Using Clear Ocean Scenes to Constrain Changes in Instrument Response in OCO-3

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Introduction

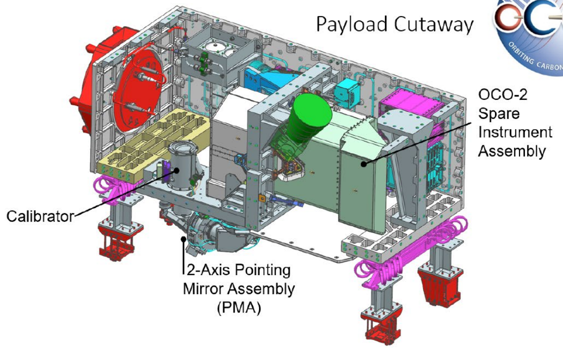
OCO-3

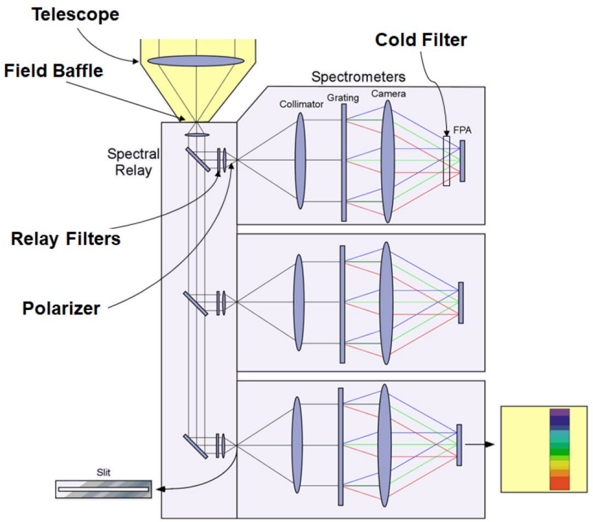
- Launched on May 4th, 2019;
- Uses the flight spare spectrometers from OCO-2 to obtain high resolution spectral images a resolving power near 20,000.
- It observes reflected solar light in three infrared spectral channels centered at 0.765, 1.61, and 2.06 microns.
- Prelaunch radiometric calibration was performed at NASA's JPL using an Integrating Sphere Source calibrated with respect to NIST reference standards and it is updated inflight.

$$R_j = \frac{1}{k_j(t)} \sum_{i=1}^{3} c_{ij}(dn_j(t))^i.$$

R_j - Radiance per sample j.
dn_j – Dark subtracted counts per sample j.
c_i - Calibration coefficients.
k - Inflight degradation coefficients.

- Inability to perform solar calibration and initial geolocation and pointing imprecision delayed plans for vicarious calibration, intercomparison with OCO-2, and lunar calibration.
- As a consequence, OCO-3's inflight radiometric calibration depends solely on its onboard calibrator.





Onboard Calibrator

Inflight updates to gain degradation

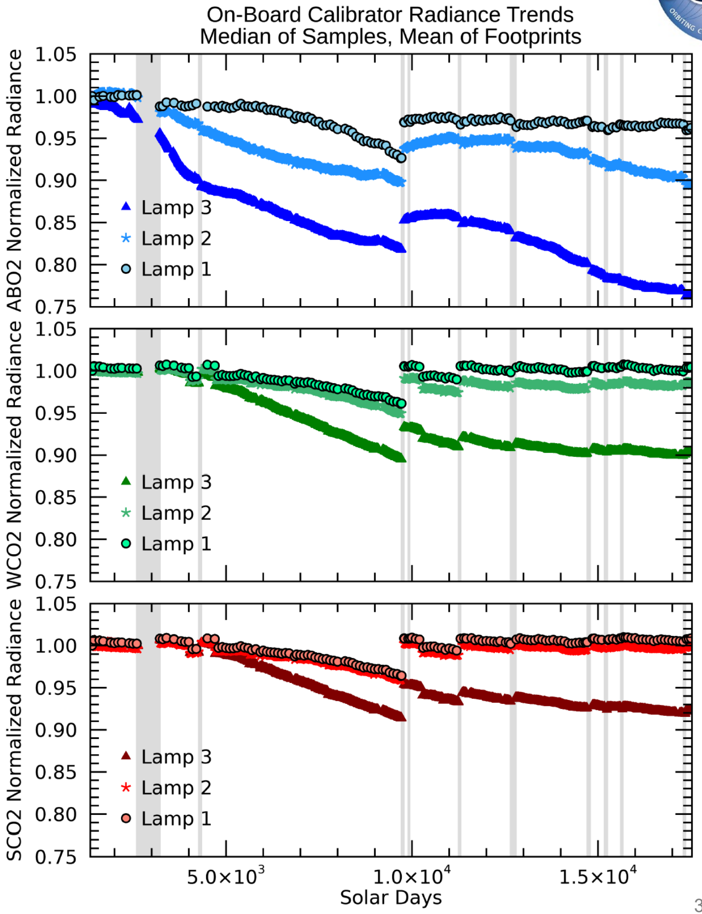
- Three Tungsten halogen lamps illuminate a gold coated reflective diffuser.
- Comparison between lamp observations inflight and prelaunch are used to assess the degradation of the instrument response, but lamp aging is a confounding factor.
- The lamps are observed at different cadences:

