Measuring CO₂ from Space: The NASA Orbiting Carbon Observatory-2 (OCO-2)

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Global Measurements from Space are Essential for Monitoring CO₂ Sources and Sinks over the Globe
To limit the rate of atmospheric carbon dioxide buildup, we must
– Control emissions associated with human activities
– Understand & exploit natural processes that absorb carbon dioxide
We cannot manage what we cannot measure

CO₂ from
The
Jet
Propulsion
Laboratory,
for
the
OCO
for
CO₂
Global
Measurements

Space and Ground Based CO₂ Measurements are Complementary
• Ground based measurements - greater precision and sensitivity to CO₂ near the surface, where sources and sinks are located.
• Space-based measurements – improve spatial coverage & resolution.
• Source/Sink models - assimilate space and ground-based data to provide global insight into CO₂ sources and sinks

Measuring CO₂ from Space

High precision is Essential for Quantifying CO₂ Sources and Sinks from Space-Based Measurements
CO₂ sources and sinks must be inferred from small spatial variations in the (390 ±5 ppm) background CO₂ distribution
• Largest variations near surface
• Space based observations of reflected sunlight constrain column averaged CO₂ dry air mole fraction, X_CO₂

Small spatial gradients in CO₂ verified by pole-to-pole aircraft measurements (Wofsy et al. 2010)
These variations are superimposed on a background of “CO₂ weather” (Kawa et al. 2010)

Coverage: Precise Measurements are Needed over Oceans as well as Continents
• The ocean covers 70% of the Earth and absorbs/emits >10 times more CO₂ than all human activities combined
• While the oceans have few intense sources, coverage of the ocean is essential to minimize errors from CO₂ transport in and out of the observed domain
• Solar remote sensing observations over the ocean are intrinsically challenging because the ocean typically reflects only 0.5% to 1% of the incident sunlight toward the zenith.
• Clouds and optically thick aerosols contribute a large fraction of the reflected radiation, introducing optical path length uncertainties.

Spatial Resolution and Sampling
A Small Footprint:
• Increases sensitivity to CO₂ point sources
• The minimum measurable CO₂ flux is inversely proportional to footprint size
• Increases probability of recording cloud free soundings in partially cloudy regions

Low Spatial Coverage
Medium Spatial Coverage
High Spatial Coverage

Record spectra of CO₂ and O₂ absorption in reflected sunlight
Retrieve the column averaged CO₂ dry air mole fraction, X_CO₂ over the sunlit hemisphere
Validate X_CO₂ retrievals to ensure accuracies of 1 - 2 ppm (0.3 - 0.5%) on regional scales.

High Sampling Rate:
• Soundings can be averaged along the track to reduce single sounding random errors

The NASA Orbiting Carbon Observatory (OCO)
NASA’s Orbiting Carbon Observatory (OCO) was designed to provide estimates of atmospheric carbon dioxide (CO₂) with the sensitivity, accuracy and sampling density needed to quantify regional scale carbon sources and sinks over the globe and characterize their behavior over the annual cycle.

The Loss of OCO and the Birth of OCO-2
• February 2009: The OCO spacecraft was lost when its Taurus XL launch vehicle’s fairing failed to deploy
• December 2009: The U.S. Congress added funding to the NASA FY2010 budget to restart the OCO Mission
• The OCO-2 mission is currently on track for a launch as early as 2013

The OCO-2 Instrument – same as OCO
• 3 co-bore-sighted, high resolution, imaging grating spectrometers
• O₂: 0.765 μm-A band
• CO₂: 1.61 μm band
• CO₂: 2.06 μm band
• Resolving Power: > 20,000
• Optically fast: f/1.8
• Narrow Swaths: < 0.8°
• 8 cross-track footprints sampled @ 3 Hz
• Footprint: < 1.29 x 2.25 km at nadir (< 3 km²)
• Mass: 144 kg, Power: 105W

OCO-2 Spacecraft Bus – same as OCO
The spacecraft bus is used to:
• Support and point the instrument
• No pointing mechanism needed
• Facilitates Nadir/Glint/Target Obs
• Formation fly in the A-train
• Facilitates synergy with other missions
• Record and downlink the data

Experience gained working with the Japanese Greenhouse gases Observing Satellite, GOSAT
• The ACOS/OCO-2 team is retrieving global maps of X_CO₂ from GOSAT
• Close collaboration between calibration, validation, and retrieval algorithm teams has led to rapid progress in data analysis
• Vicarious Calibration campaigns in Railroad Valley, NV provided data need to identify and correct instrument calibration changes
• Validation against Total Column Carbon Observing Network (TCCON) measurements and other data sets being used to detect and correct large scale biases

Conclusions
• Space-based remote sensing observations hold substantial promise for future long-term monitoring of CO₂ and other greenhouse gases, providing:
  – Spatial coverage (especially over oceans and tropics)
  – Sampling density (needed to resolve CO₂ weather)
• The principal challenge is the need for high precision
• To reach their full potential, space based CO₂ measurements must be validated against surface measurements to ensure their accuracy.
• The TCCON network is providing the transfer standard
• A coordinated global network of surface and space-based CO₂ monitoring systems as well as sophisticated models that can assimilate these data are needed to provide insight into the processes controlling atmospheric CO₂

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