Historical Climate off the Atlantic Iberian Peninsula

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Rebuttal to Referee # 1

The authors want to thank referee 1 for the careful revision and all the given input.

Minor comments were all taken into consideration. The major comments relate to 4 different aspects, and are discussed below.

1 – Substitute NAO reconstruction of Trouet et al, (2009) by the more recent reconstruction done by Ortega et al., (2015) using more advanced methods, in figures 4 and 5.

Figures 4 and 5 contain the instrumental record, as well as Luterbacher et al (2002), Cook et al., (2002) and Trouet et al., (2009) reconstructions. The reconstruction of Ortega et al., (2015) has been plotted in Fig. 1R1 for comparison with the previous, and will be included in the revised version of this paper. The difference between the reconstructions of Ortega and Trouet's is mainly in terms of magnitude and for the period 1100 to 1420 CE. However, the NAO index is still positive for most of the MWP, as such, it has no influence on the discussion and conclusions of this study.

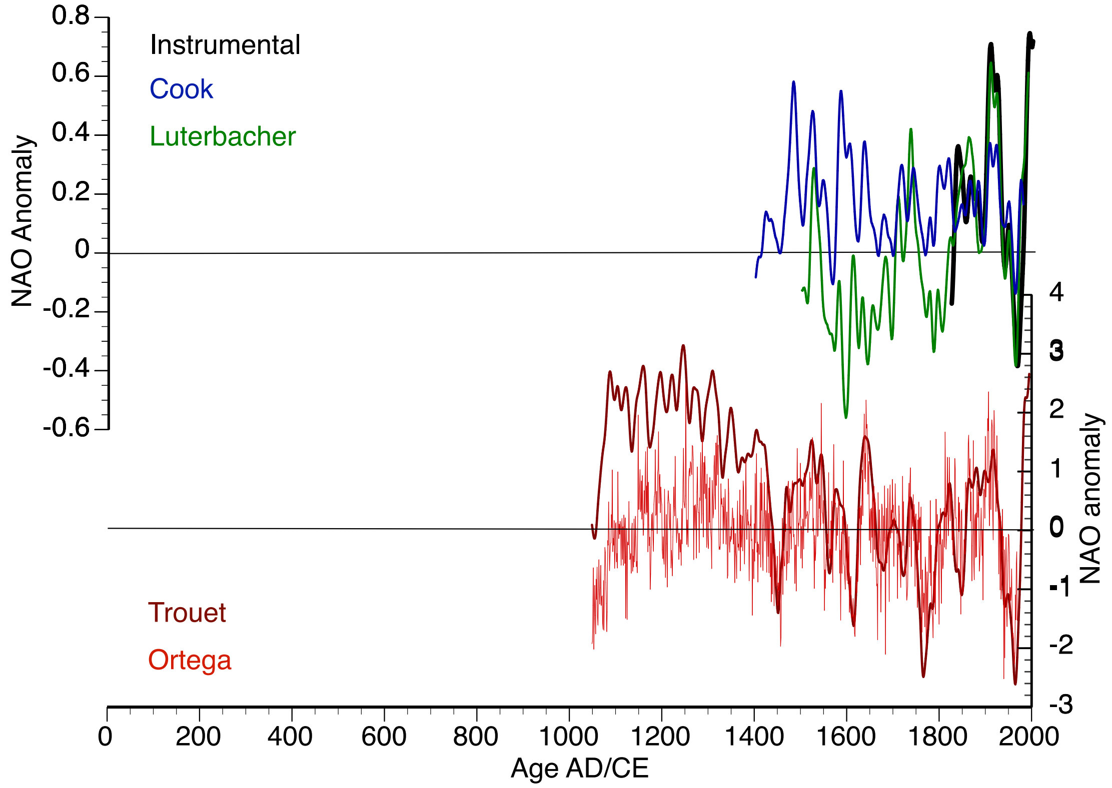

Figure 1R1 - NAO index Instrumental, Cook et al. (2002), Luterbacher et al. (2002), Trouet et al. (2009) and Ortega et al. (2015).

2 - The need to prove the relative importance of EA and SCAND for the precipitation and temperature regimes at the selected locations, and the need to include a reconstruction of the two atmospheric circulation modes or in turn, the relationship between winter precipitation and temperature from the locations of the study sites (Porto, Minho, Targus, Algarve) and the NAO, EA and SCAND atmospheric teleconnection patterns for the 1951-2010 period, either as a spatial correlation map or in a numerical table.

