Committee on Earth Observation Satellites

# OCO-2 and OCO-3

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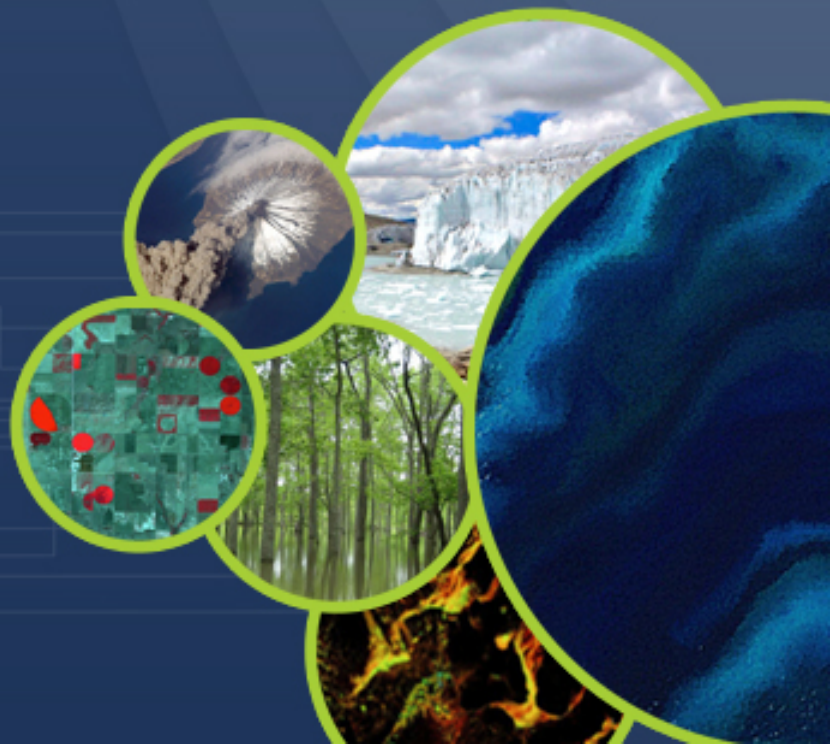
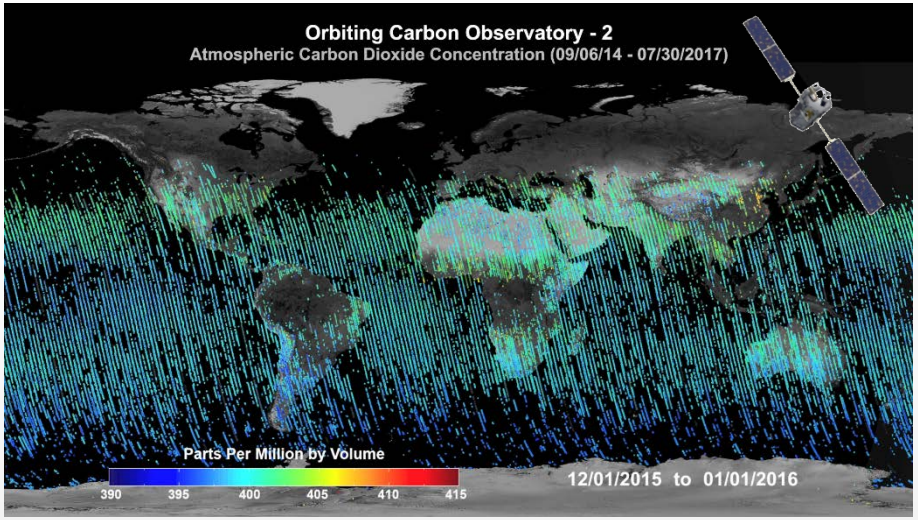
College Park, MD, USA

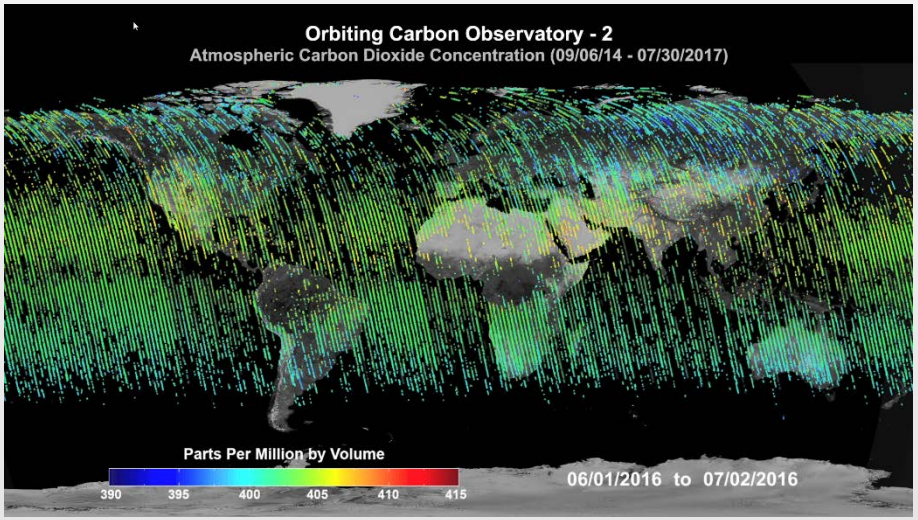
2-4 May 2018



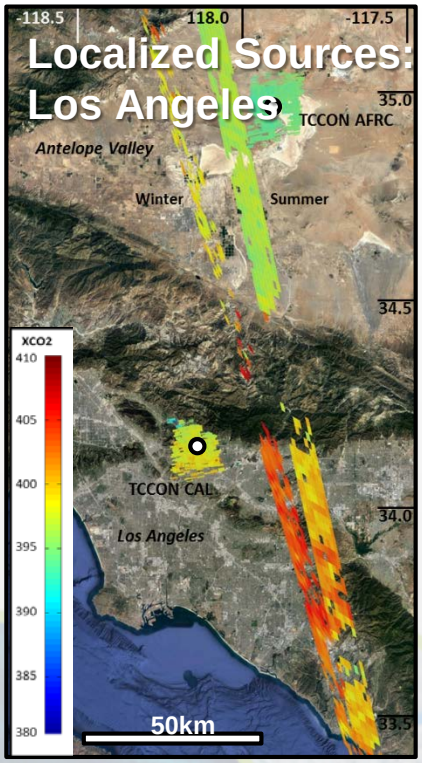
# NASA Orbiting Carbon Observatory-2 (OCO-2)

