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In-situ measurements of tropical cloud properties in the West African Monsoon: Upper tropospheric ice clouds, Mesoscale Convective System outflow, and subvisual cirrus

Stephan Borrmann (1,2), Wiebke Frey (1), and the SCOUT-AMMA science Team

(1) Max Planck Institute for Chemistry, Particle Chemistry Department, Mainz, Germany, (2) Institute for Atmospheric Physics, Johannes Gutenberg University, Mainz, Germany

During the SCOUT-AMMA campaign in Ouagadougou, Burkina Faso, in 2006, measurements in tropical upper troposphere/lower stratosphere (UT/LS) clouds were performed aboard the Russian high altitude research aircraft M55 Geophysica. The cloud properties were measured with a Cloud Imaging Probe (CIP) and a Forward Scattering Spectrometer Probe (FSSP-100). While the FSSP obtains ice particle size distributions in the size range of $2-47\,\mu$m, also single particle information along with particle shapes are provided by the CIP as it delivers 2-dimensional shadow images of particles in the size range of $25-1600\,\mu$m. Furthermore, a particle counter for ultra-fine aerosol, the COPAS (COndensation PArticle counting System) has been installed. It measures aerosol particles between sizes of 6 nm, 10 nm, and 15 nm up to 1 μm in diameter.

A total of 117 ice particle size distributions were obtained from the measurements in the vicinity of Mesoscale Convective Systems (MCS). Compared to former measurements above maritime regions (during CEPEX and SCOUT-O3) the African measurements showed a proportionate higher amount of large ice particles. With the help of trace gas measurements of NO, NO_y, CO_2, CO, and O_3, trajectory analysis, and satellite images clouds in young, recent, and aged MCS outflow were identified. The encounters occurred at altitudes between 11.0 km and 14.2 km corresponding to potential temperature levels of 346 K to 356 K. Three case studies of MCS outflows of different ages are performed. The young outflow yields much higher ice particle number concentrations and IWCs than the aged outflow, both differing by about two orders of magnitude. In the young outflow rimed ice particles with maximum dimensions exceeding the CIP detection limit (1.6 mm) were found, whereas the largest particles in the aged outflow had maximum dimensions of 61 μm.
Close to the tropopause subvisual cirrus were encountered four times at altitudes of 15 km to 16.4 km. These observations are juxtaposed with all other known in-situ measurements of subvisual cirrus. An exponential fit on all size distributions can be provided as parameterisation for modelling.

A comparison of aerosol to ice particle number concentrations, in order to obtain an estimate on how many ice particles result from activation of the present aerosol, yielded low activation ratios for the subvisual cirrus cases of roughly one cloud particle per 30000 aerosol particles, while for the MCS outflow cases, and also cases of convective overshooting as observed during the SCOUT-O3 campaign, this resulted in a high ratio of one cloud particle per 300 aerosol particles.