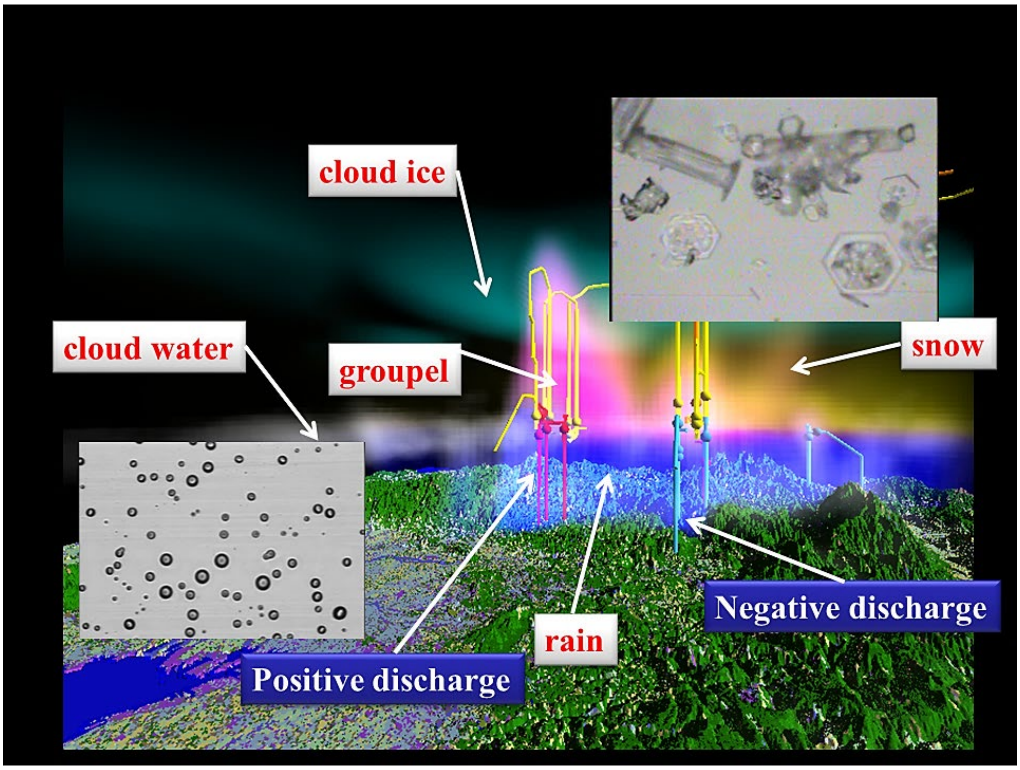
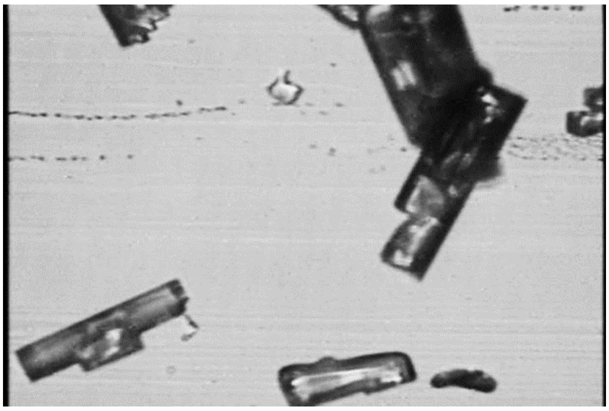
Project for Aerosol and Cloud Formation

Hydrometeors and aerosols interact closely in their generation and dissipation, and play important roles in atmospheric water circulation, the formation of convective clouds and typhoons, and the Earth's radiation budget. However, they are some of the most unknown quantities in the atmosphere. Thus far, hydrometeors and cloud-precipitation systems have been studied at the Hydrospheric Atmospheric Research Center, and aerosols and related processes have been studied at the Solar–Terrestrial Environmental Laboratory. In a joint research program, researchers from both centers will cooperate to study the interaction between aerosols and hydrometeors, their variations in the formation of precipitation, and cloud-aerosol-radiation interactions by field observations and numerical simulations. On the basis of field observations, the numerical model will be improved for the quantitative simulation of cloud and aerosol processes. In cooperation with the Center for Orbital and Suborbital Observations, we will conduct *in-situ* observations of typhoons using aircraft, balloons, and drones. This research will improve CReSS and study the impact of aerosols on typhoon clouds.





Upper: A mesoscale convective system and hydrometeors simulated by the CReSS model.
Lower: The superimposed images show hydrometeors expected to be present in the convective system. Balloon observation of typhoon clouds. Launching balloon (left) and observed hydrometeors (right).

