Dear Reviewer,

We would like to express our sincere gratitude for your valuable comments and suggestions on our manuscript titled **" ENSO statistics, teleconnections, and atmosphere-ocean coupling in the Taiwan Earth System Model version 1"**. In response to your comments, we have carefully addressed each point and made two major revisions:

1. (Question#3) In response to the comment, we have conducted an analysis on ENSO diversity in TaiESM1 by dividing the simulated El Niño events into Central Pacific El Niño (CP) and East Pacific El Niño (EP) based on the Niño3-Niño4 indices (Kug et al., 2009). Our analysis revealed that TaiESM1 has overestimated the frequency of CP El Niño events compared to observations. However, it captures a similar teleconnection spatial pattern when compared to observations (see Figure R1). These findings have been added to the revised manuscript, providing a more comprehensive understanding of the ENSO diversity in TaiESM1.
2. (Question#4) To investigate the impacts of the background state on ENSO variability in TaiESM1, we conducted an analysis comparing the changes in the background state between two 30-year time periods, namely 1984-2014 and 1950-1980. Our findings indicate that TaiESM1 exhibits a La Niña-like background during the 1984-2014 period, when weaker ENSO variability prevails, consistent with previous literature (see Figure R2). These results have been included in the revised manuscript to enhance our understanding of the relationship between the background state and ENSO variability in TaiESM1.

Please view the attached pdf file for the complete response report. Thanks again for your comments in improving the quality and clarity of this research.

Sincerely,
Yi-Chi Wang and Coauthors

RC1: 'Comment on gmd-2023-41', Anonymous Referee #1, 10 Apr 2023 reply

This paper evaluates the Taiwan Earth System Model version 1 (TaiESM1), a recent addition to the class of CMIP models, against various data sets. The model is shown to have a too strong and regular ENSO cycle similar to the model is it derived from (CESM). The model also exhibits the usual systematic errors, like a cold tongue bias and a positive SST-SW radiation feedback in the eastern Pacific which the authors argue accounts for many of the biases in the model ENSO cycle. The paper will be useful addition to the literature for those interested in the analysis of CMIP models, particularly their ENSO variability. There are a few issues that that authors should address in a revision of the manuscript, listed in order of appearance in the paper. The most significant issues are raised in points #3 and #4.

1. Lines 82-83. Is this the resolution of the ocean component, the atmospheric component, or both?

Thank you for the question. In TaiESM1, the atmospheric component has a resolution of 0.9° latitude × 1.25° longitude, as stated in the manuscript. In the meantime, the ocean component has a grid resolution of approximately 1.125° in longitude and 0.47° in latitude.

We have revised the text as:

"The historical run is conducted based on the pre-industrial control run of TaiESM1. It utilizes an atmospheric model with a horizontal resolution of 0.9° latitude × 1.25° longitude and 30 vertical layers. The community land model employed in the historical run shares the same resolution as the atmospheric model. Additionally, the POP2 ocean model has a resolution of approximately 1.125° in longitude and 0.47° in latitude."

2. Line 102. Why did you use a base period for the model that was different than for the data? What are the differences between the model base period used and a 1970-2000 base period?

Thank you for your question. After double-checking our analysis, we found that we misspelled the base period of TaiESM1 as 1970-2000 in the manuscript. The correct base period for TaiESM1 aligns with the ERSSTV5 dataset, spanning from 1900 to 2014.

The revised manuscript now accurately reflects the base period for both TaiESM1 and the ERSSTV5 dataset as:

"For the observational Niño 3.4 index, we use a base period between 1900 and 2014 from ERSSTV5, following the Niño index calculation of the Climate Prediction Center, NOAA. In contrast, we use model data from 1900 to 2014 as the base period for TaiESM1's historic run."

3. The authors use a composite of eight observed ENSO events (lines 110-111) to compare with the model output. However this set is comprised of a combination of eastern Pacific (EP) and central Pacific (CP) El Niños with distinctly different spatial structures (McPhaden et al., 2011; Capotondi et al., 2021). The authors should include a discussion of how well TaiESM1 simulates ENSO diversity as this is one of the most important problems in ENSO research today.

