Response to Reviewer 1

1. L39-40 seems a bit simplified, please at least include references to back up this claim.

: We sincerely thank the reviewer for this valuable comment. In our final response, we will provide further clarification and revise the manuscript accordingly by adding relevant references and additional explanations to better support our discussion.

2. L160-165: It says twice here that precipitation is underestimated in high latitudes, I would suggest removing one of those sentences. This also does not stand out to me as a feature – perhaps a difference plot would make this more obvious (see comment below)? Looking at the plots for a longer time, I think you might mean the North Pacific and Southern Ocean – it would help to name a few specific examples. Also, South America really stands out as a land region with large precipitation biases (perhaps due to the land model and lack of vegetation-atmosphere feedbacks?). I appreciate South America is not the focus of this paper but I think it would still be interesting to point this out, as it is a global model which others might want to use for studying other regions.

: We will remove the redundant statements from the manuscript and specify the geographical regions more clearly, as suggested. Furthermore, since this section presents the global precipitation distribution, we will revise the manuscript to briefly discuss precipitation biases in other regions as well, providing a more comprehensive evaluation of the model's performance.

3. Figure 1: A difference plot would be really helpful here to identify regions with large precip biases. Also, why not just use a linear colorbar?

: As suggested, we will add a precipitation difference plot to allow readers to more readily identify the spatial distribution of precipitation biases.

Regarding the use of a nonlinear color scale, we chose this approach because precipitation rates below 4 mm day^{-1} are widely distributed, particularly over East Asia and the western North Pacific. When a linear color scale is applied, spatial differences in precipitation within this range become less distinguishable. Therefore, we adopted a color scale with nonuniform intervals to provide greater detail in regions with relatively low precipitation rates and to better highlight differences in their spatial distributions.

Furthermore, precipitation rates vary considerably between the equatorial region, where precipitation is relatively high, and the high latitudes, where precipitation is generally low. We therefore considered a color scale with nonuniform intervals more appropriate than a linear color scale for effectively representing precipitation patterns across these regions.

4. L179 – 185: The geopotential height bias is discussed for the Tibetan Plateau and linked to surface temperature biases here, but from the plots it appears that the geopotential height biases are quite zonally uniform. Perhaps a difference plot would show the Tibetan Plateau stand out more clearly? Does figure 1f actually show the cold bias over the Tibetan Plateau (as it is a zonal mean) or did you mean Fig 1e, because it looks like other regions e.g. Northern Africa would also be contributing to the zonal mean cold bias of surface temperature. I'd also be curiousto see a timeseries plot (could be in supporting info) of how quickly the cold bias develops in the model from the initialised state. Can you explain a bit more about the land-surface model and why you think it can explain the cold bias?

: We acknowledge that our original description may not have been sufficiently clear and could have led to some misunderstanding. Our intention was to explain that the widespread geopotential height biases are primarily associated with the global cold temperature bias simulated by the model. In addition, we intended to discuss how the cold bias over the Tibetan Plateau may influence the East Asian summer monsoon (EASM). We will revise the relevant explanations to clarify these points and correct the figure references accordingly. We will also incorporate the additional supplementary material suggested by the reviewer.
Furthermore, previous studies have reported that the Noah land surface model, which is currently employed in Coupled GRIMs–NEMO, exhibits cold biases in simulated land surface temperature under certain conditions (Chen et al., 2010; Zheng et al., 2014). We will include these references in the revised manuscript to provide further support for our discussion. In addition, our preliminary sensitivity experiments have shown that replacing the current land surface model with an alternative model reduces the cold bias in lower-tropospheric temperature. We will provide a more detailed explanation of these findings and their implications for the simulated temperature biases in the revised manuscript.

References

Chen, Y., Yang, K., Zhou, D., Qin, J., & Guo, X.: Improving the Noah land surface model in arid regions with an appropriate parameterization of the thermal roughness length. *Journal of Hydrometeorology*, *11*(4), 995-1006, https://doi.org/10.1175/2010JHM1185.1, 2010.

Zheng, D., van der Velde, R., Su, Z., Booij, M. J., Hoekstra, A. Y., & Wen, J.: Assessment of roughness length schemes implemented within the Noah land surface model for high-altitude regions. *Journal of Hydrometeorology*, *15*(3), 921-937, https://doi.org/10.1175/JHM-D-13-0102.1, 2014.

