Implementing a GHG Constellation - Lessons learned from the OCO-2 / GOSAT collaboration

OCO-2 Status

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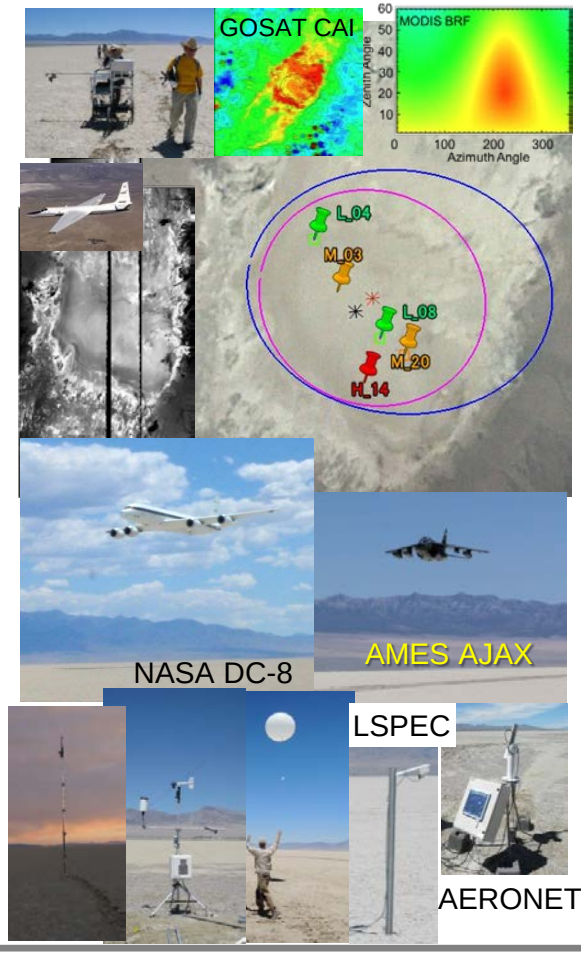
Processing the Data from OCO-2: The ACOS/GOSAT Collaboration

Vicarious Calibration

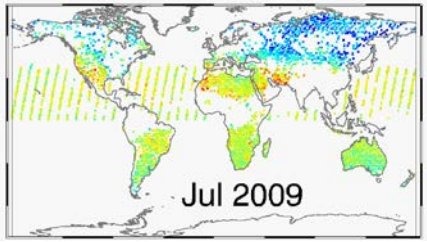


Retrieval Algorithm

Forward Radiative Transfer Model
Spectra + Jacobians

Instrument Model
Spectral+Polarization

Inverse Model
- Compare obs. & simulated spectra
- Update State Vector

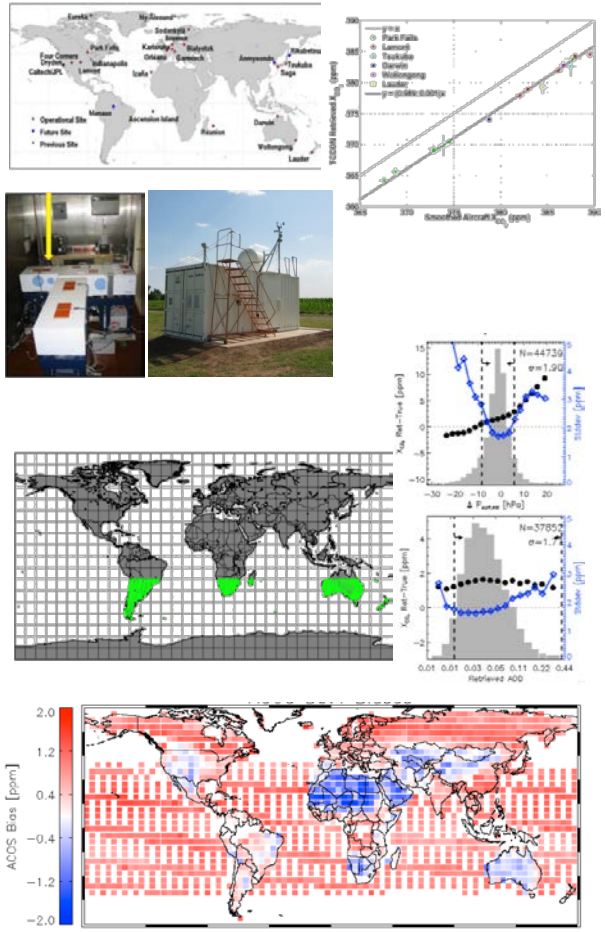


not converged

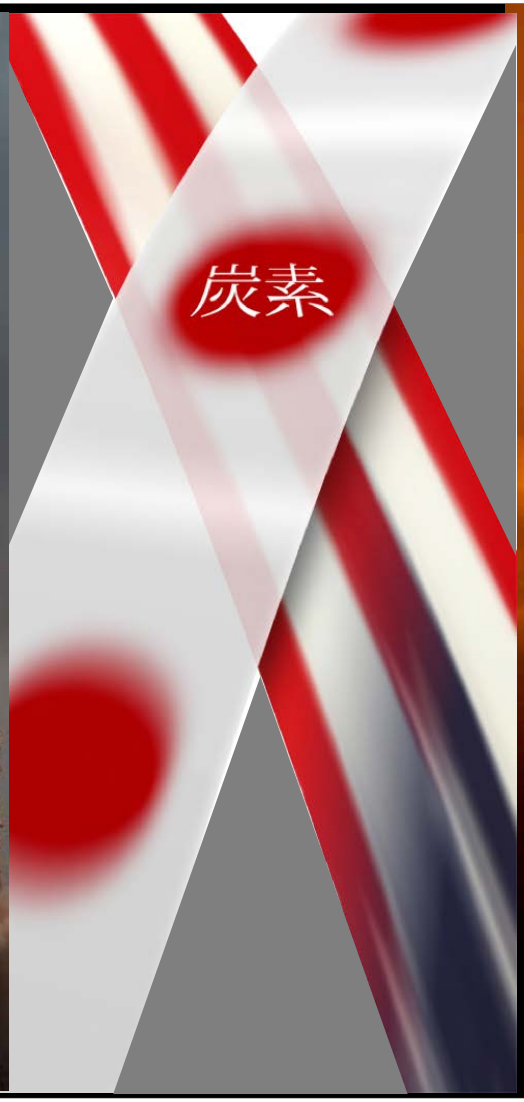
?

