2008 Stray Light Correction Work

MLML Presenter: Stephanie Flora

MLML: Michael Feinholz, Mark Yarbrough

NIST: Carol Johnson , Steve Brown, Keith Lykke,

Al Parr, Dennis Clark , Eric Shirley, Bob Saunders and David Harris

NOAA: Mike Ondrusek

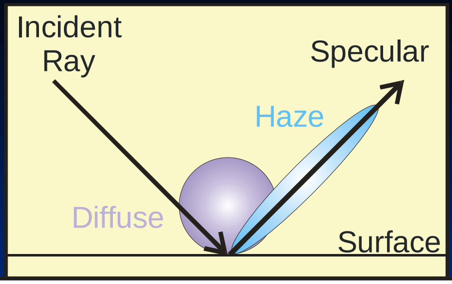
Funded by NOAA/NIST MOU

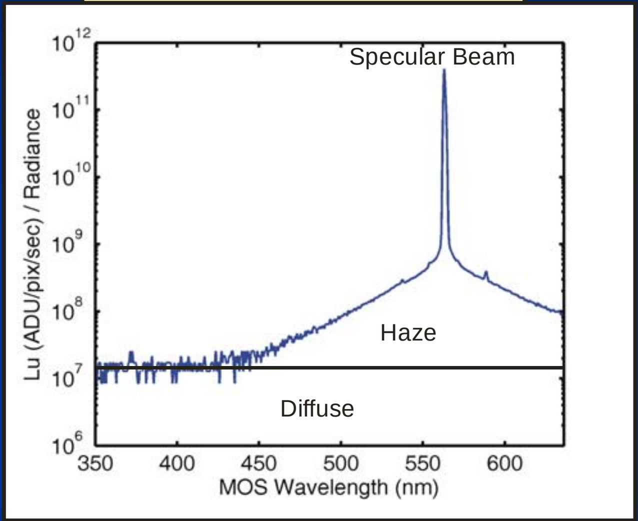
Outline

- Quick overview of stray light problem
- Overview of NIST 2008 data collection, processing and matrix creation
- TASKS
  - Analysis of the laser observations
  - Extension to the other collectors
  - Validate matrix results by implementing alternate techniques
  - Test on 2008 in situ MOBY data and compare to existing method
  - Validate method with CIE color coordinate analysis of Es results and the use of specialized validation sources
  - Generate report

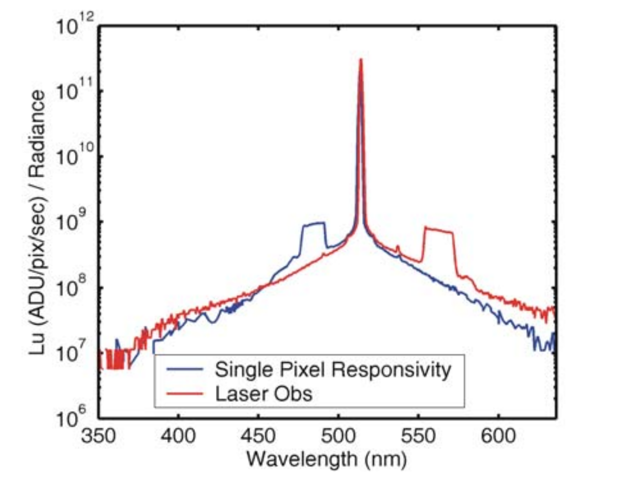
Laser Data

- Stray light is light scattered off optical surfaces
- Three contributing factors: haze, diffuse and reflections.
- One laser scan tells us how light at this wavelength affects the CCD detectors
- What we want is how light at any/all wavelengths affects one part of the CCD (wavelength).
- A single pixel responsivity is the function that defines this effect at one measurement wavelength for all other wavelengths.
- Matrix for the entire CCD



