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Interactive comment on "Spatial Signature of Solar Forcing over the North Atlantic Summer Climate in the Past Millennium" *by* Maria Pyrina et al.

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The authors would like to thank Referee 2 for agreeing to review the manuscript, as well as for the thorough revision and suggestions.

The authors agree with the reviewer that the low TSI scaling used in the current study is most likely the reason for the signal not appearing robust, but that is the current standard value used for solar forcing in many CMIP5 simulations (Kopp and Lean, 2011; Prša et al., 2016). As the reviewer pointed out, the question whether a solar signal can be detected in NH summer is of interest even if the answer is negative. This result is important in order to support or put into question the interpretation of the solar signal, which as it has been claimed is reflected in proxy records (Jiang et al., 2005;

Moffa-Sánchez et al., 2014; Sejrup et al., 2010).

In the following, we provide a point-by-point answer to the reviewer's comments. Specifically:

1. In the revised version of the manuscript, we will substantiate qualitatively the differences in the methods' results. We will refocus the manuscript, robustly show whether we identify a clear solar forced response in the 1000-year long simulations, and discuss the implications that this might have for comparisons between models and proxy data. We will therefore implement an additional chapter specifically dedicated on the discrimination between internal and solar forced signals. Our null-hypothesis will be that the CESM simulations do not show any response to changes in solar activity. The null-hypothesis will be tested through point wise correlations between the individual CESM ensemble members. The null-hypothesis can eventually be rejected for those regions (taking care of global significance) showing correlations exceeding the 5% significance level. Significant temporal correlations among the members will identify regions that respond to the common forcing. In the case that we identify a robust solar signal, then for determining the time scales of the signal we will additionally use cross-wavelet analysis of the climatic variable and solar forcing, for the NA sub-regions that are indicated by the CESM ensembles as regions with commonly forced signal. To test the significance of the periodicities of the signal, we will investigate the existence of similar periodicities in synthetic time series with prescribed statistical properties.

2. The periods Medieval Climate Anomaly and Little Ice Age were chosen in order to show that it is problematic to identify the solar signal on SSTs during periods which, even though might turn out not to be appropriate for this purpose, they were indeed used by other studies for the investigation of surface response to solar forcing (i.e. Mann et al., 2009; Deng et al., 2017). In the revised version of the manuscript for signal identification, we will use linear methods and composite analysis, but we will exclude the method MCA-LIA. Moreover, we will use a consistent terminology in the updated version and use the term "response" instead of "signal" if changes in solar

activity are evident in climatic variables.

3. The reviewer is correct that we mean that the simulations analyzed here show virtually no robust responses. We will rephrase and use more carefully the language in the revised version.

4. We analyzed diabatic heating from turbulent energy fluxes because the heat extracted from the ocean by the atmosphere is related to the air–sea turbulent fluxes and therefore implies a decrease or increase, respectively, in SST. In the revised version of the manuscript, we will address the robustness of the atmospheric response using the point wise correlations among the CESM ensemble members. As stated previously, the null-hypothesis will be that the CESM simulations do not show any response to changes in solar activity.

5. In a revised version we will cite other studies using the same models or calculate how the ESMs that we used simulate: a) global mean near surface temperature responses to 11-year solar variability b) models' responses in the tropics or NH winter and add supplementary information on the simulation of the NH summer climatological state.

6. Regarding the formulation of hypotheses about the expected responses analyzed with the three different methods, we have explicitly formulated questions (lines 64-65, 359-361). We can extend those questions to expected outcomes (i.e. a direct signal manifested in increased sea-surface or land-temperatures during periods with increased TSI and vice versa) or to other variables such as SLP or geopotential height. However, the response of such variables might be more difficult to hypothesize, as to date no clear hypotheses exist for the summer circulation caused by changes in TSI over the North Atlantic region. If anything, one might use the hypotheses formulated in the context of changes in circulation during winter and test whether similar response can be found for summer.

7. Regarding a time lagged analysis, as stated in the line 411, we have indeed provided with preliminary results. These results do not indicate a lagged response during

summer (SI Figures S14-S16). They indicate that introducing a lag does not change the qualitative nature of our results. In a revised version, we will elaborate more on the results of this analysis. Moreover, the lead-lag issue would implicitly be resolved by the point-by-point correlation analysis among the CESM ensemble members. Assuming that the physical mechanisms leading to different lags in the different regions of the North Atlantic are the same for the different realizations, then the results of the correlations will include spatially different lag structures in the same plot.

8. Regarding composite analysis, we will also add a discussion on the temporal distribution of the years contributing to the composites.

Deng, Wenfeng, et al. "A comparison of the climates of the Medieval Climate Anomaly, Little Ice Age, and Current Warm Period reconstructed using coral records from the northern South China Sea." Journal of Geophysical Research: Oceans 122.1 (2017): 264-275.

Jiang, H., Eiríksson, J., Schulz, M., Knudsen, K. L., & Seidenkrantz, M. S. (2005). Evidence for solar forcing of sea-surface temperature on the North Icelandic Shelf during the late Holocene. Geology, 33(1), 73-76.

Kopp, G., and Lean, J. L.: A new, lower value of total solar irradiance: Evidence and climate significance, Geophysical Research Letters, 38, 2011.

Mann, Michael E., et al. "Global signatures and dynamical origins of the Little Ice Age and Medieval Climate Anomaly." Science 326.5957 (2009): 1256-1260.

Moffa-Sánchez, P., Born, A., Hall, I. R., Thornalley, D. J., & Barker, S. (2014). Solar forcing of North Atlantic surface temperature and salinity over the past millennium. Nature Geoscience, 7(4), 275-278.

Prša, A., Harmanec, P., Torres, G., Mamajek, E., Asplund, M., Capitaine, N., Christensen-Dalsgaard, J., Depagne, É., Haberreiter, M., and Hekker, S.: Nominal values for selected solar and planetary quantities: IAU 2015 Resolution B3, The Astronomical Journal, 152, 41, 2016.

Sejrup, H. P., Haflidason, H., & Andrews, J. T. (2011). A Holocene North Atlantic SST record and regional climate variability. Quaternary Science Reviews, 30(21-22), 3181-3195.

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