Watching the Earth Breath –Measuring carbon dioxide with the Japanese GOSAT and NASA OCO-2

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Space based remote sensing provides new tools for quantifying carbon dioxide (CO_2) emissions from fossil fuel combustion, biomass mass burning, and other human activities. These measurements are also essential for monitoring changes in the emission and absorption of CO_2 by the land biosphere and ocean as the natural carbon cycle responds to climate change. High resolution spectra of reflected sunlight within near infrared CO_2 and molecular oxygen (O_2) absorption bands are well suited for this application because they can be analyzed to estimate the column-averaged CO_2 dry air mole fraction, X_{CO2}. These X_{CO2} estimates can be assimilated into chemical transport models to infer the spatial distribution of surface CO_2 fluxes over the globe. This is a particularly challenging space based measurement, however, because the even the largest human and natural emission sources and natural absorbers produce only small (< 0.25%) changes in the background X_{CO2} field. High precision is essential to resolve the small variations and high accuracy is needed because small biases in the retrieved X_{CO2} distribution could be misinterpreted as spurious CO_2 fluxes.

The Japanese Greenhouse Gases observing SATellite, GOSAT (nicknamed “Ibuki”) and the NASA Orbiting Carbon Observatory (OCO) were the first two satellites designed specifically to exploit this measurement approach. OCO used high resolution imaging grating spectrometers to measure the absorption by CO_2 near 1.61 and 2.06 microns and O_2 near 0.765 microns. GOSAT used a Fourier transform spectrometer to observe the same O_2 and CO_2 bands, as well as the methane (CH_4) band near 1.67 microns. GOSAT was successfully launched in January 2009, and has been returning measurements of X_{CO2} and X_{CH4} since April 2009. OCO was lost in February 2009 when its launch vehicle malfunctioned. It was replaced by OCO-2, which was successfully launched in July 2014 and has been returning measurements of X_{CO2} since September 2014.

While these to pioneering missions each have unique capabilities, the GOSAT and OCO teams realized early in their development that their scientific benefits could be improved if their measurements could combined to produce a uniform climate data record. The two teams formed a close collaboration to cross calibrate the GOSAT and OCO measurements and cross-validate their retrieved X_{CO2} estimates against internationally recognized standards. Early in the GOSAT mission, this collaboration accelerated the development of calibration methods, retrieval algorithms, and validation techniques. Since the OCO-2 launch, these methods have been applied to both missions.

Near-simultaneous observations of the vicarious calibration site at Railroad Valley, Nevada, U.S.A. indicate that a small (5%) radiometric offset between the OCO-2 and GOSAT 0.765 and 1.61 micron bands that is currently under investigation. Comparisons of GOSAT and OCO-2 X_{CO2} estimates with results from the ground-based Total Carbon Column Observing Network (TCCON) indicate that both are yielding X_{CO2} estimates with accuracies better than 0.5%.

The approach used to cross calibrate and cross validate the OCO-2 and GOSAT results has become a model for future greenhouse gas missions. Its extension to GOSAT-2 and OCO-3, both expected to launch in 2018, has been formalized through a Memorandum of Understanding between NASA and the GOSAT-2 partners. Similar collaborations have also been discussed for the European Space Agency’s CarbonSat mission and French Space Agency (Centre national d'études spatiales, CNES) MicroCarb mission. If implemented, this approach could yield a continuous X_{CO2} record that extends from 2009 through the early 2020’s.

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