We appreciate your insightful comment. We have analyzed TaiESM1's capability in simulating ENSO diversity, distinguishing between Eastern Pacific (EP) and Central Pacific (CP) El Niño using the Niño3-Niño4 approach (Kug et al., 2009). We acknowledge that 23 CP events and 17 EP events are identified in TaiESM1 historical period, exhibiting a higher frequency of CP events compared to observations, consistent with previous findings in CMIP models (Capotondi et al., 2020; Chen et al., 2017; McPhaden et al., 2011). The model also depicts higher SSTA in both EP and CP scenarios, aligning with the stronger ENSO magnitude noted in our research (Figure R1a).

The composite of surface temperature and SLP was constructed based on four East Pacific (EP) events and four Central Pacific (CP) events during the observation period (1980-2014), as well as CP and EP events during the historical TaiESM1 period (1900-2014). In terms of the EP composite, TaiESM1 successfully captures the observational features over the tropical Pacific, as demonstrated in Figs. R1b and R1c. However, the CP events identified in TaiESM1 exhibit elongated warm sea surface temperature anomalies in the tropical region, but with weaker teleconnections to the midlatitude in the northern hemisphere (Figs. R1d and R1e). Additionally, the warming over North America is less pronounced and retreats towards the polar region, whereas the observed cold surface temperature anomaly is replaced by a warm anomaly. It is likely that the biases in the model's mean state contribute to the model's biases in ENSO diversity and teleconnection patterns observed in TaiESM1, which is a common issue seen in other climate models as well (Ham & Kug, 2012).

The discussions of ENSO diversity are now incorporated into the revised manuscript.

