

Reviewer’s Summary of Manuscript

In “Effects of Coupling a Stochastic Convective Parameterization with Zhang-McFarlane Scheme on Precipitation Simulation in the DOE E3SMv1 Atmosphere Model,” Wang et al. document their modifications to the Plant-Craig 2008 (PC08) stochastic convective parameterization necessary for its incorporation in the Energy Exascale Earth System Model v1 (E3SM), and they document the performance of the model. The stochastic version of E3SM has higher frequency of extreme precipitation events and more precipitation contributed from extreme precipitations; these changes bring the model statistics closer to those observed in TRMM and GPCP. Large scale precipitation also becomes more intense, which the authors attribute to grid-scale CAPE being allowed to accumulate between timesteps due to the randomness of when the stochastic parameterization does (or does not) trigger. The authors show that the use of the stochastic parameterization reduces the frequency of light rain rates (drizzle), since the stochastic parameterization tends to generate higher rain rates in general and because the intermittency reduces the frequency of convection overall.

The authors argue that the mean state of the model is essentially the same between the stochastic and control versions of E3SM. They suggest that further modifications to the parameterization would be necessary for use at higher resolution.

Summary of Review

Overall, the authors present a thorough overview of the stochastic E3SM’s performance. They make insightful use of modeling experiments (e.g., running the default ZM parameterization along the stochastic version to determine why the stochastic version has less drizzle), and overall they provide a relatively strong case that the use of the stochastic version improves the model performance.

The manuscript is generally well written, the chosen manuscript category of “development and technical papers” seems appropriate given the content, and the manuscript is clearly appropriate for GMD.

There are a number of additional analytic improvements that would substantially strengthen the manuscript: consideration of observational uncertainty in precipitation (especially for extremes), quantification of changes in the spatial structure of precipitation, inclusion of process-focused evaluation diagnostics, and (relatedly) analysis of the CAPE-precip relationship in observations.

In addition to these analytic issues, the manuscript needs to be modified in order to comply with the GMD code and data policy.

Given that the manuscript is clearly appropriate for GMD, and given that it would benefit from substantial additional analysis, I am recommending that the manuscript be returned to the authors for major revisions.

The major concerns noted above are described in more detail below, and the final section points out some specific, minor issues.

Major Concerns

Precipitation observational uncertainty: FROGS

The authors compare simulated precipitation with observations throughout their manuscript (i.e., Figures 1–8). Recent studies have shown that uncertainty in observed precipitation is quite large: especially in the tails of the distribution, which is where the authors focus most of their analysis. In most cases, the authors' analysis shows that the stochastic E3SM is closer to observations than the default; but would that picture be as clear if observational uncertainty were included?

Fortunately, a recent effort (published in a related EGU journal in fact) has produced a dataset of essentially all existing daily precipitation datasets on a common 1x1-degree grid: see Roca et al. (2019). Therefore it should be relatively simple for the authors to investigate and/or show the impact of observational uncertainty on their main conclusions.

Roca, R., Alexander, L. V., Potter, G., Bador, M., Juca, R., Contractor, S., Bosilovich, M. G., and Cloche, S.: FROGS: a daily 1×1 gridded precipitation database of rain gauge, satellite and reanalysis products, *Earth Syst. Sci. Data*, 11, 1017–1035, <https://doi.org/10.5194/essd-11-1017-2019>, 2019.