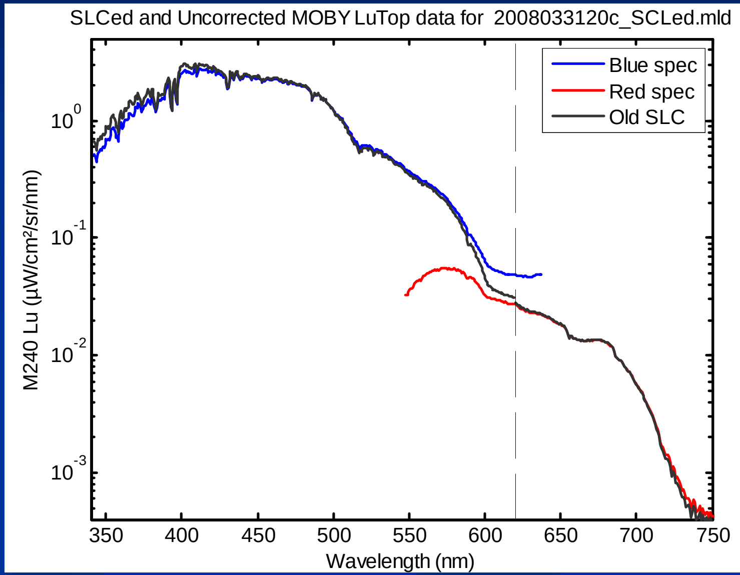


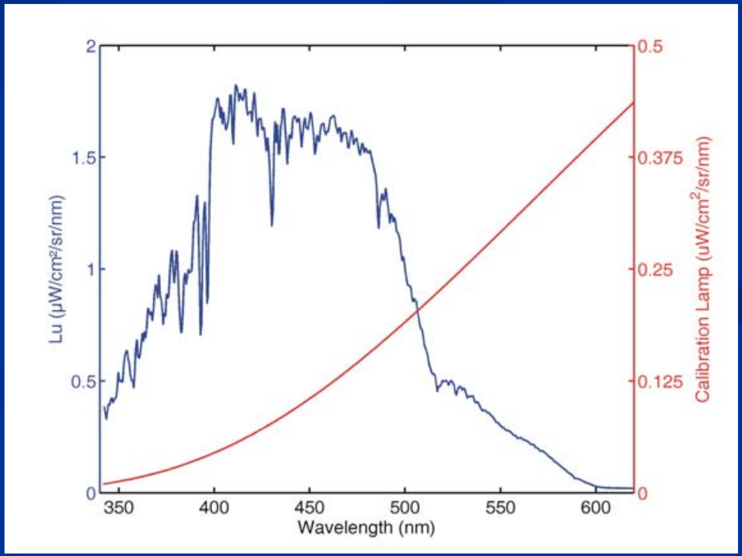
Modeled Single pixel responsivity (SPR)



Why Stray light Correct

- Because otherwise we have a spectral bias = wrong answer
- Problem worsened by calibrating with a white source and measuring a blue source.
- The evidence is blue and red spectrographs do not meet in the overlap (black line = 620 nm).
- The matrix created from laser data removes the stray light from the in-water and system response data.

