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Research on Airborne Ultrafine Particulate Matters around an Airport Based on Advanced Analytical Techniques

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Civil aviation has grown rapidly as a result of global economic development (Masiol & Harrison, 2014; ICAO, 2017). The International Civil Aviation Organization (ICAO) has authorized a new regulatory standard for emissions from turbofan engines in terms of particle mass and number. Consequently, the environmental impact of aircraft emissions, especially ultrafine particles (UFPs; diameter <100 nm), has been recognized as an important issue. The major purposes of this project were to obtain a better understanding of the physical and chemical characteristics of UFPs emitted from in-use aircraft, and to investigate the potential impacts of aircraft emissions on the spatial distributions of UFPs in and around Narita International Airport (NRT), Japan. We used advanced analytical techniques to measure the number and mass concentrations and size-resolved chemical composition of UFPs. We also used numerical model simulations to estimate the dispersion of aircraft emissions around the airport.

We conducted field measurements of UFPs near a runway at NRT in February 2018 and July-August 2018. The online aerosol instruments used for the field measurements consisted of an ultrafine condensation particle counter (UCPC; TSI, d_{50} = 2.5 nm), a condensation particle counter (CPC; TSI, d_{50} = 10 nm), a scanning mobility particle sizer (SMPS; TSI), and an engine exhaust particle sizer (EEPS; TSI). The sampling inlet for the UCPC, CPC and SMPS was switched between an unheated mode and a 350°C-heated mode to measure total and non-volatile particles, respectively (Takegawa et al., in press). Furthermore, size-resolved aerosol samples were collected using two sets of cascade impactors (Nano MOUDI II; MSP Corp.) for offline chemical analysis. We used thermal-desorption gas chromatography mass spectrometry (TD-GC/MS), thermal/optical carbon (EC/OC) analysis, and particle-induced X-ray emission (PIXE) analysis to quantify the chemical composition of aerosol samples (Fushimi et al., 2019; Saitoh et al., 2019). An analysis of the elemental compositions of jet engine lubrication oil and jet fuel was also performed using in-air PIXE (Saitoh et al., 2018).

Figure 1 shows an example of the total (unheated) particle number and mass size distributions derived from the SMPS data. The data indicate that the particle number size distribution functions below ~30 nm in the aircraft plume event showed significant increases compared with those in the non-plume event. The particle mass size distribution function below ~30 nm also exhibited significant enhancements in the plume event, suggesting that the chemical characterization of aerosol particles with diameters smaller than ~30 nm is a key point in understanding the formation mechanisms of aircraft exhaust particles. A comparison between the unheated and heated data suggests that the number and mass concentrations of UFPs in the observed plumes were mostly volatile. The TD-GC/MS analysis revealed that organic compounds in aerosol particles with diameters ranging from ~10 to 30 nm were dominated by nearly intact forms of jet engine lubrication oil (Fushimi et al., 2019). This finding provides direct evidence for the importance of unburned lubrication oil as a source of aircraft exhaust nanoparticles.

We estimated the particle number emission indices (EIs) from in-use commercial aircraft during take-off phases using the UCPC, CPC and EEPS data. More than half the particle number EIs were in size ranges smaller than 10 nm for both total and non-volatile particles in most of the observed take-off plumes (Takegawa et al., in press). The significance of sub-10 nm size ranges for the total particles in the take-off plumes was qualitatively consistent with previous studies (e.g., Lobo et al., 2012), but that for the non-volatile particles was unexpected (Takegawa et al., in press).

We performed numerical simulations of UFPs in and around NRT using an Aviation Environmental Design Tool (AEDT) model. In case studies for the field observation period, we estimated that the highest number concentrations of UFPs occurred near the terminal areas of NRT, whereas moderately high number concentrations of UFPs tended to be spread over wide areas with a horizontal scale of 20 km.

To summarize, we have successfully obtained new datasets and simulation results for improving our understanding of particulate emissions from aircraft and UFP dispersion around an airport. The project outcomes should provide a firm scientific basis for future assessments of the effects of aircraft emissions on climate and human health. Our findings may also contribute to the development of future engine technologies for reducing particulate emissions from aircraft.

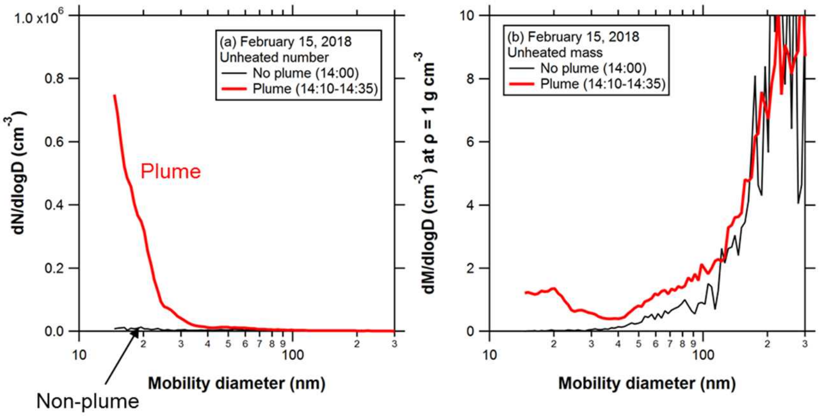

Fig. 1 Example of total (unheated) particle number and mass size distributions derived from the SMPS on February 15, 2018. The red line represents data obtained from aircraft exhaust plumes (plume events), and the black line represent those from background air (non-plume events). The particle mass size distributions were estimated by assuming a particle density of 1 g cm^{-3}.

References

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