温室効果ガス観測技術衛星GOSATにおける航空機観測
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.

キーワード：GOSAT、TANSO-FTS、ARIES、AJAX、S-HIS
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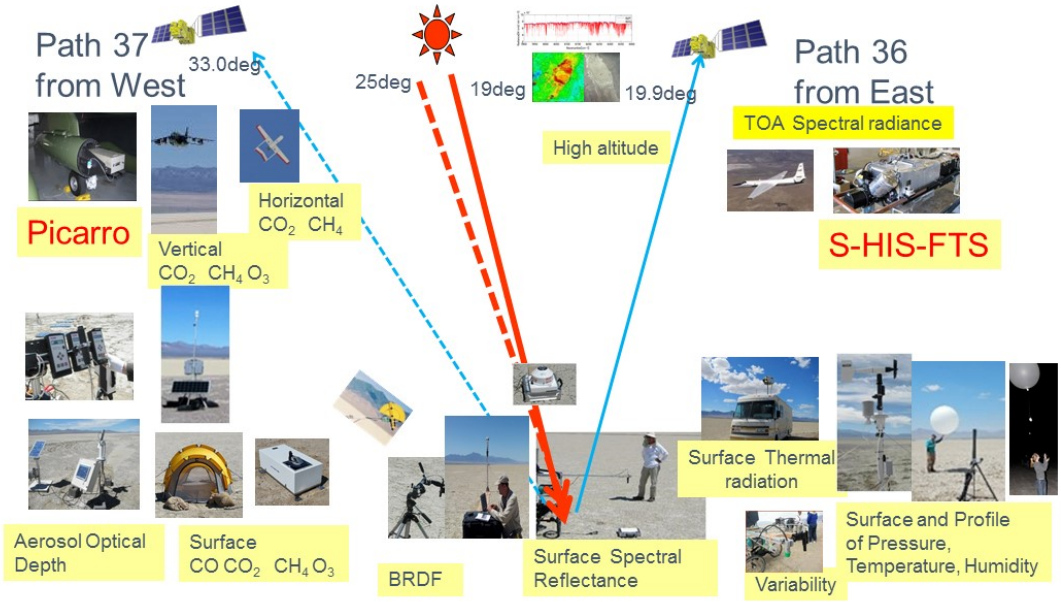

Closure between CCN and Cloud Droplet Concentrations for Warm Clouds over Japan Based on In-situ Aircraft Measurements

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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.

キーワード：雲核、雲粒、エアロゾル
Keywords: CCN, Cloud droplet, Aerosols

バイオマス燃焼から生じたエアロゾル粒子の航空機観測
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.

キーワード：電子顕微鏡、ターボール、バイオマス燃焼
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.

キーワード：航空機、温室効果ガス、対流圏、成層圏
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.

キーワード：台風、ドロップゾンデ、航空機観測
Keywords: Typhoon, dropsonde, aircraft observation

CPSゾンデを用いた雲粒子観測と航空機観測への適用可能性

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

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雲内の雲物理過程を理解するためには、レーダなどを用いたリモートセンシング技術に加えて、粒子の特徴（粒径・相・形状・数濃度）を直接観測により把握する必要がある。雲粒子ゾンデHYVISは気球の浮力により上昇していく際に、フィルム上に落下してきた雲・降水粒子を動画として撮影し、1680 MHz帯の電波を用いて動画データを受信機に転送する測器であり、氷晶粒子の形状の観測や偏波パラメータの検証に有効である。このHYVISを航空機観測に適用（HYDROS：Murakami et al. 1994）しようとする場合、機器の重量、形状に加えてデータ転送の周波数帯（1680 MHz帯での長距離のデータ転送）に課題がある。

近年、Fujiwara et al. (2016) により開発されたCPSゾンデは、近赤外光を射出するダイオードレーザと2つの受光器を内部にもち、粒径が2～80μmの雲粒子について、数濃度と一部の粒子の粒径と相（液相か固相か）を観測することのできる観測機器である。粒子の数濃度などのテキスト情報を転送するために、通常の業務で使用されるGPSゾンデと同じ400 MHz帯をデータ転送に使用している。また、機器の大きさも十数センチであり、HYVISに比べて重量（～200 g）やコストの点でも航空機観測への適用が有望である。そこで、本研究では、CPSゾンデを用いた初期観測結果を紹介するとともに、航空機観測への適用可能性について議論を行う。

2016年梅雨期に沖縄においてHYVIS＋CPSの結合ゾンデを４基と、遮光筒の有無のCPS結合ゾンデ２基を放球した。CPSゾンデはGPSゾンデと結合して放球されるため、雲粒子の特徴とともに、取得時の高度・気温・湿度も同時に観測を行うことができる。これらのCPSゾンデは気球による上昇中のみならず、下降中でも雲粒子の数濃度や粒径・相を観測できており、航空機から投下する形での観測を行うことが可能であることを示した。また、観測される偏光度の値は融解層の上層と下層で明瞭に異なる値を示しており、粒子の相が明確に区別できることを示している。しかしながら、融解層よりも上層での液相（過冷却水滴）の特定を行うことはできない。CPSでは受光部に直達光もしくは地表面からの反射光が到達してしまうことで観測ノイズが生じる。日中の観測では、遮光筒を付けることで観測ノイズを低減できるが、遮光筒を付けることで液相粒子の取得数が劇的に少なくなることを確認した。航空機観測は日中に行われるために、厚い雲層内での遮光筒無しのCPSでの粒子取得量の評価が課題となる。

キーワード：航空機観測、雲微物理、直接観測、CPSゾンデ、雲粒子ゾンデ
Keywords: Aircraft observation, Cloud microphysics, In situ observation, Cloud Particle Sensor (CPS), Hydrometeor Videosonde (HYVIS)

