

Reply general comments 1.3:

Thank you for this important question. Poaceae/Ephedra ratio between these taxa (figure 7) show high values during the first half of unit 5, between ca. 13-10 ka, suggesting relatively humid conditions. After, a trend to decrease in the pollen ratio suggest upward of low vegetation belt associated to drier conditions. After ca. 9.0 ka a slight reversion in trends suggest relatively more humid conditions until 7.5-8.0 ka. Between 6.0-4.5 ka the values are the lowest, particularly around ca. 6.5 and 5 ka, suggesting the maximum expansion of lower vegetation belts and increase of drier conditions. Ac-

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cording to this indicator, the driest period occurred around 6,5 ka. The late Holocene is characterized by higher values of this pollen ratio, suggesting expansion of high altitude belt and retraction of low elevation vegetation belt, associated to more humid conditions during this period. A slight trend to increase of pollen ratio is recorded throughout the late Holocene

2. Minor corrections referee #3:

2.1 Line 6. “We produce an age model based. . .”

Reply general minor 2.1: Done

2.2 Line 7. “According to this age mode, early Holocene. . .” An adjective for early Holocene is missing in this sentence.

Reply general minor 2.2: Done

2.3 Line 12. “During the late Holocene, the tephra layers show. . .”

Reply general minor 2.3: Done

2.4 Line 21. Consider change sentence to “. . .have documented major changes in the productivity of terrestrial ecosystems, atmospheric and oceanic circulation. . .”

Reply general minor 2.4: Done

2.5 Line 22. “western slopes”

Reply general minor 2.5: Done

2.6 Line 32. “. . ., does show that this is a regional hazard to central Chile.”

Reply general minor 2.6: Done

2.7 Line 49. “. . .during known rapid climate changes. . .”. There is no need to create an acronym (RCC) if it is not going to be used again.

Reply general minor 2.7: Done

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2.8 Line 51. “70 âŮę 30’W” Line 68. “CO2”

Reply general minor 2.8: Done

2.9 Line 130. Please provide the country of the Keck Radicarbon Facililty.

Reply general minor 2.9: Done

2.10 Line 135. It seems that radiocarbon ages were not calibrated and simply reported as conventional 14C years. This might be problematic and inconsistent with Figures 5 and 7, which have their temporal axes in the calendar age scale. Please provide an explanation to this issue.

Reply general minor 2.10: Done. We have changed the phrase to: “Radiocarbon data are reported as radiocarbon age in years before present (relative to CE 1950). Radiocarbon ages were calibrated using the Southern Hemisphere Calibration curve (SHCal13) applying the reservoir effect in the ages of aquatic organic matter inside R package Bacon v2.2 .”

2.11 Line 139. There is no explanation of how the Quizapú ash layer was identified in the methods section. There is a mention later (Line 310), but I my opinion it should be included here.

Reply general minor 2.11: According to the stratigraphic correlations between short cores and the 210Pb/137Cs age model, we assumed that T1 is the 1932 plinian eruption fro Quizapú. The Quizapú eruptions of 1846-47 and 1932 were of nearly identical magma, but the first eruption was effusive and the second plinian with a VEI index = +5 (Fontijn et al., 2014). Fortunately, the stratigraphic correlation of all short cores was easily performed by comparing TOC profiles and the key ash layer located at a similar depth in all cores, also is consistent with what is described by Hildreth and Drake, (1992) and Servicio Nacional de Geología y Minería (SERNAGEOMIN).

2.12 Lines 169-171. There is something missing in the sentence starting with “The finer grain size of . . .”. Please revise.

