Initial Inflight Calibration Status of the OCO-2 Mission

Randy Pollock, Lars Chapsky, Richard Lee, Robert Rosenberg & Carol Bruegge
OCO-2 Calibration Team

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Jet Propulsion Laboratory
California Institute of Technology

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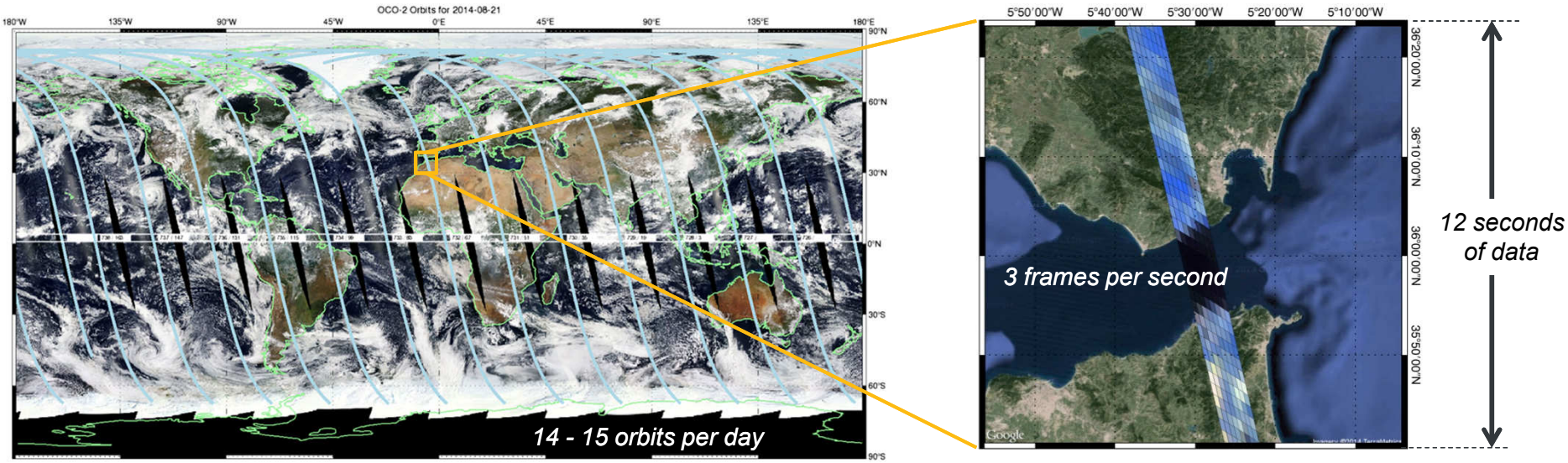
Calibration Overview

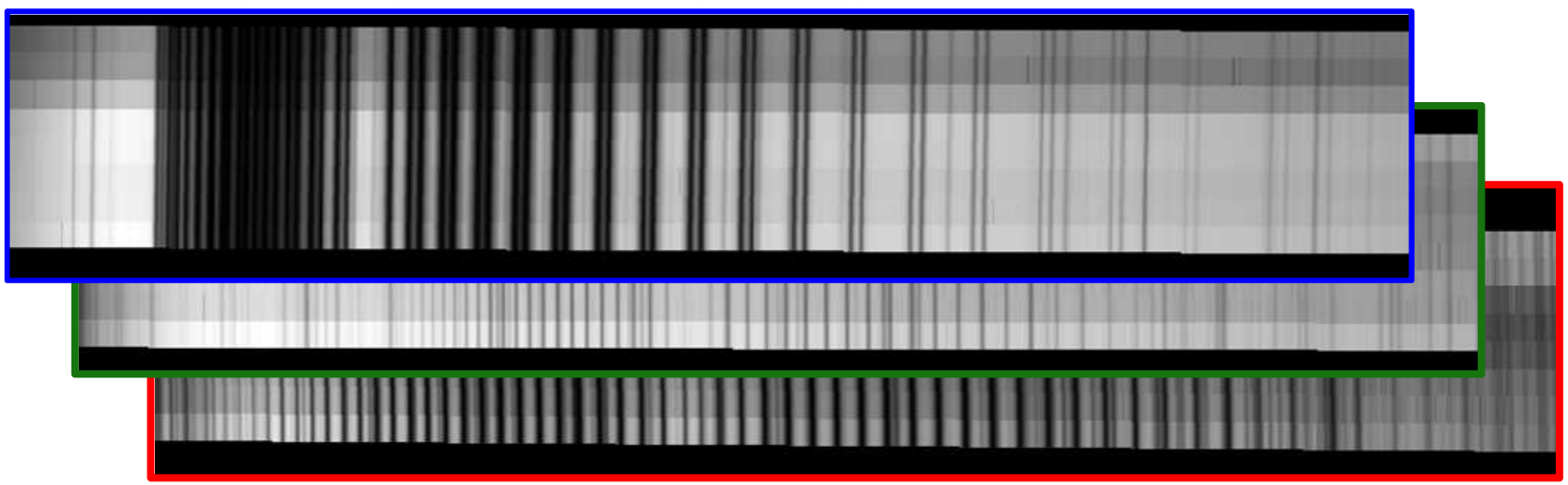
- OCO-2 Level 1b Data (calibrated spectra) will be publicly released later this month (December 2014)

