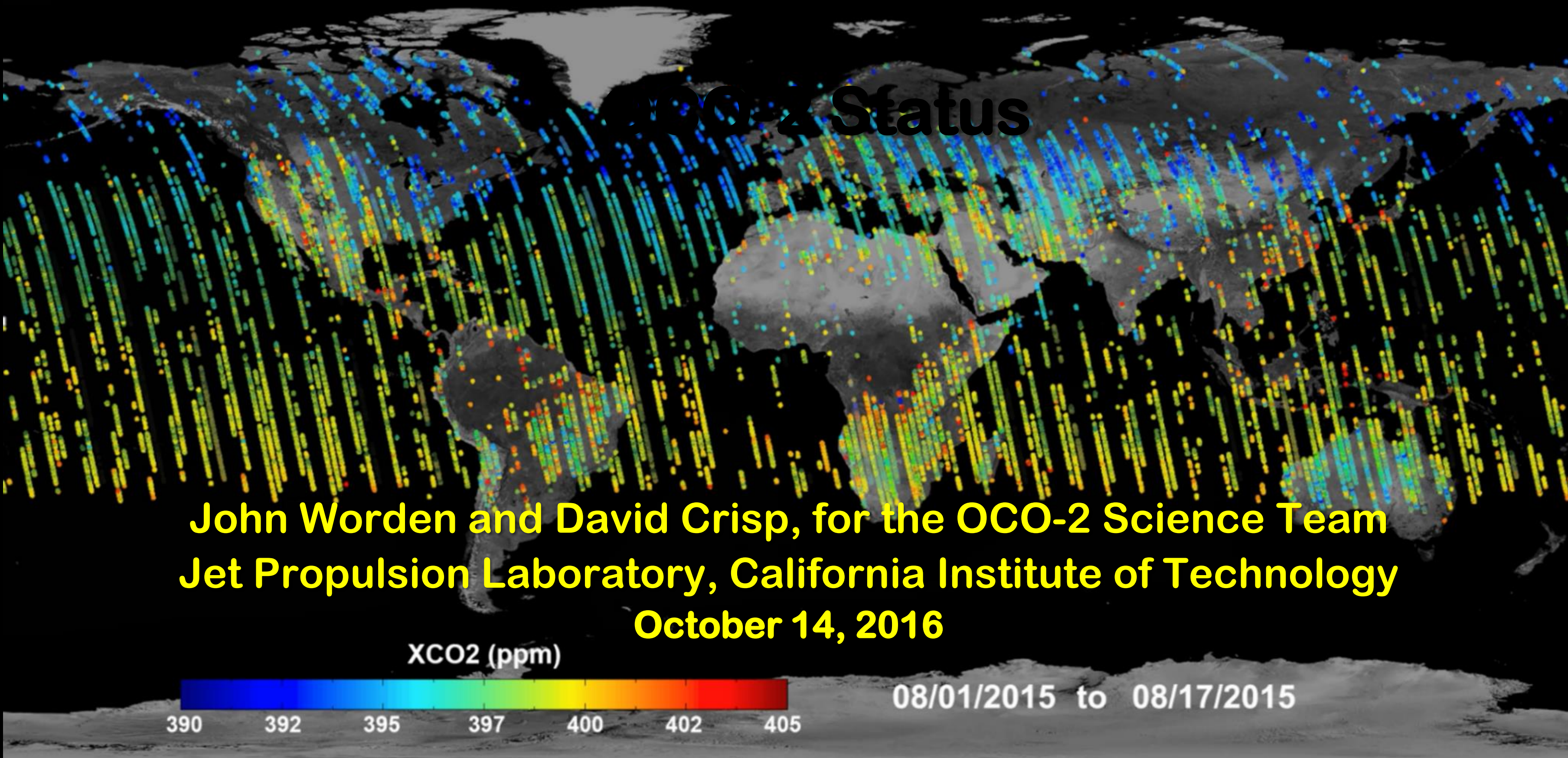
CEOS ACC-12

OCO-2 Results



John Worden and David Crisp, for the OCO-2 Science Team
Jet Propulsion Laboratory, California Institute of Technology

October 14, 2016

Agenda

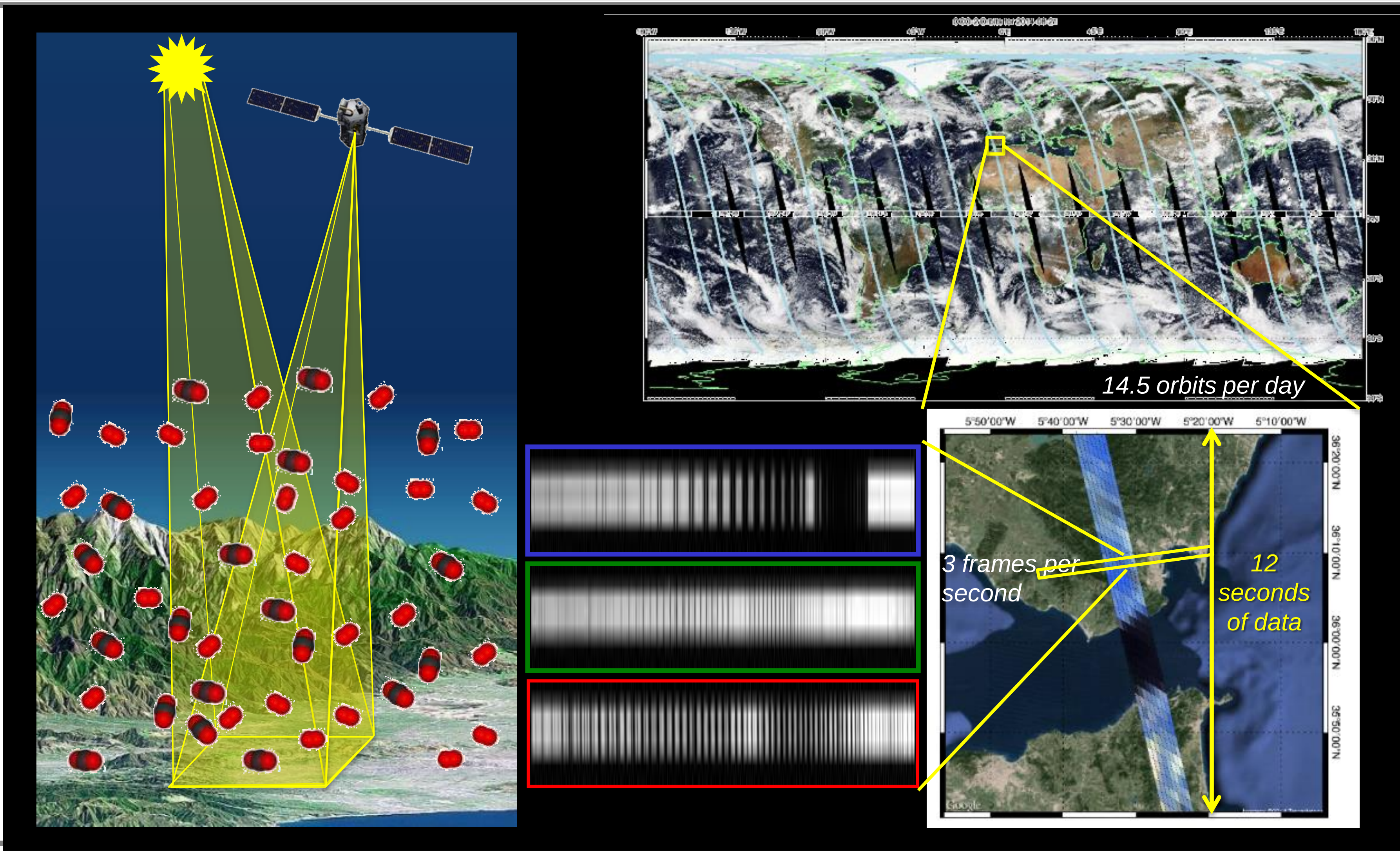
- Observatory and Instrument status
- OCO-2 Measurements
  - Data signal-to-noise ratios and single sounding random errors
  - Validation status
  - Known biases and their sources
  - Studies of compact sources
  - Solar Induced Chlorophyll Fluorecense (SIF)
  - The response of atmospheric CO2 too the 2015 El Niño
- Coming attractions: Version 8 Testing
- Conclusions

