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Comment on acp-2021-446

Anonymous Referee #3

Referee comment on "Global evidence of aerosol-induced invigoration in marine cumulus clouds" by Alyson Douglas and Tristan L'Ecuyer, Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2021-446-RC1>, 2021

Review on "Global Evidence of Aerosol-induced Invigoration in Marine Cumulus Cloud" by Douglas and L'Ecuyer

The authors explore aerosol effects on warm convective clouds using a set of observations from several instruments and reanalysis data. They explore the concept of cloud invigoration by aerosols on key cloud properties such as rain properties, evaporation/condensation/entrainment rates, vertical motion, and the estimated latent heat release.

They explore invigoration in the context of environmental stability and the level of cloud clustering estimated by the size of the rain system.

The observed cloud liquid water path (LWP) is limited to a narrow range of 150 to 200 g/m² in order to focus on other than LWP effect of aerosols.

Cloud type and properties are determined using CloudSat and CALIPSO, aerosol index AI from MODIS, LWP from AMSR-E, cloud extent from CloudSat-CPR, and the WALRUS algorithm is used for latent heat and W. Reanalysis data is used to classify the profiles to stable and unstable and the measurements are separated into two pollution classes: clean AI < 0.042 and polluted AI > 0.09.

The presentation is clear and the results are interesting. They show how a combination of drier atmosphere and unstable conditions act together to enhance cloud top evaporation and how in general invigoration depends on environmental stability. But I have a few comments and concerns that should be addressed:

- **Subdividing the AI into two end-groups:** Such separation may miss cloud sensitivity to the optimal aerosol loading. As the authors know (and cite) aerosol effects on clouds were shown to be non-monotonic. A competition between core (invigorating) and periphery (enhance evaporation and entrainment) processes dictates an “optimal aerosol concentration”. It means that properties like maximal cloud depth, updrafts, maximal LWP, and rain may have their maximal values in a given aerosol concentration (the “optimal” concentration (or optimal AI) of the invigorated branch) and a further increase in the concentration will enhance evaporation and entrainment and therefore will result in lower values of these key properties. Previous work has suggested that the optimal AI depends on environmental conditions. Clouds in a more unstable environment will “enjoy” higher optimal AI. Theoretically, it is possible that the optimal AI is missed in the central values that are not analyzed here and the trends shown in this work are samples of the beginning of the ascending branch vs. the end of the descending. The sensitivity to the environmental properties could be much richer than what is shown here.
- **LWP slicing:** While holding one key variable and checking sensitivity in other variable approach makes sense when looking at the aerosol concentration (or the AI) as a measure for CCN as a continuous variable, here the subdivision to two end groups may infer problems. Along the same lines as the first comment, changes in aerosol concentration can strongly affect LWP. Therefore by comparing clouds in two very different aerosol concentration regimes with a similar LWP, may imply that under the same aerosol conditions these clouds will have a completely different LWP and therefore evolve in different thermodynamical conditions. This should be noted and considered in the analysis.
- The study area (60S to 60N) is large. It includes the tropics, subtropics, and mid-latitudes. Marine warm clouds over this region can be very diverse. They depend on the SST, the MBL properties, winds, free atmosphere properties, as well as aerosols. Trends in cloud properties can be related also to the cloud location – wouldn't it be better to limit the study area to the subtropic? Or at least the authors should show that there are no correlations between the cloud properties and their geographical area.
- On a similar note to the comments above, classifying the environment to only two states (stable and unstable) using EIS threshold is a bit limited. Theoretically, there are many types of profiles that can be regarded as stable and many others as unstable and these profiles may yield different clouds. Limiting the study area to a more uniform one

(with respect to environmental conditions) can solve this issue.

- Many space instruments are being used in this analysis – I miss a critical discussion on their limitations. I miss a discussion on possible biases due to measurement limitations.
- Estimate inversion strength (EIS) is a key variable – would be nice (and not too complicated) to provide details on exactly how it is calculated.