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Biomass burning and anthropogenic aerosol influence on cumulus cloud microphysical properties during CAMP2Ex

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Biomass burning (BB) and anthropogenic aerosols and their influence on clouds represent one of the poorly quantified uncertainties in radiative forcing of the climate system. Cumulus clouds, common over maritime regions impacted by BB or anthropogenic aerosols, are important regulators of the global radiative energy budget and global hydrologic cycle. In 2019, a NASA-funded field campaign, the Cloud, Aerosol and Monsoon Processes Philippines Experiment (CAMP^{2}Ex) based in South East Asia sampled three distinct regions around the Philippines, the West Pacific, the South China Sea, and the Sulu Sea. The aerosols and clouds located in these three areas were sampled by instruments mounted on the NASA P3 aircraft, quantifying the microphysical properties of clouds and the chemical composition of aerosols. Our analysis focuses on analyzing the statistical properties of cloud-pass statistics as a means to compare the relationships between cloud properties and their aerosol environments.

During CAMP^{2}Ex the NASA P3 penetrated 1698 clouds just above cloud base. The cloud pass diameters ranged from 0.11 km to 4.5 km with most clouds in the range of 0.2 - 0.3 km. Updraft strengths ranged from 0.1 to 3.0 m/s. The cloud droplet concentrations ranged from 171.4 to 1971.6 cm^{-3} with the smallest number concentration found in marine cumulus outside the region of BB plumes and aerosol plumes originating from anthropogenic and natural sources of the Asian continent. The highest particle concentrations were within BB plumes. In biomass burning regions, organic aerosol ranged from 32.1 to 53.4 μg/m^3, sulfate aerosols ranged from 4.9 to 7.6 μg/m^3, and black carbon ranged from 90.1 to 181.3 μg/m^3. In comparison, anthropogenic aerosol regions, where sulfate aerosol was dominant, had sulfate ranging from 1.5 - 15.0 μg/m^3 and organics from 0.1 - 3.3 μg/m^3. The Manila plume recorded a range of sulfate aerosols of 1.2 - 10.2 μ/m^3, nitrate 0.8 - 3.4 μg/m^3, and ammonium 0.7 - 4.7 μg/m^3 and black carbon 20 - 615 ng/m^3. These aerosol source regions were compared to open-ocean marine aerosol with chemical masses less than 0.1 μg/m^3 for all species measured by the on board aerosol mass spectrometer.

The relationship between cloud number concentrations (N_d), effective radii (r_e), liquid water content (LWC), and cloud drop size distributions just above cloud base within updrafts exceeding 0.4 m/s are related to aerosol chemical composition in four aerosol regimes, biomass burning, industrial anthropogenic aerosol over the South China Sea, the Manila plume around Metro Manila, and open ocean marine aerosol.