5. L193: It is mentioned here that the temperature and geopotential height biases would affect the precipitation distribution (i.e. via the circulation/dynamics), but would the cold bias not also imply lower specific humidity (thermodynamic) issues which might at least contribute to the negative precipitation bias in the model?

: We appreciate the reviewer's insightful suggestion, which allows us to further clarify and expand our discussion. The simulated cold bias is associated with reduced atmospheric specific humidity, particularly at high latitudes, where a decrease in specific humidity is also evident in our model results. This reduction in atmospheric moisture availability likely contributes to the underestimation of precipitation in these regions. We will revise the relevant section of the manuscript to provide a more detailed explanation of the relationship between the cold temperature bias, reduced specific humidity, and negative precipitation bias.

6. Fig 2 caption: Please state explicitly in the caption what the “difference” is in panels e and f, i.e. which one is subtracted from which one. Presumably CPL minus ERA5?

: The differences shown in the figure represent CPL minus ERA5 (CPL − ERA5). We will explicitly clarify this in the figure caption to avoid any ambiguity.

7. L206: Please include references here to studies that show impact of ENSO, BSISO and PJ on EASM. Are these the most important modes of variability for EASM? What about IOD, PDO,…? I am not suggesting to analyse all of these, but it would be helpful for the reader to include a stronger motivation for why the three mentioned above were chosen.

: We appreciate the reviewer's insightful comment and agree that a clearer motivation for selecting ENSO, BSISO, and the Pacific–Japan (PJ) pattern would strengthen the manuscript.

We acknowledge that EASM variability is influenced by multiple climate modes, including the Indian Ocean Dipole (IOD) and Pacific Decadal Oscillation (PDO), in addition to ENSO, BSISO, and the PJ

pattern. Therefore, we do not intend to suggest that the three selected modes are necessarily the most important modes governing EASM variability.

Rather, we selected these three modes to evaluate distinct aspects of the model's ability to reproduce the variability of the Asian summer monsoon system across different timescales and through different physical mechanisms.

ENSO plays an important role in modulating EASM variability on interannual timescales, we selected it to assess the model's ability to reproduce this interannual variability (Wang et al., 2003). BSISO was selected to assess the simulation of intraseasonal convective variability, particularly the northward and northwestward propagation of convection over the Indian Ocean and western North Pacific (Lee et al., 2013; Kikuchi, 2021). The PJ pattern was selected to evaluate the model's ability to reproduce tropical–extratropical atmospheric teleconnections associated with convection over the western North Pacific, which play an important role in modulating East Asian summer circulation and precipitation (Nitta, 1987; Kosaka et al., 2013). We will revise the manuscript to include the relevant references and provide a clearer explanation of the rationale for selecting ENSO, BSISO, and the PJ pattern.

8. L240: Please include relevant citation for definition of the BSISO life cycles.

: Gao, Yingxia. Code - BSISO in SP GCMs: effects of air-sea coupling and mean-state biases. figshare. Software. https://doi.org/10.6084/m9.figshare.11911410.v2, 2020.

We have used the references mentioned above to support our discussion and will include the relevant citations in the revised manuscript.

9. L243-245: The authors attribute the dry bias over India to a “warm SST bias in the Indian Ocean”, however from Fig 2 it actually looks like there is a cold SST bias in the Indian ocean? And a warm bias over land (the latter could perhaps be at least partly due to lack of rainfall, and thus enhanced sensible instead of latent heat release). This would be expected to strengthen the land-sea thermal contrast and enhance monsoon circulation… In addition, it would be interesting to expand this discussion on what impacts the BSISO biases have on the East Asian Monsoon, since this region is the focus of the current study.

: We appreciate the reviewer's constructive comments, which have helped us identify an incorrect interpretation in the original manuscript. Our further analysis suggests that the underestimation of precipitation over India is associated with the cold SST bias over the Indian Ocean. This cold bias reduces evaporation and atmospheric moisture availability, thereby weakening moisture transport from the Indian Ocean toward India.