- This talk will summarize the quality of this initial release and the plans to improve later deliveries

General Calibration Status	Data Artifacts Under Review
• Polarization	• Bad Pixels
• Radiometric Calibration	• Non-uniformly Illuminated Footprints
• Geolocation Calibration	• Radiation Events
• Spectral Calibration	• Bad Samples

OCO-2 Sampling Approach





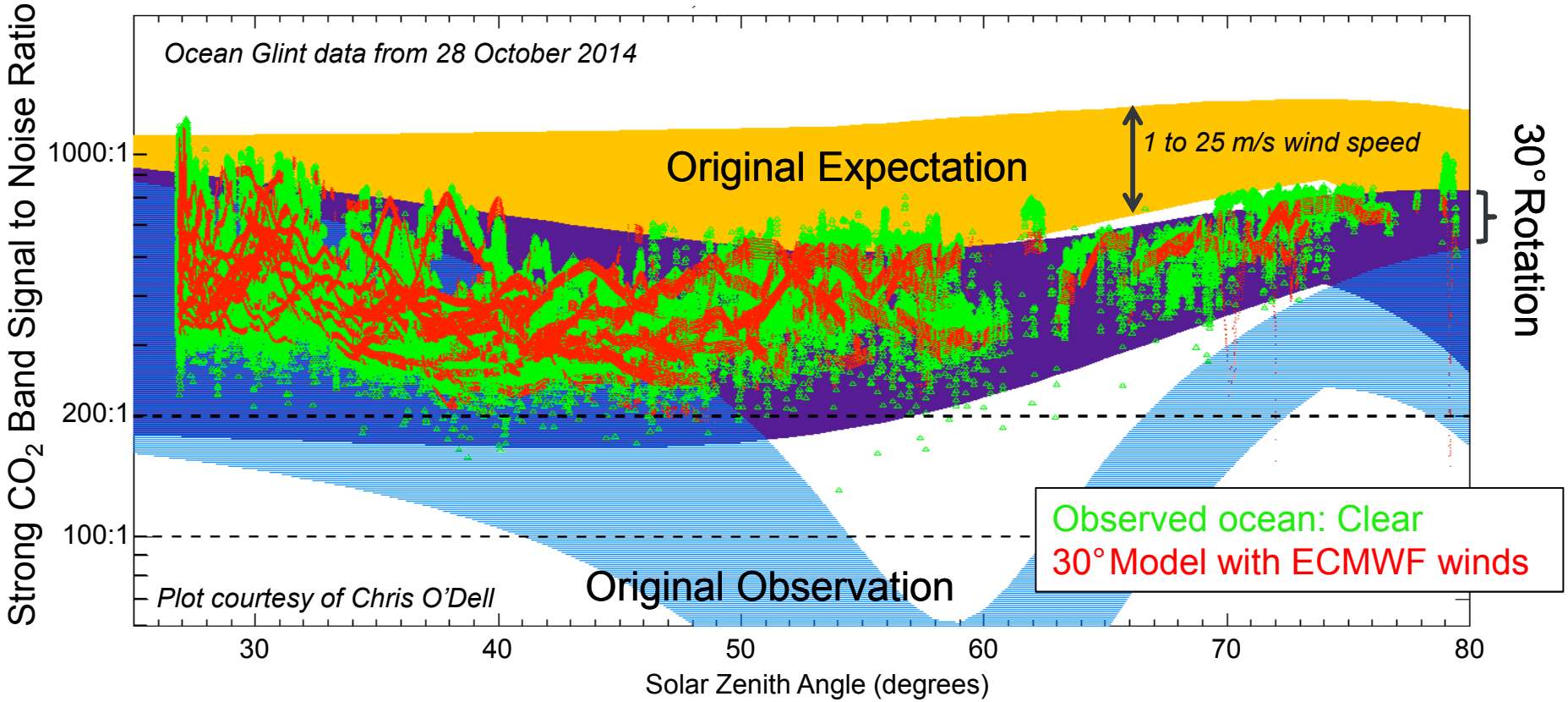
Each 1/3 of a second frame includes 8 spatial footprints with 1,016 wavelengths sampled in the O_2 A-band and Weak and Strong CO_2 bands

