

OCO-2 Calibration: Successes & Surprises

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Committee on Earth Observation Satellites:
Working Group on Calibration and Validation
WGCV-56 W5.3
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Sioux Falls, SD

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Program History and Status

The Orbiting Carbon Observatory -2 is a NASA Earth System Science Pathfinder mission

Launch July 2014, first light in August, public science record began in September following the first Bad Pixel Map update, completed prime mission October 2016

Sun-synchronous polar orbit (705 km “A-Train”), 16-day repeat, 13:36 equator crossing

3rd mission extension cycle ends in September 2026, presented Senior Review last week

Announcement for Partnership Proposals opened Jan 8 and closed Mar 31, “make efficient use of unique national assets”...“open to all proposals and novel ideas”

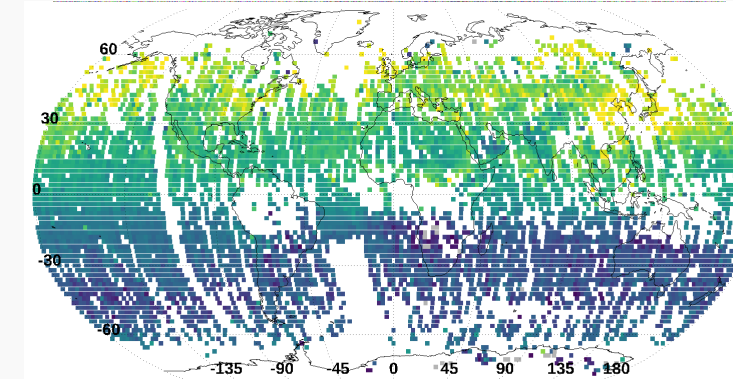
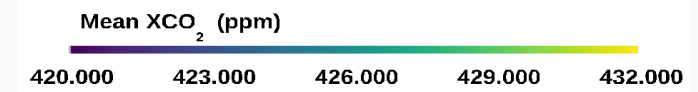
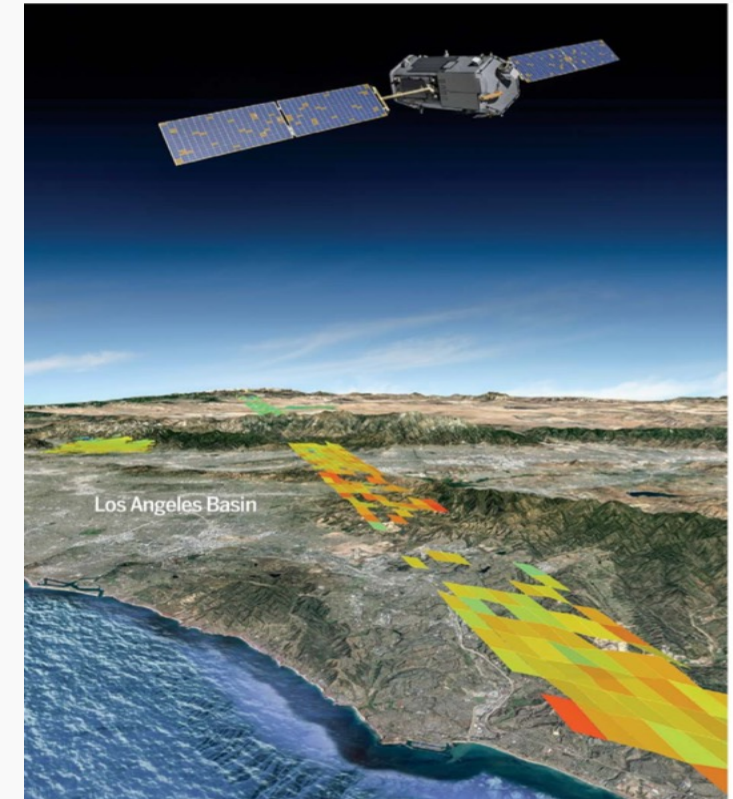
Instrument is “Build to print” of OCO, which was lost in a launch vehicle failure Feb 2009

A spare was built and converted into OCO-3 (launch May 2019) which is operating fantastically on the International Space Station

Instrument is healthy & performing well; the spacecraft has over a decade of fuel left

Life-of-mission reprocessings 2015, 2017, 2019, and 2021 (cal delivered before science)