converged

Validation & Screening



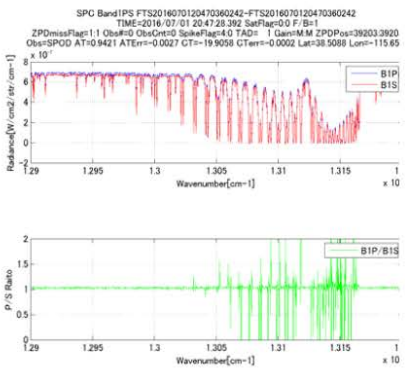
Calibration

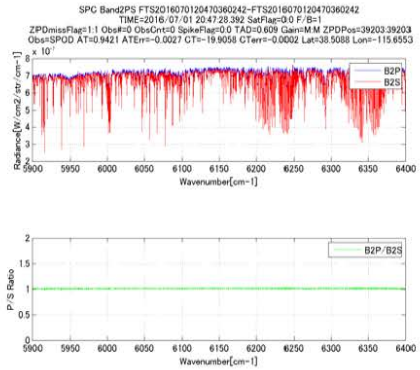


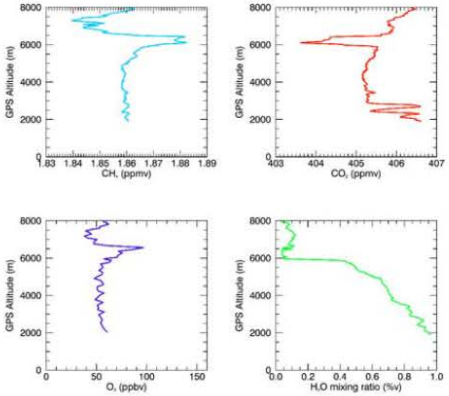
2016 Railroad Valley Campaign

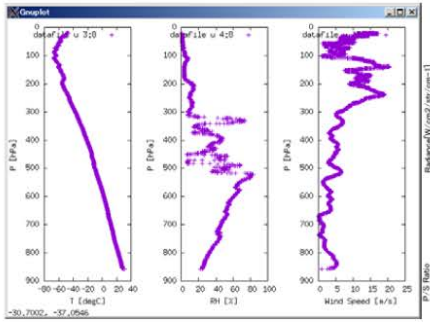
[Kuze et al.]

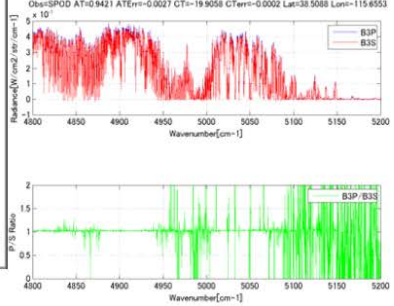
July 1, 2916 (path 36) Clear no cloud only above GOSAT foot print, GOSAT-OCO-2-alpha jet

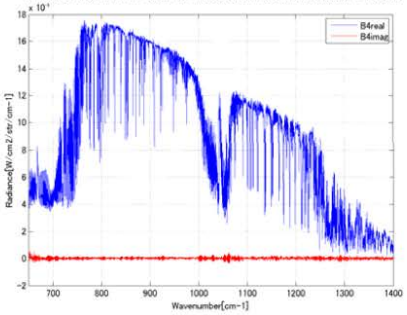










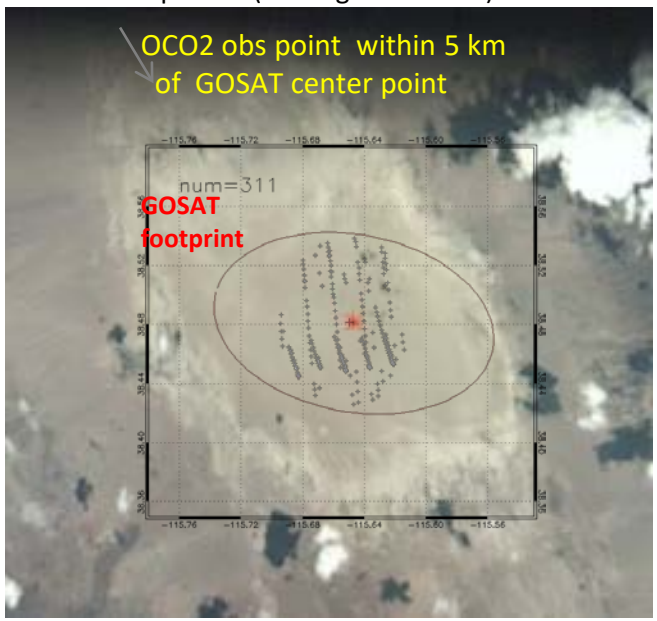


Clouds have been a problem this year, but cloud-free data were collected on 1 July 2016, which included OCO-2 (orbit 139) and GOSAT (orbit 36) overpasses.

OCO2- GOSAT Spectra Comparison

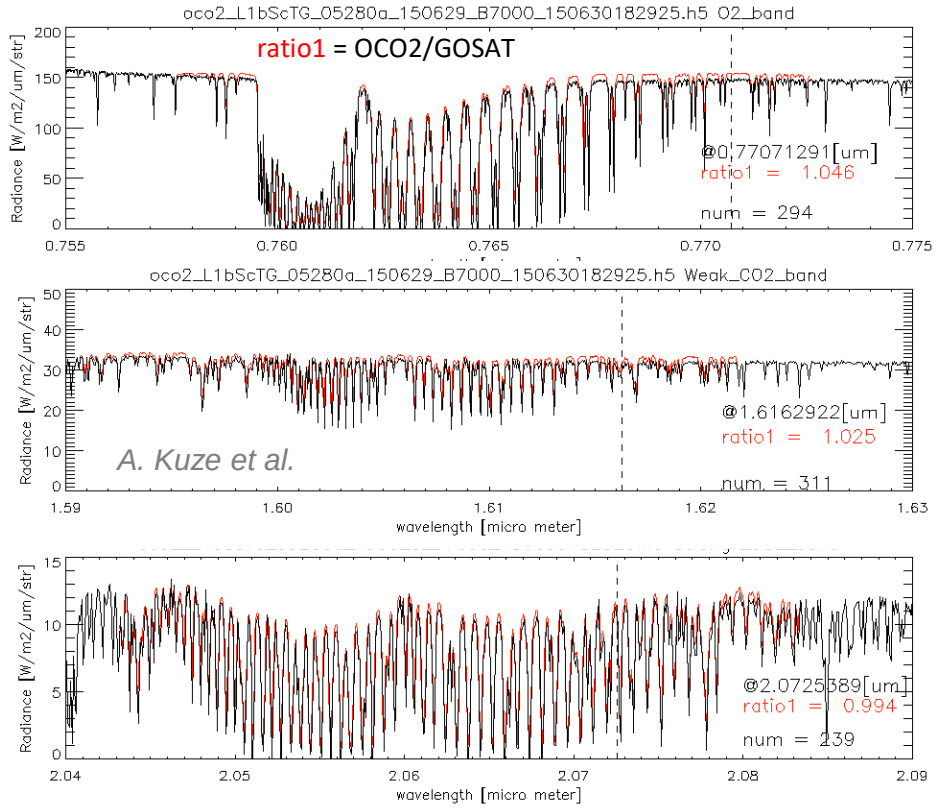
Comparisons between OCO-2 and GOSAT also indicate a ~5% high radiometric bias.