Process-focused diagnostics

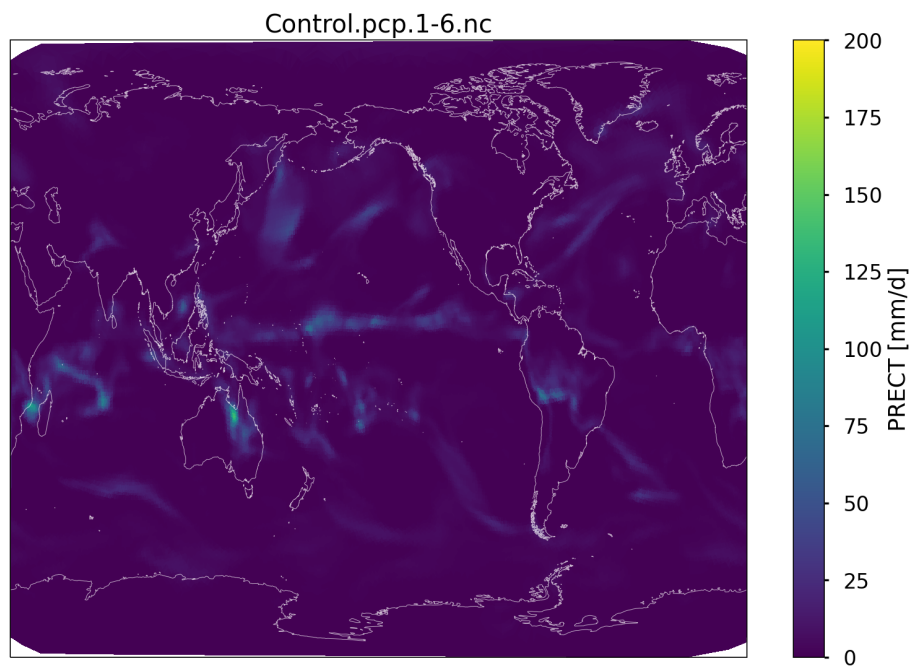
The authors do a good job of assessing the statistics of precipitation and convection in stochastic E3SM, but I was a bit surprised that the authors never showed any process-focused comparisons of the model's convection with observations. Given that this is a DOE-funded effort, I could imagine—for example—performing hindcast simulations and comparing with the extensive atmospheric observations provided by ARM: does the hindcast CAPE improve, does the hindcast precipitation improve, etc. I suspect that this shouldn't be too difficult, since another DOE-funded author has provided a framework for generating hindcasts with E3SM (see <https://github.com/zarzycki/betacast>).

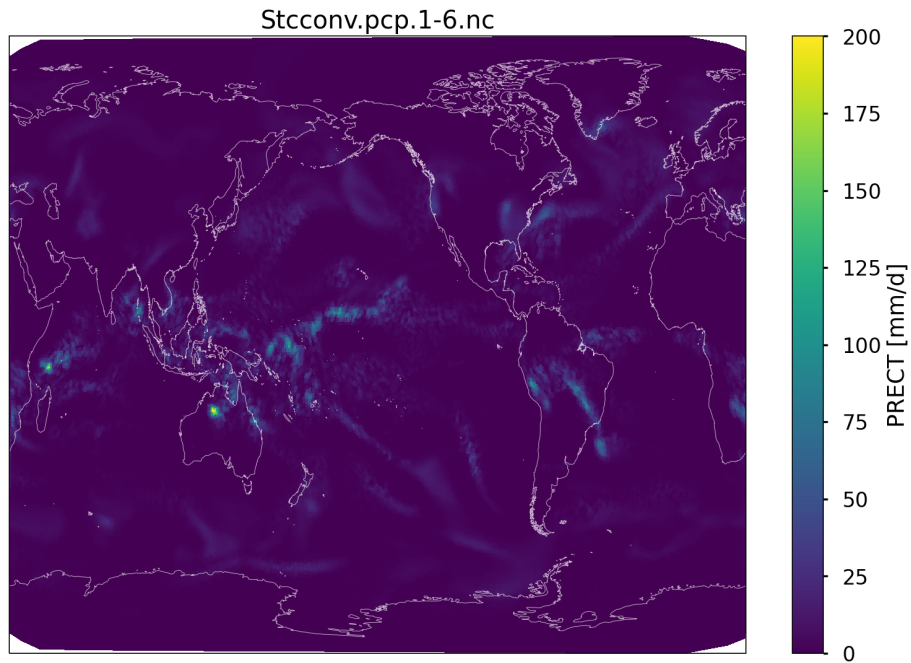
Alternatively or additionally, it might be useful to look at the convective pickup relationship, which has increasingly been used as a bulk diagnostic of tropical convection in models: e.g., see Kuo et al. (2018). At the very least, I would imagine that the stochastic parameterization increases spread in the precipitable water-precipitation relationship, but I wonder if it improves the model relative to observations or not?

