Comment on esd-2021-49

Anonymous Referee #3

Referee comment on "Atmospheric rivers in CMIP5 climate ensembles downscaled with a high-resolution regional climate model" by Matthias Gröger et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2021-49-RC3, 2021

The authors make use of downscaled versions of global climate simulations from the CMIP5 ensemble to study the atmospheric rivers reaching Europe in the present and future climates. They find that ARs will become more frequent and stronger in the future, especially in the RCP8.5 scenario. The results also show that the orientation of ARs will change with for example more ARs coming from the south reaching Scandinavia (Norway).

The study is interesting but I got confused with some of the fields presented in the figures, which quality is not great. Some information about the methods and the fields displayed in the figures is missing, the methodology and results are not well discussed and compared to previous studies, and there are many technical mistakes (typos, English, missing words). Therefore, I think the manuscript needs major revision in order to be in a publishable state.

Major comments:

About the methods:

- The temporal scale of the RCA model outputs is not clear. From line 209, it seems to be 6-hourly but it would be great to also mention it in section 2.1 or in section 2.2. In the same line, is the extreme precipitation determined from 6-hourly or daily data?

- The authors use an AR minimum length threshold of 1500 km. This is quite short compared to previous studies and I guess the reason for this low value is the limited extension of the domain to the west. Can the authors state the reason for such threshold and maybe discuss it in light of previous studies?

- Can the authors confirm that only one AR is detected at every timestep? What happens when an AR covers two latitudinal bins and/or exceeds the IVT 85th percentile in two adjacent 5º bins?

- Do the authors define a mask of every AR to link them to precipitation?

- Lines 223-224: I think the authors should emphasise the fact that the AR detection threshold is different between the present and future periods in contrast to previous studies and what the advantage of this method is. As for now, it is written later in the manuscript (section 5.2) but it should appear upfront. I believe that this choice limits the influence of the larger moisture content in the atmosphere in the future climate on the results. Is that true? Can this aspect be discussed if relevant?

- I believe the ERA-Interim reanalysis is not really described. For example, the spatial and temporal resolution used in the study is missing.

- In the caption of Fig. 2 and line 329, it is written that ARs are tracked. However, the AR tracking is not explained. I suspect the tracking is used to check the AR persistence and involves ARs masks. Therefore, please add this information in section 2.3.

About Section 3.2.3:

Lines 351-354: Can the authors explain a bit more how a negative temperature bias in the regional climate model is linked to a "too high moisture load" and to the higher number of ARs in September in the hindcast compared to ERA-Interim? I would expect a higher temperature to be linked to more moisture. Moreover, wouldn't it be more useful to look at the precipitation in the hindcast, in ERA-Interim, and in the E-OBS dataset, instead of looking at the temperature? Could it also be useful to assess the difference in the specific humidity between the hindcast and ERA-Interim?

Lines 354-356: This sentence must be rewritten. It is not clear at all.

What would be the impact of using the E-OBS precipitation instead of ERA-Interim's in the results displayed in the right column of Fig. 5b-d?

About section 5.2:

Gao et al. (2016) showed that ARs became more frequent north because of the poleward shift of the eddy-driven jet. That is not what the authors seem to obtain by distinguishing the "origin" of the ARs. I believe it would be more interesting and useful to look at the eddy-driven jet response in all scenarios to explain the responses in the number of days with ARs and AR-forced precipitation?

Remove sentences "At least… (Ma et al. 2020). The authors…likely reasons." on lines 546-548 because it is not relevant for the present discussion.

About the figures' content:

- Figure 2: is the 85th percentile determined using all points within the 5º bins and all time steps? In any case, please state somewhere how the values shown in this figure were calculated.

- Figure 4, 7: how is the "average moisture transport over land" calculated? Are the authors using a mask for the ARs and averaging the IVT within the mask? Please explain.

- Figure 5: Row a): the authors describe this row as AR frequency in the caption but, as written in the text, it is only a number of days. One would have to divide by the total number of days in the period to get a frequency. Moreover, since the model output is 6-hourly, I do not understand how the authors convert it to a number of days. What if an AR covers two days during its lifetime? Is it counted twice? Also, if the AR lasts a minimum of three time steps (because of the 18h minimum duration) in the same day, it is counted only once, correct?

Rows b), c), and d): I find not clear what is shown in those panels. It is worth mentioning in the text how those "indices" are calculated and keep the same names throughout the manuscript. Can the authors explain why ARs contribute to the yearly maximum (row b) over southwestern Norway or northern UK but barely contribute to the extreme precipitation (row c)?

Row b): I understand this figure as the percentage of years (among the 30 years of the period) for which the maximum precipitation occurs when there is an AR. Is that correct? In any case, the text should be clarified. The same comment applies to the rows c) and d).

Row c): how do the authors relate the low values for the Norwegian coast to the study of Benedict et al. (2019) who found that 85% of the extreme precipitation events are related to ARs?