Jun29,2015
OCO2: path139 (looking from West)
GOSAT: path37 (looking from West)



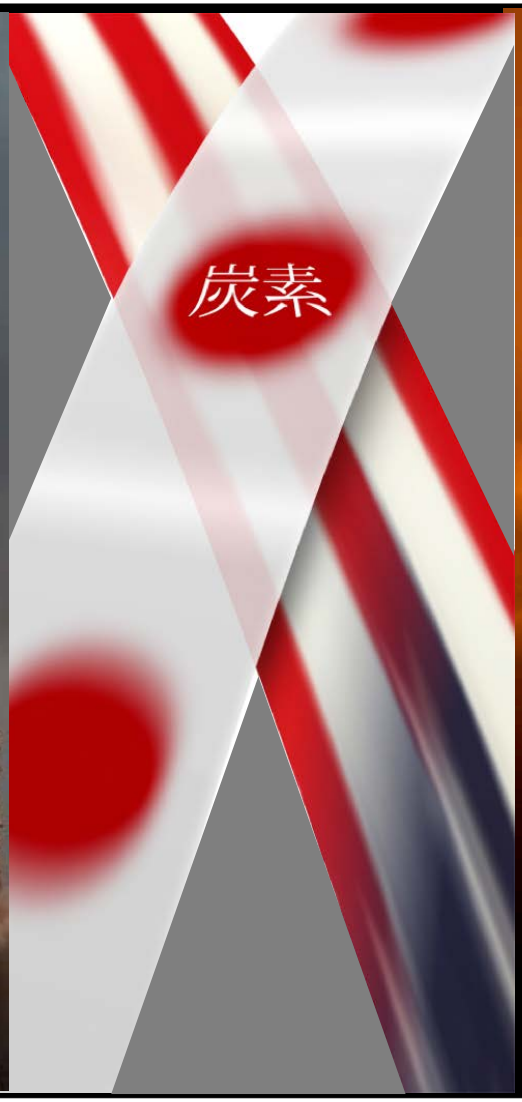
OCO-2 spectra collected within the GOSAT footprint over Railroad Valley, NV on 29 June 2015 are compared.

oco2_L1bScTG_05280a_150629_B7000_150630182925.h5
GOSATTFTS2015062921160370242_1BSPOD161161.01
GOSAT Rad
OCO2 average Rad within 5km of GOSAT cnt point X 2

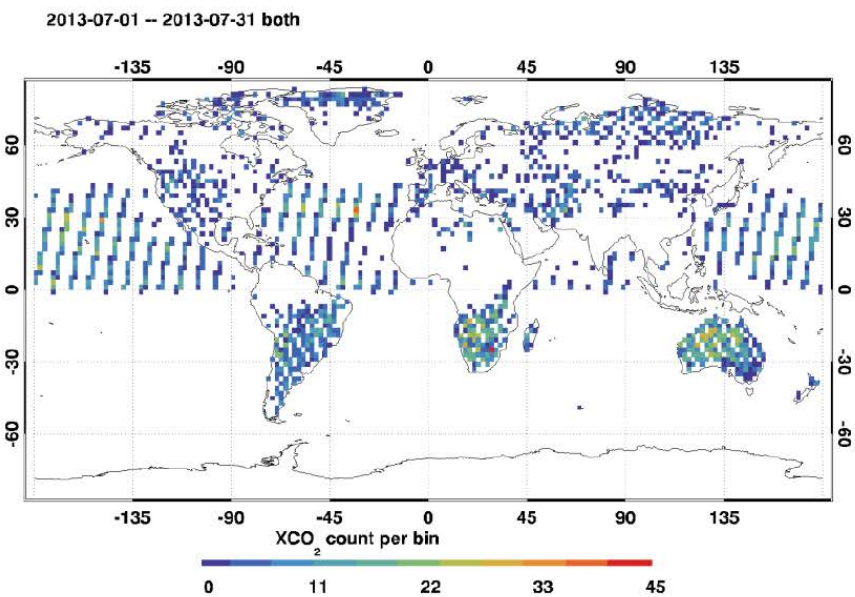


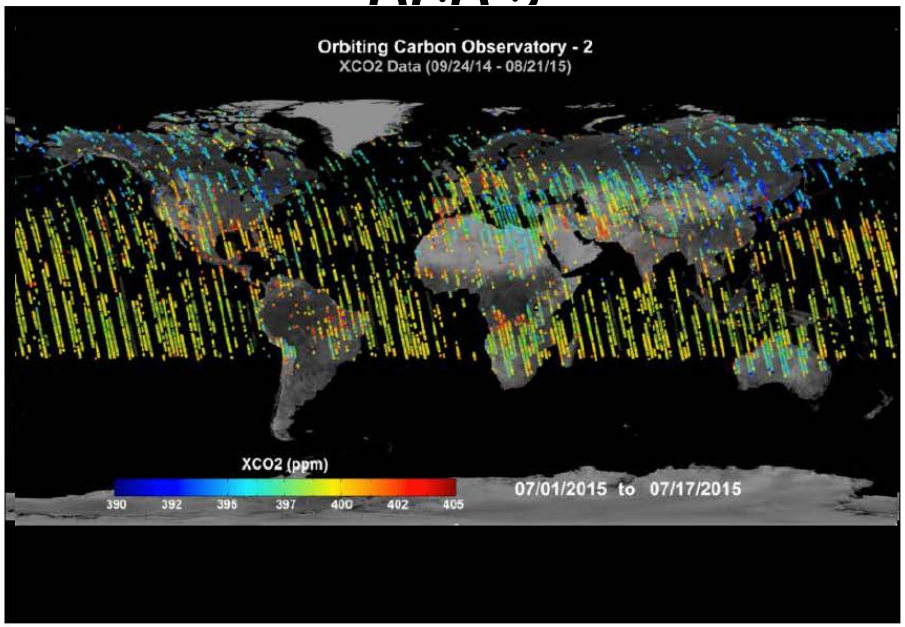
The continuum level of the OCO-2 L1B spectra is typically ~5% above that seen by GOSAT

Retrieving XCO2



Retrieving XCO2 from GOSAT and OCO-2 Data





GOSAT TANSO-FTS has been returning data since April 2009. The ACOS/GOSAT team has been using these data to retrieve XCO2.