L1 – 1% of the time. Every 100 SDs or 6.5 days;

L2 – 19% of the time. Every 5 SDs or 8 hours;

L3 – 80% of the time. Every SD excluding those above.

- We assume L1, the least used, does not age and use L1 data to constrain aging of lamps 2 and 3 to mitigate lamp aging and at the same time retain the temporal resolution allowed by lamp 3.

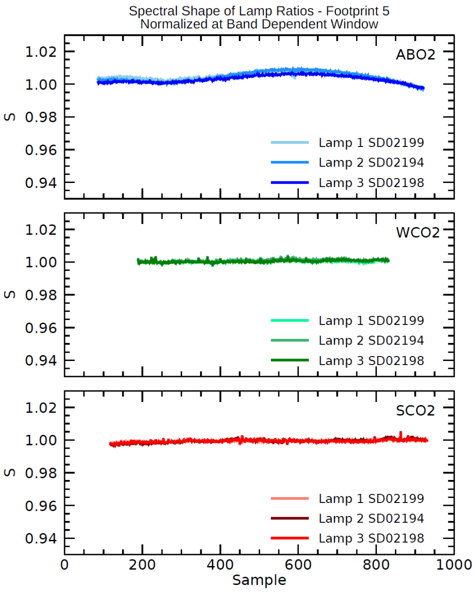


Spectral Profile of Lamp Observations

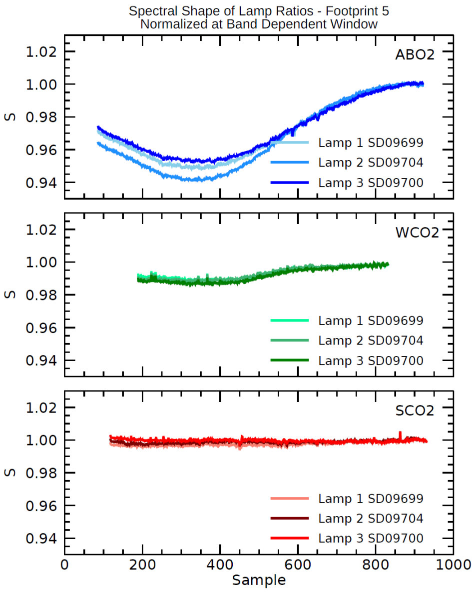
Changes at different points in the mission

- Both the ABO2 and the WCO2 bands display important changes in the spectral shape of lamp observations, but the main causes are different.
- We define the Shape parameter S, as on the right, to describe the curvature observed.

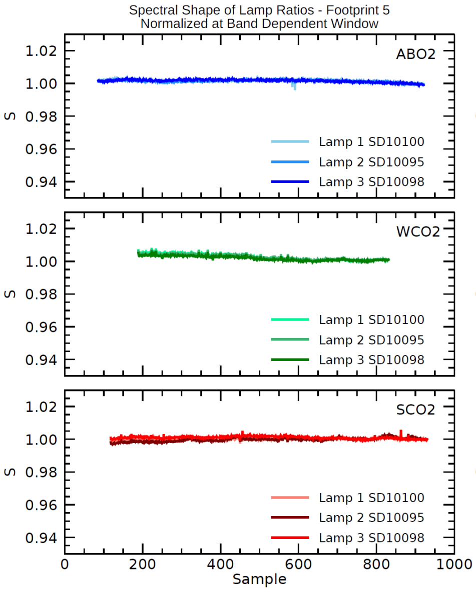
$$S_j(t) = \frac{\frac{R_j(t)}{\overline{R}_{j_{start}:j_{end}}(t)}}{\frac{R_{ref\ j}}{\overline{R}_{ref\ j_{start}:j_{end}}}},$$