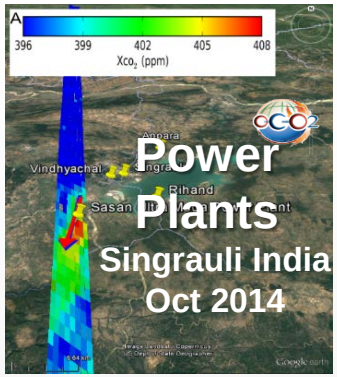
- OCO-2 was launched in July 2014
- Since then, it has been collecting one million soundings each day
- About 85000 of these are sufficiently cloud free to yield estimates of $X_{CO2}$ with single sounding random errors < 0.5 ppm and regional scale biases < 1 ppm
- These data have been used to
  - describe the $CO_2$ distribution with unprecedented resolution, and coverage
  - study emission from compact sources (cities, power plants) the tropical carbon cycle response to the 2015-2016 El Niño

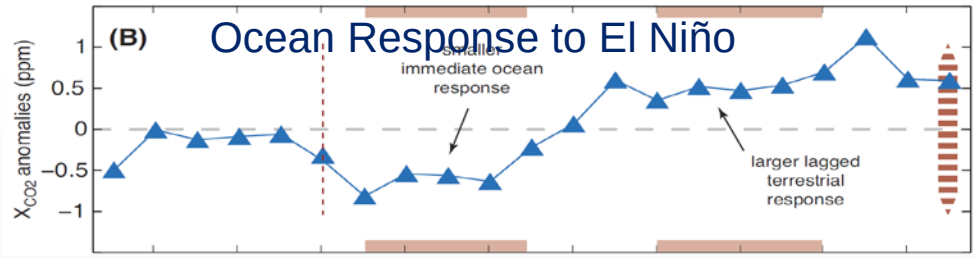


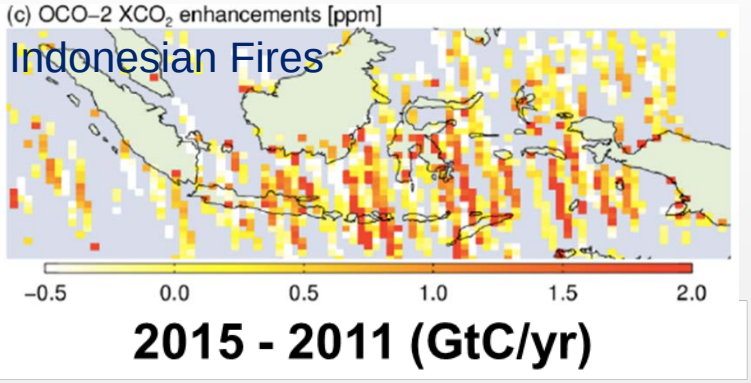



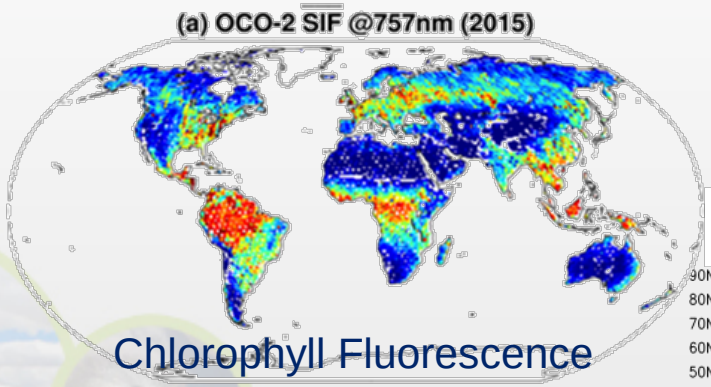
# A Quick Look at OCO-2 Science Results

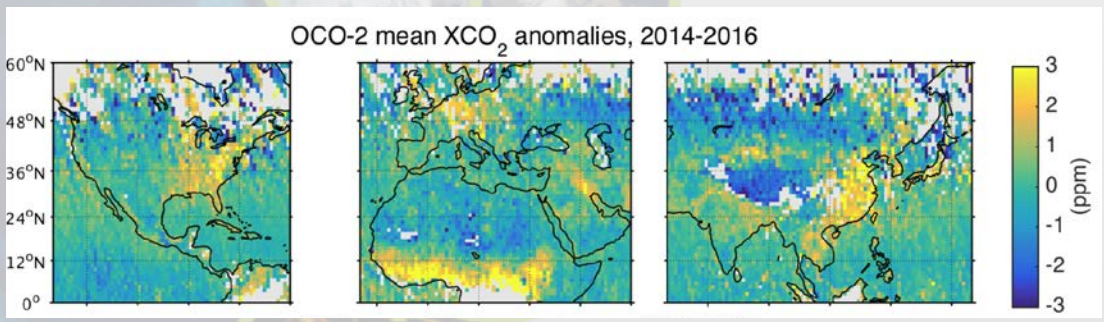


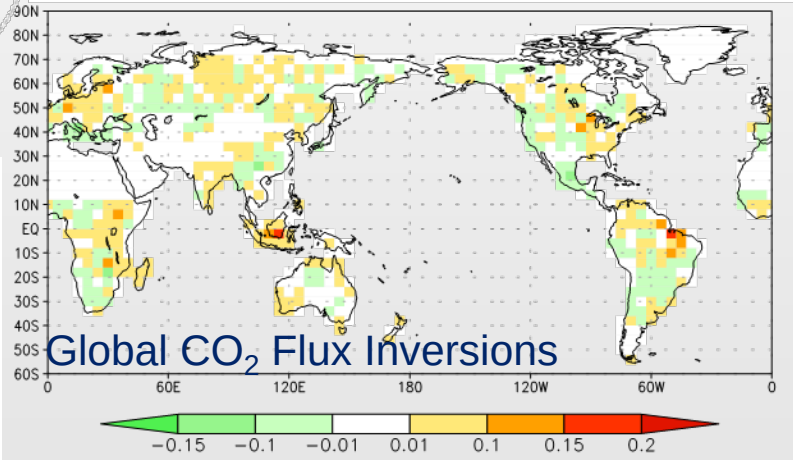



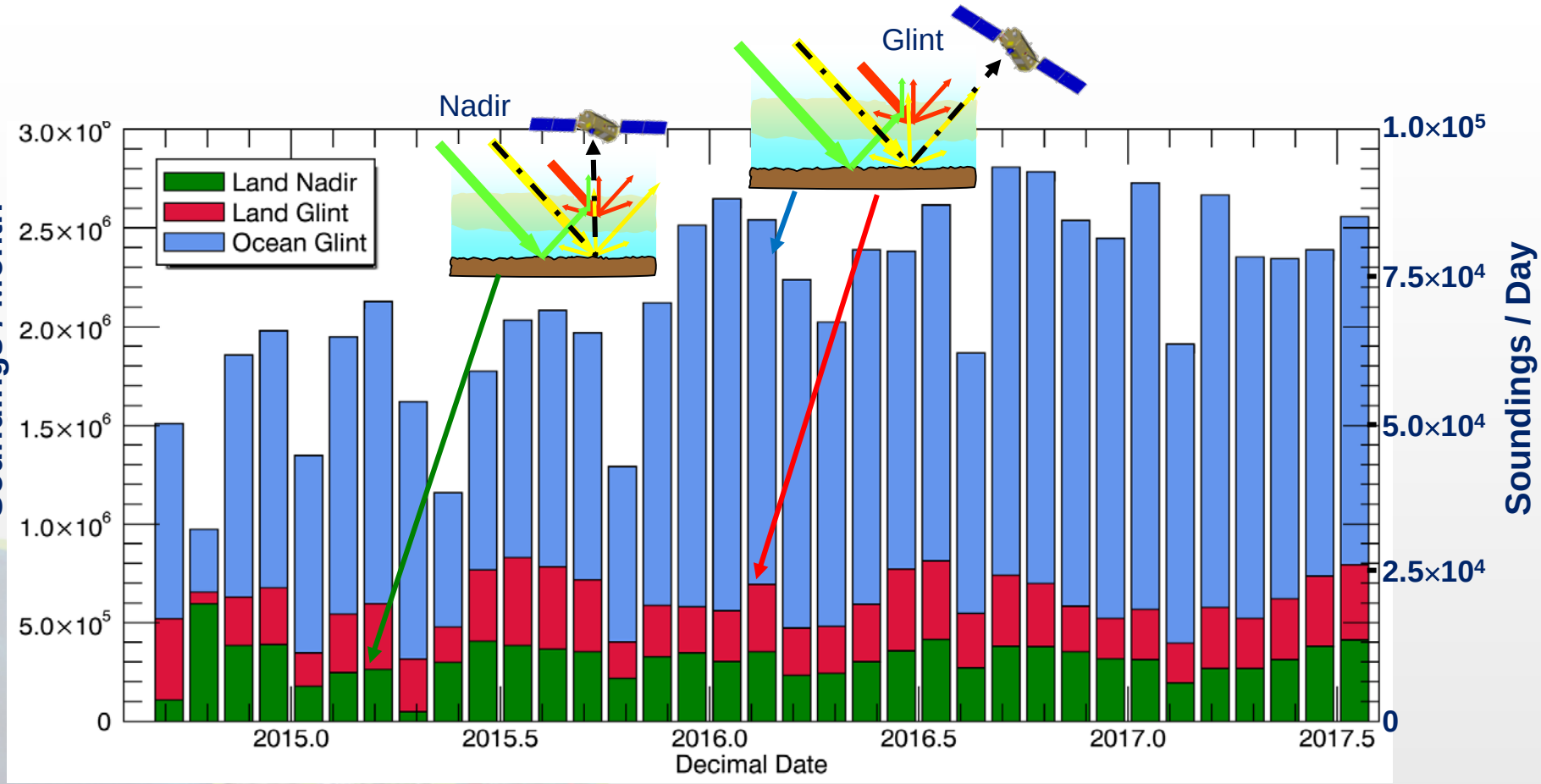



# A New OCO-2 Data Product: Build 8 (B8)

- Improved Calibration
  - Fast (icing) and slow (solar diffuser) degradation corrected
  - Corrected zero level offset A-band detector
