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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "The fine-scale structure of the trade wind cumuli over Barbados – an introduction to the CARRIBA project" *by* H. Siebert et al.

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Response to the anonymous reviewer:

We thank the anonymous reviewer for the comments, which have significantly improved the manuscript. In the following, the reviewer comments are italic and the responses are regular. The main criticism of this review is that we should focus more on the unique observations possible only with the ACTOS/SMART-HELIOS packages. This has been done by including a new analysis section which does not present selected highlights from the two campaigns anymore, but presents two days identical in terms of

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Interactive Discussion

Discussion Paper

meteorology but quite different in terms of aerosol load in the sub-cloud layer resulting in different cloud microphysical properties. We have discussed the consequences of the different cloud droplet size distribution and number concentration for turbulent mixing and droplet-droplet interaction in a turbulent environment and the radiation effect. This analysis is definitively unique to the ACTOS deployment and cannot be done with other aircraft. Furthermore, this analysis highlights also the differences to other previous campaigns performed in the trades. There are a few comments in this review we do not completely agree with but we take these comments into account for future flight and sampling strategies.

This manuscript provides an overview of results from two field campaigns operating from Barbados that were designed to explore the aerosol, cloud, radiation, and turbulence associated with fair-weather cumuli during two separate one-month periods. The observations are based on unique observing platforms deployed on a helicopter. Although the manuscript gives a useful compilation of the type of observations that were made, it provides neither a compelling justification for the project nor an adequate highlight of the unique observing capability offered by the helicopter-borne instrument packages for sampling in and around clouds. This is a good first report and summary of the accomplishments, but this compilation in its current form is not sufficient to justify publication. A more detailed description of the issues related to this overall assessment is provided below. No minor comments are provided in this review, since major efforts will be needed to develop a manuscript that can be accepted for publication.

Major Issues:

Using the acronym CARRIBA in the title is not very useful. By itself it will have little or no meaning to the majority of potential readers. In studies that are part of major projects or programs that are well known, an acronym can be used in the title, but in general the use of acronyms in the title is not optimum.

We think that this is a matter of personal style and we prefer to keep the acronym in

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the title.

The introduction provides a good historical perspective of research on fair-weather cumulus clouds, but the coverage is broader and more general than needed. Similar summaries can be found in the literature. The authors go back to the earliest studies, but spend less time discussing the contemporary issues that motivate this project. Thus, for example, it would be good to know what this study provides that was not already explored during RICO or other recent projects focusing on small cumuli. The unique aspect of CARRIBA is that it makes use of instrumented package operated from a helicopter to provide detailed high-spatial and temporal measurements that cannot be obtained from traditional instrumented aircraft. The helicopter-borne platforms are ACTOS (Airborne Cloud Turbulence Observation System) and SMART-HELIOS (Spectral Modular Airborne Radiation measurement system). These platforms have impressive observing capabilities. But most of the observations shown in the manuscript could be obtained with an instrumented aircraft and offer little new insight into a range of scientific issues involving small cumulus clouds.

We completely agree with the second part of this comment and therefore have rewritten the data analysis part of the manuscript (Chapter 4). We now present data/results, which are more unique to the ACTOS/SMART-HELIOS setup because we make use of the high resolution turbulence data We prefer to keep the "broad“ introduction, but we have included a few sentences describing the differences of our approach compared to recent campaigns such as RICO.

Further, the actual amount and kind of cloud sampling is limited relative to that from an aircraft. Since each flight has duration of about 2 hours, the total amount of time available for sampling is about 50 hours for the two months of time at the observing site. A single aircraft during a two-month period could easily make 200 hours of observations and due to the speed of the aircraft it's sampling path would be substantially longer than that from the helicopter.

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It is not clear to us what you want to imply by this comment. The amount of flight hours are a question of available money, so in theory ACTOS can fly much longer in one month time, but the 50 flight hours is what we could get. Aircraft indeed do have a larger spatial coverage, but at the expense of spatial resolution, which is one of the advantages of ACTOS.

It is not clear from the description of the flights how much of this sampling time was actually devoted to making the unique observing capabilities of this platform. In addition to the summary of the duration of the flights, it would be useful to know how many hours of cloud sampling were obtained on these flights and how many clouds were sampled.

The flight strategy – as pointed out in the text – was designed such that we tried to satisfy all different aspects including profiling, aerosol and turbulence measurements under cloud-free and cloudy conditions. The high-resolution data as obtained by ACTOS is unique under all of these conditions, so the referee comment is somewhat ambiguous. Concerning the time spent in clouds and the number of clouds sampled, it has to be said that it is difficult to exactly determine this, as the definition of an individual cloud is not straightforward. However, one can roughly estimate the fraction of time for cloud sampling from the flight example in Fig. 2.