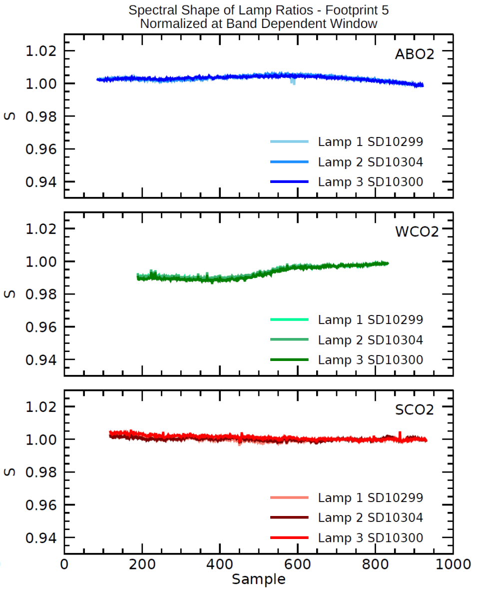
(a) Early Mission.



(b) Right before decontamination event ending on SD 9780.



(c) Right after decontamination event ending on SD 9780.



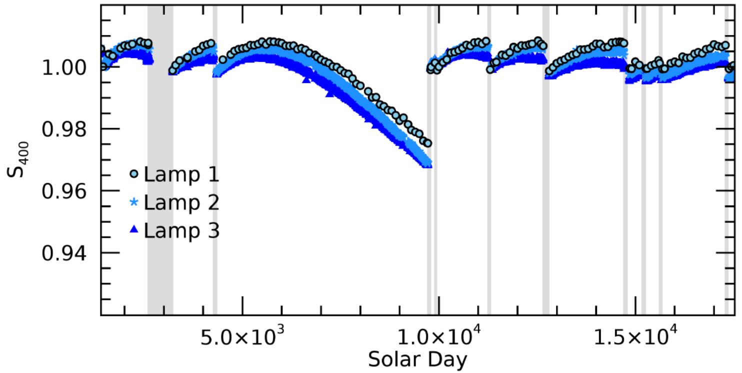
(d) After instrument reset at SD 10264.

Spectral Profile of Lamp Observations

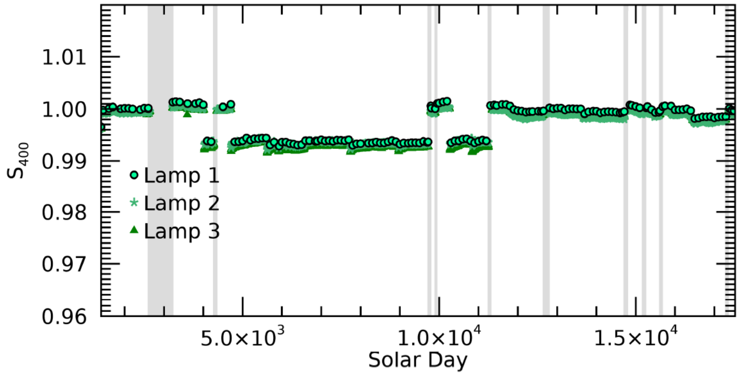
Time Trends

- Curvature develops gradually in the ABO2 and is abruptly removed by a decontamination event.
- Changes in the spectral shape of the WCO2 band don’t build up with time. They are sudden and coincide with AFE (Analog Front-End Electronics) power cycles, which happen during instrument resets and decontamination cycles.
- The three lamps diverge in terms of ABO2 curvature as contamination builds up.

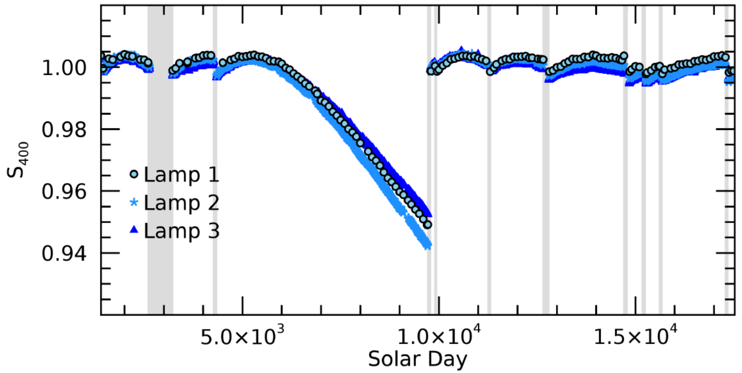
Spectral Shape Trends at Sample 400 from Lamp Observations.
ABO2 - Footprint 1.



