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Comment on esd-2021-51

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Referee comment on "Atmospheric regional climate projections for the Baltic Sea region until 2100" by Ole Bøssing Christensen et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2021-51-RC1, 2021

GENERAL COMMENTS

The paper reviews regional climate model (RCM) projections of 21st century climate change in the Baltic Sea region. It is mainly based on a large ensemble of high-resolution (12.5 km) atmospheric RCM simulations produced in the EURO-CORDEX project, but also uses a smaller ensemble of simulations with a single coupled atmosphere – Baltic Sea RCM to assess the effect of the regional atmosphere-ocean coupling. Furthermore, comparison is made with the ENSEMBLES RCM simulations used in the previous Baltic Sea Basic Climate Change Assessment. Six climate variables (temperature, precipitation, wind speed, solar radiation, snow cover and Baltic Sea ice) are covered.

The main value of this paper is in the vast volume of results that are put together – in terms of both the number of model simulations and number of variables. This will make the paper a valuable resource for those needing an overview of climate change projections in the Baltic Sea area, even though there are few surprises in the results compared with earlier generations of model simulations. Naturally, the wide coverage comes at the cost that the physical mechanisms behind the projected changes cannot be discussed in much depth (although some attempts are made), and the results of individual simulations only appear as points in scatter diagrams. Nevertheless, the analysis methods are sound, and, with a couple of minor exceptions, the interpretation of the results is well justified.

The largest need of development in this paper concerns the quality of its graphics. The general approach where multi-panel figures are compared with scatter diagrams to represent the typical features and variation between model results works well, particularly in Section 3. Beyond this, however, there are many ways in which the reader-friendliness and informativeness of the figures could be improved. Suggestions for this are given below in “Comments on figures”. Other detailed comments are collected under “Comments on substance and text” and “Minor technical comments”.

COMMENTS ON FIGURES

Many of the figures in the manuscript could be fine-tuned for a better reader experience. In particular,

- In multi-panel figures like Fig. 1 (and all the others in the same format), it is annoying for the reader to have to look back and forth between the figure and the caption to try to identify which panel is which. This can be improved by adding the relevant information directly into the figure. In case of Fig. 1, this can be done by adding the texts "25%", "50%" and "75%" above the three columns and the texts "Winter" and "Summer" to the left of the two rows.
- The scatter diagrams (Figure 3 and other similar figures) would be easier to understand if a legend on the meaning of the different markers and colours were added directly to (at least) the first figure panel.
- The scatter diagrams could also be improved by using coloured markers, not only for the coupled RCA4-NEMO ensemble but also for the EURO-CORDEX simulations. As it stands now, the different scenarios and data sets are difficult to separate visually, particularly in Fig. 3 where the number of data points is the largest. Use of colours would also allow a slight decrease in the symbol size, thus reducing the crowding in the diagrams.
- Still one suggestion for the scatter diagrams: add horizontal and vertical zero lines to make it easier to count/estimate the number of simulations with positive and negative changes.
- The map collections related to Section 4 (Figs. 10, 11, 13 and 15) need rethinking. The focus and new information in this section is the effect of the Baltic Sea – atmosphere coupling on the projected changes, not the uncertainty in the projections. Therefore, the lower and upper quartile maps appear redundant. Instead, it would seem better to show just three maps for each case: the median for the uncoupled simulations, that for the coupled simulations, and the difference between the latter and the former. Apart from focusing on the results that are of the highest relevance for this section, this would halve the total number of figure panels.
- Figures 12 and 14 are not mentioned at all in the text, and Figure 16 is only mentioned very briefly. If there is no need to discuss these figures in the text, they should be omitted.
- If Figures 12, 14 and 16 are retained: please use colours. Otherwise, it is very difficult to distinguish between the coupled and uncoupled simulations.
- The colour scale in the figures that show changes in solar irradiation (Figs. 7, 15 and S19-S24) is potentially misleading. Intuitively, red and yellow colours are linked to drier conditions (hence more solar radiation) and green colours to wetter conditions (hence less solar radiation). This is just the opposite to the scale in these figures.
- Figure 9. Remove the titles (which are too long, and do not differentiate the coupled and the coupled simulations). Add the labels "Uncoupled" / "Coupled" to the left of the two rows, and "25%" / "50%" / "75%" above the three columns.
- Figures S1-S24. Please label the periods ("2041-2070" and "2071-2100") to the left of the figures and the percentiles ("25%" / "50%" / "75%") on the top of the figures.
- Figure 3(d) should represent land south of 60°N in DJF, not land north of 60°N.

