Presentation to the NOAA ESRL GMD Annual Conference

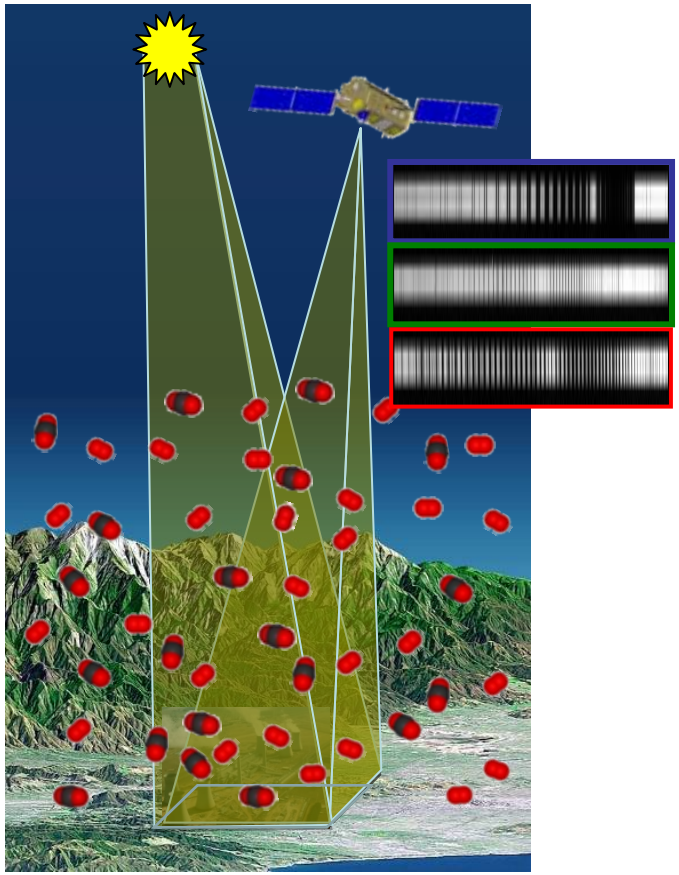
CO_2 Measurements from Space: The Japanese GOSAT and NASA OCO-2 Missions

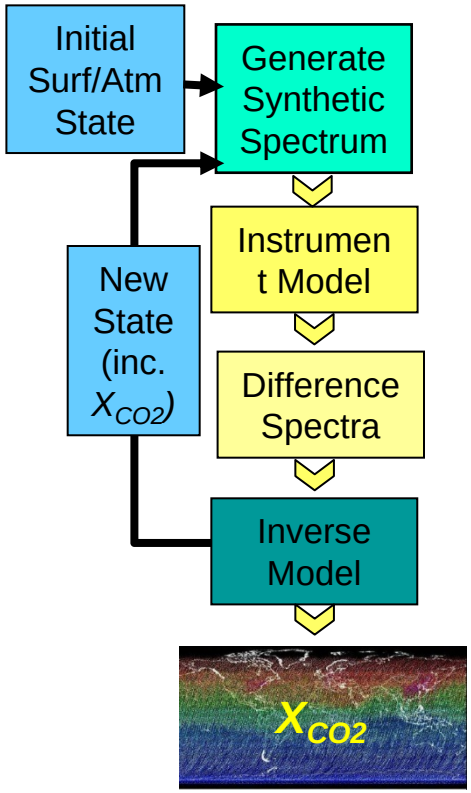
David Crisp
OCO-2 Lead Scientist
Jet Propulsion Laboratory,
California Institute of Technology

May 16, 2012

Measuring CO_2 from Space

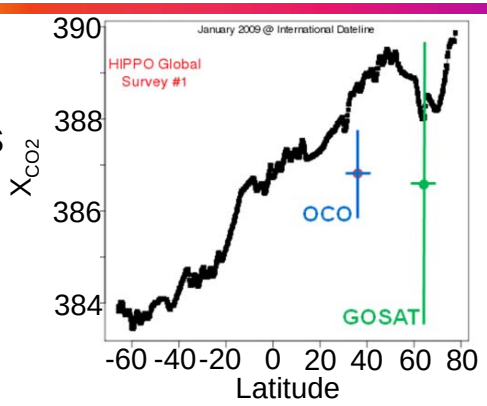
- **Record** spectra of CO_2 and O_2 absorption in reflected sunlight
- **Retrieve** variations in the *column averaged CO_2 dry air mole fraction, X_{CO2}* over the sunlit hemisphere
- **Validate** measurements to ensure X_{CO2} accuracy of 1 - 2 ppm (0.3 - 0.5%)

