“Calibration uncertainty in ocean color satellite sensors and trends in long-term environmental records”

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INTRODUCTION

- **There has been considerable interest in estimating trends in the oceanic phytoplankton activity in response to climate change and anthropogenci forcing.**
- **Observed changes in chlorophyll *a* concentration is a key indicator of change in phytoplankton activity.**
- **Spatial and temporal patterns of chlorophyll *a* concentration in the upper layers of the ocean can be estimated synoptically using remote sensing.**
- **However, before we can make statements about changes or trends in chlorophyll a, we must quantify how much can be attributed to uncorrected variation in the instrument.**
- **This study introduces an initial study connecting residual instrument change on satellite chlorophyll data.**

INTRODUCTION

- ❑ **Several sources of uncertainty could change with time, and thus could affect trends (or effect spurious trends) in ocean color data products.**

  - ★ **Instrument calibration trend uncertainty.**

    - **Extapolation Uncertainty**
    - **Solar Diffuser Stability Monitor**
    - **Relative Spectral Response Change**
    - **Polarization Response Change.**
    - **Counts-to-Radiance Conversion**

INSTRUMENT CALIBRATION TREND UNCERTAINTY

WHAT WE KNOW :

- ❑ Errors in at-sensor measurements stem from calibration and instrument effects (e.g., noise).

- ❑ Measurements of the ocean surface require removal of the atmospheric contribution to at-sensor measurements. The NIR bands assist with this step.

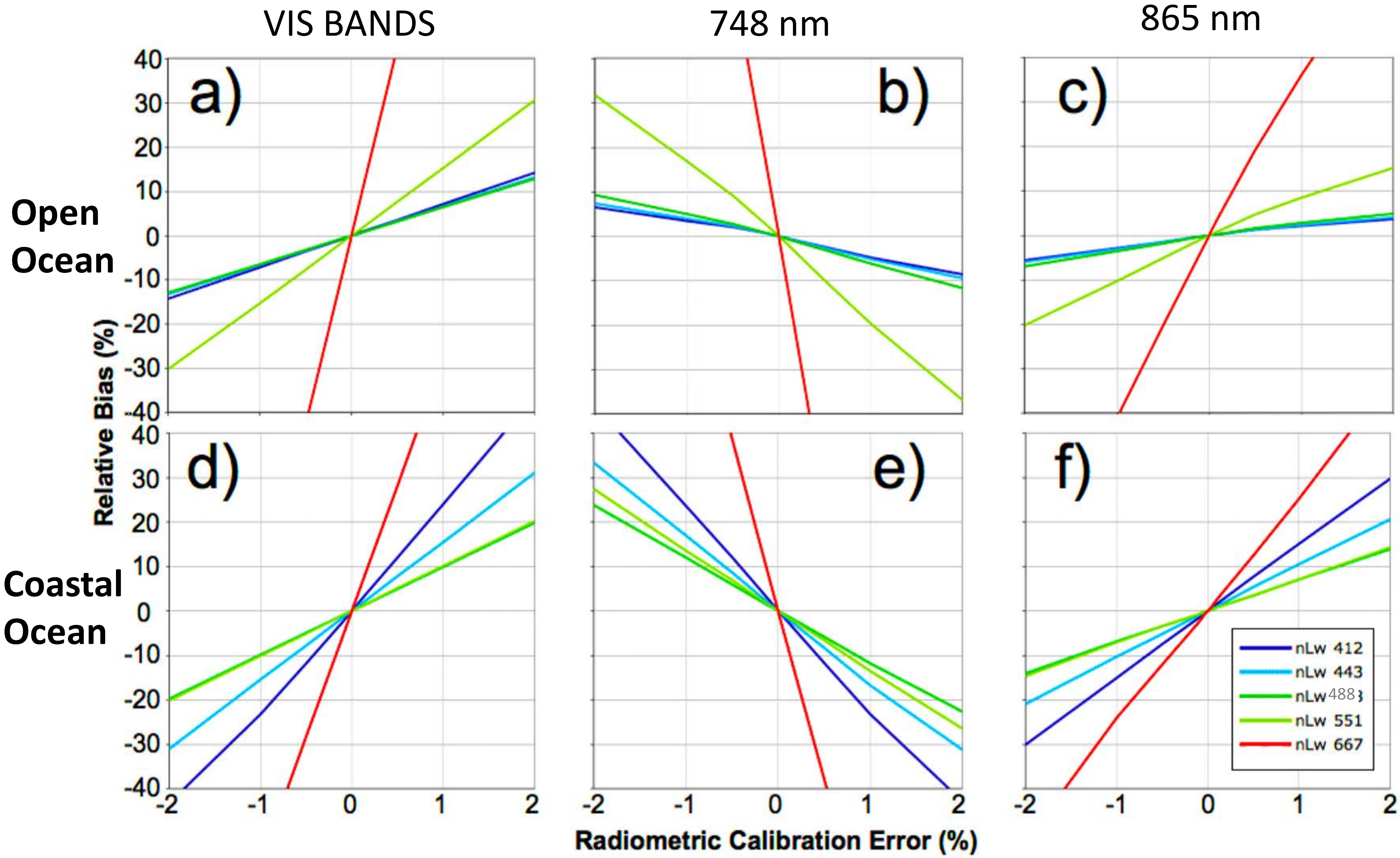
- ❑ Because the atmosphere contributes to ~90% of the measured light, a small error is relatively large to the remaining surface contribution.