Observatory and Instrument Status

- The spacecraft is healthy as it approaches the end of its 2-year prime mission
  - Extended mission proposal under development

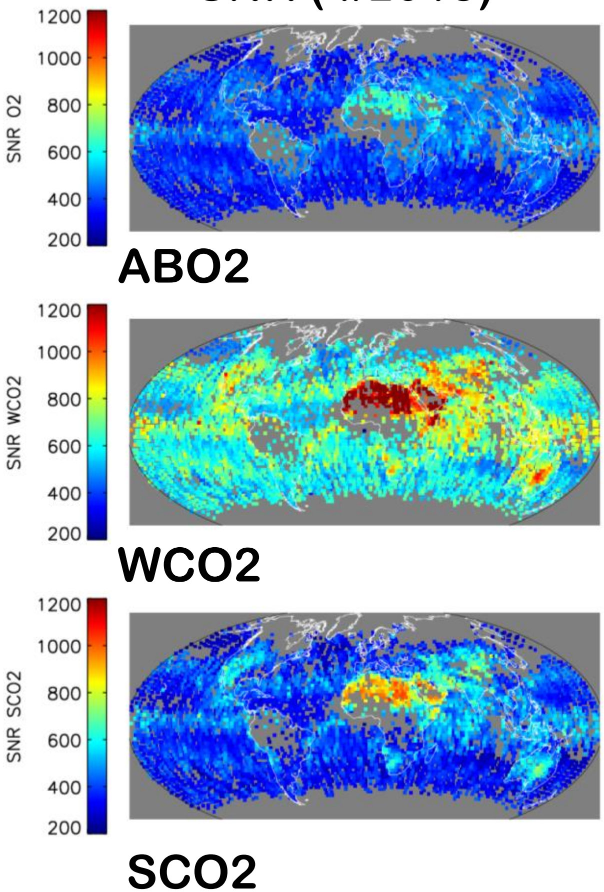
- The instrument experienced an anomaly from 10-21 August
  - At 4:28 UTC on Wednesday 10 August, just after OCO-2 few over Rio de Janeiro, the instrument performed a spontaneous reset and was shut down by the fault detection system (Orbit 11212)
  - After completing an anomaly investigation, the instrument was successfully powered on at 16:39 UTC on Sunday 14 August, and commanded to perform a standard 28 C decontamination cycle
  - The instrument optical bench and FPAs were back at their operating temperatures and collecting science data on Sunday, 21 August (Orbit 11376)
  - Level 2 science data production was resumed on 20 September
    - 10 days of science data lost (10-20 August 2016)
    - All science data from 21 August is recoverable and will be available in the V7R product delivered the GES DISC

OCO-2 Sampling Approach

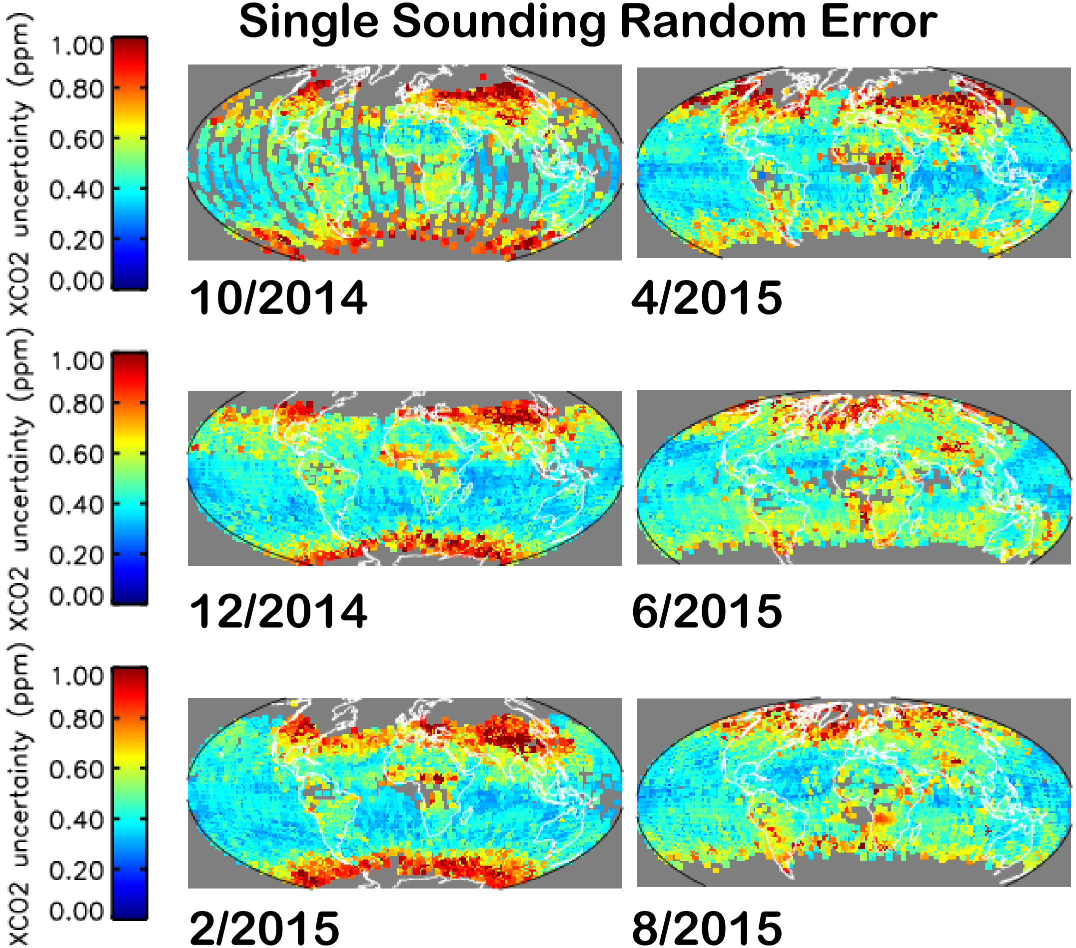


SNR and Single Sounding Random Error

SNR (4/2015)

