Division for Meteorological and Atmospheric Research

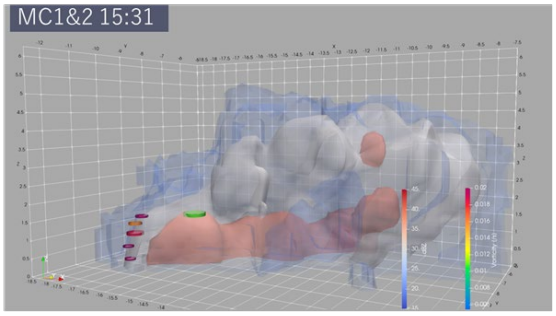
- Precipitation measurements by advanced polarimetric radars and hydrometeor videosondes
- Development of new instrumental technology
- Clouds and precipitation observed by multiple satellites
- Millimeter-wave/infrared spectroscopy of green house gases and ozone-depleting substances
- Measurements and analyses of properties and behaviors of aerosols using advanced techniques

Ongoing global warming caused by increasing carbon dioxide concentrations and other greenhouse gases will cause gradual climate change and intensification of weather extremes and ecological catastrophes. Among the most urgent tasks for confronting global environmental problems more effectively is closely monitoring the atmosphere using different observation methods and gaining a better understanding of the atmosphere via theoretical insights and numerical modeling. To address these issues, the Division for Meteorological and Atmospheric Research is dedicated to several research projects to explore the atmosphere from various angles.

Main Activities in FY2022

Analysis of misocyclones producing waterspouts using PAWR

Phased Array Weather Radar (PAWR), the latest radar technology, is approximately 10 times shorter in observation time than conventional radar and can make three-dimensional observations with no gaps in the elevation direction, demonstrating its effectiveness in the analysis of torrential rains and tornadoes. In this study, we used NICT's PAWR in Onna Village, Okinawa Prefecture, to detect misocyclones, which are vortices less than 4 km in diameter in the parent cloud that generate waterspouts, and analyzed the changes in their three-dimensional structure along with the development of precipitation echoes. In this case, two misocyclones were detected at the leading edge of the developed echo. The analysis of vorticities demonstrated that the potential vorticities of earlier misocyclones increased with time, suggesting that the vortices were enhanced by the outflow from the dissipation of the strong echo.

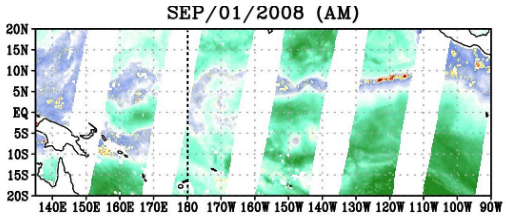


Misocyclones and radar echo observed on May 15, 2017 at 15:31. The vorticity of the misocyclones is depicted in color, and the diameter of the vortex is depicted as the size of circles.

The edge intensification of eastern Pacific ITCZ Convection

Tropical precipitation is climatologically most intense at the heart of the intertropical convergence zone (ITCZ); however, this is not always true in instantaneous snapshots. Precipitation is amplified along the ITCZ edge rather than at its center from time to time. In this study, satellite observations of column water vapor, precipitation, and radiation as well as the thermodynamic field from reanalysis data are analyzed to investigate the behavior of ITCZ convection in light of the local atmospheric energy imbalance. The key findings are as follows: When precipitation peaks at the ITCZ center, suppressed radiative cooling forms a prominent positive peak in the diabatic forcing to the atmosphere, which is

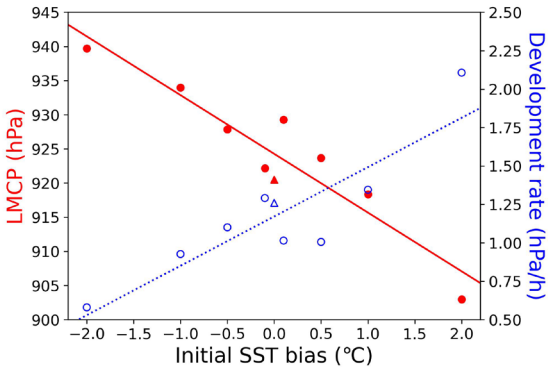
counteracted by the export of moist static energy (MSE) owing to deep vertical advection and a large horizontal export of MSE. Conversely, when convection develops at the ITCZ edges, a positive peak of the diabatic forcing is only barely present. An import of MSE due to a shallow ascent on the ITCZ edges presumably allows edge intensification to occur despite the weak diabatic forcing.