- ❑ **Opposite-signed errors between the two NIR bands lead to significant effects in the surface measurements.**

- ❑ **Errors in surface measurements for the blue and green bands lead to errors in the estimate of Chlorophyll *a*.**

- ❑ **Trends in these errors can lead to spurious trends in Chlorophyll *a*.**

Relative Mean Bias for nLw

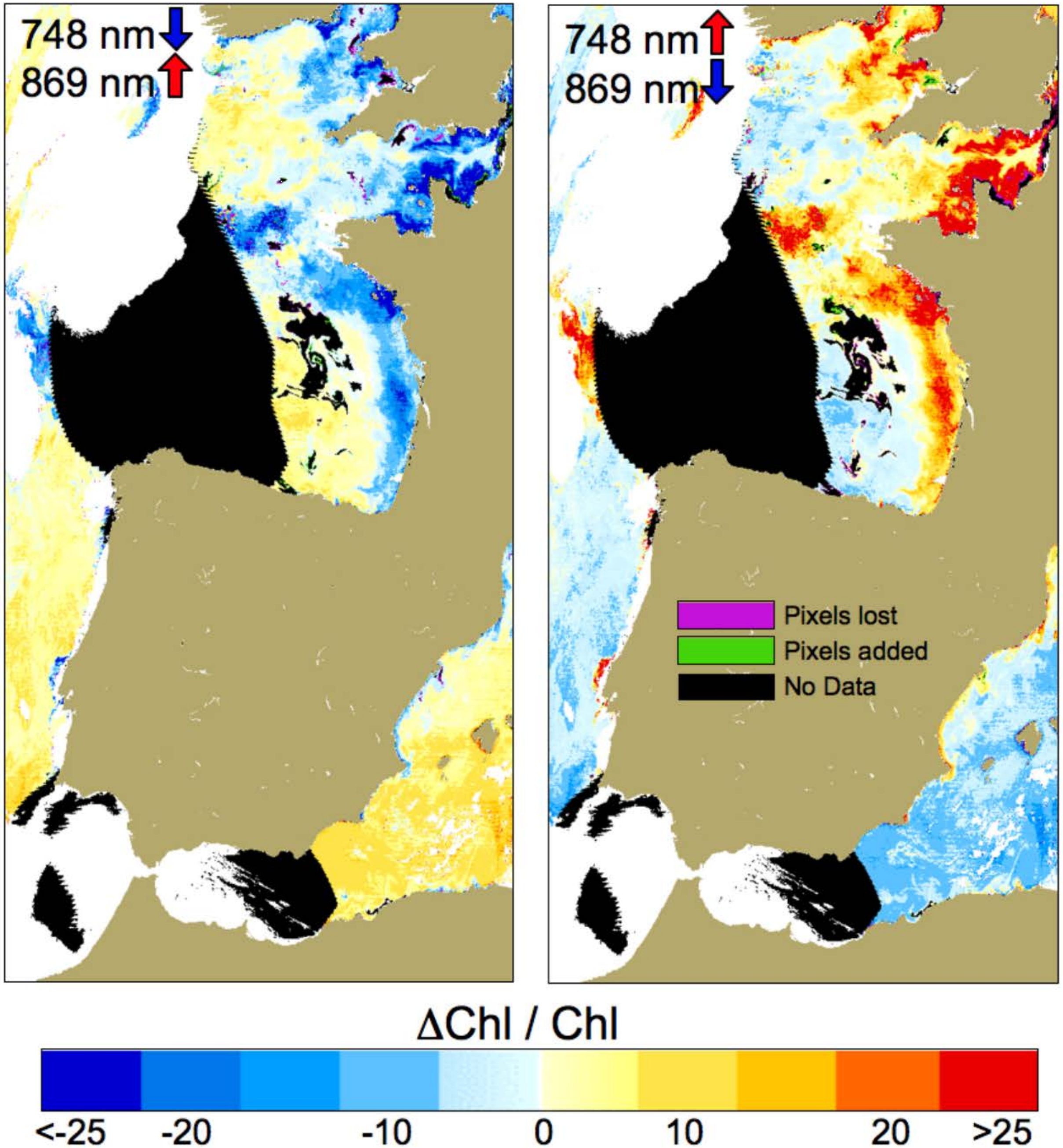


A small relative error in the at-sensor measurement leads to a relative error in the surface measurement that is an order of magnitude larger.

