Overview of the proposal to the master plan 2017 on the aircraft observation of climate and earth system sciences

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The science council of Japan announced for proposal for the master plan 2017 in March 2016. The meteorological society of Japan proposed “Promotion of Scientific Research on Climate and Earth System Sciences Using Aircrafts.” In this report overview the proposal and current activities.

“Promotion of Scientific Research on Climate and Earth System Sciences Using Aircrafts”
The aim of this proposal is to promote the climate and earth system research in the area of atmospheric science, oceanography including sea ice, glaciology, volcanology and ecology by a dedicated aircraft observation system.
Although in-situ measurements by the state-of-the-art instruments on board aircraft has great advantages to provide accurate data for estimating key parameters with high temporal and spatial resolutions, which lead to improve our understanding of the critical processes, Japan does not have an aircraft dedicated to the Earth observation. This is the motivation of this proposal.
The expected research area in which a breakthrough is achieved with aircrafts is the mechanism of the changes in the climate and the earth system. The climate change, especially the global warming, is caused by changes in the Earth radiation balance due to greenhouse gases such as carbon dioxide. On the other hand, aerosols, clouds and their interaction are known as the most uncertain factor on the radiation balance. Response of clouds to precipitation sometimes appears as heavy rainfalls and typhoons and it is also urgent issue. Since Japan has been leading the world by the sophisticated numerical modeling and the satellite observations, synergetic use of the aircraft observations with them will lead great progress of research in this area. Furthermore, Asian region remains an observational gap of aircrafts though it is the “hotspot” of aerosols including PM2.5 and greenhouse gases and most frequently experiences strong tropical cyclones, so that Japan’s contribution and leadership of the aircraft observation in this region is highly anticipated.
The aircraft which we think most suitable for our research is the Mitsubishi Regional Jet (MRJ) since it has enough space to simultaneously equip several observational instruments and it can be relatively easily refurbished for equipping the instruments by taking advantage of the domestic production.
Having an aircraft for exclusive use for earth sciences has great advantages for both types of researches which requires long-term monitoring such as greenhouse gases and agile observations of hazardous events such as typhoons, heavy rainfalls and volcanic eruptions.
The Center for Orbital and Suborbital Observations, Institute of Space-Earth Environmental Research, Nagoya University will lead the program in the framework of the “Joint Usage/Research Center (JURC)”.
A JURC steering committee that consists of specialists of each research area from various organizations will be responsible for the research and operational plan.
Having the dedicated aircraft for the earth observation benefits the research fields other than the atmospheric sciences such as hydrology, ecology, oceanography, glaciology, volcanology, and Earth surface remote sensing.

Future activities

On the future activity, based on the activities of the aircraft observation promotion committee, strengthen cooperation with related organizations in order to establish the activity base.

Keywords: aircraft observation

Observation of Lightning by Aircraft

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Observation of lightning from aircraft has been used to design a satellite sensor to detect and locate lightning discharge. Optical Transient Detector (OTD), and Lightning Imaging Sensor (LIS) are all designed based on the data obtained in the field campaing using ER2 aircraft NASA and these measurement provides the characteristics of peak amplitude, optical pulse duration, and pulse interval from the illuminated cloud by lightning. Based on the success of these missions, recently GLM (Geostationary Lightning Mapper) was successfully launched into the geostationary orbit and is in operational mode this year. The GLM is expected to give us time and location of lightning discharges with more than 90% detection efficiency, and the data is useful to have early warning to tornado and hazardous pheonomena cause by lightning producing thunderstorm.
On the other hand, GLIMS (Global Lightning and Sprite Measurements) mission showed that the multi frequencies observation of optical lightning from space could discriminate cloud to ground and cloud lightning by taking the ratio of amplitude between the different wavelength (Adachi et al. 2016), which is not possible with the GLM sensor.
In this presentation, a proposal on the optical observation of lightning at multiple frequencies with high temporal resolution from aircraft will be presented. Also some scientific and social background are also presented.

Keywords: Lightning, Aircraft

Airborne remote sensing in active fault research

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Aerial photograph interpretation at 1:40,000 to 1:20,000 scales has introduced to geomorphology since 1960s, which brought significant progress in active research in Japan. Tectonic Geomorphologists intensively observed aerial photographs and recognized active faults throughout Japan. As a result, "Active fault in Japan" was published by University of Tokyo Press in 1980, and revised in 1991. In 1980s, it was said that "the era of active fault discovery is over". However, several active faults have been newly discovered since the 1990s after the introduction of 1:10,000 aerial photographs, seismic reflection, and excavation studies to active fault research.

