



Early Results from the NASA Orbiting Carbon Observatory-2 (OCO-2)



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for the OCO-2 Science Team

California Institute of Technology, Jet Propulsion Laboratory

08 June 2015



The Next Step – OCO-2



Credit: Bill Ingalls, NASA



Credit: Jeff Sullivan

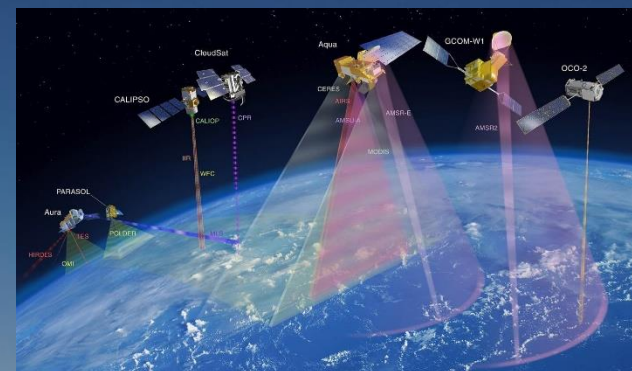


Credit: NASA

Separation!



Credit: Jeff Sullivan



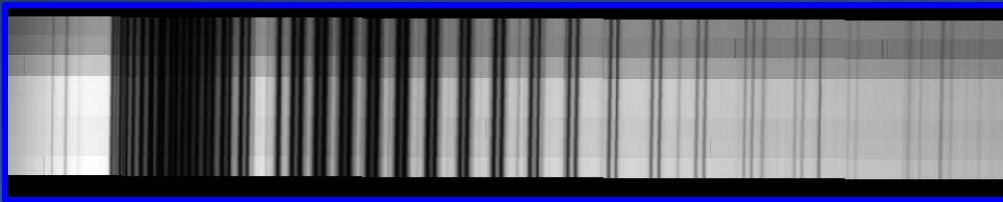
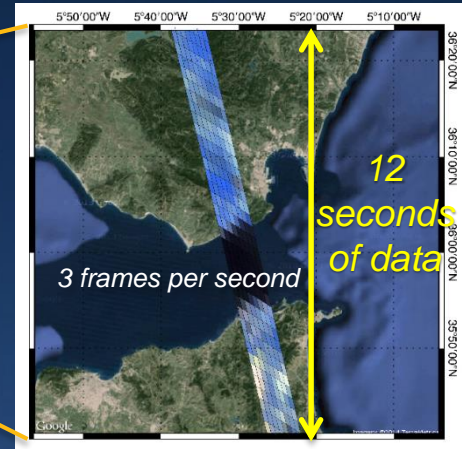
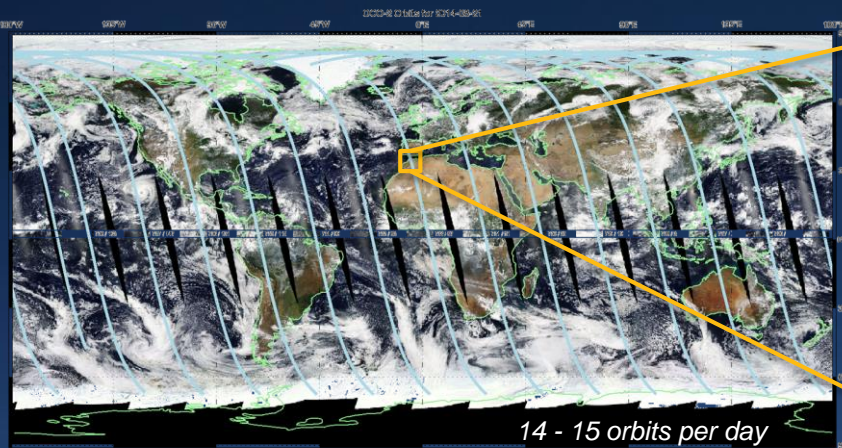
Joining the A-Train 3 August 2014