- Retrieval algorithm updates
  - Gas absorption cross sections (ABSCO 4.2 vs 5.0)
  - Added an optically-thin, stratospheric aerosol type
  - More realistic land surface reflectance model (soil BRDF)
  - Updated cloud screening, bias correction, and warn levels
  - Other small improvements
    - Changed prior meteorology from ECMWF → GEOS5 (FP-IT)
    - Revised $X_{CO2}$ and Cirrus priors
    - Updated top of atmosphere solar spectrum

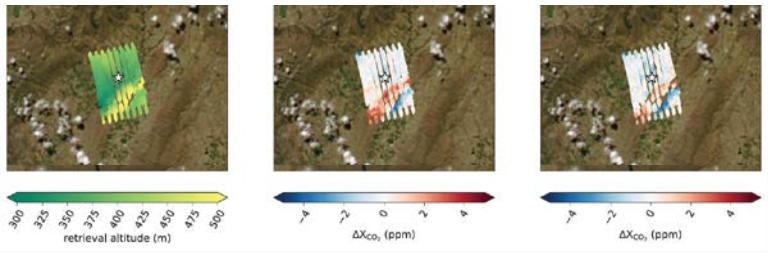
# The V8 Sounding Yield



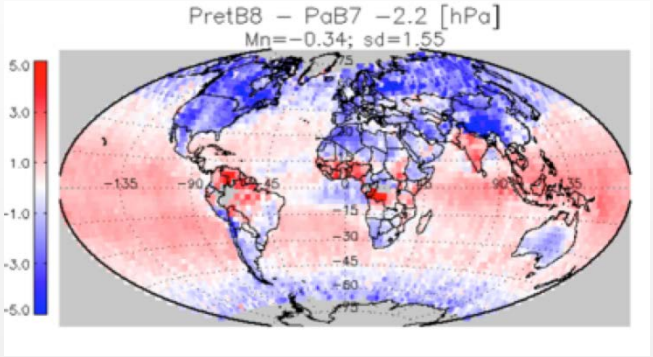

The glint/nadir observation strategy was refined to maximize the number of full-column $X_{CO2}$ retrievals. The “optimal” strategy, implemented in November 2015 acquires ocean glint on orbits predominately over the Atlantic or Pacific Oceans.

# Know Issues with B8

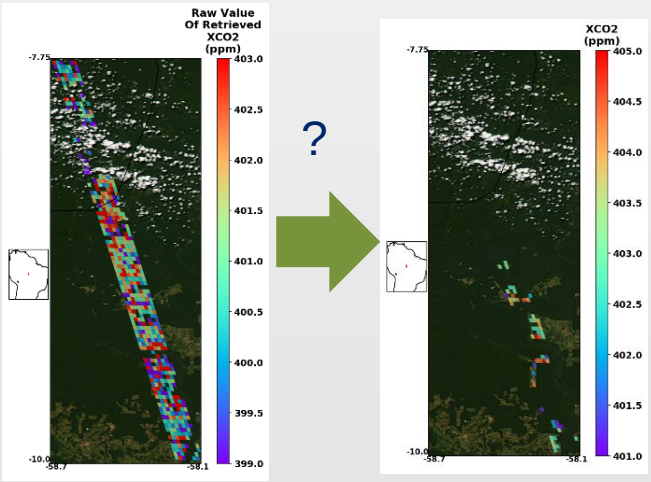
- Small (~100 arc-sec) Pointing/Geolocation errors introduce systematic biases in regions with significant topography




