20th International Workshop on Greenhouse Gas Measurements from Space

Wednesday 29 May 2024 15:00-15:15 MDT

Empirical Orthogonal Functions to Diagnose and Correct OCO-2/3 Calibration Errors

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Introduction

- Mission goals for XCO2 precision & accuracy demand an aggressive retrieval & post-processing approach
- We are still learning the fundamental physics underlying this measurement! This creates persistent structures in spectral residuals (difference between measured & modeled radiance, often normalized)
- Empirical Orthogonal Functions were not introduced specifically for calibration, but they have been the most sensitive measure of what we need to improve

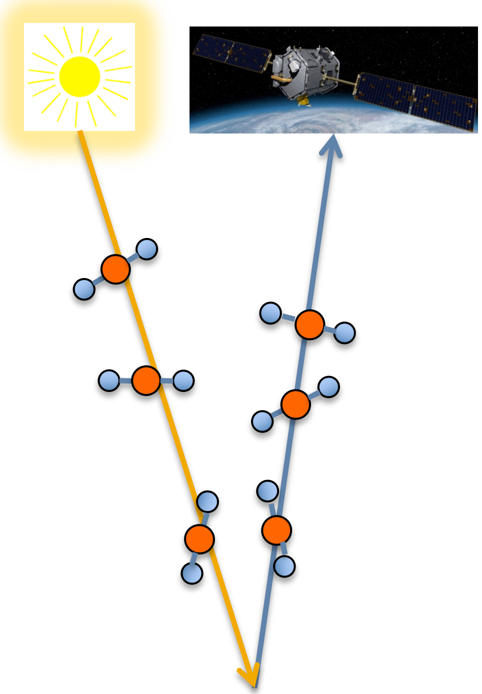
ACOS Retrieval Algorithm

Both missions using Version 11

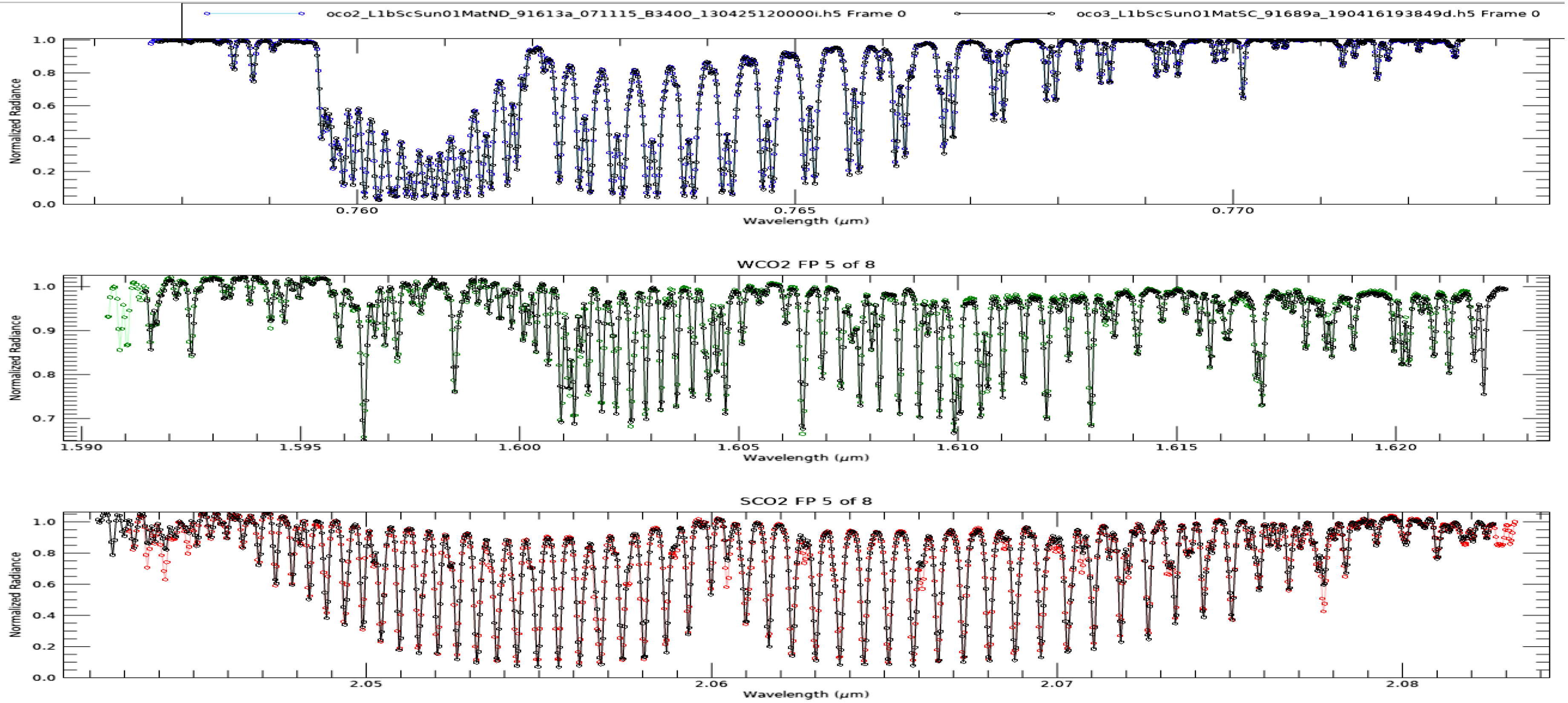
- Atmospheric Carbon Observations from Space Level 2 full physics retrieval well-described by ATBD & several journal publications

