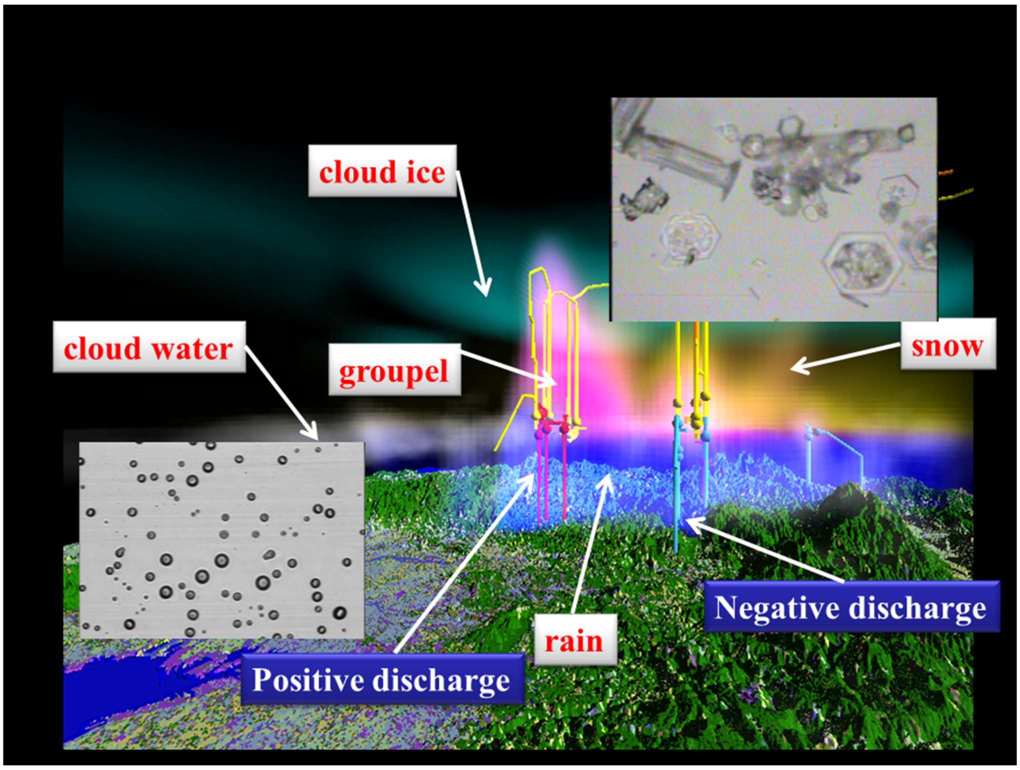
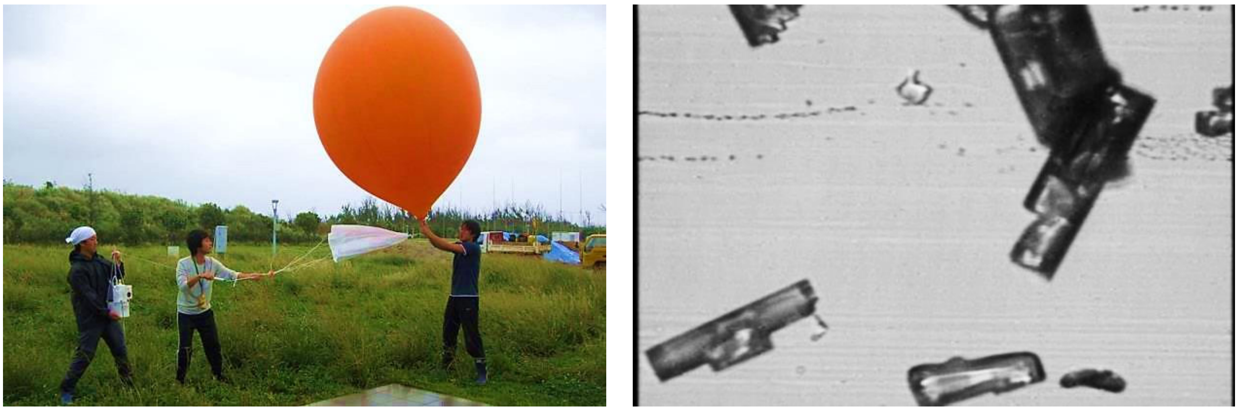
Project for Aerosol and Cloud Formation

Hydrometeors and aerosols closely interact with each other in their generation and dissipation, and play important roles in atmospheric water circulation, formation of convective clouds and typhoons, as well as in the Earth radiation budget. However, they are some of the most unknown quantities in the atmosphere. Thus far, hydrometeors and cloud-precipitation systems have been studied in the Hydrospheric Atmospheric Research Center, whereas aerosols and related processes have been studied in the Solar-Terrestrial Environmental Laboratory. In the 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 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 an aircraft, balloons, and drones. This research will improve CReSS and study the impact of aerosols on typhoon clouds.



