Contributions to GOSAT Data Analysis by the NASA Atmospheric Carbon Observations from Space (ACOS) Team

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The OCO and GOSAT teams formed a close partnership during the implementation phases of these 2 missions to:

- Cross calibrate the OCO instrument and TANSO-FTS
- Cross validate OCO and GOSAT $X_{CO2}$ retrievals against a common standard

The primary objectives of this partnership were to:

- Accelerate “learning curve” for this new data source
- Facilitate combining results from GOSAT and OCO to improve spatial and temporal coverage
The Launch of GOSAT and Loss of OCO

GOSAT launched successfully on 23 January 2009

OCO was lost a month later when its launch system failed
Working with the GOSAT Team

• Immediately after the loss of the OCO Mission, the GOSAT Project manager invited the OCO Team to participate in the GOSAT data analysis

• NASA reformulated the OCO team as the “Atmospheric Carbon Observations from Space” (ACOS) team

• This collaboration benefits the GOSAT team by:
  – Combining the ground based calibration and validation resources of both teams to maximize the accuracy of the GOSAT data
  – Combining the scientific expertise from both teams to accelerate our understanding of this new, space-based data source

• This collaboration benefits the NASA OCO by
  – Providing direct experience with the analysis of space based CO₂ measurements
  – Accelerating the delivery of precise CO₂ measurements from future NASA carbon dioxide monitoring missions
Elements of the ACOS/GOSAT Collaboration

- The ACOS team is collaborating closely with the GOSAT teams at JAXA and NIES to:
  - Conduct vicarious calibration campaigns in Railroad Valley, Nevada and analyze results of those campaigns
  - Retrieve $X_{CO_2}$ from GOSAT data
    - Model development, implementation, and testing
    - Data production and delivery
  - Validate GOSAT retrievals through comparisons of
    - GOSAT retrievals with TCCON measurements
    - Other validation standards (surface pressure, aircraft and ground-based CO$_2$ measurements)
The NASA and GOSAT teams are collaborating to collect ground based and aircraft measurements over Railroad Valley, Nevada during GOSAT overflights to monitor the calibration of the GOSAT instruments.
Retrieving $X_{CO2}$ from GOSAT Data

The OCO Retrieval Algorithm was modified to retrieve $X_{CO2}$ from GOSAT measurements:
- “Full-physics” forward model
- Inverse model based on optimal estimation

**Calibrated GOSAT Spectra (L1B Data)**

- **Forward Model Spectra + Jacobians**
- **State Vector First Guess**
  - not converged
  - converged

**Apriori + Covariance**

- **Inverse Model (Optimal Estimation)**

**Update State Vector**

- **State Vector**
  - CO$_2$ profile (full)
  - H$_2$O profile (scale factor)
  - Temperature profile (offset)
  - Aerosol Profiles
  - Surface Pressure
  - Albedo (Mean, Slope)
  - Wavelength Shift (+ stretch)

- **Calculate XCO$_2$**
- **Diagnostics**
Preliminary Retrievals

- The ACOS/SDOS team is now routinely generating global maps of $X_{CO2}$ and other L2 data products
  - Now processing all GOSAT repeat cycles
    - Only land values are available because L2 algorithm still cannot process glint data from GOSAT
    - Products include XCO2 and a series of other retrieved components of the surface/atmosphere state vector ($P_s$, aerosol optical depth (AOD), surface albedo, etc.)

- An experimental ACOS “Standard Product” is currently being released from the GSFC DAAC
  http://mirador.gsfc.nasa.gov/
Validation of GOSAT Products

GOSAT $X_{CO2}$ retrievals are being compared with those from the ground based Total Carbon Column Observing Network to verify their accuracy.
Comparisons of GOSAT and TCCON

- ACOS GOSAT retrievals show
  - A consistent global bias of ~2% (7 ppm) in $X_{CO2}$ when compared with TCCON and aircraft measurements.
  - A systematic air mass bias
  - $X_{CO2}$ variations that are a factor of 2 to 3 larger than that measured by TCCON.

When the global and airmass biases are removed, the ACOS/GOSAT $X_{CO2}$ retrievals do a good job of simulating the seasonal cycle over North America

Wunch et al.
Biases in the $X_{\text{CO}_2}$ Maps

- A $\sim 10 \, \text{hPa}$ (1%) high surface pressure bias contributes $\sim 2/3$ or the bias
- This bias may be associated with
  - Radiometric and spectroscopic calibration errors in the ACOS L1B data
  - Line mixing, line shape or other issues with the $O_2$ A-band absorption cross sections

Typical $O_2$ A-band retrieval residuals.
Unscreened $X_{\text{CO}_2}$ retrievals from 1-8 August also show anomalously high values over the Sahara Desert (due to dust contamination), but enhanced CO$_2$ near Moscow.
Errors can be further reduced by post-screening retrievals, based on a series of criteria, including:

- Measurement SNR
- Convergence
- Goodness of spectral fit
- Surface pressure error
- Evidence for clouds or optically thick aerosols
- A posteriori retrieval error
- Evidence of known biases

The cloud screen is responsible for the largest data reductions.
- Improved cloud screening algorithms are a major focus of our development effort
Screening removes anomalous dust contaminated values over the Sahara, but also removes most data north of 50 degrees latitude.
Conclusions

• The ACOS/GOSAT collaboration is beginning to return benefits to both teams
  – The vicarious calibration experiments have helped to identify and correct for changes in the pre-launch GOSAT radiometric calibration parameters.
  – Comparisons with TCCON measurements have revealed a global, -2% bias in the preliminary ACOS $X_{CO2}$ retrievals
  – Comparisons between surface pressure retrievals and the ECMWF prior indicate that about half of this bias can be attributed to a +10 hPa bias in the retrieved surface pressure
• GOSAT data are also being used to assess the impact of clouds, optically thick aerosols, and other environmental conditions on the accuracy, coverage, and total yield of $X_{CO2}$ soundings
• Lessons learned from this experience are expected to substantially accelerate the delivery of high quality products from the OCO-2 mission, which is currently scheduled for launch in February 2013