## Author's response to Martin Grosjean (Editor) 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 your observations and recommendations. These certainly improve our manuscript. We have incorporated all them in the revised version of our report.

***I- Scientific comment:*** *I am not really sure and convinced that the picture of humidity changes is as consistent as it appears from the text (e.g. Fig. 5) and coincides with the periods RWP and DACP (the MCA and LIA are ok). The series presented in Fig. 5 seem at least partly inconsistent (at least for the MCA and the early RWP the C/N data show a different picture than the other proxies, the SSTs do not show any change prior to ca 600 BP). Also it appears from the distribution of the $^{14}C$ data presented, that the wet periods coincide rather with the TRANSITIONS from the Iron Age to the Roman Age (2200- 2300 BP) and from the RWP to the DACP than with the periods per se. Judging from the $^{14}C$ data distribution (Fig 5), I would conclude that most of the RWP was dry in QM/Ramaditas in N-Chile, but certainly the ONSET was wet (as you correctly state on page 3178 L 23)*

**Reply:** We believe that there are two different aspects that need to be treated differently as done below.

**On the relationship between QM hydroclimate anomalies and C/N record from Laguna el Junco:** C/N ratios in sediments from El Junco Crater Lake are not well resolved for the period between 2100-900 cal. yr BP and furthermore shows very little variation during this interval. This would imply a remarkable (and suspect) stability of the hydroclimate at Galápagos. Following the reasoning presented in the section 4.3 of our manuscript ("What drives the long-term hydrological and ecological dynamics of the PdT system?") we have replaced the C/N curve for the clay percentage curve which is also available for Laguna El Junco (Conroy et al., 2008). This proxy

co-varies positively with C/N ratios but is better resolved temporally and evinces important rainfall anomalies at the site during the past 2500 yrs.

**On the extent and expression of the RWP at QM:** Yes, the editor is correct. Both wetter periods evinced at QM prior to 1350 cal. yr BP occur during the transitions between the Iron Age-RWP and the RWP-DACP. In the original manuscript we left the impression of an overall positive hydroclimate anomaly during the RWP even though our record is not continuous for this period. Hence, we tied positive hydroclimate anomalies detected at 2500-2040 and 1615-1350 cal. yr BP to the intervals **"**RWP onset" and "RWP-DACP transition", respectively. This new description (last paragraph of section 4.3) corresponds better with the actual data shown in Fig. 5A.

**II- Technical comments**

**Comment 1:** 3168 Line 11: I would clarify that these periods are understood as chronostratigraphic periods rather than global expressions of climate anomalies.

**Reply:** We have modified the corresponding phrases as follows: "*Paleoclimate evidence for the past centuries is now reaching a certain level of consensus regarding the temperature and/or hydroclimatic anomalies that were global in extent. In particular, during those intervals often included within broad definitions of the Roman Warm Period (RWP; 2200–1500 cal. yr BP), Dark Ages Cool Period (DACP; 1500-1000 cal. yr BP), Medieval Climate Anomaly (MCA; 1050-600 cal. yr BP) and Little Ice Age (LIA; 600-100 cal. yr BP)…. "*

**Comment 2**: 3170 line 17 check syntax

**Reply:** The phrase syntax was corrected as follow: **"**The southernmost PdT is completely separated from the high Andean basins by the Sierra Moreno. Hence, local hydroclimatic and

ecological patterns are strongly tied to summer rainfall variability along the central Andean highlands."

**Comment 3:** 3171 line 3: triggered (?).

**Reply:** we have changed "trigged" for "triggered".

**Comment 4:** 3171 line 6: .. global. . .? I don't think this claim can be made. It would mean that the climate history of QM could be used as a predictor for global climate . . . replace with <regional>.

**Reply:** You are certainly right! As the sentence is written, our statement is quite exaggerated. We corrected the corresponding phrase to read: "*Paleoclimate reconstructions for the inactive canyons from the southern PdT basin thus represent established proxies for evaluating the hydrological response of the central Andes to global centennial-scale shifts in climate*".

**Comment 5:** 3176 L21: explain the first time m.b.g.l.

**Reply:** In the revised version of our manuscript we have included an explanation for the abbreviation mBGL (meters below ground level).

***Comment 6:*** *3178 L9: archaeological*.

**Reply:** we have changed "archaelogical" for "archaeological".

***Comment 7:*** *3179 L16: do Bird et al 2011 make any statement about temperature? I don't think so (at least could not find anything)*

**Reply:** In the revised manuscript we have deleted the reference to Bird et al. 2011. Apart from Neukom et al. 2010 we have provided two more appropriate references (Ljungqvist, 2010; Mann et al., 2008) for the statement in page 3179, line 16.

***Comment 8:*** *3179 L27: I don't think we have made this statement; our statement holds rather for the second part of this sentence.*

**Answer:** This was an inadvertent mistake that slipped through our final edits. We have corrected the reference for the first part of the sentence (for sustained climate stability at the Altiplano over the past 3000 years) attributed to Baker et al. 2005 and added the Grosjean et al., 2001 paper to back the statement regarding negative moisture anomalies over the last 3000 yrs where it is more appropriate (also see our reply to Comment 9).