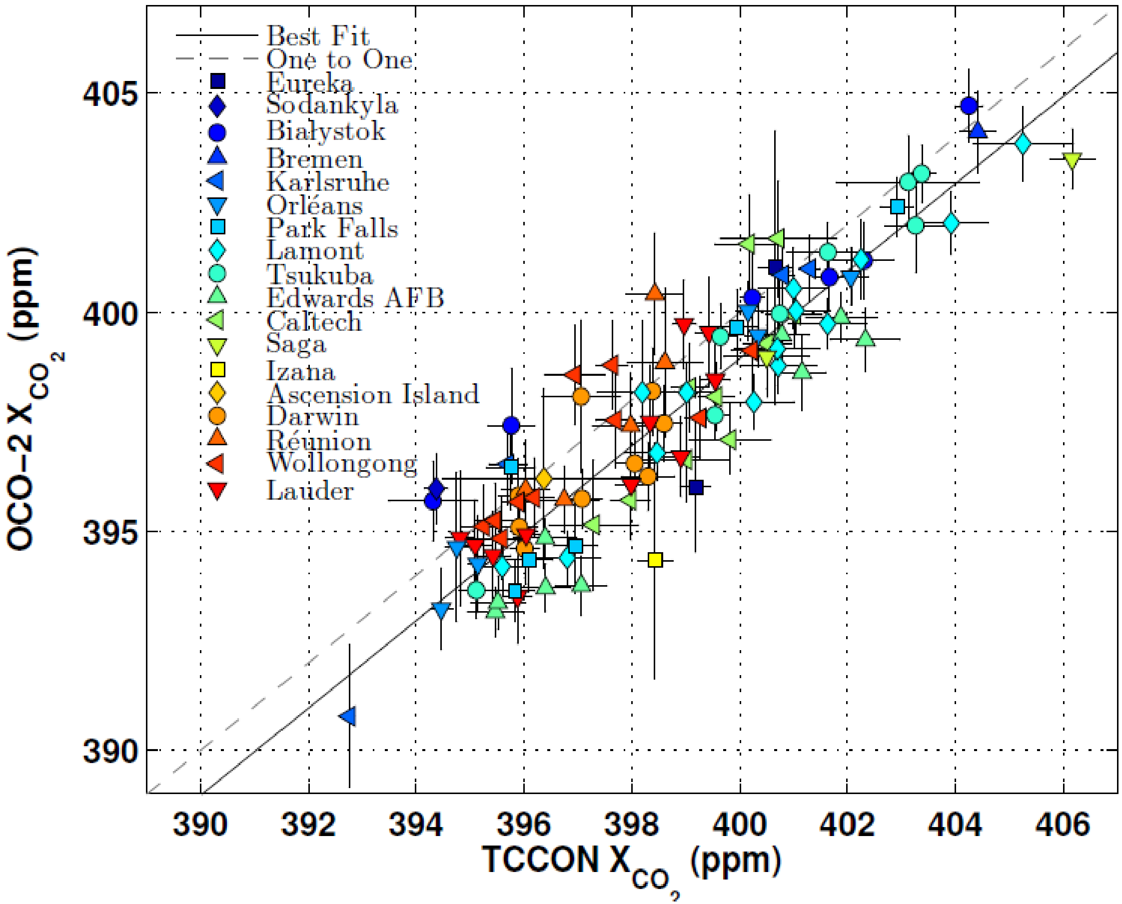


Single Sounding Random Error



High SNR → **Low Random X_{CO2} Error**

Comparison of TCCON and OCO-2 X_{CO2}

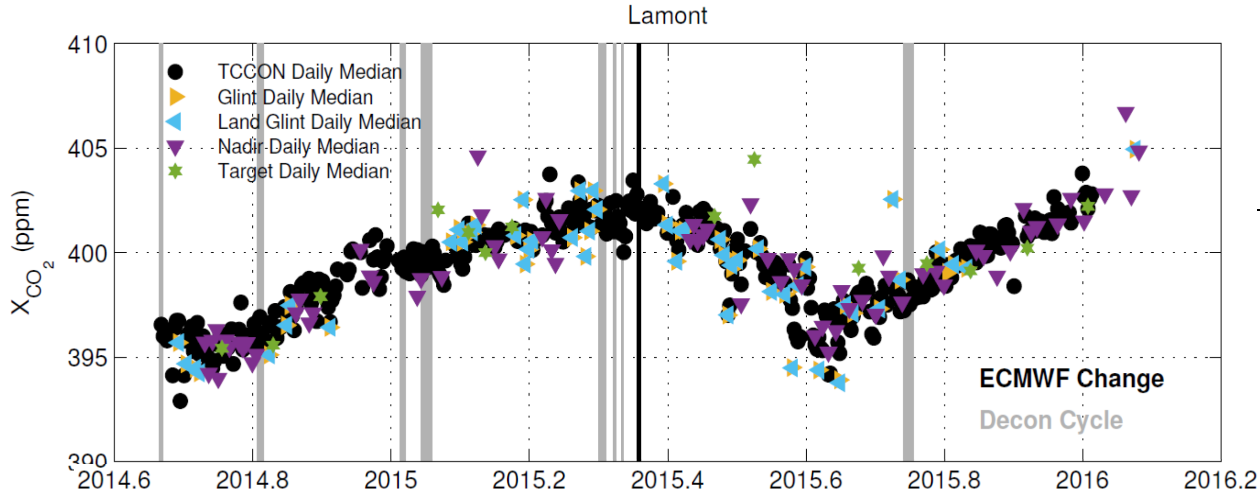


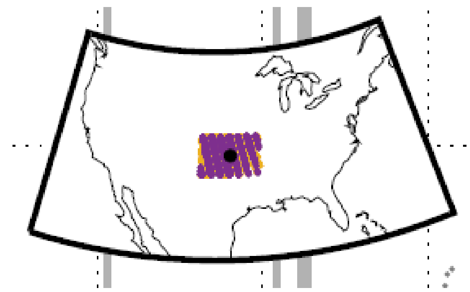
Comparisons with Total Carbon Column Observing Network (TCCON) stations are being used to identify and correct biases in target observations.

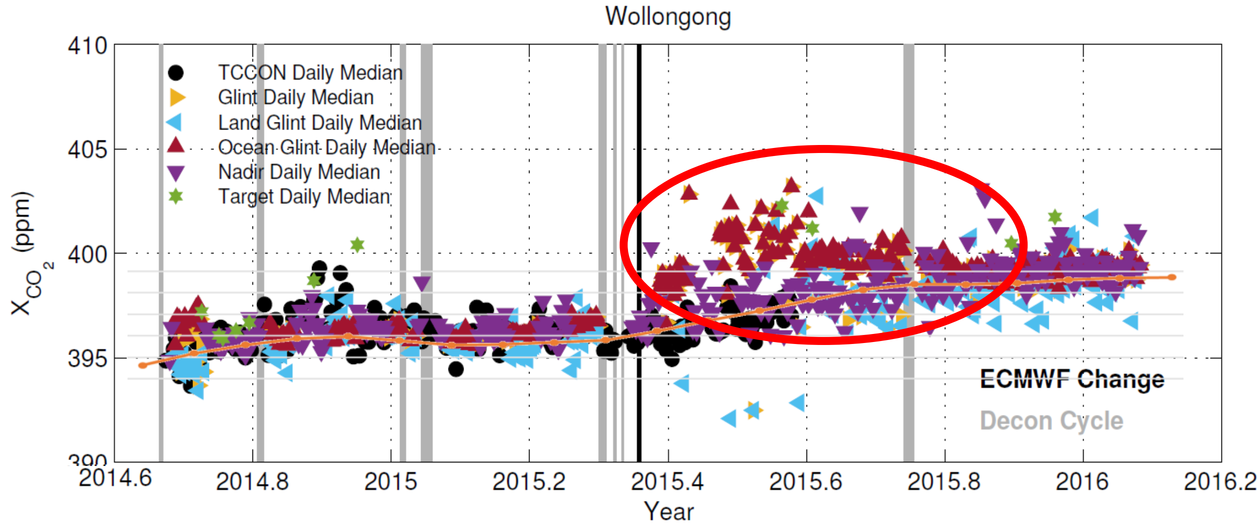
After applying a bias correction

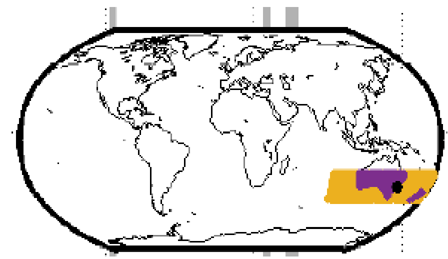
- Global bias is reduced to < 1 ppm
- Station-to-station biases reduced to ~1.5 ppm