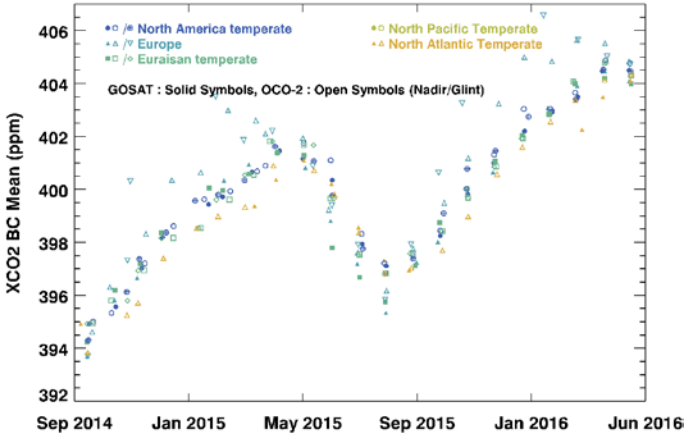
OCO-2 has been returning data since September 2014. The ACOS/GOSAT algorithm has been modified to retrieve XCO2 from these data.

ACOS B7.3 vs OCO-2 V7r

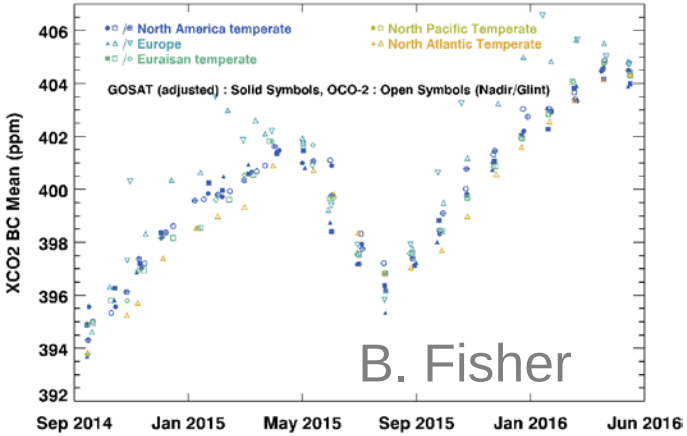
- Comparisons use monthly averages over 18 TRANSCOM regions for overlap period (22 months)
- Compare XCO2 vs time for GOSAT land gain H and ocean
- 3 sets of plots for each:
  - Northern Hemisphere regions
  - Tropical regions
  - Southern Hemisphere regions

- Latitude sampling bias adjustment needed to correct for sampling differences between GOSAT and OCO-2:
  - Use CarbonTracker sampled at OCO2 locations to create zonal mean XCO2 field (4 degrees of latitude bins)
  - Calculate mean latitude of OCO2 and GOSAT for each month/region
  - Adjust GOSAT XCO2 by difference between CarbonTracker zonal mean values at OCO2 and GOSAT latitudes

ACOS GOSAT vs V7 OCO-2 XCO2



29 Jul 2016



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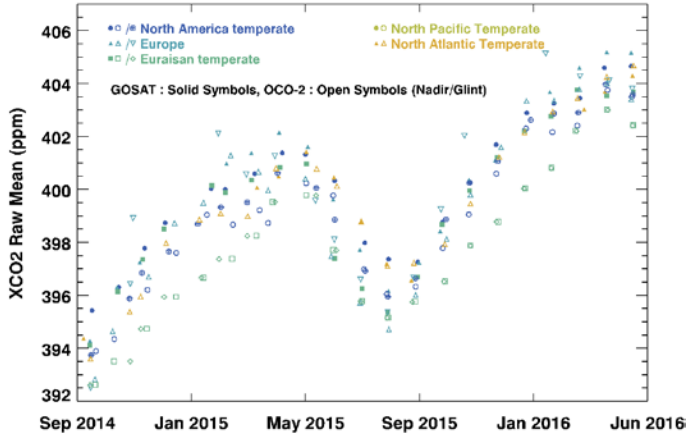

