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Earth System Dynamics
Discussions

Interactive comment on "The "NorESM1-Happi" used for evaluating differences between a global warming of 1.5 °C and 2 °C, and the role of Arctic Amplification" *by* Trond Iversen et al.

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The authors look at a range of different versions of the NorESM1 model, and consider how those models hold up against reanalysis. They consider changes in many modes of variability, specifically related to key regional changes. Overall the paper was not what I expected, from the title I expected the paper would be about NorESM1-Happi, Paris Agreement and Arctic Amplification. Very little of this was even mentioned until Figure 17!

As it stands the paper is a model description/validation paper, and a science paper. The science is completely lost due to the first part. Due to this, and a number of other

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major concerns, I recommend substantial corrections.

Major concerns

1. In my view, the paper needs to be split into two. A paper focussing on the Arctic Amplification differences under Paris would be very welcome. So one suggestion is to put everything up to Figure 17 in online material, and just start the paper from there. Any reader that comes to this paper due to the title will be otherwise be completely lost in details of various models, and it will not be a productive read for them. More material would be needed for the science part though (see comments below). Alternatively, you could make this a model development only paper.

– Reply: As mentioned in the response to Referee #1, we agree that for the publication in ESD, the paper should be considerably restructured, and we propose to condense and move considerable parts of the sections that address pure validation of the NorESM1-Happi model, into a "supplementary material". In the main text, we will only keep those parts, which are directly relevant for the discussion of the difference between a 1.5 and a 2.0 degrees warmer world than pre-industrial, emphasizing the polar amplification of the temperature response.

Tentatively, we consider moving the following to supplementary material: Tables 1, 2, 3, 4, and 6 Figures 1, 3, 4, 5, 6, 7, 8, 10, 11, 12, 15, and 16. (Some of these figures will also be considered removed.).

There are also some numbers in the present main text that probably will be summarized in a new table. The text belonging to these items, which now fills up several pages in the manuscript will be compressed into one sub-section of the model description chapter. The text in the supplementary material will predominantly be written as extended Table headings and Figure legends.

What may remain in the main text are the discussions on climate feedbacks and sensitivity, with extended to underpin the discussions on Arctic amplification and the design

of external forcing for reaching the given temperature targets with the fully coupled NorESM1-Happi model. Furthermore, we will keep the discussion on the representation of sea-ice (Figure 9), extratropical cyclone activity (Figure 13) and blocking (Figure 14).

Thus, the paper will be shorter and much more focused, while still documenting important aspects of NorESM1-Happi as a valid global climate model in the supplementary material.

2. The title makes it seem that NorESM1-Happi is the main model here, but actually it is not, the SO version is used the most, and the –M and –AMIP versions are used equally as much. I often got confused about which one was being used, as the paper jumped around a fair bit. It was not until half way through that I realised that the Happi version of the model did not have prescribed SSTs (as HAPPI is synonymous with prescribed SSTs).

– Reply: This confusion should be considerably reduced after the proposed paper reorganization. The definition of model versions (the AMIP, the slab-ocean (SO) and the fully coupled NorESM1-Happi) will be made already in the introduction. The NorESM1-M model is the CMIP5-version published in 2013, and is used only for documenting improvements in the NorESM1-Happi, and will thus be used for comparison in the supplementary material, and will not be prominent in the main text. We consider to possibly use the name NorESM1-HappiCPL for the fully coupled model version, while NorESM1-HappiSO will be kept for the slab ocean version and NorESM1-HappiAMIP for the AGCM version.

3. I was hoping to see more of a connection to Arctic Amplification here. Such as more of a focus on latitude temperature gradients, changes in wave characteristics associated with this, and then relating this to blocking etc. This link was missing, and AA just seemed to be a 'hot topic' term. The authors should look at the recent work by Screen on this topic.

– Reply: It is mentioned in the introduction (p.3, l.26-20) that the intention of this paper's discussion of Arctic amplification is not to specifically address the potential impacts on planetary wave amplitudes and weather persistence.

We agree to extend the list of references to include publications by Screen, and we will mention the recently approved Polar Amplification MIP for CMIP6 (to which the NorESM-group plans to contribute). We should also mention that Figure 21 actually shows that there are more statistically significant changes in blocking occurrence in the NH in the slab ocean experiments than in the AMIP experiments. The AMIP experiment is not designed to produce a realistic Arctic amplification due to the way the sea-ice is prescribed (see our reply to pt. 4 of referee#1).

However, we disagree with the referee's statement that "AA just seemed to be a 'hot topic' term". Arctic amplification of the global warming is well established as a temperature signal, which deserves attention in its own right. Indeed, when discussing the difference between a "1.5 degree world" and a "2.0 degree world", this may prove to be the difference between an ice-free summer Arctic or not (e.g. Sanderson et al, 2017; and the results shown in our Figures 22 and 23), because of the amplified temperature response in the Arctic.

4. A more comprehensive analysis seems to have already been done by the authors, in Li et al, (https://www.earth-syst-dynam-discuss.net/esd-2017-107/). Can the authors highlight what their study adds?

–Reply: While Li et al is a multi-model study on the response of selected features of the large-scale atmospheric dynamics entirely based on the HAPPI protocol of AMIP experiments, our paper's intention is to focus on the Arctic amplification of surface temperatures, which is not well represented in the HAPPI experimental set-up.

As emphasized in our reply to pt. 4 of referee#1, the reason for this is that some properties of the prescribed sea-ice in the AMIP experiments are not realistic. It is likely to misrepresent the Arctic surface temperature amplification, and therefore the

differences between the 1.5 degree and the 2.0 degrees global warming in the Arctic, including sea-ice cover itself. There is a component of Arctic amplification in the HAPPI AMIP-experiments, but this is dominated by the prescribed SSTs and sea-ice concentrations in the 1.5 and 2.0 degrees warmer climate.

One consequence of this can be seen in the smaller response in NH extratropical storminess in our own AMIP results than in the results from both the slab ocean runs and the fully coupled NorESM1-Happi runs with RCP2.6 (Fig. 19). In pt.3 above, we have furthermore already mentioned the changes in NH blocking (Fig.21) and in Arctic sea-ice (Figs 22 and 23)

We have in the pipeline for the updated manuscript, longer simulations with the fully coupled model targeting the 1.5 degree and the 2.0 degrees warmer world.

5. I was very surprised by some of the differences between the SO model and the AMIP model. Surely the AMIP model will have smaller biases that the SO model (e.g. some Scaife papers could be referenced). It is not always clear that this is the case.

– Reply: (It would help if the referee#2 more specifically pointed to which results he/she is surprised to see.) The way we have calibrated and relaxed (i.e. bias corrected) the slab-ocean model for present-day conditions, we expect only small differences between the AMIP and SO model when comparing with e.g. re-analysed data for present-day conditions.

This was also found for NH storminess and blocking (Figs. 18 and 20), and these results encouraged us to further employ the SO-model for the purpose of Arctic amplification on the target scenarios.

A more traditional way to calibrate the slab-ocean model (e.g. to study equilibrium climate sensitivity as mentioned in section 3.1), is likely to produce larger biases than in AMIP runs, where SSTs are prescribed from observationally based data.

At this stage, I am not sure minor comments are useful.

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