Temporal Changes in X_{CO2}: Comparisons with TCCON and other Standards





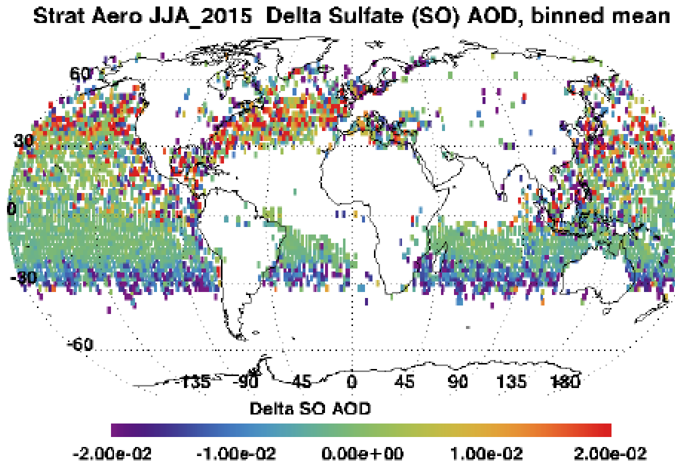


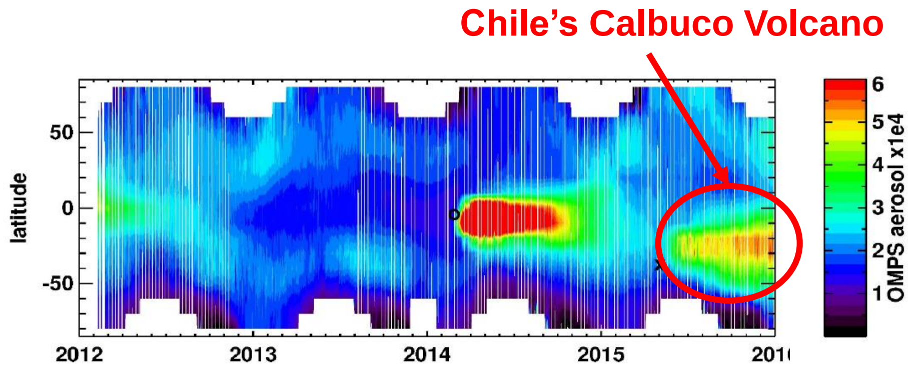


CSIRO Marine and Atmospheric Research and Australian Bureau of Meteorology (Cape Grim Baseline Air Pollution Station)

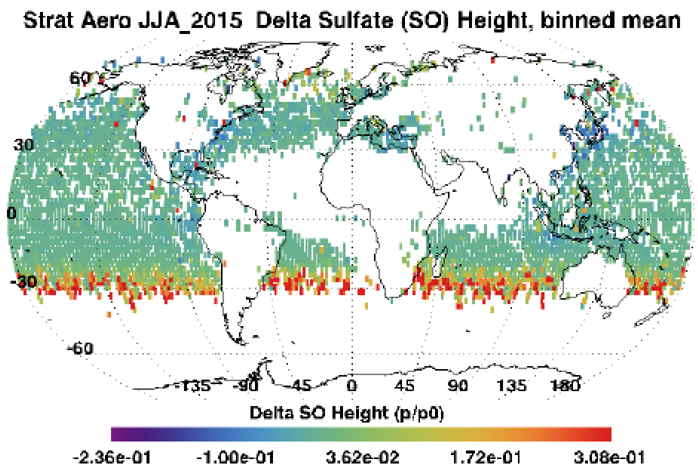
The 2015 Chilean Calbuco Volcano Eruption

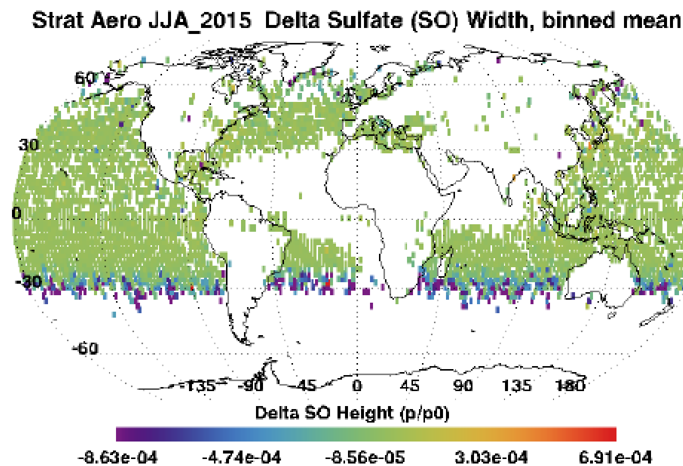
The 2015 Data affected by the Chilean Calbuco volcano eruption





OMPS detected a significant enhancement in stratospheric H_2SO_4 aerosols in mid 2015

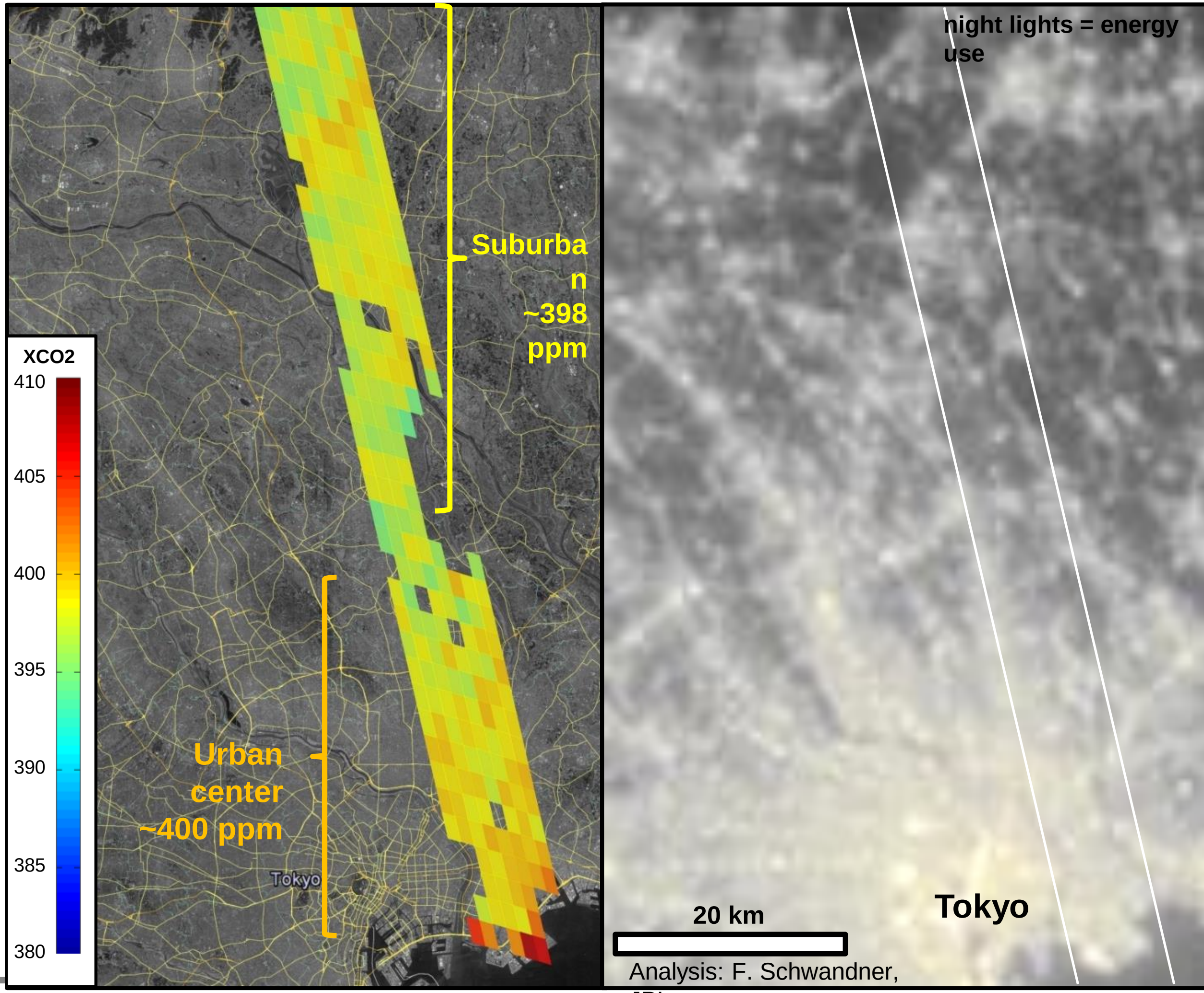




Distinguishing Small Scale CO_2 Emission Structures Using OCO-2:Schwandner et al.

