Opportunities for Coordinated Observations of CO_2 with the Orbiting Carbon Observatory (OCO) and Greenhouse Gases Observing Satellite (GOSAT)

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The Orbiting Carbon Observatory (OCO) and the Greenhouse Gases Observing Satellite (GOSAT) are the first two satellites designed to make global measurements of atmospheric carbon dioxide (CO_2) with the precision and sampling needed identify and monitor surface sources and sinks of this important greenhouse gas. Because the operational phases of the OCO and GOSAT missions overlap in time, there are numerous opportunities for comparing and combining the data from these two satellites to improve our understanding of the natural processes and human activities that control the atmospheric CO_2 and it variability over time. Opportunities for cross-calibration, cross-validation, and coordinated observations that are currently under consideration are summarized here.

Key Words: Carbon Dioxide, Climate, Remote Sensing

Nomenclature

CO_2	Carbon dioxide gas
FTS	Fourier Transform Spectrometer
GOSAT	Greenhouse Gases Observing Satellite
JPL	Jet Propulsion Laboratory, California Institute of Technology
km	kilometer
NASA	U.S. National Aeronautics and Space Administration
OCO	Orbiting Carbon Observatory
O_2	Molecular oxygen
ppm	Parts per million by volume
TCCON	Total Carbon Column Observing Network
WMO	World Meteorological Organization
X_{CO2}	Column integrated CO_2 dry air mole fraction
λ	Wavelength of light (color)
$\Delta\lambda$	Minimum resolvable difference in wavelength
μm	microns

1. Introduction

The Orbiting Carbon Observatory (OCO) is currently under development at the Jet Propulsion Laboratory (JPL), in preparation for a launch late in 2008[1]. Like the Greenhouse Gas Observing Satellite[2] (GOSAT), this NASA Earth System Science Pathfinder mission will make global, space-based measurements of the column-averaged atmospheric carbon dioxide (CO_2) dry air mole fraction, X_{CO2}. This is a particularly challenging space-based measurement because the surface sources and sinks of CO_2 must be inferred from subtle spatial and temporal variations in X_{CO2}. Modeling studies predict that X_{CO2} variations will rarely exceed 2% (8 parts per million by volume, or *ppm*, out of the ambient ~380 ppm background) on regional scales.[3] Validation of these space-based measurements will also be a challenge because few measurement systems can sample the entire atmospheric CO_2 column in the same way as these spacecraft. Fortunately, the operational phases of the OCO and GOSAT missions overlap, providing numerous opportunities for cross-calibrating and cross-validating the data from these two satellites.

2. OCO Measurement Approach

OCO consists of a dedicated 3-axis stabilized spacecraft bus that carries a 3-channel, imaging grating spectrometer designed to make coincident measurements of reflected sunlight in near-infrared CO_2 and molecular oxygen (O_2) bands. High spectral resolution ($\lambda/\Delta\lambda$>24,000) measurements of the CO_2 bands near 1.61 and 2.06 μm yield CO_2 column abundance estimates that are most sensitive CO_2 variations near the surface, where most sources and sinks are located. High resolution ($\lambda/\Delta\lambda$>21,000) measurements within the 0.765-μm O_2 A-band constrain the total atmospheric mass and provide cloud and aerosol profiles to reduce pathlength uncertainties associated with multiple scattering. Each spectrometer collects between 12 to 24 measurements per second while the spacecraft is over the sunlit hemisphere of the Earth, yielding contiguous measurements with a small measurement footprint (< 3 km^2 at nadir). Coincident measurements of the CO_2 and O_2 spectra are analyzed to retrieve spatial variations in X_{CO2}. Each spectrometer channel also returns 4 to 20 “colors” at 20 times the nominal spatial resolution to facilitate the detection of clouds and aerosols within each sounding.