Changes between band pairs can also have effects.

For instance, opposite-signed errors in NIR ratios can cause coastal and open ocean waters to change in opposite directions.

Such changes could suggest false geophysical interpretations.



Affects on Chlorophyll of opposite signed errors in NIR bands of 0.3%

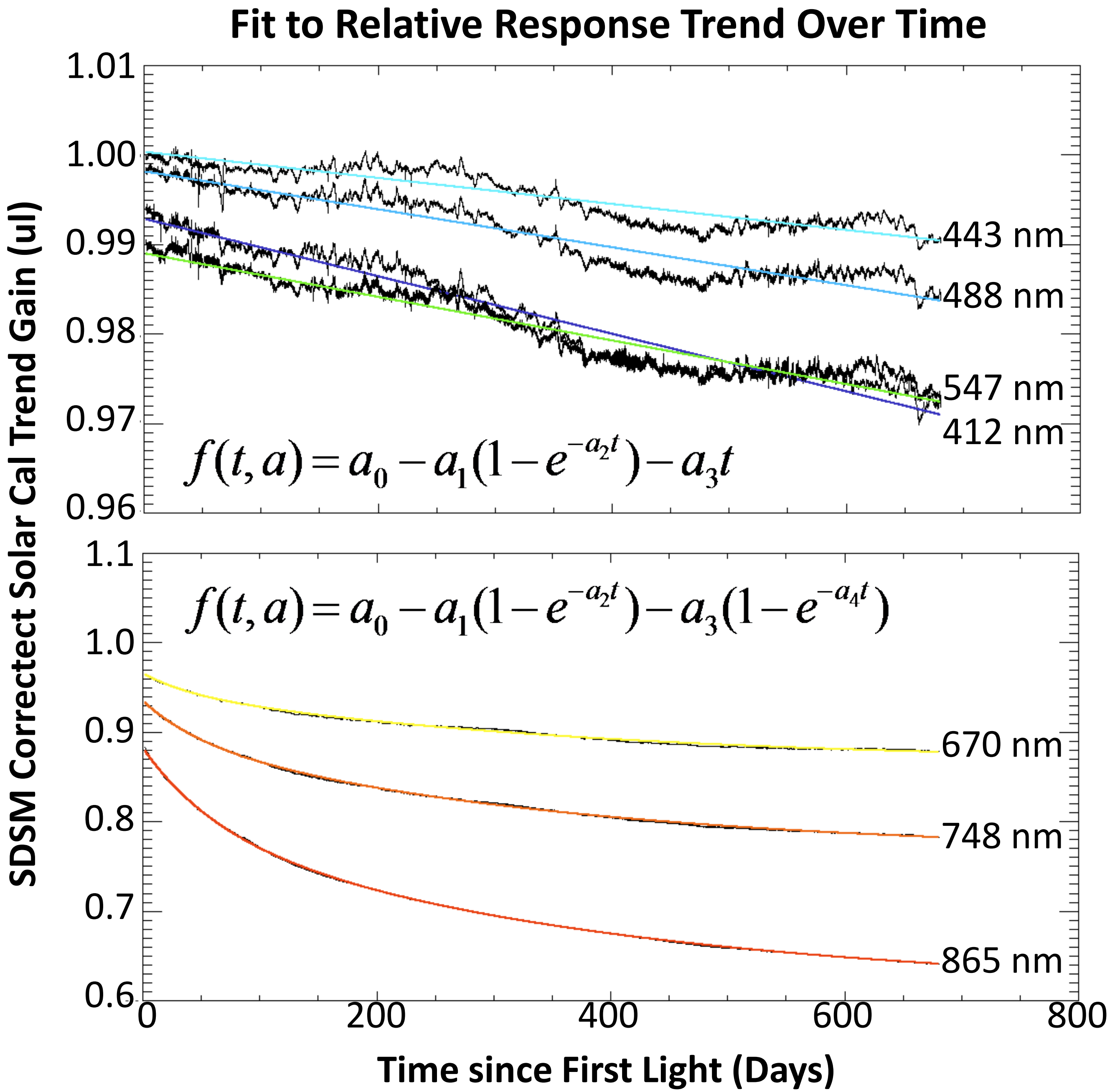
INSTRUMENT CALIBRATION TREND UNCERTAINTY