Example of ITCZ edge intensification illustrated with column water vapor overlaid by precipitation

Intensity sensitivity of Typhoon Mindulle (2021) on initial SST

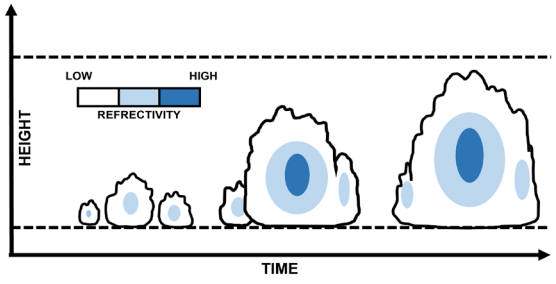
There is a strong relationship between sea surface temperature (SST) and typhoon intensity, and a small difference in SST may cause large differences in maximum intensity. However, SSTs given as initial conditions in numerical models have some types of uncertainty. To elucidate the sensitivity of typhoon intensity to initial SST values for Typhoon Mindulle (2021), one control and two sets of sensitivity experiments were performed using Cloud Resolving Storm Simulator (CreSS), a cloud-resolving model that incorporates a vertical 1-D ocean model. The sensitivity experiment set I examined the sensitivity of SST biases ranging from −2 to +2 °C in the initial SST. The results indicate that there is a clear negative correlation between the initial SST bias and lifetime minimum central pressure (LMCP), and a positive correlation between the initial SST bias and the intensifying rate in the development period from the initial time to the LMCP time (Figure). These results verify that the maximum intensity of a typhoon strongly depends on its initial SST bias. The sensitivity experiment set II examined the intensity sensitivity to perturbations ranging from ±0.01 to ±2.0 °C in initial SST. No correlation was found between the amplitude of the perturbations and the LMCP or the intensifying rate until the LMCP. This indicates that the forecast error of the typhoon intensity does not depend on the amplitude of the random error of the initial SST values.



Scatter diagram of the initial SST bias, LMCP, and intensifying rate. Black circles and triangles (left axis) indicate the LMCP, and white circles and triangles (right axis) indicate the intensifying rate. Dotted lines represent regression lines.

Early detection of rapidly developing convective echoes using a Ka-band radar

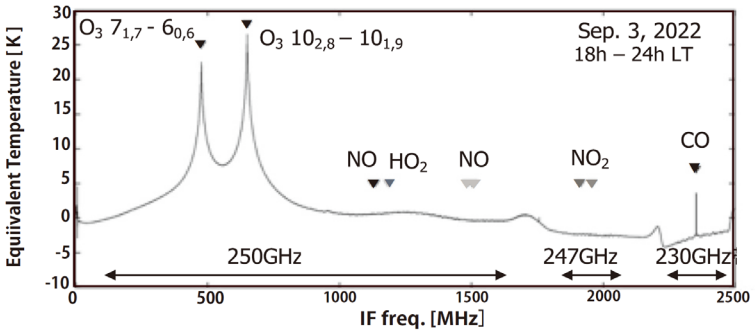
The rapid development of isolated convective cells bring about sudden heavy precipitation. This study attempts to early detection of developing isolated convective echoes using horizontal distributions of reflectivity obtained every 2 min by a Ka-band radar installed in Kobe City in the summer of 2018. We define the “developing” convective echoes as the maximum rainfall intensity exceeds 20 mm/h in an isolated convective precipitation region obtained every 1 min by the X-band radar network. Fourteen convective echoes are analyzed on August 6 and 16, 2018, and two echoes are evaluated as the developing convective echoes. There is no significant difference in the time series of the vertically averaged reflectivity (VAR) between the developing and non-developing echoes; however, the time series of the VAR area of the developing echoes is clearly larger than those of the non-developing echoes. The developing echoes tend to merge with the surrounding small/weak echoes and rapidly increase their are.