Lift-off at 2:56 am
PDT, 02 July 2014





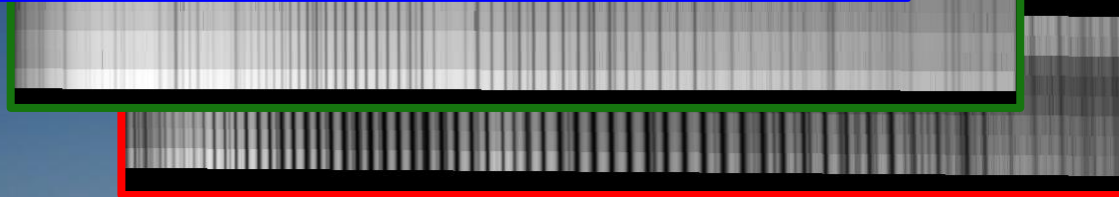
OCO-2 Sampling Approach



O₂ A-Band

CO₂ 1.61 μm Band

CO₂ 2.06 μm Band

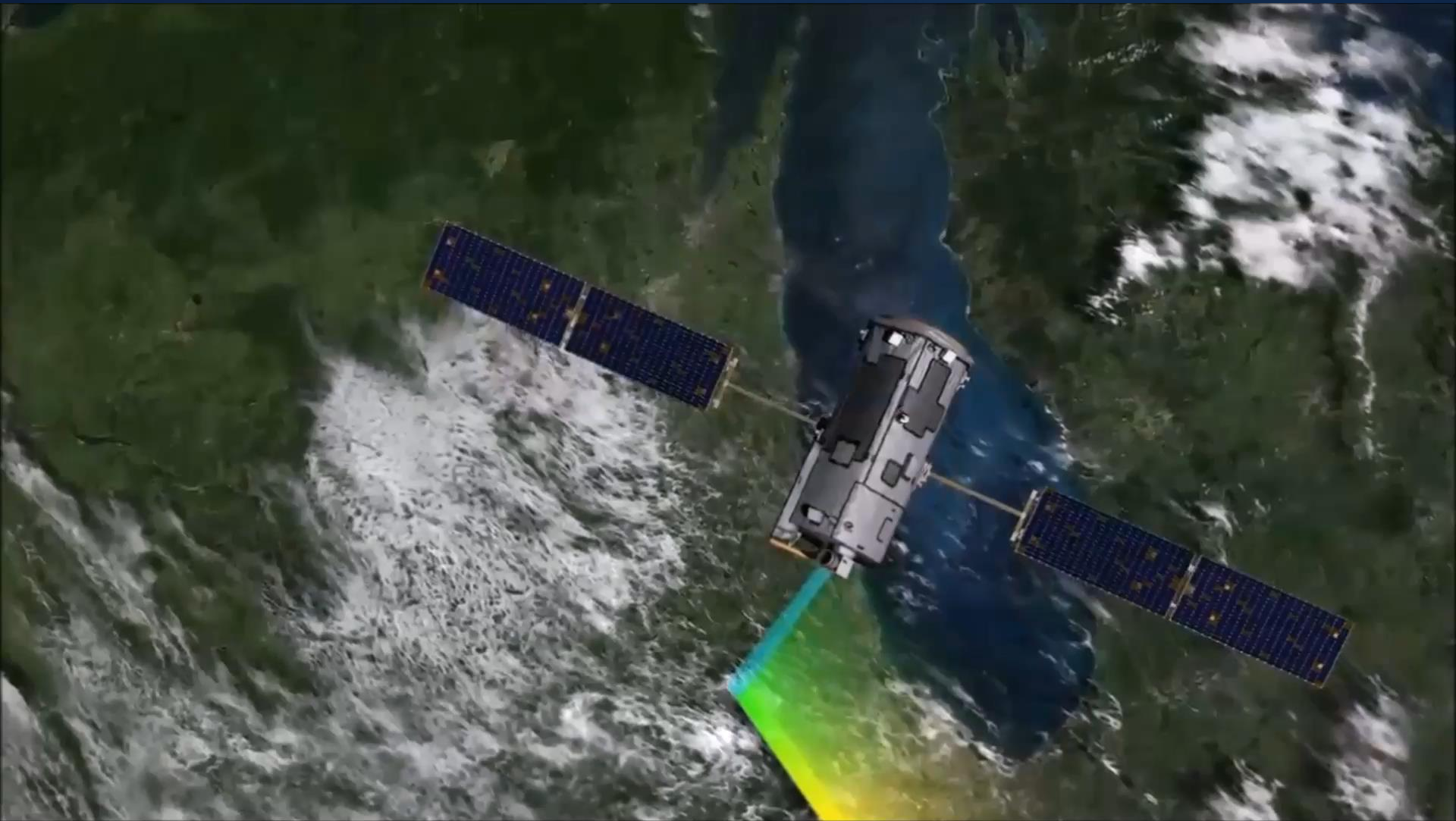


Each 1/3 of a second frame includes 8 spatial footprints with 1,016 wavelengths sampled in the O₂ A-band and Weak and Strong CO₂ bands yielding almost 1 million soundings each day