Polarization Response

- The polarization response of the OCO-2 instrument is rotated 90° from the prelaunch expectation
  - Design error made in 2004 and not caught in ground testing
- The spacecraft continuously rotates about the instrument boresight to align instrument peak response to S Polarization from the scene
  - Especially important in glint mode over the ocean where P Polarization will approach zero at a solar zenith angle of ~57°

Polarization Solution

- Taking advantage of power and thermal margin, glint mode is now flown with a 30° rotation about the boresight
- This now provides a typical Signal to Noise Ratio of ~400:1, well above the 200:1 required to minimize instrument noise's impact on the XCO2 uncertainties



Radiometry: Stability from Ground Testing

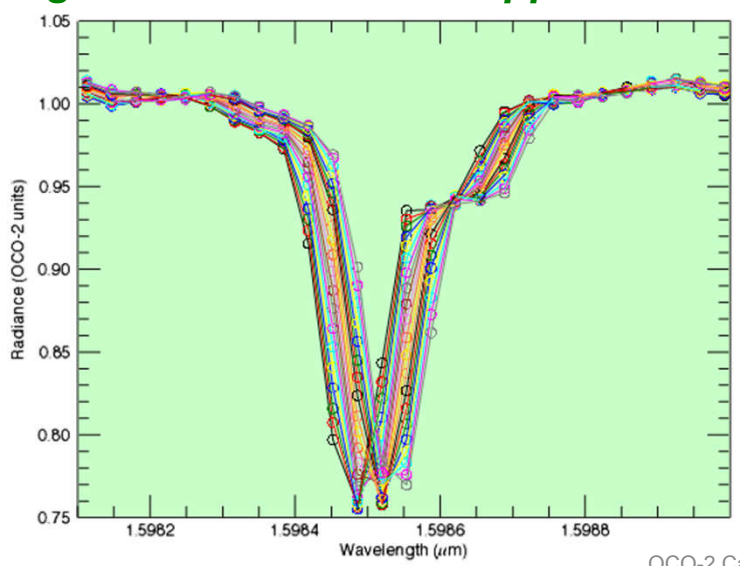
Band	Initial Post Launch Calibration			Basis of Estimate
	A-Band	Weak CO_2	Strong CO_2	
Onboard Lamps	101 ± 3%	101 ± 3%	102 ± 3%	Repeatability during ground environmental testing
Railroad Valley	103 ± 8%	100 ± 9%	100 ± 10%	Kuze et al, 2014 + extra uncertainty due to increased sensitivity to geolocation due to much smaller footprint
Lunar Calibration	100 ± 10%	100 ± 10%	101 ± 10%	ROLO model + correction factor from by Viticchie et al, 2012 & Lacherade & Meygret, 2014
Mean *(weighted)*	101 ± 3%	101 ± 3%	102 ± 3%	-

- Since launch, solar calibration and lunar calibration trending indicate slow degradation in A-band response
  - Validation of apparent trend underway using other calibration approaches (e.g. vicarious calibration and cross calibration with other sensors)
  - Degradation will not be corrected in the initial public release L1b files, but will be included in reprocessed data released in the Spring of 2015