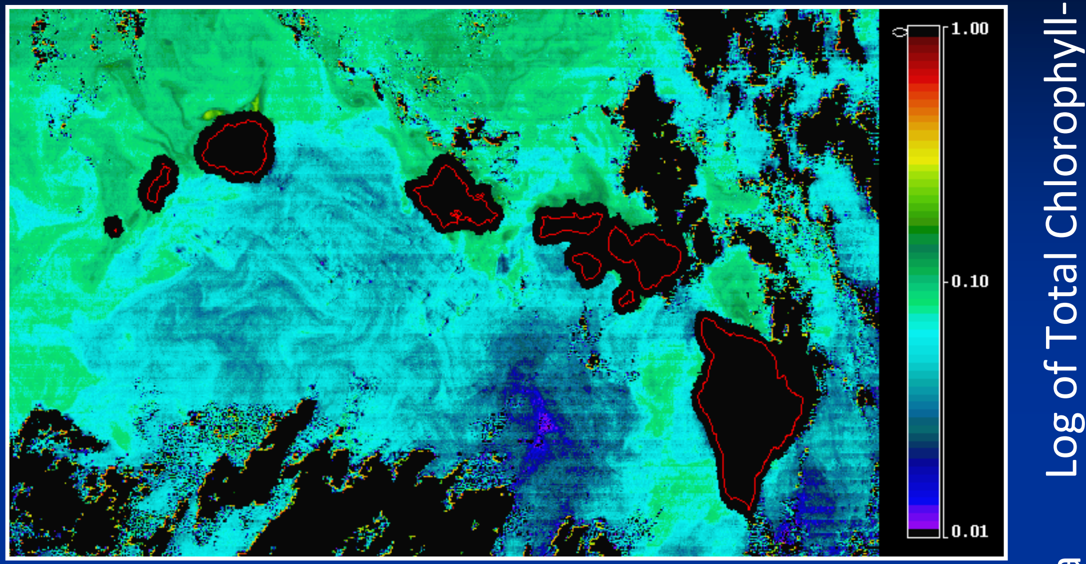




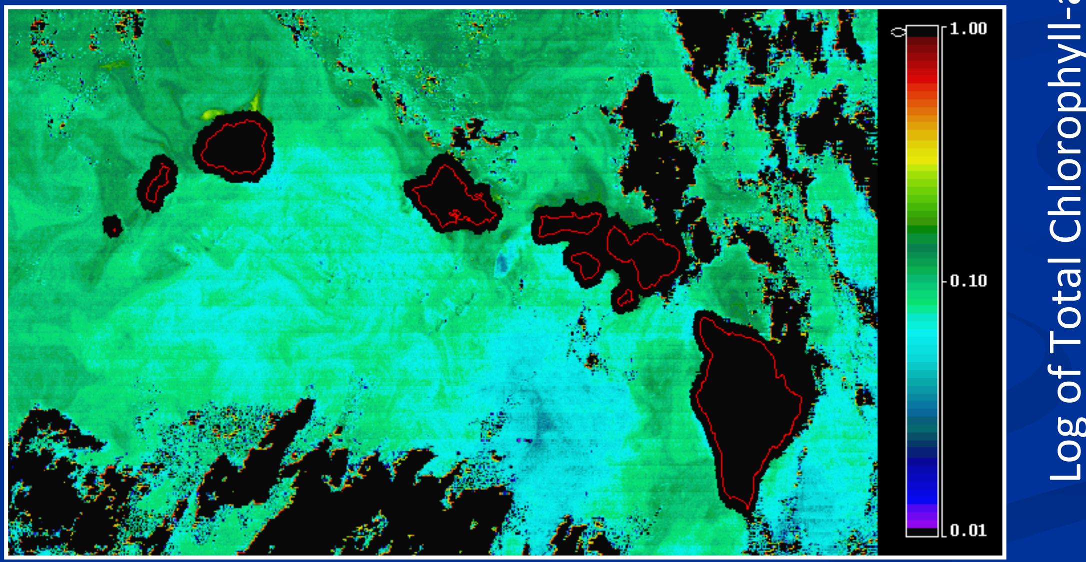
Yuqin Zong, Steven W. Brown, B. Carol Johnson, Keith R. Lykke, and Yoshi Ohno, "Simple spectral stray light correction method for array spectroradiometers," Appl. Opt. **45**, 1111-1119 (2006)
http://www.opticsinfobase.org/abstract.cfm?URI=ao-45-6-1111