<u>Example:</u> Tokyo, Japan
2011 metro pop. 35.7 mil.
Orbit 2095 nadir,
2014/11/23, vers. B7000

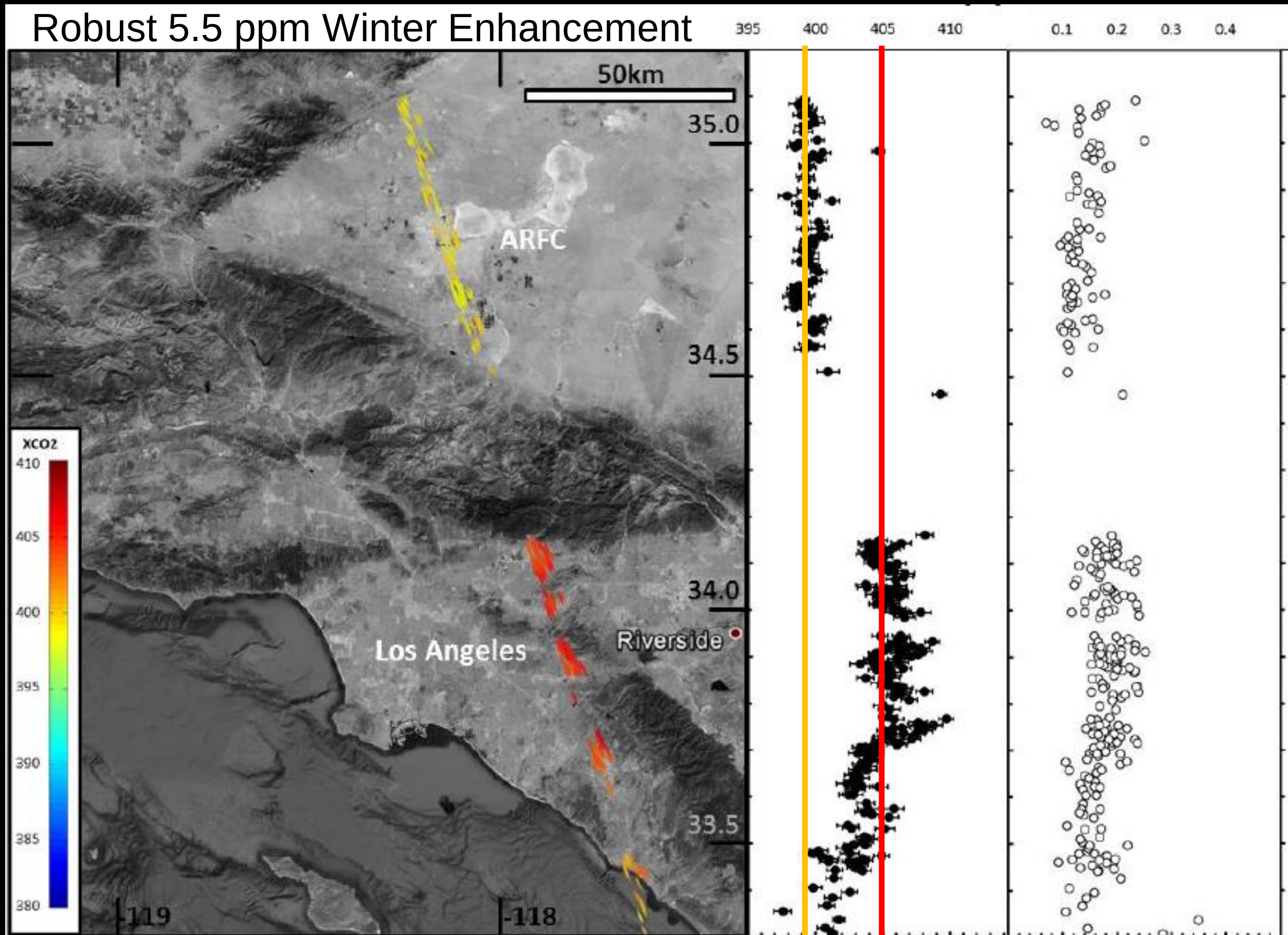
- Each parallelogram is a single X_{CO2} footprint.
- Enhancement of ~2 ppm observed over Tokyo center vs. suburban belt, in late November 2014.
- "Night Lights" image (on right) illustrates the extent of urbanization and energy consumption.



Analysis: F. Schwandner, JPL

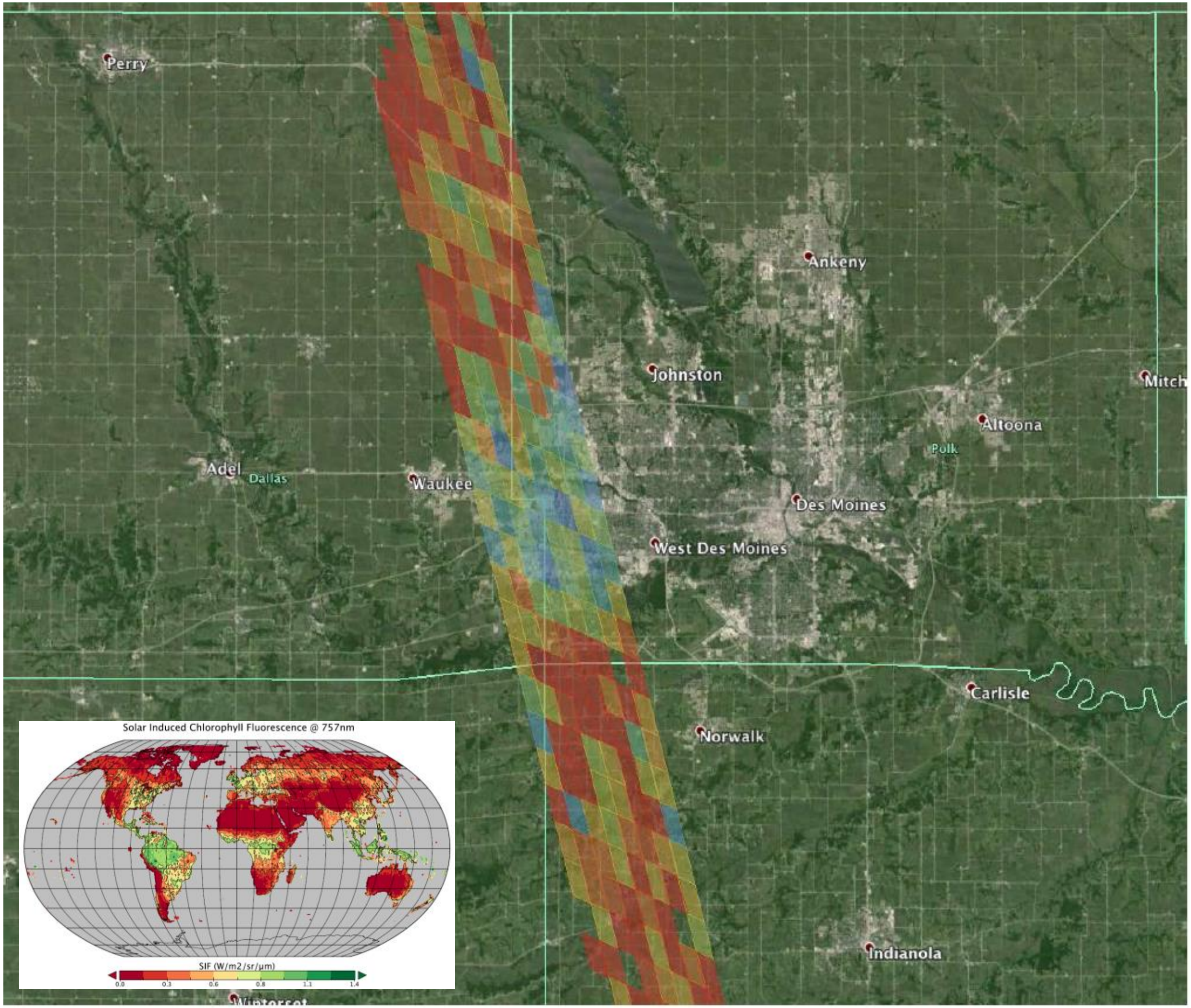
Small-Scale Emission Structures

2015/01/13 Glint orbit 2848 over Los Angeles and Antelope Valley



[Schwandner et al.]