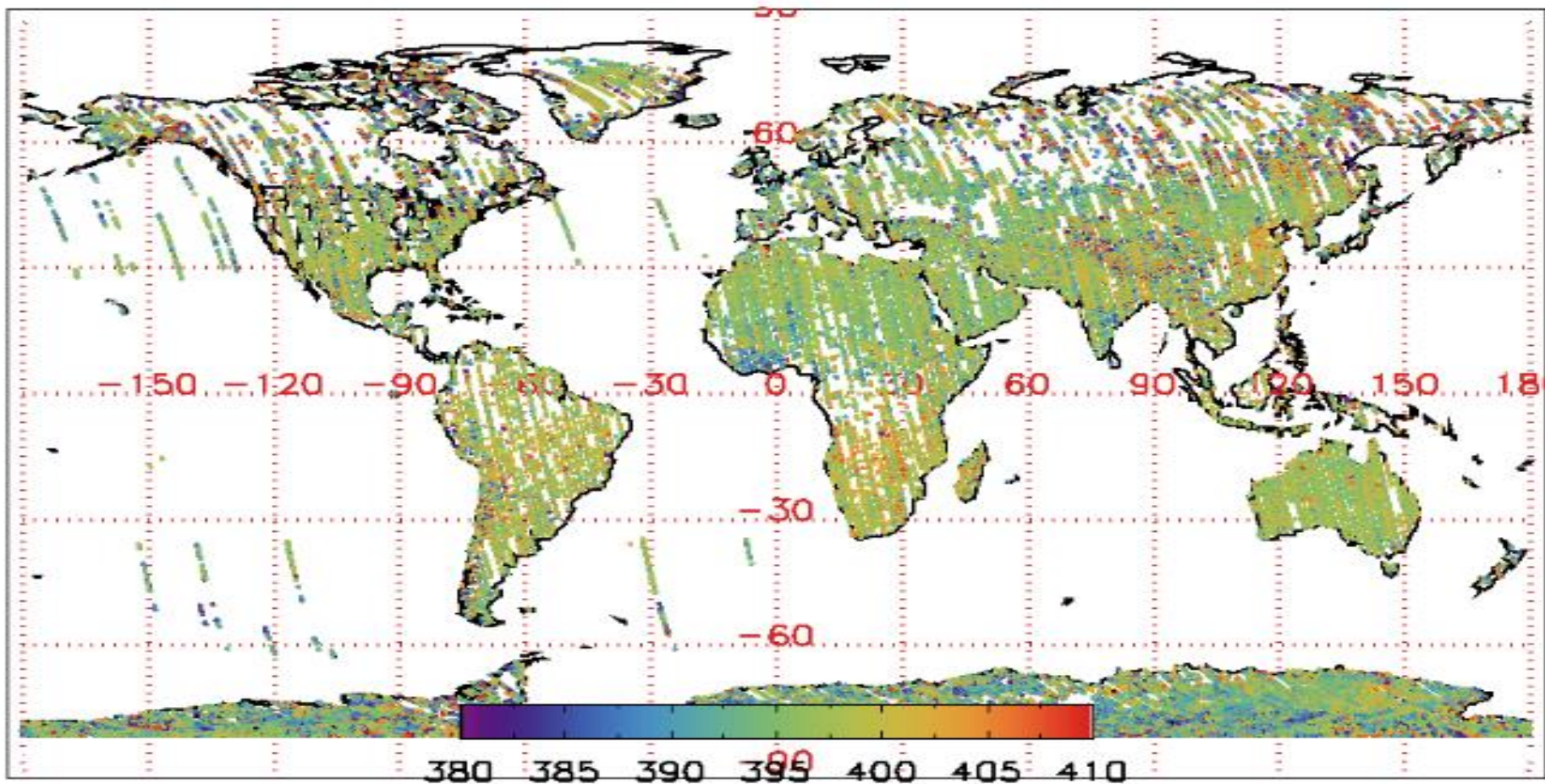


Nadir Observations





Preliminary Nadir Land X_{CO_2} Estimates



Nadir observations provide good coverage of land, but no coverage of the ocean

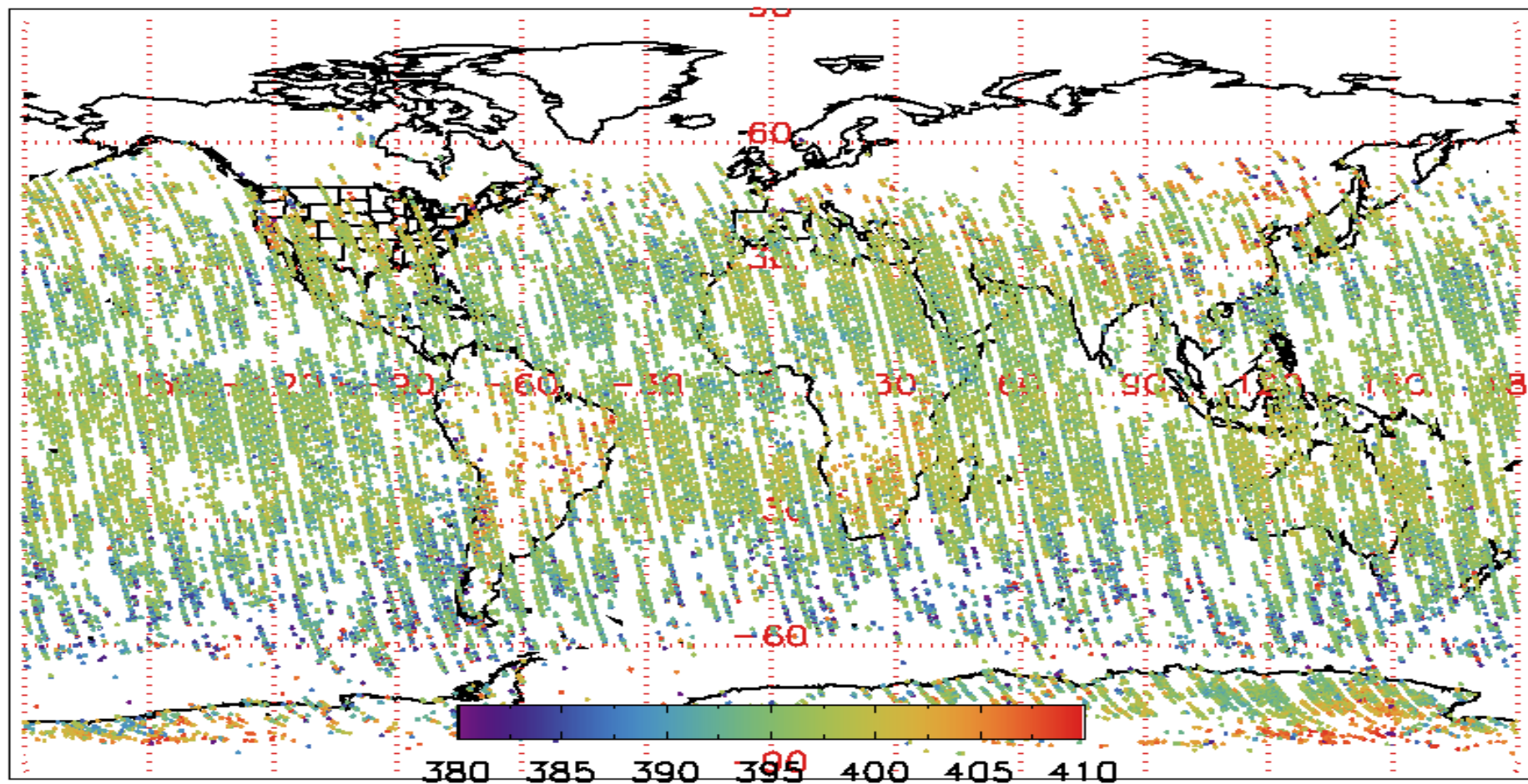


Glint Observations





Preliminary Glint X_{CO_2} Estimates

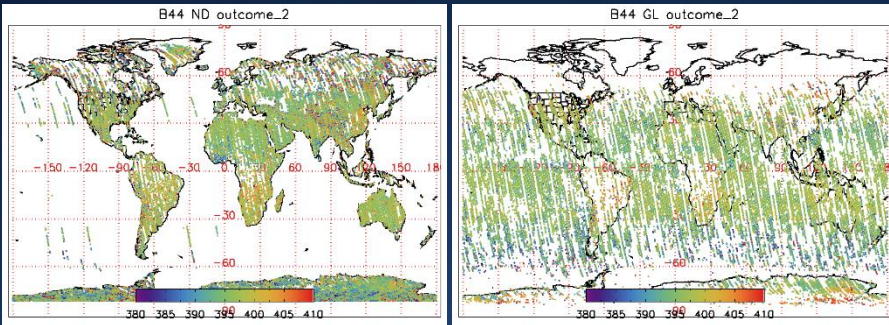


Glint observations provide better coverage of the ocean, but less coverage of high latitude continents.

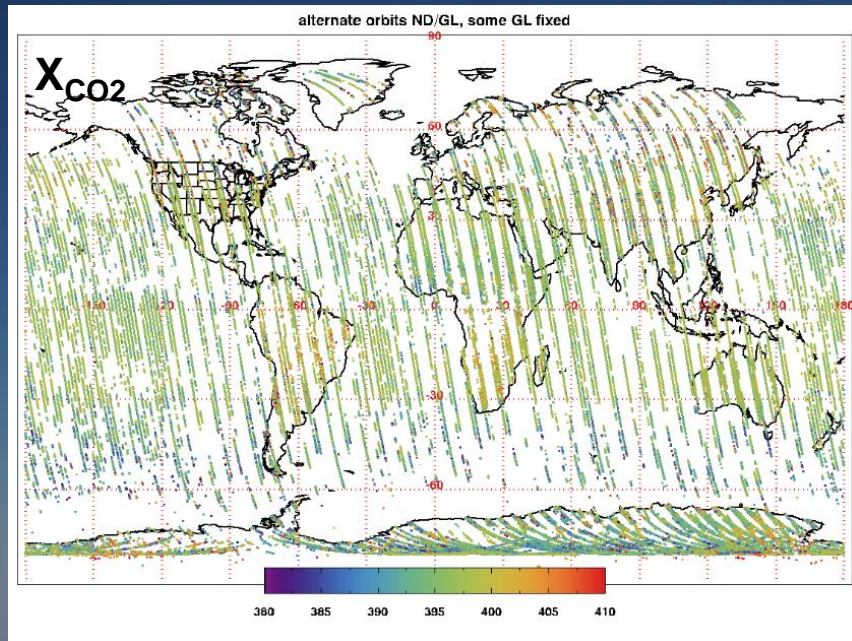


Changes in the Glint/Nadir Scheduling

Current Approach



Revised Approach



- Current sampling approach
 - Alternates between glint and nadir on successive 16-day ground repeat cycles
 - Precludes observations of oceans and high latitude continents for 16-day periods
- Revised glint/nadir strategy:
 - Step 1: Alternate between glint and nadir on successive orbits that include both land & ocean
 - Step 2: For orbits that are predominately over ocean, always stay in glint
- Changes implemented in early summer 2015