In addition, the cold bias over the Tibetan Plateau may lead to insufficient heating of the middle troposphere, suppressing the development of ascending motion and weakening the southwesterly monsoon flow. These circulation changes may further reduce moisture transport toward India, contributing to the underestimation of precipitation in this region. The combined effects of these thermodynamic and dynamical biases may also help explain the weaker northwestward propagation of the precipitation band associated with the BSISO in Coupled GRIMs–NEMO.

We will correct the interpretation in the revised manuscript and provided a more comprehensive explanation of these physical mechanisms and their implications for the simulated BSISO variability.

10. Fig.5 : Missing labels in caption (which column is ERA5 and which is the coupled model). Also, I would suggest extending the latitude range to ~ 60N (as in Fig 7). Currently we can barely see the EASM region and half of it is cut off, which is odd given the focus of the paper.

: The left column of the figure presents the ERA5 results, while the right column shows the results from Coupled GRIMs–NEMO. We will explicitly clarify this in the figure caption.

Regarding the geographical extent of the figure, we focused on the tropical and subtropical regions because the primary convective activity associated with the BSISO life cycle is concentrated in these regions. Nevertheless, in response to the reviewer's suggestion, we will consider extending the northern boundary of the figure to approximately 40°N to provide a broader view of the BSISO-related precipitation patterns. The region between 40°N and 60°N is not directly addressed in our analysis of the BSISO life cycle, which primarily focuses on the propagation of tropical and subtropical convection.

Although the main convective activity associated with the BSISO is concentrated in the tropical and subtropical regions, its northward and northwestward propagation can influence the expansion and contraction of the western North Pacific subtropical high (WNPSH). These circulation changes can, in turn, modulate the position of the East Asian summer monsoon (EASM) rainband. Therefore, we will expand the discussion in the revised manuscript to clarify the physical connection between BSISO-related convective propagation, variations in the WNPSH, and the spatial distribution of EASM precipitation. This additional explanation will also provide a clearer scientific rationale for the geographical extent selected for the figure.

11. L258, L290 and others: The authors mention “the negative relationship between SSTs and precipitation”, but there are also large areas of positive feedback (Fig 6) so I would be a bit more specific about this in the text throughout that you are referring to specific regions where the correlation is negative. At the moment, it sounds like a blanket statement.

12. L255-257: I would change these two sentences to present tense as the analysis is yet to come. I also would not say that this analysis (figure 6) is “over the East Asian region”, but rather over the North Pacific (nothing is actually plotted over East Asia).

13. L262-266: The authors discuss that the ATM model does not capture regions of negative correlation between precipitation and SSTs, and then discuss that the coupled model does capture this relationship. These two arguments need to be separated, because currently it sounds like *because* ATM does not capture this relationship, CPL does. Please rephrase, otherwise it’s confusing to the reader.

14. L272-274: I don’t think you need to say again here that ATM “was conducted using the GRIMs atmospheric model, a component of Coupled GRIMs–NEMO”

: We appreciate the reviewer's valuable suggestion. We will revise the relevant text in the manuscript to improve clarity and avoid any potential misunderstanding.

15. Figure 6: I think including a subplot for ATM_CSST would be interesting here to isolate the air-sea feedback (as done in Fig 7). Also, please include precipitation contours because currently we can’t see whether regions of negative correlation are actually associated with strong precipitation. I would also argue that the sign of the correlation in CPL compared to the observations is actually the opposite in key regions – why is this the case? This might be related to different precipitation distribution.

: As recommended, we will include the ATM_CSST results and add precipitation contours to the figure to facilitate a clearer comparison and interpretation of the results.

The regions where the correlation coefficients in CPL exhibit signs opposite to those in the observations

appear to be associated with differences in the spatial distribution of precipitation between CPL and the observations. As shown in Fig. 7, a comparison of Figs. 7a and 7c reveals that CPL overestimates precipitation over the equatorial western Pacific. In this region, excessive precipitation is likely accompanied by enhanced cloud cover, which reduces incoming shortwave radiation at the ocean surface and promotes SST cooling. This process may contribute to the negative correlation observed in Fig. 6c.

