The paper of Zhang et al. simulates future climate projections over California using the Simplified Convection Permitting E3SM Atmosphere Model Version 0. Overall, the paper is well organized, and it can help in understanding future climate change in the California region, providing more detail due to the higher model resolution. However, some issues still need to be improved. Main concerns about this manuscript are listed below.

Thank you for your nice suggestions. We have revised the text and figures (17 figures updated in the main text, 9 supplementary figures added). We have added much of the relevant literature you recommended. Again, we thank you for your suggestions and thorough review.

1. Why does the author analyze the SSP585 scenario? The author mentions in section 2.1.5 that SSP585 is a worst-case scenario with a high probability that it will not occur. However, many studies show that the warming of the SSP370 scenario cannot be ignored either (IPCC AR6). Of course, it is not necessary for the author to simulate the SSP370 scenario again, but it is necessary to explain it again in the article. I think just referring to the study of Tebaldi et al. is not convincing enough.

Reference:

Masson-Delmotte V P, Zhai P, Pirani S L, et al. Ipcc, 2021: Summary for policymakers. in: Climate change 2021: The physical science basis. contribution of working group i to the sixth assessment report of the intergovernmental panel on climate change[J]. 2021.

Sorry for the lack of clarity. First, SSP585 and SSP370 are of comparable scientific importance to us, with the former allowing us to study a more extreme scenario that is more relevant to the interests of energy infrastructure users, and the latter being more conservative in its predictions. For work that emphasizes scenario differences, we would choose to simulate both scenarios, but limited resources would limit the number of years we could simulate. The more critical reason is operational. We had to re-run the publicly available version of E3SM as nudging data for the coarse grid region, and we only had E3SMv1 to choose from, while the publicly released v1 future projection only has the SSP585 scenario.

We have added more explanation of the use of SSP585 in the main text according to your nice suggestion:

> “We recognize that SSP5-8.5 is a ``worst'' case scenario that is unlikely to happen, due to policy interventions that promote carbon emission mitigation and sequestration, and thus represents an upper bound case of the ScenarioMIP \citep{Kriegler2017}. However, the differences between the more

plausible SSP3-7.0 and SSP5-8.5 before 2050 are relatively small \citep{Masson2021,Tebaldi2021}. Both of these scenarios predict similar development trends, including high GHG emissions, increased energy usage, and limited climate change mitigation measures before 2050 \citep{ONeill2016}. The chief reason for our choice to run the SSP5-8.5 scenario is due to the fact that we had to re-run the publicly available version of E3SM (i.e., version 1) to produce the necessary nudging data for the coarse grid region, and SSP5-8.5 is the only scientifically validated scenario for the publicly released v1 future projection."

2. Sometimes the resolution of the model described by the author is 3.25 km (Line 3), and sometimes it is 3 km (Line 47), which needs to be unified.

When specifying a description of our California RRM, we have uniformly used 3.25 km. When describing the broader concept of the convection-permitting models, the use of ~3km has been standardized.

3. Line 3: the author says that they have "developed" a CARRM model, but after reading the research, I think the author only applies the relevant model to the climate simulation field, so I suggest modifying the relevant expression. In my opinion, designing the new RRM grids and generating the model configurations cannot be considered as "developing" the new model.

Sorry for the inaccurate terminology here. In the main text we use the description "develop a California convection-permitting climate modeling framework", which, in addition to designing the RRM grid, also includes conducting the full suite of future projection simulations (re-running the low-resolution GCM, preparing nudging data and lower boundary conditions, designing simulation strategies, and basic validation). In addition, the design of the RRM grid itself is quite different from limited-area regional climate models, and the preliminary work to prepare the RRM grid has been non-trivial. Instead of simply specifying a user-level name list, the model code must be modified, all grid configuration files must be prepared using a series of stand-alone tools, and the grid may require multiple iterations to be suitable for long-term simulations. I would consider this to be development work, as future projections of CARRM are far from "out of the box". Of course, we agree that we are not developing the "whole" model itself, since the host model SCREAM, on which CARRM is based, is not part of the development effort.

We have modified this sentence to:

> “We developed a 3.25 km California climate modeling framework by leveraging regional mesh refinement (CARRM) using the U.S. Department of Energy's (DOE) global Simple Cloud Resolution E3SM Atmospheric Model (SCREAM) version 0.”

4. Figures 1-19: For each subfigure, it is recommended to add legends such as (a) (b).

Thanks for the suggestion. All subfigures have added (a), (b)...

5. Line 82: The author should briefly introduce the difference between “Modern regionally refined model (RRM)” and convective-permitting model (CPM) in their research. In fact, CPM has been widely used in climate simulations in various regions.

Reference:

Prein A F, Langhans W, Fosser G, et al. A review on regional convection-permitting climate modeling: Demonstrations, prospects, and challenges[J]. Reviews of geophysics, 2015, 53(2): 323-361.

Kendon E J, Ban N, Roberts N M, et al. Do convection-permitting regional climate models improve projections of future precipitation change?[J]. Bulletin of the American Meteorological Society, 2017, 98(1): 79-93.

