

Author's response to Vera Markgraf interactive comment on “Hydroclimate variability in the low-elevation Atacama Desert over the last 2500 years” by E. M. Gayo et al.

We greatly appreciate Vera’s comments and suggestions to our manuscript. In our revised version, we will include the following aspects:

I- Comments about Figure 5

Comment 1: Fig. 5, the key figure, is far too small to be deciphered; I hope it could be enlarged.

Answer: Yes, we agree. The submitted original file was formatted either for *standard* U.S. letter or A4 (original size: Width: 30.3 cm; Height: 48.5 cm). So, we will request to fit this figure so that it takes up a full page of the Journal.

Comment 2: Some of the data should also be better explained in the text, especially 5B: La Niña (arrow down in red) versus La Niña (arrow up in black); both curves look similar. I guess it would be excellent to provide a map of precipitation anomalies of La Niña phases, showing regional differences over the eastern Pacific and Peru/Chile land areas, which would help explain the curves presented in Fig. 5.

Answer: ENSO impacts along western South America are all well documented features of the modern climate described in many papers and we feel that there is no need to go into this detail here. The records presented in Figure 5 such as lithic concentrations and C/N ratios are therefore complementary as both are records of large-scale variations in rainfall that in turn are highly correlated with positive ENSO events in the eastern tropical Pacific. For example, both the Galápagos Islands and the central Peruvian coast experience large positive (negative) rainfall anomalies at inter-annual timescales during El Niño (La Niña) events (Rein et al., 2004; 2005; Conroy et al., 2008; 2009). Hence, a regional coordinated response to past variations in ENSO activity is actually expected, a result of the decreased (increased) precipitation in both regions

when the Tropical Pacific was locked into a “La Niña-like” mode (“El Niño-like” mode).

We agree with the referee that the opposite directions of the arrows offered for climate interpretations of Galápagos and off-Perú records can be somewhat confusing at first instance since both curves reveal similar rainfall trends over the last 2,500 years. The differences in the arrow directions, however, arise from the nature of each proxy as these track changes in local specific processes and mechanisms (inherent to its corresponding system) controlled by regional hydroclimate. For example, Rein et al. (2004; 2005) have shown that sedimentary layers across the SO147-106KL marine core resulted from ENSO-induced droughts along the continent as local sediment discharge was reduced significantly on the Peruvian shelf. Conversely, these same hydroclimate conditions led to ephemeral/shallow ponds and the proliferation of terrestrial vegetation within the El Junco closed-basin, which in turn determine deposition of organic matter enriched in C/N ratios (Conroy et al., 2008).

For the reasons described above, we feel that the addition of a rainfall-anomalies map contrasting Galápagos and off-Perú areas would not contribute to a better understanding of both curves presented in the figure. We have, however, modified the caption for the figure as follows:

“Fig. 5: Comparison of paleoclimate records: (A) all ¹⁴C dates on paleoecological and archaeological samples from Quebrada Maní. Green circles: relict tree mounds and rodent burrows; Red circles: organic materials associated with farming (irrigation) structures. Yellow circles: maize remains (in situ canes and corn cob found in a rodent burrow). Heavy horizontal dark line with circles indicates the chronology for Ramaditas archeological site (Rivera, 2005). (B) Proxies of past ENSO activity. Red line: A 30-year running average for lithic concentrations derived from sediment core SO147-106KL collected offshore central Perú; low lithic concentrations are interpreted as reduced precipitation runoffs associated to prevailing La Niña-like conditions (red arrow down) over the Tropical Pacific (Rein et al., 2004). Black line: C/N ratios of sediments from El Junco Crater Lake in the Galápagos Islands; higher C/N ratios indicate reduced lake levels and increased influx of land-derived organic matter resulting from negative precipitation anomalies driven by sustained La Niña-like state (black arrow up; Conroy et al., 2008). Purple line: Cholesterol abundance in the sediment core from the Perú margin

continental shelf (Site 1228D); elevated concentrations indicate enhanced upwelling of nutrient-rich cold waters determined by persistent negative SST-gradients along the Tropical Pacific (purple arrow up; Makou et al., 2010). (C) North Atlantic paleo-records. Magenta solid line: August SST inferred from planktic stable isotopes and planktic foraminiferal assemblages preserved in two marine cores (JM97-948/2A and MD95-2011) recovered from the Norwegian Sea at the Vøring Plateau (Andersson et al., 2003); dashed horizontal line indicate the modern summer SST at the site (11.4–11.6 °C). Green solid line: Winter NAO reconstruction (further details on the estimation of NAOs see Trouet et al. 2009); negative NAOs values are interpreted as a subdued Atlantic meridional overturning circulation (AMOC; green arrow down). Major global climate events over the last 2500 years such as Little Ice Age (LIA), Medieval Climate Anomaly (MCA), Dark Ages Cool Period (DACP) and the Roman Warm Period (RWP) are indicated at top of figure”.

II- Comments on the chronology

Comment 1: The described intervals (not events) of apparent increased moisture (according to Fig. 5) should read: 2650 to 2100, 1700 to 1300 and 1050 (one date though 1150) to 650.

Answer: Horizontal bars in figure 5a represent the corresponding confidence interval for a median age of a calibrated ¹⁴C-date at a 95% confidence level. According to the referee’s suggestion, we should chronologically constrain our intervals of increased water availability based on the aggregation or sum of confidence intervals obtained independently for different median ages. We argue, however, that this procedure is not correct for the following reasons: i) a confidence interval is an inference of statistical significance for a single parameter (in this case a single median age); ii) confidence intervals do not represent dispersion parameters (i.e. sample or crude ranges) of a dataset; and iii) by summing several dates, we would assume (incorrectly) that we have a 95% of probability to observe all obtained median ages within a range. In contrast, the correct procedure for obtaining statistically significant temporal coverage of a specific interval made up of several dates is by computing a pooled mean age at 2 sigma (see Stuiver et al., 2005). Nevertheless, considerable differences exist between the confidence intervals extrapolated by the

referee and those obtained from pooled mean procedures. For example, the referee proposes that the temporal coverage for the interval spanning the MCA should range from 1150 to 650 cal. yr. BP. Hence, confidence intervals resulting from the pooled mean (n= 17 dates; pooled mean= 925 cal. yr BP) argues for a much shorter duration of the positive hydroclimate conditions during the MCA, constraining it between 915 and 930 cal. yr BP. Certainly, this latter procedure obscures the real pattern of ¹⁴C-dates distribution across the MCA, which encompasses of seventeen calibrated dates significantly different ($T= 373.0316$; $Xi^2= 25.6$, $\alpha=0.05$) and which medians ranging from 1050 to 680 cal. yr. BP.

Comment 2: In general description should list from oldest to youngest.

Answer: We agree with the referee that climate change across a record is conventionally described from oldest to youngest. Nevertheless, we have decided to organize our report by listing first the major positive anomaly during the MCA that is most robust, compared to oldest events as supported by our radiocarbon chronology (n= 17 dates).

III- Grammar errors across our manuscript:

a-) Page 10, line 24: 1350 to 1150: for reasons presented in the section “Comments on the chronology” we keep the hiatus chronology at “1350-1050”.

b-) Page 11, line 14: we have changed "argue" for "argues"

c-) Page 11, line 21: we have changed “analyses” for “analysis”

d-) Page 18, line 23: we have changed “led” for “lead”

e-) Page 19, line 25: we have changed “argue” for “argues”

References

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