- Algorithm & state vector change with each version, so do inputs such as geolocation, absorption coefficients, and calibration

- Early in development, define "quick test set" (QTS) to span the ever-lengthening record in space, time, footprint, other variables



Example Up-looking Spectra (Prelaunch)



Contributors to Spectral Residuals

Many are calibration, many are not

- Begin by processing a large volume of data without EOFs in state vector
- EOFs (principal components) of residuals identify patterns in the mean of a large population that may not be easily identified from few soundings
- Functions ranked by fraction of variance explained, usually stop at 3 or 4

- Only filtered ocean data has been used for operational processing
- Land has also been evaluated as a diagnostic
  - Higher radiance (important for assessing detector nonlinearity correction)
  - Different parameterization of in-band spectral shape (linear vs. quadratic)
- EOFs never perfectly ”associated” with any feature, but ABSCO dominant

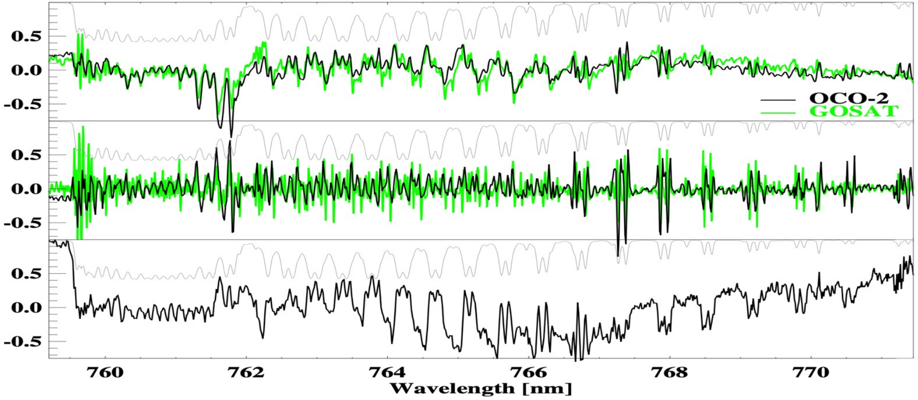
OCO-2

- EOF shapes very similar to GOSAT, which has same ABSCO input but entirely different instrument/calibration artifacts

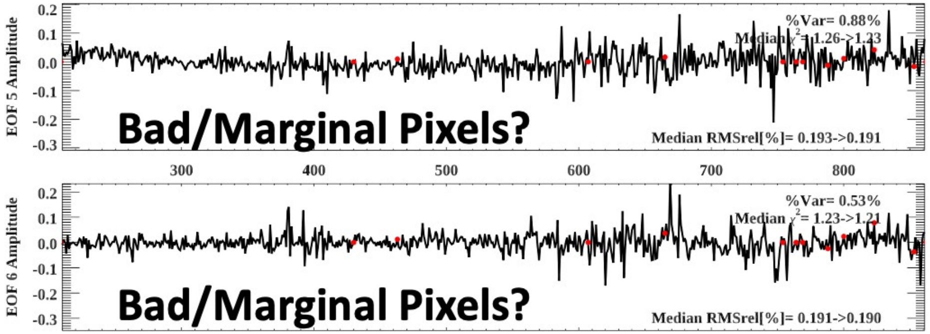
- Severe degradation of focal plane arrays in Bands 2 & 3 between ground testing and launch