Orbit 2¹⁶ this fall



Level 1 & Level 2 Overview

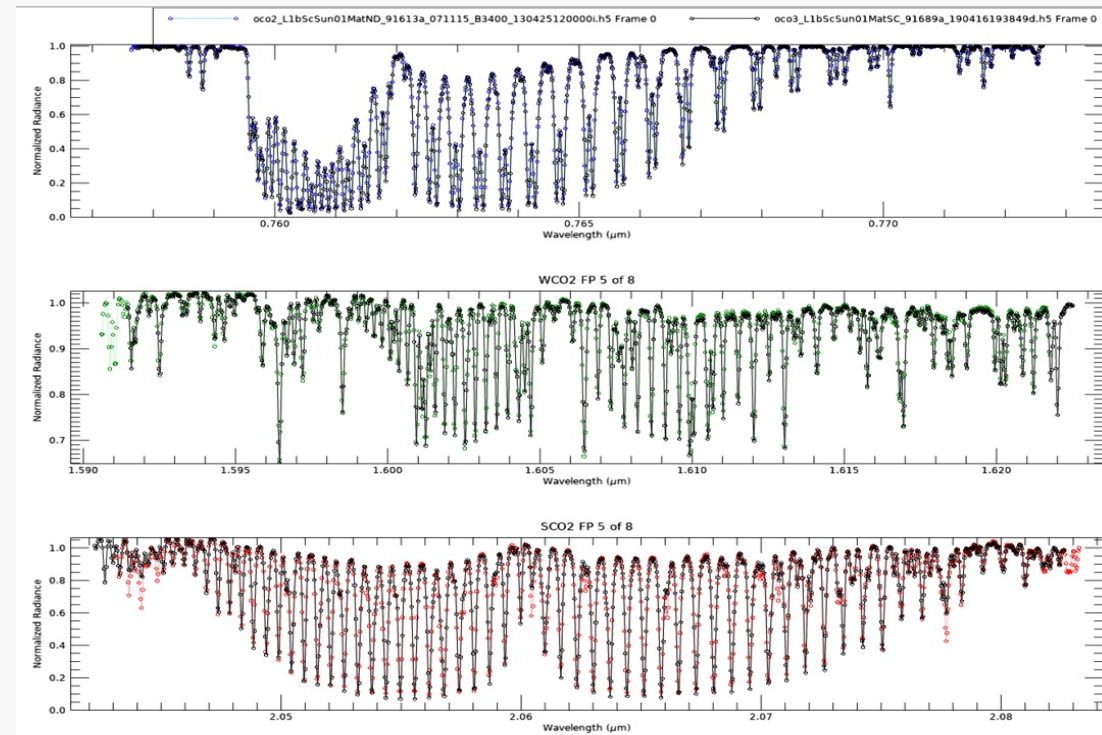
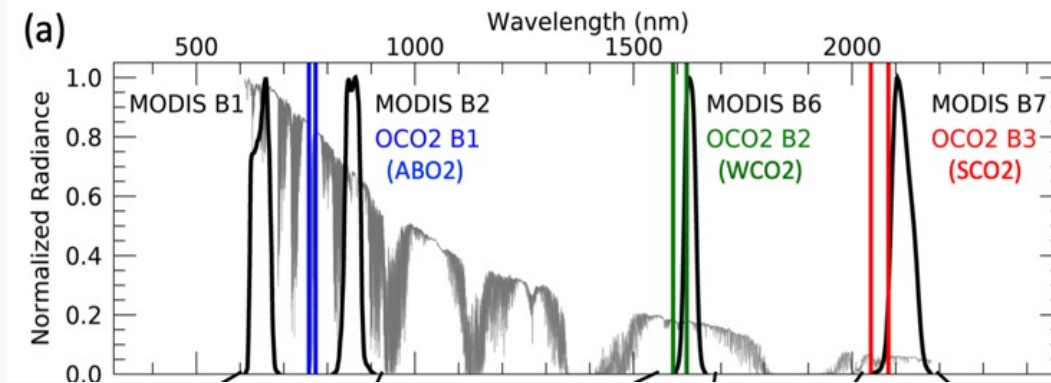
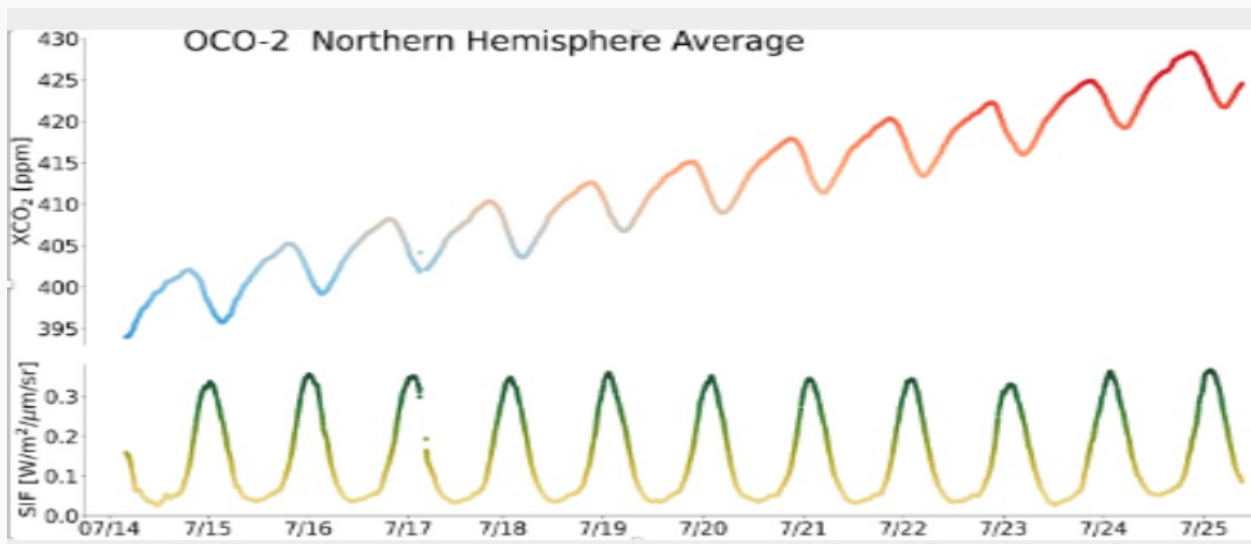
Watching the Earth Breathe, Seeing Plants Glow When They Grow

3 narrow bands, ~20,000:1 resolution, ground footprint up to 3 km²

Requirement: 1 ppm precision = 0.25 % of 400 ppm background

Current performance: 0.85 ppm = 0.20 % of 425 ppm background

CO₂ growth rate included in 2025 Global Carbon Project for 1st time



Color: OCO-2 test, 20 Apr 2012, 395 ppm
 Black: OCO-3 test, 27 Apr 2018, 412 ppm

Bad Pixels

20x compression in spatial dimension to conserve data volume

Flight software applies a BPM during this process, calibration data still regularly collected in pixel mode (lower frame rate)

OCO-1 spares, # bad in HgCdTe WCO2 & SCO2 channels roughly tripled between test in 2012 and IOC in 2014