Since the onset of the 21st century, new active fault studies have started to combine aerial photography and LiDAR. Suzuki et al., 2003 conducted LiDAR measurements along the Itoigawa-Shizuoka Tectonic Line for the first time, and confirmed the technique’s efficiency in identifying small-scale tectonic landforms. They then produced detailed digital elevation models (DEMs) using old aerial photographs taken before artificial modification. Moreover, they took aerial photographs at 1:10,000 scale originally along the whole fault line with POS-IMU measurements. The purpose was to enable detection of co-seismic displacement with future earthquakes.

Recently, Suzuki et al., 2015 presented an innovative LiDAR study in which the uplift distribution caused by the 2013 Kamishiro fault earthquake was revealed. Moreover, they conducted to take aerial photographs again for the focal region, and crustal deformation was photogrammetrically measured by comparing aerial photos before and after the earthquake. The results indicated that the severely damaged Horinouchi area was remarkably uplifted and dislocated to the west due to low-angle reverse faulting.

For the 2017 Kumamoto Earthquake, satellite SAR is appreciated because it revealed co-seismic surface deformation in the wide area. However, airborne LiDAR data have significantly contributed to the detection of local surface deformation. Therefore, it is essential to upgrade crustal deformation analysis methods to combine airborne LiDAR, satellite SAR, and aerial photogrammetry.

Keywords: LiDAR, Aerial photograh, active fault

Promotion of solution-oriented remote sensing by the use of UAV

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The concept of UAV remote sensing was almost established. We will present several case studies trying to manage social requirements. Next challenge will be the combination of satellite and UAV remote sensings to establish total package for solution-oriented technology.

Keywords: Unmanned Aerial Vehicle (UAV), UAV Remote Sensing, Crop Monitoring, Ecosystem Monitoring, Land Surface Temperature Monitoring, Dose Rate Monitoring

Forest Canopy Structure Measurement Using close-distance Remote Sensing Technology

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In research on biodiversity, which has drawn attention in recent years, it is said that the diversity of tree species that constitute forests and the three-dimensional structure of forests are closely related to the diversity of the inhabitants. It is thought that grasping the three-dimensional structure of the forest canopy in the target area is important for development of a method to evaluate forest biodiversity by remote sensing technology. On the other hand, the three-dimensional structure of the forest canopy is important as a source of the influence of BRDF on the satellite received signal for the observation of vegetation by satellite remote sensing, and the importance of three-dimensional structure measurement for that has been recognized. So far, authors have used LIDAR and SfM technology to measure the canopy structure in various forests to estimate BRDF in the forest. We believe that the measurement method can be applied to biodiversity evaluation research in many cases.
In this research, we describe what can be clarified for the forest canopy structure measurement at present using the Terrestrial LIDAR, the close-measurement aerial LIDAR and by SfM technology, and the results of organizing the problems to be solved in the future.

Keywords: LIDAR, UAV, SfM, Remote Sensing

Pi-SAR2 observation of the disaster areas affected by volcanic eruption and earthquake

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Japan is an area where earthquakes often occur and volcanic activities are active. The sudden eruption of Mt. Ontake in 2014 and the 2016 Kumamoto earthquake are still fresh in our minds. For the estimation of damage scale and the preparation of restoration activities, it is important to quickly grasp the damage situation in disaster areas. However, the direct access to such areas is often difficult due to traffic situation, risk of secondary disaster, and so on. In this context, one of the effective means is the remote sensing from airplane and/or satellite, which allow us to widely observe disaster areas without direct access. Among the remote sensing instruments, the synthetic aperture radar (SAR) is especially interesting due to its capability for operating in day-and-night and all-weather conditions. NICT has developed the airborne SAR named Pi-SAR2 since 2006. Pi-SAR2 can perform full-polarimetric observations of the ground with the spatial resolution of 0.3 m. At the same time, height measurements and/or moving target detection can be performed owing to the interferometric SAR function of Pi-SAR2. Moreover, the onboard SAR processor enable us to send quick look images from the airplane via the commercial satellite network connection within approximately 10 min after the observation. In this presentation, we introduce the Pi-SAR2 observations performed for volcanos and disaster areas affected by earthquakes and discuss the differences between the satellite and airborne SAR measurements.