Benedict, I., K. Ødemark, T. Nipen, and R. Moore (2019): Large-Scale Flow Patterns Associated with Extreme Precipitation and Atmospheric Rivers over Norway. Mon. Wea. Rev., 147, 1415-1428. https://doi.org/10.1175/MWR-D-18-0362.1

- Figure 8: is this figure showing a simple difference between the future and the historical experiments or does it show a relative change?

Caption: I would not call what is displayed "climatological indices". Please remove. Panel b) does not show "precipitation rates" if it is similar to Fig. 5. Please use the same wording for Fig. 8 as for Fig. 5.

"Note all non-robust" -> Note that all non-robust

What is the difference between panels c and d? One of the two is not shown in Fig. 5.

Why is the unit in panel c is % if the what is shown is "the number of of events" as written on lines 400-401?

- Figure 10: Are the authors sure that panel a) is for ARs originating north of 60ºN and panel b) for ARs originating south of 45ºN? It does not seem in agreement with the text. For example, the sentence "the RCA ensemble clearly shows a relative increase of those ARs originating south of 45ºN (Fig. 10a)." However, Fig. 10a only shows negative values and the caption says that panel a) is for ARs originating north of 60ºN. Please make sure that the caption and text (from line 458 to 475) correspond to the figure. Can the

category 45-60ºN be displayed as well? In the caption, what does "relative contribution" mean? Does it show the relative difference between the future and historical experiments or is it a simple difference?

- Figure 11: Why does the colorbar for the standard deviation panels exhibit negative values? A standard deviation is positive. Is the STD panel a difference between the future and historical standard deviation or the standard deviation of the responses displayed?

About the figures' quality:

I think the quality of the figures should be improved.

Figures 2, 3, 4, 8, 9, 10, and 11 exhibit gray frames around the panels and around the colorbars. Could they be removed?

Figure 9 exhibits a colored line in between the two panels as if another figure was below.

Figures 1, 5, 9, and 10 exhibit weird coastlines over Greece. Moreover, Crete and the Balearic Islands are missing.

Figure 11 has too small labels for the latitudes (longitudes missing) and for the colorbars. Moreover, the coastlines are discontinued at 20ºE.

Figures 4, 6, and 7: the frames, tick marks, and background grids are almost invisible. Please make them darker or black.

Figures 7, and 11, and Tables 2 and 3: Please arrange the GCMs in alphabetical order as the authors did for Fig. 2.

It would be great if all figures showed the same domain.

Figure 8: can the columns be rearranged such that RCP2.6 is on the left and RCP8.5 on the right? I find it more intuitive and it would be consistent with Figs. 2 and 7 and Tables 2 and 3.

Figure 2: the gray and yellow lines are barely visible.

Figure 5: In the left column, panels b), c), and d) should have RCA_MEAN as title instead of RCA_ENSM. Better remove the titles of the three bottom rows as it would make the panels bigger, improving their readability.

Minor comments:

Lines 25-28: it seems from this sentence that Norway is in Central Europe. Please rewrite this sentence, maybe splitting it in two.

Sometimes, the authors write ERA-I and sometimes ERAI. Please be consistent in the text and captions and make sure the same acronym is used everywhere (I suggest ERAI).

Line 138: why is the coupling between the RCA model and NEMO only over the North and Baltic seas? What about the Mediterranean and the Norwegian seas?

Line 151: "in a huge ensemble": to which ensemble do the authors refer to? Does it have a name? This ensemble seems similar to the one used in the present study so why not using it?

Caption of Figure 1: Please rewrite it. This figure mainly shows the topography of the domain in brown and the bathymetry in blue-green colors.

The authors very often use very "greenhouse gas scenarios". I suggest to use instead "greenhouse gas emission scenarios" or probably better "GHG emission scenarios".

Lines 202-203: please add the units of g, the wind, and dp.

Line 203: "In the two hydrostatic models…": I assume that the authors here refer to the regional climate model RCA and to the IFS model. Why does the reader need this information?

Caption of Fig.2 : "IVT thresholds" -> 85th percentile of IVT

"…for the ensembles' historical…" -> … for all models and the historical…

Line 278 (page 10): "heavy precipitation": please write that this is defined using the 95th percentile in order to relate it to what is shown in Fig. 5c.

Lines 279-280: What are "the mean climatic conditions in Europe"? Moreover, it rains a lot in Southwestern Norway and that is not reflected in Fig. 5a.

Line 296: What is meant with "weather regimes"? Moreover, what is the point of lines 295-298?

Line 321: Do you mean effect of the downscaling? With "regionalization", it sounds to me like the authors split the domain into different regions.

Line 324: Can the authors explain the "factor of 10"?