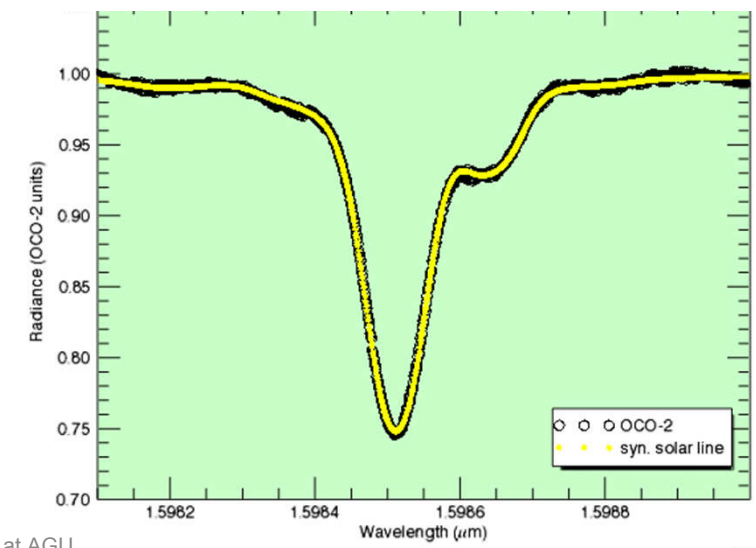
Spectral Calibration

- Wavelength Accuracy
  - Shifts between ground and flight are $\leq$ 0.000 002 ($\Delta\lambda/\lambda$)
  - Small corrections applied using atmospheric & solar lines for reference
- Instrument Line Shape
  - Studies with small changes in the line width show preflight measurements are still valid
  - Tests where the sun is observed with a Doppler shift of +/- 5 km/s confirm good match to preflight calibration data

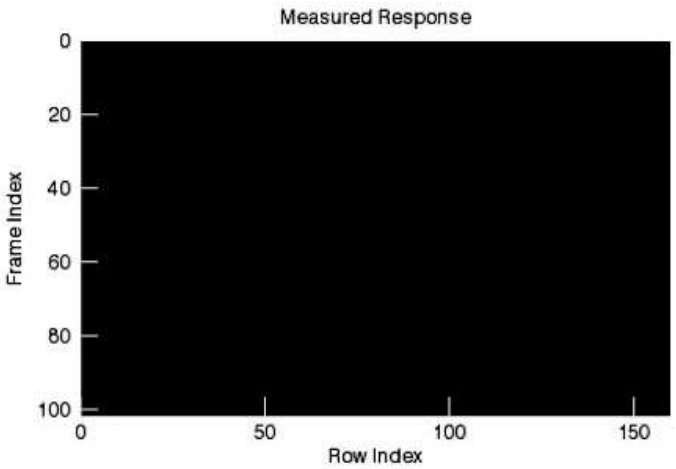
Single Solar Line at 21 Doppler Velocities

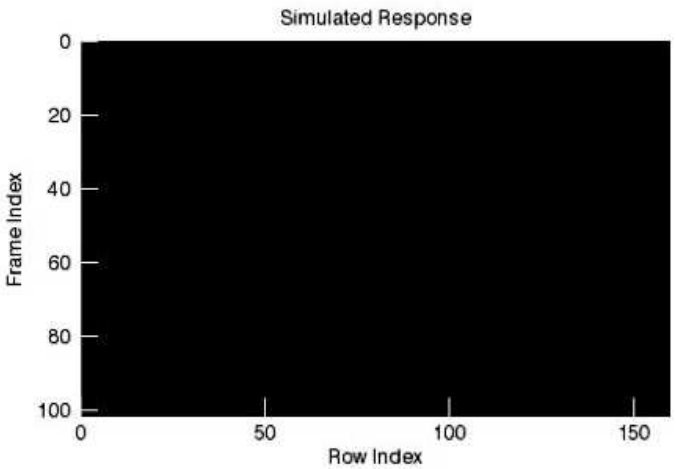


Same Data, Doppler Corrected
(yellow line is theoretical response)