Kuo, Y. H., K. A. Schiro, and J. D. Neelin, 2018: Convective transition statistics over tropical oceans for climate model diagnostics: Observational baseline. *J.*

Quantification of spatial structure of variability

Related to the above, in playing around with the model output (see images below), I noticed that the spatial patterns of precipitation were substantially (and unsurprisingly) noisier in the stochastic version. It struck me that the texture of the precipitation field seemed somewhat unrealistic. It would be useful to compare the simulated precipitation with observed precipitation: especially if the authors are able to run a hindcast simulation.





Alternatively, it might be useful to quantitatively examine the spatial statistics of precipitation: e.g., looking at structure functions (aka variograms), or equivalently power spectra. My concern is that the stochastic parameterization introduces too much small-scale noise, and if so, this should be quantified and documented.

CAPE-precip relationship in observations

Related to the above, in Figure 9 the authors use the CAPE-precip relationship to argue why the statistics change with vertical resolution. This seemed like an ideal opportunity to compare this process-oriented relationship with observations: is the dramatic change in the CAPE-precip relationship an improvement relative? Was the bimodality in the CAPE-precip relationship in the control simulation a realistic feature (presumably not)?

This should be relatively easy for the authors to reproduce, given that multiple reanalysis datasets reside in a semi-public location on the DOE-funded NERSC CFS filesystem in association with the CMIP6 data that have been collected for the DOE community. If the authors are unfamiliar with how to access this repository at NERSC, their program manager can likely help direct them.

Code and data availability and appropriate use of archival repositories

The authors do point to the E3SM code in their “Code and data availability” section, but there are two fundamental issues with the way that the authors have done this. First, it does not appear that the code for the stochastic version of the ZM parameterization is available in the public release of E3SM, or if it is, it is not in an obvious location. The GMD policy (see (https://www.geoscientific-model-development.net/about/manuscript_types.html#item2)[https://www.geoscientific-model-development.net/about/manuscript_types.html#item2]) requires that “In the case where new code is described in the paper. . . The code should be made available.”

The code and data policy requires that code be archived in a long-term repository, and it explicitly states that github is not appropriate for this purpose. Similar to what the authors have done with the EAMv1 data, they should upload the E3SM code—that was used for this study—and they should amend the “Code and data availability” to make it clear where the new code resides in the repository.

Metadata in deposited code

In checking out the EAMv1 data that the authors uploaded to Zenodo, I noticed that the data files lack the lat/lon arrays; this effectively renders the data files unusable unless a person knows somewhere to find the lat/lon data for this model configuration. The authors should upload new versions of the files with the lat/lon fields added.

Specific, minor issues

Model version

I think that the title of the paper should also be amended to reflect the specific version of E3SM that was used. In browsing through the E3SM tags, I see that several iterations of the E3SMv1 model exist (e.g., v1.1.0), so the use of “E3SMv1” is ambiguous.

Misinterpretation of O’Brien et al., (2016)

On lines 359–362, the authors state that the vertical resolution dependence they see is consistent with that shown in O’Brien et al., (2016). I believe this is a misinterpretation of O’Brien et al. (2016). Their resolution-dependence result is described in more detail by Rauscher et al. (2016); in Equation (2) of Rauscher et al., there is a term related to the vertical grid spacing. Once terms are rearranged to solve for W , this yields the relationship $W \propto \Delta p$. Therefore, the result of Rauscher et al., (2016) and O’Brien et al., (2016) implies that vertical velocity should *increase* as vertical grid spacing increases. Figure 10 seems to

show higher moisture flux values for the 30L simulations, which is consistent with this theory. However, this appears to be inconsistent with the language used in the manuscript, which tangentially states that “refining horizontal resolution should result in more large-scale precipitation.”

Rauscher, S. A., T. A. O’Brien, C. Piani, E. Coppola, F. Giorgi, W. D. Collins, and P. M. Lawston, 2016: A multimodel intercomparison of resolution effects on precipitation: simulations and theory. *Clim. Dyn.*, 47, 2205–2218, <https://doi.org/10.1007/s00382-015-2959-5>.

Grammar and syntax

There are a number of few places in the manuscript with grammar and syntax issues. I recommend that the manuscript be thoroughly proof-read by someone outside the authorship team prior to resubmitting.