Application to a MODIS Image

uncorrected for stray light



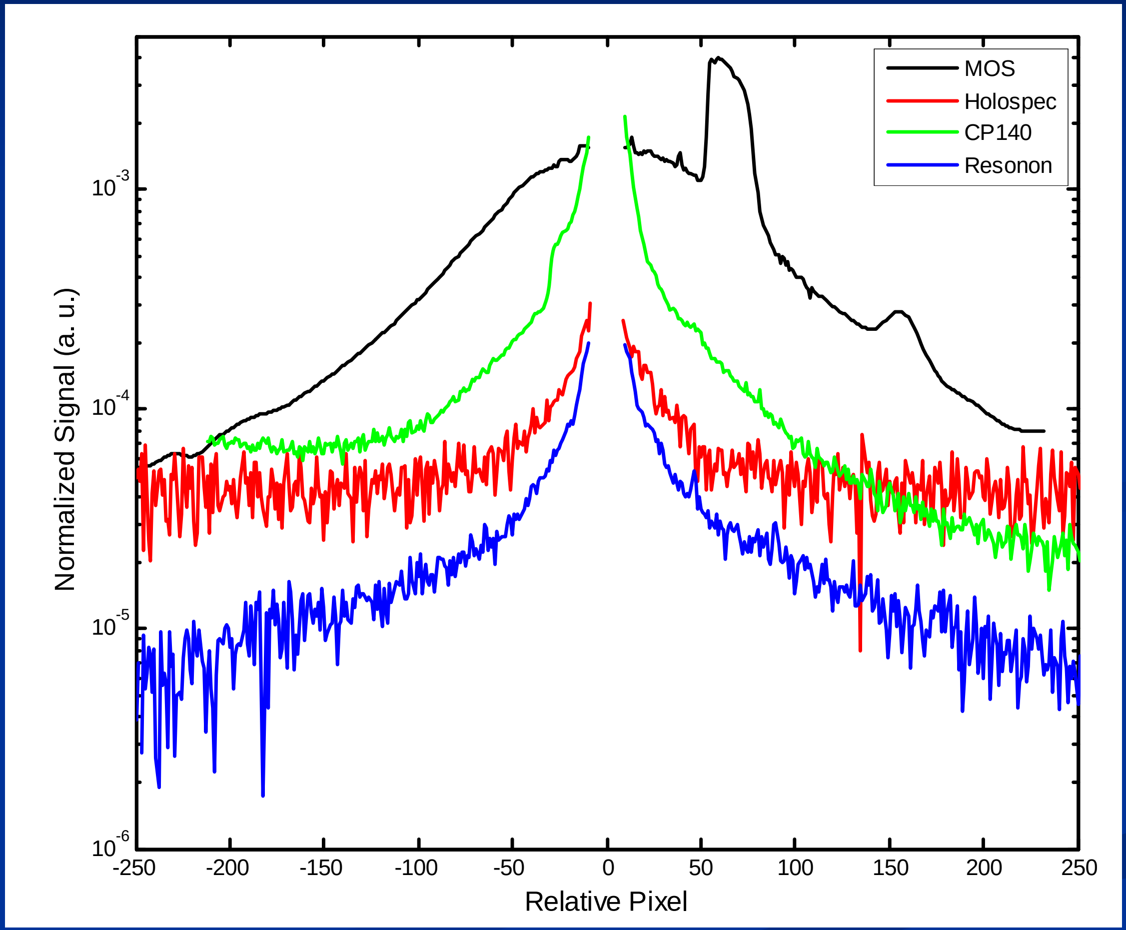
corrected for stray light



- ✓ **Know chlorophyll concentration did not change**
- ✓ **Algorithm change has to account for the change in band ratio**

