Quantifying vertical wind shear effects in shallow cumulus clouds over Amazonia

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General comments:

This manuscript studies the evolution of shallow cumulus clouds over the Amazon in response to vertical wind shear. The role of wind shear is not well-studied and this study can make an important contribution to the field. The results indicate that a high value of vertical wind shear leads to (marginally) larger and shallower clouds, with a relatively smaller core area. They also find that there is more (localized) evaporation in the cloud layer under shear which may destabilize the cloud layer and have consequences for subsequent convection. Similar to what previous studies have found, the results also suggest there is not a linear relationship between cloudiness and wind shear, whereby high vertical wind shear can also increase the total water content present in the domain.

I think the authors did a nice job at explaining the cloud tracking algorithm that they use, at synthesizing the results and reflecting on the findings in light of the uncertainties in the simulation, the tracking and the complexity of the problem. Yet I agree that there is important information missing regarding the setup of the winds that requires clarification, which I outline below. There are also aspects of the sampling of core and margins that are unclear and I believe there are opportunities for using the cloud tracking statistics to explain how clouds of different sizes and LWC contribute to the overall increase in total water in the domain.

I would advise a **major revision** based on the **main comments** below:

1. The manuscript does not describe the evolution of wind profiles, the large-scale wind forcing and the surface stress. One aspect of the setup that is not clarified is that the winds will evolve during the course of the simulation: they will be mixed and slowed down throughout the BL in response to surface stress and the winds will gain an ageostrophic component. The shear present at noon would be different from the initial shear profiles.
   The development of the wind profiles during the simulation influence how we interpret the differences in clouds that are presented as a result of differences in shear in the cloud layer.
   A directional shear is prescribed in the initial profiles that turns counter-clockwise with height: usually you have a veering of the wind with height e.g. a clockwise wind turning (while friction would lead to a backing of the wind and a counter-clockwise wind turning towards the surface). Your geostrophic winds at 5 km imply that upon friction near the surface (or turbulence in the boundary layer) a westerly wind component will develop. Could this decrease the shear throughout the simulation period and lead to smaller shear differences as the simulation evolves?

   Shear in the mixed layer can trigger indirect (as you mention, non-linear) effects. Helfer and Nuijens (2021) find that under forward shear in the subcloud layer there is the tendency for convection to become more organized and deepen more (although vertical updrafts within clouds are still hampered due to the slanting of clouds).
   The positioning of clouds relative to their sub-cloud layer roots can play a role in convective deepening by promoting stronger updrafts already in the subcloud layer. Under forward shear in the sub-cloud layer the updraft and downdraft region become

more separated and the coherent circulations and resulting convergence may be strengthened.

https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015JD023253

The different wind speeds that develop at different heights is also relevant for the numerical diffusion of clouds, which is an issue with LES and the use of an all-or-nothing cloud scheme. The differences in cloud diameters between the shear cases is only 1 or two grid cells, something which I can imagine would be influenced by the differences in wind speed in the cloud layer (and such differences will be there even though a Galilean transform is applied, because the wind profiles are sheared).

2. Can the authors clarify the core and margin selection and the results in Figure 8: am I right that the diameter of the core and margin sum up to be larger than the cloud diameter? This means that margins are occupying an area that is roughly the cloud diameter - core diameter (not really the margin or edge), or even larger, which would imply that there is overlap in the classification. It was my understanding that you try to contrast edges versus cores of the cloud, how should I be interpreting this?

3. It would be nice if the authors make (more) use of tracking algorithm to delineate the contribution of clouds sizes/depths to LWC/LWP under different shear and to indicate whether there is more organization, which in studies of deep convection is clearly related to the wind shear imposed. For instance, are there more merging events?

