What controls cloud droplet number concentration of trade wind cumuli?

F. Ditas[1], B. Wehner[1], H. Siebert[1], T. Schmeißner[1], M. Simmel[1], H. Wex[1] and A. Wiedensohler[1]

[1]Leibniz Institute for Tropospheric Research (TROPOS), 04318 Leipzig, Germany
Keywords: aerosol-cloud-interaction, activation, trade wind cumuli
Presenting author email: ditas@tropos.de

Aerosol and cloud microphysical properties of trade wind cumuli were determined during the CARRIBA (Clouds, Aerosol, Radiation, and tuRbulence in the trade wInd regime over BArbados) experiment in November 2010 and April 2011. Measurements were performed with the helicopter-borne measurement platform ACTOS (Airborne Cloud Turbulence Observation System, Siebert et al., 2006) with high temporal and spatial resolution. For detailed information about the aerosol instrumentation the reader is referred to Ditas et al. (2012).

This study deals with the statistical analysis of aerosol-cloud-interactions of 730 individual clouds measured during 11 research flights under comparable meteorological conditions. The analysis provides information on the number concentration of activated particles (N_{act}), activation diameter ($D_{p,\ act}$) and critical supersaturation (S_{crit}). The calculation of N_{act} is based on the comparison of total particle number concentration outside of clouds and the interstitial particle number concentration inside clouds. This method is validated against cloud droplet number concentration data (N_d). Activation diameter and critical supersaturation are derived using the measured particle number size distribution and Köhler theory.

Furthermore, the cloud microphysical parcel model of Simmel and Wurzler (2006) is applied to compare to observed N_{act} and to calculate flight-averaged CCN (cloud condensation nuclei) concentration for a fixed updraft. An updraft of 2 m s^{-1} was used for the data shown here ($N_{CCN,\ 2\ m\ s^{-1}}$), representing typical updraft velocities observed during the campaign.

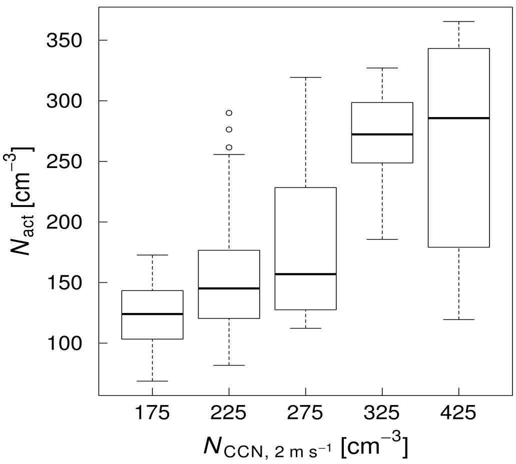

Fig. 1. Boxplot of number of activated particles versus the CCN concentration calculated for a fixed updraft of 2 m s^{-1}. Boxes cover 50% and error bars 75% of the observed data which are grouped into bins of 50 cm^{-3}. Horizontal line inside boxes denote the median, single circles denote outliers.

Figure 1 shows a boxplot of N_{act} versus $N_{CCN,\ 2\ m\ s^{-1}}$ for 239 more active clouds (selected under consideration of vertical wind velocity and adiabatic liquid water content). The median N_{act} indicates a positive trend for increasing $N_{CCN,\ 2\ m\ s^{-1}}$. This emphasizes a strong influence of the available aerosol on the observed number concentration of activated particles.

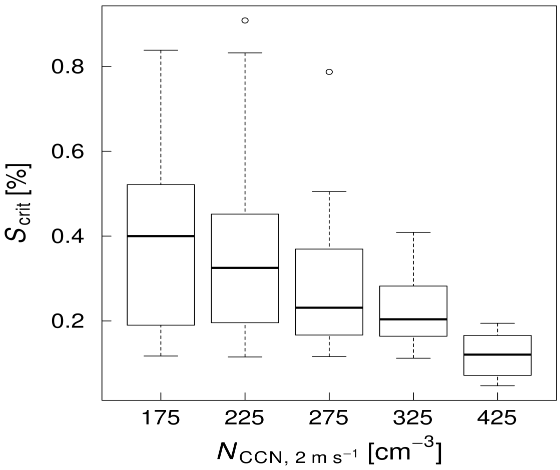

Fig. 2. Boxplot of derived critical supersaturation versus the CCN concentration calculated for a fixed updraft of 2 m s^{-1}. The chart design is similar to Figure 1.

In Fig. 2, the relationship between S_{crit} and $N_{CCN,\ 2\ m\ s^{-1}}$ is investigated. The median S_{crit} and upper error bars feature a decrease for increasing $N_{CCN,\ 2\ m\ s^{-1}}$. This effect results from the faster redistribution of water vapor in cases of higher CCN or cloud droplet concentration (N_d indirectly proportional to phase relaxation time). Hence, the highest critical supersaturation values on the order of 0.8% are derived for the lowest aerosol concentration.

Finally, to decide which parameters control the cloud droplet number concentration, the susceptibility of N_{act} to $N_{CCN,\ 2\ m\ s^{-1}}$ and the measured vertical wind velocity (w) was investigated. Concentrating on one flight (with constant aerosol number size distribution), a variation of w highly influences N_{act}. However, taking into account the results of all flights, the flight to flight variability of $N_{CCN,\ 2\ m\ s^{-1}}$ overrules the variability in N_{act} caused by w. Hence, the amount of available aerosol is dominating the number concentration of activated particles and cloud droplet number concentration, respectively.

We thank the CIMH (Caribbean Institute for Meteorology and Hydrology), Horizon Helicopters, enviscope GmbH, and Barbados Concorde Experience. This project was funded by DFG-grant SI 1534/3-1 and the TROPOS.

Ditas, F., R.A. Shaw, H. Siebert, M. Simmel, B. Wehner, and A. Wiedensohler (2012). *Aerosols-cloud microphysics-thermodynamics-turbulence: evaluating supersaturation in a marine stratocumulus cloud. Atmos. Chem. and Phys.*, 12(5), pp. 2459–2468.

Siebert, H., H. Franke, K. Lehmann, R. Maser, E. W. Saw, D. Schell, R. A. Shaw, and M. Wendisch (2006). *Probing Fine-Scale Dynamics and Microphysics of Clouds with Helicopter-Borne Measurements, Bull. Amer. Met. Soc.*, 87, 1727 – 1738.

Simmel, M. and Wurzler, S. (2006). *Condensation and activation in sectional cloud microphysical models. Atmos. Res.*, 80(2-3), pp. 218–236.