Paper on methods for assessment of model: response to reviewers

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Response to Reviewer 3

We are grateful to the reviewers for their insights and believe their comments have substantially improved our manuscript, especially in visualization and text clarification. We address all their comments below, point-by-point, in blue. We trust that our changes to the manuscript will satisfy the reviewers and the Editor.

Replies to general comments

Review: “"Selecting CMIP6 GCMs for CORDEX Dynamical Downscaling over Southeast Asia Using a Standardised Benchmarking Framework ".

The manuscript proposes a hierarchy of statistical indices and precipitation features (drives, teleconnection pattern, and climate change signal) with the aim of selecting the most suitable CMIP6 global climate models (GCMs) to be used for dynamical downscaling in Southeast Asia (SEA). The proposed methodology evaluate simulated precipitation following the steps: a) first, GCMs ability to simulate precipitation in SEA is statistically checked considering their mean absolute relative error, spatial correlation coefficient, annual cycle and time trends; b) second, the 850 hPa winds are used to discuss the ability of GCMs in reproduce observed monsoon characteristics, while the teleconnections are evaluated by considering the time correlation with two SST indices for ENSO and IOD; 3) third, GCMs are checked considering their independence and climate change signal in future SSP-3.70 scenario. Overall, the methods used are appropriate to reach the aims of selecting GCMs, with an abstract/conclusion reflecting the main results that recommends two independent groups of GCMs to dynamical downscaling in SEA. However, I have some minor comments before the acceptance of the manuscript.

Thank you for your constructive feedback on our manuscript. We appreciate your positive assessment of our proposed methodology for selecting CMIP6 global climate models (GCMs) for dynamical downscaling in Southeast Asia (SEA). Your comments have helped to substantially improve our manuscript. Please see below for our detailed responses to each of your comments:

Replies to specific comments

Minor points

1. I would like to know from the authors if all models in Table 1 have enough data available (atmospheric variables in three dimensions at each 6 hours) for dynamical downscaling. I did not have time to do this check.

Thanks for pointing out the potential value of including data availability in Table 1. We have reviewed the tables and included the requested information by highlighting the models that offer atmospheric variables in three dimensions at 6-hour intervals. These models are now marked with an asterisk in their names (Table 1 and L130-132).

2. Section 3.3 - I do not understand the criteria of analyzing the "... GCMs that simulated at least monthly tas (near-surface air temperature) and pr (precipitation) for the SSP-3.70 scenario only …" since simulations having only these two variables are not appropriated to dynamical downscaling. We know that atmospheric variables in three dimensions at each 6 hours are required for dynamical downscaling. In my opinion this should be the first criteria to select GCMSs, **being essential to exclude models that do not pass this criterion of the manuscript analysis**. Please, clarify.

Thank you for your thoughtful comments. We understand your concern regarding the criteria for selecting GCMs for dynamical downscaling. In our manuscript, we have used a parallel approach to assess GCMs based on different criteria, including (1)Model Performance (2)Future Climate Change and (3)Model Dependency. We recognize that for effective dynamical downscaling, models must indeed provide atmospheric variables in three dimensions at 6-hour intervals. However, to maximize the number of CMIP6 GCMs we can evaluate, we initially included models that offer at least basic precipitation and temperature data at the SSP 370 as required from the CORDEX CMIP6 experiment guide. This approach allows us to assess a broad range of models' future climate responses.

We agree that the availability of 6-hourly atmospheric variables is crucial and will clarify this in our manuscript. We will revise our criteria and discussions to better emphasize this requirement for dynamical downscaling and to highlight models that meet this criterion in our analysis (L531-536 and L588-589). Thank you again for bringing this to our attention.

