Early Results from the NASA Orbiting Carbon Observatory-2 (OCO-2)

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The Next Step – OCO-2

Lift-off at 2:56 am PDT, 02 July 2014

Credit: Bill Ingalls, NASA

Credit: Jeff Sullivan

Credit: NASA

Separation!

Joining the A-Train
3 August 2014

Credit: Jeff Sullivan
Each 1/3 of a second frame includes 8 spatial footprints with 1,016 wavelengths sampled in the $O_2$ A-band and Weak and Strong $CO_2$ bands yielding almost 1 million soundings each day.
Nadir Observations
Preliminary Nadir Land $X_{CO2}$ Estimates

Nadir observations provide good coverage of land, but no coverage of the ocean
Glint Observations
Glint observations provide better coverage of the ocean, but less coverage of high latitude continents.
Changes in the Glint/Nadir Scheduling

• Current sampling approach
  – Alternates between glint and nadir on successive 16-day ground repeat cycles
  – Precludes observations of oceans and high latitude continents for 16-day periods

• Revised glint/nadir strategy:
  – Step 1: Alternate between glint and nadir on successive orbits that include both land & ocean
  – Step 2: For orbits that are predominately over ocean, always stay in glint

• Changes implemented in early summer 2015
Target Observations
Validation: Targeting Total Carbon Column Observing Network (TCCON) Stations

OCO-2 Target Measurements of Carbon Dioxide Over Pasadena, Calif.

380 385 390 395 400 405 410 PPM
The Total Carbon Column Observing Network (TCCON) provides the primary means of validating GOSAT and OCO-2 products against WMO standards.
Initial OCO-2 Data Product Deliveries

**L1B: Spectra**
- Dimensions
- FootprintGeometry
- FrameConfiguration
- FrameGeometry
- FrameHeader
- FrameTemperatures
- InstrumentHeader
- Metadata
- Shapes
- SliceMeasurements
- SoundingGeometry
- SoundingMeasurements

**L2: XCO2, SIF, ...**
- AerosolResults
- AlbedoResults
- Dimensions
- DispersionResults
- L1bScSoundingReference
- Metadata
- PreprocessingResults
- RetrievalGeometry
- RetrievalHeader
- RetrievalResults
- Shapes
- SpectralParameters

**Mapped Products**

**L3: X_{CO2} Maps**

**L4: Fluxes**

*December 30, 2014*

*March 30, 2015*

*As Available*

http://disc.sci.gsfc.nasa.gov/datacollection/OCO2_L1B_Science_V5.html
Known Issues with the Initial Data Product

- An analysis of the L2 production products revealed large (> 1%) residuals in spectral fits in the CO$_2$ channels and X$_{CO2}$ biases
  - The large residuals were traced to errors in the calibration tables used to produce the version 6 and 6R L1B production products
  - Large numbers of new bad pixels formed between the 2012 pre-launch calibration activities and launch
  - Errors in the way that the bad pixel gain corrections were implemented in the production product introduced the X$_{CO2}$ errors

- All data (back to 6 September 2014) are recoverable.

- Final testing of a revised product (v7/v7R) is currently under way
  - Deliveries of this new product to the GES-DISC begin in late June
  - Supercomputers will be used to accelerate the reprocessing effort
Anomalous Spectral Residuals and $\chi^2$ Values

Large spectral residuals in v6 L2 fits. Reduced spectral residuals in v7 L2 fits

B6: with EOF’s

Footprint 1

Footprint 8

B7 Tests: with EOF’s

Footprint 1

Footprint 8

Brendan Fisher

Crisp: OCO-2 Mission
Comparisons of V6 and V7 L2 Products

A single orbit of OCO-2 data, comparing the **Version 6** and **Version 7** L2 products.
Preliminary Results from OCO-2 Target Observations

- Preliminary OCO-2 target overflights are yielding new insights into biases and random errors.

**Target observations over Lauder, New Zealand show negligible airmass dependence.**

**Target Observations over the TCCON station at Armstrong/Dryden show more air mass dependence.**
Comparison of TCCON and OCO-2 $X_{CO2}$ comparisons with Total Carbon Column Observing Network (TCCON) stations are being used to identify and correct biases in target observations. (Wunch et al.)

Initial differences between OCO-2 and TCCON $X_{CO2}$ estimates were smaller than $\sim$2 ppm (0.5%).
A Sneak Peak at Version 7

One week of V7 Nadir data (370,000 points, May 13-20)
A New Product: Solar-Induced Chlorophyll Fluorescence (SIF)

April 2015

SIF / (W m^{-2} micron^{-1} sr^{-1})
V7 Processing Approach

- **Objective:** Finish and deliver the new product as soon as possible
- **Method:** Use a simple data selection approach (i.e., cloud screening) rather than a more sophisticated sounding selection.
  - Attempt to process 10% to 20% of all soundings
  - Postpone work on bias corrections and warn levels but incorporate in “lite files” for end users
  - Add to OCO-2 cluster to handle a larger forward stream
  - Reprocessing on supercomputers can accommodate the larger percentage of soundings
- **Nominal Schedule**
  - **L1B:** Start delivering data to GES-DISC before 05 June
  - **L2:** Start deliveries to GES-DISC on or before 19 June
Exploiting the Benefits of Multiple Missions

• Space-based remote sensing observations hold substantial promise for future monitoring of CO$_2$ and other greenhouse gases
  – complement existing ground-based data with increased spatial coverage and sampling density

• Within the next decade, a series of missions with a range of CO$_2$ & CH$_4$ measurement capabilities will be deployed in low Earth orbit
  – GOSAT, OCO-2, TanSat, GOSAT-2, OCO-3, MERLIN, CarbonSat…

• Much greater benefits could be realized if these missions could be coordinated, and their products can be cross-calibrated and cross validated so that they can be combined to yield a self-consistent, continuous climate data record

• NASA, JAXA, and NIES members of the GOSAT and OCO-2 teams have been pioneers in the implementation of this approach.
Next Steps: GOSAT/OCO-2 Cross Calibration and Validation

Vicarious Calibration
- GOSAT CAI
- NASA DC-8
- AMES AJAX
- LSPEC
- AERONET
- AERONET
- AERONET

Retrieval Algorithm Intercomparisons
- Forward Radiative Transfer Model
  - Spectra + Jacobians
- Instrument Model
  - Spectral + Polarization
- Inverse Model
  - Compare obs. & simulated spectra
  - Update State Vector

Cross Validation
- GOSAT and OCO-2
- Tower
- Aircraft
- Flask
- FTS

Crisp: OCO-2 Mission
Summary

• OCO-2 was successfully launched on 2 July 2014, and began routine operations in early September 2014
  – Now returning about 1 million measurements each day over the sunlit hemisphere
  – Between 10% (nadir) and 25% (glint) of these measurements are sufficiently cloud free to yield accurate estimates of XCO2

• An initial L2 data product was released on 30 March
  – An early analysis revealed errors that have been traced to calibration issues that have been identified and corrected

• An updated product that addresses these issues is being tested
  • All data will be reprocessed for delivery this summer