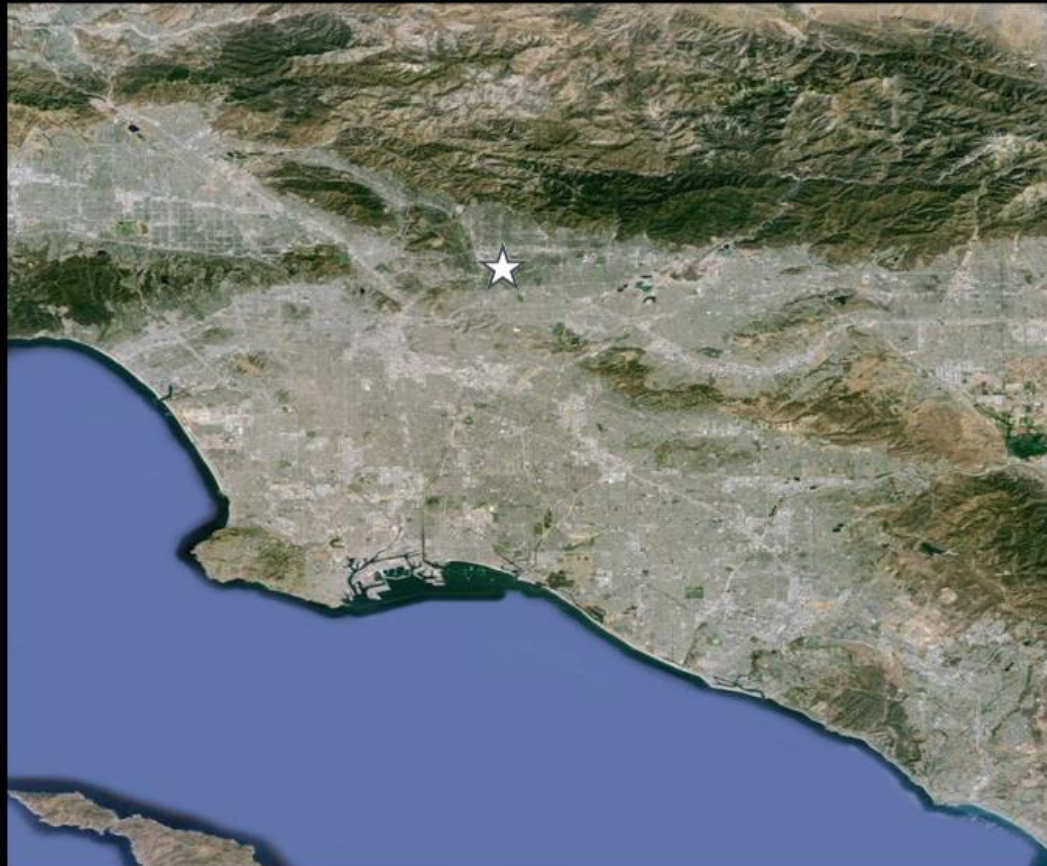
Target Observations





Validation: Targeting Total Carbon Column Observing Network (TCCON) Stations

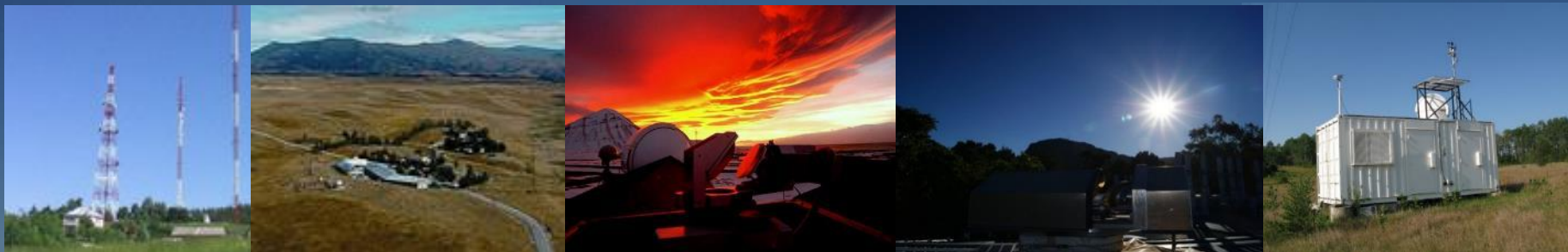
OCO-2 Target Measurements of Carbon Dioxide Over Pasadena, Calif.



380 385 390 395 400 405 410 PPM



Validation of GOSAT and OCO-2 with TCCON



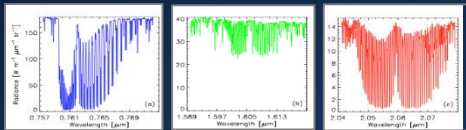
The Total Carbon Column Observing Network (TCCON) provides the primary means of validating GOSAT and OCO-2 products against WMO standards.





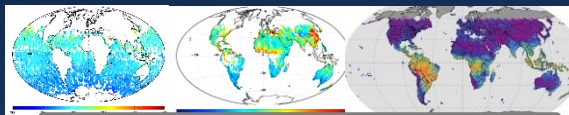
Initial OCO-2 Data Product Deliveries

L1B: Spectra



- oco2_L1bScND_89220a_1009
- Dimensions
- FootprintGeometry
- FrameConfiguration
- FrameGeometry
- FrameHeader
- FrameTemperatures
- InstrumentHeader
- Metadata
- Shapes
- SliceMeasurements
- SoundingGeometry
- SoundingMeasurements

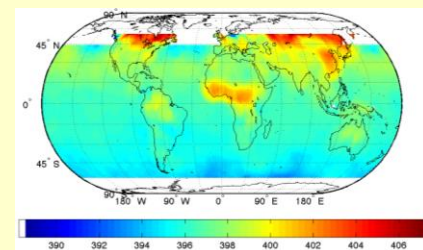
L2: XCO2, SIF, ...



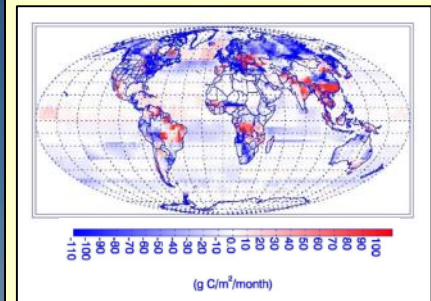
- oco2_L2StdND_89220a_100923_
- AerosolResults
- AlbedoResults
- Dimensions
- DispersionResults
- L1bScSoundingReference
- Metadata
- PreprocessingResults
- RetrievalGeometry
- RetrievalHeader
- RetrievalResults
- Shapes
- SpectralParameters

Mapped Products

L3: X_{CO2} Maps



L4: Fluxes



December 30, 2014

March 30, 2015

As Available

http://disc.sci.gsfc.nasa.gov/datacollection/OCO2_L1B_Science_V5.html





Known Issues with the Initial Data Product

- An analysis of the L2 production products revealed large ($> 1\%$) residuals in spectral fits in the CO_2 channels and X_{CO_2} biases
 - The large residuals were traced to errors in the calibration tables used to produce the version 6 and 6R L1B production products
 - Large numbers of new bad pixels formed between the 2012 pre-launch calibration activities and launch
 - Errors in the way that the bad pixel gain corrections were implemented in the production product introduced the X_{CO_2} errors
- All data (back to 6 September 2014) are recoverable.
- Final testing of a revised product (v7/v7R) is currently under way
 - Deliveries of this new product to the GES-DISC begin in late June
 - Supercomputers will be used to accelerate the reprocessing effort