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Reply general minor 2.12: Done

2.13 Line 175. “Biogenic silica concentrations range from 5 to 26%....”

Reply general minor 2.13: Done

2.14 Line 178. “Well-define peaks (throughs). . .”. Not clear.

Reply general minor 2.14: Done

2.15 Line 284. “ratios”

Reply general minor 2.15: Done

2.16 Line 284. Please provide a climate interpretation for “an upward shift to lower vegetation belts”.

Reply general minor 2.16: Done

2.17 Line 298. “the promulgations of the forest law in 1931 that had a large impact in deforestation. . .” How can a deforestation process be associated with a sharp increase in a tree (Pinus)?

Reply general minor 2.17: Due to the replacement of native forests by the introduction of novel exotic forest tree of eucalyptus and pinus.

2.18 Line 300. “Unit 4”

Reply general minor 2.18: Done

2.19 Line 307. “likely due to. . .”

Reply general minor 2.19: Done

2.20 Line 338. “36Cl”.

Reply general minor 2.20: Done

2.21 Line 352. Triggering process (3) does not follow the same grammatical structure

tan processes (1) and (2). Reply general minor 2.21: Done

2.22 Line 377. Unlike all the other variables, δ13C and δ 15N are not shown in Figure 7. Perhaps it will be useful to include them in order to facilitate comparisons.

Reply general minor 2.22: Due to limitations of space we have included these data in the figure S12

2.23 Line 382. “(Meyers and Teranes, 2002)

Reply general minor 2.23: Done

2.24 Line 395. “. . .settings), reflecting. . .”

Reply general minor 2.24: Done

2.25 Line 417. “. . .beginning of this phase followed by a decreasing. . ..”

Reply general minor 2.25: Done

2.26 Line 446. “. . .exhibits centennial-scale oscillations. . .”

Reply general minor 2.26: Done

2.27 Line 473. “carbonate-producing”

Reply general minor 2.27: Done

2.28 Line 494. I which way a strengthening of ENSO would lead to a southward shift of the ITCZ? Reply general minor 2.28: One possibility is through the mechanism explained by Schneider et al., 2014. due to a change in the atmospheric energy balance. Averaged over a span of longitudes wide enough that one can focus on meridional fluxes, the ITCZ can be expected to lie near the “energy flux equator”. Ocean energy uptake in boreal winter is approximately 15Wm2 smaller during El Niño than during La Niña, with the largest changes in the eastern Pacific. This reduction in ocean energy uptake increases, which in the zonal mean in boreal winter more than doubles from typical La Niña to El Niño. It implies that the displacement of the energy flux equa-

tor and of the ITCZ away from the Equator is reduced by more than a factor of two - sufficient to account for the observed shift in ITCZ position. The effect of changes in the atmospheric moist static energy flux equator F0 is smaller (about a quarter of the total shift). Thus, ENSO variations of the ITCZ position appear to be primarily driven by tropical changes in the atmospheric energy input. (Schneider et al., 2014)

Schneider, T., Bischoff, T., and Haug, G. H. (2014). Migrations and dynamics of the intertropical convergence zone. Nature, 513(7516), 45–53. doi:10.1038/nature13636

2.29 Line 494. Define “ITCZ”

Reply general minor 2.29: Done

2.30 Line 509. “...a progressive increase up to. . .”. A progressive increase of what?

Reply general minor 2.30: “...a progressive increase in effective moisture occurred around 5.7 ka with the development of a fresher water lake...”

2.31 Line 519. “. . .during the early-to-mid Holocene, with clear. . .”

Reply general minor 2.31: Done

2.32 Line 530. “mid-latitude”

Reply general minor 2.32: Done

2.33 Line 531. “Variation in the strength of the. . .”

Reply general minor 2.33: Done

2.34 Line 542. “. . .favors a climate influence. . .”

Reply general minor 2.34: Done

2.35 Line 555. “Both greater fluctuations in water levels. . .”

Reply general minor 2.35: Done

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2.36 Line 565. Define “LIA”, both acronym and chronozone.

Reply general minor 2.36: Done

2.37 Line 566. Provide chronozone for Medieval Climate Anomaly.

Reply general minor 2.37: This phrase has been deleted

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