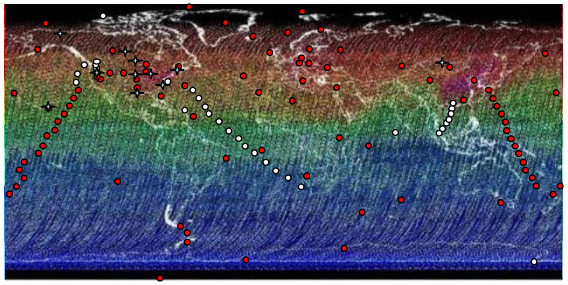


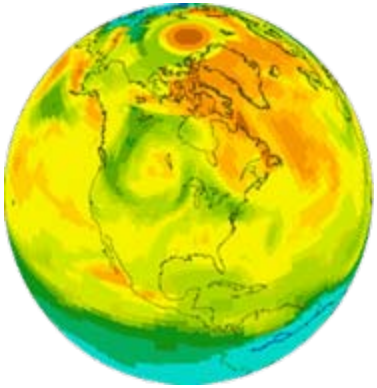


Driving Requirements for Space-based CO_2 Measurements

- Precision and accuracy
  - High precision required to resolve small (0.2-0.3%) variations in CO_2 associated with sources and sinks
  - High accuracy essential to avoid regional-scale biases
- Spatial coverage
  - Near-global sampling required over continents and ocean
- Spatial resolution and sampling
  - Sensitivity to point sources scales with area of footprint
  - Small measurement footprints reduce impacts of clouds
- Temporal sampling
  - Fixed time of day to reduce uncertainties associated with diurnal variations in CO_2
  - Synoptic-scale sampling with a 1-4 day repeat cycle needed to resolve transport of CO_2 by local weather systems
  - Monthly measurements required over > 1 year to resolve seasonal and inter-annual variability in CO_2







The Pioneers: GOSAT and OCO

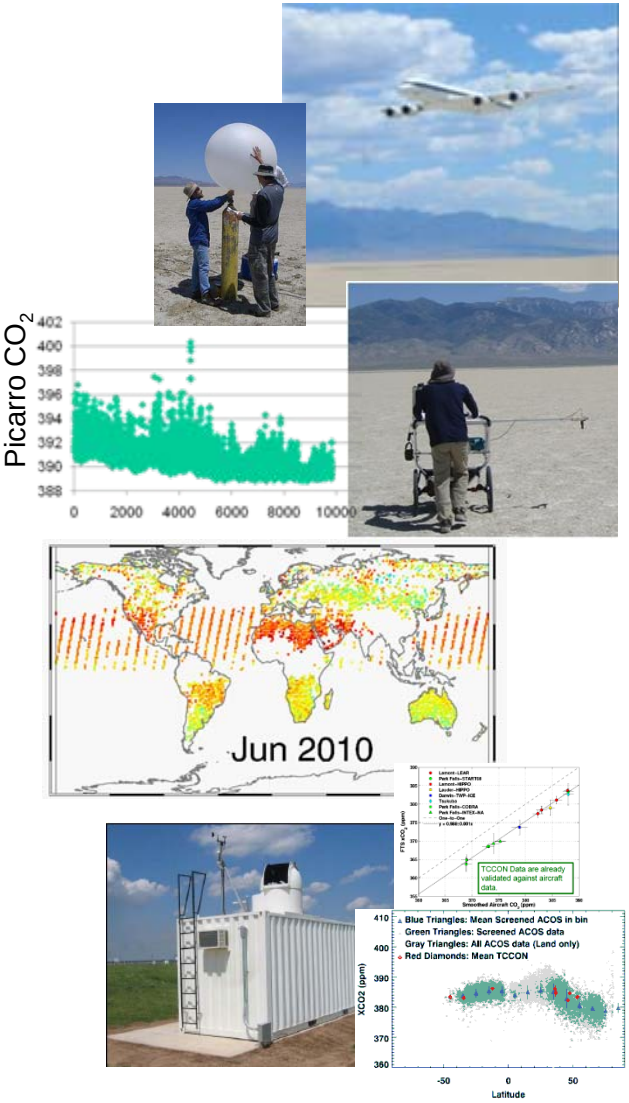
GOSAT launched successfully on 23 January 2009