Conceptual model of the time series of early development of a convective precipitation cell. Shading depicts the reflectivity obtained by the Ka-band radar.

Simultaneous multi-line observations for understanding the process of atmospheric composition changes in the polar regions due to precipitating energetic particles

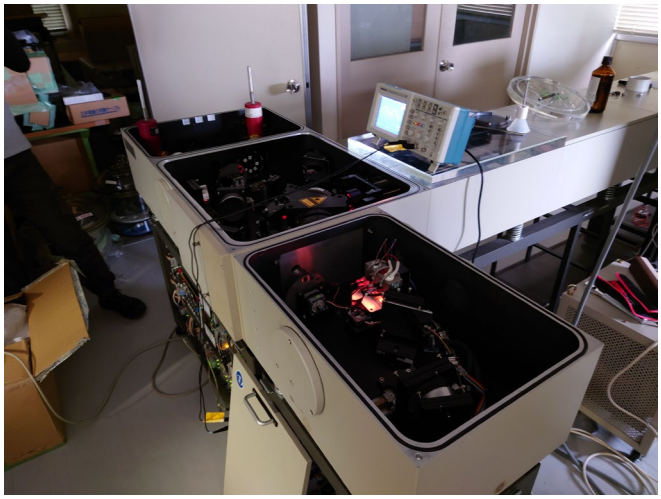
Millimeter-wave spectral radiometers have been installed at Syowa Station in Antarctica and at the EISCAT facility in Tromsø, Norway, to comprehend the effects and mechanisms of composition changes in the middle atmosphere caused by energetic charged particles precipitating into the polar regions as a result of solar activity. At Syowa Station, we began simultaneous multi-line observations in 2020 by modifying the receiver to multi-frequency using a waveguide multiplexer that we developed independently. However, because it could not achieve the expected performance as initially planned, owing to component defects, further modification of the receiver system was initiated in January 2022. The receiver cooling system was improved to achieve a minimum temperature of 4.9 to 5.0 K and a temperature instability smaller than 50 mK (p-p), resulting in a receiver noise temperature of 120 to 235 K (SSB). Furthermore, with the implementation of a superconducting filter in the receiver system and the extension of the bandwidth of the digital spectrometer to 2.5 GHz, the frequency bands of O_3, NO, CO, NO_2, and HO_2 emissions can now be observed as initially planned. In particular, for NO, the simultaneous observation of six hyperfine structure lines in the 250 GHz band improved the signal-to-noise ratio and reliability of the data. However, we could not perform observations in Tromsø in FY2022 owing to the COVID-19 pandemic.



Example of spectral data obtained by simultaneous multi-line observations of the new millimeter-wave spectral radiometer at Syowa Station

Establishment of an urban air quality monitoring site using high-resolution FTIR in Nagoya, Japan

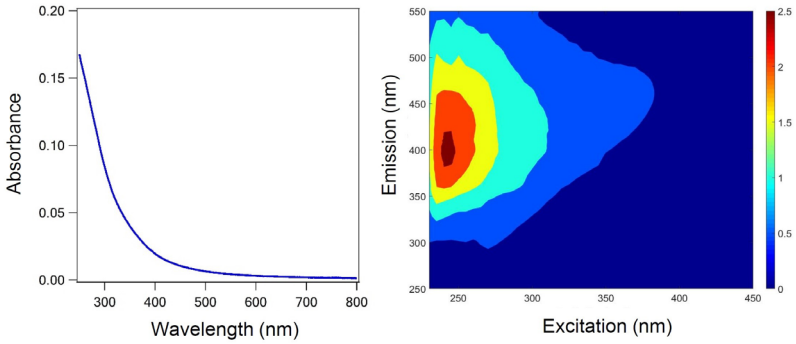
ISEE newly installed a high-resolution Fourier Transform Infrared spectrometer (FTIR) at the Higashiyama campus of Nagoya University and measured the tropospheric and stratospheric minor constituents, including air pollutants in the urban area. The air pollutants are harmful and induce health issues; therefore, their long-term variability is crucial for protecting air quality in urban areas. Various minor constituents in the troposphere and stratosphere can be retrieved simultaneously from a solar absorption spectrum measured using a ground-based high-resolution FTIR spectrometer. Therefore, it is one of the most powerful tools for this purpose. We built up the FTIR spectrometer and measured the instrumental line function. Additionally, the installation of a solar tracker and meteorological instruments at the site is in progress. The vertical distribution and column amount data for more than 20 species of the minor constitutes obtained from the monitoring observations with the FTIR in ISEE will be made publicly available as part of the ISEE Joint Usage/Research program.



