Space Based Observations of CO2 with the NASA Orbiting Carbon Observatory-2 (OCO-2)

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Overview

• Quick review of the OCO-2 mission architecture and observing strategy

• A quick look at OCO-2 $X_{\text{CO}_2}$ soundings
  – Point sources

• Status of data validation effort

• Introduction to Flux Inversion Results

• A glance into the future of space based greenhouse gas measurements
Measuring CO₂ from Space

- **Record** spectra of CO₂ and O₂ absorption in reflected sunlight.

- **Retrieve** variations in the *column averaged CO₂ dry air mole fraction, X_{CO₂}* over the sunlit hemisphere.

- **Validate** measurements to ensure X_{CO₂} accuracy of 1 ppm (0.25%).

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**Initial Surf/Atm State**
- Generate Synthetic Spectrum
- Instrument Model
  - Difference Spectra
  - Inverse Model

**New State (inc. X_{CO₂})**

**X_{CO₂}**

**Platforms:**
- GOSAT and OCO-2
- Tower
- Aircraft
- Flask
- FTS
The OCO Instrument – Optimized for Sensitivity

Each 1/3 sec frame includes 8 spatial footprints with 1,016 wavelengths in 3 spectral channels.

0.765µm O₂ A-Band  CO₂ 1.61µm Band  CO₂ 2.06 µm Band
The OCO-2 instrument collects 24 soundings each second as it flies over the sunlit hemisphere of the Earth, yielding almost 1 million soundings each day.
The OCO-2 XCO2 Retrieval Algorithm

State Vector First Guess
- CO₂
- Δτ_ads
- Altitude
- CO₂ Mixing Ratio
- Temperature
- Aerosol

Gas Cross Sections
Cloud & Aerosol Optical Properties
Solar Spectra
Full-res Spectrum
Simulated Spectrum
Retrieved State Vector
X_CO₂

Forward Radiative Transfer Model
Spectra + Jacobians

Instrument Model
Spectral + Polarization
Full-res Spectrum
Calibration
Observed Spectra

Inverse Model
- Compare obs. & simulated spectra
- Update State Vector

Final State & Diagnostics
- converged
- not converged

Apriori + Covariance

Viewing geometry
Retrieved State Vector
- Altitude
- CO₂
- Δτ_ads
- Mixing Ratio
- Temperature
- Aerosol

The OCO-2 XCO2 Retrieval Algorithm
A Quick Look at the First 17 Months of Operations
Robust 5.5 ppm Winter Enhancement

[Schwandner et al.]
Small-Scale Emission Structures
Alberta Tar Sands, Canada [Schwandner et al.]
Target Observations
Comparison of TCCON and OCO-2 $X_{CO_2}$

Comparisons with Total Carbon Column Observing Network (TCCON) stations are being used to identify and correct biases in target observations.

After applying a preliminary bias correction, differences are approaching 1 ppm.

Debra Wunch – July 17, 2015
Temporal Changes in $X_{CO2}$
Impact of Bias Corrections

CSIRO Marine and Atmospheric Research and Australian Bureau of Meteorology (Cape Grim Baseline Air Pollution Station)
Biases Relative to Multi Model Medians

- High bias at high southern latitudes in southern winter
- Persistent low bias over tropics

OCO-2 v7BC – Model Median $X_{CO2}$ [ppm]

-3.0  -1.8  -0.6  0.6  1.8  3.0
“Top-Down” Flux Inversion Estimates

Prior Fluxes

Ocean Flux

Land Flux

FF Inventories

Transport

In situ CO$_2$

Satellite X$_{CO2}$

Flux Inversion Model

Optimizer

Optimized Fluxes
Preliminary CO₂ Flux Inversion Results

GOSAT & OCO-2 inversions indicate larger sources in tropics and larger sinks at higher latitudes [J. Liu et al.]

CO₂ flux amplitude depends on bias correction applied to OCO-2 data [D. Baker]
If carefully coordinated, these missions can be integrated into an ad hoc constellation and their measurements can be combined to produce a continuous data record.

However, none of these missions provides the capabilities needed to quantify fossil fuel emissions and other human activities. For that, we need a constellation.
• OCO-2 was successfully launched on 2 July 2014, and began routine operations on 6 September 2014
  – Now returning about 100,000 full-column measurements of $X_{CO_2}$ each day over the sunlit hemisphere
  – These products are being validated against TCCON and other standards to assess their accuracy

• Over 18 months of data has been delivered to the Goddard Earth Sciences Data and Information Services Center (GES-DISC) for distribution to the science community
  – September 6 2014 – 4 May 2016 delivered

• This product is now being used by the carbon cycle science community to identify and quantify the CO$_2$ sources and sinks on regional scales over the globe
Coming Attractions!

• P-11 David F. Baker, et al., Using In Situ CO2 Measurements to Help Understand GOSAT and OCO-2 Column CO2 Retrievals

• Brendan Byrne, Dylan Jones, and Kim Strong, Sensitivity of CO2 Flux Inversions to the Temporal and Spatial Distribution of Observations

• P-12 Heather Q. Cronk, et al., A Multi-sensor Approach to Cloud and Aerosol Detection in Support of OCO-2 XCO2 Retrieval Validation

• P-32 Robert R. Nelson and C.W. O'Dell, Total Column Water Vapor from OCO-2

• P-9 Xinxin Ye, Imprint of Urban CO2 Emissions Detected by OCO-2 Observations of Total Column CO2
Thank You for Your Attention

Questions?