OCO was lost a month later when its launch system failed

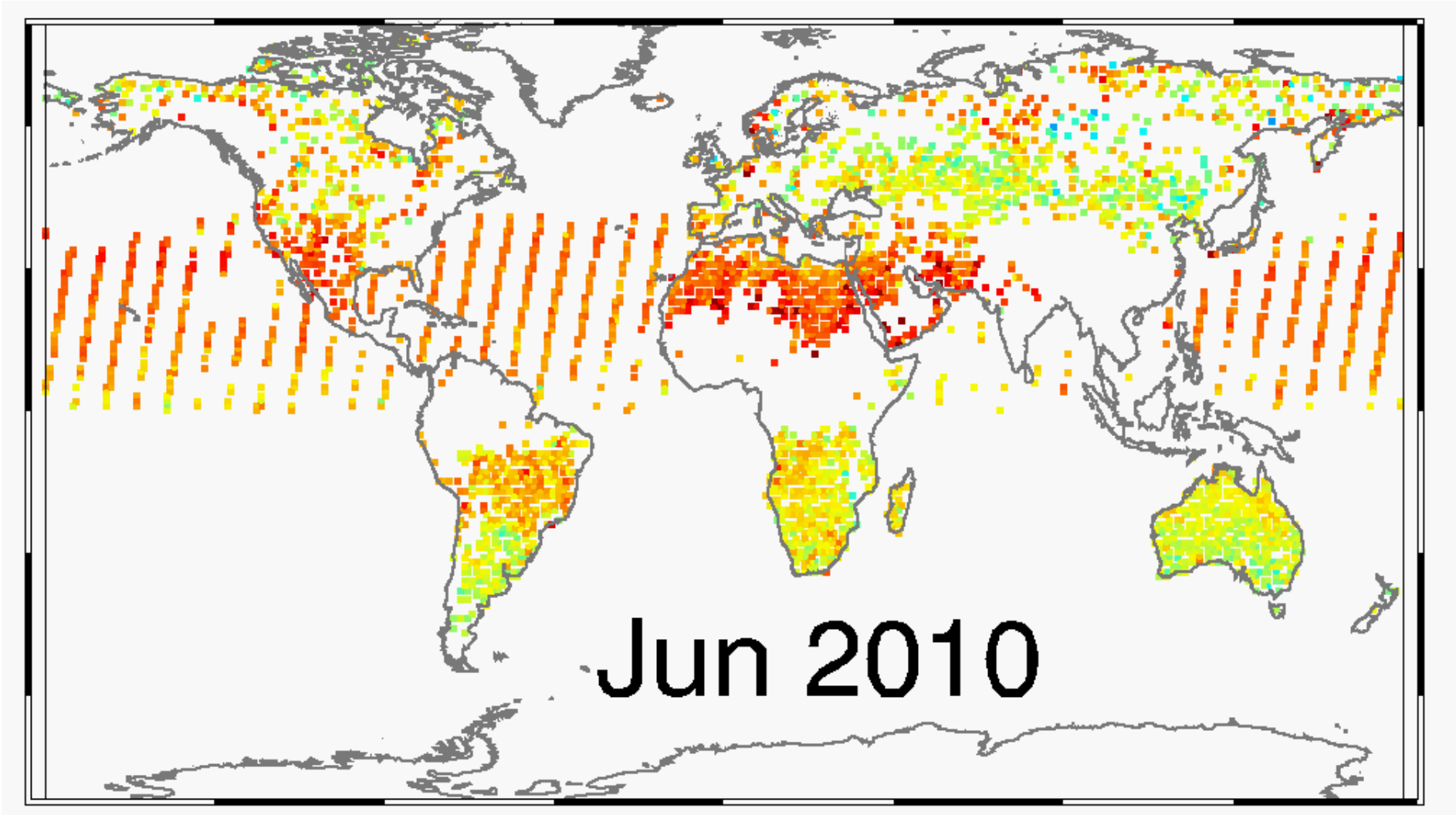
The OCO/GOSAT Collaboration

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

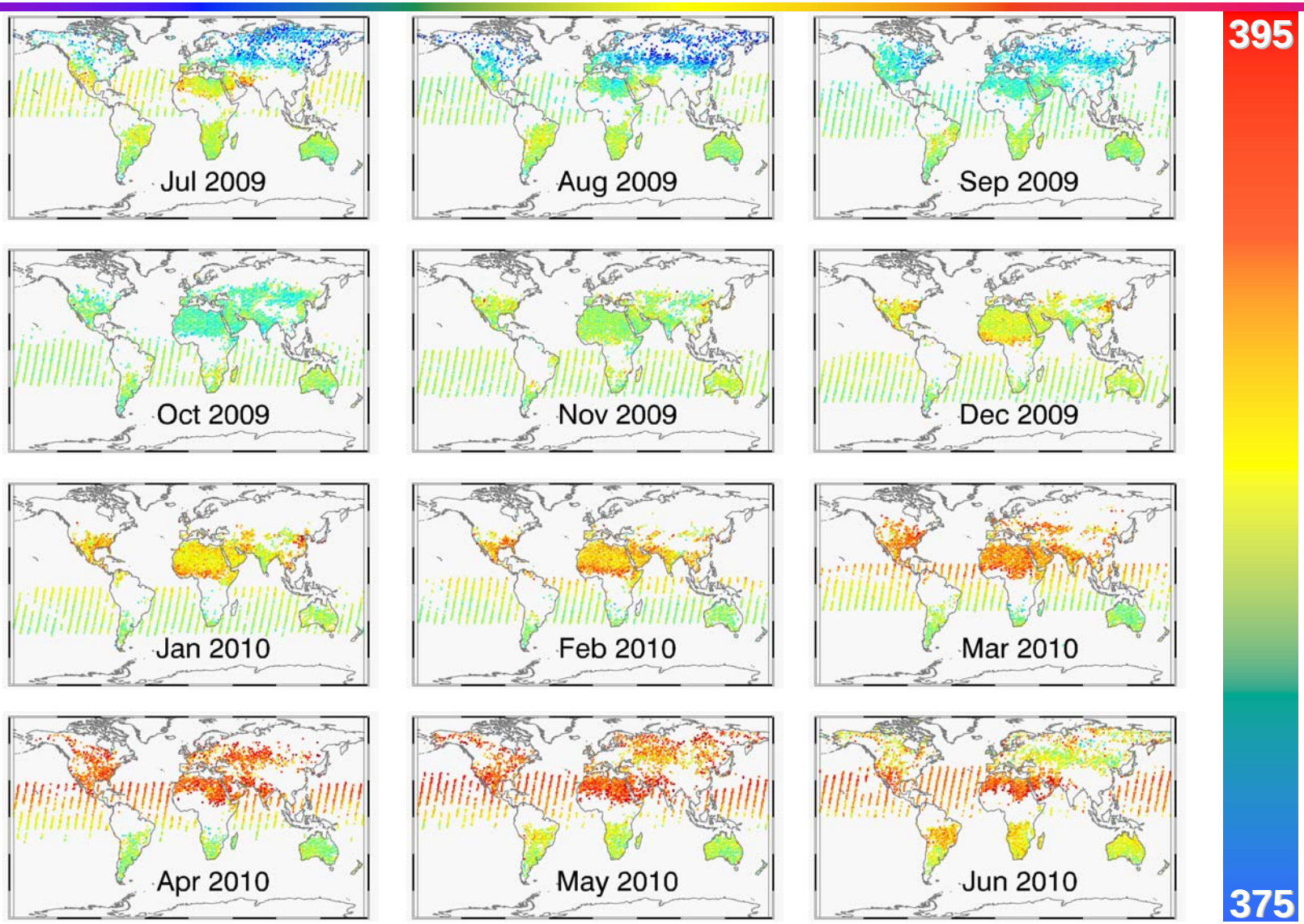
- This Collaboration includes:
  - Conducting vicarious calibration campaigns in Railroad Valley, Nevada, U.S.A.
  - Retrieving X_{CO2} from GOSAT spectra
    - Model development & testing
    - Data production and delivery
  - Validating GOSAT retrievals by comparing GOSAT retrievals with TCCON measurements and other data