Keywords: volcano, earthquake, airborne SAR

How the GOSAT program has used airplane observations for its demonstration, calibration, and validation

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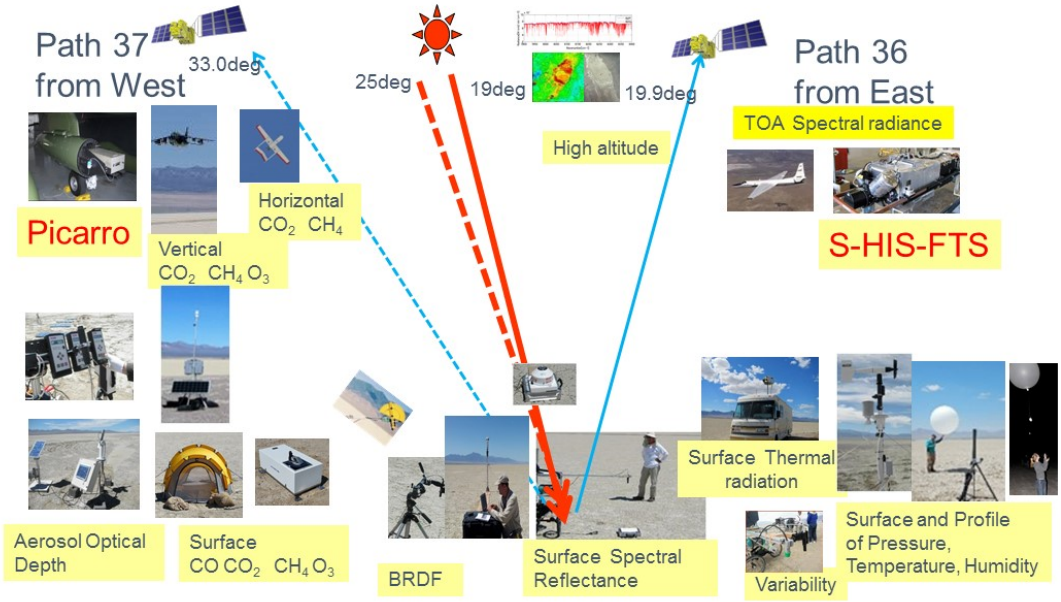
The Greenhouse gases Observing SATellite (GOSAT) is the first satellite program designed to accurately and precisely monitor carbon dioxide (CO_2) and methane (CH_4) from space. In-situ and remote optical measurements onboard airplanes have made GOSAT a successful mission as described below.
(1) Demonstration of GHG column density retrieval from solar scattered light
At the beginning of the GOSAT program, we installed a breadboard model to a high altitude airplane to acquire spectra and to detect and correct light path modifications by aerosols and clouds. We acquired high resolution spectra of O_2A, CO_2, and CH_4 at SWIR, but validation without a simultaneous aerosol Lidar measurement was not possible.
(2) TIR radiometric, spectroscopic and polarimetric calibrations
GOSAT observes wide spectral range radiation between 650 and 1800 cm^{-1} from both the surface and the atmosphere. Double difference comparison using spectra acquired by GOSAT, airplanes, and forward calculation can remove model-dependent errors. S-HIS-FTS by the University of Wisconsin onboard ER-2 at 25 km flown over the hot desert of Railroad Valley (RRV) and S-HIS and the Met Office ARIES FTS operated onboard FAAM flown over cold Greenland provided calibration data for detector non-linearity correction. Additionally, high spectral resolution data from air-borne FTSs validated spectroscopic and polarimetric calibrations.
(3) Validation of GHG vertical profile
A multiplex advantage of GOSAT-FTS can cover both solar scattered light at the SWIR band for column density and thermal radiation from the atmosphere at the TIR band for profile retrieval. NASA Ames' s Alpha Jet Atmospheric eXperiment (AJAX) uses a Picarro spectrometer for the in-situ vertical spiral profiling of CO_2 and CH_4 from the surface to the upper troposphere and coincident flight data for GOSAT over RRV.
In addition to the above applications, airplanes can provide plume emissions with a higher spatial scale to validate amount from point sources.

Keywords: GOSAT, TANSO-FTS, ARIES, AJAX, S-HIS



Closure between CCN and Cloud Droplet Concentrations for Warm Clouds over Japan Based on In-situ Aircraft Measurements

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Aerosol particles acting as cloud condensation nuclei (CCN) and ice nuclei (IN) determine the microphysical structures of cloud and precipitation, and affect a short-range precipitation forecast and climate change projection. Also an efficiency of hygroscopic seeding is dependent upon the characteristics of background CCN as well as physico-chemical properties of seeding particles and cloud types. Therefore we investigated the physico-chemical properties and CCN ability of background aerosols and cloud microphysical structures using an instrumented aircraft (B200T) over Shikoku district of Japan in the summers of 2008, 2009 and 2010 as a part of Japanese Cloud Seeding Experiments for Precipitation Augmentation.

