Author's response to Referee #1

We thank Referee # 1 for such a detailed and careful review and for all constructive comments and suggestions. These have been taken all into consideration and have significantly contributed to improve the quality of the revised version. We list below comments and corresponding responses to each point raised.

The Referee's comment below are in italics and our answer in bold font.

- *One of my main concerns is that bisaccate pollen with its particularly excellent eolian transport characteristics accounts for 80% of the pollen sum in several samples, and not only in the lower part of the record, which means that the counting sum for the remaining pollen types is only 60 grains... Thus, I wonder how robust the pollen signal is. In a marine record, you would probably exclude Pinus/bisaccate pollen – I am not sure if this would not also make sense in case of Laguna Hondera, since I would expect this pollen type to be overrepresented. At least, you should discuss aspects like eolian transport affecting the pollen data.*
  We agree that bisaccate pollen is indeed favoured by wind transport and has a larger dispersal area than other tree species. Nevertheless, the higher concentrations of *Pinus* in the LH record make sense as they occurred during the Early Holocene and the Iberian Roman Humid Period (IRHP), the two warmest and most humid periods in the whole Holocene. Laguna Hondera is located at 2899 masl only 99 m above of the upper boundary of the oromediterranean belt (between around 1900-2800 masl) where *Pinus sylvestris* is the main tree species. Therefore, this apparently anomalous high concentration may be caused by an upward migration of the oromediterranean belt and treeline towards higher elevations and around the LH during these warmer periods, which could have been overstate due to the high pollen-production and dispersal of *Pinus*. For this reason we think that we should not exclude *Pinus*/bissacate pollen from the total sum, because we are recording a regional climatic signal, without allocthonous influence. In any case, we have expanded the discussion about the possible effect of enhanced wind conditions during those times, affecting the amount of *Pinus* pollen input into the LH site (see comment below).

- *Eolian transport is often discussed in the MS in context with the geochemical data, but, if I have not missed it, not in context with the pollen signal. I could for example imagine that even minor changes in wind direction may lead to significant signals in the Pinus signals. Maybe there is even the possibility to use the geochemical data to get an idea how wind direction and energy changed over time? It is unfortunate that the pollen preservation and sample density is not high in the lower part of the record, it seems to me that otherwise you could find a correlation between K/Ti and tree pollen.*
  This comment about wind direction changes is very interesting. However, it is difficult to find proxies to solve this question. The oromediterranean vegetation belt, rich in *P. sylvestris*, occurs in Sierra Nevada in all directions surrounding the studied site and if any change in wind direction occurred, the lake would have received the same amount of *Pinus* input (See Fig.1). Furthermore, there is a moderate anticorrelation between *Pinus* and Zr (r=-0.51; p=<0.01) and no correlation between *Pinus* and Ca (r=-0.12; p=0.46). This suggests that the abundance of *Pinus* pollen in our lake sediments is not linked to the enhancement of southern winds (which are related with arid conditions) but to warm and humid climatic condition favouring *Pinus* development in the surrounding area. Nevertheless, one factor that could have changed the amount of *Pinus* input in our

record is changes in the <u>wind energy</u>. Since persistent negative NAO results in more humid conditions and higher westerlies influence over southern Europe, the higher presence of *Pinus* in the surrounding area, along with the higher wind energy over Sierra Nevada could have resulted in more bissacate pollen input into our lake. This is consistent with the anomalous high percentages of *Pinus* recorded during the IRHP and support the significance of our pollen data. There is no correlation between *Pinus* and K distribution or the K/Ti ratio, likely because of the reasons that you exposed in your question. We have included a new paragraph in the manuscript with some more discussion about this, lines 268-276.

- *In this context, I also wonder if it is a good move to use the pollen zonation also as a base to describe the geochemical results. Particularly in the lower part, the CONISS based zonation does not seem to be very relevant considering the resulting dendrogram depicted in Fig. 3.*

  Yes, we fully agree. We rewrote the geochemical results without using the pollen zonation. See section 4.4.