As we introduced in paragraph 5, CPM is a resolution concept, emphasizing that the resolution reaches 5 km or more, so that deep cumulus parameterization can no longer be needed. CPM includes both global and limited-area (regional) models, the latter of which is the subject of the two papers you mentioned, including WRF, MetUM, COSMO-CLM, RegCM4, and so on. On the other hand, RRM is a global model as is global CPM. Since the simulation we use here is to constrain RRM by nudging it to given lateral forcings at coarse resolution (outside the region of interest), it works “like” a regional climate model, but RRM itself covers the entire globe and can provide global results, just because we focus on California here, so no other regions are shown. When RRM is run freely, it works exactly like a typical GCM (e.g., Tang2023), and there are papers discussing the upscale effects of the refined area in large-scale circulations (e.g., Sakaguchi2016). Thus, RRM and limited-area regional models are fundamentally different in terms of grid structure and evolutionary history, although they both can be classified as CPM when pushed to a CP resolution.

We have added the sentences when we first introduce RRM according to your suggestion:

”In contrast to regional CPMs, which refer to regional climate models with limited areas \citep[e.g.,][]{Prein2015,Kendon2017}, RRMs are global models. When RRM is run freely, it works exactly like a typical GCM \citep[e.g.,][]{Tang2023}, and there are studies discussing the upscale effects of the refined area in large-scale circulations \citep[e.g.,][]{Sakaguchi2016}. Thus, although both can be pushed to a CP resolution, RRM and limited-area regional models are fundamentally different in terms of grid structure and evolutionary history.”

6. Section 2.1.5: In the historical period, is there any quantitative standard to describe the model's ability to simulate ENSO? This part is very important, because once the model cannot accurately simulate ENSO, the following years are not actually representative. In addition, the author should also emphasize how the simulation results related to future projections are related to ENSO.

Thank you for pointing this out. Section 5.5 of the E3SMv1 review paper discusses ENSO in piControl and historical ensemble simulations (Golaz2019). Overall, the ENSO variability in E3SMv1 is slightly closer to observations compared to CESMv1-LE, but strongly shifted to a 3-yr period. The overall score for spatial pattern compared to observations is higher than CESM-LE, but not enough along the North American coast.

Following your nice suggestions, we have cited the ENSO performance in the historical E3SMv1, and added the discussion of the future projections related to ENSO:

“In retrospect, when we examine the relationship between precipitation and ENSO across the four segments, the 5-yr mean precipitation barely reflects the ENSO signal. In addition, we do not see a significant modulation of the ENSO on monthly precipitation. Instead, the climate change signal seems to be more dominant, with heavy precipitation events occurring essentially every year at the end of the century. Compared to CESMv1-LE, the ENSO variability in E3SMv1 piControl and historical ensemble simulations is slightly closer to observations, while strongly shifted to a 3-yr period. The overall score for the spatial pattern compared to observations is also higher, but still muted along the North American coast \citep{Golaz2019}. This may partially limit the ability of ENSO to modulate the climate in our simulations.”

7. Line 329: 2-m temperature -> T2m

Modified.

8. Lines 342-345: Here, the author briefly analyzes the reasons for the biases of model precipitation simulation. In fact, regional climate models generally overestimate the meridional moisture flux. For example, the study of Gao et al. found that the WRF model overestimates southerly wind transport over eastern China. I suggest the authors cite this work to strengthen the reliability of the results

Reference:

Gao Z, Yan X, Dong S, et al. Object-based evaluation of rainfall forecasts over eastern China by eight cumulus parameterization schemes in the WRF model[J]. Atmospheric Research, 2023, 284: 106618.

Thanks for recommending this work. I'm not sure if it's comparable here: CARRM is a global model with 3.25km resolution, no deep cumulus parameterization, constrained by E3SMv1 outside of California, while Gao2023 did WRF 30km simulations with sensitivity to cumulus schemes as its research focus, constrained by observations; precipitation in California and eastern China is also controlled by very different synoptic systems. In terms of moisture fluxes here, we see no significant differences between CARRM and E3SMv1 nudging data.

Since all emphasize cumulus schemes, we have added this paper and the two papers mentioned in question 10 to the introduction that refers to uncertainties associated with deep convection parameterizations.

9. Section 3.2.2: In fact, for precipitation, the most obvious added value of the convective-permitting model is the simulation of diurnal variations and MCS. Can the authors show some figures related to diurnal variations in the supplementary material?

Reference:

Guo Z, Fang J, Shao M, et al. Improved summer daily and sub-daily precipitation over Eastern China in convection-permitting simulations[J]. Atmospheric Research, 2022, 265: 105929.

Yun Y, Liu C, Luo Y, et al. Warm-season mesoscale convective systems over eastern China: Convection-permitting climate model simulation and observation[J]. Climate Dynamics, 2021, 57: 3599-3617.