Number concentrations of CCN activated at SSw of 1% ranged from 400 –3,000 cm^{-3} while number concentrations of CN ranged from 1,000 –30,000 cm^{-3} even during the southerly wind periods. The number concentrations of CCN activated at SSw=1% and aerosol particles larger than 0.1 mm showed a good correlation. Estimated hygroscopicity of the atmospheric aerosols was on the order of 0.1. The aerosol size distributions and CCN spectra in the Pacific Ocean region air masses showed that their shapes were similar to those in the East Asia coastal region air masses, but total number concentrations of aerosol particles and CCN number concentrations were about 1/2 of those in the continental/polluted air masses from the East Asia coastal region. These concentrations were much higher than typical values in maritime air masses, but were close to typical values in continental air masses, suggesting that maritime air mass was very much influenced by pollution from Japan and big cities and industrial areas in the East Asia.

Typical maximum cloud droplet number concentrations near cloud bases were 300~1,500 cm^{-3}. The ratio of cloud droplet number concentration and CCN number concentration activated at SSw=1.0% increased with decreasing the CCN number concentration and increasing updraft velocity. The estimated maximum SSw near cloud bases ranged from 0.2 ~ 1.0% and also increased with decreasing CCN number concentration and increasing updraft velocity.

Keywords: CCN, Cloud droplet, Aerosols

Aircraft measurements of biomass burning aerosol particles

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Biomass burning from forest fire or agricultural burning emits a huge amount of aerosol particles and gases in a global scale. Thus, its influence on the climate and regional pollution are significant. Especially, biomass burning is one of the major sources of light absorbing aerosol particles such as black and brown carbon, and the understanding of their contributions to global climate is critical.

Aerosol particles from biomass burning depend on types of fire, i.e., smoldering or flaming, fuel sources, and evolution after emission. The evolution of biomass burning aerosol after emission is relatively rapid (~hours), and it changes its chemical, physical, and optical properties within smoke through, for example, dilution, condensation, coagulation, cooling, oxidation, and photochemical processes. To understand the effects of biomass burning influences on the atmospheric phenomenon, it is necessary to accurately observe the evolution (or aging) process within smoke. In this study, we measured and collected biomass burning smoke from wild fires in North America during the Biomass Burning Observation Project (BBOP) 2013 aircraft campaign. The BBOP campaign was the aircraft-based field campaign to study the near-field evolution of particulate emissions from biomass burning from July to October 2013.

This study mainly focuses on the measurements using transmission electron microscopy to analyze the physical and chemical changes within biomass burning smoke. This study found tar balls, which are spherical organic particles and were abundant in relatively aged smoke (>several hours from emission). The number fraction of tar balls increased as the biomass-burning plume aged and reached more than half of all aerosol particles with aerodynamic diameter between 100 and 700 nm. Aircraft-base measurement is powerful and almost the only method to measure such rapid processes occurred in high altitude and will be important observation technique in the atmospheric sciences.

Keywords: Transmission electron microscope, Tar ball, Biomass burning

Distributions and temporal changes of greenhouse gases in upper atmosphere observed by aircraft

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More accurate prediction for future levels of atmospheric greenhouse gases such as carbon dioxide (CO2) requires the quantitative understanding of global cycles in these gases. Precise spatial and temporal variations of these gases can reduce the uncertainties of flux estimation at earth’ s surface. The atmospheric observations of greenhouse gases, however, are not enough in several areas in the world. Measurements in upper atmosphere are, especially, quite limited compared to surface ones. The observed data in upper atmosphere are free from local sources and sinks and thus have representativeness in wide area/region. These data are also useful for validating the vertical transport of global transport models.
Aircraft is one of the most reliable tools to observe the atmospheric compositions in troposphere and lower stratosphere. We will present some examples of aircraft measurements conducted by Tohoku University (TU), Meteorological Research Institute (MRI) and National Institute for Environmental Studies (NIES), Japan. One is the observations of CH4 concentrations from the lower to upper troposphere over Japan during 1988-2010 based on aircraft measurements from the TU. Second one is the systematic measurements of the atmospheric O2/N2 ratio using aircraft over Japan since 1999 by TU. Last one is the observation project for greenhouse gases using commercial airliner (CONTRAIL) conducted by MRI and NIES since 2005.