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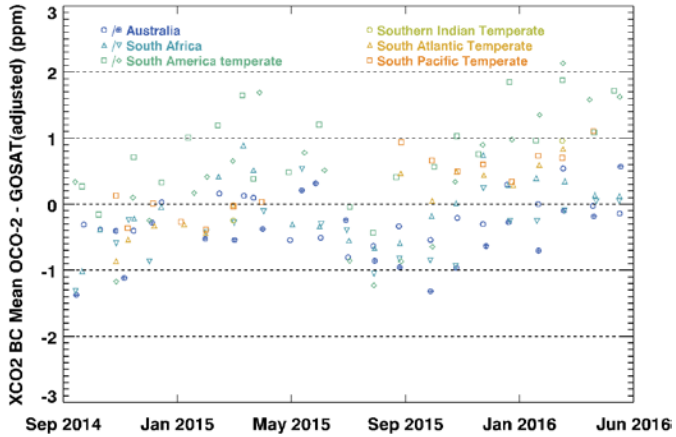
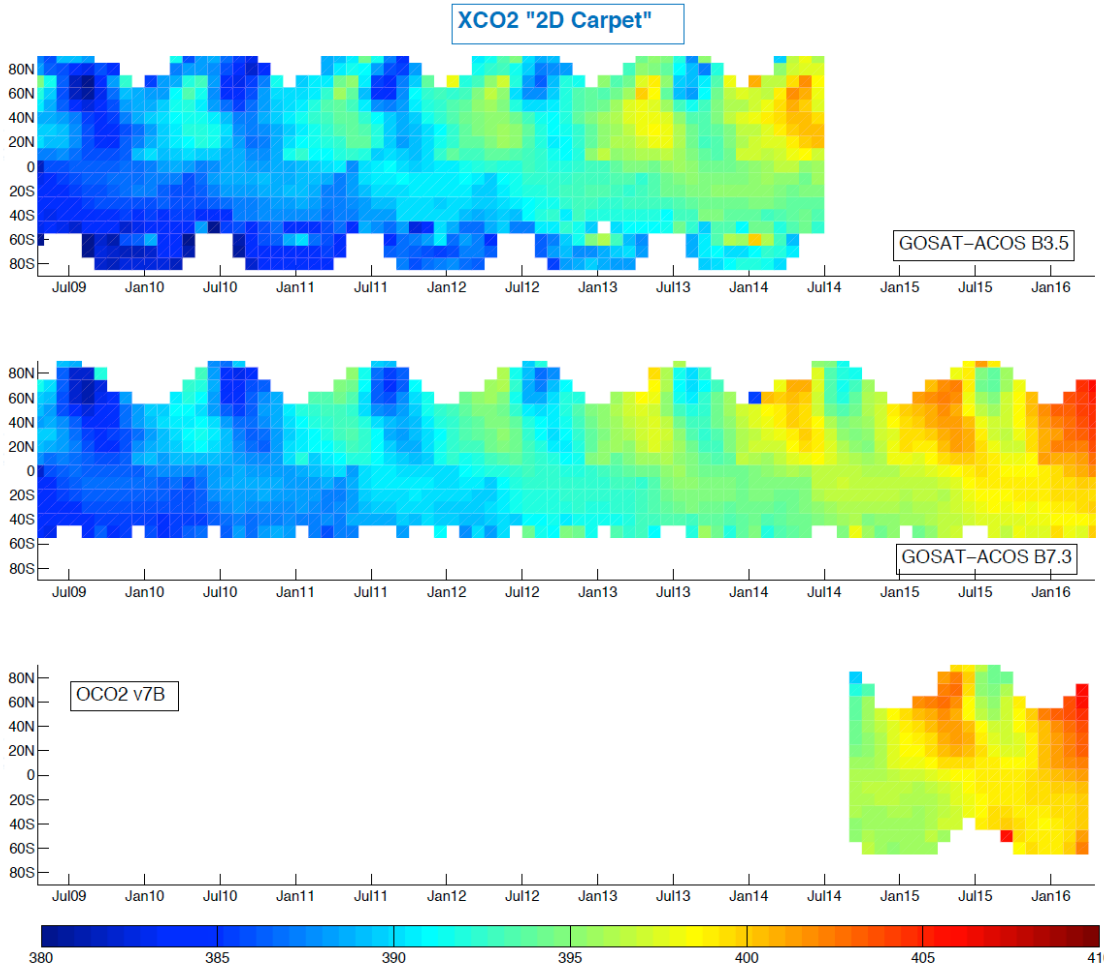


29 Jul 2016

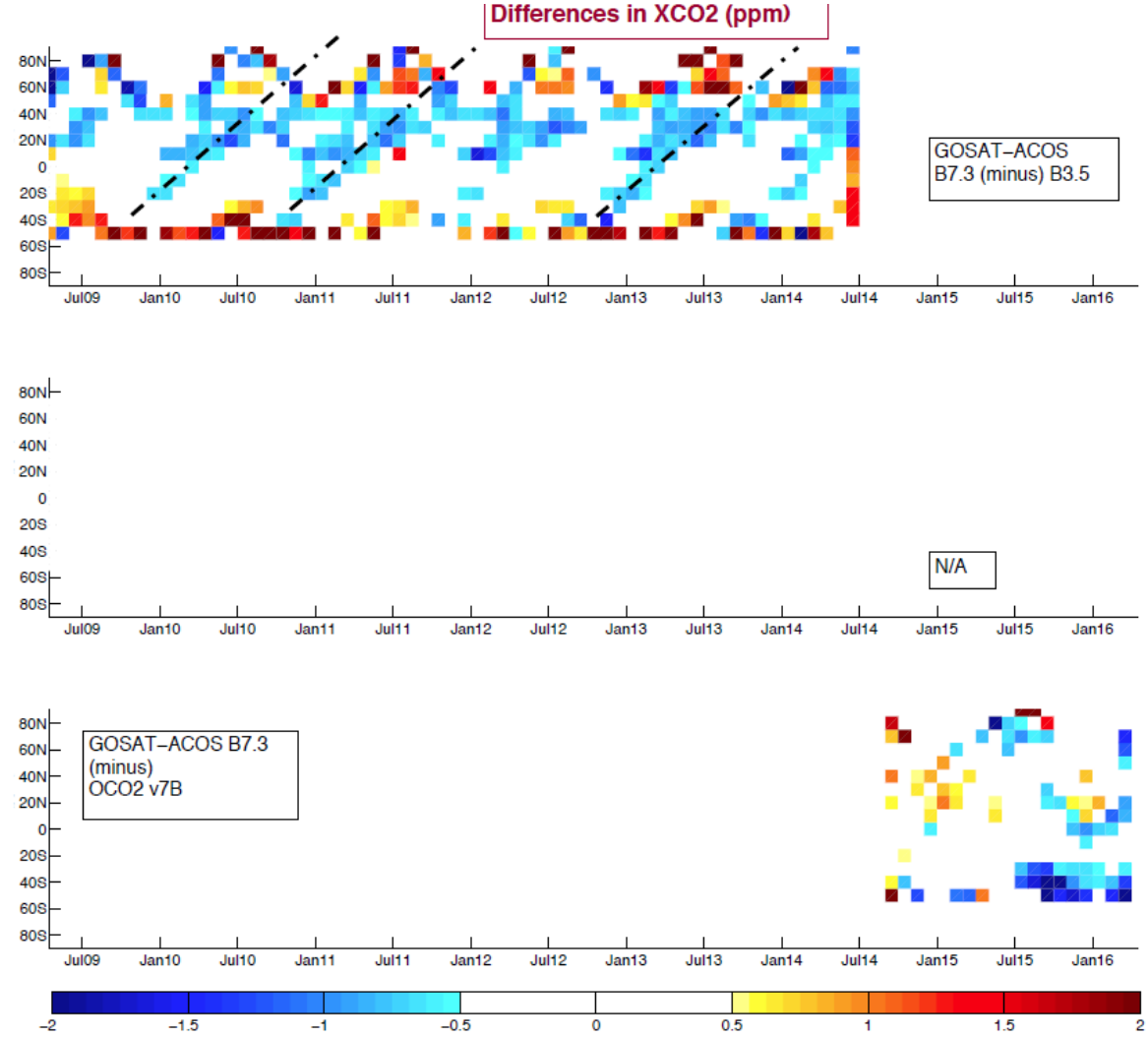
ACOS/GOSAT B3.5, B7.3, and OCO-2 v7 XCO2



Latitude vs time "XCO2 Carpet" plots for all 3 data sets.