- A pole-to-pole surface pressure bias was introduced by the updated A-band gas absorption coefficients

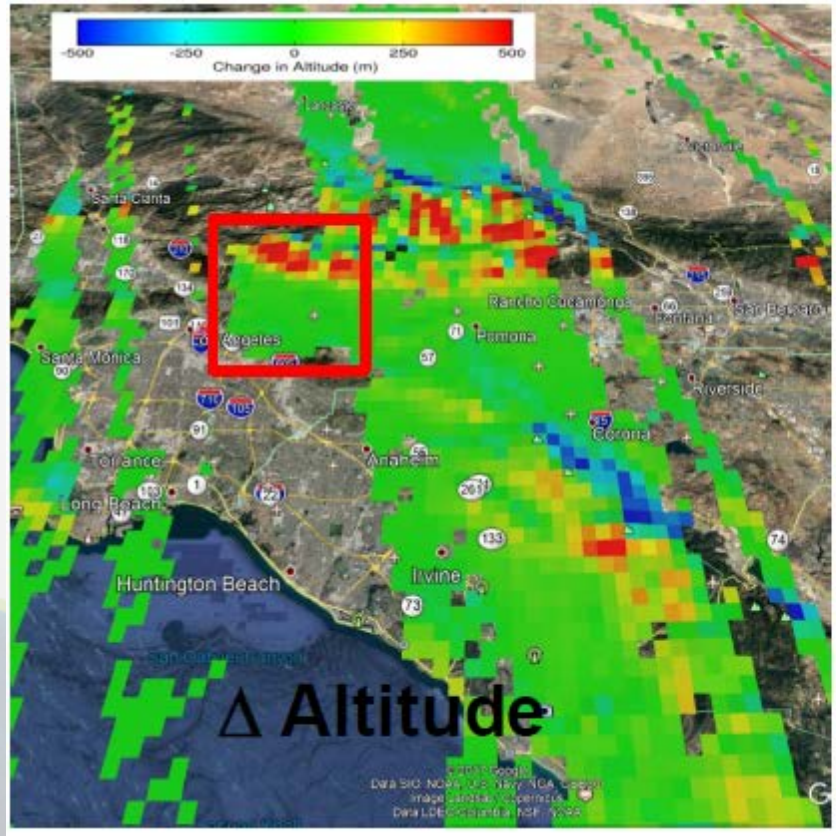


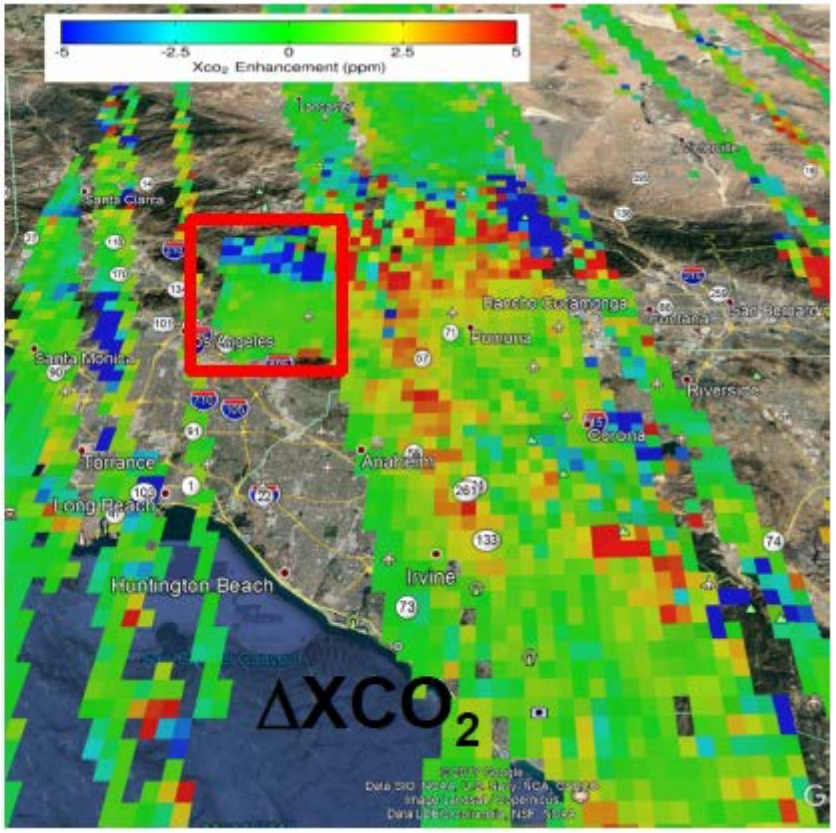

- Comparisons with TCCON show a long-term drift in the $X_{CO2}$ product




- Dark surface albedo screening is too aggressive

# Correlation between Surface Elevation and $X_{CO2}$ Anomaly

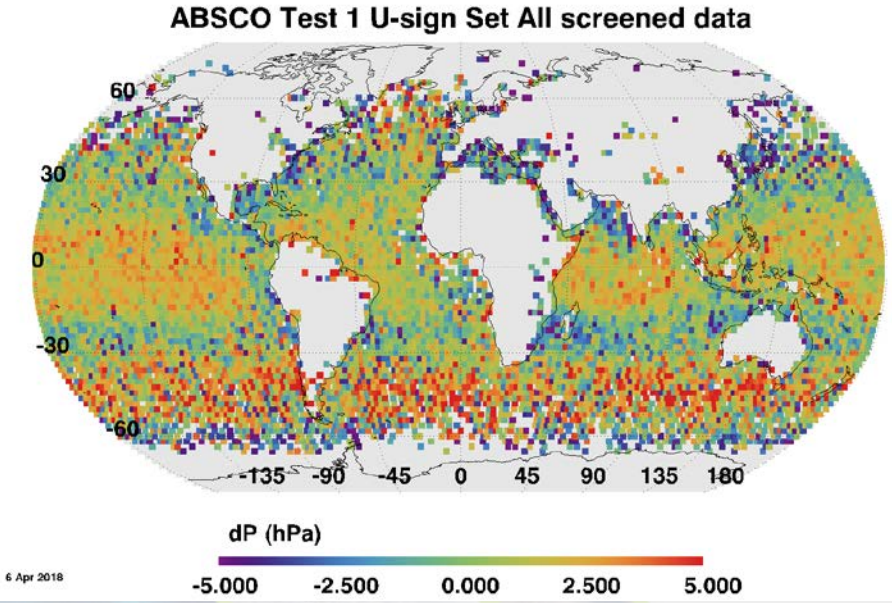


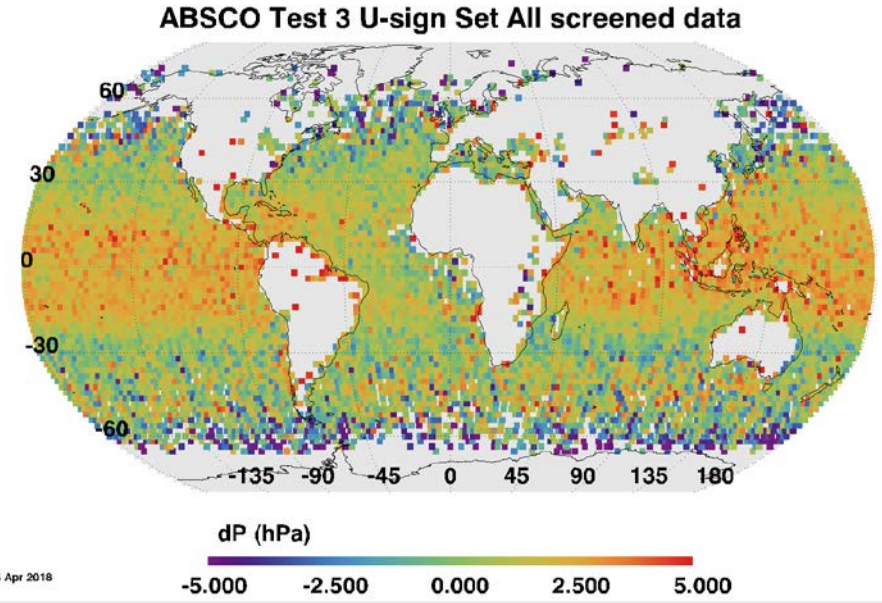

Maps of surface elevation (left) and $X_{CO2}$ anomaly over the LA basin show that positive anomalies are correlated with slopes with altitude increasing to the north or east. Target observations (red boxes) show the opposite correlation. These observation are consistent with a pitch error (Nassar and MacDonald).

# Surface Pressure Bias Introduced by ABSCO

V7 Baseline with Version 4.2 ABSCO




V7 Baseline with Version 5.0 ABO2 ABSCO



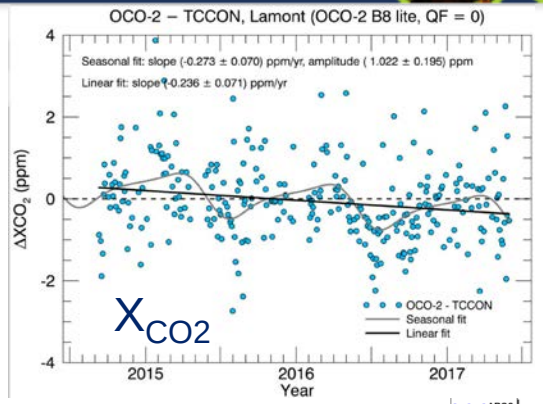

- Version 5 O2 gas absorption coefficients (ABSCO, right) substantially reduced the amplitude of land/sea and ocean glint surface pressure biases and scatter seen in Version 4.2 ABSCO (left).