Keywords: Aircraft, Greenhouse gases, troposphere, stratosphere

A research plan of typhoon observation using an aircraft: T-PARCII

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Typhoons are the most devastating weather system occurring in the western North Pacific and the South China Sea. Violent wind and heavy rainfall associated with a typhoon cause huge disaster in East Asia including Japan. Typhoons are still the largest cause of natural disaster in East Asia. Moreover, many researches have projected increase of typhoon intensity with the climate change. This suggests that a typhoon risk is increasing in East Asia. However, the historical data of typhoon include large uncertainty. In particular, intensity data of the most intense typhoon category have larger error after the US aircraft reconnaissance of typhoon was terminated in 1987.The main objective of the present study is improvements of typhoon intensity estimations and of forecasts of intensity and track. We will perform aircraft observation of typhoon and the observed data are assimilated to numerical models to improve intensity estimation.
In typhoon seasons (mostly in August and September), we will perform aircraft observations of typhoons. Using dropsondes from the aircraft, temperature, humidity, pressure, and wind are measured in surroundings of the typhoon inner core region. Then, more accurate estimations and forecasts of the typhoon intensity will be made as well as typhoon tracks. After a test flight in March 2017, typhoon observations will be made for next 4 years; 2017-2020. The main target area of observation is the south of Okinawa where a typhoon reaches the maximum intensity and often changes its moving direction. This research will advance aircraft observation technique of typhoon in Japan. The aircraft observation will be a breakthrough to improve typhoon intensity estimations. Assimilation of the aircraft observation data to the cloud-resolving model will improve intensity estimations and forecasts of typhoons. This is the first step for the future advanced aircraft observation and will contribute to prevention or reduction of typhoon disasters.

Keywords: Typhoon, dropsonde, aircraft observation

Cloud particle observation using Cloud Particle Sensor and its possibility of application to aircraft observation

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To understand microphysical processes in a precipitation system, it is necessary to grasp properties of particles; such as their size, phase (liquid or solid), shape, and number concentration, by direct (in situ) observations using aircraft or balloon. The Hydrometeor Videosonde (HYVIS) is a balloon-borne instrument. It can capture images of particles and transmits movie data by 1680 MHz band. In particular, it is useful to confirm the shape and size of ice crystal. The drop-type HYVIS (HYDROS) was developed and applied to aircraft observations (Murakami et al. 1994), however, there are several problems of HYDROS; such as the frequency of data transmit (1680 MHz band is not suitable to transmit data in long distance from the instruments to the receiver equipped on the aircraft), its weight and cost.
Recently, the Cloud Particle Sensor (CPS: Fujiwara et al. 2016) is developed. It is equipped with a diode laser at ~790 nm and two photo detectors with a polarization plate for one of the detectors. It can observe number of particles, their size ranging from 2 to 80 micrometers, and phase by degree of polarization. It transmits the particle information using 400 MHz band that is same as the GPS sounding observations. It has small (approximately 15 cm * 10 cm * 10 cm) size, light weight (~200 g), and relatively low cost with the HYVIS, thus we can expect to apply it to the aircraft observation. In the present study, we introduce the preliminary analysis using CPS soundings and discuss their possibility of application to the aircraft observation.
We conducted a filed observation at Okinawa in the Baiu season in 2016 and launched 4 CPSs combined with HYVISs and 2 CPSs with and without light shading tubes. All CPSs combined with GPS radiosondes, thus particle information can be obtained with altitude, temperature, and humidity simultaneously. The CPS is able to observe the particle information not only during the ascending period, but also during the descending one after the balloon bursts, therefore, it is possible to make the CPS dropping observation from the aircraft. The degree of polarization below the melting level is greater than 0.5 and is different from that above the melting level. This fact shows that the phase of particles can be clearly distinguished below the melting level by the CPS, however, supercooled waterdrops cannot be identified. The CPS sometimes observes noise that the detector receives direct or reflecting light from the sun or ground surface during the daytime. To reduce the noise, it attaches light shading tubes both at the upper and lower inlets. By attaching the tubes, we confirm that the obtained number of liquid particles with tubes is reduced over 10 times lesser than that without tubes. On the other hand, that of solid particles is reduced about 70-80%. Since the aircraft observation is expected to be conducted during the daytime, the noise in the thick cloud layer without tubes should be evaluated.

Keywords: Aircraft observation, Cloud microphysics, In situ observation, Cloud Particle Sensor (CPS), Hydrometeor Videosonde (HYVIS)