Spectral Shape Trends at Sample 400 from Lamp Observations.
WCO2 - Footprint 1.



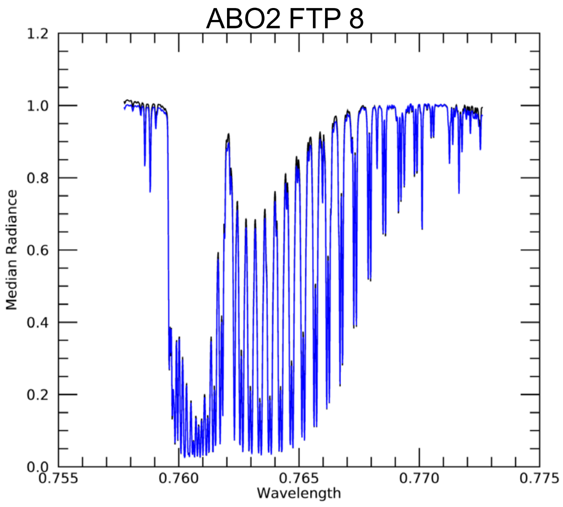
Spectral Shape Trends at Sample 400 from Lamp Observations.
ABO2 - Footprint 5.

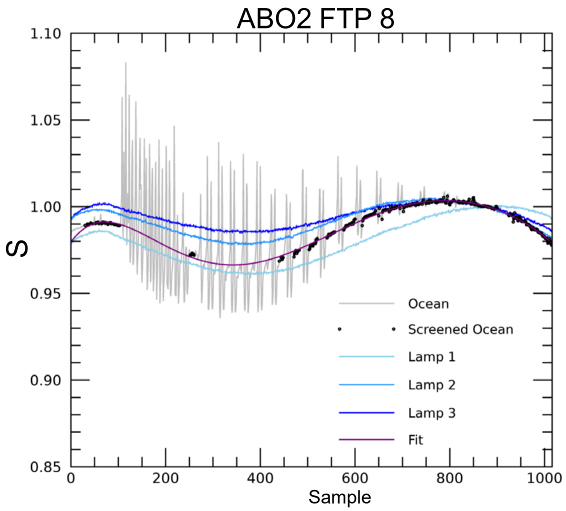


Curvature from Clear Ocean Scenes

Lamp x Earth discrepancy

- During periods of high contaminant buildup, the ABO2 spectral curvature imparted to each lamp is different and so is the curvature imparted to clear ocean scenes (right panel).
- Clear ocean scenes observed near the glint spot are stable scenes that should look similar at different times and locations, if aerosols, polarization (via zenith angle), and windspeed are controlled for.
- We averaged thousands of clear ocean scenes soundings for a low- and a high-contaminant period (blue and black lines on the left panel, respectively). Before averaging, the data was calibrated, a dispersion correction was applied, spectra were normalized to the median radiance of a continuum window, and further aligned in the spectral direction using a correlation function. Residual spectral line profiles were screened out. Similarly normalized lamp data were overplotted.