To our knowledge, no reconstructions are yet available for either EA or SCAND, and the existing records only cover 1951 to present (Fig 2R1). As to the regional effect of all three modes of atmospheric circulation (NAO, EA and SCAND) on the SST and precipitation for both winter and summer conditions over the Iberian Peninsula, it has been determined by Hernández et al., (2015) and is presented in their figure 5 (Hernández et al., 2015). In our discussion (pg 14 ln 27-28), such figure (reproduced below) is used to justify our proposal of a positive SCAND mode to explain the strong precipitation in the north of IP but not in the south.

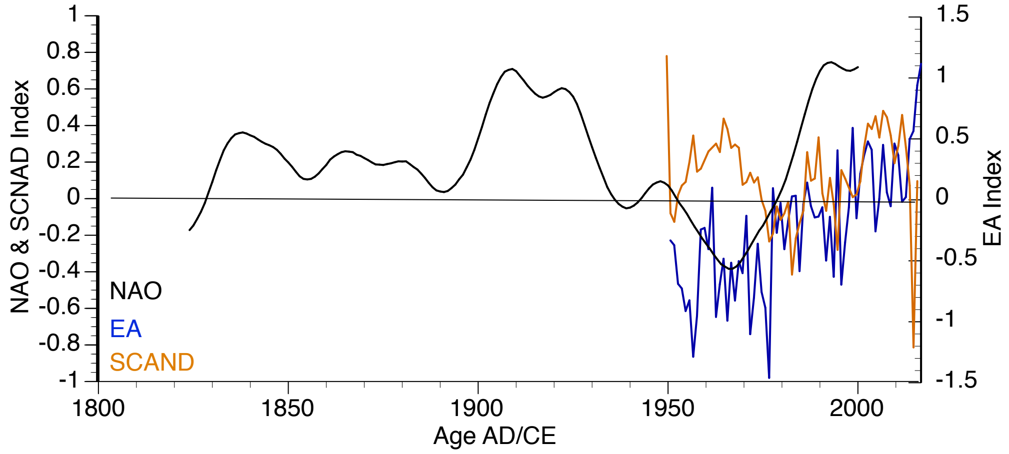

Figure 2R1 – Instrumentally derived NAO, EA and SCAND index.

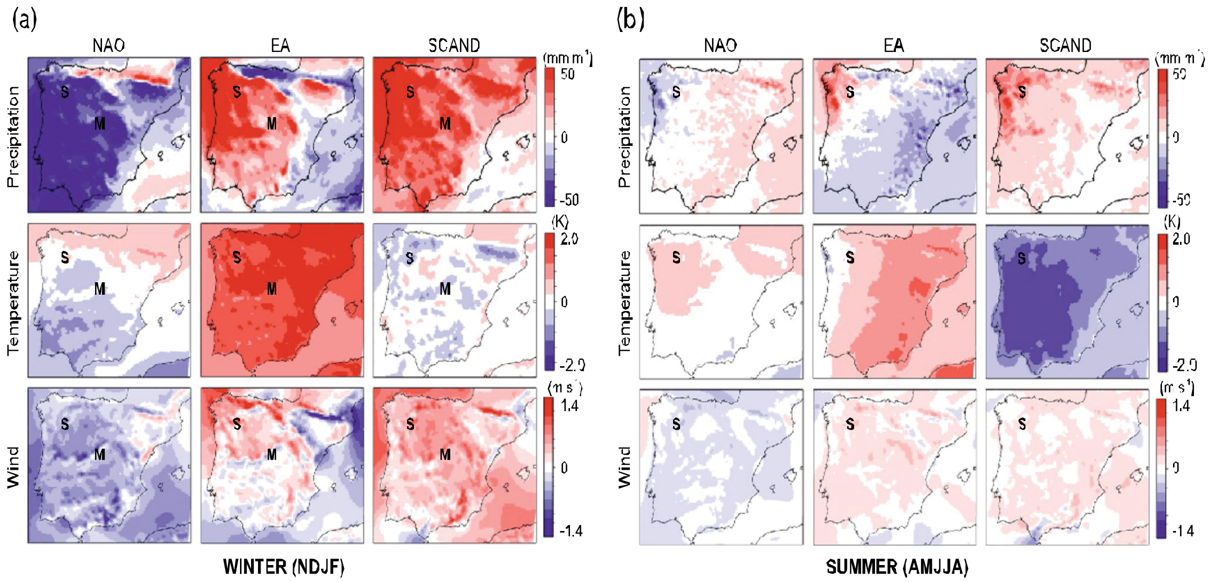

Fig 5 of Hernandéz et al., (2015) NAO, EA and SCAND modes on the mean precipitation, temperature and wind speed. 1 month lag time winter months (NDJF avg), and summer months (AMJJA avg).