- Other subtle features associated with icing & decontamination

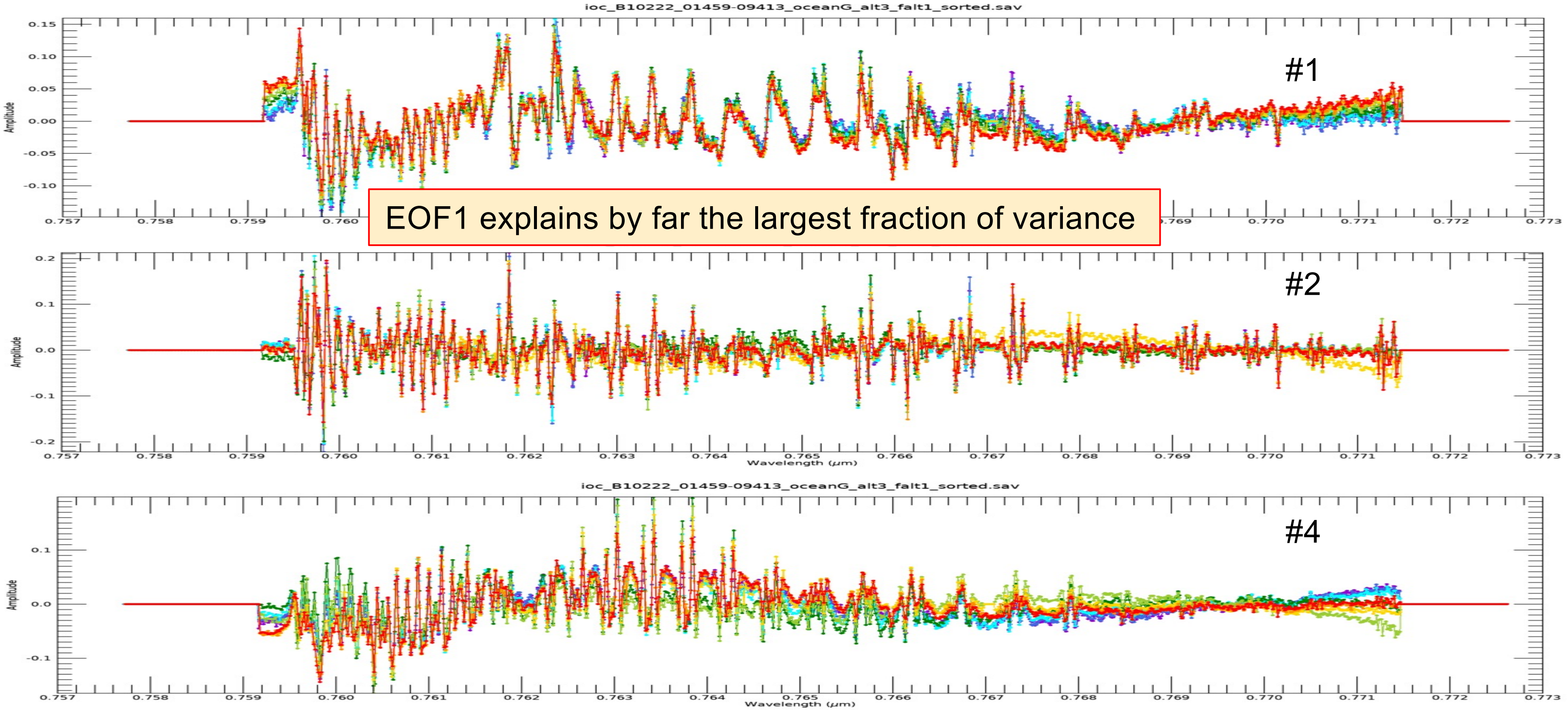
ABO2: OCO-2 FP 4 B7 & GOSAT B3.5



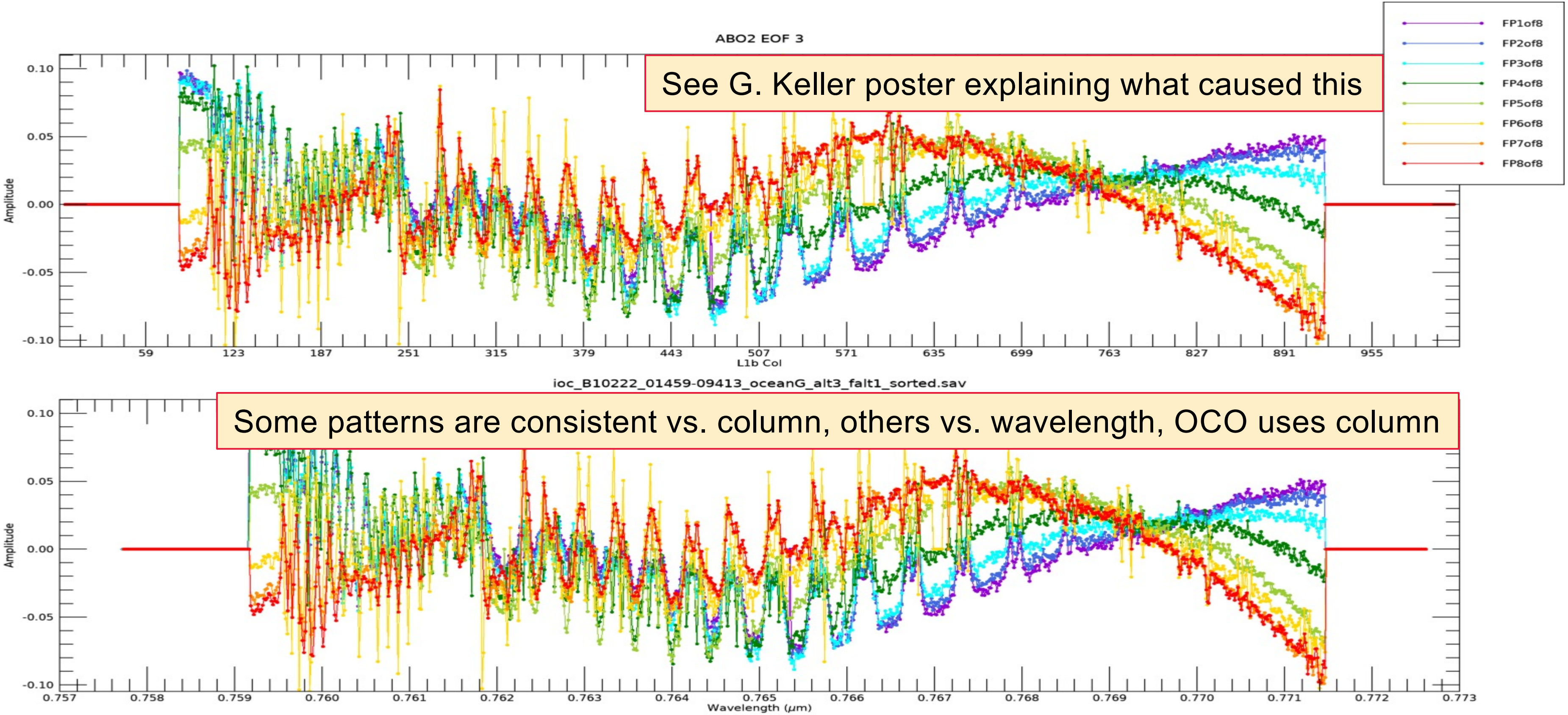
WCO2: OCO-2 FP 1 B11



OCO-3: B10.3 ABO2 EOF 1, 2, 4 Shape vs. Wvl