- However, it apparently introduced a larger, more coherent pole-to-pole bias.
- This difference is well compensated in the bias-corrected XCO2 data included in the V8 Lite files.

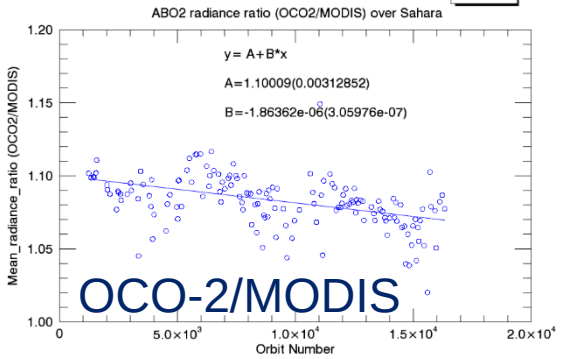
Brendan Fisher and Vivienne Payne

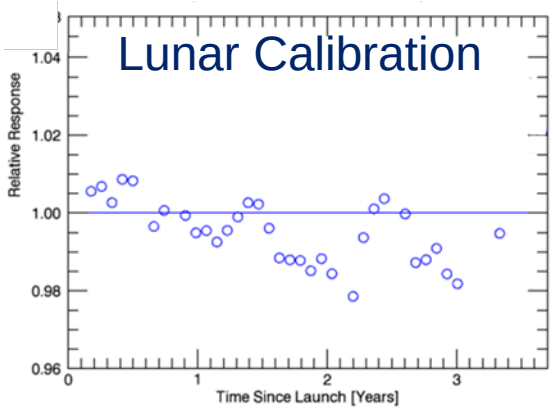
# Long Term Radiometric Drifts

Shanshan Yu

- Comparisons of the OCO-2 V8 product with TCCON indicate a long-term drift (0.1 ppm/yr)
- This drift is correlated with a long term drift in the radiometric calibration of the V8 L1b product
  - OCO-2 was cross calibrated against MODIS Aqua over the Sahara
    - Location box: 15°-23°N, 5°-17.5°E
  - Differences in viewing geometry (BRDF) and spectral interpolation may account for overall biases (based on RRV experience)
  - Comparisons indicate ABO2 ($O_2$ A-band) channel has a drift of -0.9% / year
- Similar drifts seen in lunar calibration trends
- These changes will corrected in the next data product.