MOBY vs MOBY-C

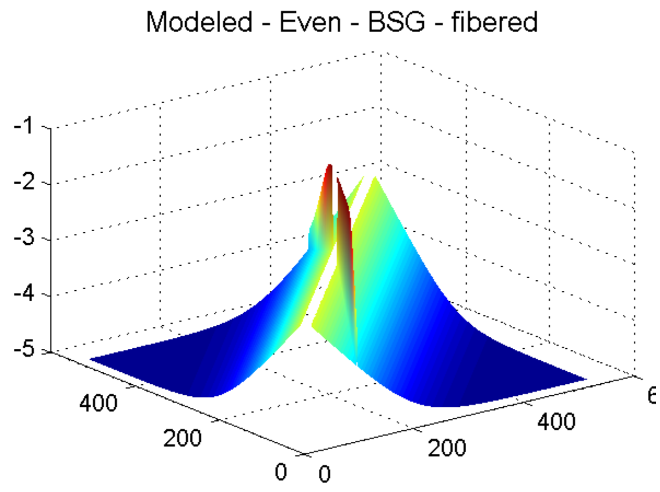
- Stray light performance of MOBY-C is expected to be 20 times less than MOBY
- Holospec and CP140 were test instruments: Resonon is the final design



Yarbrough, M.A., S. Flora, M.E. Feinholz, T. Houlihan, Y.S. Kim, S.W. Brown, B.C. Johnson, K. Voss, and D.K. Clark (2007b) **Simultaneous measurement of up-welling spectral radiance using a fiber-coupled CCD spectrograph**. Proc. SPIE Coastal Ocean Remote Sensing. 6680:66800J.

Existing MOBY SLC

- 2001-2002: laser data collected in Hawaii.
- Even and Odd buoy's blue and red spectrograph, limited spectral coverage.
- Laser scan data were modeled using analytical functions.
- Stray light correction (SLC) is applied with an iterative approach.
- The final and current version of this approach was applied in Jan 2005.

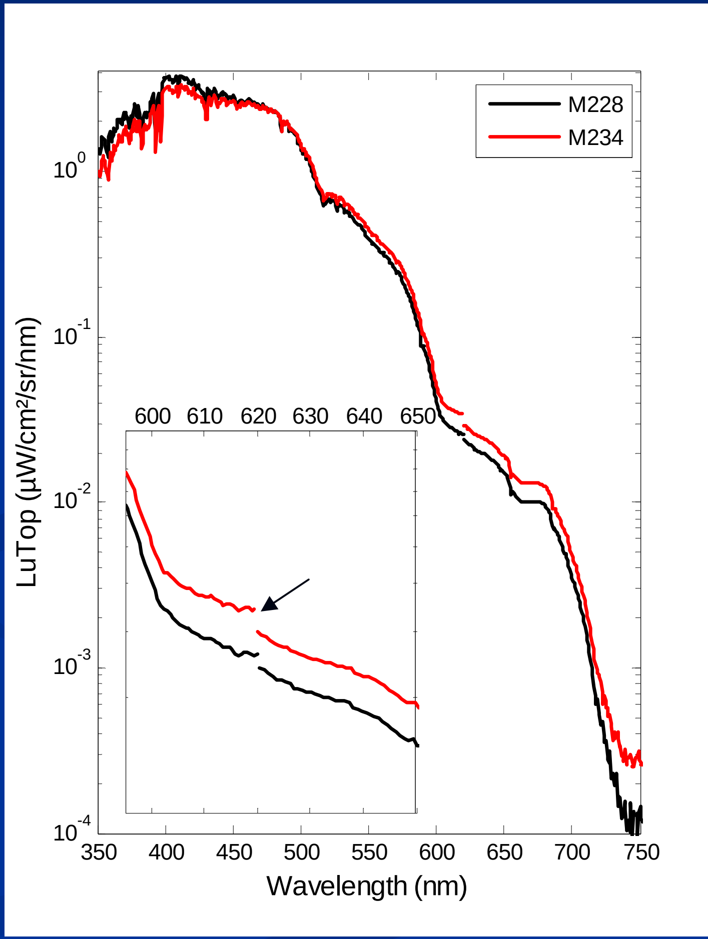


Habauzit, C., S.W. Brown, B.C. Johnson, M. Yarbrough, M. Feinholz, and D.K Clark (2000). Radiometric Characterization and Calibration of the Marine Optical System (MOS) For the Marine Optical Buoy (MOBY) Project. Oceans from Space. Venice, Italy, October 9-13.