Line 378: "AR" -> ARs

The reference Massoud et al. (2020) does not seem appropriate here as the paper is not about the US but about the Middle East. Maybe the authors meant the following reference:

Massoud, E. C., H., Lee, P. B., Gibson, P., Loikith, and D. E., Waliser (2020): Bayesian Model Averaging of Climate Model Projections Constrained by Precipitation Observations

over the Contiguous United States, Journal of Hydrometeorology, 21, 2401-2418. https://doi.org/10.1175/JHM-D-19-0258.1

Lines 418-419: what is meant with "contribution anomalies"? Could it be replaced by responses?

Line 488: RCA-IPSL and RCA-MPI have weaker responses than GFDL, CAN, and NORESM over the North Atlantic, don't they?

Lines 524-525: "This was done… period (Neiman et al. 2008)." I do not understand how this sentence justifies the use of a different 85th percentile in the historical and future experiments.

Lines 558-559: "Generally the AR imprint…eastern Europe." Isn't this sentence in contradiction with Fig. 5 where larger values are found over western Europe?

Technical issues:

Consider using commas much more often than currently.

Line 22: "ER" -> ERA

Line 24: "eat" -> east

Lines 34, 426: "maximal" -> maximum

Line 37: "Iberia(15" -> Iberia (15

Line 40: "likely the originate" -> likely originate

Line 41: "from >60 ºN" -> from latitudes >60 ºN

Line 64: "Pacific Sectors of the World Ocean" -> Pacific sectors

Lines 75, 79, 194: "Laver" -> Lavers

Line 80: "However they" -> However, they

Line 90: "AR" -> ARs

Line 103: "framework employed" -> frameworks

Line 114: "4.5,RCP8.5" -> 4.5, RCP8.5

Line 118: "a validation RCA" -> a validation of the RCA

Line 135: "2005)and" -> 2005) and

Caption of Fig. 1: "Bathymetricy" -> Bathymetry

Line 165: "hindcasst" -> hindcast

Line 180: "W/m2" -> W/m^2

Line 206: Remove "Then".

Lines 223-224: "for each of the ensemble members respectively" -> for each model

Caption of Fig. 3: "below the threshold" -> below the 85th percentile

Caption of Table 3: "number ARs" -> number of ARs

Caption of Fig. 4: "b):" -> b)

Line 253: "AR" -> ARs, "Fig. 4" -> Fig. 4b

Line 281: "Bretagne" -> Brittany (to be consistent with line 579)

Line 300: Add parenthesis before Fig. 5.

Lines 279, 290, 299, 300, 422: "Figure" -> Fig.

Line 304: "respectively calculated as 0.98" -> respectively 0.98

Line 306: remove "respectively"

Line 314: "is" -> are

Caption of Fig. 6: "detercted" -> detected, "precentage" -> percentage, "AR" -> ARs

Line 323: "is" -> are

Line 325: "of spatial" -> of the spatial

Line 332: "ERAI-" -> ERAI

Line 333: "and larger" -> and a larger

Lines 335, 559: "distal" -> distant

Line 336: "This implies ARs" -> This implies that ARs

Line 338: "as in in semi aride": remove one "in"

Line 339: "effect the of" -> effect of

Line 346: "Fig. 5b" -> Fig. 5d

Line 360: remove "which is notably lower"

Line 383: "frequency" -> number

Line 398: "5b) no" -> 5b) but no

Line 400: "Figure 8c shows the number" -> Figure 8c shows that the number

Line 404: remove "Apart from this"

Line 412: "Figures" -> Figure

Line 420: "stronger" -> more

Line 421: "response" -> responses, "is" -> are

Line 424: the reference to the paper of Teichmann et al. 2018 is missing in the reference section.

Line 440: add comma between "latitudes" and "it" and remove comma after "found".

Line 445: "main driver AR" -> main driver of AR

Line 446: "Jet" -> jet

Line 451, 454: maybe not use "incidents" but rather events

Line 455: "for high" -> for the high

Line 460: remove "degree"

Lines 473-474: "sectors" -> sector

Line 483: "frequency of ARs" -> number of days with ARs

Line 484: "similar RCA" -> similar to the RCA

Line 489: "RCA-ECE show" -> RCA-ECE shows

Lines 490-491: "one realisation shows wider" -> RCA-MIROC shows wide, and remove "(RCA-MIROC)" at the end of the sentence.

Line 496: add comma after RCA-MPI

Line 501: "the most heavy" -> the heaviest

Line 504: "is" -> are

Lines 507-508: remove at least one of the "likewise".

Caption of Fig. 11: "forrcing" -> forcing

Line 519: "2016; 2016;" either a reference is missing or there is one "2016" too much.

Line 541: "Norway(Fig. 11c)" -> Norway (Fig. 11c)

Line 551: "model with" -> model ensemble with, "was applied" -> was created

Line 552: "regionalization" -> downscaling

Line 555: "the contribution to" -> the contribution of ARs to

Line 563: "climate" -> climates

Line 571: "of orographic" -> by orographic

Line 575: "show ARs" -> show that ARs

Line 588: "favors" -> favor

Line 589: "stronger" -> more strongly

Line 596: "arriving Scandinavia" -> arriving to Scandinavia