In contrast, the region exhibiting a positive correlation near 25°N, south of Japan, corresponds to an area where CPL underestimates precipitation. In this region, the positive correlation suggests that the relationship between warmer SSTs and enhanced precipitation may be more dominant, indicating that increased SSTs may favor enhanced convective activity and precipitation.

Nevertheless, despite these discrepancies in the spatial precipitation patterns, the simulated relationships between precipitation and SST remain physically plausible in terms of atmosphere–ocean interactions. We will incorporate these explanations into the revised manuscript to provide a clearer interpretation of the correlation patterns and the underlying physical mechanisms.

16. L294-298: I think the statement that in CPL the rainband migration is “similarly reproduced” as in IMERG is a bit generous. There is a weak signal of precipitation that appears to be moving northward but nowhere near as strong and organised as IMERG. To me CPL and ATM_CSST look very similar to each other and ATM_CSST even looks like it is capturing the rainfall later in the season a bit better than CPL. Also why did you choose to take an average over the region 120-140E, which is off the coast of Eastern China? I think it’s important to include land regions of the EASM in this hovmoeller plot (see e.g. Chen and Bordoni 2013 (DOI: 10.1175/JCLI-D-13-00479.1), Fig 9), especially given the focus of the paper.

: We appreciate the reviewer's constructive comments and agree that our original description may have been overly definitive. We will revise the manuscript to provide a more detailed and balanced interpretation of the differences between CPL and ATM_CSST.

For June, we consider that CPL better reproduces the spatial organization of the northward-migrating precipitation band than ATM_CSST. In ATM_CSST, the overestimation of precipitation extends over a broad region near the equator, and the simulated precipitation exhibits a continuous northward extension from the equatorial region rather than a distinct, organized precipitation band near 30°N. In contrast, although CPL underestimates precipitation intensity compared with IMERG, it reproduces the spatial structure of the organized precipitation band relatively well.

A similar feature is observed during the latter part of the analysis period. In ATM_CSST, precipitation is consistently overestimated around 20°N, and the precipitation distribution appears as a continuous band extending northward toward 30°N rather than a distinct, organized precipitation band. Nevertheless, we agree with the reviewer that ATM_CSST performs slightly better than CPL in reproducing precipitation intensity during this period. We will revise the relevant discussion to distinguish more clearly between the simulation of precipitation intensity and the spatial organization of the precipitation band, thereby avoiding an overly generalized assessment of model performance.

Furthermore, we agree with the reviewer that including the land regions would provide a more comprehensive representation of the EASM precipitation. Accordingly, we will revise the figure as shown below and incorporate the updated version into the manuscript.

