Reviewer's report for gmd-2021-421

Summary

In this paper, the authors present a modeling study that aims to improve the representation of sub-grid heterogeneity when coupling with the atmospheric boundary layer (ABL). A new coupling parameterization is implemented into the E3SM model which accounts for the variability from each individual sub-grid patch and inter-patches variability. The new parameterization is tested in a single-column model over the ARM site in Southern Great Plain and the results are analyzed for non-precipitating days, cloudy days, and precipitating days.

This research topic is very important in the land and atmosphere modeling communities and the authors have documented the new parameterization in detail in this manuscript. Please see the attached document for some places where the authors could further improve this manuscript. Please see the comments and questions below.

General comments

There is no observation data shown in the manuscript. If this study is performed with the ground truth fraction of land patches in the ARM site, it makes sense to compare the HET and HOM simulation performance with site observation data, if there are any. Many of the analyses conducted in the paper, i.e. temperature, humidity, cloud fraction, precipitation, can be compared with observation data. This can add creditability to this study and readers can have a direct sense of the HET performance over HOM.

Another point would be that water and vegetated bare ground are two major contributors to inter-patch variability, which is also a major component in HET different from HOM, while these two patches only account for a small portion of the study area. Generally, in a model sensitivity study, authors can have larger free space perturbing the different fractions for the eight patches. Would it be possible to demonstrate to what extents the findings in this paper are subject to fractions of land patches? A similar question would also apply to the atmospheric forcing too.

Specific comments

1. Introduction

The authors briefly summarized the representation of subgrid heterogeneity in land and atmosphere components in ESMs, with a specific focus on E3SM version 1. It will benefit a larger group of readers if the authors can provide how the coupling process is handled between the land and atmosphere model in other ESMs or RCMs. If it is a common issue, the new parameterization and findings in this paper could be a valuable lesson for a large modeling community.

2. Methodology

Table 1: It will be good to show or describe the spatial extent of the ARM SGP site, i.e. how large is the study area?

L118 “A schematic diagram ...”: should it be Fig. 1 or Fig. 2? Fig. 1 shows the potential temperature for eight different patches, indicating spatial heterogeneity. (I couldn’t find the description of these different potential temperatures in the texts).

L132 “A short-term hindcast approach ...”: Can the authors provide more details on this configuration used in the SCM? What are the large-scale prescribed forcing and initialization data? A note to this run 48-hour hindcast is that it may not have enough time for land surface feedback to the atmosphere, so the land model may be strongly controlled by the atmospheric forcing.

3. Results

Figure 3: the modified HET simulation is quite different from the default HOM at two time periods in a day, near 18:00 LT and 12:00 LT. While the authors explain the discontinuity between two consecutive days is expected due to the hindcast configuration, why does it affect more strongly on HET than HOM simulation? It is because HET simulation is more sensitive to the initialization at 18:00 LT? But the first 24 hours are not included in the analysis. It might be good to provide an explanation.

L189: it is surprising that the sensible and latent heat flux between HET and HOM are not so different. From a modeling perspective, what does this finding suggest? Is it because the study area is by half occupied by the croplands while water and vegetated bare ground only make up a small portion? Can one expect larger differences in turbulent fluxes between HOM and HET with a higher fraction of water and bare ground fraction?

Fig. 9a: the cloud fractions for both HOM and HET seem very low for cloudy days.

Table 3: another possible thought that HOM and HET are very similar might be the radiative and turbulent fluxes are so strongly controlled by the atmospheric forcing, while land surface heterogeneity, under this configuration, does not provide sufficient feedback to the atmosphere. The authors may provide a more enriched discussion on this and readers will surely benefit from it. Similar comment to section 3.3 as well.

Fig. 12: it will also be good to show the precipitation observation in the same figure to demonstrate whether HET improves from HOM.

L244-L253: the authors are trying to make connections between the vanishing of inter-patch variability with precipitation occurring in June. So, it might help to show also the timeseries of the inter-patch variability in Fig. 14. What’s also helpful is the potential temperature and water content for different patches, as in Fig. 4 or 5, during precipitating days. This will help to make this argument stronger.