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Interactive comment

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

Anonymous Referee #1

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The study of Maria Pyrina et al., investigate the spatial signature of solar forcing over the North Atlantic summer climate in the past millennium, which is barely involved in previous works of solar forcing influence. This study proposed three very important questions in their introductions: (1) how the solar forcing interact with the summer surface climate and atmosphere circulation? (2) how is the solar signal transferred to surface? And (3) how do different methods (correlation, regression, composite) condition the understanding of the solar effect? These three questions show the focus and significant of this study. However, there's no conclusive answer in in their following text. Below I describe some concerns/points that the authors may tackle. I think a proper revision will require more time than that is usually given as a major revision and I would suggest a re-submission of a considerably revised manuscript.

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1. data and method: The author described the methods firstly and then gave the model simulations. I would suggest show the data (model simulations) first, because many experiments with brief description are involved in the method part, which I have to check and figure out the details in the following “model simulations” section when I read the method section first.

1) There two models used in this study, one is MPI-ESM-P model forced by full external forcings as PMIP3, the other model is CESM-LME forced only by solar forcing. The MPI-ESM-P only has one member (R1) and four ensemble members from CESM-LME (E1, E2, E3, E4). There's no description about what's the difference between these four ensemble members? Different initial conditions? Each ensemble member includes one experiment or more? As the author noticed, the solar signal is weak and maybe concealed by other external forcings (like volcanic eruptions) and internal variability, ensemble mean of solar forced experiment (CESM-LME) provides a possible way to distinguishing the solar signal from internal variability, however, the analyzed results from each ensemble members were shown in this paper, which still includes the internal variability. Is there more than one ensemble members in E1? More details about the ensemble members need to add. I would suggest add a table to shown all the models, experiments, forcing data, ensemble members et al., involved in this study.

2) Is there any difference in the solar forcing data for the two experiments? There's no discussion about this. As described in the “model simulation” section, these two models forced by two different TSI reconstruction data. Figure 1 shows the TSI anomalies, where is this solar forcing data from? Is it one of the solar forcing data for the two experiments?

3) the solar signal at inter-annual and decadal timescale was investigate in this study. How to separate these two timescales? Low-pass filter with 11-year running mean was applied to get the decadal time series. How much the solar signal left in the time series after 11-year running mean? In my experience, the 11-running mean would erase the original solar signal. So please check the 11-year running mean over the TSI firstly

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and add this running mean time series in figure 1. And after low-pass filtered, no only the decadal, but also the inter-decadal and longer term will be left. The intern-annual signal is obtained by high-pass filtered? So more information about separating the inter-annual and decadal timescal is needed.

4) composite analysis: this composite was did based on high and low TSI, how many years involved in the high and low TSI respectively? I would suggest add some indications on figure 1 about the high and low TSI. Which timescale this composite result belongs to? The climate variables (SST, SLP, geopotential height) were pass-flitered before composite?

5) A two-tailed Student's t-test was used to test the significance of correlation, however, this involves statistical test of hypothesis that is conducted at individual gird points at nominal significant levels of 5% resulting in fields of test-statistics, where significant values are stippled. it is not apparent that outcomes are "field significant" in the sense of, for example, Livezey and Chen (1983, Monthly Weath. Rev.). This means that the regions in these maps that are contoured as being statistically significant could simply be the result of random error. The fact that these areas tend to be spatially organized, even if not field significant, provides relatively little useful information in single fields (large scale dynamics and thermodynamics naturally impart spatial structure). In addition, the method of significance test for regression and composite is absent in the method section.

2. results and discussions: This paper try to show the responses to solar forcing in SST, SLP, and geopotentail hight (500) through three methods (correlation, regression, composite) on inter-annual and decadal timescales. Due to the unclear method description, the results are not described very clearly and less conclusive results are found for the solar signal and barely physical mechanism described or discussed to help understanding the response patterns. Even though the authors try to show a possible link between TSI, surface heat flux and geopotential height at 300hPa in the composite results, it's still no clear about the possible physical mechanisms involved in

the possible “bottom-up” or “top-down” transport.

1) linear methods and the solar signals: it’s hard to expect the correlation or regression analysis can separate the solar signal from internal variability and no surprise the pattern is strongly shaped by the model internal variability, as the solar forcing is very weak at some period (like 1400-1550) and the internal variability is strong in the north Atlantic. So same question as mentioned above, is there many ensemble members in E1? What the internal mode looks like in this region? What the response pattern looks to solar forcing? As the author proposed at the beginning, how dose the solar forcing interact with summer surface climate?

2) composite results: I assume the composite difference maps are the composite in the high TSI years minus low TSI. According to the description in the method section, the high and low TSI are selected in different period, due to no information about the specific years of the high and low TSI, not sure these composite results are the responses on the decadal timescales or on multi-decadal timescales. It seems a blocking-like pressure pattern response to the high TSI forcing in the composite results in both two models, and the block regions depend on the ensemble members. However, no more evidence for this blocking pattern and no figure to show how the blocking regions change according to the number of ensemble members. Further more, the two models using different external forcing data, it’s hard to say this blocking pattern is common response to the solar cycle forcing. As this blocking pattern resembles to the 3rd EOF mode of the geo500 variability (inter-annual?), it’s necessary make clear which is response pattern to the external forcing or solar forcing, which is the internal mode. Same as the linear methods, in theses composite results, the internal variability at various timescales and the responses to the other external forcing (like volcano) still might be misleading the explanation of the solar signal. The author tried to explain these composite results through the surface heat flux anomaly (bottom-up) and the thermodynamics in troposphere (air temperature latitudinal gradient and zonal wind anomalies), but there’s no clear solar-induced heat flux pattern which related to the

blocking response and no clear dynamical mechanism shown in this part. In addition, maybe there's a possible way that the decreased pole-ward air temperature gradient leads to an anomalous easterly wind over the high-latitude in the high solar activity years in these high-top models, but the figures in the supplement file only shown the troposphere and without significance test, it's hard to get some clear information about this "top-down" influence route. So the blocking response in the composite results is not robust in present version, more analysis about the pattern and more discussion about the possible mechanism are needed.

3) Comparison of MCA and LIA: This study also compared the MCA and LIA difference based on two model simulations as these two epochs are related two different solar activity period and significant differences were tested. These analysis may show some light on how the solar forcing influences the surface climate on long-term scale. However, no consistent response found in these two models simulations, as discussed in the paper, the model internal variability may shape the climate change in these two epoch. So it's necessary to separate the external forced component (e.g. solar forced) from the internal variability when checking the response pattern. But, how the "high-frequency" internal variability impacts on the mean state response (long-term) to the external forcings? Some analysis or discussion about this part might be help to understand the results shown in this study.

This study using two high-top model simulations to investigate the solar signal in the north Atlantic summer climate in the past millennium, it's a new work at some extent because most previous works are focus on the winter season. But no consistent (conclusive) spatial signature of solar forcing is found in this study, no answers to the supposed questions at the beginning, the whole story is not clear as the the responses are mixed up at different timescales and the internal variability included in every individual simulations.

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