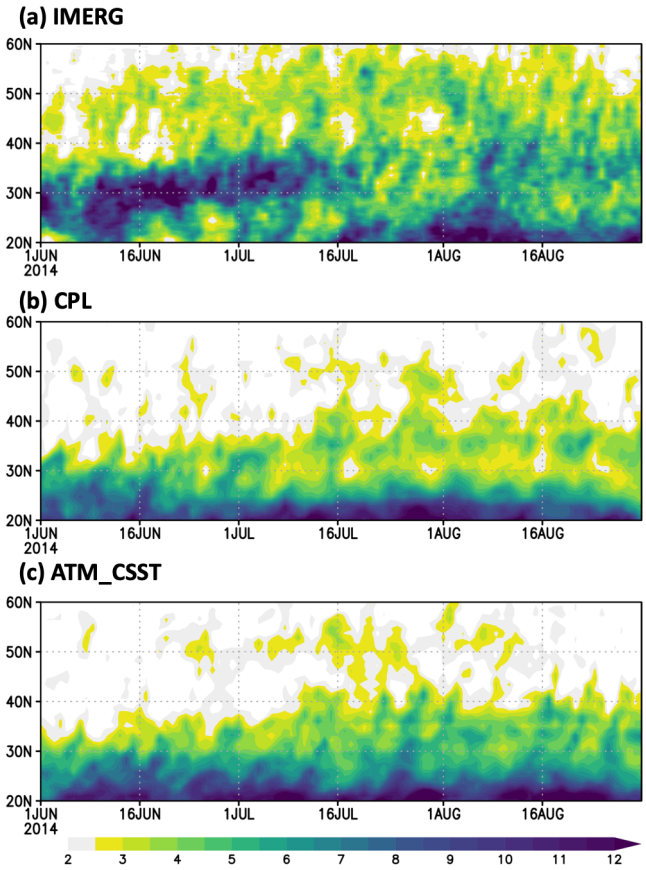


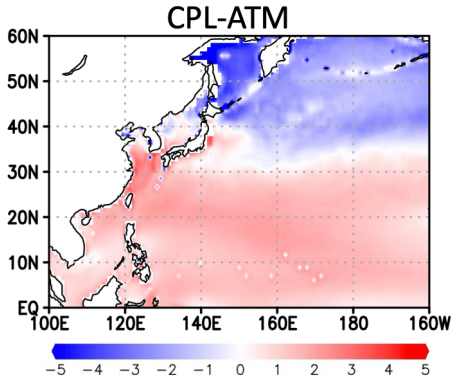
Figure 8 Hovmöller diagram of precipitation averaged over 100˚E-140 ˚E (mm day^{-1}): (a) IMERG, (b) CPL, (c) ATM_CSST. IMERG precipitation data©NASA.

17. L330, L337: The authors refer to a "warm SST bias" in the coupled model, yet in Fig 2e it very much looks like a cold bias almost everywhere except over India (and the high latitudes)?

: The model results presented in this section were obtained using a different experimental configuration from that used for Fig. 2e. Specifically, these results are based on simulations conducted for the period 2014–2023, during which the simulated sea surface temperature (SST) exhibits a warm bias.

We initially considered that this warm SST bias could be inferred from the differences in surface heat fluxes between the ATM and CPL experiments and therefore did not explicitly present the SST biases. However, we acknowledge that this interpretation may not be sufficiently intuitive for readers and that surface heat flux differences alone cannot directly explain the simulated SST biases.

Therefore, to provide a clearer and more direct representation of the SST biases, we will revise Fig. 10 to include an SST difference field. This addition will help readers better understand the relationship between the simulated SST biases and the differences in atmospheric responses between the ATM and CPL experiments.



JJA mean sea surface temperature difference between CPL and ATM (CPL-ATM).

18. L335: "the negative relationship between precipitation and SSTs": As mentioned above, there is more subtlety here, not all regions have a negative correlation. I understand the argument about cloud feedbacks, but there are several things that impact the correlation between precipitation and SSTs (generally precipitation is concentrated in regions of high SSTs, so would expect a positive correlation). I would at least say something like "the negative relationship between precipitation and SSTs in some regions"

: We agree with the reviewer's suggested revision to the wording and appreciate this helpful comment. We will revise the relevant text in the manuscript accordingly to improve clarity and precision.

19. Manuscript Title: I appreciate the region of interest for this paper is the EASM, but is there anything specific to the model that would imply that simulation of EASM would be better than any other region of the globe? The title of the paper implicitly suggests that the model has been developed specifically for studying the EASM, but there doesn't seem to be anything in the model that would make performance in the EASM better than anywhere else. I would suggest changing the title to make it clearer that a global model has been developed, and is here tested on the EASM. Perhaps: "Development of the GRIMs–NEMO fully coupled global model v1.0 and evaluation of its performance in simulating the East Asian Summer Monsoon"

: We appreciate the reviewer's valuable suggestion regarding the manuscript title. In accordance with the reviewer's recommendation, we plan to revise the title as follows:

"GRIMs–NEMO v1.0: A Fully Coupled Global Model and Its Performance in Simulating the East Asian Summer Monsoon"

20. All figures: I would find it easier to look at the figures if the labels were added as titles to the subplots/in legends, rather than having to skip between the figure caption and the subplots to see which one is CPL, ATM, IMERG, ERA5 etc

: We will revise the figures by adding appropriate titles to each subplot to facilitate identification and comparison of the results.

21. Reproducibility: I note that the model has been uploaded to zenodo but is currently with restricted access - presumably the authors are planning to make it available upon acceptance of the manuscript (?)

: Yes, that is correct. The model code currently uploaded to Zenodo will be made publicly available upon publication of the manuscript. We plan to provide the model source code, the input data required to reproduce the simulations, and a user manual to ensure the reproducibility of the model experiments and facilitate its use by the research community.