

Response to Reviewer #1

Thank you very much for your remarks. We have tried to incorporate all your suggestions. Please find below a point by point response to your comments.

Specific comments:

Page 3, line 10/ page 4 line 31 - page 5, line 2 The division in high and low/standard resolution models should be explained already in section 2.1 (page 3 about line 10) instead of at the end of section 2.3 because it is use throughout the complete paper, not only for the ENSO analysis. It would also be better to introduce the abbreviations (Hi-res, Std-res or HR, LR) there and then only use one kind, not e.g. Hi-res (mainly used), high resolution (page 11, line 4), and HR (used in section 4.3 and 5.3).

The following sentence has been added to Section 2.1 and has been deleted from section 2.3 and section 2.4.

“For the analysis, the models are separated into high resolution (Hi-res) and standard resolution (Std-res) model configurations. The models that are included in the Hi-res are HadGEM3-GC31-HM, EC-Earth3-HR, MPI-ESM-XR and ECMWF-HR. Their respective low/standard resolution counterparts constitute the Std-res”. We have standardized the abbreviations, Hi-res and Std-res throughout the manuscript.

Page 6, line 11 I think it is too early to draw the conclusion here that differences for zonally averaged hi-res and std-res models remain low, "mainly due to averaging out of over- and underestimation". At this point this should be rather written as assumption or question. Especially since it seems not to be true for all models according to page 6, line 26: "The impact of the resolution seems to be fairly negligible in the ECMWF model."?

This statement was made to convey that when one only look into the zonal averages, where we have plotted the CREs at the TOA from both Hi-res (solid lines) and Std-res (dashed lines) of the different models used in this study, the differences between these resolutions remain low. However, the spatial patterns reveal these differences more vividly. Hence, the spatial plots were added.

Page 10 For the CREs at TOA there is a detailed discussion of the spatial (meridional) pattern (shown in Fig. 2 and 3), but these pattern are not at all mentioned for the CREs at the surface in Section 3.2. While it is probably not necessary to show similar figures like Fig. 2 and 3 also for the surface (such figures could be include in a supplement, though) it should be mentioned if the spatial pattern are in general similar to the ones at TOA or if there are any striking differences?

Following the reviewer suggestion, the spatial patterns (for DJF and JJA means) of the differences in CREs at the surface are now plotted and added to the supplement. The following text is added to the manuscript mentioning the similarities and differences. “Similar to the TOA, the differences in spatial distribution in the SW CREs between the Hi-res and the Std-res model configurations are analyzed at the surface and are shown in Fig.A1 and Fig.A2 in Appendix-A for mean DJF and JJA respectively. It can be seen that the differences at the surface are similar, both spatially and in magnitude to what is seen at the TOA in winter. However, large differences are seen in the surface LW CREs. As in the case of the TOA, the ECMWF model is insensitive to a change in resolution. The Hi-res set up of the MPI-ESM model significantly underestimates the LW CREs north of 40N compared to its Std-res configuration. The DJF mean LW CRE biases are much smaller in EC-Earth3 model, but, the Hi-res set up overestimates the LW forcing over the oceans and underestimates over the continents. A strong overestimation is also seen in the Hi-res set up of

HadGEM3 model over the Southern Oceans and Eurasia. In summer, the SW CREs at the surface follow the same pattern as is seen at the TOA. However, the summer LW CRE biases at the surface are considerably weaker as compared to in winter. ”

Page 11, line 8ff The calculation of the intermodel differences should be explained in more detail. What happens if not all models agree on the sign? Especially in Fig 13 and 14 there are some surprising low values in areas with high values (off the US East-coast), are these missing values/ values where the sign does not agree? If yes they should be marked by an easier to distinguish color.

We would really like to thank the reviewer for raising this issue. This is because, while revising the relevant figures showing intermodel differences (IMD), we discovered an inconsistency in our assumption, wherein the IMDs were calculated in the majority of the model set ups (i.e. 5 or more) agreeing on the sign of the bias instead of all the 9 model set ups agreeing. This is now corrected. The areas where all 9 model set ups do not agree in sign are marked with grey colour in the revised figures.

The revised text now reads as:

“The intermodel differences are calculated as follows. At each grid point, if all 9 model set ups agree on the sign of bias with respect to the CERES observations, the absolute difference between the model set ups showing the highest and lowest bias is reported as the intermodel difference. The regions, where all 9 model set ups do not agree in the sign of the bias, are marked in grey colour.”

Page 26, line 8 Here, it should be also mentioned, that the study is based on atmosphere only simulations as stated in the last sentence of the Abstract: "However, we note that these results are obtained from atmosphere-only simulations and the impact of changes in atmospheric resolution may be different in the presence of coupled climate feedbacks."

It is clarified in the revised manuscript. A final discussion is added to the ‘Conclusions’ section to sum up the main results.

Technical corrections

There are three different ways to write "setups" ("set ups", "set-ups") in the paper?

“set ups” is now consistently used throughout the manuscript.

Page 2, line 22-25: The sentence is hard to understand, maybe there is something missing? Better split it in two sentences.

The sentence is rephrased in the revised manuscript as,

“Here, in the context of this PRIMAVERA project, the surface and top of the atmosphere cloud radiative effects (CREs) are analyzed in global climate models from four European modelling centers, each with varying spatial resolutions. The observed flux estimates from NASA's CERES-EBAF (Clouds and the Earth's Radiant Energy System-Energy Balanced And Filled) instrument are used for the evaluation.”

Page 3, line 8: Maybe better "... simulations. The forcing includes ..." instead of "... simulations that include ..." would be easier to understand?

The sentence is rephrased as,

"The atmosphere-only simulations are forced by SST and sea ice concentrations from the HadISST2.2 \citep{ken17} dataset."

Page 3, line 16: "The CREs ... are defined ..." instead of "The CREs ... is defined ..."

Table 1 and several places in the text: Shouldn't it be "MPI-ESM" instead of "MPIESM"?

Page 4, line 20: "... associated solely with ..." instead of "... associated solely by ..."?

All these details are corrected in the revised manuscript.

Page 5, line 14-15: This explanation would not be necessary if the separation between Hi-res and Std-res would be introduced in section 2.1 as mentioned in the specific comments.

The following sentence has been added to Section 2.1 and has been deleted from section 2.3 and section 2.4.

"For the analysis, the models are separated into high resolution (Hi-res) and standard resolution (Std-res) model configurations. The models that are included in the Hi-res are HadGEM3-GC31-HM, EC-Earth3-HR, MPI-ESM-XR and ECMWF-HR. Their respective low resolution counterparts constitute the Std-res. "

Page 6, line 21: "most notable" instead of "notable"

Page 6, line 34: "probability density function" is the more common?

The above suggestions are incorporated in the revised manuscript.

Fig. 1 and 4: Add a y-label?

Fig. 2 and 3: Use only one color bar and try to enlarge the size of the panels?

The figures are revised to incorporate the above-mentioned suggestions.

Page 11, line 4-5: At the moment it is explained in section 2.3 (not 2.2) and I think it should be explained in section 2.1, see specific comments.

Rephrased as,

"To investigate the simulated responses, the ensemble mean of the Hi-res and Std-res model configurations is analyzed."

Page 12, line 34: The abbreviation "AMIP" is not explained.

Fig. 5 and 7, caption: There is no reason to explain the abbreviations Hi-res and Std-res again?

This is modified in the revised manuscript.

Page 26, line 28-30: There is something wrong in this sentence, probably an extra "the" at "that the they are"?

Page 26, line 33: Following the discussion in section 5.3 it should be rather "variability" than "uncertainty"?

This is modified in the revised manuscript.