Solar Induced Chlorophyll Fluorescence (SIF)



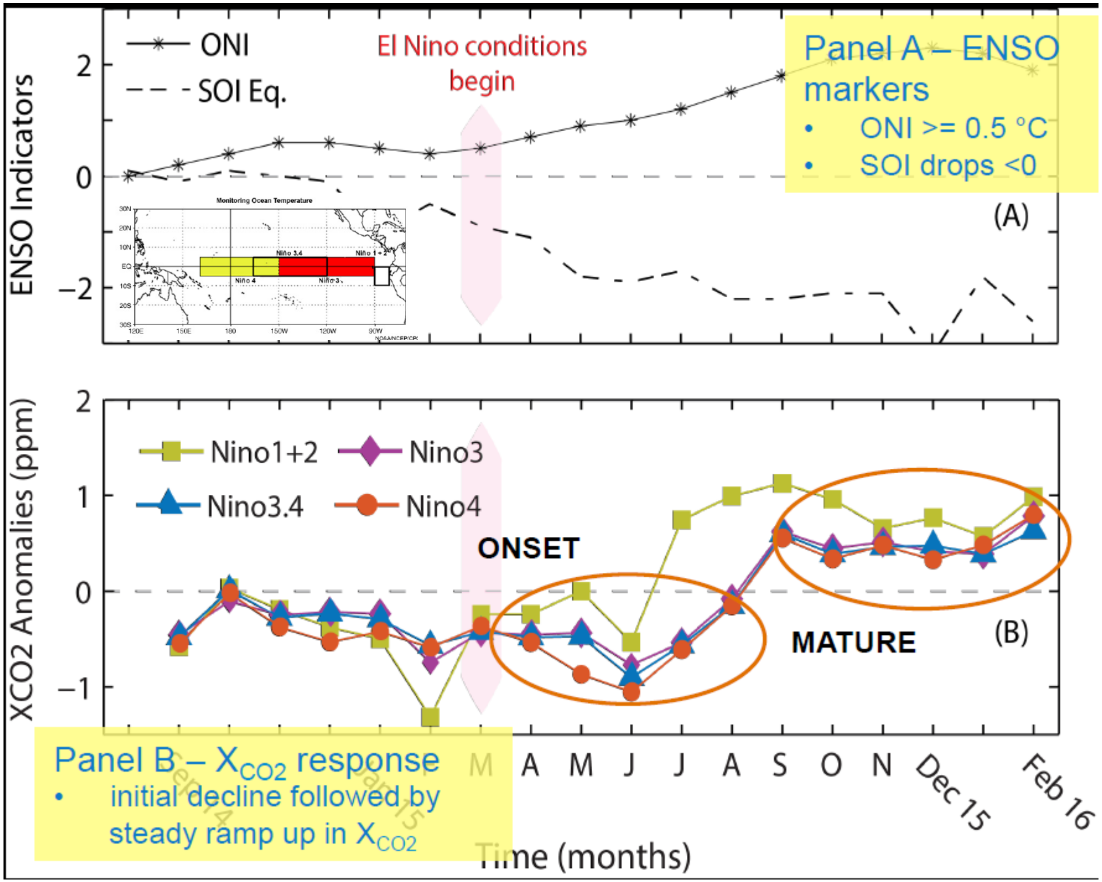
OCO-2 Flies over Des Moines, Iowa.

If not removed from the O_2 A-Band radiances, SIF will introduce biases in the dry air mole fraction and other A-band products

SIF measurements also provide a constraint on the spatial distribution of CO_2 uptake by photosynthesis

Influence of El Niño on Atmospheric CO_2: Findings from OCO-2: Chatterjee et al.

- OCO-2 data constrain the magnitude & phasing of ENSO-CO_2 relationship
- The ENSO-CO_2 effect is consistent with sparse in situ data



Two-Step Process

- **Development Phase**
  - Reduction in CO2 outgassing over Tropical Pacific, with negative anomalies over Nino 3 and 4
- **Mature Phase**
  - Higher CO2 over Nino 3 and 4 from biomass burning over SE Asia and reduced biospheric uptake

Conclusions for El Niño Observations

- The effects of El Nino on the carbon cycle are far more complex than deduced from sparse surface observations.

- El Niño affects surface *ocean* and *land* CO_2 fluxes.

- El Niño causes a transient *increase* in ocean carbon storage by reducing tropical outgassing.

- El Niño causes permanent losses of *forest carbon* as drought reduces forest productivity and increases biomass burning.

- Northern hemisphere carbon uptake continues during El Niño years, despite regional droughts.

Coming Attractions – OCO-2 V8 Testing

- Updates in the gas absorption coefficients and solar fluxes
  - Significant improvements in the O2 A-band absorption coefficients reduce dry air mass and surface pressure biases
  - Improvements in the temperature dependence and continuum absorption in the CO2 2.06 micron band reduce XCO2 bias
  - Updates in top-of-atmosphere solar spectrum reduce residuals

- Updates in the surface refection model
  - Improved BRDF model reduces viewing angle biases over land

- Recent insights into the cause of the southern hemisphere winter XCO2 glint anomaly
  - The CO2 bias over the ocean is very sensitive to the presence of a thin (AOD ~0.005), high altitude (stratospheric, 30 hPa) aerosol layer that was omitted in the version 7 product
  - Tests show that adding a thin stratospheric aerosol layer reduces (eliminates) the observed southern hemisphere glint XCO2 bias