WHAT WE KNOW :

- ❑ VIIRS (like SeaWiFS or MODIS) experiences changes in responsitivity with time.
- ❑ This change is expecially pronounced for Suomi-NPP VIIRS in the NIR.
- ❑ Measurements of the Solar Diffuser (SD) to track and account for these changes.
- ❑ **Like MODIS, NASA OBPG fits functions to the SD measurement trends and those are used to correct data in the Earth-view measurements.**
- ❑ **Small, residual errors in this process could lead to spurious trend errors in surface measurements.**
- ❑ **This can be assessed with examination of trending residual and a Monte Carlo experiment.**

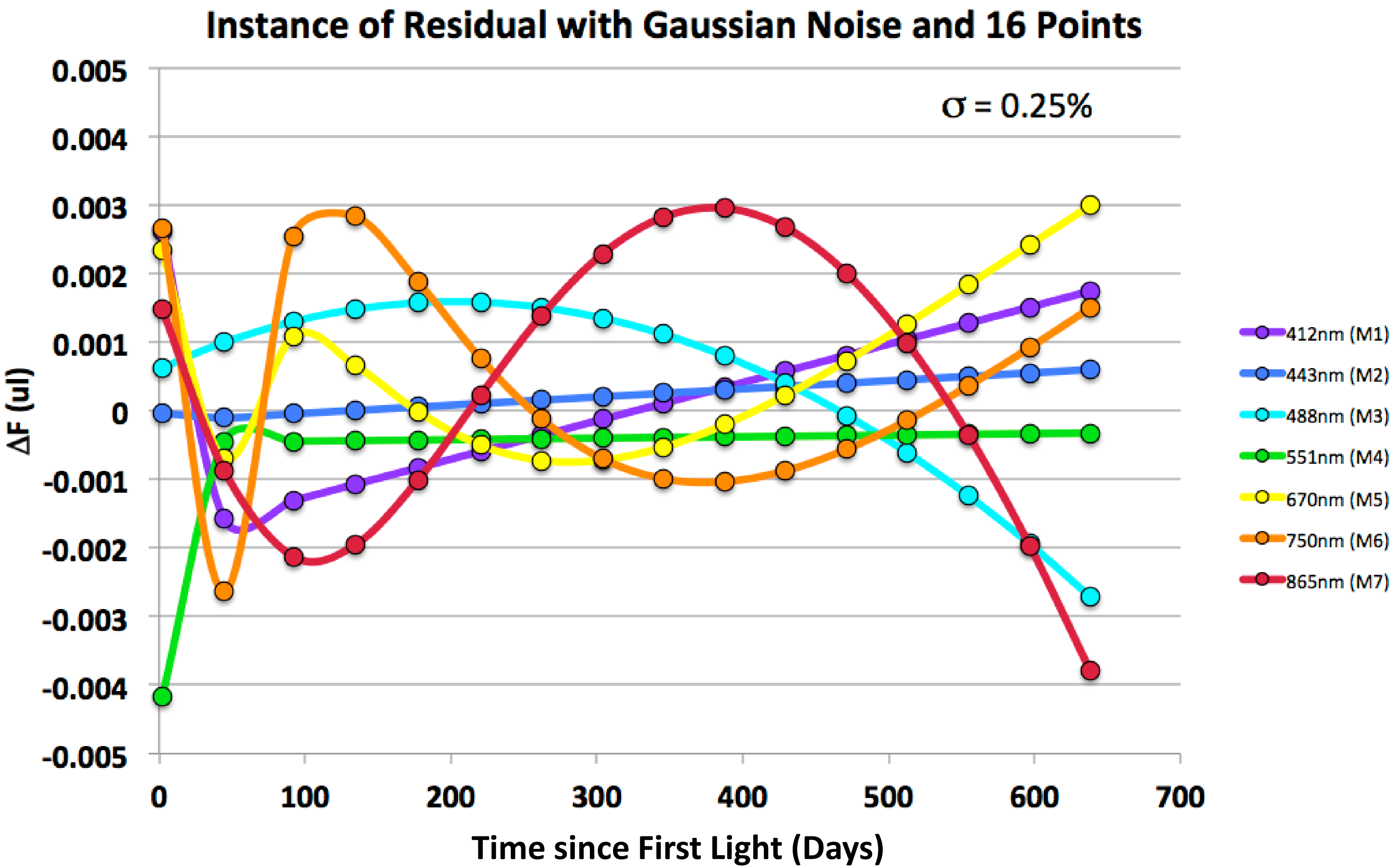
METHODOLOGY

- Calibration trends are fitted using the same methods used for SeaWiFS and MODIS.
- Nonlinear fit using Levenberg-Marquardt optimization
- For VIIRS, a linear combination of Exponential and Linear terms fit to blue-green band trends.
- Linear combination of two Exponential terms are fit to red-NIR band trends.