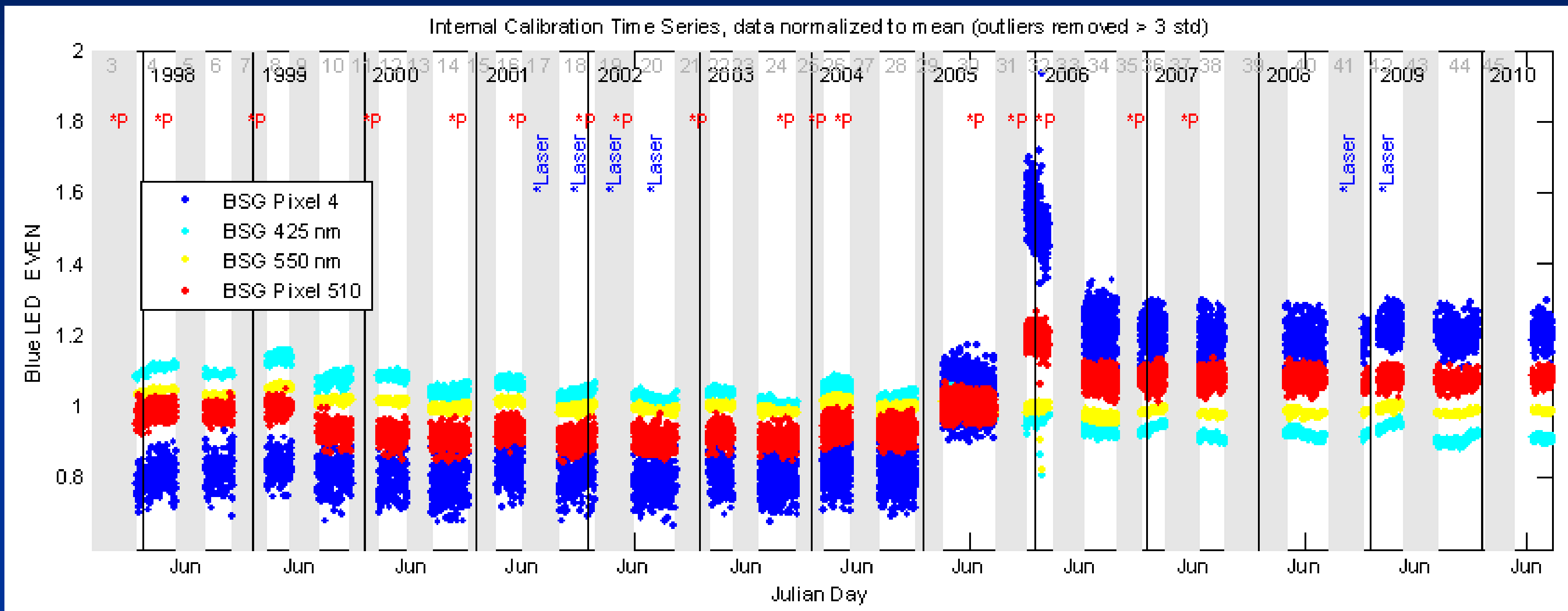
Brown, S.W., B.C. Johnson, M.E. Feinholz, M.A. Yarbrough, S.J. Flora, K.R. Lykke and D.K. Clark (2003). **Stray light correction algorithm for spectrographs**. Metrologia 40:S81-S84.

