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First Steps Toward Space-based CO_2 Measurements: GOSAT, OCO-2, and GOSAT-2

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Human activities including fossil fuel combustion, land use change, and cement production are now adding more than 40 billion tons of carbon dioxide (CO_2) to the atmosphere each year. These emissions have increased the atmospheric CO_2 concentration by more 40% since the beginning of the industrial age. Interestingly, precise measurements from a global network of greenhouse gas monitoring stations indicate that less than half of the CO_2 emitted by these human activities stays airborne. The rest is apparently being absorbed by natural processes at the surface, whose identity and location are poorly understood. Ground-based CO_2 measurements accurately record the global atmospheric CO_2 budget and its trends but do not have the resolution or coverage needed to identify the *sources* emitting CO_2 into the atmosphere or the natural *sinks* absorbing this gas. This information is critical to any carbon management strategy.

One way to improve the resolution and coverage of CO_2 measurements is to collect high resolution observations of the column-averaged CO_2 dry air mole fraction (X_{CO2}) from space. The NASA Orbiting Carbon Observatory (OCO) and the Japanese Greenhouse gases Observing SATellite (GOSAT, nicknamed *Ibuki*) were the first two missions designed to collect space-based observations of X_{CO2} with the sensitivity, coverage, and resolution needed to quantify CO_2 fluxes on regional scales over the globe. The GOSAT and OCO-2 teams have collaborated closely since 2004 to cross calibrate the measurements and cross validate the retrieved products from these missions.

GOSAT was successfully launched on 23 January 2009 and has been returning global measurements of CO_2 and methane (CH_4) since late April of that year. The OCO mission was lost on 24 February 2009 when its launch vehicle malfunctioned and failed to reach orbit. Immediately after the loss of OCO, the GOSAT scientists, engineers, and managers from JAXA and NIES, invited the OCO team to contribute to the analysis of measurements collected by the GOSAT Thermal And Near infrared Sensor for carbon Observations-Fourier Transform Spectrometer (TANSO-FTS). NASA responded by reformulating the OCO science team as the Atmospheric CO_2 Observations from Space (ACOS) team and encouraged this collaboration. Since 2009, this effort has provided an independent GOSAT X_{CO2} product as well as valuable insights into X_{CO2} retrieval algorithms, calibration methods, and validation techniques.

On 2 July 2014, GOSAT was joined by the NASA Orbiting Carbon Observatory-2 (OCO-2), which was successfully launched from Vandenberg Air Force Base in California. In early August, OCO-2 joined the 705-km Afternoon Constellation (A-Train), just ahead of Japanese GCOM-W1 satellite. Its instrument, a 3-channel, imaging grating spectrometer, was then cooled to its operating temperatures and started collecting almost one million soundings over the sunlit hemisphere each day. Between 15 and 30% of these measurements are sufficiently cloud free to yield precise, full column estimates of X_{CO2}. Initial deliveries of calibrated OCO-2 spectra to the NASA Goddard Earth Science Data and Information Services Center (GES DISC) began on December 30, 2014. Routine deliveries of X_{CO2} to the GES DISC are expected to begin on 30 March, 2015.

The GOSAT and OCO-2 teams are continuing to work closely together to cross calibrate the measurements and cross validate the data products from these two missions so that they can be combined to enable more comprehensive studies of CO_2 sources and sinks. As the GOSAT and OCO-2 products are harmonized, this team will turn its focus on their next goal, the GOSAT-2 Mission, which will measure CO_2, CH_4 and carbon monoxide (CO). This presentation will summarize the capabilities of these three missions and highlight the scope of the collaboration needed to integrate their data products into a precise, continuous climate data record.

Keywords: Carbon dioxide, Orbiting Carbon Observatory-2, Greenhouse gases Observing SATellite, OCO-2, GOSAT, Ibuki