"In this section, we examine the climate change signals from CMIP6 GCMs that provide at least mean temperature and precipitation data for the SSP3-7.0 scenario across two distinct seasons (see Fig. 12). Note that some models, such as CNRM-CM6-1-HR and EC-Earth3-Veg-LR (listed in Table 1), do not offer the sub-daily data (e.g., atmospheric variables in three dimensions at 6-hour intervals) required for dynamical downscaling at the time of writing. Nevertheless, we include these models in our analysis to gain insights into the future climate change responses of CMIP6 GCMs."

"Models from these two groups also offer atmospheric variables in three dimensions at 6-hour intervals required for dynamical downscaling (Table 1)."

3. L530-531 - Please, remove the affirmation "historical simulations were constrained by … observed SST)" since it is not correct because all GCMs listed in Table 1 are coupled GCMs having an oceanic component. Therefore, even in the present climate the SST is a model product without any "constraint" with observation.

Good point. We have now removed this sentence. Thanks.

4. L184-202 - The description of how ENSO/IOD indices are correlated with seasonal precipitation is hard to follow. I suggest to the authors to include a diagram to make this point clear.

Thank you for the excellent suggestions for enhancing the paper. We have acted on this and added a diagram in Supplementary Material for better clarification.

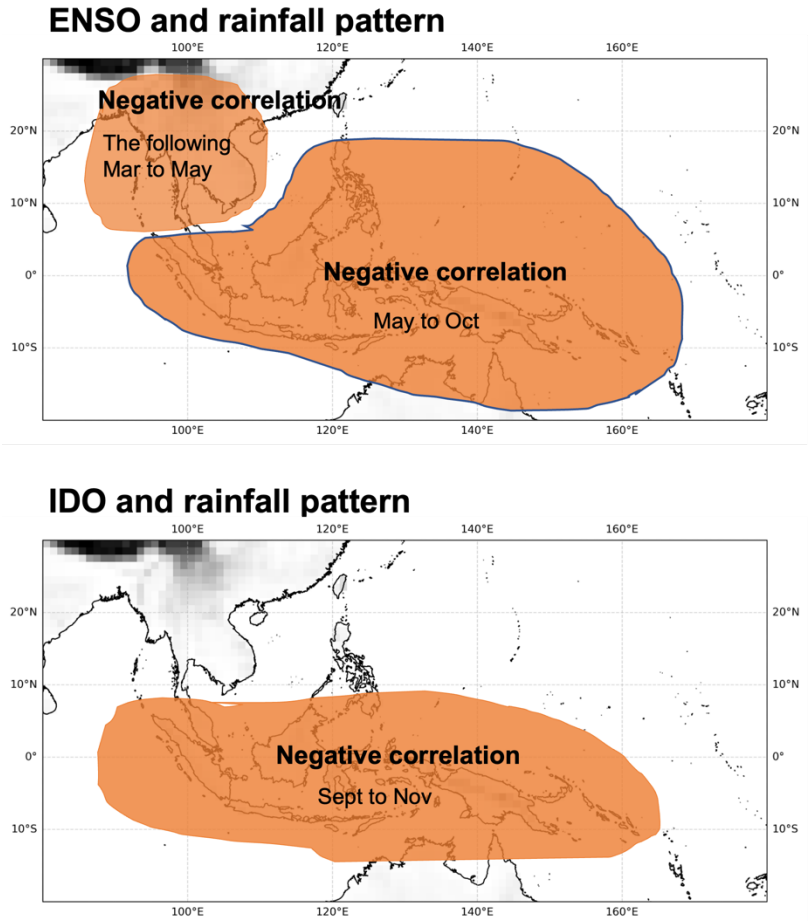

***Figure s2**. The schematic shows the impact of ENSO and IOD on the rainfall pattern over Southeast Asia. The correlation coefficients are calculated between DJF Nino3.4 or SON DMI indices and each regionally averaged precipitation anomaly during the corresponding marked period.*

5. L120 - should be "grid spacing smaller than 2 x 2 " since there is no model with grid spacing "greater than 2x 2" in Table 1.

Revised (L125-126).