3 – The inclusion of the previously published Galicia records from the Ria de Ria de Vigo and Ria de Muros.

The authors are well aware of the existence of these sedimentary sequences and their value. However, the decision to not include them in our STACK was based on two reasons:

- Both of them were recovered in enclosed environments with an estuarine type of circulation, mainly driven by tides and freshwater discharge (Prego and Bao, 1997). That is, an environment quite different from the open ocean sites compiled in this study. Furthermore, the Vigo site was a restricted environment where the exchange with open ocean waters was diminished before 1000 AD (Diz et al., 2002).

-The SST record for the Ria de Muros is estimated from diatoms through the use of a regional transfer function, and the use of SST estimates from different proxies as interchangeable is known to be problematic (Lawrence and Woodard, 2017).

As such, neither of the records could be considered for the construction of the stack, but can certainly be used for comparison with the records and the STACK presented in this study, as shown in Fig. 3R1.

Vigo SST values are comparable to the Porto site (blue), furthermore, SST's are quasi-constant throughout the first 1300 CE, when SST starts to decrease in Vigo. However, lower SSTs in the Rias de Vigo and Muros appear to record the late

LIA minima associated to the Sporer and Maunder solar minima, while the IP oceanic records considered in this study show also the Wolf minimum.

Of major importance is the fact that the results do not contradict the oceanic IP observations and do not change our conclusions.