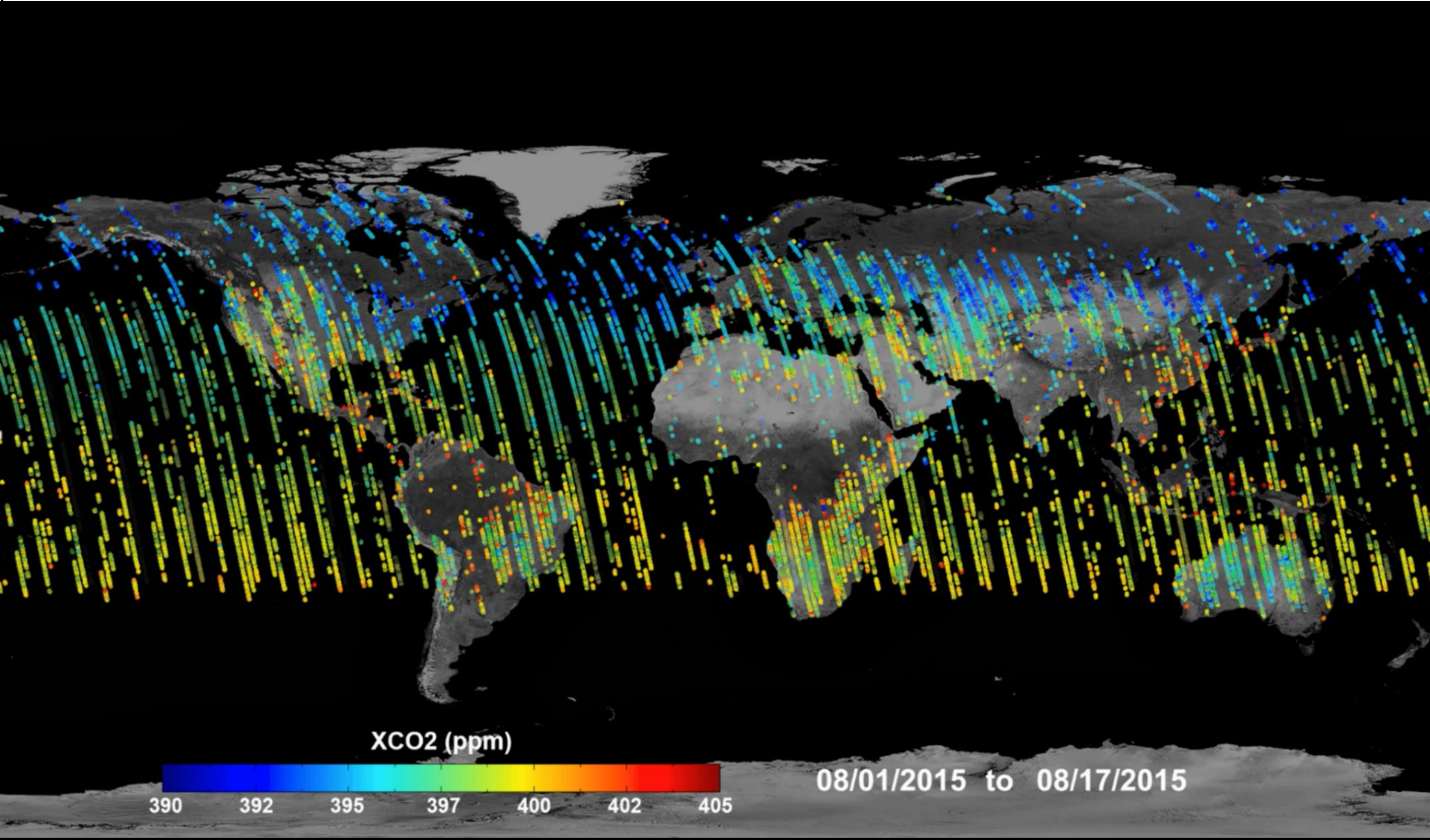
Summary

- OCO-2 was successfully launched on 2 July 2014, and began routine operations on 6 September 2014
  - Now returning about 100,000 full-column measurements of X_{CO2} each day over the sunlit hemisphere
  - These products are being validated against TCCON and other standards to assess their accuracy
- Over 18 months of data has been delivered to the Goddard Earth Sciences Data and Information Services Center (GES-DISC) for distribution to the science community
  - September 6 2014 – 4 May 2016 delivered

http://disc.sci.gsfc.nasa.gov/OCO-2

- This product is now being used by the carbon cycle science community to identify and quantify the CO_2 sources and sinks on regional scales over the globe

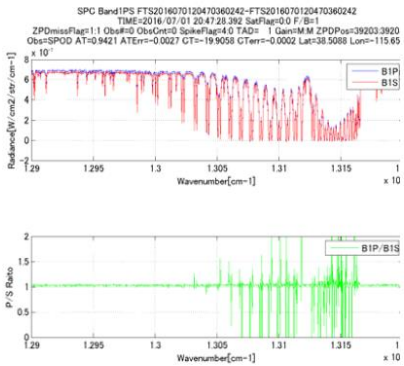
ACOS GOSAT B7.3 vs OCO-2 V7r

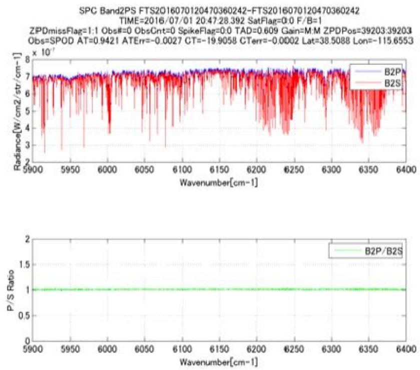


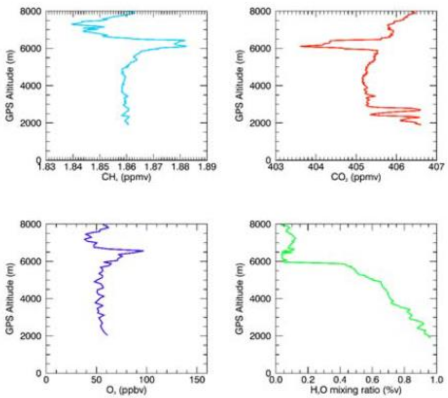
2016 Railroad Valley Campaign

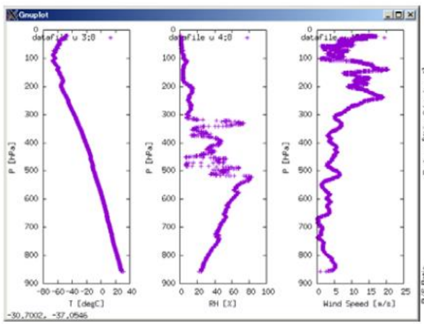
[Kuze et al.]

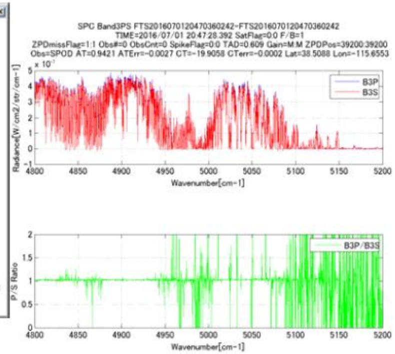
July 1, 2916 (path 36) Clear no cloud only above GOSAT foot print, GOSAT-OCO-2-alpha jet

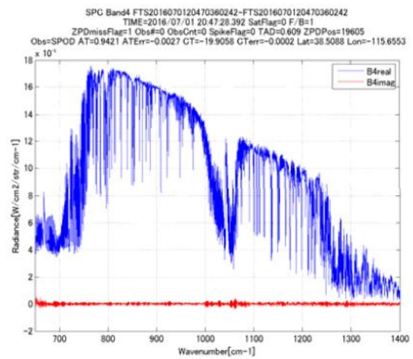












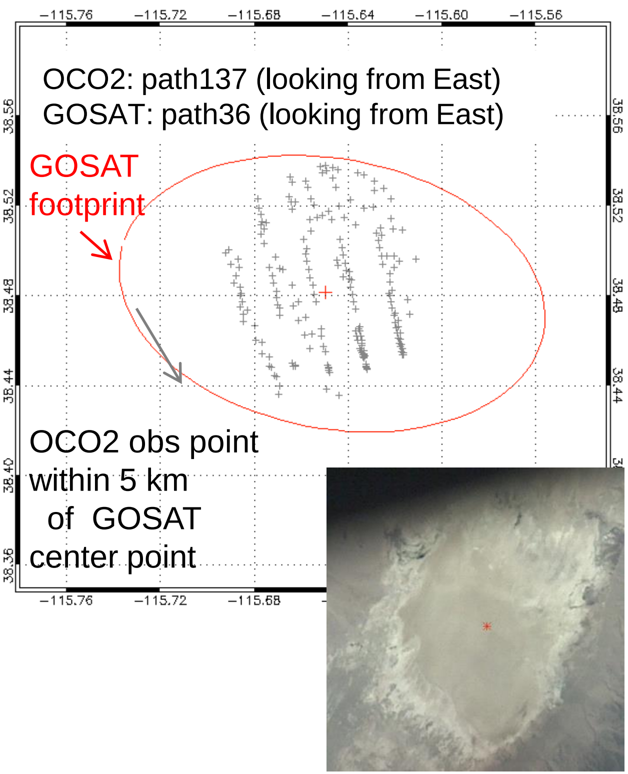
Clouds have been a problem this year, but cloud-free data were collected on 1 July 2016, which included OCO-2 (orbit 139) and GOSAT (orbit 36) overpasses.

OCO2- GOSAT Radiometric Comparison
[Kataoka et al.]