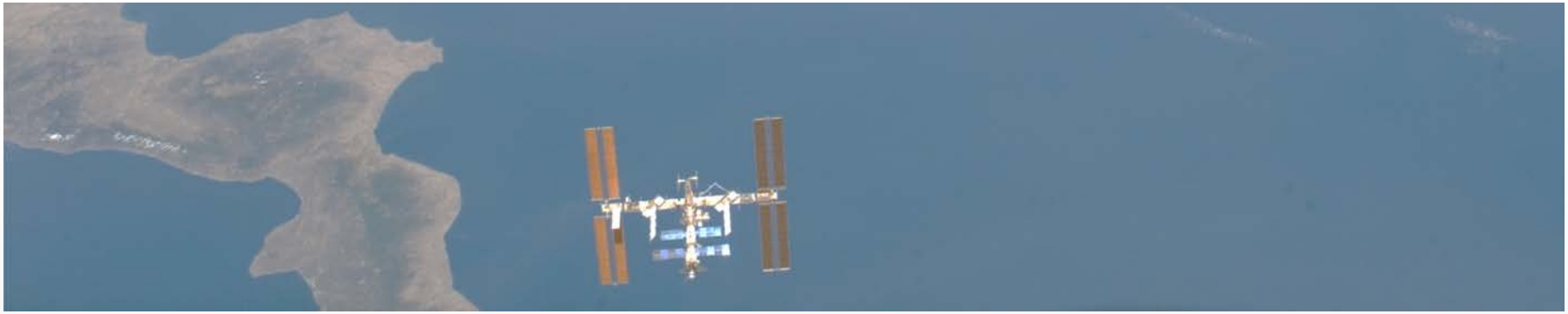



# Updated Lite Files: B9

- The OCO-2 data products that are routinely delivered to the Goddard Earth Science Data and Information Services Center (GES DISC) are
  - L1B - calibrated, geolocated spectral radiances
  - L2 Standard products - XCO2, SIF, other geophysical variables, consisting of 14.5 orbit-based “granules/day
  - L2 XCO2 “Lite files” – a streamlined version of the XCO2 products that include both raw and bias corrected values as one file/day
  - L2 SIF “Lite files” – a streamlined version of the SIF product consisting of one file/day
- A updates series of Lite Files will delivered during the summer of 2018
  - Corrected pointing/geolocation biases
  - Refined surface pressure bias correction
  - Possible corrections in the SCO2 dark surface screen to improve yields over tropical forests

# OCO-3 Status



- JPL has been instructed to complete the preflight testing, deliver, and prepare for a launch to the International Space Station (ISS) in early 2019

- The OCO-3 team is conducting the “final” thermo vacuum (TV) test at JPL April/May of 2018

# Comparison of OCO-2 and OCO-3 Measurements

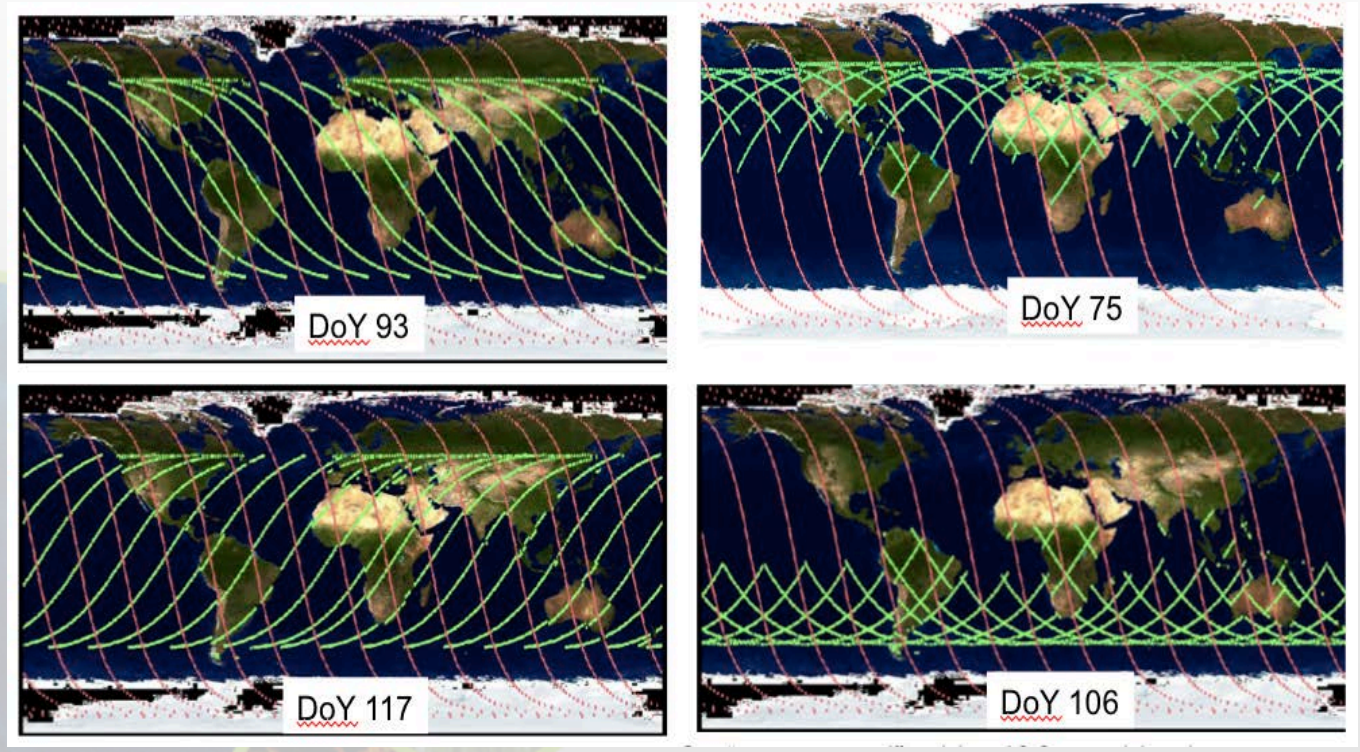
| | OCO-2 | OCO-3 on ISS |
|---|---|---|
| Latitudinal coverage | +/- 80 degrees | +/- 52 degrees (on ISS) |
| Local time of day sampling and repeat | ~1:30pm with 16 day routine and repeated measurements | Ranges across all sunlit hours with variable revisit (0 to multiple per day) |
| Land Sampling | Every day (using glint and nadir measurements) | Every day |
| Glint/Ocean Sampling | 16 days on/16 days off (originally) | Every day |
| Target/mapping mode capability | Target mode achieved with spacecraft pointing | Target and mapping expanded with pointing mirror assembly |
| Polarization approach | Keep instrument slit in principal plane (actually 30 degrees off) | Collect data at wide range of polarization angles |

As an integrated dataset:

- The OCO-2 and OCO-3 missions in series provide an extended time series of $X_{CO2}$
- OCO-3 has different sampling characteristics and therefore different error characteristics, this will need to be accounted for when using the datasets together
- Existing retrieval algorithm does not need to be modified for use with OCO-3 data