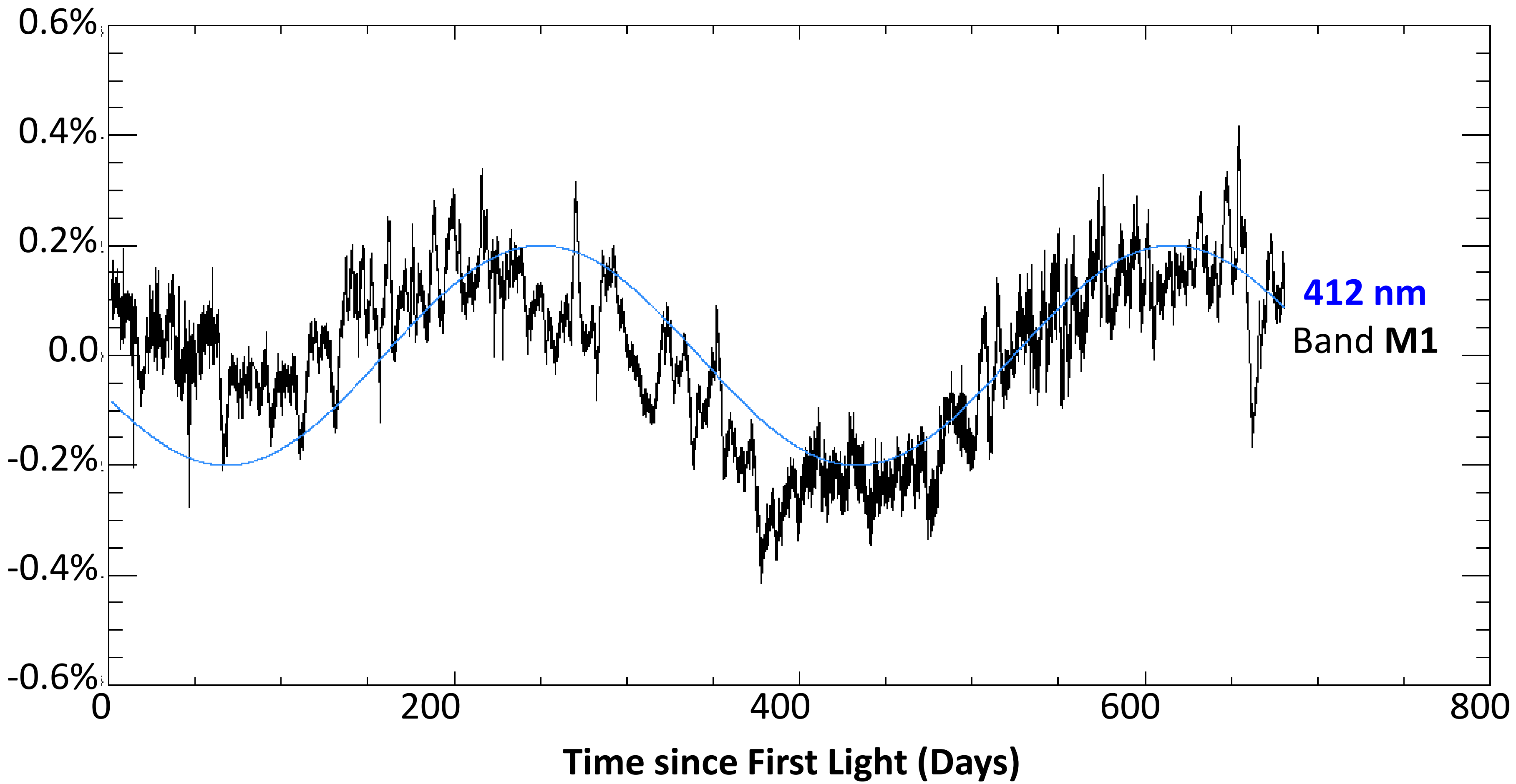
METHODOLOGY

- ❑ **Declare the operational fitted functions as the "true" instrument trend.**
- ❑ **Add a random noise model using Gaussian (white) noise plus a systematic, seasonal signal.**
    - **Gaussian noise component has a standard deviation of 0.1%, matching the original fit residuals.**
    - **Systematic effect is given an amplitude of 0.2% matching the original fit residuals.**
- ❑ **Fit the original trend curve plus the noise model.**
- ❑ **Take the difference between the original "true" trend and the new fitted curve to get the modeled spurious trend.**
- ❑ **Compute the root mean squared error (RSME) of the modeled spurious trend.**
- ❑ **Repeat the process many times, each time collecting RSME of the modeled spurious trend.**

