Monitoring CO$_2$ Sources and Sinks from Space with the Orbiting Carbon Observatory (OCO)

http://oco.jpl.nasa.gov

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What Processes Control Atmospheric CO₂?

Carbon dioxide (CO₂) is the main:

- Atmospheric component of the global carbon cycle – *essential to life*
- Man-made greenhouse gas

Only half of the CO₂ emitted by human activities is remaining in the atmosphere.
The Orbiting Carbon Observatory (OCO)

OCO will acquire the space-based data needed to identify CO₂ sources and sinks and quantify their variability over the seasonal cycle.

Approach:

• Collect spectra of CO₂ and O₂ absorption in reflected sunlight over the sunlit hemisphere.

• Use these data to resolve spatial and temporal variations in the column averaged CO₂ dry air mole fraction, $X_{\text{CO}_2}$.

• Validate measurements to ensure $X_{\text{CO}_2}$ accuracies of 1 - 2 ppm (0.3 - 0.5%) on regional scales at monthly intervals.
What is $X_{CO2}$?

Measured Spectra

CO$_2$

O$_2$

Column Abundance

Path Dependent

Path Independent

Mixing Ratio

Ratio

$X_{CO2}$
Precise Measurements are Needed to Characterize CO₂ Sources and Sinks

Precisions of 1–2 ppm (0.3–0.5%) on regional scales could:

- Resolve (8ppm) pole to pole $X_{CO2}$ gradients on regional scales
- Resolve the $X_{CO2}$ seasonal cycle in the Northern Hemisphere
- Reduce surface CO₂ flux errors by about a factor of 10
Making Precise CO₂ Measurements from Space

- High resolution spectra of reflected sunlight in near IR CO₂ and O₂ bands used to retrieve the column average CO₂ dry air mole fraction, $X_{CO₂}$
  - 1.61 μm CO₂ band: Column CO₂
  - 2.06 μm CO₂ band: Column CO₂, Aerosols
  - 0.76 μm O₂ A-band: Surface pressure, clouds, aerosols
- Why high spectral resolution?
  - Enhances sensitivity, minimizes biases
OCO Mission Implementation Approach

Project Management (JPL)

Single Instrument (Hamilton Sundstrand)

Dedicated Spacecraft Bus (Orbital Sciences)

Dedicated Taurus 3110 Launch Vehicle (Orbital)

Mission Operations (JPL/Orbital Sciences)

September 2008 Launch from Vandenberg AFB
OCO Will Fly in the A-Train

OCO files at the head of the A-Train, 4 minutes ahead of the Aqua platform
OCO Observing Strategy

Observing Modes

• Nadir Observations: tracks local nadir
  + Small footprint (< 3 km²) isolates cloud-free scenes
    − Low Signal/Noise over dark ocean
• Glint Observations: views “glint” spot
  + Improves Signal/Noise over oceans
    − More interference from clouds
• Target Observations
  • Tracks a stationary surface target to collect large numbers of soundings

Data acquisition schedule:

• alternate between Nadir and Glint on 16-day intervals
• Acquire ~1 Target observation each day
OCO Sampling over a 16-Day Repeat Cycle

• **OCO Sampling Rate/Coverage**
  - Glint: +75° SZA, Nadir: +85° SZA
  - Longitude resolution 1.5°
  - 12-24 samples/second collected along track over land and ocean
  - 200 to 400 samples per degree of latitude along orbit track on day side of the Earth
  - 7 and 14 million soundings over the globe once every 16 days.

• **OCO Spatial Sampling Approach**
  - Measurements are collected along narrow ground tracks
  - Subsequent orbit tracks are separated by ~24° longitude

Prevailing Winds

Chevallier et al. 2006
Combination of Glint and Nadir observations provides high sensitivity even over dark surfaces.
Crisp, NACP 2007

Horizontal Footprints

- Each OCO sounding describes the average mixing ratio along
  - an incoming optical path between the surface measurement footprint and the sun,
  - an outgoing optical path that extends from the surface footprint and the spacecraft.

- High resolution source-sink inversion calculations must account for the effective horizontal projections of the $X_{CO2}$ columns retrieved from OCO data.
A rigorous validation approach will speed acceptance of OCO data by the Science Community

- The space-based measurements must be validated against the surface CO₂ standard

Global $X_{CO₂}$ FTS Network

CO₂ Ground Network

Selected
Pending
OCO Fills a Critical Measurement Gap

![Diagram showing spatial scales and CO₂ error](image-url)