- The magnitude of differences between GOSAT-ACOS B7.3 and OCO2 v7B are within ±1 ppm for overlap regions

Difference Plots: ACOS GOSAT B3.5*, B7.3, and OCO-2 V7 (Abhishek Chatterjee)



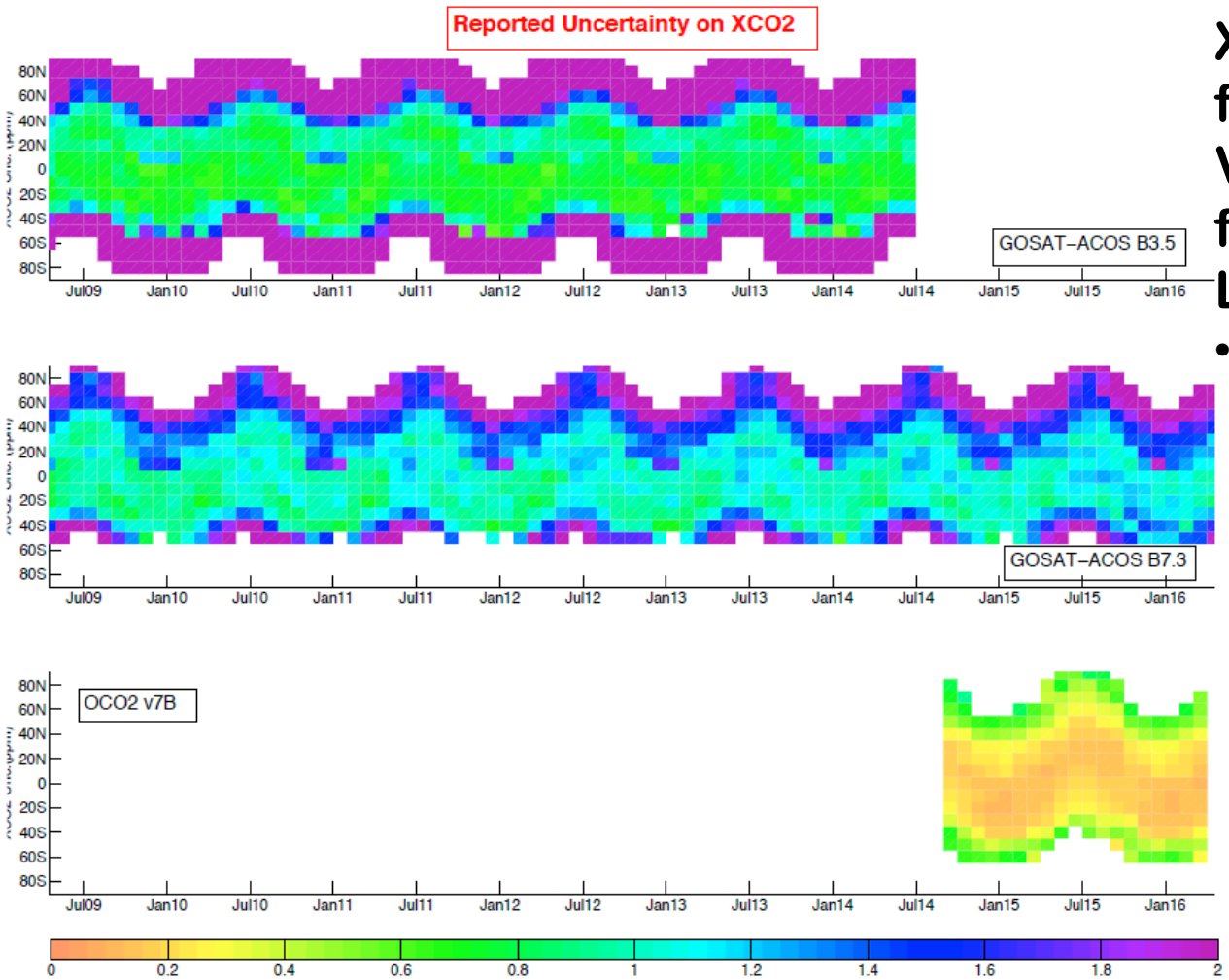
XCO2 differences between B7.3 and V7 are shown as a function of Latitude and time

- B7.3 and B3.5 r1 are different in both magnitude and phase
- The magnitude of differences between GOSAT-ACOS B7.3 and OCO2 v7B are within ±1 ppm

*B3.5 r01 shown here

Reported Uncertainties

(Abhishek Chatterjee)