Thank you for your question. We did not do an analysis of diurnal cycle of precipitation because precipitation in California occurs mostly in winter and is dominated by large-scale processes (atmospheric rivers, mid-latitude cyclones). To the best of my knowledge, the diurnal cycle of precipitation rarely seems to be a research focus in California, and diurnal cycle studies in the U.S. are largely focused on the central Great Plains. Though, we do recognize that studying the diurnal cycle of precipitation in CA during summertime monsoon events over the Sierra Nevada and southeastern portion of the state could warrant some investigation in the future. Since diurnal cycle was not initially included as one of our evaluation objectives, we ran the experiment without outputting hourly precipitation, and E3SMv1 only outputs 6-hourly precipitation, making direct comparisons meaningless. However, the review paper for the host model SCREAMv0 documents the diurnal cycle of precipitation (its Figure 15), showing that SCREAMv0 is able to capture morning peaks over the oceans as well as late-afternoon peaks over land (Caldwell2021).

We have added a brief discussion in the last paragraph of this section:

> “Given that precipitation in California is primarily influenced by large-scale processes such as atmospheric rivers and mid-latitude cyclones, the diurnal cycle is not as significant a consideration as it is in the central Great Plains. However, as with other GCPMs, CARRM's host model SCREAMv0 captures diurnal cycles that are generally consistent with observations \citep{Caldwell2021}. Though, we do recognize that studying the diurnal cycle of precipitation in California during summertime monsoon events over the Sierra Nevada and southeastern portion of the state could warrant some investigation in the future.”

10. Section 3.2.4: The author points out that the lack of marine stratocumulus clouds is a common issue in low-resolution model. In fact, for models with higher resolution but not enough to explicitly resolve the cumulus convection process, the simulation of cumulus clouds also has significant shortcomings. Cumulus clouds will release latent heat through condensation, affecting stratus clouds and ground temperature. Authors are advised to cite relevant work:

Reference:

Chikira M, Sugiyama M. A cumulus parameterization with state-dependent entrainment rate. Part I: Description and sensitivity to temperature and humidity profiles[J]. Journal of the Atmospheric Sciences, 2010, 67(7): 2171-2193.

Gao Z, Zhao C, Yan X, et al. Effects of cumulus and radiation parameterization on summer surface air temperature over eastern China[J]. Climate Dynamics, 2023, 61(1-2): 559-577.

Thank you for the recommended works. The cumulus parameterization is undoubtedly important for models that still require it, although the model we use here turns off the deep cumulus parameterization, so exploring the importance and bias of the cumulus parameterization is beyond the scope of our study. In addition, California is not a region dominated by cumulus convection (unlike the central Great Plains), so we have paid little attention to it. Marine stratocumulus clouds are discussed here because - in addition to reflecting improved horizontal and vertical resolution and improved turbulence scheme - they themselves have a significant impact on the climate of coastal California. We do recognize that SCREAM does not have high enough resolution to simulate shallow cumulus clouds and this process is parameterized by the SHOC turbulence scheme (Bogenschutz and Krueger 2013).

We have added these two papers to the introduction that refers to cumulus clouds (please see the response to question 8).

11. Line 498: Although this is a commonly used variable, give the formula for calculating the short-wave radiative forcing.

Thanks for the suggestion. We have added the formula for SWCF here:

> "SWCF = FSNTOA - FSNTOA_C, where FSNTOA is net solar flux at TOA, FSNTOA_C is clear-sky net solar flux at TOA."

12. The author calculated multiple variables in the California region in the research. I would like to know whether these variables have an impact on each other? Or, how are they related? Can the author give a schematic diagram like the following article?

Reference:

Wang X, Chen D, Pang G, et al. Effects of cumulus parameterization and land-surface hydrology schemes on Tibetan Plateau climate simulation during the wet season: insights from the RegCM4 model[J]. Climate Dynamics, 2021, 57(7-8): 1853-1879.
Citation: https://doi.org/10.5194/egusphere-2023-1989-RC1

The variables we show here are organized primarily for the interests of the reader who cares about California climate, so attention is given to the most basic variables (temperature, precipitation, snow), and marine stratocumulus clouds which have a large impact on California. It is not organized from the perspective of understanding model biases. As in your recommended work, more sensitivity testing based on the choice of physical schemes is needed to make careful inferences about the relationships between different variables. However, SCREAMv0 does not have an optional physical parameterization suite, and we didn't perturb any physical parameters to get a conclusive plot like Wang2021's Figure 15. Nevertheless, speculatively, the relationships we find here are: a) a link between warming and reduced snowfall (well known), b) an increase in precipitable water due to warming leading to a strengthening of individual storms without significant changes in the winds (not surprising), and c) a link between warming / increased CO_2 and reduced stratocumulus clouds (weakened SWCF) through thermodynamic and radiative mechanisms (findings in the stratocumulus field); validation here requires checking variables such as specific humidity gradient, turbulent entrainment rate, cloud-top longwave radiative cooling, etc. The distinct comparison between E3SMv1 and SCREAMv0 CARRM on the shortwave cloud radiative feedback deserves an in-depth separate analysis.