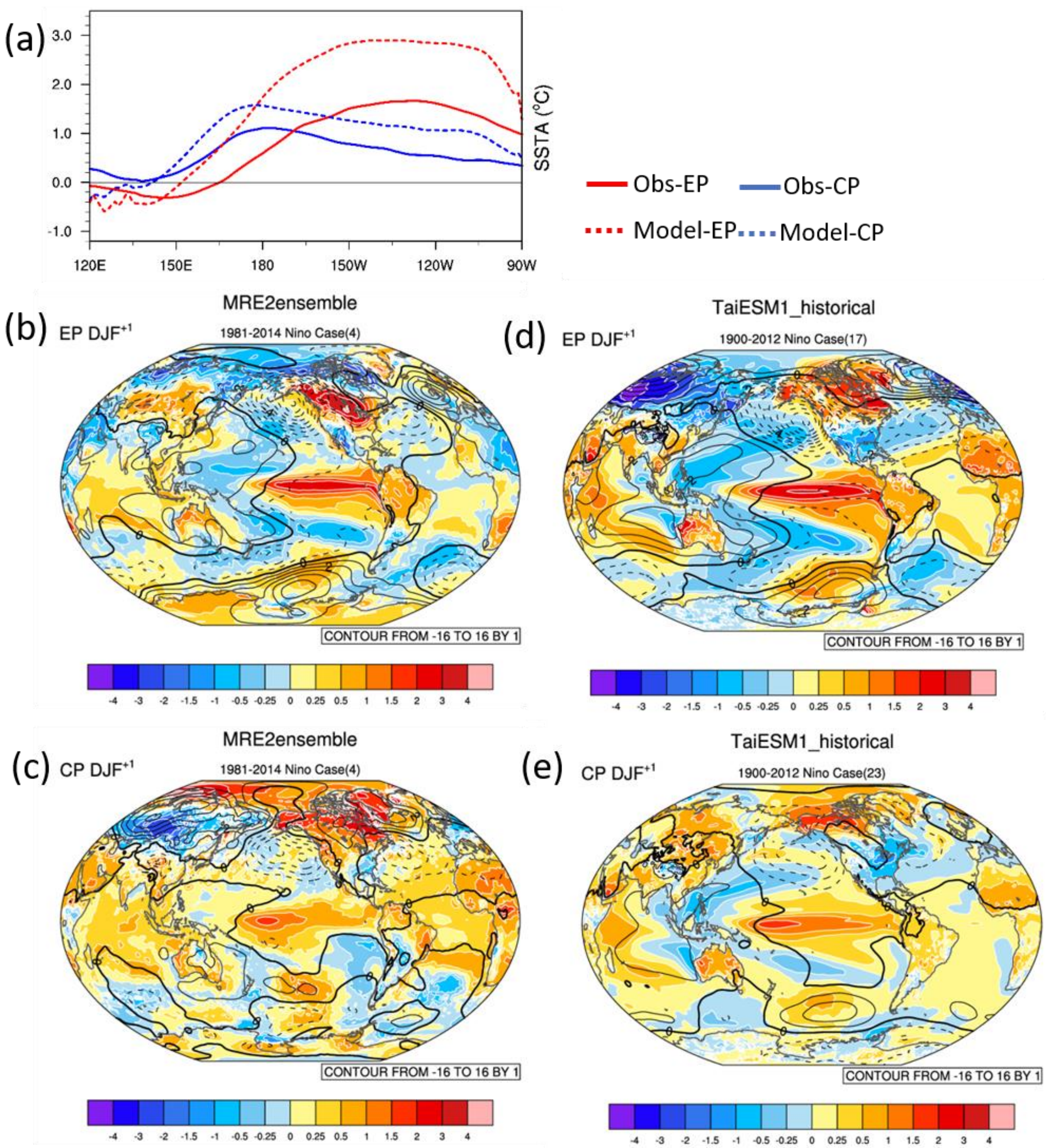

Figure R1: (a) Composites of equatorial SSTA profiles averaged in 5°S-5°N for EP (red line) and CP (blue line) events identified in ERSST5 (solid line) and in TaiESM1 simulations (dashed line). (b-c) Composites of surface temperature and SLP of MRE2 ensemble based on EP and CP events. (d-e) Composites of surface temperature and SLP of TaiESM1 historical runs based on EP and CP events.

4. Lines 127-28. The comment about diminishing ENSO amplitude is interesting but not further elaborated on. Is the background state in the model changing like in observations, i.e. becoming more La Nina like? We know changes in background state affect ENSO (Fedorov et al., 2021; Cai et al, 2021). This sentence warrants further elaboration since ENSO in a changing climate is also one of the most important problems in ENSO research today.

Thank you for your suggestion. To understand the impact of the model's background state on the ENSO variability changes in TaiESM1, we have compared sea surface temperature (SST) and surface winds between the two 30-year periods of 1950-1980 and 1984-2014 (Fig. R2). TaiESM1 exhibits stronger ENSO variability during 1950-1980 and weaker ENSO variability during 1984-2014 (Fig.2).

Fig. R2 reveals a shift in the background state to a La Niña-like state with increasing zonal temperature gradient over the tropical Pacific and strengthening of the trade winds during 1984-2014, compared to the period of 1950-1980. Previous researches on the ENSO response to changes in the observed mean state indicates that such an increase in zonal wind stress could cause a weakening of feedbacks related to El Niño (Fedorov et al., 2020; Zhao & Fedorov, 2020). This aligns with the observed weakening of ENSO variability in TaiESM1 during 1984-2014.

We have incorporated these discussions on the changes in the background state into the revised manuscript and added figure R2 to our supplementary figures.

