The Orbiting Carbon Observatory (OCO-2) L2 Retrieval Algorithm: First Tests With Greenhouse gases Observing SATellite (GOSAT) Data

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and the OCO-2 L2 Algorithm Team

Overview

• Driving Science Questions

• Overview of Measurement Approach

• Driving Requirements
  – Flight System
  – Algorithms
  – Validation

• Retrievals of GOSAT Data
The Mystery of the Missing CO₂

- Humans have added >200 Gt C to the atmosphere since 1958
- Less than half of this CO₂ is staying in the atmosphere
- Where are the sinks that are absorbing over half of the CO₂?
  – Land or ocean?
  – Eurasia/North America?
- Why does the CO₂ buildup vary from year to year with nearly uniform emission rates?
- How will these CO₂ sinks respond to climate change?
Measuring CO₂ from Space

- **Collect** spectra of CO₂ & O₂ absorption in reflected sunlight over the globe
- **Retrieve** variations in the *column averaged CO₂ dry air mole fraction*, \( X_{CO₂} \), over sunlit hemisphere
- **Validate** measurements to ensure \( X_{CO₂} \) precision of 1 - 2 ppm (0.3 - 0.5%)

V&V in Pre-launch Tests

Documented in L2 ATBD. Verified with GOSAT data.
OCO-2 Requires Agile Spacecraft

Nadir Observations:
+ Small footprint (< 3 km²)
  – Low Signal/Noise over dark surfaces (ocean, ice)

Glint Observations:
+ Improves Signal/Noise over oceans
  – More cloud interference

Target Observations:
• Validation over ground based FTS sites, field campaigns, other targets

Local Nadir
Glint Spot
Ground Track

Park Falls, WI
447-m WLEF Tower

O₂ A Band
Weak CO₂
Strong CO₂
Heliostat/TCCON Observations Verify End-to-End Instrument Performance

Observations of the sun with the flight instrument taken during TVAC tests provide an end-to-end verification of the instrument performance.

1.6 µm CO₂

TV Chamber with Flight Instrument

FTS

Heliostat

TCCON FTS

OCO-2

11:52 am on 25-Jan-2012
Retrieving $X_{\text{CO2}}$ from OCO-2 Spectra

Interpolated Meteorology

Level 1B Data

Pre-Processing Filter

$X_{\text{CO2}}$ Retrieval Algorithm

Post-Processing Filter

OCO-2 Retrieval Algorithm
- Optimal Estimation
- “Full Physics”
- 3-band (ABO2, WCO2, SCO2)

Forward Radiative Transfer Model

Instrument Model

Inverse Model

Final State and $X_{\text{CO2}}$
Immediately after the loss of OCO, the GOSAT Project manager invited the OCO Team to participate in GOSAT data analysis.

The ACOS team is collaborating closely with the GOSAT teams at JAXA and NIES to:

- Conduct vicarious calibration campaigns in Railroad Valley, Nevada, U.S.A.
- Retrieve $X_{CO2}$ from GOSAT spectra
  - Algorithm development & testing
  - Data production and delivery
- Validate GOSAT retrievals by comparing GOSAT retrievals with TCCON measurements and other data.
ACOS GOSAT B2.10 $X_{\text{CO}_2}$ Retrievals
Validation of GOSAT Products against TCCON Reduces Regional Scale Bias

GOSAT $X_{\text{CO2}}$ retrievals are compared with those from the ground based Total Carbon Column Observing Network (TCCON) to verify their accuracy.

Near-simultaneous observations are acquired over TCCON station.
Surface Pressure Bias

(a) Histogram of surface pressure bias (ΔP_{surf}) in hPa.

(b) Color-coded map of surface pressure bias (ΔP_{surf}) across the globe.
TCCON Comparisons Show Improvements in Bias and Random Error over Time

B2.7

B2.8

B2.9

B2.10
Retrieval Processing Time

**Processing Time per Sounding**
*July 24-26, 2009 GOSAT repeat cycle*

- **B2.8**
- **B2.7**
- **B2.9**
- **B2.10**

**Goal:**
- O2 A-band spectral sampling
- Code efficiencies
- Goal 5 minutes/Converged Sounding

Date Processed:
- Jul-10
- Oct-10
- Jan-11
- Apr-11
- Aug-11
- Nov-11
- Feb-12
- Jun-12
Retrieval Processing Time

Processing Time per Sounding
July 24-26 GOSAT repeat cycle

- B2.5a
- B2.5.2
- B2.6
- B2.6.1
- B2.6.2
- B2.7
- B2.8
- B2.9

- LIDORT radiative transfer
- IFORT compiler
- LIDORT efficiency improvement
- Only Intel processors
- Cloud screening filter used
- Improved convergence criteria
- Glint mode retrievals

Date Processed:
- Sep-09
- Dec-09
- Mar-10
- Jul-10
- Oct-10
- Jan-11
- Apr-11
- Aug-11
- Nov-11

Minutes/Converged Sounding:
- 0
- 50
- 100
- 150
- 200
- 250

Slide 14 IRS 06 Aug 2012
Conclusions

• GOSAT data provide invaluable resource to test ACOS/OCO-2 L2 algorithm

• Spectroscopy and radiative transfer model improvements have helped remove most of the bias in $X_{CO2}$ retrievals

• Detection and quantification of regional scale biases in ACOS $X_{CO2}$ product by comparing ACOS/GOSAT and TCCON retrievals

• Opportunities to refine vicarious calibration and validation approaches for OCO-2 mission

• Ready for large inflow of data from OCO-2 due to L2 algorithm speed improvements
Outlook

- Instrument characterization and thermo-vacuum testing completed
- Instrument meets specifications
- Observatory undergoing final testing
- Launch vehicle selected
- Launch date set for July 2014