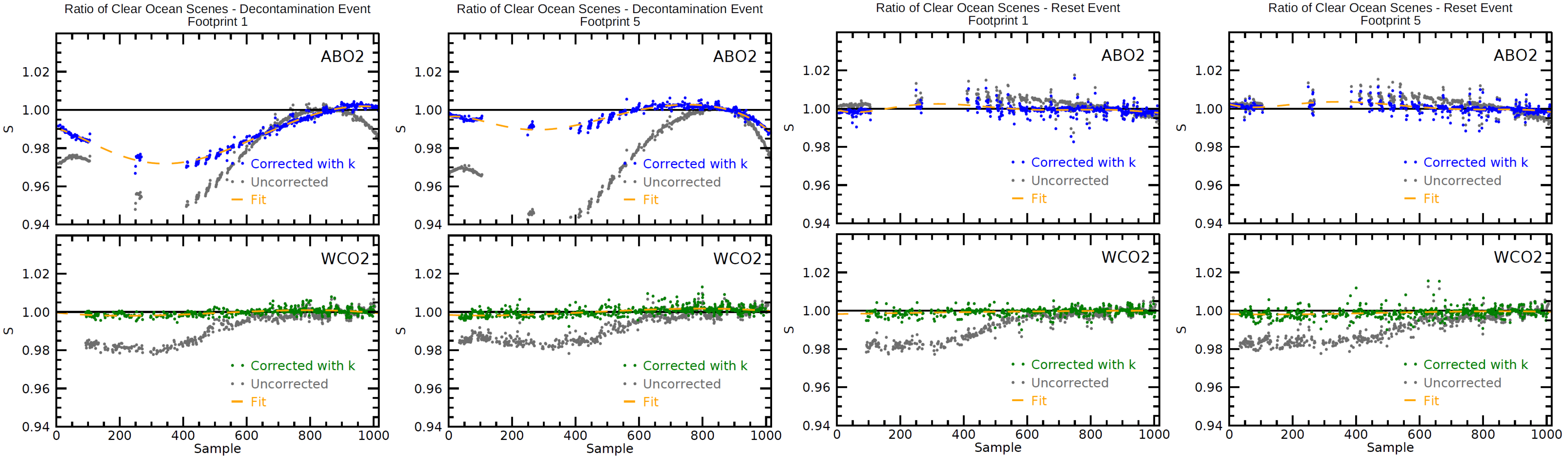




Curvature from Clear Ocean Scenes

Assessing Inflight Gain Degradation Using Clear Ocean Scenes

- Thousands of clear ocean scenes before and after a decontamination and a reset event are used to assess gain degradation in the ABO2 and WCO2 bands.
- During the period of high contamination, inflight gain degradation cannot properly correct ABO2 curvature due to lamp observations being affected differently and also differently from Earth observations.



(a) Decontamination event, footprint 1.

(b) Decontamination event, footprint 5.

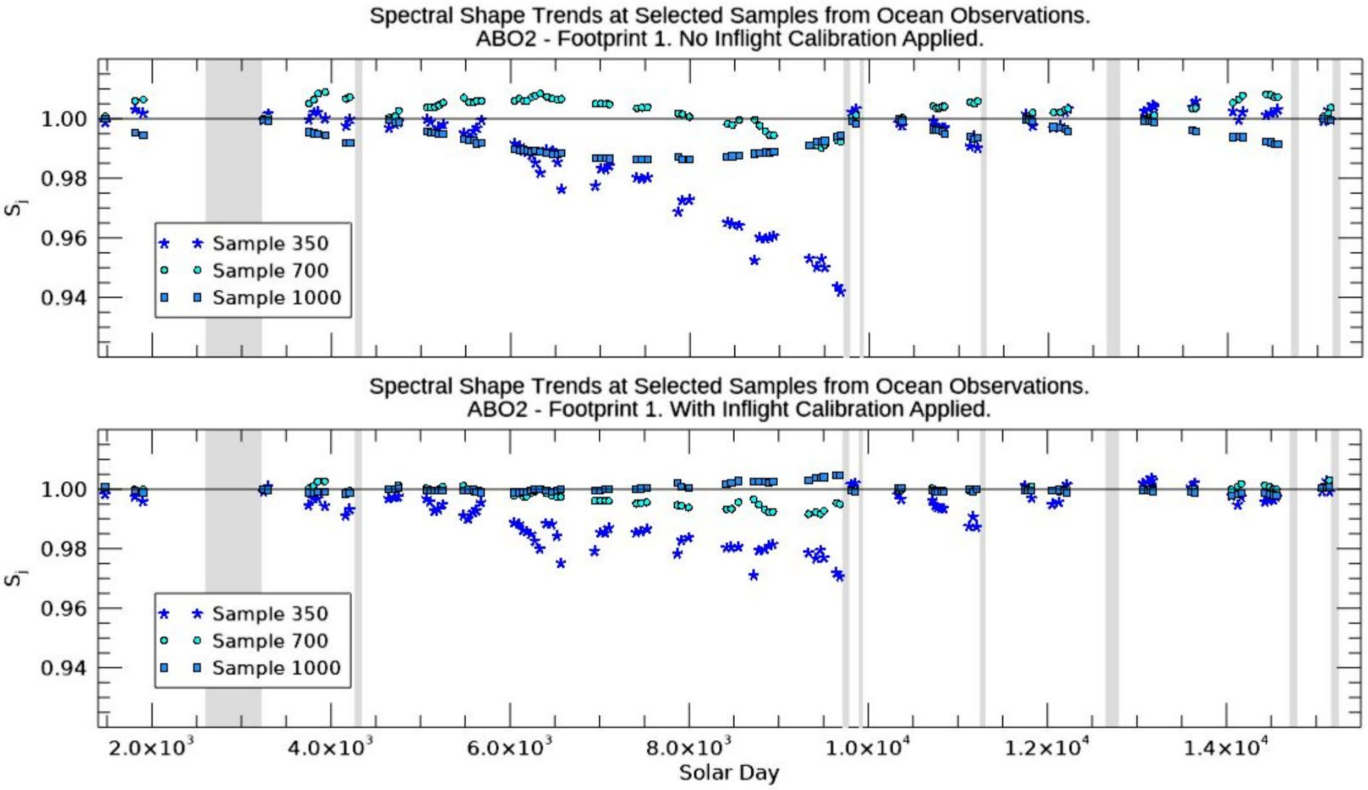
(c) Reset event, footprint 1.