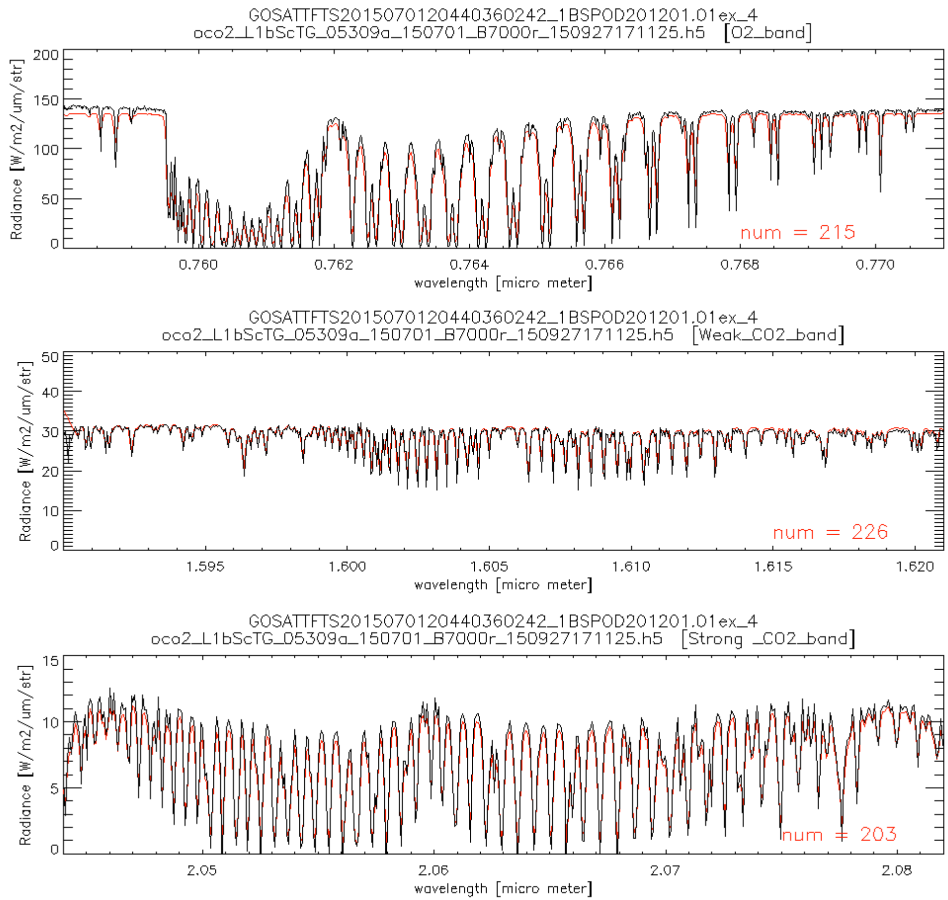
Comparisons between OCO-2 and GOSAT also indicate very good agreement

Jul01,2015 [1]

oco2_L1bScTG_05309a_150701_B7000r_150927171125.h5
GOSATTFTS2015070120440360242_1BSPOD201201.01



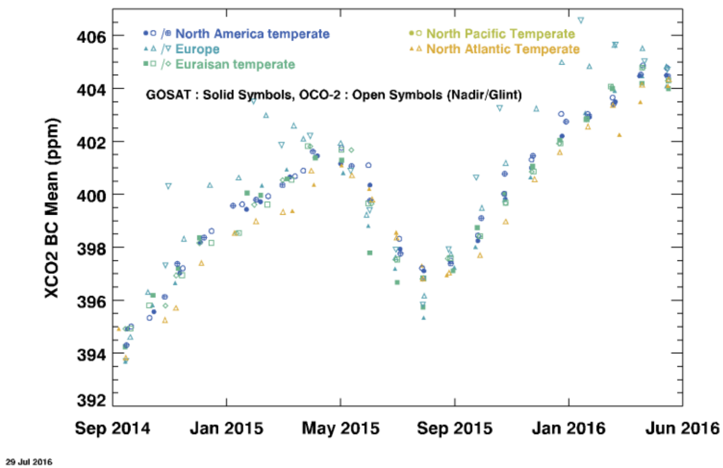
GOSAT Rad
OCO2 average Rad within 5km of GOSAT cnt point X 2
ratio1 = OCO2/GOSAT

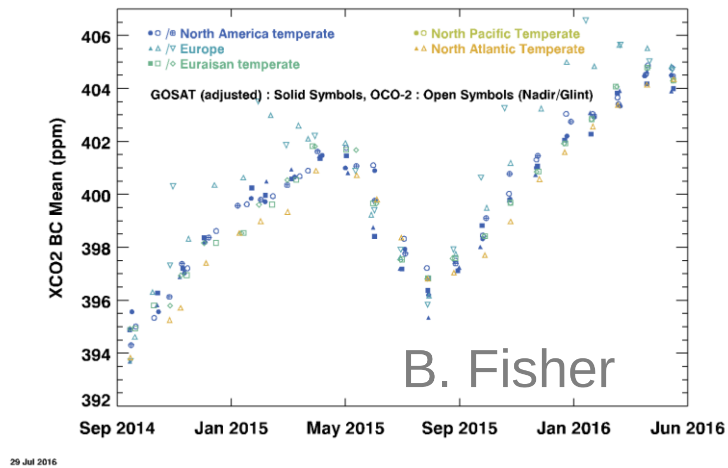


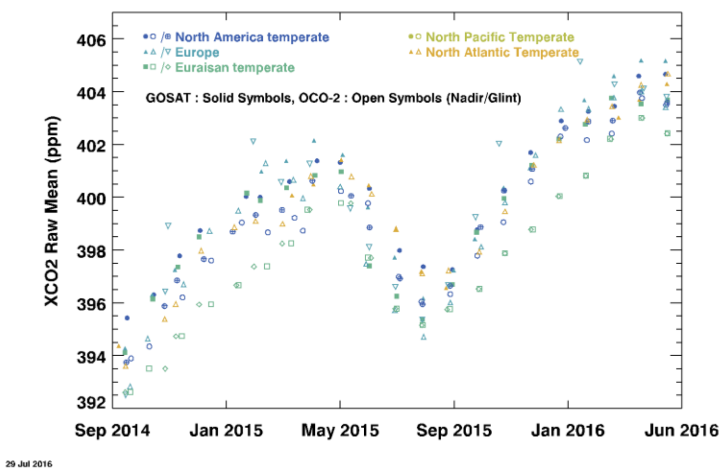
ACOS B7.3 vs OCO-2 V7r

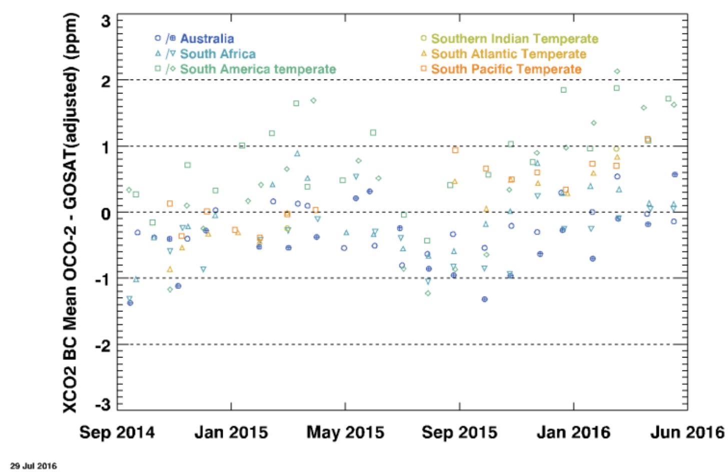
- Comparisons use monthly averages over 18 TRANSCOM regions for overlap period (22 months)
- Compare XCO2 vs time for GOSAT land gain H and ocean
- 3 sets of plots for each:
  - Northern Hemisphere regions
  - Tropical regions
  - Southern Hemisphere regions
- Latitude sampling bias adjustment needed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









Observations

- In general, the ACO2 GOSAT 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
- Ice AOD Lower and less variable in OCO2 but Ice Height much more varied in OCO2