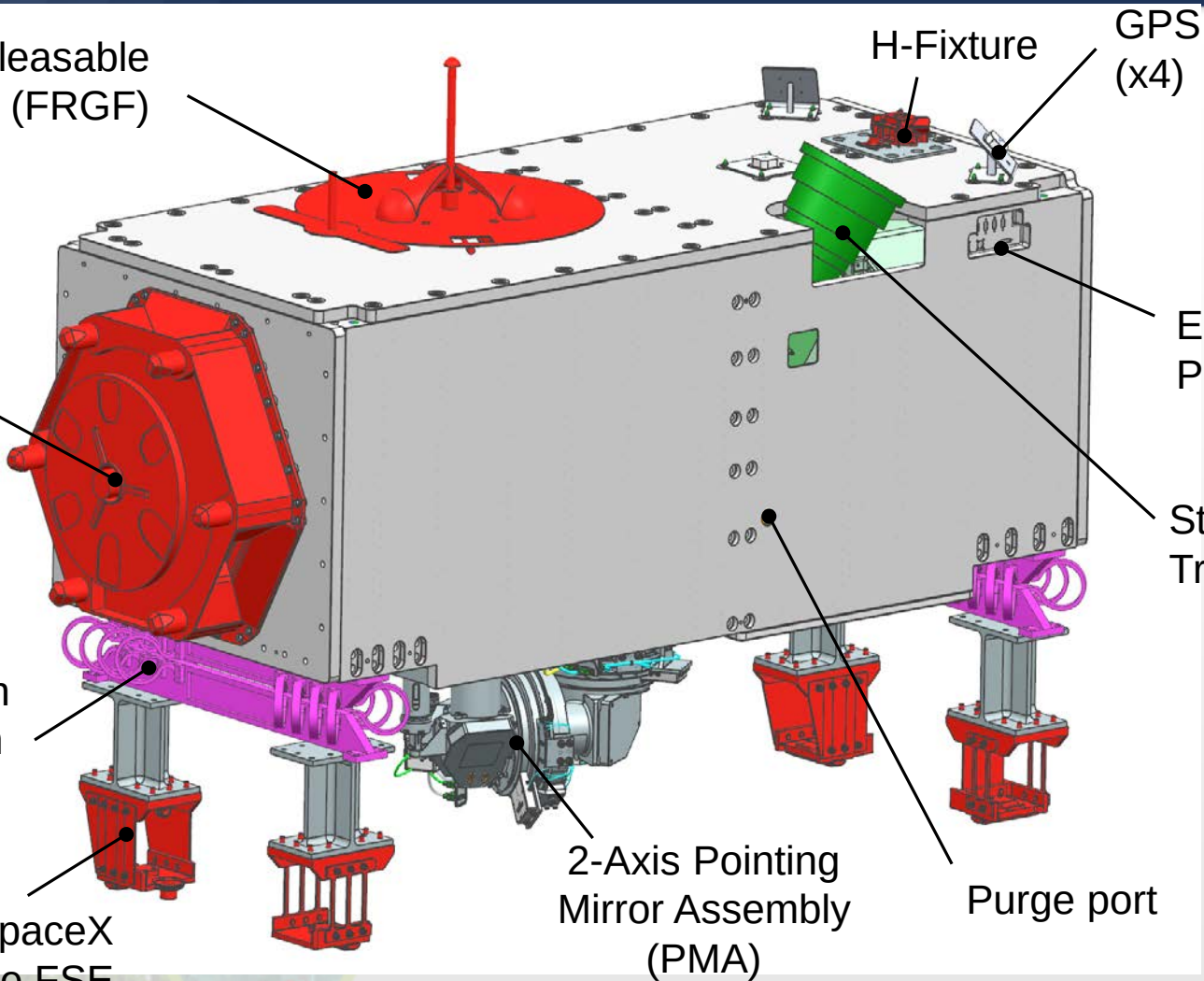
# Seasonal and Latitudinal Variations of OCO-3

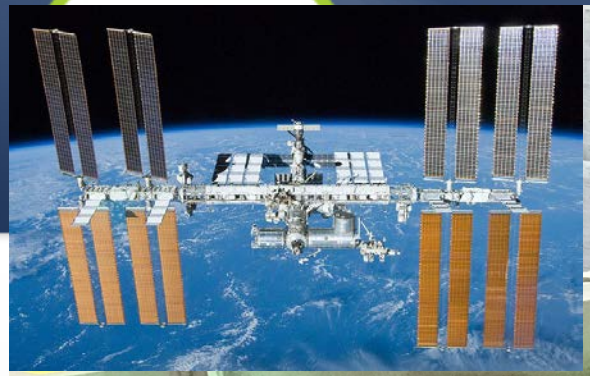
- Sampling would be dense at mid-latitudes, while providing good coverage of tropics and sub-tropics
- The 2-axis pointing system would enable new operations concept with nadir *and* glint observations taken on every orbit, increasing the number of useful samples over oceans as compared to OCO-2



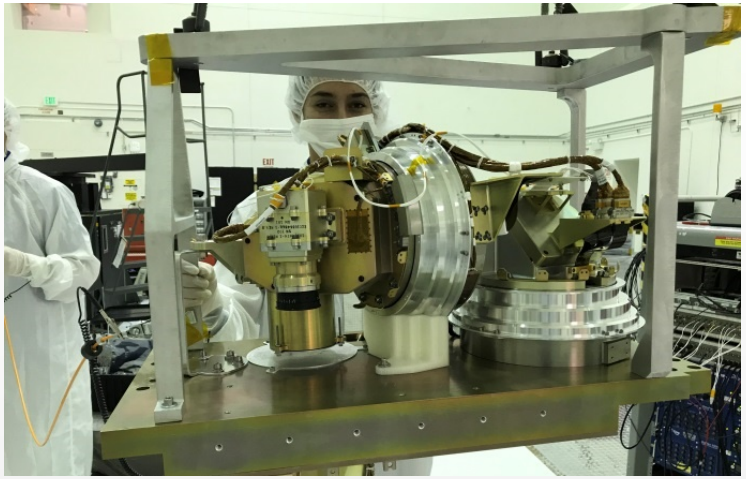

OCO-3/ISS orbits (green) and OCO-2 (pink). On “turn-around” orbits, ISS would provide better coverage of mid latitudes of one hemisphere.

# OCO-3 Payload Exterior





# The OCO-3 Pointing Mechanism Assembly



- Unlike the OCO-2 spectrometer, which is pointed by the spacecraft, the OCO-3 instrument uses an agile, 2-axis pointing mechanism
- provides capability to look towards the ocean glint spot and validation targets.
- Also allows for a snapshot mapping mode to collect dense datasets over 100km by 100km areas.