"We consider only models which have a horizontal grid spacing finer than 2°× 2° to avoid the impact of the coarser GCMs on dynamical downscaling."

6. L123 - The phrase "At the time …" is incomplete. What happens with the first member of some models?

Revised (L128-129).

"At the time of this analysis, the first member of some models (e.g., CNRM-family models, UKESM1-0-LL, and HadGEM3-GC31-MM) was not available so another member was utilized."

7. L144-147 - Please, use these lines to define BMF and MSM. They only are defined in the legend of Figure 1.

Thanks, we added the section "2.2.1 Minimum standard metrics" to define the BMF and MSMs (L156-179).

"**2.2.1 Minimum standard metrics**

The BMF introduces a set of minimum-standard metrics (MSMs): 1. mean absolute percentage error (MAPE), 2. spatial correlation (Scor), 3. seasonal cycle (Scyc) and 4. significant changes (SigT) (Isphording et al., 2024) to assess the skill of climate models in simulating very fundamental characteristics of precipitation (e.g., magnitude of biases, spatial distributions, annual cycles and temporal variability). Before exploring complex processes, a model should meet performance expectations for these MSMs. Therefore, we initially calculate the MSMs for precipitation. In addition, we acknowledge that models should produce adequate present-day simulations of other fundamental climate variables like near-surface temperature. Hence, we also apply the MSMs for near-surface temperature in the supplementary information. Given the strong seasonality of precipitation in the region (Juneng et al., 2016), the analyses related to precipitation are conducted at a seasonal scale (e.g., the dry season November-April – NDJFMA and the wet season May-October – MJJASO). Meanwhile, temperature analyses are conducted at the annual scale."

8. L174 - Please, write that theta is the wind direction … and only "ui refer to simulated wind speed …"

Thanks. Revised (L199-200).

9. L183 - should be " … ENSO/IOD indices"

Revised (L207-208).

10. L198 - "DMI" is not yet defined. Move its definition in L205 to L198.

We have now moved the paragraph defining DMI and Nino3.4 index to L209-216.

11. L207 - Please, move "We use a … " as a new paragraph.

Revised.

12. L260 - Write out “MAPE" to be coherent with "Spatial correlation (Scor)".

Revised (L284).

13. L264 - Please, use the correct symbol for "greater or equal".

Revised (L285)

14. L281 - Please, to make clear what is "regionally-averaged climatologies". Is it referring to the average over all grid points over the continent inside the domain?

Thank you for your clarification. Added (L306-307).

15. L337 - should be "... the signal of statistically significant … trends using the wet (Fig. 5) and dry (Fig. 6) seasons accumulated precipitation”.

Revised (L364-365).

16. L366 - remove "of variable sign"

Revised (L392).

17. L369 - should be "temperature annual cycle"

Revised (L395-396).

18. L403 - Please, to improve the description of the winds. I am seeing "easterly-northeasterly winds in the North Hemisphere" crossing the Philippines.

Revised (L420-421).

19. L405 - should be "westerly winds predominate between …"

Revised (L422).

20. L410 - should be " … all MSM-selected models for precipitation …"

Revised (L427).

21. L417 - should be " … the extended summer season …"

Revised (L444).

22. L414-415 - change to "To benchmark CMIP6 GCMs, three metrics (HR, MR and FAR, see section 2.2.3) are calculated for each GCM considering the thresholds ≥50% for HR and ≤65% for MR and FAR, given the limited number of simulations used at this stage".

Changed (L446-448).

23. L433 - to refer to Fig. 10 " …CMIP6 GCMs (Fig. 10)"”

Changed (L469).

24. L463 - should be "... metrics stages (Fig. 11)."

Revised (L497).

25. L509 - change " … both signal and magnitude …"

Revised (L537).

26. L533 - remove the last "MJJASO".

Revised (L560).

Figures

27. Figures 4,5 - It is hard to see the wind direction. Please, improve these Figures, maybe using a less intense shading for wind speed.