Updated the bad pixel map 4 times in first half year of mission

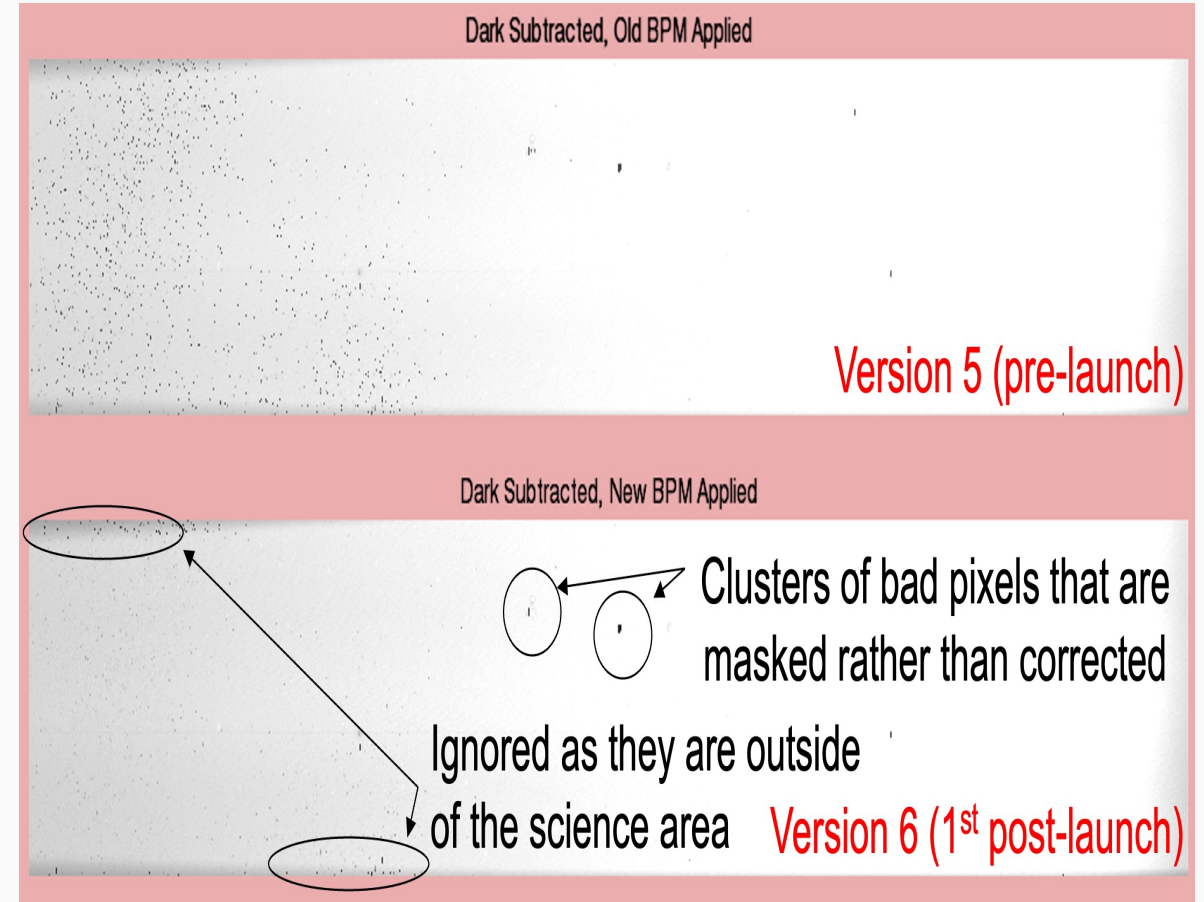
Introduced random forest classifier to use a prior map and the time series of dark & lamp data to calculate per-pixel likelihood

Updated using ML results in August 2018, checked routinely but no upload since then