***Comment 9:*** *3080 L8: .. preceded the LIA ? The wet period at Pumacocha lasted throughout the LIA. I think it should be noted that the Pumacocha record shows largely the opposite of QM for the LIA and the MCA, before that the Pumacocha record remained remarkably stable (no changes). This is interesting, because according to Garreaud et al 2009 (Figs 8 and 10) precipitation in both localities (QM and Pumacocha) are positively correlated with the MEI (certainly for DJF which counts, JJA and SON are largely irrelevant). In consequence one would expect a positive correlation in the humidity changes in both areas. (I read again in detail the Bird et al paper and think the line of argument about the influence of ENSO is inconsistent). In my view the long-term changes in the PP regime in parts of South America have more to do with changes in the PDO, which has a very similar spatial structure and expression as ENSO (see also Garreaud et al 2009).*

**Answer:** We totally agree. Your suggestion has been incorporated in the revised text. So, the revised paragraph regarding the observed discrepancies between our record and existing

paleoclimate reconstructions from the Altiplano now reads: "*Many paleoclimate reconstructions from the central Andes, however, do not agree or are inconclusive regarding our chronology of hydroclimate changes. For example, limnogeological records from the Altiplano indicate that present-day conditions have remained stable over the last 3000 years (e.g, Baker et al., 2005) or that the centennial-scale variability over the last two millennia* was marked predominantly *by negative precipitation anomalies (e.g, Grosjean et al., 2001). Peaks in inorganic concentrations and Cyperaceae pollen analyzed in a core retrieved from the Marcacocha basin (13ºS; 3355 m asl) have been interpreted as evidence for negative rainfall anomalies at 2450; 1850; and 1400 cal. yr BP and during the entire interval encompassing the MCA and the LIA, ~1050-150 cal. yr BP (Chepstow-Lusty et al., 2003). Similar conclusions were reached for the Titicaca basin record (16ºS, ~3810 m asl) which shows three dry events at 2400-2200; 1900-1700 and 900-600 cal. yr BP, the latter followed by a period of increased moisture throughout the LIA (Abbott et al., 1997; 2003; Mourguiart et al., 1998). Contrasting hydroclimate conditions have been also inferred from a calcite record recovered from varves at lake Pumacocha (10ºS, 4300 m asl) during the MCA and LIA intervals (Bird et al., 2011). Modern inter-annual precipitation variability at Pumacocha is under the same climate regime as the QM headwaters (Garreaud et al., 2009), yet increased* $\delta^{18}O_{calcite}$ *in the lacustrine sediments suggest that the Peruvian Altiplano experienced dry conditions during the MCA (1050-850 cal. yr BP; Bird et al., 2011). In contrast, negative values in* $\delta^{18}O_{calcite}$ *by 650 -130 cal. yr BP argue for maximum precipitation throughout the LIA (Bird et al., 2011).*

**Comment 10:** 3181 L 21: PdT

**Reply:** we have changed "PDT" for "PdT".

**Comment 11:** References: check upper and lower case and formatting!

**Reply:** reference format was corrected accordingly in the revised version of our manuscript.

**Comment 12:** Refs: check if <Latorre et al 2005> is quoted in the etxt (I might have missed it).

**Reply:** This citation was quoted either in the text and reference section of our previously submitted manuscript.

**Comment 13:** Include McCormac et al 2004.

**Answer:** we included this citation within text and references of our revised manuscript.

**Comment 14:** Rein et al 2004 or 2005 (as in txt – caption Fig 5).

**Answer:** lithic concentrations from the sediment core collected offshore central Perú are reported in Rein et al. 2005 - as stated in the figure's caption-. So, within the revised text we have replaced "Rein et al. 2004" for "Rein et al. 2005".

**Comment 15:** Fig 1: the Nr 1 (left hand side of the light blue line) is very difficult to read in b/w.

**Answer:** According to the Editor's suggestion we chosen a compatible b/w color for numbers and the line that describe the elevational transect shown in Figure 1.

**Comment 16:** Fig 2: maybe mark the terraces in the picture.

**Reply:** we have marked both terraces that appear in the panoramic photograph shown in Figure 2.

**Comment 17:** Fig 3: legend: . . . containing rodent . . .

**Reply:** we changed "containg" for "containing"

**Comment 18:** Fig 4: yes this is very small! Fig 4c: Horizontally laminated silts.

**Reply:** we have reduced the number of photos in Fig. 4 to make it more effective and moved the

remaining images into an appendix. (Appendix A). In the legend of the stratigraphic section for QM-26 deposit (now Figure A2, Appendix A) we changed "Horizontally laminated sits" for "Horizontally laminated silts".

**Comment 19:** Fig 5c SST Aug (C◦).

**Reply:** we replaced "SST aug (ºC)" with "SST Aug (Cº) in the ordinate axis label for the Vøring Plateau SST record.

**III- References**


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