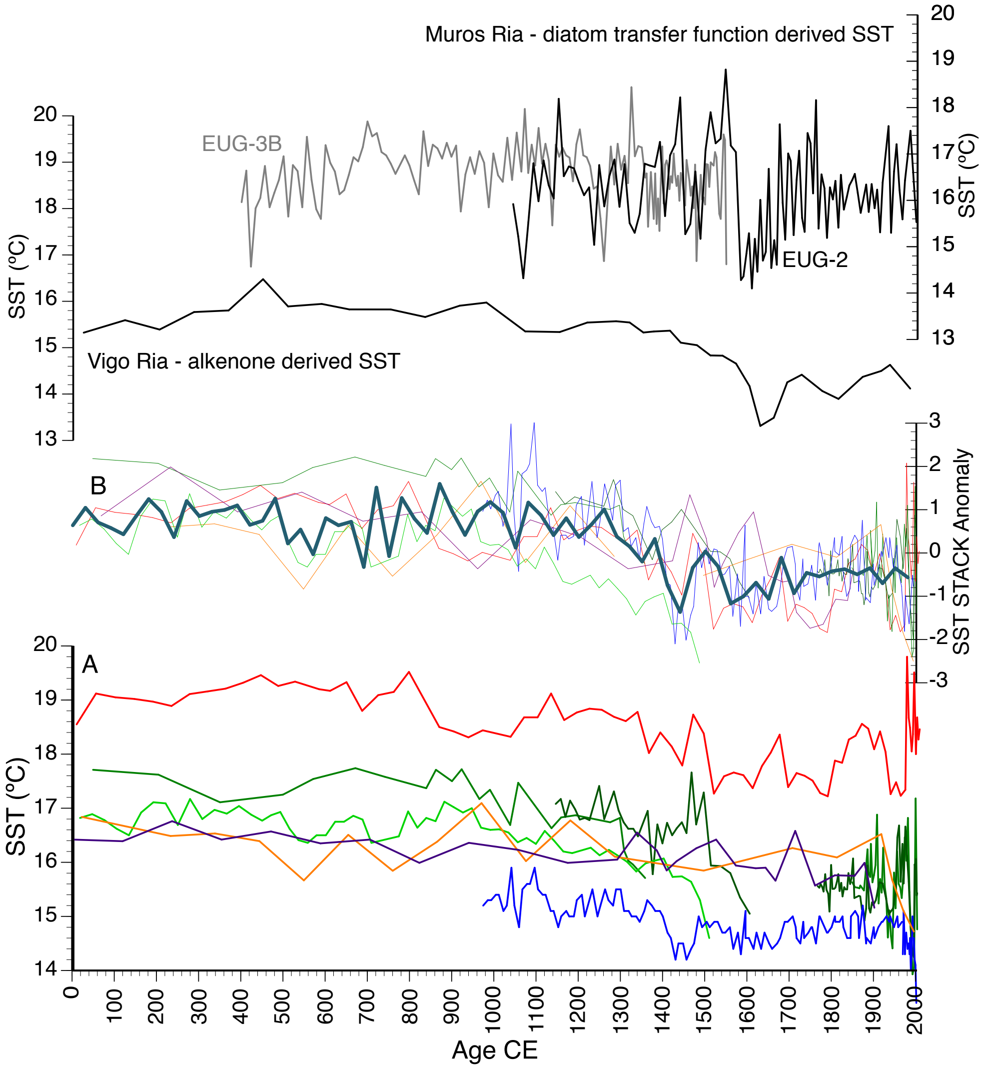

Figure 3R1 – Comparison of the SST records of the various cores (A) used for the Iberian Margin STACK construction (B), with the Ria de Vigo Ria alkenone-derived SST and the Ria de Muros diatom-derived SST for sites EUG-2 and EUG-3B (Stroynowski, 2009).

In which respects the pollen record, TPC is not available for the Ria de Vigo but the good agreement of the pollen composition in Vigo (Desprat et al., 2003) and the new records is referred in section 5.2 of our manuscript, but the record is indeed not shown in our Figure 6. Figure 4R1 shows the comparison of Desprat et al, (2003) data to the new data produced as part of this study.

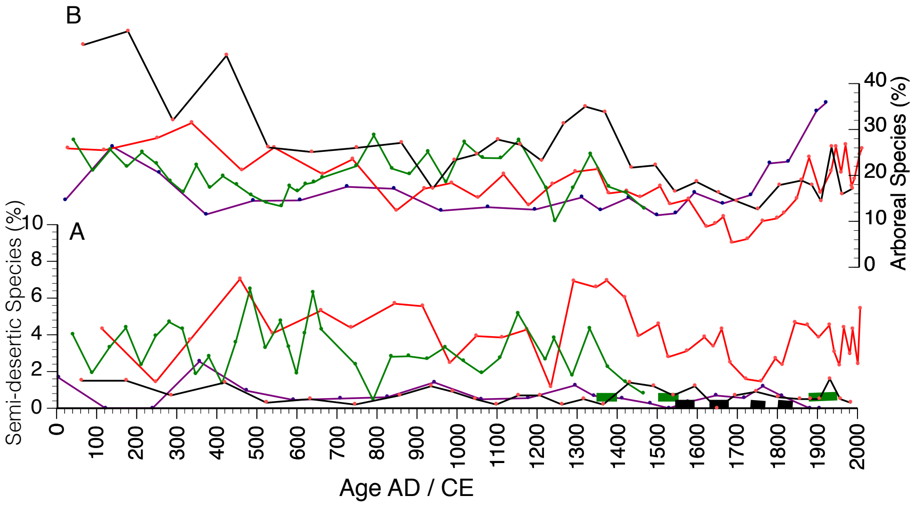

Figure 4R1 – Variability of the semi-desertic plants percent abundance (A); arboreal species percent abundance (B) along cores Minho, Tejo, Algarve and Vigo (black line);

The arboreal pollen (AP) percentage data from the Vigo record fits the general tendencies shown by the Minho, Tagus and Algarve sites. Higher abundances, in particular before 1,000 CE, can be inflated by the sedimentation conditions within the closed environment of the Ria particularly between 0 and 1,000 yr.

The very low contribution of the semi-desertic species in Vigo, come as further confirmation that the southern sites are drier than the North of Iberia.

4 – A better justification for the use of [n-alk] as a proxy for on-land precipitation.

n-alkanes ([n-alk]) are long linear chain lipid molecules that mostly originated from cuticles of the vascular plants, which concentration in oceanic sediments have been widely used as a proxy for river discharge (e.g. (Farrington et al., 1988; Pelejero and et, 1999; Prahl et al., 1994). Furthermore, previous work on Iberian Margin has shown a good agreement between [n-alk] and River flux (Abrantes et al., 2005; Rodrigues et al., 2009). However, the authors agree with the referee, for the need of a more robust regional calibration for this proxy. That can be accomplished through the comparison of the [n-alc] data obtained for the most recent sediments of the Porto, Tejo and Algarve sites to the average river runoff for the Douro, Tejo and Guadiana Rivers during the NAO winter months (DJFM). The results reveal a Pearson correlation of 0.54 at p>0.01 and n=47, confirming it as a good proxy to evaluate the intensity of River runoff on the Iberian Peninsula.