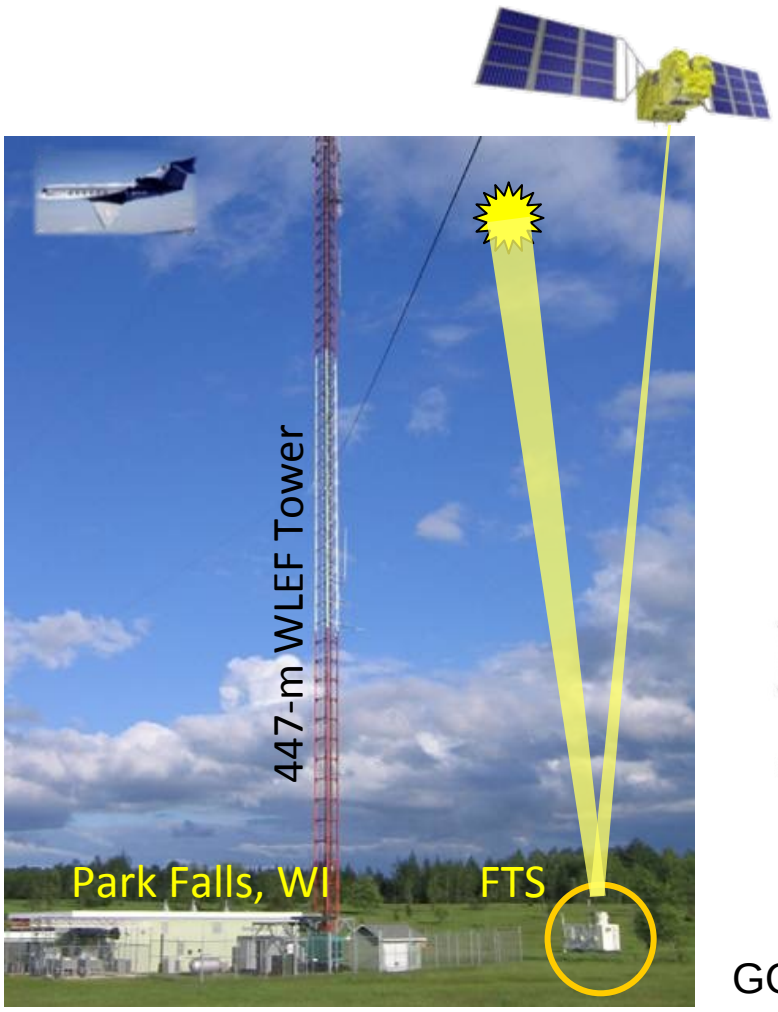
ACOS GOSAT B2.10 XCO2 Retrievals



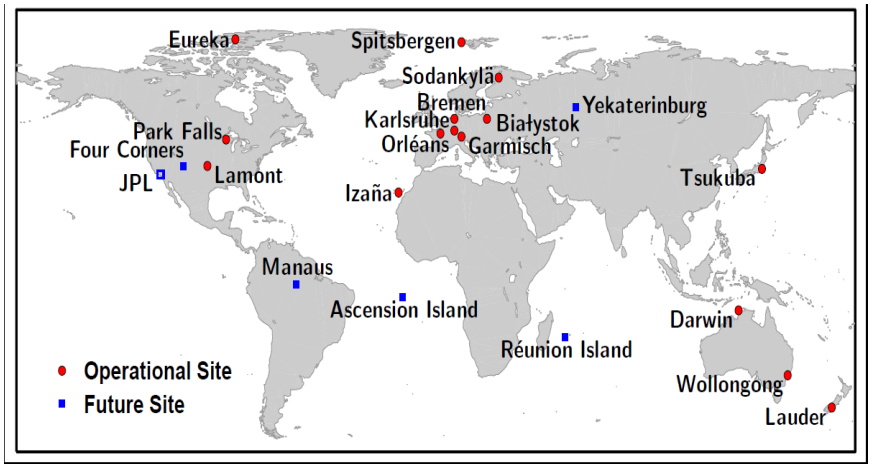
ACOS GOSAT B2.10 XCO2 Retrievals

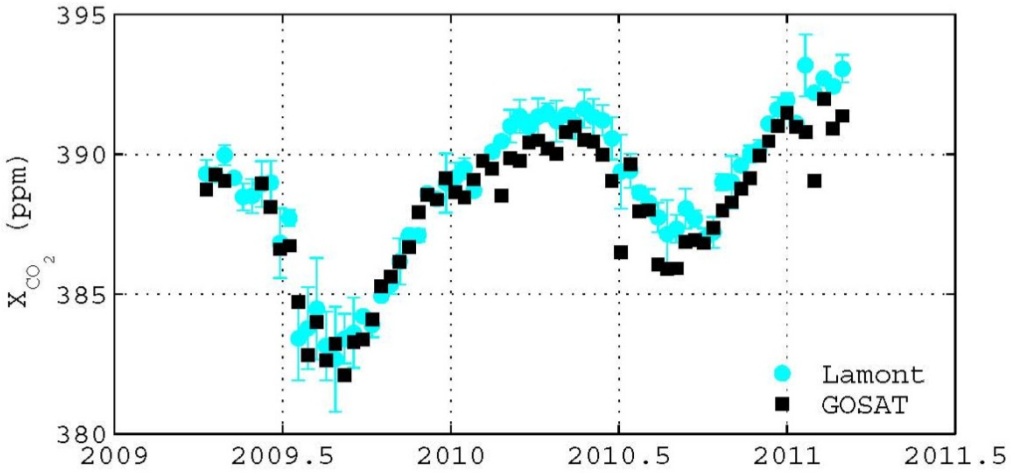


Validation of GOSAT Products against TCCON Reduces Regional Scale Bias



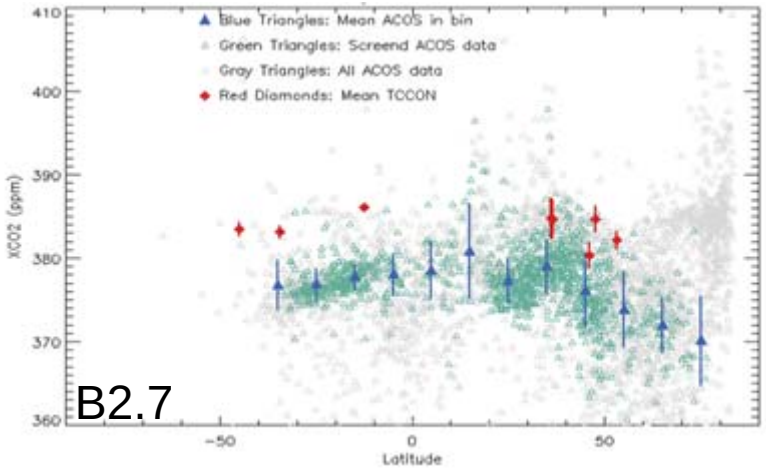
Near-simultaneous observations are acquired over TCCON station.

