

Reply on RC2

Elvis Torres-Delgado et al.

Author comment on "Measurement report: Impact of African aerosol particles on cloud evolution in a tropical montane cloud forest in the Caribbean" by Elvis Torres-Delgado et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2021-88-AC2>, 2021

This study investigates the impact of African aerosol particles on cloud evolution in a tropical montane cloud forest in the Caribbean based on case studies using measurements from Aircraft, satellite and back-trajectory model. It shows interesting results while I do not think the conclusion are very robust at this moment. Personally, I think this study is worthy to be published in ACP after a major revision.

Introduction part: The authors may consider reading and citing the recent studies in addition to the studies at early years. For example, the direct solar radiation effect of dust from Africa on the meteorology (Sun et al., 2020, doi: 10.1029/2020JD033454).

- The authors understand that the suggested reference is relevant for the article, and it has been cited now in the introduction.

Line 23-25, The authors mentioned "Great studies" but only providing one reference. More references are necessary here. Actually, there are huge amount of studies regarding aerosol-cloud-radiation interaction studies, along with the uncertainties, such as Stephens (2005, doi:10.1175/JCLI-3243.1), Garrett and Zhao (2006, doi:10.1038/nature04636), Li et al. (2011, doi:10.1038/ngeo1313), and Li et al. (2019, doi:10.1029/2019JD030758).

- The authors would like to respectfully correct the reviewer, as the text reads "great strides". However, the suggested articles were considered, and some were cited as they were relevant to the study.

Line 38-39, could the authors provide the exact or estimated hours for the cloud existence? That would be helpful to the readers.

- Previous studies have documented the frequency of clouds and their duration during various seasons. These are now referenced in the text.

Line 54, "cloud properties"

- Corrected

Section 2.1 About the sampling site map: If possible, the trade winds and the metropolitan area could be indicated in the map.

- The metropolitan area (San Juan) has been highlighted and a compass has been included in the map. Trade winds have not been included as the text states that trade winds come from the northeast (Section 2.1 – Sampling Sites).

Line 86-91, I wonder if PM₁₀-PM₁ is better to represent the dust aerosols rather than PM₁₀. If it is, the authors may consider using the difference.

- The main pollution sources that may contribute to the PM₁ are the nearby islands and Puerto Rico's metropolitan area. The contribution from the nearby islands is small and depends on the wind direction (SE) and the metropolitan area is downwind from the sampling station under most meteorological conditions except for the rare cold front. Since the winds mainly come from the E-NE directions, we do not consider anthropogenic pollution to be a major source of aerosols for these sites on the sampling days presented here. Also, the bulk of the dust aerosol is skewed towards coarse particles. Thus, we do not expect a big difference between PM₁₀ or PM₁₀-PM₁.

Line 101-102, are the size range for diameters or radius?

- Size range is for diameter. This information has been included in the methodology section.

Line 101-106, For the cloud microphysical properties measured by BCP, have the authors removed the observations within the first 2 bins as most methods used due to their large uncertainties?

- The observations within the first two bins were not removed. However, in our dataset these bins sizes only account for a small fraction of the size distributions, as can be seen on figures 5 and 6.

Line 108-110, more information about the weather data is necessary and helpful.

- We have change this section to read:
- "Meteorological data were collected at both stations using Davis VantagePro2 Plus weather stations. Total rain, rain rate, wind direction, and wind speed were measured in 15-minute averaged intervals. The meteorology, aerosol and cloud microphysical data were averaged to hourly intervals for the analysis."
- The meteorological stations are called "Weather Stations" by the manufacturer, but this is somewhat misleading since they really only measure local state variables and winds, not "Weather". Further in the manuscript we clearly describe general airflow conditions that are impacting the cloud formation and development, but since weather is a more general term that includes a variety of meteorological conditions, we do not try to describe weather patterns as that would be a major expansion of the text and not relevant to the focus of the study.

Line 116-118, I do not understand what do you mean "those with one standard deviation or less than the average are labeled as "low dust" cases". Please explain or modify.

- A sentence that better explains this procedure has been included.

Line 120-127, please provide more information about the model setup (such as physics and dynamics modes, the released particle numbers, and so on), and whether you used the clustering. The errors could vary with the location, topography, and meteorology. As indicated by Zhao et al. (2009, doi:10.1029/2008JD011671) for California region, the trajectory uncertainty could be more than 20% just due to errors in meteorology (such as boundary layer height and winds).

