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

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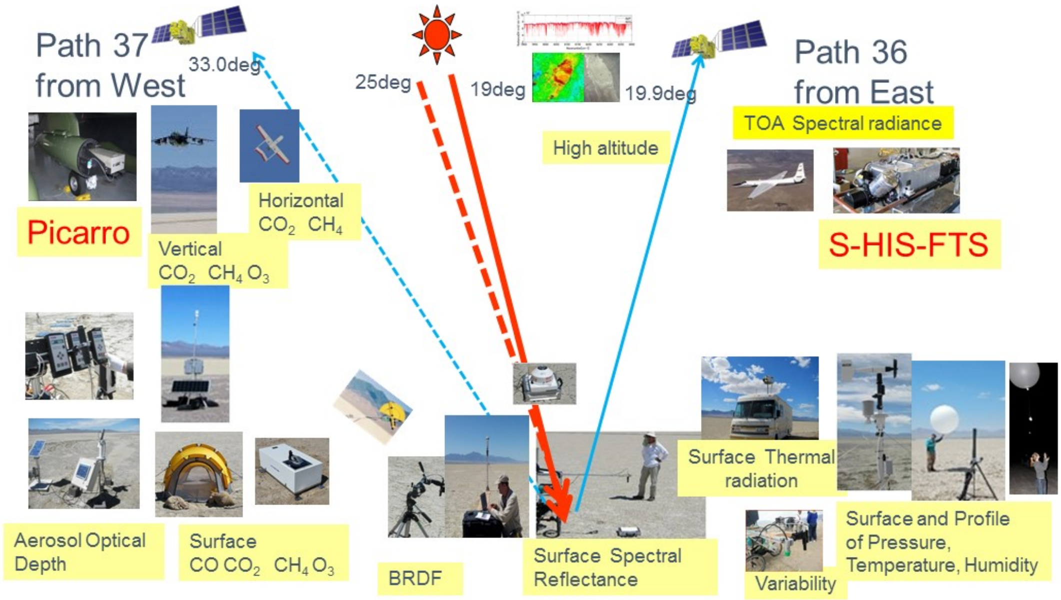
The Greenhouse gases Observing SATellite (GOSAT) is the first satellite program designed to accurately and precisely monitor carbon dioxide ($CO_2$) and methane ($CH_4$) from space. In-situ and remote optical measurements onboard airplanes have made GOSAT a successful mission as described below.
(1) 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 $O_2$A, $CO_2$, 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



Path 37
from West
33.0deg
25deg
19deg
19.9deg
Path 36
from East
TOA Spectral radiance
High altitude
Picarro
Horizontal
$CO_2$ $CH_4$
Vertical
$CO_2$ $CH_4$ $O_3$
S-HIS-FTS
Aerosol Optical Depth
Surface
CO $CO_2$ $CH_4$ $O_3$
BRDF
Surface Spectral Reflectance
Surface Thermal radiation
Variability
Surface and Profile of Pressure, Temperature, Humidity

# 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)

 