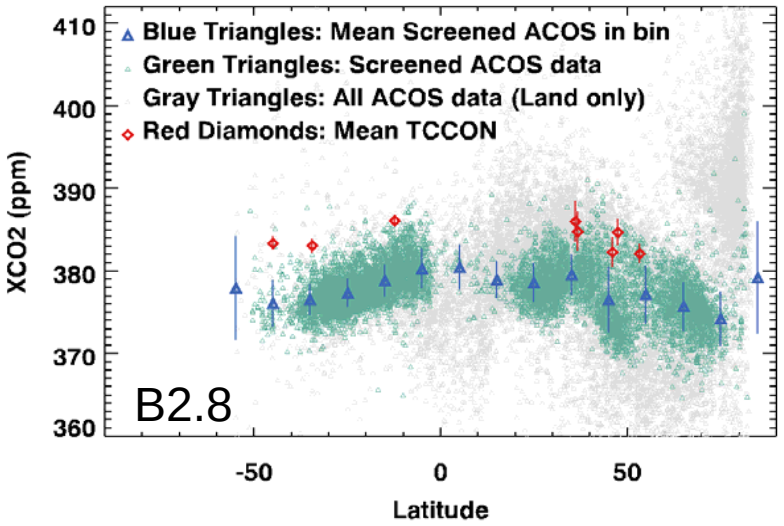


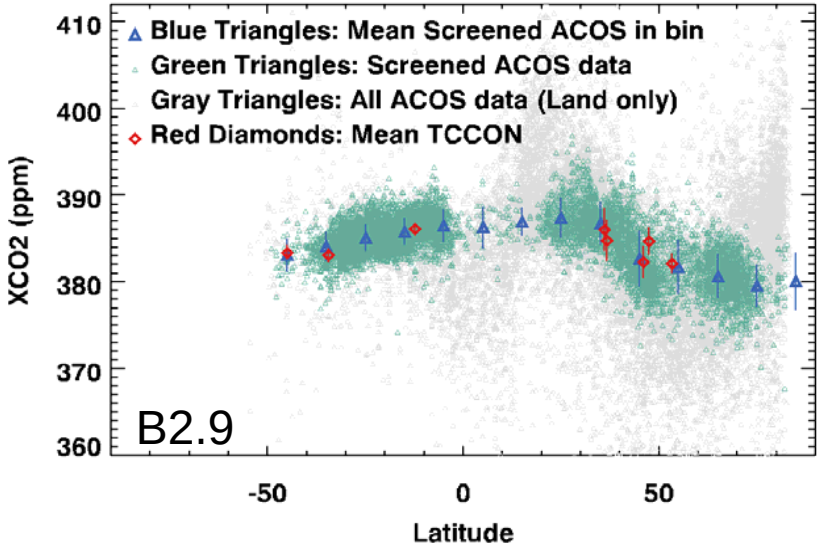


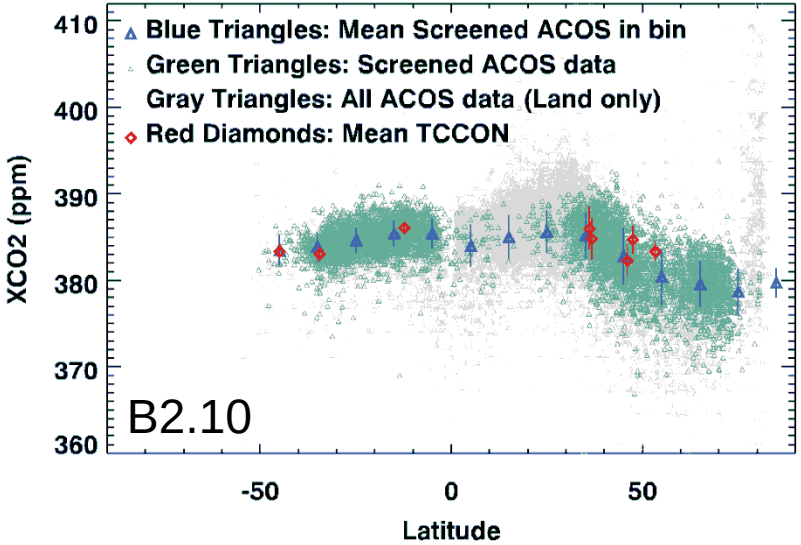
GOSAT X_{CO2} retrievals are compared with those from the ground based Total Carbon Column Observing Network (TCCON) to verify their accuracy

TCCON Comparisons Show Improvements in Bias and Random Error over Time









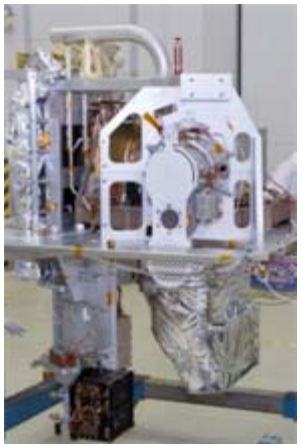
OCO-2: The Next Step

Once successfully launched, OCO-2 is expected to further improve:

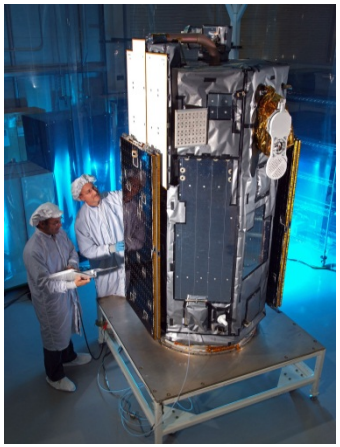
- **Sensitivity:** OCO-2 has higher SNR, especially over dark surfaces, and collects > 48 times as many soundings as GOSAT each day
- **Coverage:** OCO-2 can acquire glint observations over the entire sunlit hemisphere, for better coverage of ocean and ice covered surfaces
- **Resolution:** OCO-2 acquired continuous measurements at 2.25 km intervals along a narrow (10.5 km at nadir) ground track

The OCO-2 Mission is Under Development

3-Channel Spectrometer (JPL)



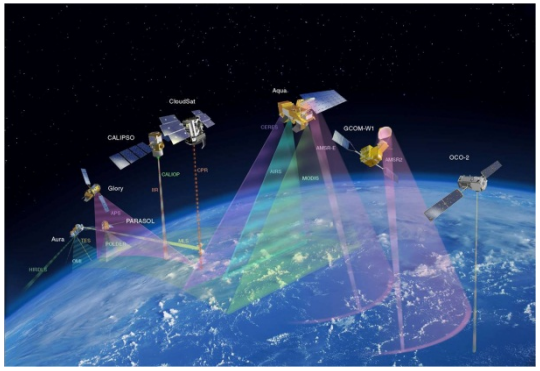
Dedicated Spacecraft Bus (OSC)



TBD Launch Vehicle

Mission Operations (OSC)

