Closure analyses of HALO cloud physics aircraft campaign

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Understanding deep tropical convective cloud processes and aerosol-cloud-interactions is a major objective of the ACRIDICON-CHUVA campaigns. Specifically, the HALO aircraft campaign aimed at documenting all the processes from aerosol formation and growth, their activity in the clouds as CCN and IN, the vertical evolution of cloud microstructure and precipitation forming processes in the water, mixed and ice phases, from cloud base to anvils. This is done mainly for constraining and validating model simulations that will provide us with the fundamental understanding and extend what we learned in the aircraft campaigns to the larger coverage in time and space that can be simulated but not measured. Therefore, complete closure analyses of the aircraft campaigns that provide the best constrains and validation to models is essential. To facilitate an tangible advancement, the problem is decompose into smaller and more tractable problems of closure studies, which can then be combined to the full picture.

More specifically, closures can be obtained in various processes. Examples for such closures include:

1. Measured CCN(S) and cloud base updraft speeds (W) provide cloud base drop concentration (Nd). A closure can be achieved when finding comparable calculated to the measured Nd. If closure is not achieved, we will go to the root of the cause, and find what needs to be fixed and redo the closure.
2. Cloud drop size distribution (DSD) and W can provide calculated supersaturation (S). We can calculate based on that when can we expect secondary nucleation in cloud updrafts, and obtain closure with the actually measured cloud DSD.
3. Height for rain initiation can be predicted by cloud base Nd (Freud and Rosenfeld, 2012) and cloud lifetime (Feingold et al., 2013). Closure can be sought between the calculated versus observed height and time for rain initiation, given the measured Nd and W.
4. Initiation of ice at temperatures higher than -10°C can be calculated based on cloud DSD and ice multiplication theory, T, W and DSD. A closure of that can be achieved against the actual measurements of development of graupel and ice crystals in the cloud.
5. At temperatures colder than -10C, development of the ice phase depends on the advection of ice from below, where possible ice multiplication may occur, and on updraft speeds, DSD, and IN. Closure might be achieved between the calculations and measurements. Here a closure is more elusive, as the knowledge of IN and glaciation processes are not sufficiently known. Therefore, minimally, a documentation of the processes in a compatible way to these calculations will be achieved.
6. Many ice particles in the anvils are produced due to secondary nucleation of cloud drops above the glaciation level, or even homogeneous freezing of haze particles. The production of such particles can be calculated based on calculated S, as obtained with water and ice particle size distributions and W, interstitial aerosol size distribution and composition. A closure can be sought between the calculated and observed new cloud particle formation above the height where all cloud water is glaciated.

We are presently advancing with the analyses from cloud base upward, according to the steps as numbered above. The overall approach and initial results will be presented. The intention is to provoke follow-on discussions with the data owners on both scientific and data quality issues, towards formal publications.