   In section 3.2 you argue that whole-domain properties such as the total domain water are heavily influenced by infrequent and large clouds. I don’t think you actually show this (yet). You could show this by plotting the cumulative cloud liquid water as a function of the cloud equivalent diameter (using all individual clouds). I'm not so sure whether it is just a single deep cloud that is responsible for the larger domain total water under high shear, because you also observe that under HS there are more frequent clouds with (intermediate) cloud depths of 600 - 1200 m: could they cumulatively explain a larger total water?

   And can you show whether the larger domain water content under shear is contributed by the larger core dimensions in absolute term, or the larger margin dimensions in absolute terms?

   In section 3.2 you also discuss that there is more evaporation under higher shear because clouds have a larger area due to tilting. At the bottom of page 13 you argue that there is more evaporation because of more liquid water content in the atmosphere (Figure 5). The cores are relatively small, but there is more cloud overall. Related to the above, it is not clear which clouds - and whether it is their cores or their margins - contribute most to the overall LWC in the domain. Can this be shown?

4. With respect to the results that are in Figure 12: Figure 4 showed that under higher VWS there is a larger difference between all cloudy pixels and tracked pixels, also at larger LWP's. There must thus be a lot of not-considered cloud pixels in the simulation that also evaporate and contribute to the heating and moistening tendencies.

   Have you compared the evaporation differences under shear to the domain-mean tendencies of humidity /temperature? All simulations have the same surface moisture

/heat flux, but the humidity and temperature may be distributed differently. Do the differences in Fig 12 carry over to the total domain-mean tendencies or do the cloudy pixels not considered in the tracking also play a role?

The difference between localized (near cloud) changes in evaporation and domain-mean humidity and temperature tendencies is unclear in the results, but better discussed in the summary/ discussion.

Some more minor comments are these:

- A rigorous grammar & spelling check would be needed before publication.
- Section 2.3: I would say that these days 21 x 21 km^2 is not that large. For shallow convection the typical domain size is now at least 50 going up to 125 km in one direction to allow for mesoscale dynamics to take place.
- P7L213: About the 10 km radius: At 7 m/s this corresponds to about 23 min, so that is the maximum length to be tracked .. Seems ok with respect to a 20 min life cycle of small clouds? (I guess you will present lifetime statistics later, but would fit here as well).
- Section 2.3.1: L 224: “we exclude …” Do you repeat the process by excluding the larger shape from the 3D volume? (is that smaller shape tracked on its own and kept in the statistics despite being in close proximity to a larger clouds at some point?) I am asking because of the difference between isolated clouds and all tracked clouds in Figure 4. How much of that is because of excluding splitting or merging cells versus removing cells in close proximity or removing stacked clouds?
  - I am asking because of the difference between isolated clouds and all tracked clouds in Figure 4. How much of that is because of excluding splitting or merging cells versus removing cells in close proximity or removing stacked clouds?
- Would section 3.1 be better placed in section 2 along with the description of the algorithm?
- Figure 8: It is confusing that the colours which were used before to indicate the amount of shear now denote the relative time duration
- I found that Figure 10 received quite some discussion but did not really aid the rest of the story.
- Figure 11 is quite busy and complex. Could it be changed to a conditional PDF (conditioned on bins of LWC) that show the distributions of vertical velocity for the NS, MS, HS cases as just a line plot? Or some other version that more quickly allows one to see the main result. BTW: does it seem that the differences in vertical velocity/updrafts are mainly pronounced at larger LWC?
- P13 393: ”VWS not only reduces the dimensions of the core”: you miss denoting “relative” I think, because Figure 8b shows larger dimensions for the cores under shear.
- P15 last (bottom) paragraph: What you write here could have also been addressed with "conventional" cloud (core) sampling in LES. Can you better emphasize the value of the tracking here? As mentioned, I think what can be really valuable is quantifying what are the cloud (sizes) that are most affected by shear: you show that while the small clouds are dissipated more quickly, the intermediate clouds may benefit and get larger. While clouds are overall shallower under more shear, there are a few much deeper clouds that develop under shear.
- P16 512: “by changing the conditions of cloud formation”: I think this can and should be explained a little further…. what conditions?