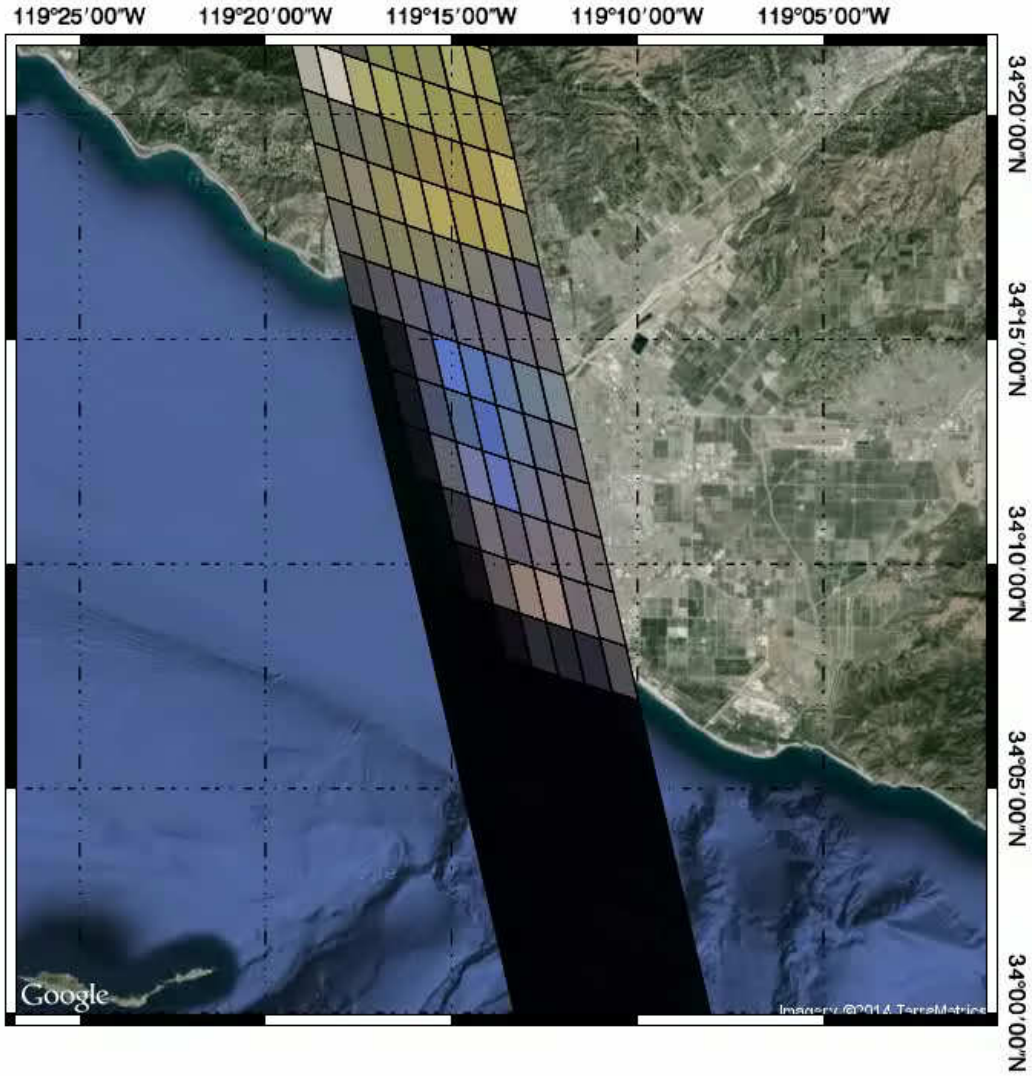


Geometric: Lunar Observations



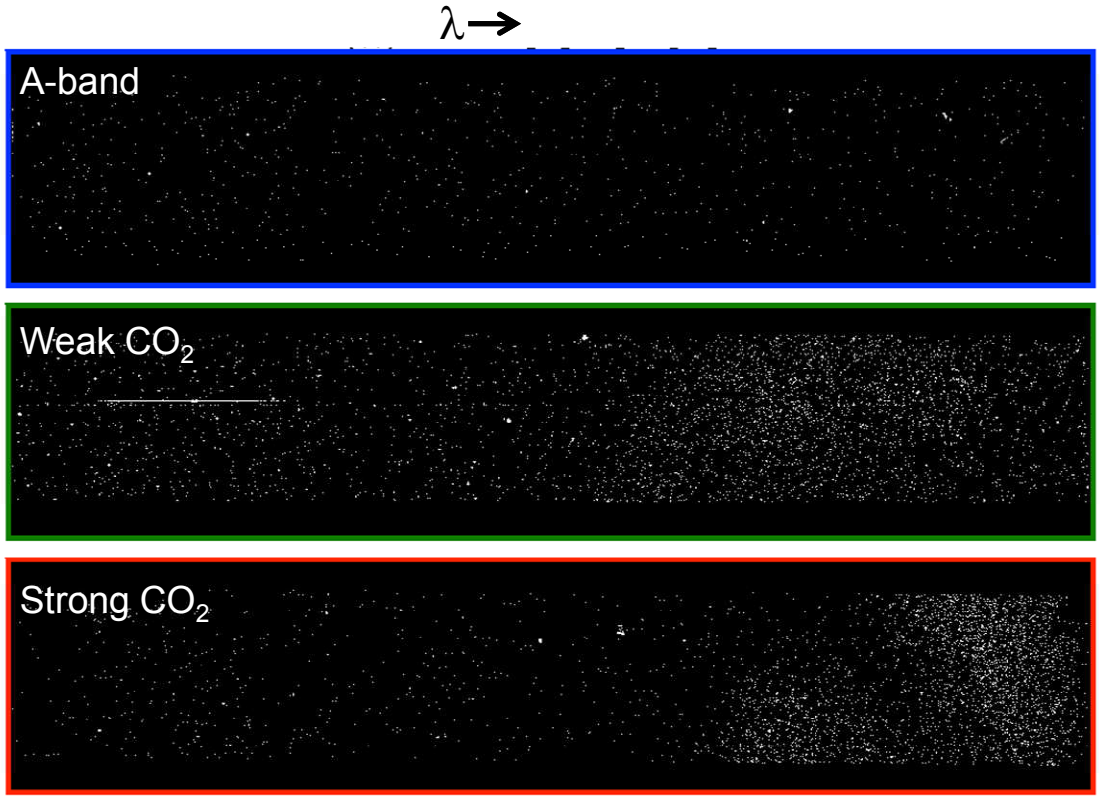


Geometric Validation



- Current Geolocation uncertainty is < 1 km (3σ) meters in nadir and glint modes
- May be slightly larger in target mode, but still collecting enough data to estimate differences