Thank you for your suggestion. We have updated the colorbar for wind speed and changed the colour of the wind vectors to white to enhance visibility and clarity (L429 and L437).

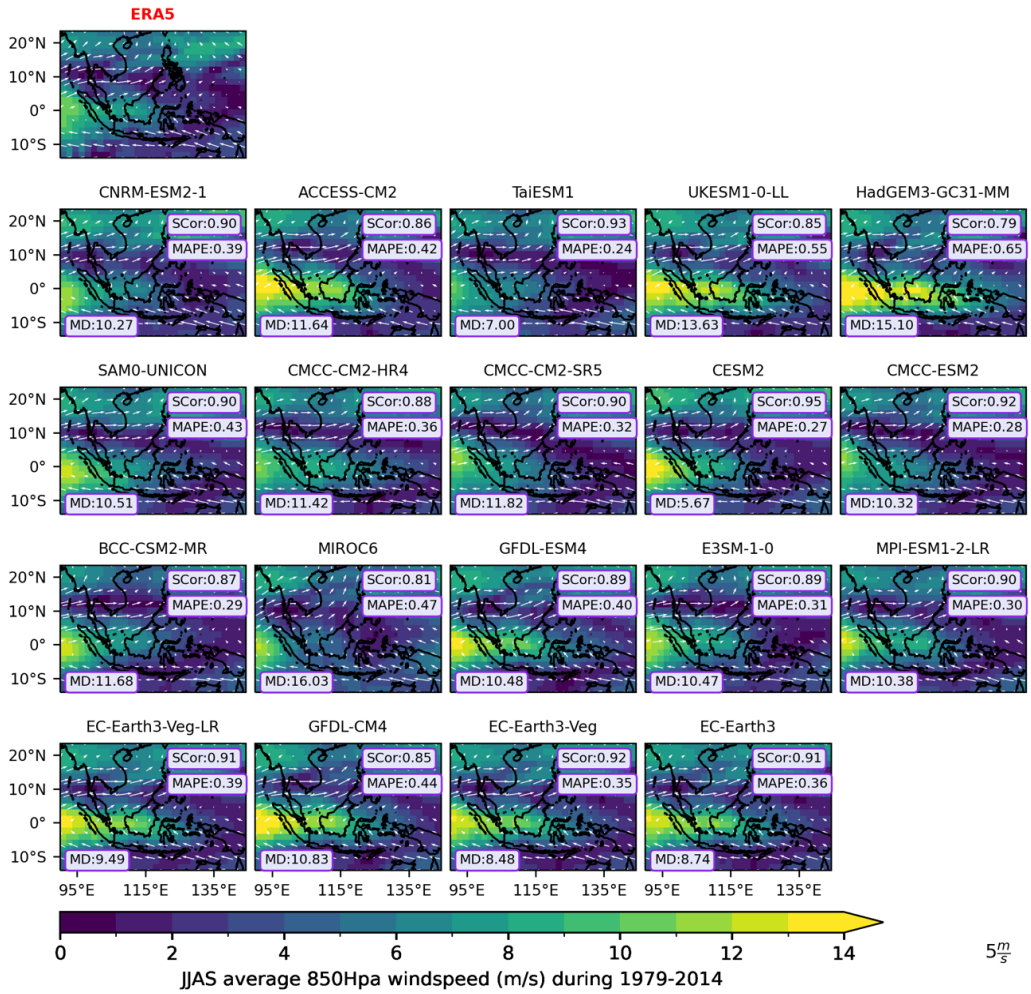

Figure 5. The spatial distribution of the climatology (1979-2014) of low-level wind circulation during the summer (JJAS).

28. Figures 2,3 - the scale in the bottom is in %, but the mean values in the boxes synthesizing MAPE in SEA are in hundredths. I would like to ask the authors to use only one unity for the same variable, for example, changing the values inside the box to %. A similar problem occurs in Figures 7 and 8, L295-296.