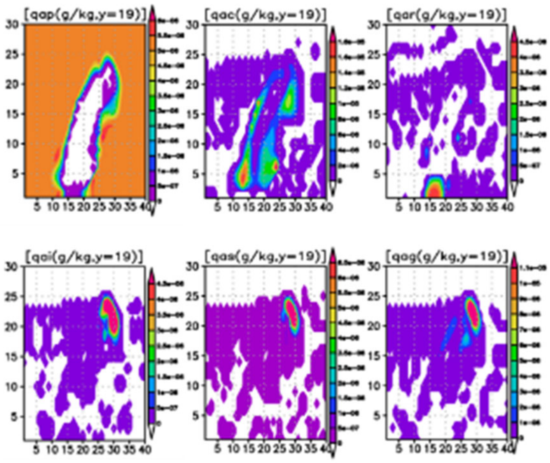


Upper: A mesoscale convective system and hydrometeors simulated by the CReSS model.
Lower: The superimposed images show hydrometeors expected to be present in the convective system. Balloon observation of typhoon clouds. Launching balloon (left) and observed hydrometeors (right).

Main Activities in FY2019

Cloud and aerosol observations in the UAE and aerosol modeling

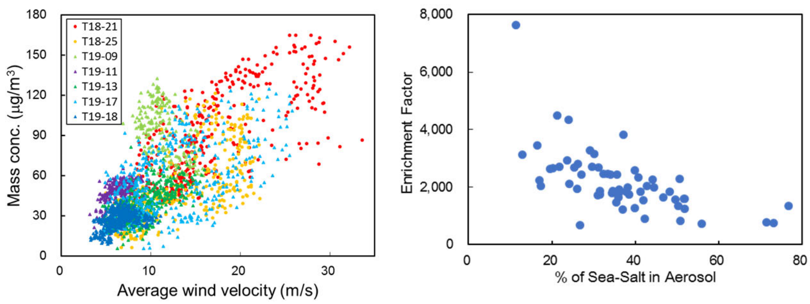
To investigate the effects of aerosols on diurnal convective clouds and their precipitation, using aircraft observations collected in the UAE in September 2017, the spatio-temporal variation of atmospheric aerosols acting as CCNs and INPs, and the microphysical structures of the clouds were analyzed in detail. The aerosols that act as CCNs are activated at water supersaturations of 0.2 to 0.5% in updraft cores near cloud bases, and the number concentrations of activated cloud droplets decreases with altitude owing to the collision-coalescence of cloud droplets and the entrainment of the surrounding dry air, except near cloud tops. Ice particles show a characteristic spatial distribution with larger particle sizes and smaller number concentrations in the updraft cores compared to the surrounding areas. An investigation of the effects of atmospheric aerosols over the UAE on the formation of diurnal convective clouds and their precipitation formation processes is planned, using CReSS implemented with aerosol–cloud-precipitation–integrated cloud microphysics parameterization (Fig.), including various types of aerosols (sea-salt, mineral dust, sulfate, inorganic carbon, organic carbon, etc.) as prognostic variables.



The effect of aerosols on convective precipitation clouds (vertical cross-section through the center of the cloud). Mass mixing ratios of atmospheric aerosols, aerosols present in cloud water, and rainwater (from upper left to upper right), and aerosols present in cloud ice, snow, and hail (from the lower left to lower right) in 1 kg of air.

Observation of aerosol particles in Okinawa

As part of the KAKENHI research project (PI: K. Tsuboki), observations were conducted in collaboration with the University of Ryukyus and Nagasaki University. We measured the size distribution of aerosol particles in the summer and autumn of 2018 and 2019, and PM2.5 mass concentrations continuously from August 2018, using an optical particle analyzer and a low-cost optical sensor, respectively, at the University of Ryukyus. For the seven typhoons that passed near the site, the effect of wind speed on the mass concentration of aerosol particles (mainly sea-salt) with diameters between 0.3 and 10 μm was analyzed. Mass concentration was found to increase by 50 μg/m^3 for a 10 m/s increase in wind speed. In addition, to study the concentrations of sea-salt and dissolved organic carbon (DOC) in the aerosols, we have been collecting bulk aerosols continuously since September 2018, even during typhoon days. The amount of sea-salt in the aerosols showed a good positive correlation with wind speed. It has been reported that when sea-salt is emitted from the surface of seawater, it attracts organic compounds to itself and can thus enrich the concentrations of DOC by several hundred to a couple of thousand times. By studying the concentrations of sea-salt and DOC in aerosols with varying wind speed, we were able to estimate that the enrichment factor was about 700 in the natural environment.



Left: Relationship between mass concentration of aerosol particles with diameters between 0.3 and 10 μm and wind speed during the passage of seven typhoons.
Right: Enrichment factor of DOC in the aerosols with respect to seawater DOC.