Bad Pixels

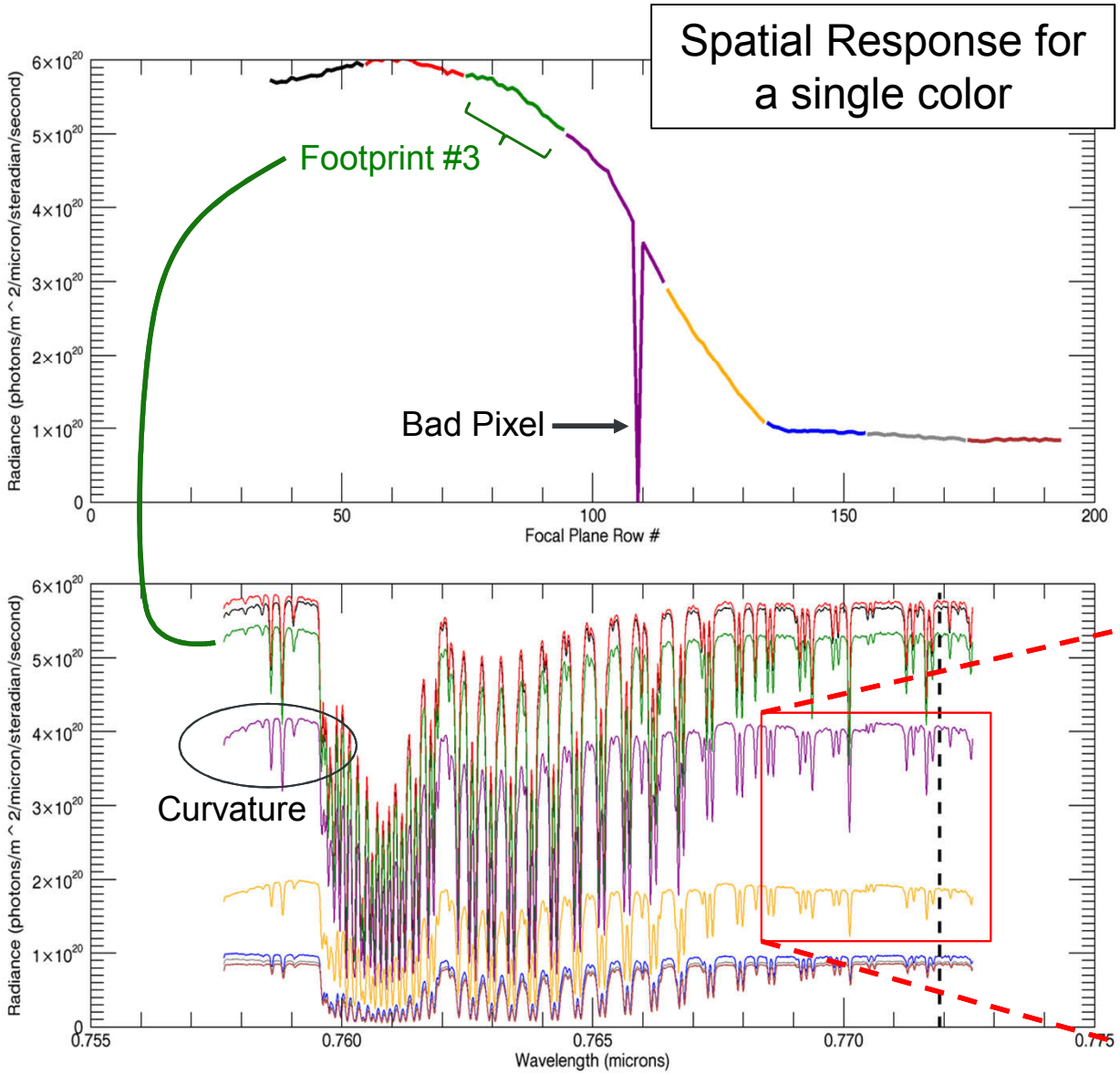


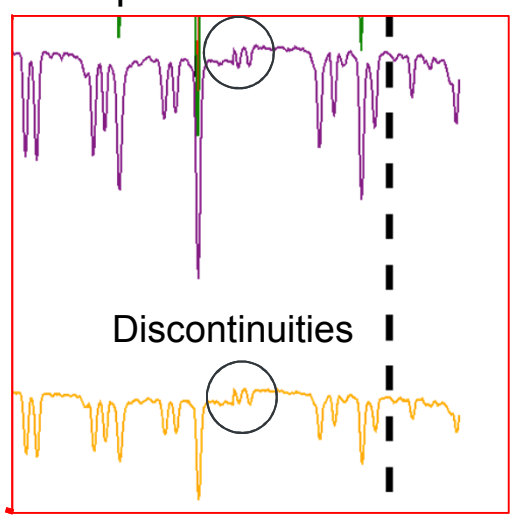
Note that the radiance data are generated from a weighted average of 20 pixels per sample – marking a few of these 20 as bad has only minor impacts on the quality of the calibration

- OCO-2 is flying spare detectors from OCO (delivered in 2006)
- During the last year or two of storage, the number of high dark current pixels has increased
- These are being identified and uploaded to the instrument to be masked in the onboard processing
- Mechanism is thought to be the same as seen in early JWST focal planes

  See "Commentary: JWST near-infrared detector degradation— finding the problem, fixing the problem, and moving forward", *Rauscher et al, AIP Advances 2, 021901 (2012); doi: 10.1063/1.473353)*