  Additionally, I cannot completely follow the zonation as described in the text, I think there are discrepancies with the cluster analysis.

  We have simplified the zonation in order to make the text more comprehensible. See discussion below.

Others remarks about the text.

- *Line 22 "magnetic susceptibility proxies" makes no sense – this sounds as if you measured a proxy for magnetic susceptibility. Rephrase.* **We rephrased this sentence, see lines 22-23.**
- *Line 22 and following: You state later in the text that the pollen record is not reliable until ~7000 cal yr BP, yet you state here that palynological proxies indicate humid conditions until ~7000 cal yr BP. This should be rephrased. Generally, I would not introduce abbreviations in the abstract.* **We totally agree, we removed "palynological proxies" and rephrased the sentence. Abbreviations were removed from the abstract, see lines 22-24.**

2.1. Regional climate and vegetation

- *Line 79: "… which in turn controls…" If this relates to "altitudinal contrasts", the verb should be in plural.* **We rewrote the verb in plural. See line 78.**
- *Line 86: "(1900 -2800 m)" – blank space behind "-"***The blank space was removed, see line 84.**
- *Line 86 and Line 89: The "," behind the brackets should be removed.* **The "," was removed. See lines 85 and 87.**
- *Line 89: Here, a long dash is used (600 – 1400 m).* **We changed it to short dash, see line 87.**

2.2. Laguna Hondera

- *Sometimes there is a blank space between value and unit ("2800 m"), sometimes not ("3366m"): Make it consistent.* **We put a blank space between value and unit. See lines 96-102.**

3.2 Pollen

- *Consider my general comment above: The counting sum is generally okay, but with both bisaccate and Poaceae included, it is not that impressive. I must also admit that I find it difficult to separate Olea pollen from, e.g., Phillyrea, at only 400x magnification. Since Olea is important for the discussion and even mentioned in the abstract, and other Oleaceae are not mentioned in the pollen diagram, it might be interesting to show an encountered Olea grain in the supplements and/or to discuss how Olea was differentiated.* **We agree that sometimes it is difficult to differentiate *Olea* from other Oleaceae at 400x magnification. We added a paragraph explaining how we differentiated *Olea* and also added a reference. See lines 127-129.**
- Line 127: "Typha" should be in italics. **"Typha" was changed by "*Typha*". See line 124.**
- *Line 127/128: "… plotted using Tilia program…" This does not sound like proper English to me.* **We rewrote the sentence. See lines 125.**
- *Line 129: Maybe a few more sentence to the cluster analyses could help. I was not aware of CONISS until now and learned from Grimm (1987) that normally the used algorithm operates on a dissimilarity matrix of squared Euclidian distances. Was this the case in your analysis? Did you do an unconstrained analyses to control your results? Generally, I wonder if it makes sense to use the algorithm of Grimm (1987) with a dataset in relatively low resolution and at the same time significant variance between stratigraphically neighboring samples (in the lower part at least), but this is probably a matter of taste and you mention the problem later to some degree...* **We specified that we used an age constrained analysis. See lines 126.**
- *Was this the case in your analysis?* **Yes, the program generates a dissimilarity matrix of squared Euclidean distance between the samples.**
- *Did you do an unconstrained analyses to control your results? Generally, I wonder if it makes sense to use the algorithm of Grimm (1987) with a dataset in relatively low resolution and at the same time significant variance between stratigraphically neighboring samples (in the lower part at least), but this is probably a matter of taste and you mention the problem later to some degree...* **We did an age constrained analysis. Visual observations confirm CONISS analyses, so we believe that CONISS works for this dataset of samples. We used CONISS because it seems to work well in most of the published pollen studies, which reconstruct fossil pollen assemblages using it.**

3.5 Statistical Analyses

- *Line 156: "PCA finds…" Is this proper English? A few more details may be interesting. What was used, R-mode or Q-mode?* **We rewrote this sentence and specified the mode used. See lines 153-154. The mode used was R-mode because we applied the PCA to variables, not to samples.**