Further, although the in-cloud sampling was limited to near cloud top, the helicopter sampling would allow for the tracking of the temporal evolution of structure near the top of clouds. This particular point needs to be more prominently discussed. At the same time, these measurements can provide valid measurements that cannot be obtained from a faster moving aircraft.

In a field of clouds characterized by different temporal evolutions it is – unfortunately - completely unrealistic to perform "tracking of temporal evolution of one individual cloud“ – this would require Lagrangian observation in individual clouds which is not possible due to the true airspeed of 20 m/s and visual flight requirements. It is definitively an interesting point and we actually tried such a sampling strategy by selecting one individ-

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ual cloud and penetrating it several times, but it proved impossible to keep track of one particular cloud during the turn of the helicopter. With this experience we stopped this sampling strategy. However, your comment is quite useful and welcome for planning of upcoming experiments but cannot improve the current manuscript.

It would be good in an overview to highlight those observations that make full use of the helicopter sampling capabilities and strategies and discuss the scientific issues that can be addressed with these observations. The use of the surface-based observations with the helicopter measurements is also a positive aspect of this project, but again this strategy is not unique to this project.

We agree with the first part of this statement and as a result of this comment we have completely re-written the analysis part (Sec. 4) but I am still convinced that the close collocation of ACTOS and ground-based measurements is more than only a positive aspect. With fast-flying aircraft, comparison with ground-based observations often means a comparison of data, which is horizontally separated by a very long distance. But I agree that not every aspect of our sampling strategy is unique.

Although the project and the treatment in this manuscript revolve around our elements clouds, aerosols, radiation and turbulence– these elements appear to be un-equal in their potential for contributing to our scientific understanding. As noted, the elements that make full use of the helicopter-borne package capabilities have the best chance of making unique contributions. The "cloud" and "aerosol" observations discussed could be made with an instrumented aircraft.

I think this comment is partly valid and has been well addressed with the new Sec 4, which still includes all four mentioned elements but we combined the four elements to one comprehensive story instead of just showing measurement examples.

The in-cloud measurements shown in Fig. 11 are not unique; although they do illustrate the utility of measurement systems used. But the advantage of the helicopter measurements for making these observations is not obvious, particularly since the

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cloud sampling is limited to areas near the top of the cloud.

This is simply not true; interstitial aerosol particles were usually measured with a CPC with time resolution not better than 1 Hz resulting in a spatial resolution of > 40 m or so (depending on the true airspeed of the aircraft but 40 m/s is already a slow-flying one). With such a spatial resolution measurements such as shown in the inlay of Fig 11 are simply not possible and one could not distinguish if the observed spikes of freshly produced particles are in the cloud or at the cloud edge. In other words, the enlarged portion of Fig 11 with classical aircraft measurements would result in one single measurement point without any details. Anyway, this figure has been removed in the revised version and this topic will be analyzed in a separate study.

Further, the utility of the helicopter "radiation" measurement from SMART- HELIOS was not fully established. Although in principle the in situ verification of the retrievals of effective radius and LWC from radiance measurements has merit, it is unclear what new insight has been gained from these measurements. Making good radiance measurements around small cumuli is very challenging because of small-scale in-homogeneities in the cloud edge structure and the cloud microphysical characteristics. Thus at some scales the radiation field is very multi-dimensional. This issue is not fully discussed.

Two manuscripts about the radiation measurements with SMART-HELIOS during CARRIBA have already been submitted; one of these manuscripts is already accepted (see references in the revised manuscript by Werner et al). The first manuscript by Werner et al describes the applied algorithms that are used for the SMART-HELIOS in very detail and also discuss the mentioned problems with 3d-effects and cloud inhomogeneities. In the revised manuscript we only make limited use of the radiation measurements to illustrate the Twomey effect for the two selected days. A third manuscript has been submitted concerning the Eagle observations

Further, since SMART cannot measure the incident radiances, the utility of these mea-

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surements is very limited.

We disagree with this comment because it has been shown by Werner et al (J Geophys. Res., 2013) that a new retrieval algorithm can overcome this “limitation”.

The “turbulence” discussion includes a description of the structure of the transition layer. The measurements shown, however, could also be obtained with a slow flying research aircraft and the characterization of the turbulence is not quantitative.

This comment is true, the analysis was not qualitative but anyway, this part has been removed from the revised manuscript.

The observations shown in Fig. 15 do highlight the unique observing capabilities available to the researchers. The LWC with turbulence dissipation rates at high spatial resolution shown in this figure are very promising. More of this type of analysis needs to be highlighted.

As suggested, the new analysis in Sec 4 of the revised manuscript includes more aspects of local turbulence by describing the parameter space for droplet-droplet interaction in a highly turbulent flow. A manuscript concerning the local structure of cloud edges including local turbulence as a result of local shear is under preparation but beyond the focus of this overview .

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 28609, 2012.