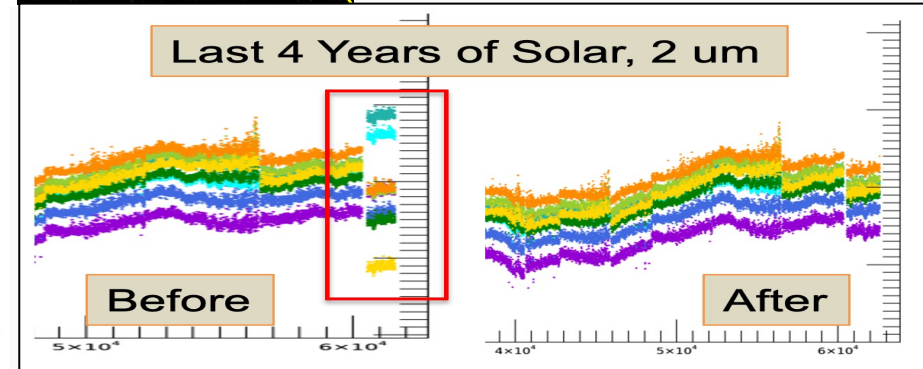
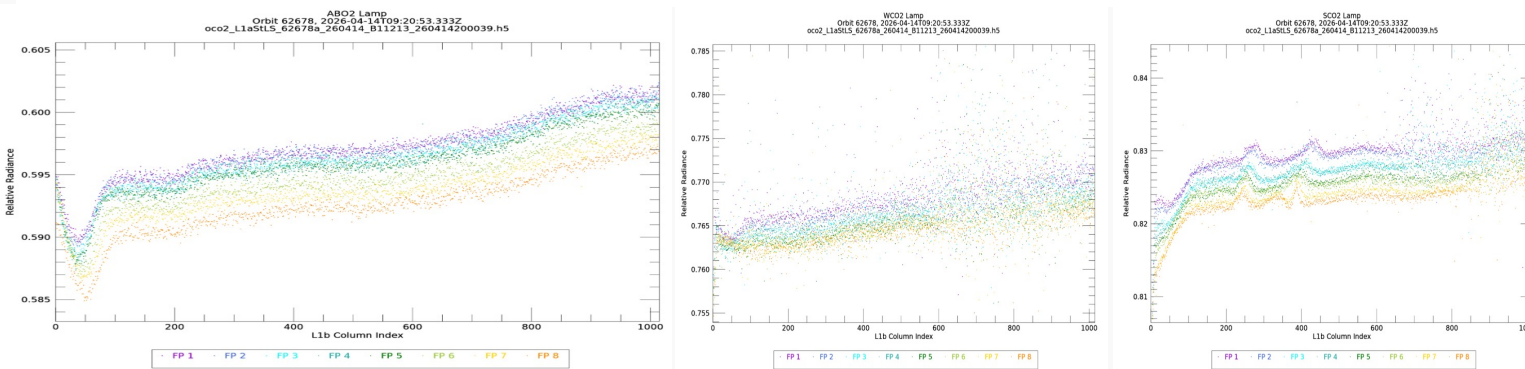
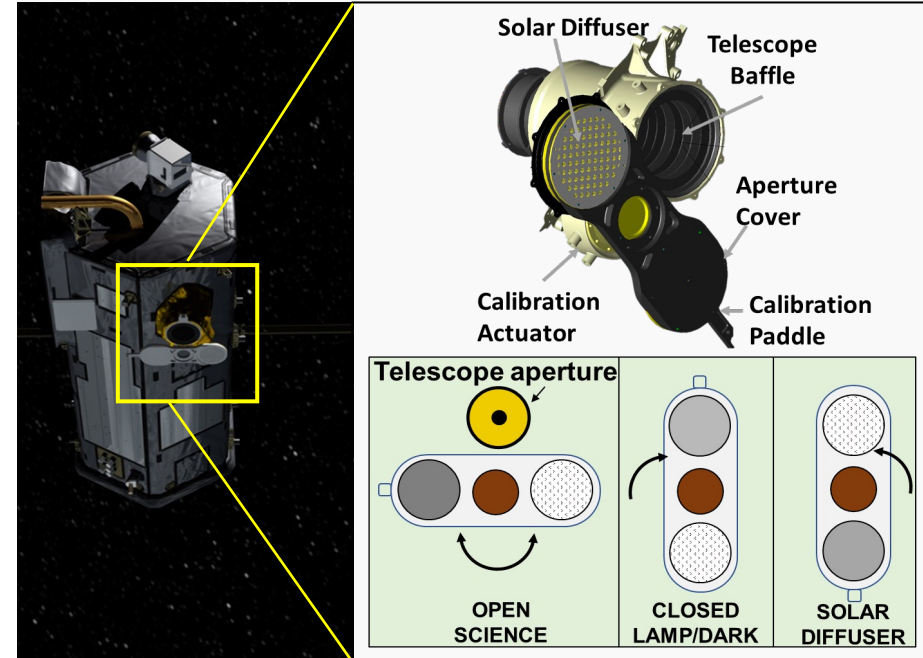
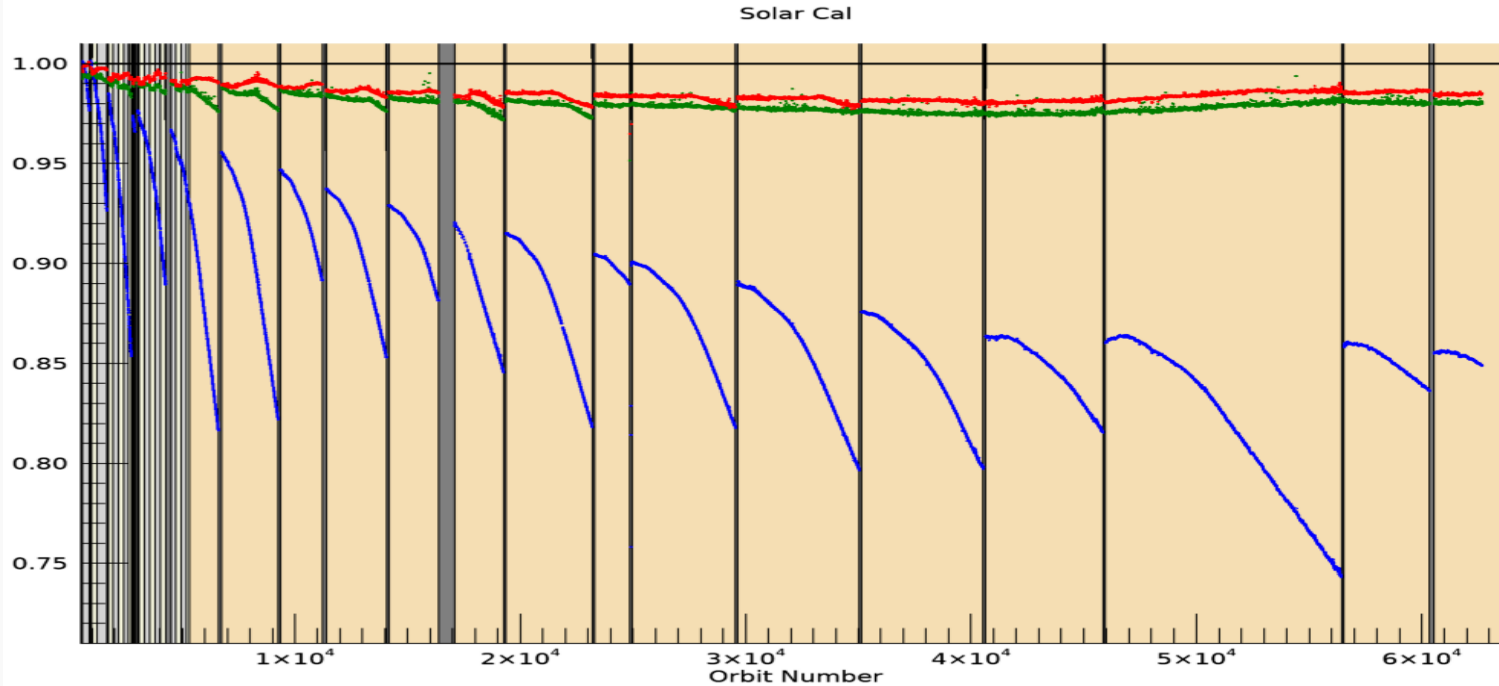
Can also exclude outliers on the ground at the super-pixel level