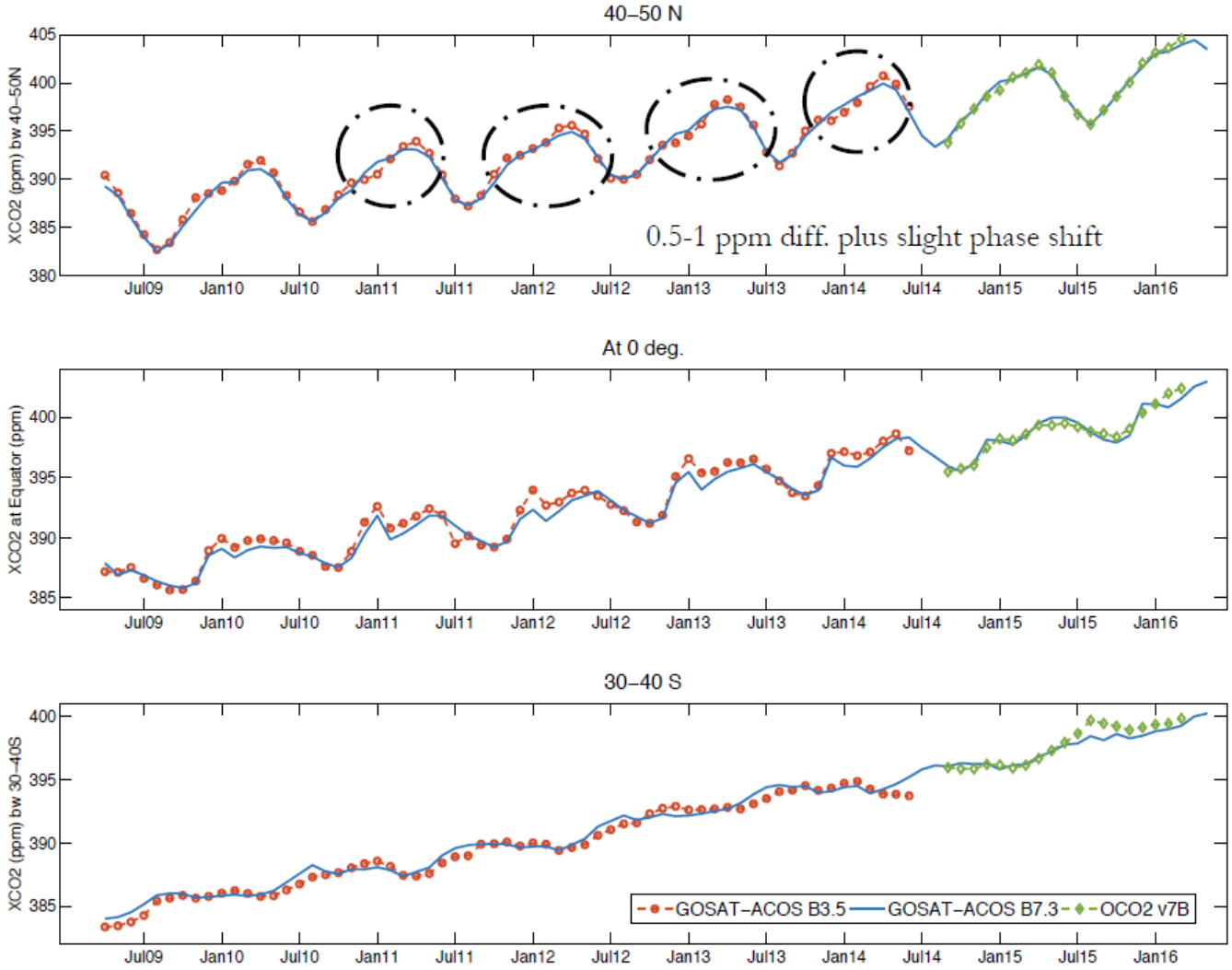


XCO2 uncertainties for B3.5, B7.3 and V7 are shown as a function of Latitude and time

- **Differences between the reported uncertainties of B3.6 and B7.3 may be due to differences in pressure covariance**

Time Series of XCO2 for B3.5, B7.3, and V7

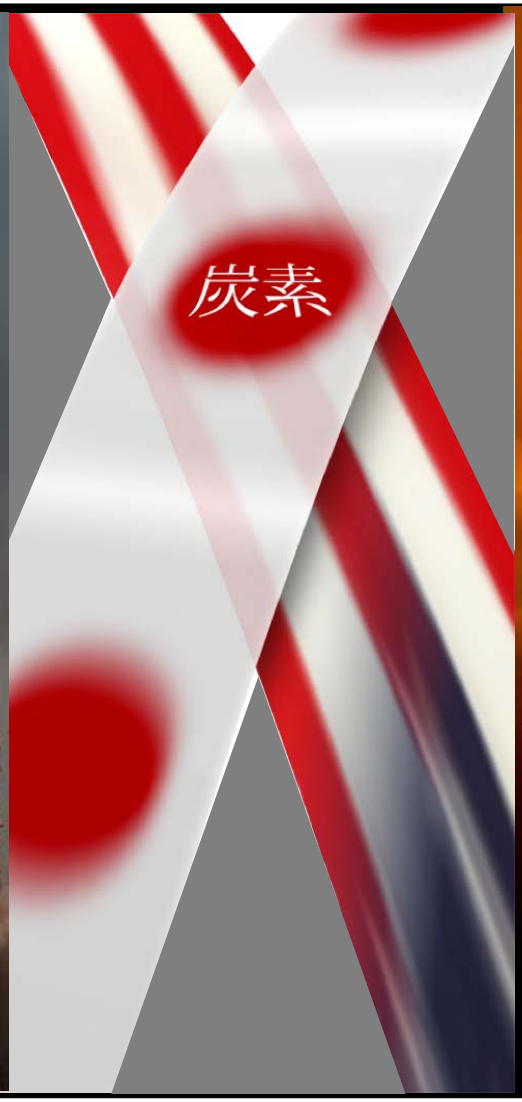
(Abhishek Chatterjee)



Observations

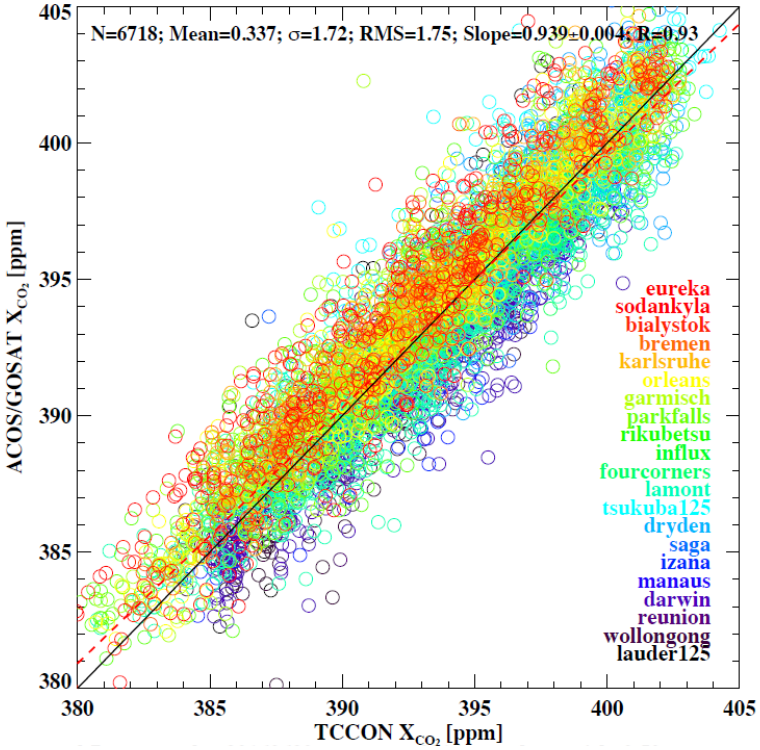
- In general, the ACO2 GOSAT B3.5, B7.3 and OCO-2 B7 products agree to ~1 ppm
- Small seasonal cycle difference between OCO2 and GOSAT persist even after latitude adjustment
- Seasonal cycle also seen in dP difference
  - might account for a portion of seasonal cycle differences in XCO2
- Other differences: Ice AOD lower and less variable in OCO2 but Ice Height much more varied in OCO2