Thank you for your thoughtful suggestion. We understand your concern regarding the consistency of metric units. In Figure 2, the scale at the bottom is presented in mm/year, which reflects the difference between simulated and observed accumulated precipitation. The values for MAPE and Scor are expressed in hundredths, as per the design by Isphording et al. (2024). In response to your comment, we have revised the units for the Hit Rate (HR), Miss Rate (MR), and False Alarm Rate (FAR) to also be expressed in hundredths (L246-248). We have updated the corresponding interpretation in the text to ensure consistency throughout the manuscript.

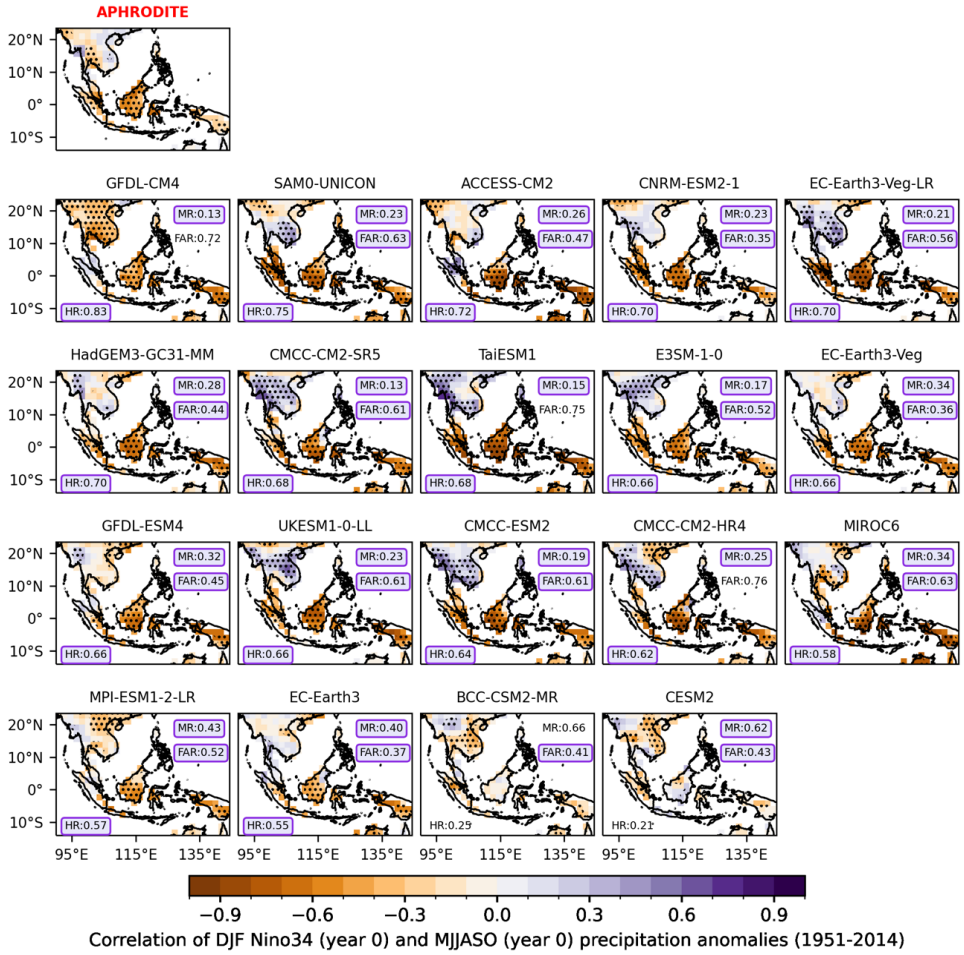

Figure 9. Lead correlation coefficients of the boreal summer (May-October, MJJASO year 0) rainfall with the mature phase of ENSO (December-January-February, DJF year 0 of Niño3.4 indices) in observation and models.

29. Figure s2 - should be "The annual climatological (1960-2014) bias of temperature …"

Revised.