Still not applying a flat field in CO2 channels

O₂ detector (Si) is nearly unchanged

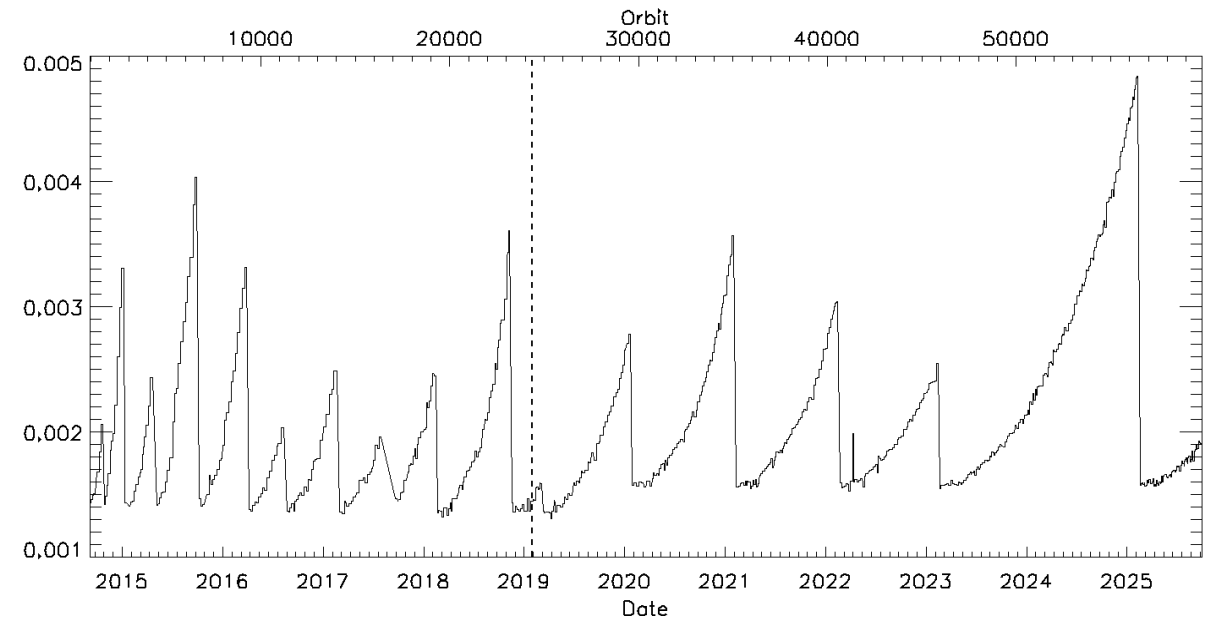
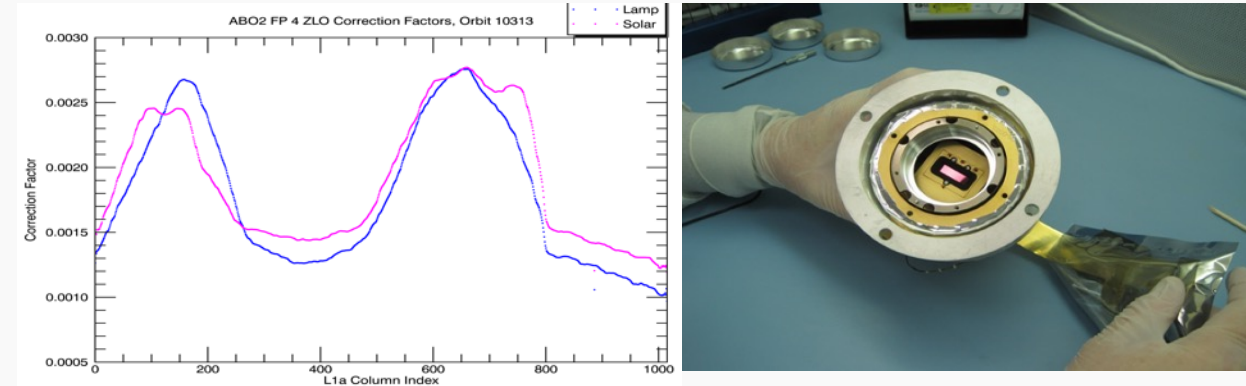