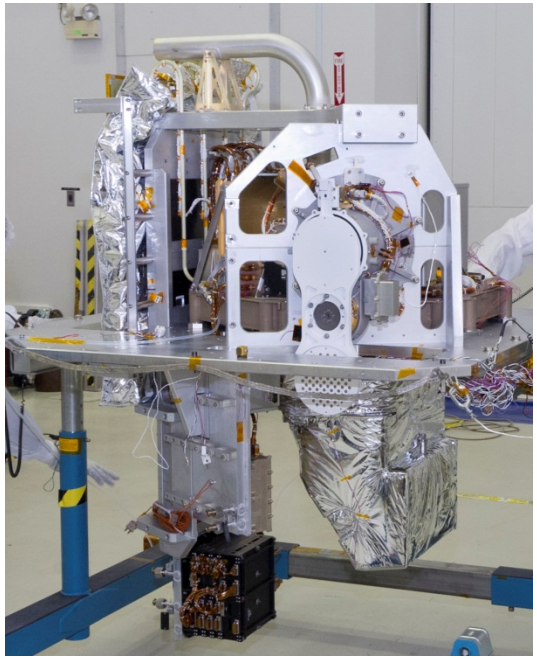
Formation Flying as Part of the A-Train Constellation

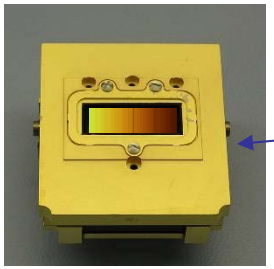


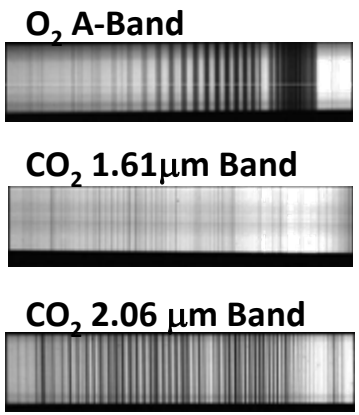
NASA NEN (GSFC) and SN (TDRSS)

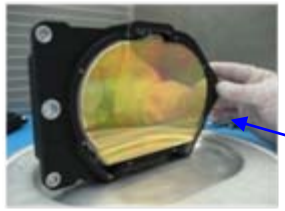
The OCO Instrument – Optimized for Sensitivity

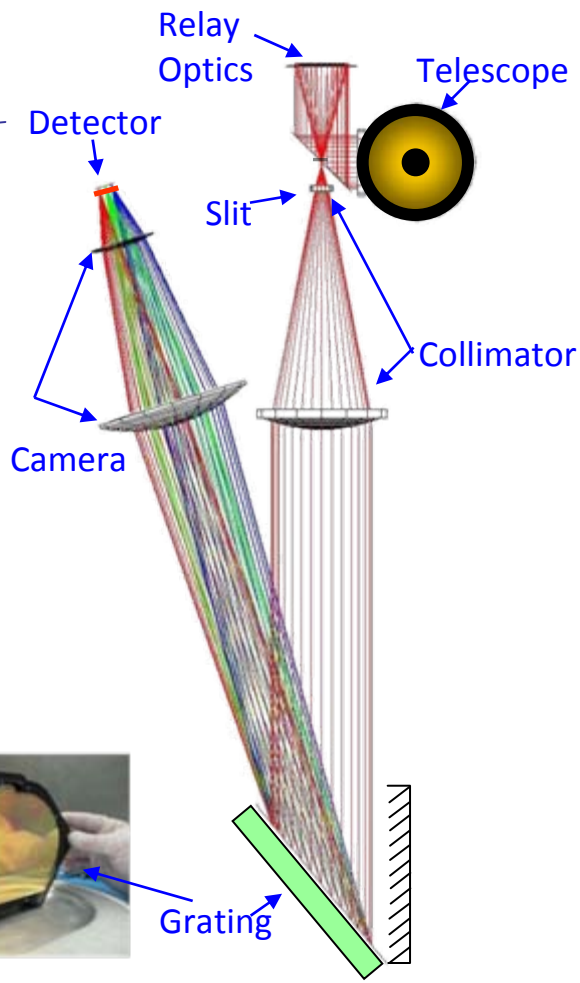
- 3 co-bore-sighted, high resolution, imaging grating spectrometers
  - Resolving Power ~20,000
  - High Signal-to-Noise Ratio
  - Collects 4 to 8 cross-track footprints at 3 Hz