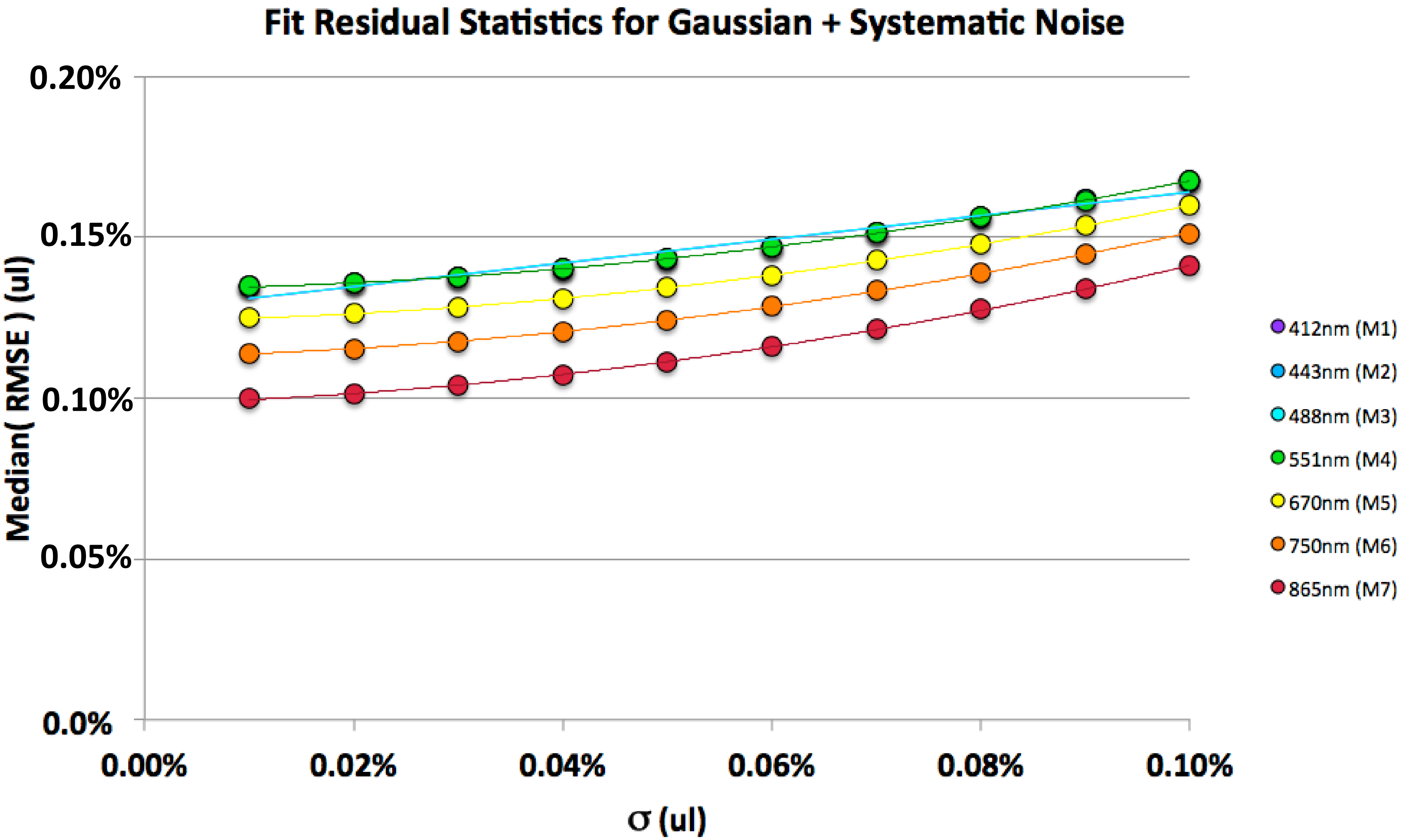


To demonstate what a single trial can look like, one was generate for a noise level of 0.25%. The spurious trends over the two year period are large and, unlike the input noise, strongly autocorrelated (note NIR bands)

ADDITION OF A SYSTEMATIC EFFECT



- This is a sinusoidal curve similar to the systematic effect seen in the blue bands.
- The longer wavelength bands are slightly more complex, but about the same amplitude.



- Increasing the noise level (σ) from 0.01% to 0.1%.
- The 0.2% systematic error effects dominate the residual.
- The band wavelength relationship is reversed from the spurious trend.

RESULTS

- The Monte Carlo experiment was repeated for several Gaussian noise standard deviation ranging from 0.01-0.10%.
- A systematic, seasonal noise component with a 0.2% amplitude as also added.
- Using noise model with a Gaussian noise component alone produced a modeled spurious trend with median RSME that was comparable to the input noise standard deviation.
- Inclusion of a systematic, seasonal noise component of 0.2% caused a ~0.1% median RSME.
- The resulting effect to Chlorophyll *a* trends would be smaller than the 0.3% effect in the example shown, but still significant, especially given the autocorrelation.

CONCLUSIONS

- We cannot know whether the functional form sufficiently describes the underlying SD trend, unless another reference is available.
- Gaussian noise alone is easy to fit through, but produces a spurious trend with slight less amplitude, but strongly autocorrelated.
- Including a 0.2% systematic, seasonal artifact, induces a significant spurious trend comparable in amplitude.
- Resulting trends are highly autocorrelated and can be anti-correlated between bands (exacerbating the effect to derived products).
- These effects could cause apparent “geophysical” trends in Chlorophyll a observations at the few to several percent level.
- Reduction in the systematic artifact (e.g., with new calibration system look-up tables) may greatly reduce most of the trend uncertainty.

RECOMMENDATIONS AND FUTURE WORK

- ❑ **Further modeling should be done for longer time series and for various sampling densities (e.g., densities analogous to lunar data).**