Baffle Calibrator Assembly



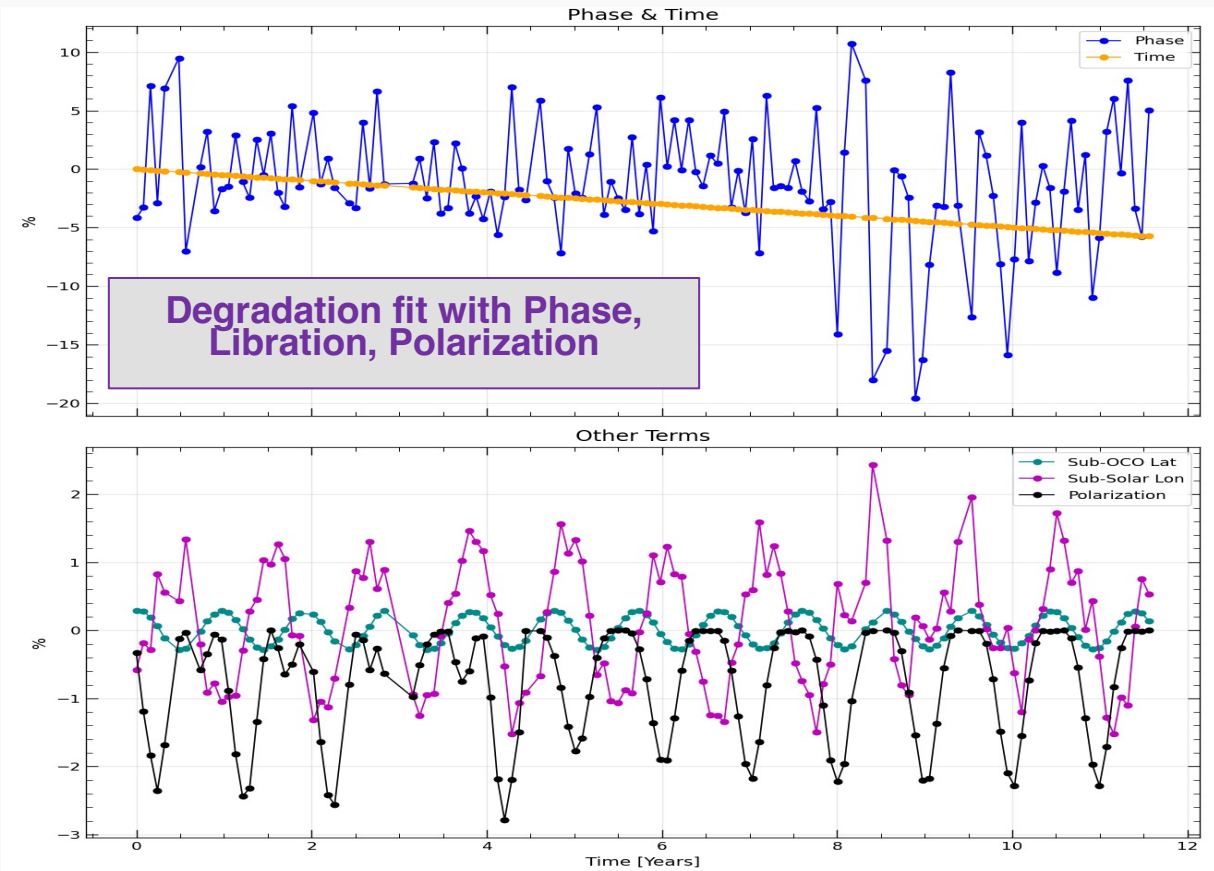
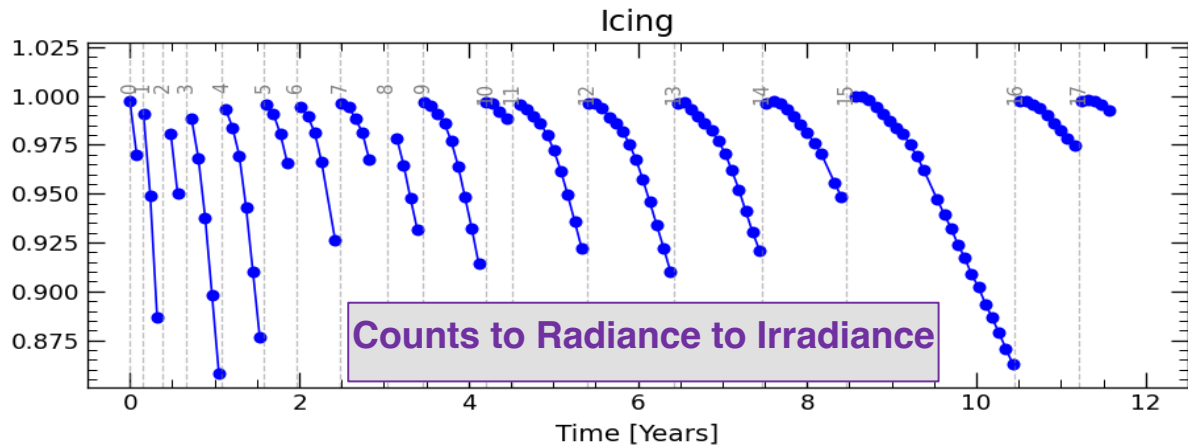
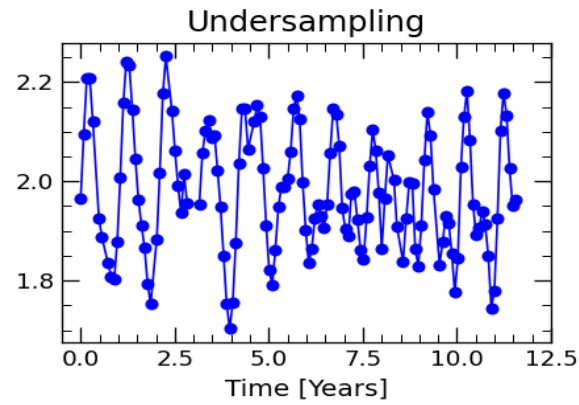
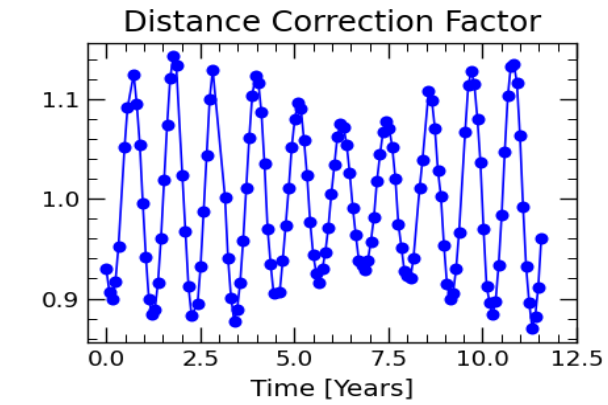
Stray Light

- Light reflected by detector hits FPA mask and returns out of focus, double-peaked in spectral dimension
- Estimated from signal reaching otherwise unilluminated rows in pixel mode (ABO2 only for OCO-2, both ABO2 & WCO2 for OCO-3)
- Correction proportional to mean signal in science area
- Identified for Version 8, led to more stable SIF trend
- Though not identified at the time, was present preflight – reprocessed radiometric and spectral calibration for latest version
- Wings of instrument line shape were reduced as described in “Orbiting Carbon Observatory-3: Preflight Spectral Calibration and Performance Evaluation”