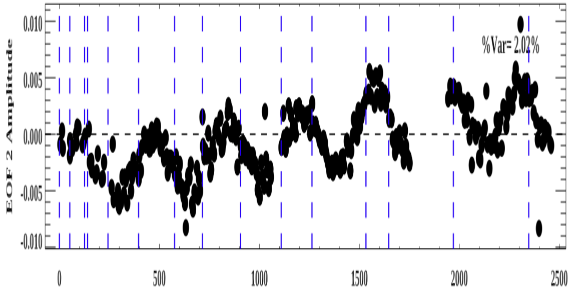


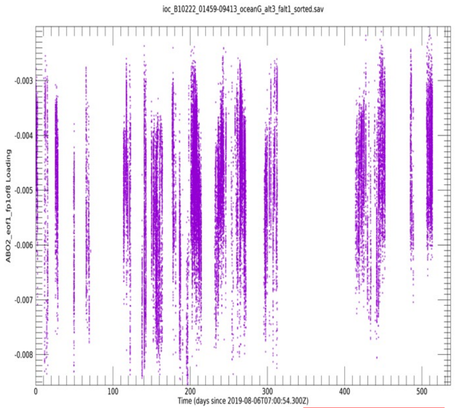
OCO-3: B10.3 ABO2 EOF 3 Shape

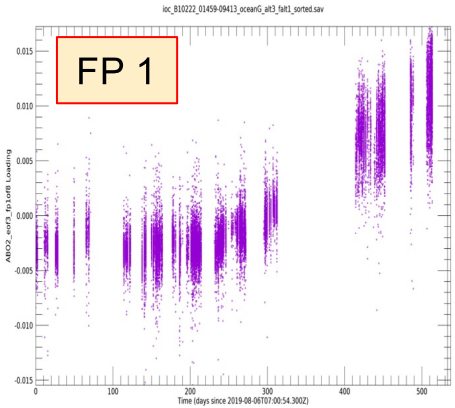


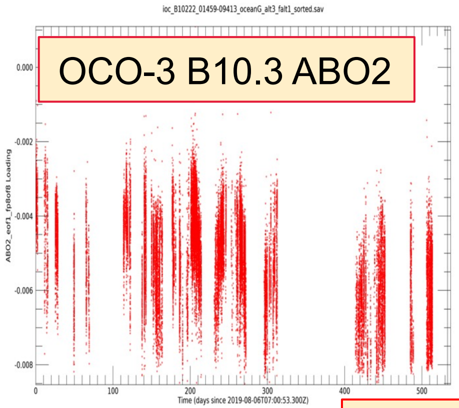
EOF Amplitude (“Loading”) Trends

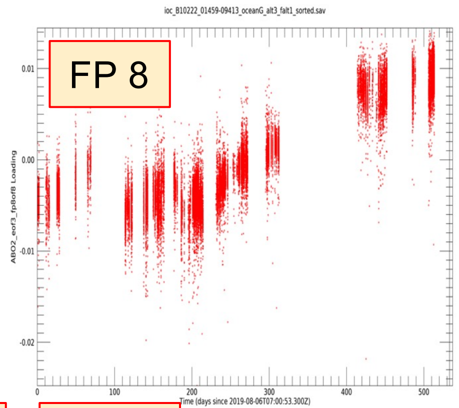
- EOFs identify leading modes of variability in spectral residual structures, as they are not generally constant
- If there are seasonal oscillations, correlations with icing / stray light, discontinuities at resets, etc., that makes interpretation considerably easier