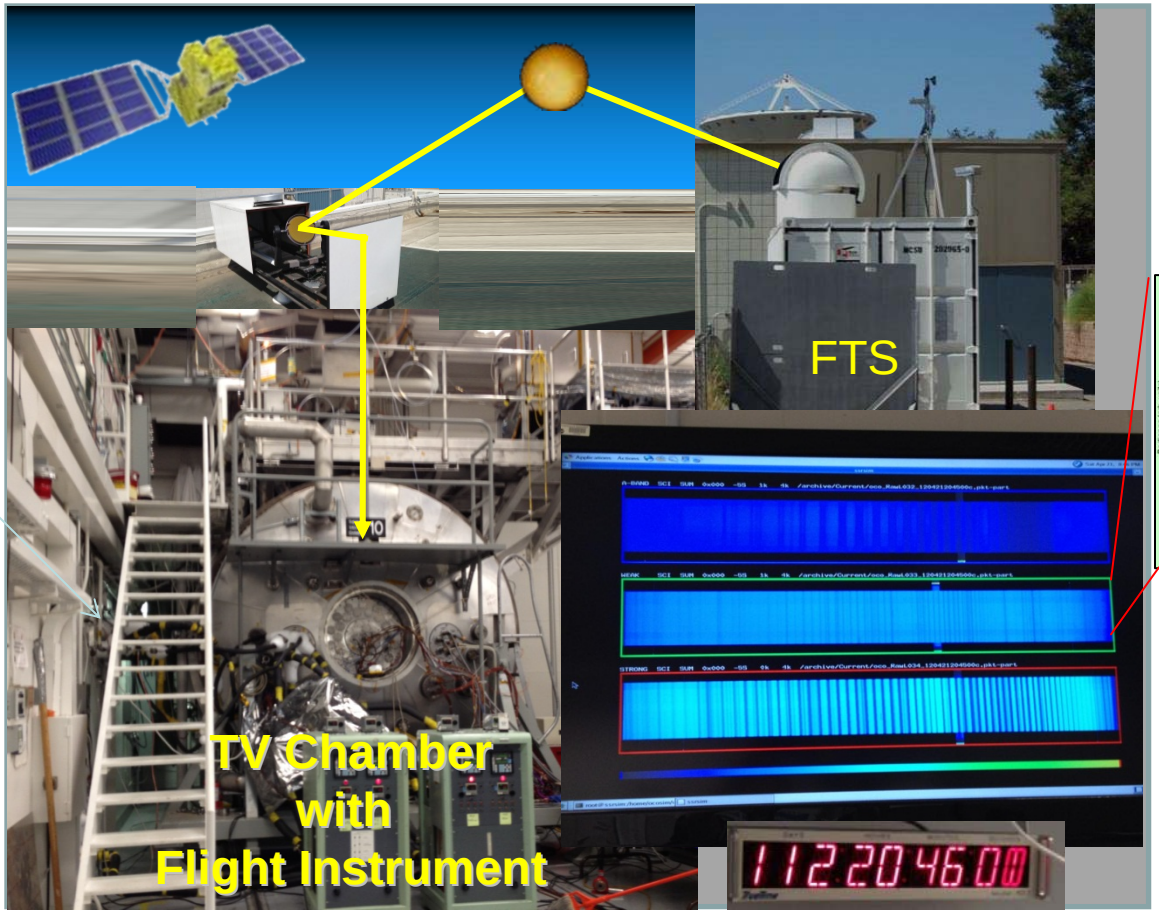




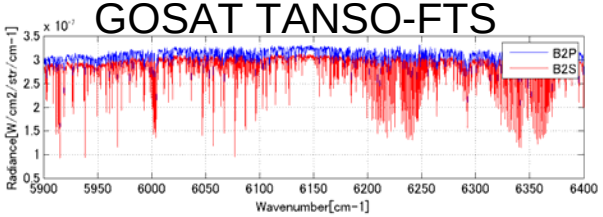
Optical path and key components of each channel.

Pre-Flight Instrument Qualification and Characterization

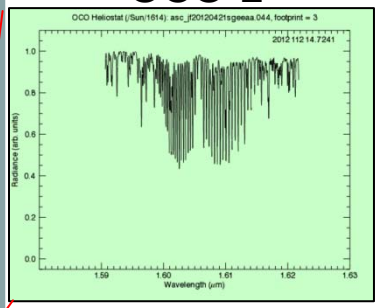
Observations of the sun with the flight instrument taken during the thermo-vacuum tests provided an end-to-end test of the instrument performance.



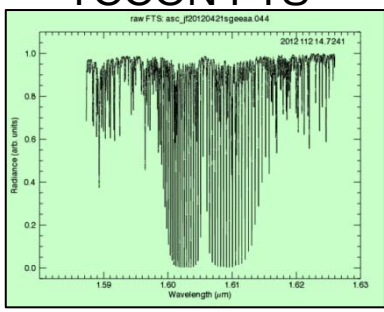
GOSAT TANSO-FTS



OCO-2



TCCON FTS



On April 20, 2012, simultaneous observations over the LA Basin were taken by GOSAT, the JPL TCCON Station, and the OCO-2 flight Instrument. Analysis is ongoing.

Next Steps

- Space-based remote sensing observations hold substantial promise for future long-term monitoring of CO_2 and other greenhouse gases
  - These measurements will complement those from the ground-based network with increased spatial coverage and sampling density

  - Improvement in the GOSAT data product and analysis techniques continue to yield reductions in bias and random error in X_{CO2} retrievals
  - Recently implemented corrections to the GOSAT TANSO-FTS calibration
  - Improvements in oxygen A-band spectroscopy
  - Advances in retrieval algorithm and data screening techniques

- Once OCO-2 is launched, it will provide additional improvements in sensitivity, coverage, and resolution
  - The OCO-2 launch date has been delayed until July 2014, at the earliest due to launch vehicle availability
  - A launch vehicle competition is ongoing – selection expected this summer