Stray light in MOS

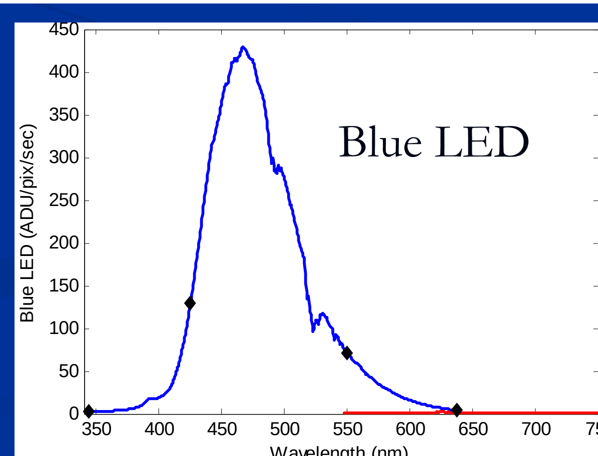
- Around 2005 (MOBY231-232), the SLC became less effective.
  - Blue/red spectrograph discrepancy at 620 nm increased
  - Band ratio using the internal calibration lamp time series also changed in 2005.
  - Implication is scattered light has changed in the MOS optics



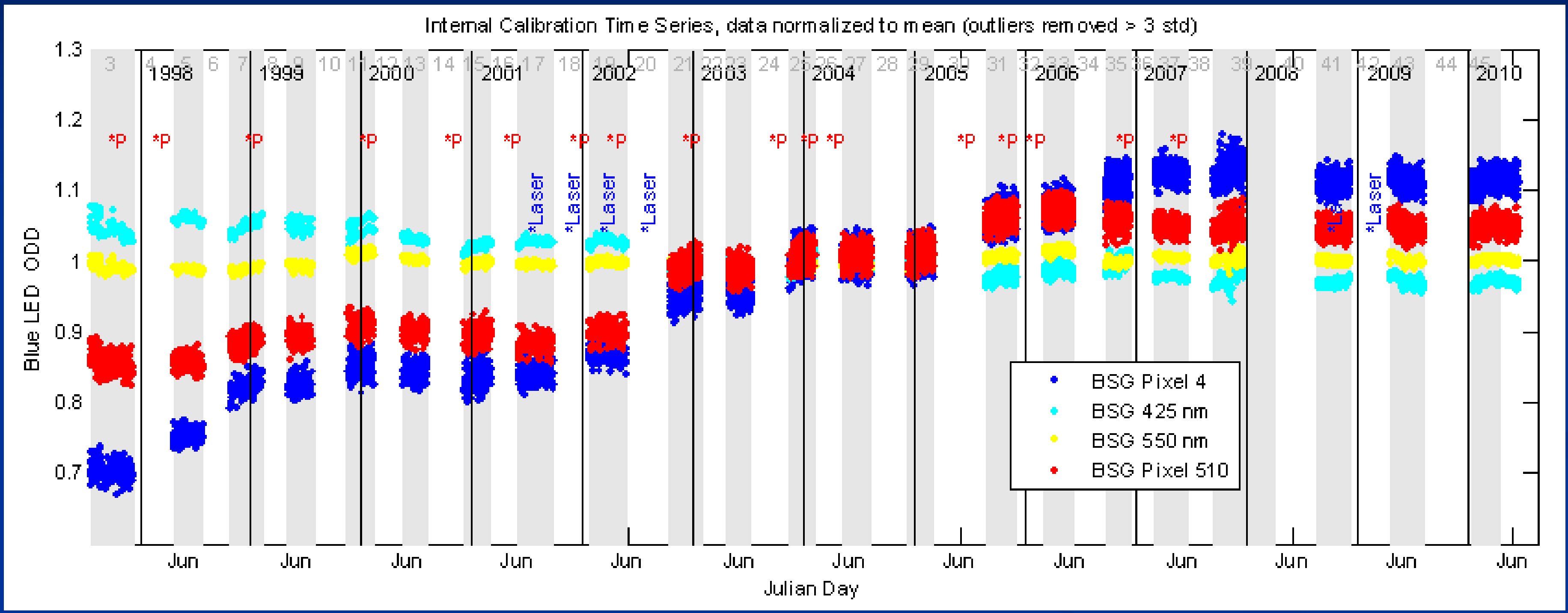
Blue LED time series - Even



- Low signal areas are highly influenced by stray light. High signal areas less so.
- Two major epochs for the even buoy.