Main Activities in FY2020

Cloud and aerosol observations in the United Arab Emirates and modeling of aerosol-cloud interaction

We have developed CReSS-4ICE-AEROSOL, which implements aerosol-cloud-precipitation integrated microphysics parameterization with various aerosols (sea salt, mineral dust, sulfate, organic carbon (OC), black carbon (BC), and so on) in the atmosphere and in hydrometeors as prognostic variables. Idealized experiments of cumulonimbus clouds with strong updrafts were conducted to investigate the effect of the amount of anthropogenic aerosols (sulfate, OC, BC) on the microphysical structure of the cloud (Fig. 1). It has been shown that increasing anthropogenic aerosols by an order of magnitude increases the number concentration and mixing ratio of cloud ice in the anvil associated with the cumulonimbus cloud by several times (Fig. 2). In the future, we plan to incorporate aerosol information from the global aerosol model SPRINTARS as initial and boundary conditions to investigate the effects of atmospheric aerosols over the UAE on the formation of diurnal convective clouds and subsequent precipitation formation processes.

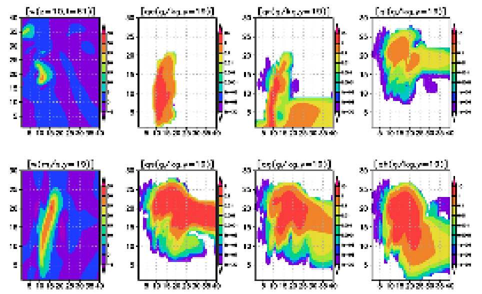


Figure 1: Results of idealized experiments investigating the effect of aerosols on convective precipitating clouds (vertical cross-sections that pass through the center of the clouds except for the horizontal cross-section at an altitude of 5 km in the upper left panel). From the upper left to lower right, vertical velocity, cloud water, rainwater, cloud ice number concentrations, vertical velocity, snow, graupel, hail number concentrations (/ kg).

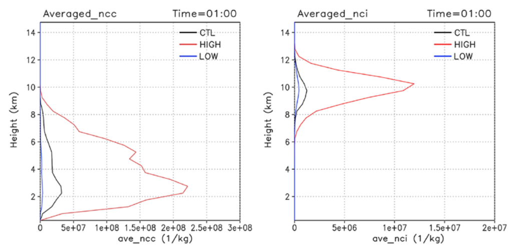


Figure 2: Vertical distribution of cloud water number concentration (left) and cloud ice number concentration (right) averaged over the model domain. HIGH is the result of a sensitivity experiment in which the number concentrations of anthropogenic aerosols are 10 times that of CTL, and LOW is 1/10.

Observation of aerosol particles in Okinawa

Observations were conducted in collaboration with the University of Ryukyus and Nagasaki University from 2018 to 2020. The size distribution of the aerosol particles was measured from June to October 2020 using an optical particle analyzer. Figure 3 (left panel) shows the relationship between average wind speed and mass concentration of aerosol particles with diametrs between 0.3 and 10 μm during the 11 typhoons passing near the observation. In most cases, a similar relationship between wind speed and mass concentration of aerosol particles was observed. Therefore, wind speed plays a critical role in determining the number of sea salt particles around typhoons. In addition, scanning electron microscopy/energy dispersive X-ray spectrometry was used to analyze sea salt collected when two typhoons (Typhoon No. 24, 2018 and Typhoon No. 13, 2019) approached Okinawa. As shown in Figure 3 (a) and (b), the colored particles overlap with Na and Cl, that is, sea salt. Typhoon No. 24, with a maximum wind speed of 53 m/s and sea salt of 32 μg/m^3, contained many fine square-shaped particles. In contrast, Typhoon No.13, with a maximum wind speed of 27 m/s and sea salt of 10 μg/m^3 contained relatively large (ca. 300 μm) complex-shaped particles but few smaller particles.

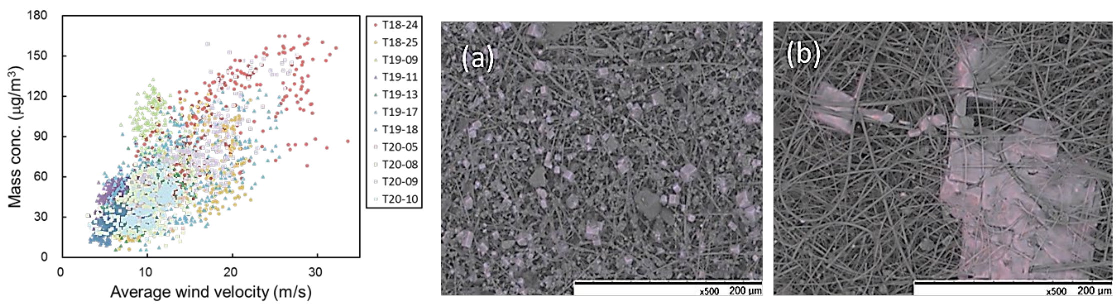


Figure 3 Left: Relation of mass concentration of aerosol particles with diameters between 0.3 and 10 μm and wind speed during the passage of 11 typhoons. Right: Electron microscope images for aerosol particles collected during approaching of the Typhoons (a) No. 24, 2018 and (b) No. 13, 2019.