Anomalous Spectral Residuals and χ^2 Values

B6: with EOF's

B7 Tests: with EOF's

O2A

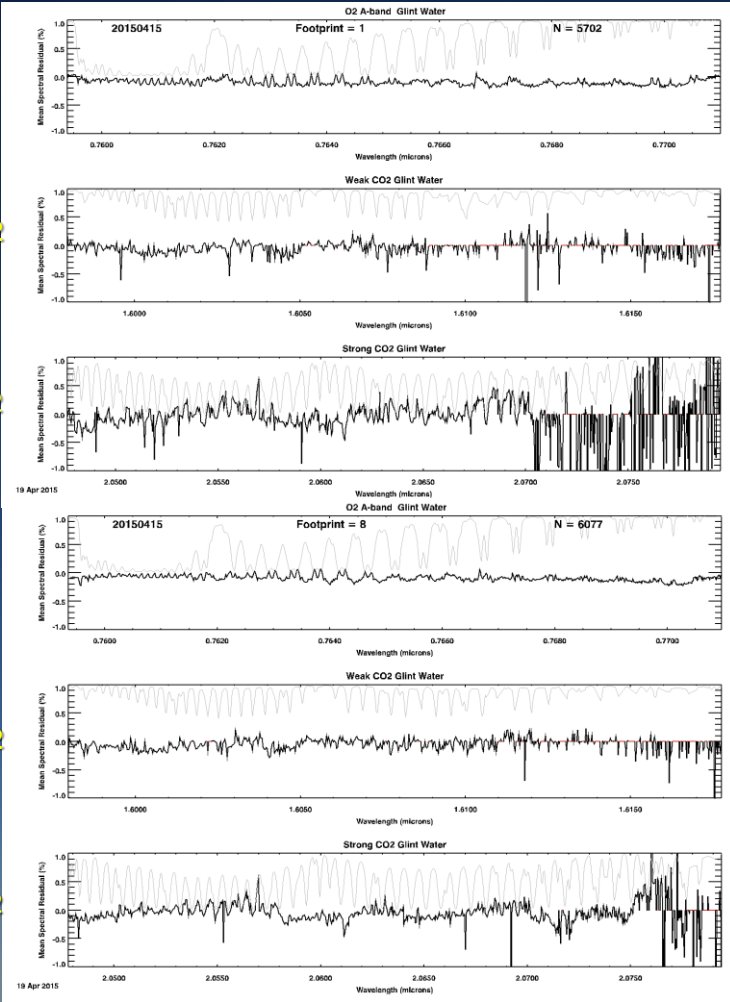
WCO2

SCO2

O2A

WCO2

SCO2



Footprint 1

Footprint 8



O2A

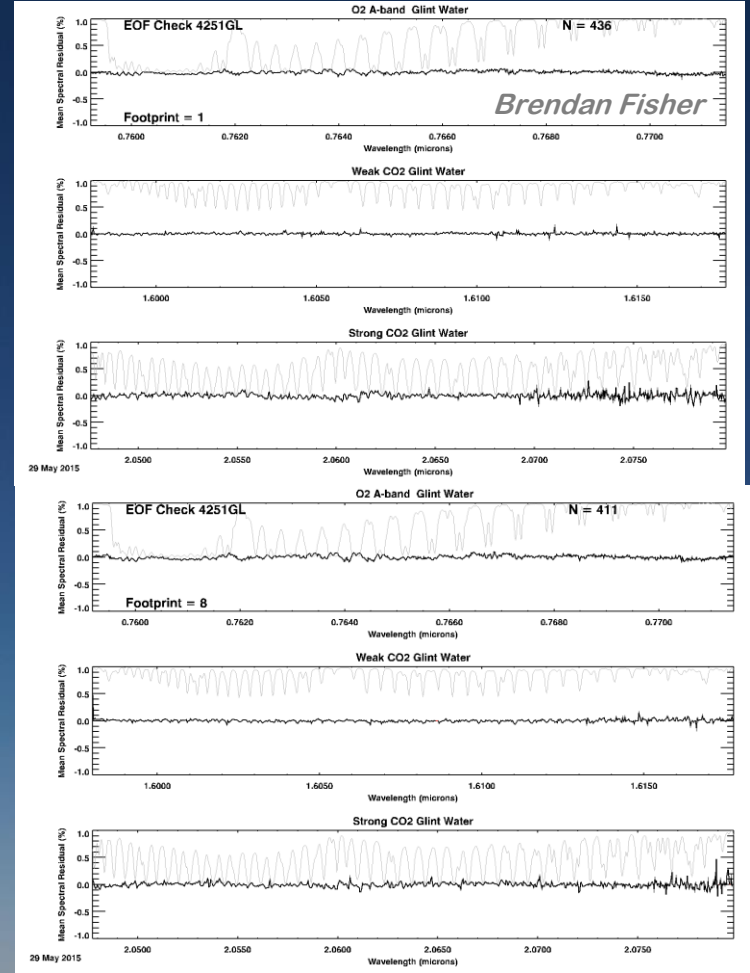
WCO2

SCO2

O2A

WCO2

SCO2



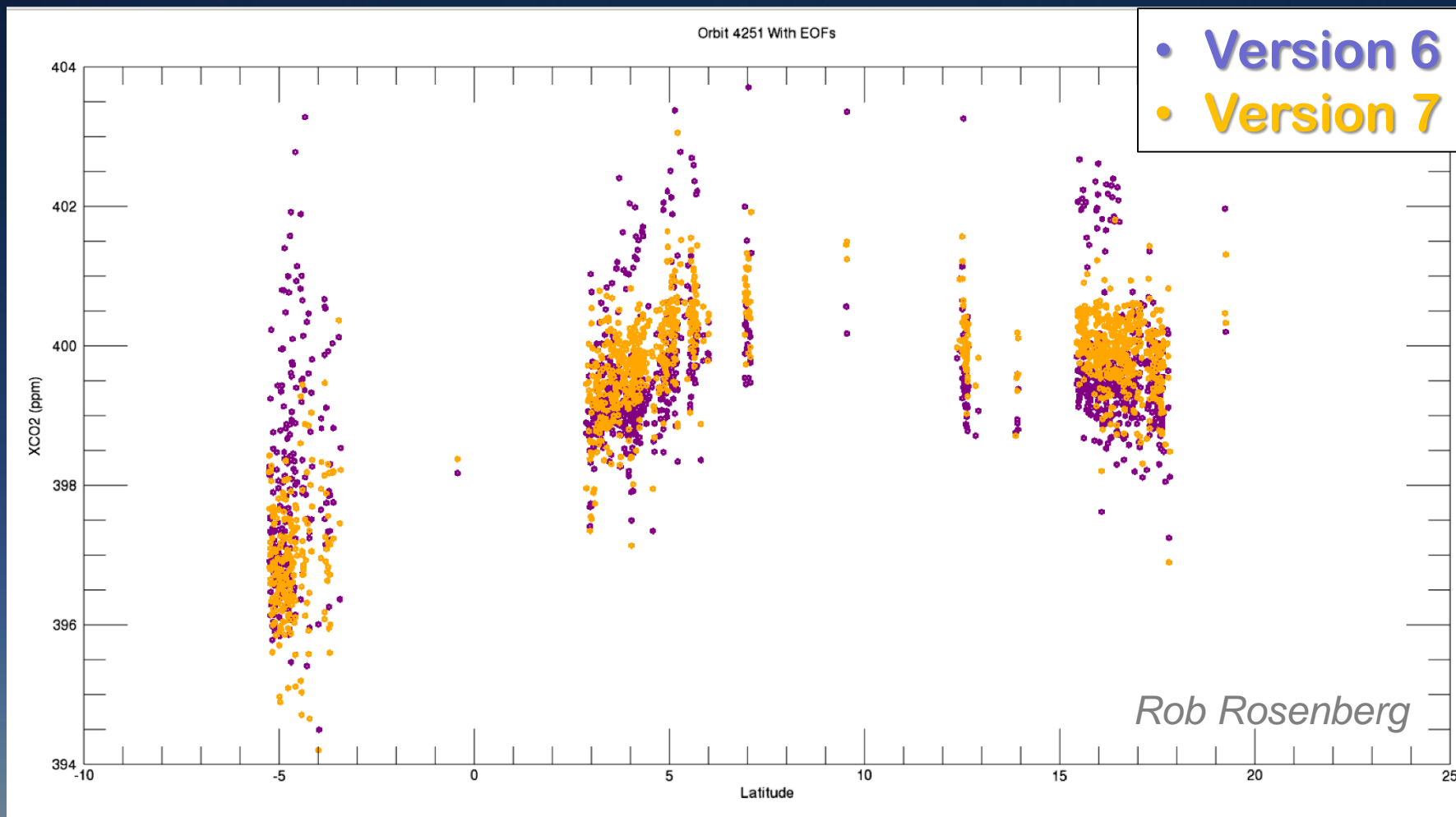
Large spectral residuals in v6 L2 fits.