(d) Reset event, footprint 5.

Curvature from Clear Ocean Scenes

Curvature Trends.

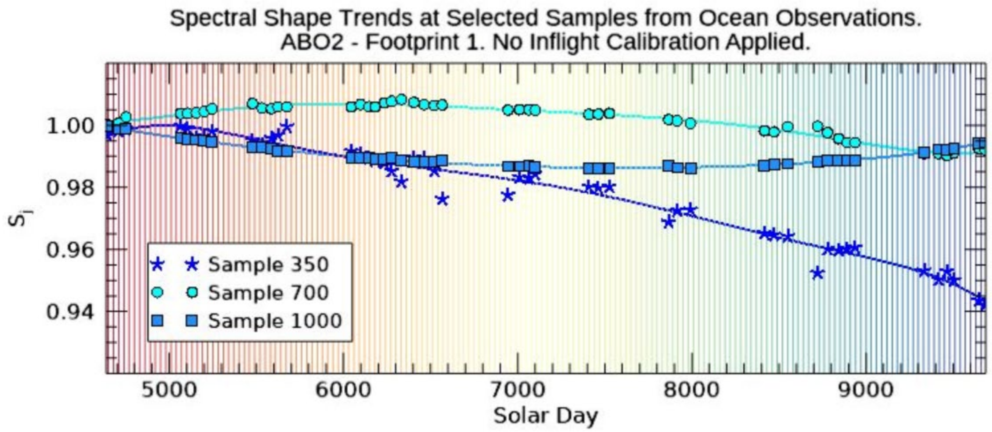
- Top panel, without inflight gain degradation applied.
- Bottom panel, with inflight gain degradation applied.
- Inflight gain degradation as currently derived, can't entirely correct curvature during periods of high contaminant buildup.

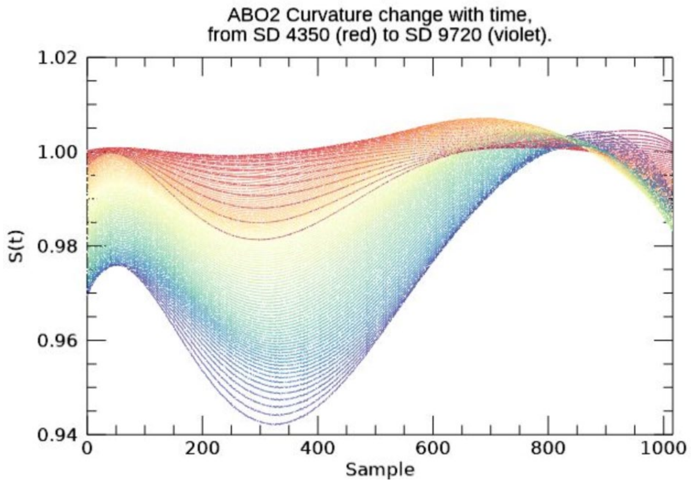


Next Step

Deriving Inflight Gain Degradation from Clear Ocean Scenes

- We will derive the spectral shape (not the magnitude) of gain degradation (S) for each sample of each ABO2 footprint by fitting a polynomial through the clear ocean scene ratio data of each decontamination cycle separately, as exemplified below, and then multiplying by the normalized gain degradation at a reference time, where we can assume contamination is low enough that gain degradation derived from lamp observations is correct.
- The plot on the left shows the polynomial fits and the one on the right, the temporal variation of the Shape parameter.





Summary

- The inflight radiometric calibration of OCO-3 in version 10 products depends solely on its onboard calibrator.
- During high contamination periods, the spectral curvatures seen in observations of the different lamps disagree, and none of the lamps agrees well with the spectral curvature seen in clear ocean scenes.
- Lamp based inflight gain degradation is unable to properly correct ABO2 curvature during periods of high contamination, which is largest on Jan 2021.
- We are using science data to directly derive the spectral shape of gain degradation.