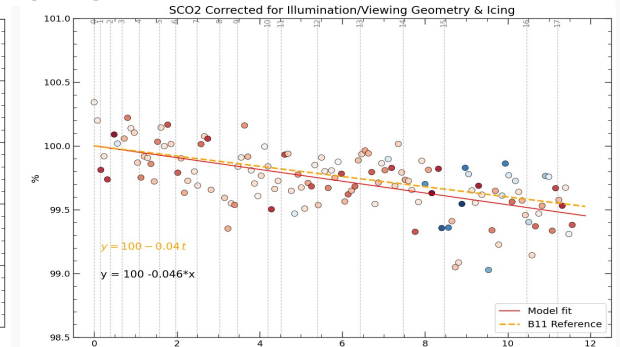
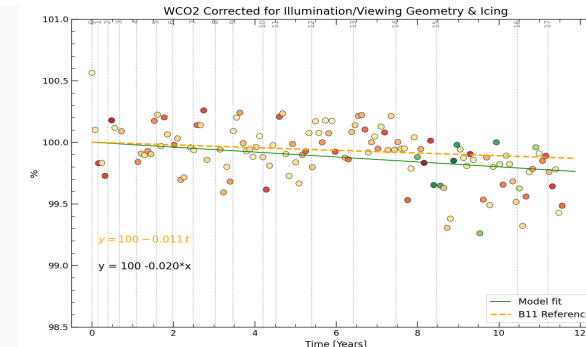
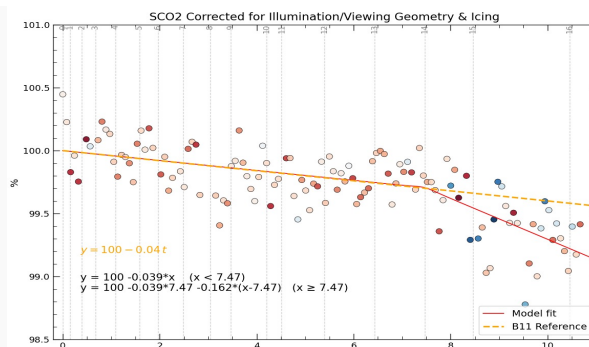
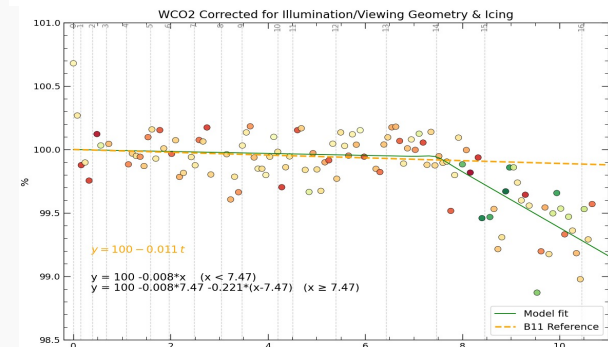
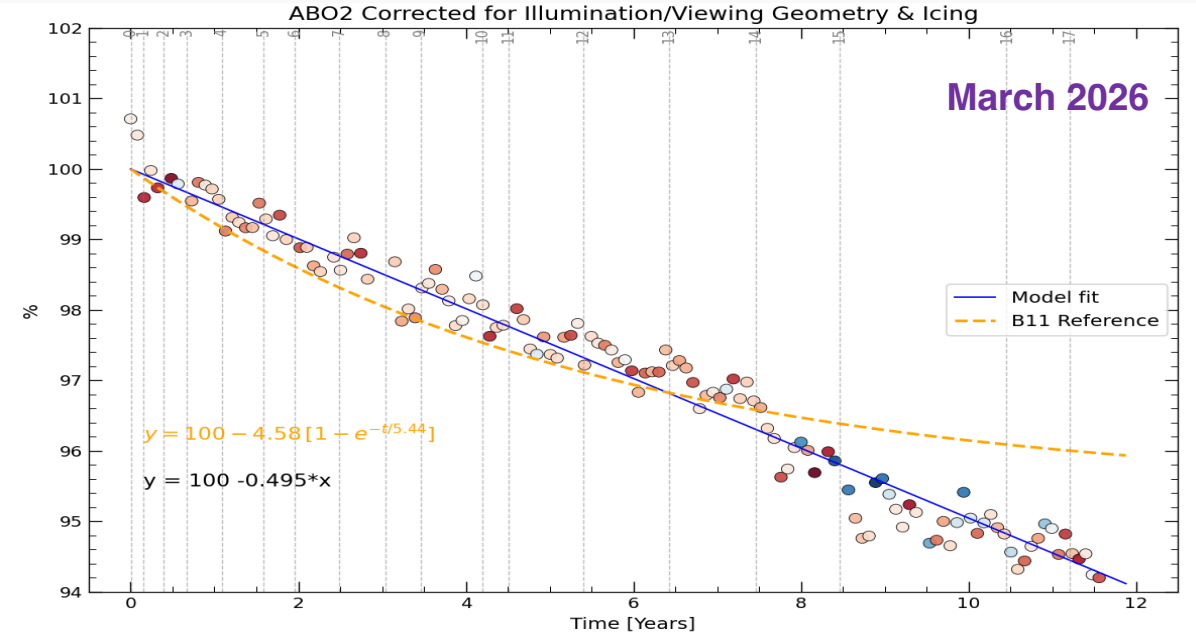
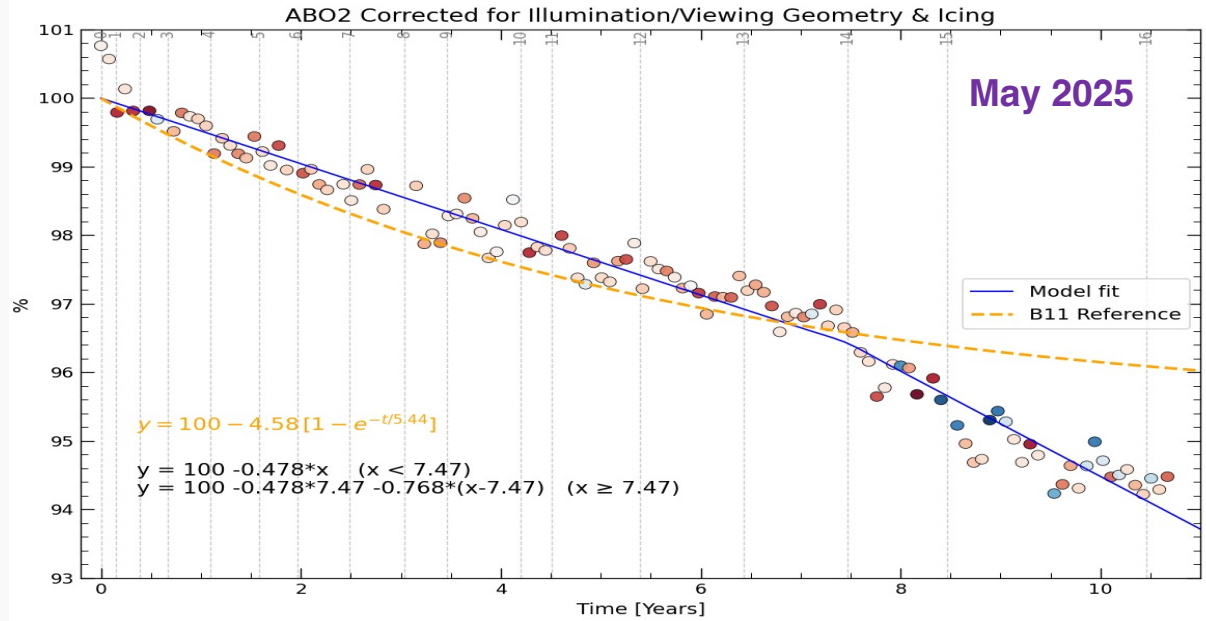