References

Abrantes, F., Lebreiro, S., Rodrigues, T., Gil, I., Bartels-Jónsdóttir, H., Oliveira, P., Kissel, C., and Grimalt, J. O.: Shallow-marine sediment cores record climate variability and earthquake activity off Lisbon (Portugal) for the last 2,000 years., Quaternary Science Reviews, doi: 10.1016/j.quascirev.2004.04.009, 2005. 2005.

Cook, E., D'Arrigo RD, and ME, M.: A well-verified, multiproxy reconstruction of the winter North Atlantic Oscillation index since A. D. 400, J. Clim., 15, 1754−1764, 2002.

Desprat, S., Sánchez Goñi, M. a. F., and Loutre, M.-F.: Revealing climatic variability of the last three millennia in northwestern Iberia using pollen influx data, Earth and Planetary Science Letters, 213, 63-78, 2003.

Diz, P., Francés, G., Pelejero, C., Grimalt, J. O., and Vilas, F.: The last 3000 years in the Ría de Vigo (NW Iberian Margin): climatic and hydrographic signals, The Holocene, 12, 459-468, 2002.

Farrington, J. W., Davis A. C., Sulanowski J., McCaffrey M. A., McCarthy M., Clifford C. H., P., D., and K., V. J.: Biogeochemistry of lipids in surface sediments of the Peru Upwelling Area at 15°S. , Org. Geochem. , 13, 607-617, 1988.

Hernández, A., Trigo, R. M., Pla-Rabes, S., Valero-Garcés, B. L., Jerez, S., Rico-Herrero, M., Vega, J. C., Jambrina-Enríquez, M., and Giralt, S.: Sensitivity of two Iberian lakes to North Atlantic atmospheric circulation modes, Climate Dynamics, 45, 3403-3417, 2015.

Lawrence, K. T. and Woodard, S. C.: Past sea surface temperatures as measured by different proxies—A cautionary tale from the late Pliocene, Paleoceanography, 32, 318-324, 2017.

Luterbacher, J., Xoplaki, E., Dietrich, D., Jones, P. D., Davies, T. D., Portis, D., Gonzalez-Rouco, J. F., von Storch, H., Gyalistras, D., Casty, C., and Wanner, H.: Extending North Atlantic Oscillation Reconstructions Back to 1500, Atmospheric Science Letters, 2, 114-124, 2002.

Ortega, P., F. Lehner, D. Swingedouw, V. Masson-Delmotte, C.C. Raible, M. Casado, and Yiou, P.: A model-tested North Atlantic Oscillation reconstruction for the past millennium, Nature, 523, 71-74, 2015.

Pelejero, C. and et, a.: The flooding of Sundaland during the last deglaciation: imprints in hemipelagic sediments from the southern South China Sea, Earth and Planetary Science Letters, 171, 661-671, 1999.

Prahl, F. G., Ertel, J. R., Goni, M. A., Sparrow, M. A., and Eversmeyer, B.: Terrestrial organic carbon contributions to sediments on the Washington margin., Geoch. Cosmochim. Acta, 1994. 1994.

Prego, R. and Bao, R.: Upwelling influence on the Galician coast: silicate in shelf water and underlying surface sediments, Continental Shelf Research, 17, 307-318, 1997.

Rodrigues, T., Grimalt, J. O., Abrantes, F. G., Flores, J. A., and Lebreiro, S. M.: Holocene interdependences of changes in sea surface temperature, productivity, and fluvial inputs in the Iberian continental shelf (Tagus mud patch), Geochemistry, Geophysics, Geosystems, 10, n/a-n/a, 2009.

Stroynowski, Z.: A high-resolution climatic study of the Norwegian and Iberian shelves during the late Holocene: a diatom perspective, 2009. Plymouth University, 2009.

Trouet, V., Esper, J., Graham, N. E., Baker, A., Scourse, J. D., and Frank, D. C.: Persistent Positive North Atlantic Oscillation Mode Dominated the Medieval Climate Anomaly, Science, 324, 78, 2009.