COMMENTS ON SUBSTANCE AND TEXT

- L12-15. I think the focus on the 12.5 km simulations should be mentioned in the abstract.
- The text from L86 to L113 is difficult to follow, partly because it jumps back and forth between the EURO-CORDEX and BACC II / ENSEMBLES simulations and partly because the EURO-CORDEX part is described in somewhat surprising order. Please first describe the EURO-CORDEX simulations, proceeding from the general (scenarios and periods, plus the "pattern scaling" sentence on L97-99) to the details (notes on missing data on L86-90). After this is done, proceed to the comparison with the earlier BACC II / ENSEMBLES simulations (L91-95) and to the way of presentation of results (L113-124, excluding the first sentence that should come earlier).
- It would be good to repeat the definition of the baseline, mid-century and end-century periods in caption of Table 2.
- L110. "many years" is an understatement. This is many decades.
- L131. Mention the resolution of the RCA4 simulations.
- L143-144. The underestimation of the inter-quartile spread is not self-evident. If the 8 GCMs can be considered as a random sample from CMIP5, the expected value of the (n-1) variance should be the same as for the whole ensemble. The same may or may not apply to the inter-quartile spread, depending on how the quartiles have been estimated.
- L154. What does "most extreme" refer to? The simulations with the largest warming or larger warming of the highest temperatures?
- L157. Do you mean the ice-albedo feedback mechanism over the Arctic Ocean? There is no sea ice, and only little snow in the highest mountains, left in JJA in this region even in the present-day climate.
- L162. summer, winter or annual mean temperature trends?
- L164-167. This text oversimplifies the dynamics of diurnal temperature range (DTR) changes, which originate from a multitude of factors (e.g., Lindvall, J. & Svensson, G, 2015: The diurnal temperature range in the CMIP5 models. Clim. Dyn. 44, 405–421). In addition to the processes discussed in the mentioned paper, it should be noted that the genuine diurnal temperature range is very small in the middle of the winter when there is little solar radiation. However, differences between the daily maximum and minimum temperatures can still be substantial due to synoptic-scale weather variability. Factors that reduce the temperature variability on synoptic time scales (e.g., reduced temperature gradients between the Atlantic Ocean and Eurasia) therefore also likely contribute to the apparent decrease in DTR.
- L177-178. Suggested rewording: … (Norway), where the amount of precipitation is particularly sensitive to different changes in the large-scale circulation?
- L209. Apparently, this should be "squared correlation coefficients of 0.5 to 0.6.
- L216-129. This is not true for temperature change in summer (for the total region, warming of ca. 2.9 K in BACC II and 3.6 K in EURO-CORDEX).
- L285-294. This text does not fit well in Section 3.3 on "Extreme precipitation". Rather place it in the end of Section 3.2.
- L319-324. When discussing the geographical distribution of wind speed changes, also refer to Figs. S13-S18.
- L367-369. It seems that the aerosol issue should already have been mentioned when discussing simulated temperature change in Section 3.1.
- L379-381. This article, based on the EURO-CORDEX 12.5 km RCMs, might also be cited: Räisänen, J., 2021: Snow conditions in northern Europe: the dynamics of interannual variability versus projected long-term change, The Cryosphere, 15, 1677–1696, https://doi.org/10.5194/tc-15-1677-2021. The conclusions are largely the same as in Räisänen and Eklund (2011).
- L387-388. This is not only, and perhaps not primarily, about orography. The baseline climate in the northern areas is colder due to the smaller amount of solar radiation as well.
- L390-391. This might also be affected by the larger increase in winter precipitation in

the BACC II simulations, at least north of 60N (Figure 3c and Tables S9-S10).

- L394. The increase in temperatures has an impact on snow cover even in high-altitude areas. Even if temperature generally remains below zero in the middle of winter, the frost season starts later in fall and therefore the accumulation of snow starts later. See Räisänen & Eklund (2011) or Räisänen (2021) (as cited in comment 17 above).
- L434-435. This might also be because the coupling has a similar effect on temperature in both the baseline and the future periods.
- L442-443. Based on Figure 9, many of the uncoupled simulations had no sea ice over the northernmost parts of the Baltic Sea, and thus no decrease in sea ice. It is therefore not surprising that the warming is larger in the coupled simulations in which the ice cover decreases (as it must as the climate warms).
- L458-475. Please refer to Fig. 13 when discussing the wind speed changes. Also, the main point of interest should be the effect of the coupling on the wind speed changes over and near the Baltic Sea. What happens at the Norwegian coast must be an artefact of the resolution difference, and uninteresting as such. Similarly, the discussion (as well as Figs. 10-11 and 13) could focus just on the median changes, because the uncertainty range is not the primary point of interest in this context.
- L479-483. The earlier text gives the impression that the three columns in Fig. 15 and other similar maps represent the 25th, 50th and 75th percentiles of time mean changes in the ensemble - i.e., variation between simulations and not from day to day. Please check this text and revise what is needed.
- L569. Based on Fig. 3, this applies in winter but not in summer.
- L582-584. Could the decrease in winter also be related to reduced snow cover? Lower surface albedo reduces multiple reflection between the surface and clouds, thereby attenuating the gross downward solar radiation flux. See the suggestion on p. 2472 in Ruosteenoja, K., & Räisänen, P. 2013: Seasonal changes in solar radiation and relative humidity in Europe in response to global warming, Journal of Climate, 26(8), 2467-2481.
- L592-593. Suggesting rewording: "… terrain, likely as an artifact of different model resolution". I would not call this an uncertainty, because it is obvious that higher resolution is better.

MINOR TECHNICAL COMMENTS

- L18-20. Suggested rewording of sentence: "In simulations with a coupled atmosphere-ocean model, the climate change signal is locally modified relative to the corresponding stand-alone atmosphere regional climate model". The text this far has not defined the coupled atmosphere-ocean model in question, which makes its definite article confusing.
- L24. coupled model inter-comparison projects (CMIPs) OR model inter-comparison projects (MIPs)
- L38. Keuler et al. (2016) is missing from the list of references. Please also check the list for other possible omissions.
- L148. Nikulin et al. (2011) *used* an ensemble
- L179. Delete the first "winter".
- L270. … higher resolution, which allows them to avoid?
- L283-284. simpler language: the increase in precipitation extremes is strongly dependent on moisture availability?
- L310. Suggested rewording for the beginning of the sentence: "Donat et al. (2011) analysed the annual 98th percentile". As it stands now, the beginning and the end of

the sentence are not consistent.

- L326. Fig. 15 should be Fig. 13
- L377. Typo in “becausesnow”
- L421. "a more detailed look at the five driving GCMs" should be reformulated, because no results for the GCMs themselves are shown.
- L473. < 2% (2 m/s would be a huge change)
- Caption of Table S20. Standard deviation of precipitation change, not temperature change.