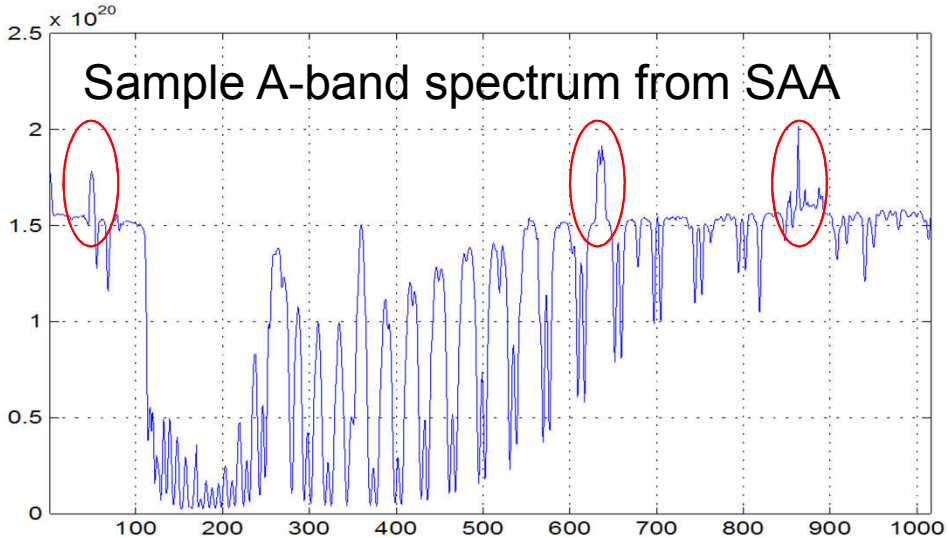
Artifacts from Non-Uniform Scenes

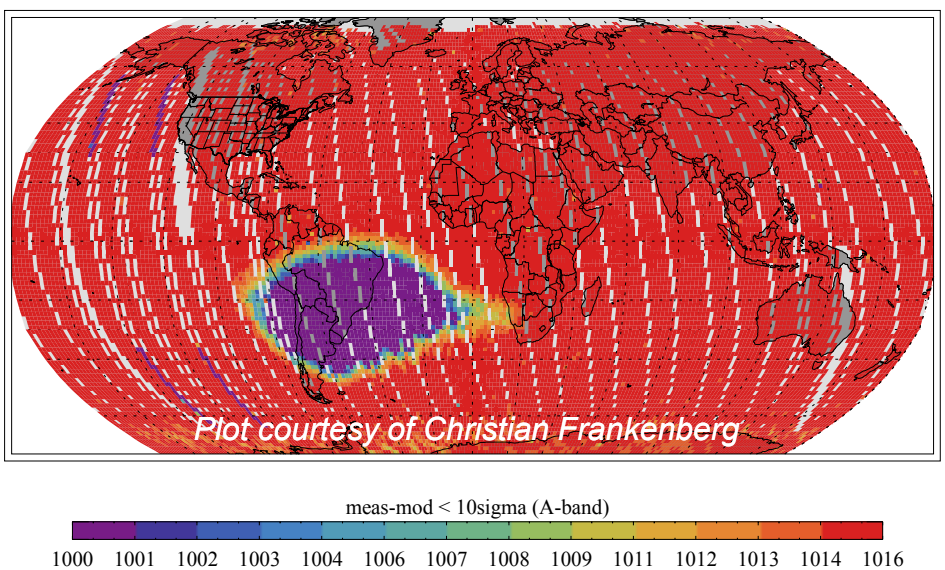




- When this illumination in not uniform across the slit, two artifacts are seen:
  - Short wavelength radiometric “curvature”
  - Small discontinuities at specific wavelengths
- Discontinuities corrected in December L1b release
- Curvature still under evaluation – listed as ‘bad samples’ for now

Radiation Events





- Instrument detectors are seeing few primary radiation events, but many small secondary events over the South Atlantic Anomaly (SAA)
  - Energy levels are too small to damage the detectors, but energetic enough to create a false signal in the pixels
- A-band is far more sensitive to this than the CO_2 bands
- Screening algorithm being developed to flag suspected radiation events in the L1b files
  - Not ready for December 2014 L1b release, but will be included in the first reprocessing in the Spring of 2015

Bad Sample Flag

- To aid in understanding the data, the L1b files have a ‘bad sample flag’ as part of the signal to noise coefficients
  - Inside the L1b file’s Instrument Header Section, there is a variable called ‘snr_coef’ with dimensions 3 x 8 x 1016 x 3

Band Index
Color Index
Footprint Index
Coefficient Index

- The last coefficient is zero if a sample is thought to be radiometrically, spectrally & spatially valid
  - The calibration team recommends ignoring any non-zero value when analyzing spectra
  - As data are reprocessed and more bad pixels are identified, the number of non-zero values is falling
  - Good samples currently number ~ 900 in A-band, 700 to 800 in CO_2 bands (varies by footprint)

Conclusion

- The OCO-2 Instrument is operating well in space
  - Inflight validation is consistent with prelaunch radiometric, spectral and geometric performance
  - Polarization error has been corrected with no significant impact on data quantity, quality or coverage
  - All instrument components are functioning as expected
  - Significant power, thermal and performance margins are compatible with a very long potential mission duration
- Several minor artifacts were discovered during mission checkout
  - These have only minor impacts on their usefulness for CO_2 retrievals
  - Plans exist to correct and/or flag these in later reprocessings of the data to further improve the quality of the instrument data
- We look forward to feedback from the wider user community following the L1b data release planned for later this month

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