

Reviewer's comment on the manuscript

“Summertime circumglobal Rossby waves in climate models: Small biases in upper-level circulation create substantial biases in surface imprint” by Luo et al.

General comments

In this manuscript, the authors assess the representation of wavenumber 5 and 7 patterns in three different climate models (EC-Earth, CESM and MIROC), and search for the reason of model biases with respect to the ERA5 reanalysis data. They find that the models represent these wave patterns reasonably well, however, small biases in the upper level circulation lead to large biases in surface variables, like temperature, precipitation and mean sea level pressure. They show a significant improvement of model performance in case the upper level circulation is nudged based on the observed one. In contrast to previous studies, the soil moisture plays only a minor role in the representation of high amplitude wave events, which can be also a consequence of the chosen weekly time scale.

The paper has a very clear structure. The scientific message is clear, useful and very relevant, it can help to improve climate models and produce more realistic future climate scenarios. The language of the paper is understandable, except some (actually, a bit too many for a submitted manuscript...) grammatical and typographical errors. Based on the importance of the message of the paper, I suggest the manuscript to be accepted for publication in WCD, however, only after the authors have taken care of the below mentioned deficits.

My main criticism concerning this work is that it concentrates only on wavenumber 5 and 7 patterns, and there is no critical discussion related to the applied methodology. I understand that previous studies have found these patterns to be relevant for simultaneous extremes, and it is important to test whether the models can represent them or not, but it would increase the scientific value of the paper if the introduction, at least, presents summertime circulation anomalies and related surface extreme events from a broader perspective. At the end, extreme events can be observed during other wavenumbers as well, thus it is important, that models are able to reproduce a wide range of wave numbers not just the mentioned 5 and 7. Although the authors show the spectrum for a range of waves in their results, this is only very shortly discussed in the paper.

In this work, the model experiments are compared to ERA5 reanalysis data, which is supposed to represent reality. Reanalysis data have, however, their biases and deficits too, which should be mentioned in the paper as well. The relatively short period of ERA5 can lead to additional biases of the statistical estimation – it can lead to an under- or over-sampling of certain wavenumbers, as shortly mentioned in the manuscript too. A short discussion of these issues would increase the degree of objectiveness of the paper. A critical evaluation of the used technical tools – Fourier decomposition of the atmospheric field, nudging - in the discussion part would be beneficial as well and would increase the scientific quality.

Overall, this is a good paper with an important scientific message, however, the scientific quality needs to be improved before publication mainly by

1) increasing the accuracy of the wording and presentation of the results,

- 2) improving the objectiveness related to the used methods and data set, and
- 3) the work should be put in a broader scientific context.

Specific comments

Figure 2: The probability densities are smoothed. This is not mentioned in the manuscript nor is the smoothing procedure and bandwidth. This information should be included, and the non-smoothed histograms should be shown as well to give a realistic picture of the involved uncertainties.

L47: *“These persistent weather extremes can have disastrous impacts on human health and societies such as wide spread crop failure, infrastructure damage and properties loss, especially when they are **defined** as compound events.”*

The word “defined” is inappropriate here: The impact is a consequence of the manifestation of a real extreme event, it does not depend on how the event is “defined”.

It is not mentioned in the manuscript what kind of observational data set is used for the nudging. This is, however, relevant information, which should be included.

L172: *“ERA5 shows the peak for both the wave amplitude and variance at **wavenumber 5**”.*

According to Fig. 1, the peak in the spectrum of ERA5 is at wavenumber 6. Please clarify this.

It is not clear why in the explanation of the Taylor diagram in L204, the root mean square error is mentioned twice.

L288-L290 *“The observations are complex and location specific as one component within a climate model might be tuned in such a way that it compensates for biases in other components. If so, nudging only one component might not necessarily reduce the overall biases, in this case, prescribing only soil moisture part.”*

The message here is not expressed clearly. It should be rephrased, explained more clearly and in a more elaborated way.

L295-L296: *“...are well captured in different climate models in terms of their climatology, variability, and **phase-locking behaviors**.”*

The phase locking behavior is captured by the analysed climate models, however I wouldn't call it “well captured” based on what Fig. 2 shows.

L327-L328: *“whereas in our soil moisture prescription experiments the soil moisture was prescribed with values from running the land component driven by atmospheric fields from reanalysis in the model offline, which thus represent much smaller forcings.”*

The formulation is not clear enough, it should be rephrased.

L356: *“increase from 0.71 and 0.99 to 0.63 and 1.06”.*

An increase from 0.71 to 0.63? Please clarify.

Technical corrections

L37: *“When applying both soil moisture prescription and the nudging of upper-level atmosphere, both the correlation and n.s.d. values are quite similar **to only atmosphere component is nudged experiments**.”*

Grammatically incorrect, please rephrase.

L50: "Röthlisberger et al. 2019" instead of "Röthlisbergera et al. 2019".

L57: The citation "Hoskins and Ambrizzi 1993" appears twice.

L72 and L74: "*some have analyzed*" and "*Some studies by Branstator et al...*"
Formulation too general.

L192: "*Then we obtained the occurrences for JJA wave-5 and wave-7 events during 1979 to 2016 for ERA5 are 8.1% and 7.1%*".
Grammatically incorrect.

L212: "Taking ERA5 data as reference" instead of "taking ERA5 data as references".

L283: "completely" instead of "completed"

"And" is not a long word and can be written out, it does not need to be replaced by the symbol "&".

L293 "*some extreme events*"
Formulation too general.

L340: "*... that persist more than 2 weeks in summer events*"
Please rephrase.

L346: "flow" instead of "slow"

L347: "large-scale circulation pattern" instead of "large circulation pattern"