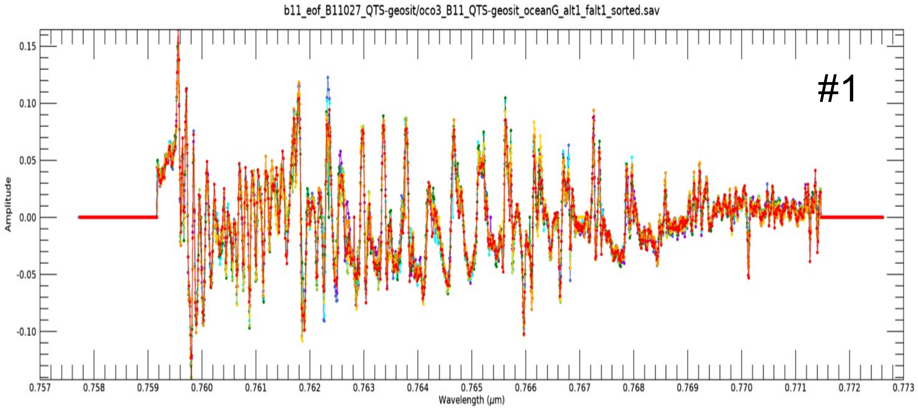


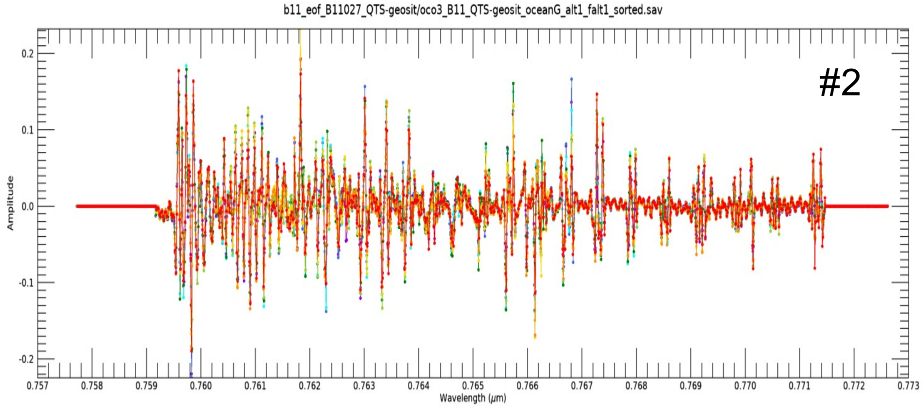


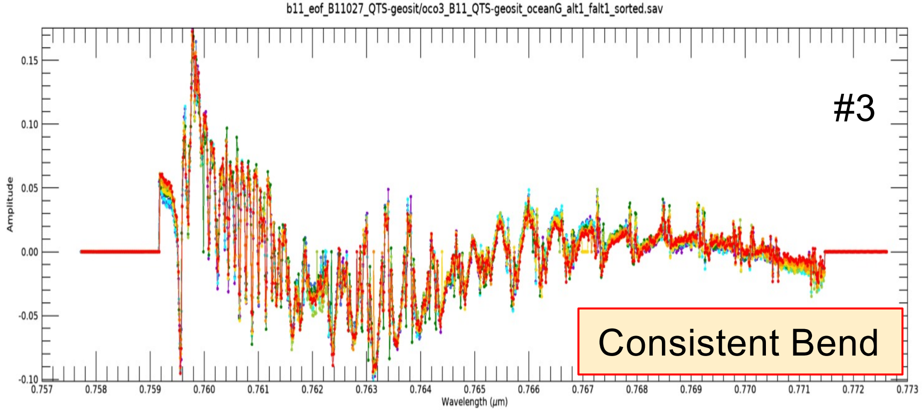


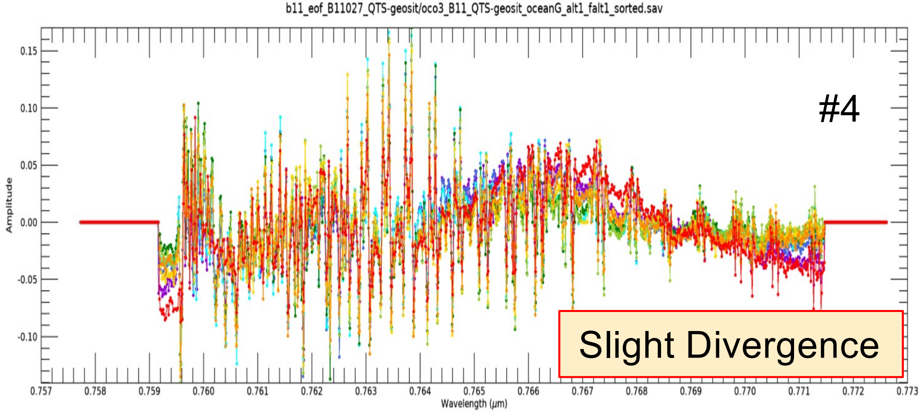


OCO-3 B11027: ABO2 EOF 1-4 Shape

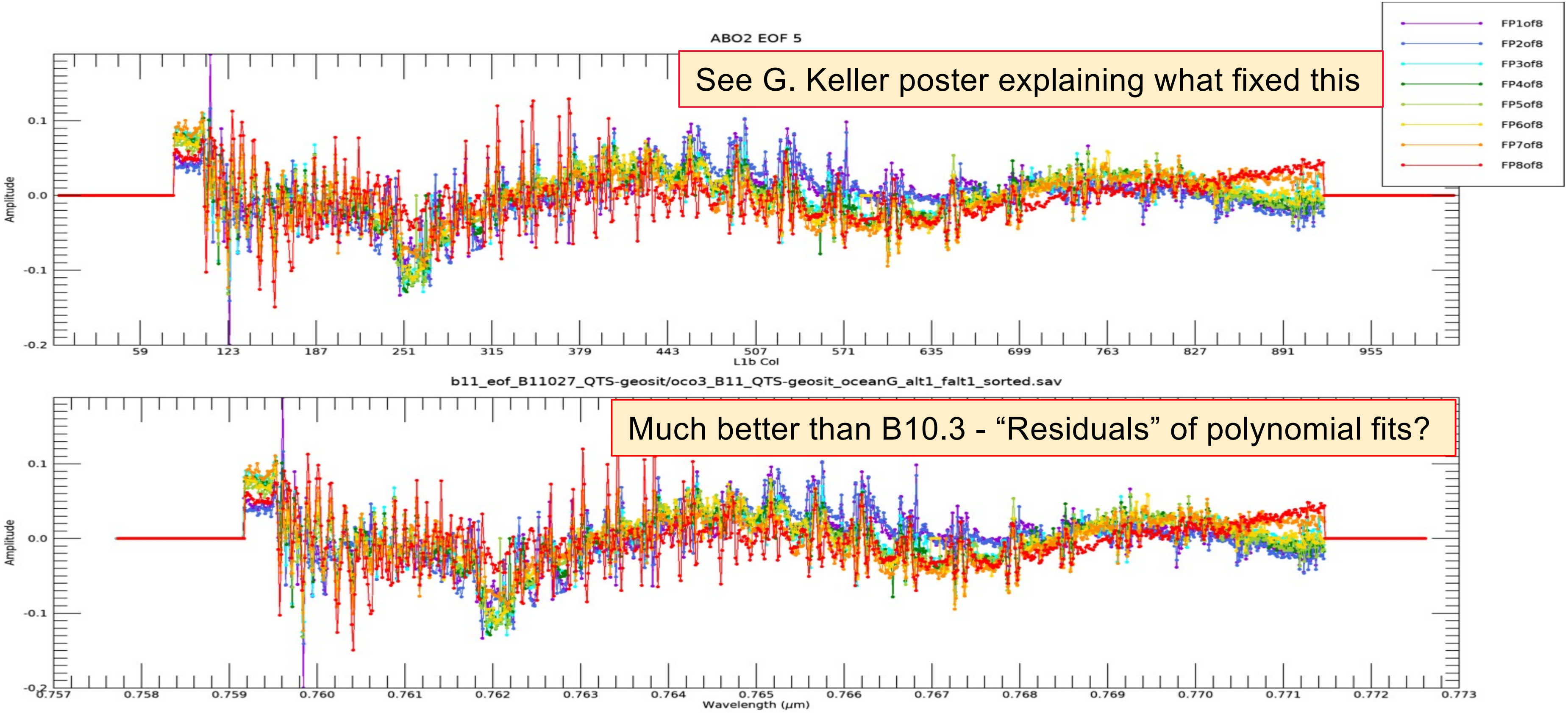








OCO-3 B11027: ABO2 EOF 5 Shape



Conclusion

Understand persistent structures in the residuals, then remove them

- EOFs often **by far** the most sensitive tool to diagnose calibration errors
- If EOF shapes vary with spatial footprint -> Calibration
- If EOF loadings are correlated with icing -> Calibration
- Incomplete solution if patterns change shape over time
- Works best if QTS covers most/all of record
    - Seasonal oscillations? SZA dependence?
- What to make of land/ocean or ND/GL differences?
    - Subset by albedo?
- Still a lot to learn!