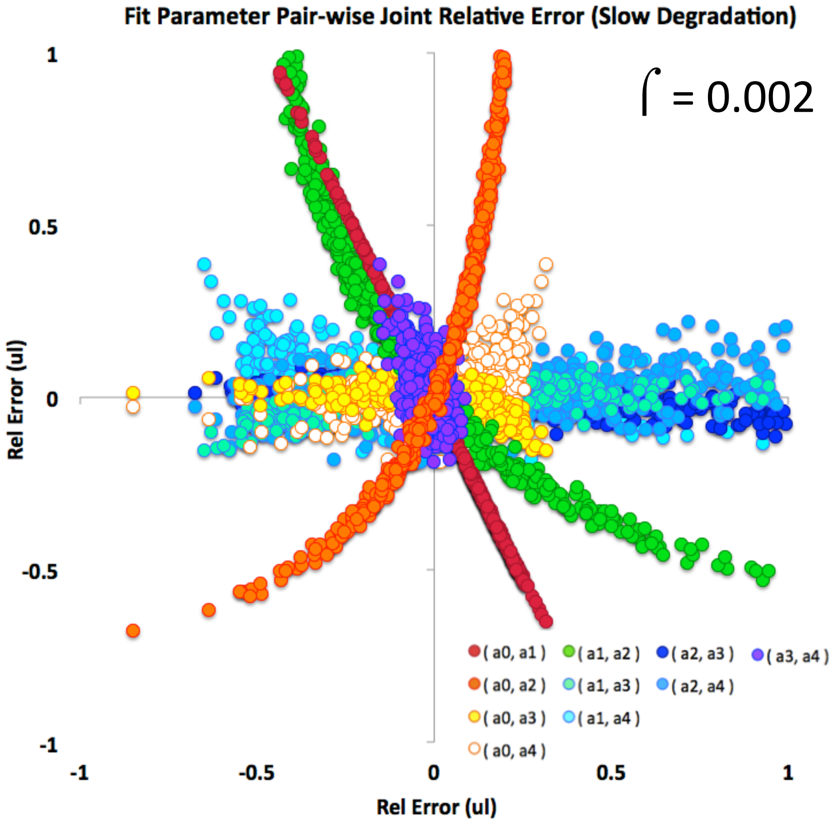
- ❑ **Resulting biases should be directly propagated to ocean surface measurements to confirm/quantify impact.**

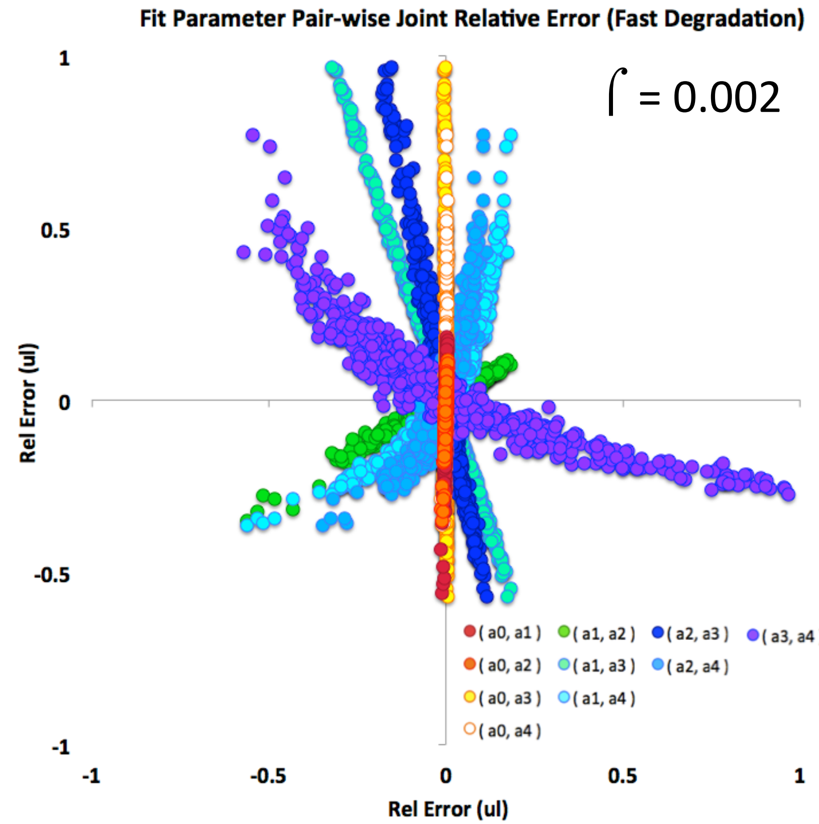
- ❑ **Other sources of trend uncertainty should be assessed.**

  - **Extapolation Uncertainty.** **(soon)**
  - **Solar Diffuser Stability.** **Monitor (NASA VIIRS Calibratin Support Team)**
  - **Relative Spectral Response Change.** **(underway)**
  - **Polarization Response Change.** **(future)**
  - **Counts-to-Radiance Conversion.** **(future)**

THANK YOU

INITIAL EXPERIMENT: EFFECT OF NOISE ON FIT PARAMETERS





RESULTS

- The fit parameters can change greatly with the random point-to-point variation.
- The parameter variation is highly correlated.
- This suggests that there are multiple or shallow minima in parameter space.
- This is similar to an underdetermined problem.
- However, we are not after the parameters themselves – so this is not a big problem.