4.2 Chronology and sedimentation rate

- *Line 169: "The age model" instead of "The age –model".* **We removed the "–". See line 167.**

4.3 Pollen

- *Generally, I think there are too many pollen zones based on the cluster analyses. Instead of 6-7 zones, I would rather suggest to reduce this to 4 zones considering the distances shown in Fig. 3. Or perhaps you should use another way to define the zones.* **We agree with this suggestion and we reduced to 4 the number of pollen zones.**
- *Line 183: I am not sure if I misunderstand something here: In Fig. 3, to me there seem to be two samples within Zone LH-1. A third sample is just above the borderline to Zone LH-2. This makes also sense since the dendrogram in Fig. 3 implies that the two lowermost samples are grouped together, while the third sample from below is more similar to the samples in LH-2. One factor which might cause this is the high abundance of Asteraceae in the two lowermost samples. However, in the text, it is mentioned that three samples define the lowermost zone (LH-1), and this is repeated*

later in line 311. This is of importance since the pollen zonation is also used for the interpretation of the geochemical data. In this context: The zone borderlines in Fig. 4 are at slightly different depths than in Fig. 3 (see below). **We changed the zonation (see above) and we decided not to use the pollen zonation for defining the geochemical results.**

- *Line 186: "takes place" sounds strange to me in this context.* **We changed it by "is identified". See line 186.**
- *Line 187: "Caryophyllaceae": I am not sure about the grammar here – while you can read many English texts using family names in singular, I still think it should be used as a plural form. In any case, here and in the following cases, it would probably be best to combine the family name with "pollen" or "pollen grains", in this case e.g. "Caryophyllaceae pollen" with singular or "Caryophyllaceae pollen grains" with plural.* **We agree, we used the plural form in the entire manuscript, because we are alluding to "(Caryophyllaceae) pollen grains".**
- *Line 191: "Quercus" should be in italics. And (see above) it may be clearer to write "Quercus pollen".* **We wrote *Quercus* in italics. See line 189.**
- *Line 193: "is less" does not sound like proper English to me.* **We rewrote this sentence. See line 190.**
- *Line 196: "Zone LH-3:… is defined primarily by a great increase in Poaceae pollen: …" This is confusing. Is it possible with CONISS to check which parameters influenced the resulting cluster more or less? Or did you make a control test without Poaceae pollen? (You are probably right, but still, I suggest to rephrase this sentence!)***We rephrased it.**
- *Line 201: You can as well remove "in this zone", it is redundant.* **We removed it.**
- *Line 210: Maybe I completely misunderstand how the cluster analysis is used. According to the dendrogram in Fig. 3, Zone LH-6A appears to be more similar to Zone LH-5 than to Zone LH-6B. Following the analyses, LH-6A should rather be LH-5B… Or did you have additional reasons to combine 6A and 6B? But then, this should be explained.* **We changed the zonation according to your previous suggestion.**
- *Line 210: Here and in Fig. 3, capitalized As and Bs are used for the subszones (LH-6A and LH-6B), but in the results concerning the geochemical data, the subzones are named LH-G6a and LH-G6b. Furthermore, in Fig. 4, there is no "G" in front of the subzone number.* **We removed the zonation concerning the geochemical data (see the previous comment).**

4.4 Sediment composition

- *Line 218: "… makes it important…" Sounds strange to me.* **We rephrased it. See line 213.**
- *Line 224/225: "… or high organic and water content that increase…" Not sure here, but I guess either "contents" or "increases".* **We corrected the orthography. See line 219.**
- *Line 249: Remove blank space after "~". Considering the geochemical data, it may make sense to have a subunit LH-6A, but as mentioned above, I think this is not really supported by the pollen data. Would it make sense to define units using both pollen and geochemical data?* **We decided do not to use the pollen zonation for defining the geochemical data.**

5. Discussion

5.1.1.