3. Comparisons of GOSAT and OCO Measurement Approaches

GOSAT retrieves X_{CO2} from the same CO_2 and O_2 absorption bands used by OCO, but uses a high resolution Fourier transform spectrometer (TANSO-FTS) rather than a grating spectrometer to make its measurements. An independent Cloud and Aerosol Imager (TANSO-CAI) is used to identify cloudy scenes[2)]. The grating and FTS techniques both offer unique advantages for this application. For example, TANSO-FTS provides greater spectral coverage and slightly higher spectral resolution, while the OCO instrument provides greater spatial resolution and slightly higher signal-to-ratios in each sounding. Comparisons of X_{CO2} retrievals from these two measurement techniques could help to identify and correct subtle measurement biases that might otherwise be missed.

4. Opportunities for Coordinated Observations

Combining the OCO and GOSAT datasets would benefit the carbon cycle science community by increasing the spatial coverage and decreasing the interval between observations by either satellite, alone. To combine these datasets without introducing biases, the OCO and GOSAT measurements must be validated a common measurement standard. Fortunately, the OCO and GOSAT mission plans are quite synergistic, providing numerous opportunities for cross validation.

OCO will fly in a 98.8 minute, 705 km altitude, sun-synchronous, orbit with a 16-day ground track repeat cycle, and an ascending nodal crossing time of ~1:26 PM. Soundings are acquired either along the ground track at the local nadir or in the direction of the "glint spot," where sunlight is reflected specularly from the Earth's surface. GOSAT will fly in a 666 km altitude sun-synchronous orbit with a 1 PM descending equator crossing time and 3-day ground repeat cycle. TANSO-FTS uses a scanner to acquire discrete soundings over a broad cross-track swath centered on the local nadir or in the direction of the glint spot. The OCO and GOSAT orbits cross many times every day, providing numerous opportunities for comparing coincident observations from these two satellites.

5. Opportunities for Cross Validation

To diagnose and resolve any disagreements between coincident OCO and GOSAT measurements, both satellites should validate their results against a common validation standard. A key element of the OCO validation plan is the Total Carbon Column Observing Network (TCCON), an array of high-resolution, ground-based, solar-looking Fourier Transform Spectrometers (FTS's). These instruments retrieve X_{CO2} from measurements of direct sunlight in the same near-infrared CO_2 and O_2 bands used by the OCO and GOSAT flight instruments. TCCON stations are co-located with ground-based CO_2 measurement sites, so that they can serve as transfer standards between the spacecraft and the ground-based World Meteorological Organization (WMO) CO_2 standard. Comparisons of TCCON observations from Park Falls, Wisconsin and Darwin, Australia with in-situ CO_2 measurements from aircraft indicate that these sites can retrieve X_{CO2} with precisions much better than 1 ppm. Regular observations of TCCON sites would therefore provide an effective method for cross-validating measurements from the OCO and GOSAT instruments.

6. Opportunities for Cross Calibration

Combing X_{CO2} data from the OCO and GOSAT missions would be facilitated by cross-calibrating the radiometric performance of their instruments. This could be done by collecting and sharing ground based and space based measurements over their vicarious calibration sites. The OCO and GOSAT teams are exploring these and other opportunities collaborate on cross-calibration and cross-validation of the data from these two missions.

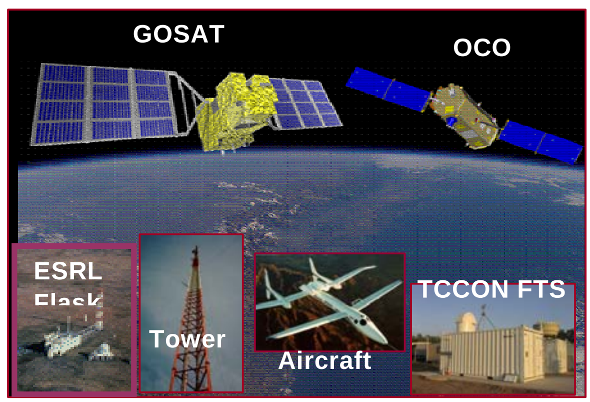

Fig. 1. The OCO mission is part of a global CO_2 monitoring network that includes the NOAA ESRL Flask and tower networks, aircraft, and the ground-based TCCON FTS's. There are also numerous opportunities to cross-calibrate and cross validate data from OCO and GOSAT missions.

7. Acknowledgements

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References

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