“Lunar Orbiting Carbon Observatory” Disk-Integrated Irradiance Model

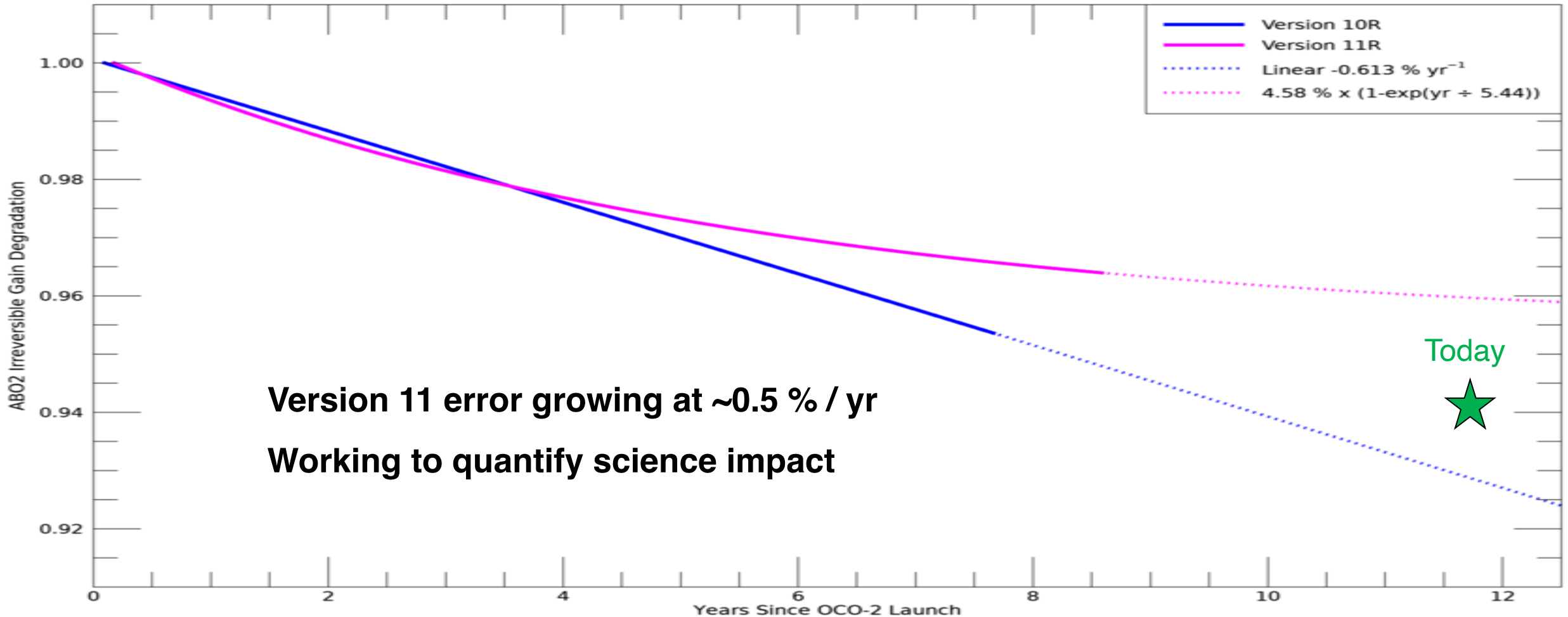
OCO-2 always measures waxing gibbous (-60°)
Also measured near-full (+10°) until 2019 IMU loss
Coincident views: OCO-3, Air-LUSI, ARCSTONE



Slow Degradation from LOCO v2 Model



Lunar Trend: Big Picture



Version 11 error growing at ~0.5 % / yr
Working to quantify science impact

Today
★

Conclusion

The combination of ambitious science goals, a sensitive instrument, a full-physics retrieval algorithm, and precise validation measurements demands an aggressive calibration effort

The carbon cycle is changing; scientists need to be confident in findings

Track both gradual and sudden changes in instrument response by delivering new coefficients weekly and reprocessing often

Version 12 didn't go forward last year, but the team accumulated a lot of valuable knowledge (which helped OCO-3 gain confidence in their latest reprocessing)

Potential pivot to “Orbiting Crop Observatory” could motivate the team to dig deeper into spatial response or other subtle artifacts