- *Line 311: See above: Why three samples?* **In this case we are describing the interval between 10800 and 7000 cal yr BP and this period only includes three pollen samples.**

5.1.2.

- *Line 383: The mentioned peak in Artemisia is quite weak, I think, and only consists of one sample. There are much stronger peaks above…* **We agree and removed the mention to this *Artemisia* peak as suggested.**

5.1.3.

- *Line 421: I think this is a good example for the "Pinus problem": In the short interval between 2300 and 1800 cal yr BP, I cannot really see the decreasing trend in tree pollen that you postulate, instead, I just see fluctuating tree pollen percentages, and this may be partly caused by pollen transport effects (e.g. changes in wind direction). Maybe the longer interval from 2500 to 1200 cal yr BP in total reflects a decrease in tree pollen (but with fluctuations).* **We rewrote this sentence, but we have no enough information supporting the "changes in the wind direction" hypothesis. See line 432-438.**
- *Line 421: "… between 2300-1800…" I would either suggest "between 2300 and 1800 cal yr BP" (add the unit!) or "from 2300 to 1800 cal yr BP". This is also occurring earlier (e.g. Line 384). But maybe it is all right the way used in the MS if it fits with the style of CoP.* **We changed the dash between ages by "and" thoughout the entire manuscript.**

5.1.4. and 5.1.5.

- *I think interpretation becomes "stronger" (if you like) in these sections, not least since the pollen data is probably more robust here. However, concerning section 5.1.4., I wondered if it is not possible to discuss differences between LH and the other mentioned records instead of just mentioning that there were arid conditions "everywhere". What differentiates your pollen record from other records from the western Mediterranean region, and how can these differences be explained?* **We have compared our record with other Iberian records showing opposite trends and we have justified these discrepancies. We have also included new references. See lines 462-470.**

Conclusions

- *Line 543: Add "at" before "~" and remove the blank space behind "~". Again, the "between XXXX-XXXX" problem occurs here several times.* **We add "at" before "~" and removed the blank space behind "~". See line 538.**
- *Line 554: replace "is" with "are".* **We removed this sentence.**

Acknowledgements

- *Line 568: Replace "acknowledge" with "acknowledges".* **We replaced "acknowledge" with "acknowledges". See line 562.**

References

- *In some cases, there are blank spaces between the initials, in some cases not.* **We made it consistent.**

Figures

- *The abbreviation "LH" should be explained in the figure texts, even if it is already explained in the main text, too, since figure texts should be understandable on their own.* **We have explained the abbreviations.**

Figure 1:

- *The figure is quite fancy, but printed (particularly in black and white), it is difficult to see what it is depicted. I would prefer outlined maps instead of the first two photos. But this is rather a remark, since it is a matter of taste.* **We appreciate the comment but in online versions figures are in color. In any case we have added a sentence referring the reader to the web version. See lines 1032-1033.**

Figure 2:

- *I think some texts are too small here, e.g. "Age " and "Depth".* **We have enlarged them.**

Figure 4:

- *It is a little confusing that you use 4 cm steps here for the depth scale, but 5 cm in figure 3. The pollen zones seem to be slightly shifted compared to Fig. 3, e.g., the borderline between zone 3 and 4 seems to be at 38 cm in Fig. 3, but 36 cm in Fig. 4. Similarly, the borderline between zones 2 and 1 seems to be at 60 cm in Fig. 3, but at 59 cm in Fig. 4. The names of the subzones differ from Fig. 3 (see above). Figure text: "Pollen zonation*

described in section 4.3 was used." Is this proper English? **We used 5 cm steps for the depth scale of both, figures 3 and 4. The zonation was removed in order to simplify the figure.**

Figure 7:

- *"Quercus" is not in italics in all cases. "Artemisia" is not in italics in the figure text.* **We changed them to italics**

Figure 8:

- *The yellow scales are quite close to each other.* **We separated the yellow scales.**