Reduced spectral residuals in v7 L2 fits





Comparisons of V6 and V7 L2 Products

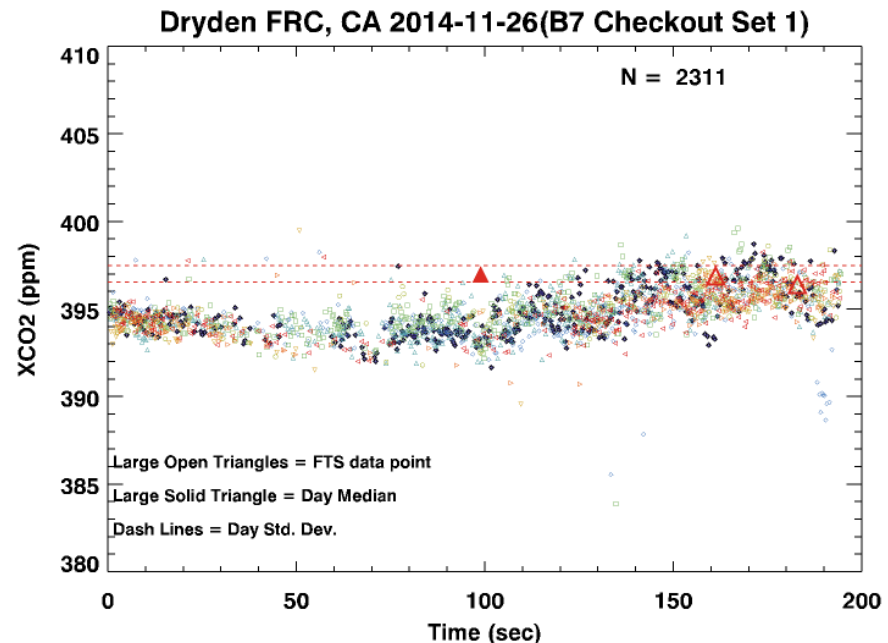
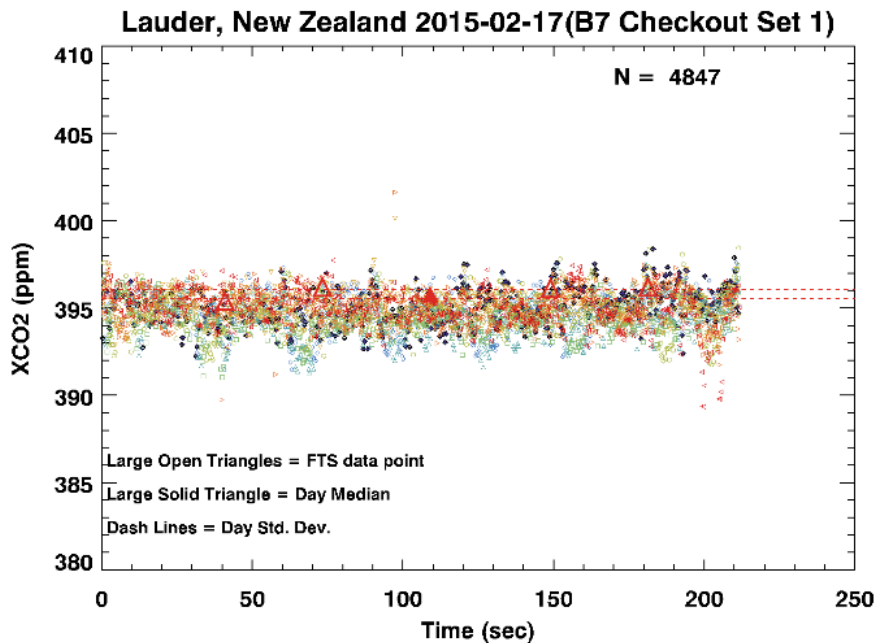


A single orbit of OCO-2 data, comparing the Version 6 and Version 7 L2 products.



Preliminary Results from OCO-2 Target Observations

- Preliminary OCO-2 target overflights are yielding new insights into biases and random errors.