End Target Mirror

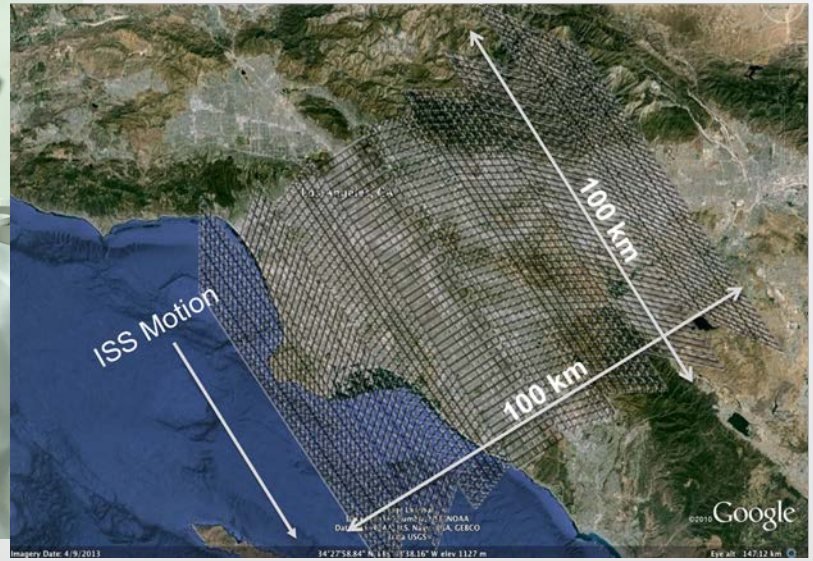
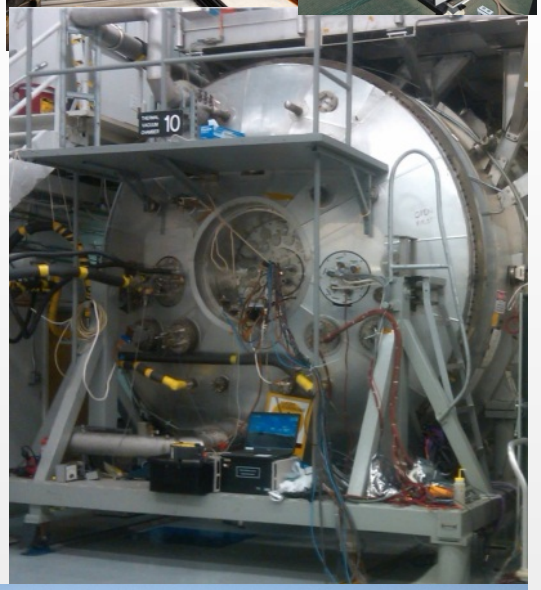



***Figure 2:*** *Google map of the Los Angeles basin showing the coverage provided by the OCO-3 snapshot mapping mode. This mode can be used to map up to 100 targets each day.*

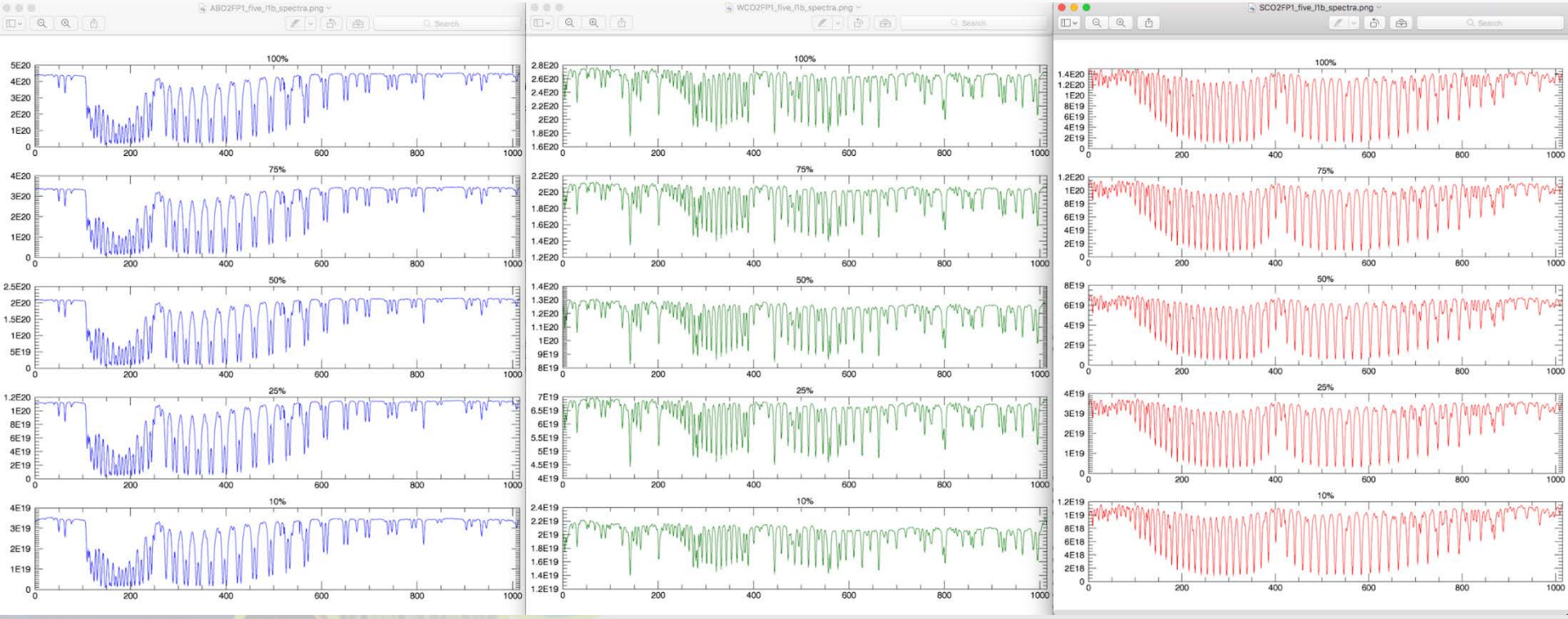
# OCO-3 is Undergoing its final Thermo-Vacuum Test

- Pre-flight testing quantifies key Instrument performance and knowledge parameters
  - **Geometric**
    - Field of view, Bore-sight alignment
  - **Radiometric**
    - Zero-level offset (bias)
    - Gain, Gain non-linearity
  - **Spectroscopic**
    - Spectral range, resolution, sampling
    - Instrument Line Shape (ILS)
  - **Polarization**
  - **Instrument stability**



# OCO-3 Heliostat Spectra

- Like OCO-2, the OCO-3 instrument can observe direct sunlight through a heliostat installed above the TV chamber
- Preliminary results from OCO-3 look very good due to a much lower number of bad pixels



# Conclusions

- OCO-2 completed its nominal mission in October 2016 and started its first extended mission with a healthy spacecraft and instrument
- OCO-2 data are now being used by the carbon cycle science community to study $CO_2$ sources and sinks
- The V8 data product was delivered in the fall of 2017
  - Provides improvements in accuracy (relative to TCCON) and coverage
  - Includes a few known issues that are being characterized and will be addressed by updated version 9 Lite files, which will be released this summer
- The final OCO-3 Thermo-Vacuum test has been initiated
- The instrument will be delivered this fall, in preparation for a launch to ISS in early 2019