- The information requested by the reviewer does not apply to this study. We only used the trajectory analysis and did not use any particle modeling. The article by Zhao et al. 2009 was focused on transport of greenhouse gases, and the model they used (STILT) is optimized for dispersion of inert gases. On the other hand, the HYSPLIT model is optimized for calculating air mass trajectories. While a STILT-like configuration can be achieved using HYSPLIT, this is beyond the scope of this study. Clustering was not used.

Line 176-182, these are interesting. I wonder how large the air speeds are. Personally, I think local emissions could play more important role when the wind speeds are low.

- For the sampling period, wind speed ranged from 2.20 to 12.10 m/s with an average of 7.24 m/s. We disagree with the reviewer's comment as through several years of studies on this site we have not found that local emissions are an important source. We have found that wind direction is more important in this regard, as long-range transported pollution can reach the site if wind directions come from the SE (nearby islands) or if we have cold fronts (common during winter, but rare during summer) and none were identified for the sampling periods presented here.

Line 192-197, SAE and AAE have not been defined yet. Please define them. Also, regarding the derivation of dust aerosols from low SAE and high AAE, recent studies could be referred, Yang et al. (2021a, b; doi:10.5194/acp-2020-921; doi:10.5194/acp-2020-1139), and Zheng et al. (2017, doi:10.5194/acp-17-13473-2017).

- Terms have been defined. The suggested studies have been evaluated but they use the extinction Ångström exponent instead of the scattering and absorption Ångström exponents. In this study we used both values to help identify dust events as described by Cazorla et al., 2013, which is a different approach to that used in the suggested articles.

Figure 4. the figure quality need improve.

- Since the reviewer has not been specific about what needs improving, we have not changed the figure but did make a small correction to the figure description for clarity.

Line 286-299, For aerosol-cloud interaction study, or for cloud seeding studies, it is necessary for us to know the cloud status including the cloud phase (warm clouds or super-cooled liquid/mixed-phase clouds) and cloud microphysical properties. As Dong et al. (2020, doi:10.1029/2020EA001196) showed, the cloud seeding effect is distinct for adding IN particles when the cloud are supercooled liquid phase clouds. If the clouds are warm clouds, dust cannot affect the clouds by serving as IN, while they can modify cloud properties by serving as CCN. Thus, I would recommend the authors provide the information of cloud properties before the dust aerosols arrive (along with the cloud properties after the dust aerosols arrive).

- Given the relative low altitude of the measurement site (1051 m asl) and considering that it is a tropical region, clouds are in the warm phase. The cloud phase found in this site has been included in the site description (section 2.1 Sampling Sites). In addition, the cloud microphysical properties, i.e. number concentrations, LWC and MVD, prior to the arrival of the air masses, are very clearly shown in Figs. 5&6 and discussed in the text.

Section 3 and 4, I wonder how the cloud droplet size distribution (since there are aircraft observations) varies with the dust amount.

- We refer to our response in the previous reviewer comment. This is discussed already

in great detail in the text and the size distributions are shown in Figs. 5 & 6.

Section 4. I love this discussion section about the potential causes for the observed findings. However, I do not feel very confident about the conclusions the authors obtained, particularly considering the highly complicated aerosol-cloud interactions with various influential factors. I wonder if the authors could provide more robust evidence. If not, I would suggest the authors weaken their tone to the conclusions.

- The type of robust evidence that the reviewer request, while desirable, is rarely available in any aerosol-cloud interaction experiment because to prove beyond a doubt that cloud microphysical properties are due to specific aerosol properties, and environmental dynamics, the experiment would need not only an analysis of droplet residuals but also measurements of aerosols at their source. Then measurements would have to be made in a Lagrangian fashion to take into account aging, removal, etc. If the reviewer can provide references to such studies, studies that don't use the type of scientific arguments that we have used in our analysis, we would welcome them. Otherwise, our approach of laying out the most probable mechanisms for forming and evolving clouds, followed with reasonable arguments based on the available information, is one that is most often used in studies published by other groups but in other locations. We see no need to weaken our conclusions as we have not made any statements that cannot be supported by the evidence.