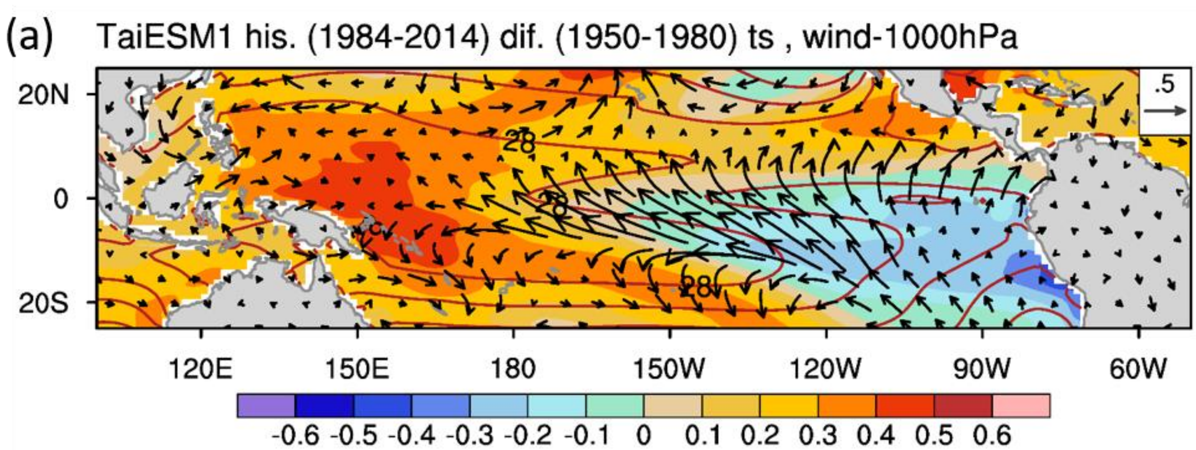

Figure R2: Difference of sea surface temperature (color shading) and 1000-hPa winds (arrows) during December, January, and February (DJF) between the two periods of weak ENSO variability (i.e. 1984-2014) and strong ENSO variability (1950-1980).

Line 176. I don't understand the meaning of "fledges" as used here.

Apologies for the confusion caused by the term "fledges." In this context, we were referring to the regions of subsidence adjacent to the ITCZ region (Fig. R3; marked in red squares). Therefore, the revised sentence would read: "In contrast, we observed an increase in downwelling shortwave flux over the subsidence regions adjacent to the ITCZ in both 10ºN and 10ºS over the east Pacific."

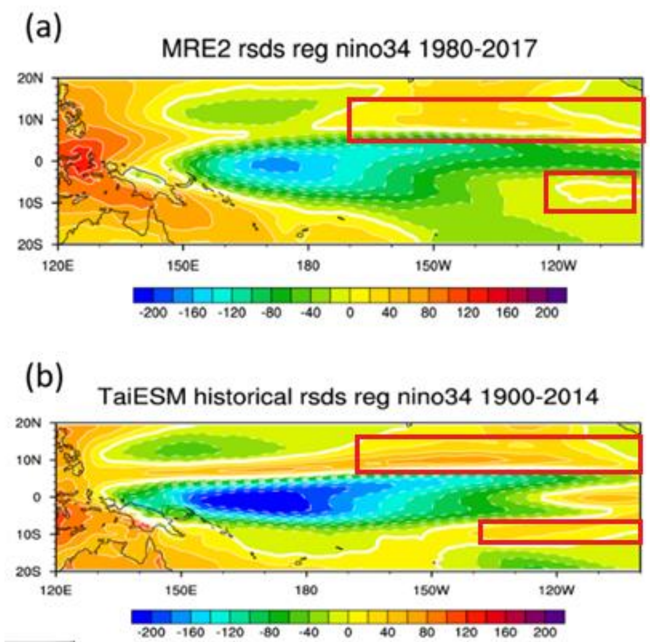

Figure R3: The regression map of downwelling shortwave flux onto the Niño 3.4 in (a) MRE2 and (b) TaiESM1. Red squares show where SST-shortwave positive feedback occurs.

5. Lines 321-25. The authors describe what needs to be done to resolve the causes of the biases in this model. But they don't say that the needed actions will actually be taken. Is there a plan to carry out more analyses to resolve the problems?

Thank you for raising this important point. Indeed, further actions are planned to address the identified biases in our model. We have added this information to our manuscript to provide a clearer outlook on our future work. Our forthcoming research will focus particularly on the two model biases related to ENSO in TaiESM1. To do this, we plan to implement ocean-only experiments with the ocean component POP2, allowing us to quantify the ocean's response to biased winds and radiation fluxes. At the same time, we will conduct AMIP-type simulations to investigate the development of westerly wind anomalies under biased SST conditions. This exploration will give us valuable insights into the influence of fast-propagating westerly wind anomalies on the formation of El Niño events. Combined with process-oriented diagnosis for these model experiments, this approach will allow us to dissect and better comprehend the causes and effects of these observed biases.

The discussion section of our manuscript has been revised to reflect these points.

References

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