Nagoya Higashiyama FTIR system under optical alignment

Analysis of the light absorption property of organic aerosol

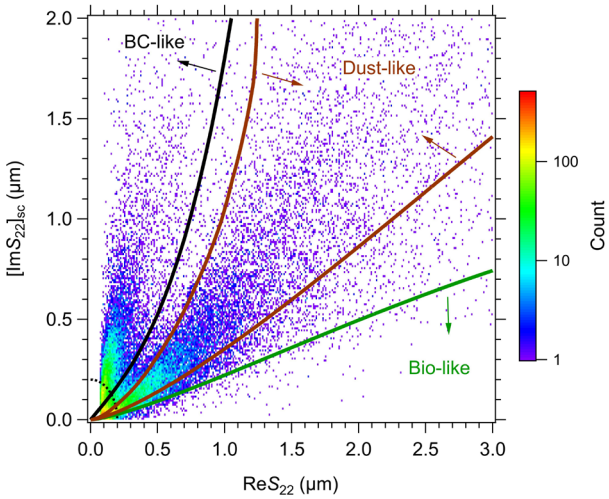
The absorption of solar radiation by atmospheric organic aerosols, in addition to that by black carbon, would affect the radiation balance and chemical reactions in gas and particle phases. Therefore, understanding the relationship between the types of organic aerosols and their light absorption properties is important to comprehend the roles of organic aerosols and their evolution processes in the atmosphere. In this study, we analyzed the light absorption properties of organic aerosol components in atmospheric aerosol samples collected during the COALA-2020 campaign in Australia. The results demonstrated that the mass absorption efficiency of organic aerosol components extracted from the aerosol samples on carbon basis (wavelength: 365 nm) was closely associated with the relative abundances of tracer compounds in biogenic secondary organic aerosols and biomass burning organic aerosols. Both of these aerosols are considered to be originated from biomass, but emitted through different pathways. This result is expected to contribute to the understanding of the contribution of these two pathways to the contrasting light absorption properties. We also measured the fluorescence spectra of the samples to further characterize the studied organic aerosols.



Examples of light-absorption and fluorescence spectra measured for the extracts (water-insoluble organic aerosol components) from atmospheric aerosol samples collected in Australia (Courtesy of Sonia Afsana)

Evaluation of a method to measure water-insoluble aerosol particles

Water-insoluble aerosol particles (WIAPs), such as black carbon (BC) and mineral dust, affect climate by interacting with radiation and clouds. However, methods for identifying WIAP types and quantifying their number concentrations are limited, leading to an insufficient understanding of their atmospheric abundance and behavior. In this study, we classified WIAPs and quantified their number concentrations using a novel approach, wherein atmospheric aerosols were collected on a filter, dispersed in water, and the complex scattering amplitude (S) of individual particles was measured. The complex scattering amplitude depends on the complex refractive index, volume, and shape of particles. The WIAPs collected from the urban atmosphere of Nagoya in the spring of 2021 were classified as BC-like, dust-like, and Bio-like particles based on their complex amplitude data. The number concentrations of BC-like particles were strongly correlated with the number concentrations of refractory BC particles measured by another instrument. BC-like and dust-like particles were the dominant WIAPs during the observation period, and the number concentrations of dust-like particles significantly increased during an Asian dust event, which was consistent with the electron microscopy analyses observations. These results indicate that our method has the potential to become a new technique for quantifying the spatio-temporal distributions of WIAPs under various atmospheric environments.



Complex amplitude (S) data for all particles from filter samples collected in Nagoya. The colored bar indicates the number of detected particles. Lines for particle classification into BC-like, dust-like, and Bio-like particles are also depicted.