Validation

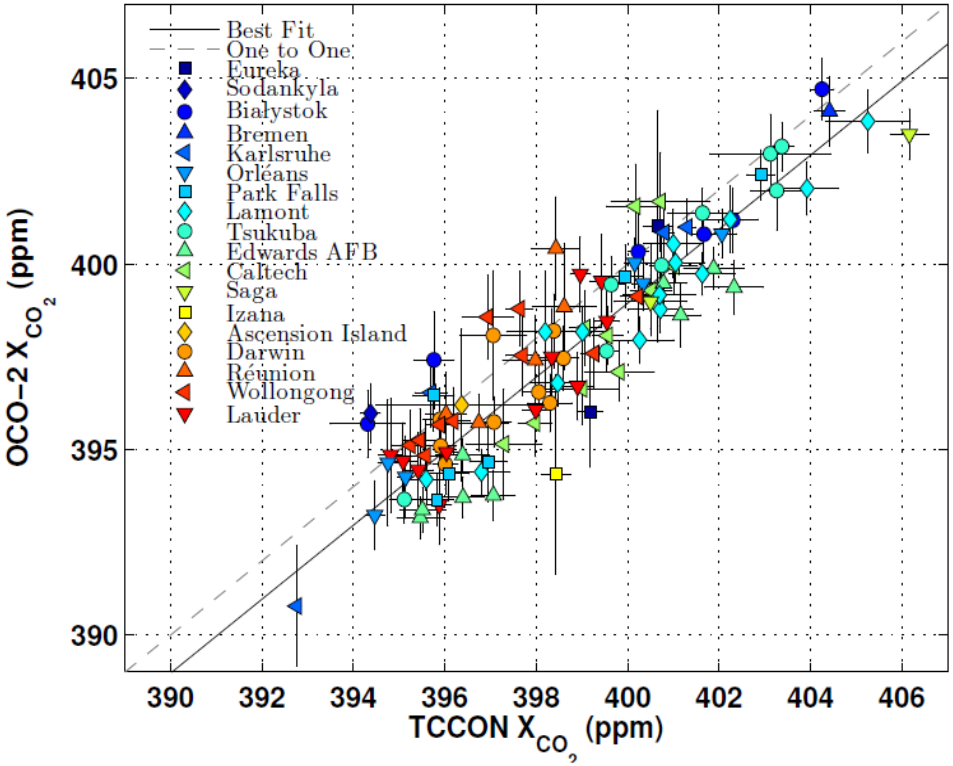


TCCON Serves as the Validation Standard for both GOSAT and OCO-2

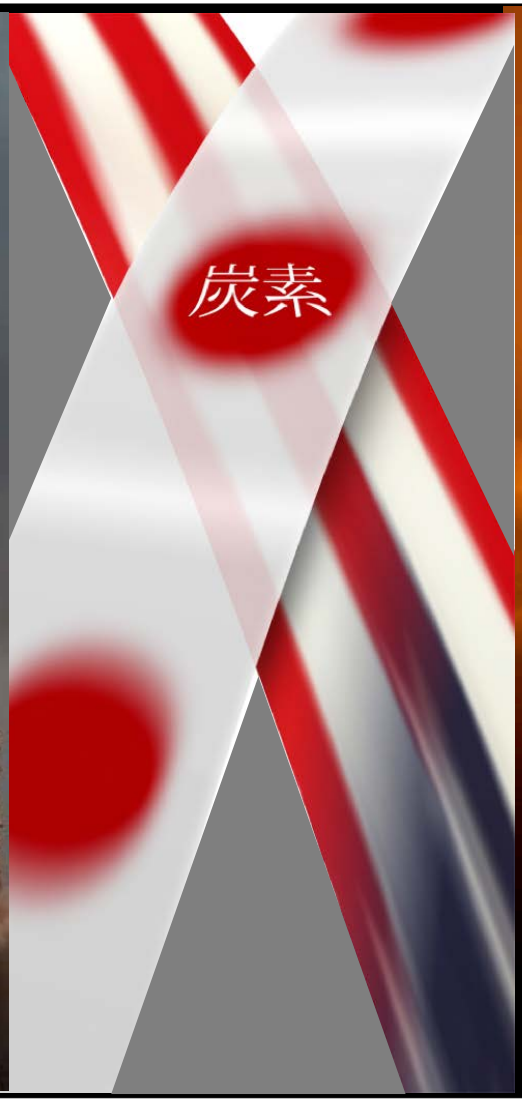
GOSAT B7.3 vs TCCON



OCO-2 vs TCCON



GHG Constellations



Advantages of GHG Constellations

- More than one satellite would
  - Reduce revisit times in the presence of clouds, since clouds move
  - Preclude the need for a very broad swath to meet the coverage and revisit time requirements
    - Broad swaths are difficult and expensive to implement, and will limit sensitivity (spectral resolution, SNR, low scattered light …)
    - Larger atmospheric path lengths at the edges of a broad swath are more likely to be contaminated by clouds
  - Provide redundancy in the case of a satellite failure
  - Provide opportunities for cross calibration and cross validation
- Partnerships will help realize this objective
  - Japan approved the GOSAT-3 mission, targeted a 2023 launch
  - Europe is planning its CO2 precursor in same time frame
  - The US is currently conducing a “Decadal Survey” for Earth Science that will most likely recommend some type of greenhouse gas mission

Constellation Options

- To monitor anthropogenic emissions on the scale of medium sized countries (e.g. France), we need to
  - Resolve and discriminate anthropogenic emissions from contributions from the natural biosphere and ocean
  - "Image" majority (~80%) of Earth's surface on weekly intervals
    - If we image the plume, we can attribute its source
- One way to meet the coverage, resolution, and precision requirements would be to fly a constellation of 3 (or more) satellites in low Earth orbit with
  - A ~200 km swath with a mean footprint size < 5 km^2
  - A single sounding random error near 0.5 ppm, and vanishing small regional scale bias (< 0.1 ppm)
  - One (or more) satellites may carry ancillary sensors (CO, NO2, CO2 Lidar)
- To diurnally varying processes (e.g. rush hours, diurnal variations in the biosphere), we will need to augment this constellation with 3 (or more) geostationary satellites

Examples of Collaborative Activities Needed to Combine Data Sets

Pre Launch:

- Cross calibration of pre-launch radiometric standards
- Exchange of gas absorption coefficient and solar databases
- Retrieval algorithm development/intercomparison
- Validation system development (TCCON + Tsukuba FTS?)
- Dual/multi-Satellite OSSE's – what do you gain with truly coordinated observations

Post Launch:

- Cross calibration of solar/lunar/Earth(vicarious: RRV+?) observations
  - Including exchange of solar and lunar (ROLO) standards
- Cross validation: TCCON (possibly adding a validation campaign or two)
- Continued retrieval algorithm development/intercomparisons
- Intercomparisons of flux inversions