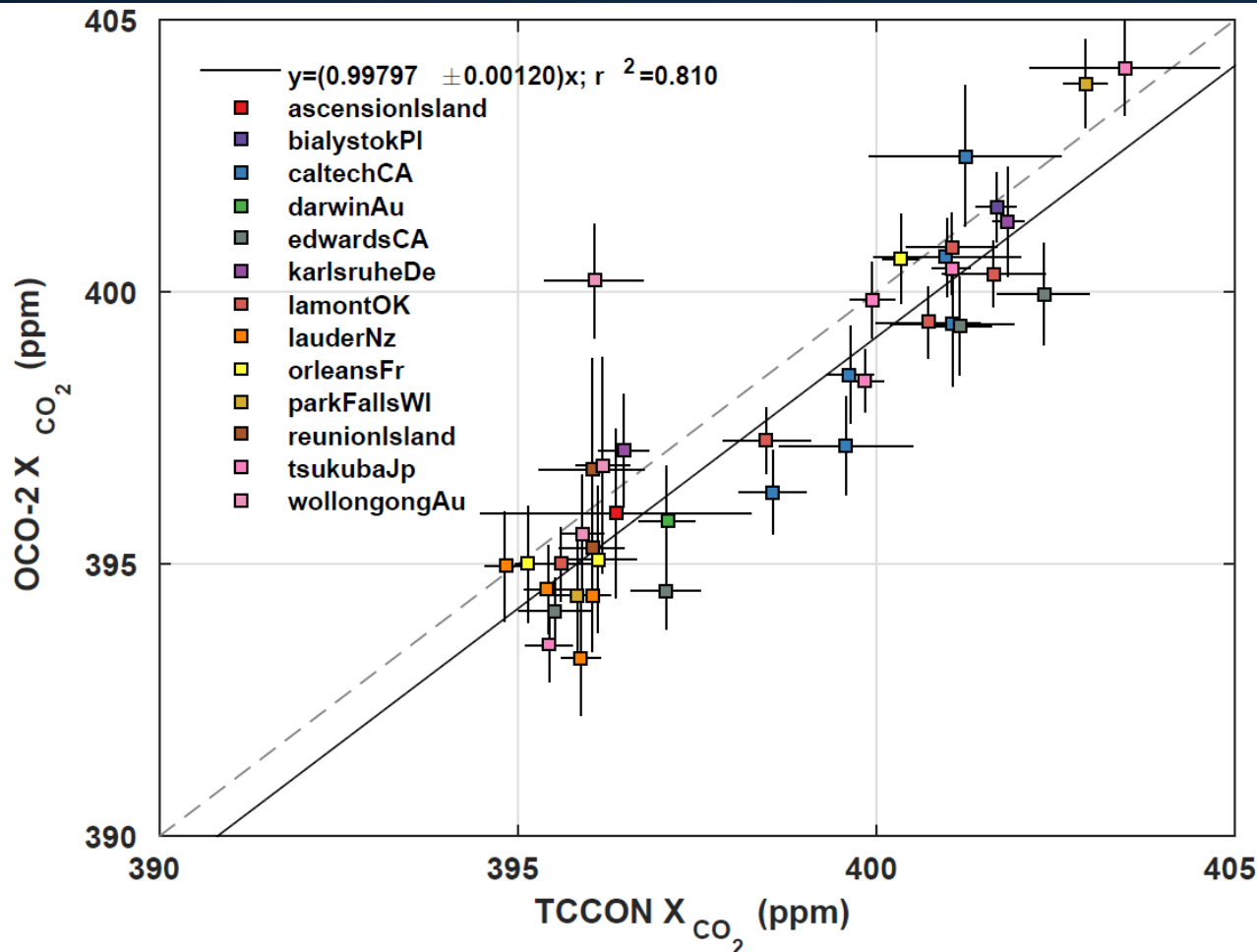


Target observations over Lauder, New Zealand show negligible air mass dependence.

Target Observations over the TCCON station at Armstrong/Dryden show more air mass dependence.



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. (Wunch et al.)

Initial differences between OCO-2 and TCCON X_{CO2} estimates were smaller than ~2 ppm (0.5%).



