OCO-2 and GOSAT: A Tale of Two Instruments

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Summary of Differences in Approach to Sampling the Earth

<table>
<thead>
<tr>
<th>Parameter</th>
<th>OCO-2</th>
<th>GOSAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial</td>
<td>o ~3 km²</td>
<td>o ~75 km²</td>
</tr>
<tr>
<td></td>
<td>o ~1,000,000 sounding/day</td>
<td>o ~10,000 sounding/day</td>
</tr>
<tr>
<td></td>
<td>o 16-day repeat cycle</td>
<td>o 3-day repeat cycle</td>
</tr>
<tr>
<td></td>
<td>o Glint mode at all latitudes</td>
<td>o Glint mode only in tropics</td>
</tr>
<tr>
<td></td>
<td>o Target mode with large variation in path lengths</td>
<td>o Target mode only at closest approach</td>
</tr>
<tr>
<td>Spectral</td>
<td>o 24,000 ILS’s</td>
<td>o 6 ILS’s</td>
</tr>
<tr>
<td></td>
<td>o 1,016 samples per band</td>
<td>o ~1,800 - 3,500 samples per band</td>
</tr>
<tr>
<td></td>
<td>o Resolution ~21,000:1</td>
<td>o Resolution varies by band</td>
</tr>
<tr>
<td>Radiometric</td>
<td>o 24,000 Gain Curves</td>
<td>o 6 Gain Curves</td>
</tr>
<tr>
<td></td>
<td>o 487,885 pixels</td>
<td>o 6 pixels</td>
</tr>
<tr>
<td></td>
<td>o Noise independent for each sample</td>
<td>o White noise</td>
</tr>
<tr>
<td>Polarization</td>
<td>o 1 linear polarization</td>
<td>o 2 linear polarizations</td>
</tr>
</tbody>
</table>
Footprint Sampling

- OCO-2 will take thousands of sample over a given region every couple of days
- GOSAT will take a few dozen sample over the same region most days
Other Sampling Notes

• Glint Mode
  – GOSAT can only track the glint in the tropics
  – OCO-2 will track the glint from pole to pole (even over land) 16 days out of every 32 days
    • OCO-2 will observe much, much longer path lengths at high latitudes
    • Especially at high latitudes, the Doppler shift is non-negligible

• Target Mode
  – GOSAT takes up to 6 spectra at a given location
    • All are at near directly overhead
  – OCO-2 takes > 10,000 spectra in the neighborhood of a given location
    • Path lengths vary from a couple of atmospheres to several atmospheres
    • Once again, the Doppler shift is non-negligible
OCO-2 Spatial Sampling is Not Independent

Typical overlap is ~30%, but the exact degree of overlap varies with latitude due to spacecraft yaw steering.

1/3 second of spacecraft motion

Normalized Spatial Response

Frame N

Frame N+1

arcseconds

0.0

0.2

0.4

0.6

0.8

1.0

-1000

-500

0

500

1000
GOSAT Has Wider Spectral Ranges
Linear Instrument Line Shapes
GOSAT = Black / OCO-2 = Colors

GOSAT has ~2x higher resolution in the A-band / comparable in the CO₂ bands
Logarithmic Instrument Line Shapes
GOSAT = Black & Grey / OCO-2 = Colors

OCO-2’s ILS falls off much faster than GOSAT’s
Less light will be detected far from the peak wavelengths
Calibration And It's Role In Data Processing

- Calibration Team provides instrument related parameters used to:
  - Convert spacecraft pointing/time data into geolocation information
  - Convert raw detector data into calibrated radiances including noise estimates
  - Convert FPA columns into wavelengths (non-Doppler corrected)
  - Model the Instrument Line Shape (ILS)
  - Model the polarization performance

* ARP = Ancillary Radiometric Product / AGP = Ancillary Geometric Product
Each OCO-2’s ILS is based on many parameters, several of which vary with wavelength or field angle:

- Simulated line shapes match the measured values well, but not exactly as the model does not capture detailed optical aberrations, filter performance, etc.
- The ILSs are therefore expressed as a series of look-up tables.

Each of the 3 bands, 8 footprints and 1,016 columns has its own look up table with 200 wavelength and 200 responses (9,753,600 values).
OCO-2 Radiometric Gains

- OCO-2 gain coefficients assume a cubic response
  - Each (band x footprint x column) has three independent terms
  - Total of 73,152 values

- For single pixel data, the number of coefficients rises to \(~1,700,000\)!
Validating Radiometric Non-linearity

By taking the ratio of a fully illuminated heliostat data set and one with ~50% of the light blocked, we can validate that the non-linearity of the instrument is well captured by the gain coefficients. If it is, then the ratio of the two spectra should be a flat line and all three bands should agree on how much light was blocked.
Validating the Dispersion and Instrument Line Shapes

FTS spectrum

OCO-2 ILS

Simulated OCO-2 spectrum

Simulated OCO-2 spectrum

Measured OCO-2 spectrum

Spectral Residuals

OCO-2 Science Team Meeting
27-29 March 2013
Validation Shows Good Performance at a Huge Range of Atmospheric Pathlengths

Test: 1613. RMS relative spectral residuals - all scans, footprint = 3,
start time = 2012-04-20T14:09:16.333Z

A-Band

Strong CO₂

Weak CO₂
Putting all the Calibration Together…

The residuals from OCO-2 spectra are quite similar to the residuals from GOSAT data.

To do this well, the instrument line shapes, the spectral dispersion and the radiometric gains (including non-linearity) have to be very good.

These charts use 100,000’s of parameters to calibrate the raw data and they all have to be quite good to get this performance.
Summary

• OCO-2 is **NOT** GOSAT-2
  – The GOSAT FTS has different performance characteristics than the OCO-2 imaging spectrometer
  – Get ready for far more data but with significantly smaller wavelength ranges

• OCO-2 Preflight Calibration is in good shape
  – Level 2 retrievals residuals validate that the 24,000 “instruments” that make of OCO-2 are well described by the ARP