UNIVERSITY OF WOLLONGONG



National Institute for Environmental Studies, Japan



NIWA Taihoro Nukurangi

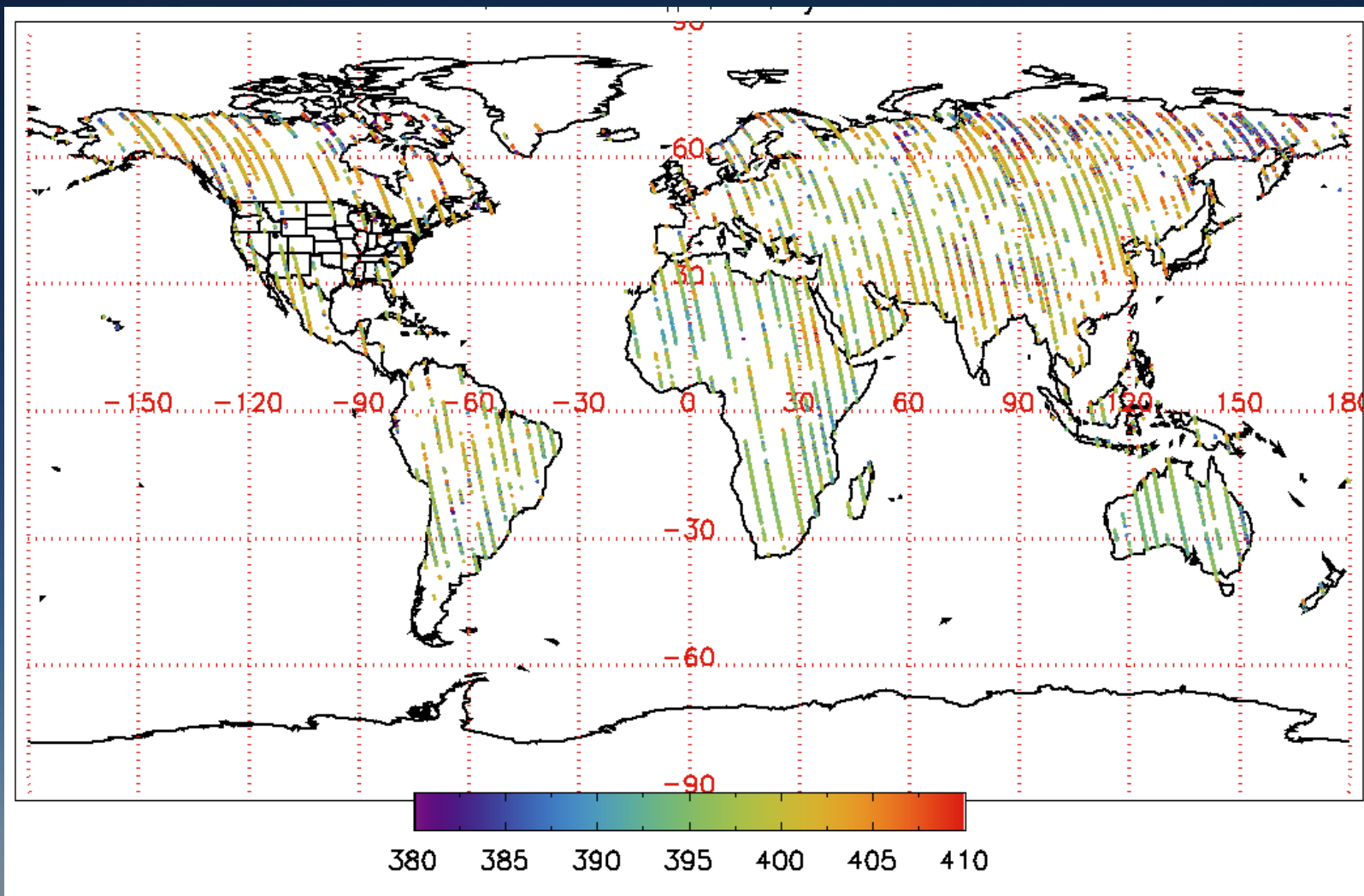


Universität Bremen





A Sneak Peak at Version 7



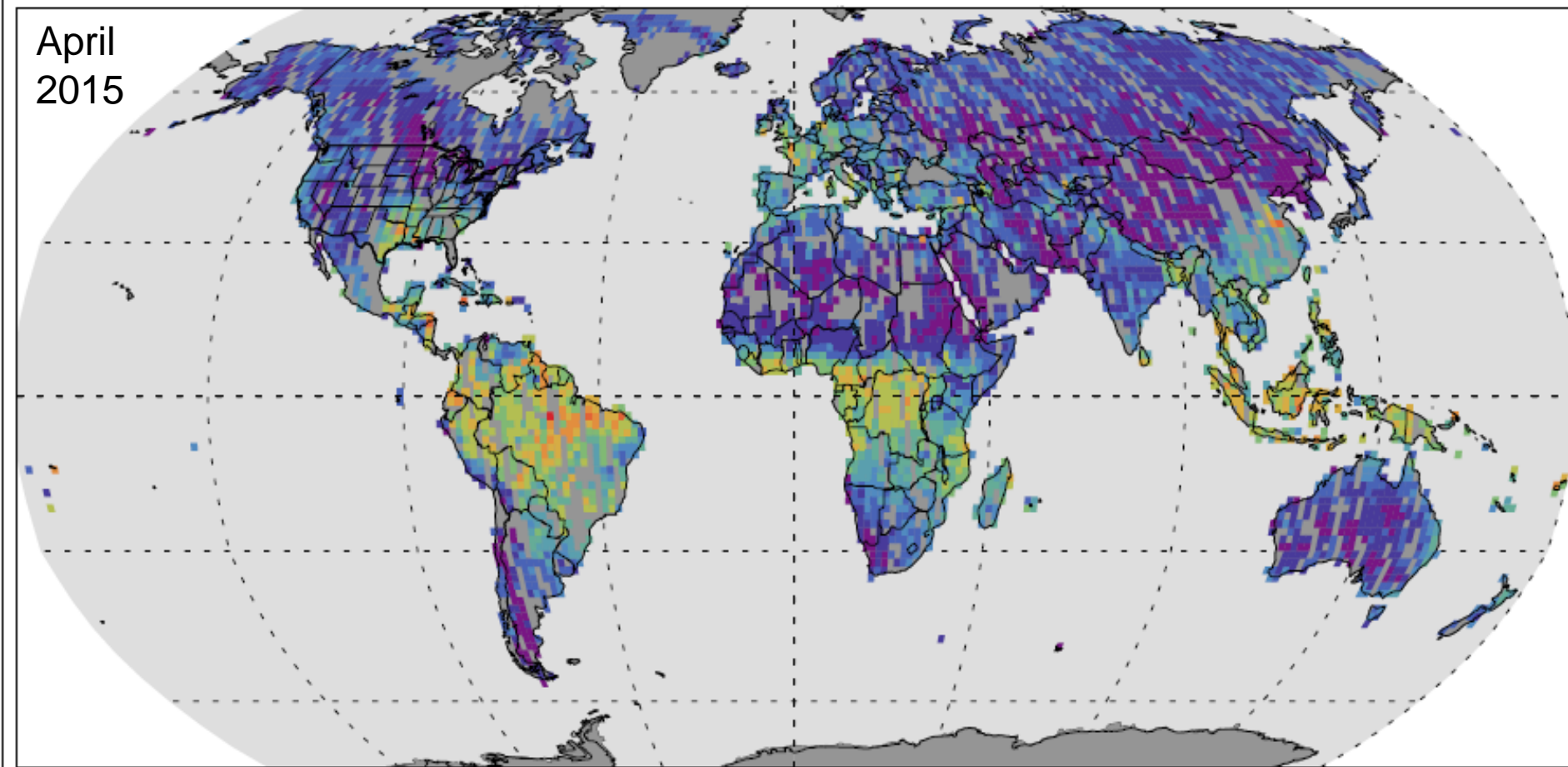
One week of V7 Nadir data (370,000 points, May 13-20)





A New Product: Solar-Induced Chlorophyll Fluorescence (SIF)

April
2015



$\text{SIF} / (\text{W m}^{-2} \text{ micron}^{-1} \text{ sr}^{-1})$

0.00 0.12 0.25 0.38 0.50 0.62 0.75 0.88 1.00 1.12 1.25 1.38 1.50



V7 Processing Approach

- **Objective:** Finish and deliver the new product as soon as possible
- **Method:** Use a simple data selection approach (i.e., cloud screening) rather than a more sophisticated sounding selection.
 - Attempt to process 10% to 20% of all soundings
 - Postpone work on bias corrections and warn levels but incorporate in “lite files” for end users
 - Add to OCO-2 cluster to handle a larger forward stream
 - Reprocessing on supercomputers can accommodate the larger percentage of soundings
- **Nominal Schedule**
 - L1B: Start delivering data to GES-DISC before 05 June
 - L2: Start deliveries to GES-DISC on or before 19 June





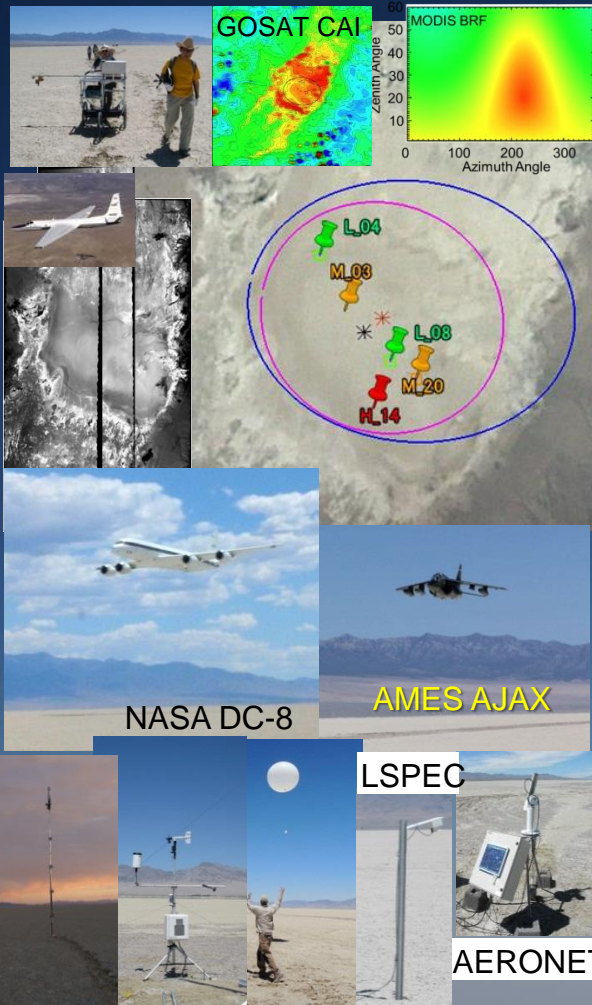
Exploiting the Benefits of Multiple Missions

- **Space-based remote sensing observations hold substantial promise for future monitoring of CO₂ and other greenhouse gases**
 - complement existing ground-based data with increased spatial coverage and sampling density
- **Within the next decade, a series of missions with a range of CO₂ & CH₄ measurement capabilities will be deployed in low Earth orbit**
 - GOSAT, OCO-2, TanSat, GOSAT-2, OCO-3, MERLIN, CarbonSat...
- **Much greater benefits could be realized if these missions could be coordinated, and their products can be cross-calibrated and cross validated so that they can be combined to yield a self-consistent, continuous climate data record**
- **NASA, JAXA, and NIES members of the GOSAT and OCO-2 teams have been pioneers in the implementation of this approach.**



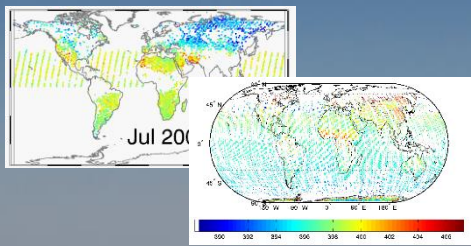
Next Steps: GOSAT/OCO-2 Cross Calibration and Validation

Vicarious Calibration



Retrieval Algorithm Intercomparisons

- Forward Radiative Transfer Model
Spectra + Jacobians
- Instrument Model
Spectral+Polarization
- Inverse Model
 - Compare obs. & simulated spectra
 - Update State Vector



Cross Validation



not converged
 ?
 converged





Summary

- **OCO-2 was successfully launched on 2 July 2014, and began routine operations in early September 2014**
 - **Now returning about 1 million measurements each day over the sunlit hemisphere**
 - **Between 10% (nadir) and 25% (glint) of these measurements are sufficiently cloud free to yield accurate estimates of XCO₂**
- **An initial L2 data product was released on 30 March**
 - **An early analysis revealed errors that have been traced to calibration issues that have been identified and corrected**
- **An updated product that addresses these issues is being tested**
 - **All data will be reprocessed for delivery this summer**