Blue LED time series - Odd

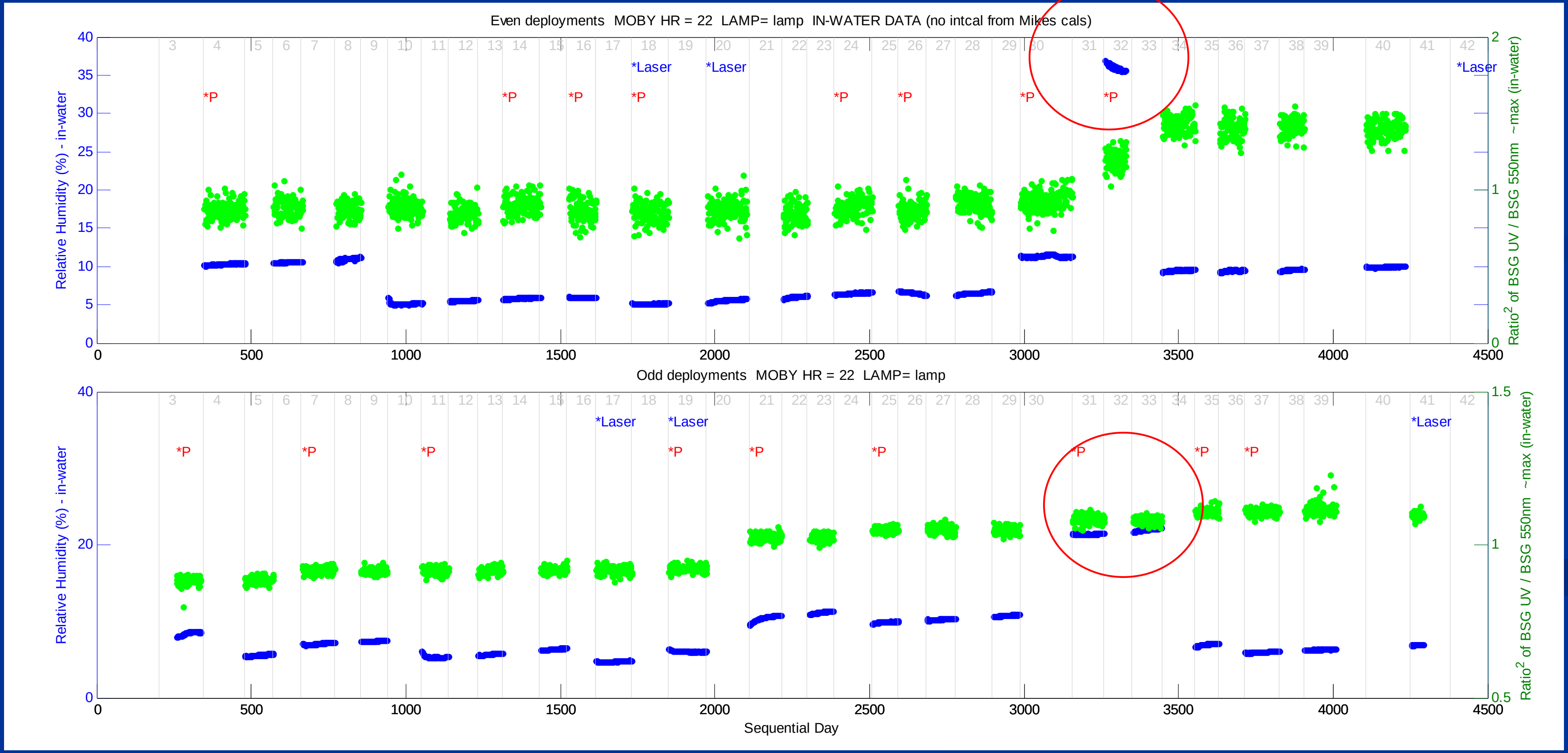


- There are a number of epochs for the odd buoy.
- A through MOBY design, which included the internal calibrations labs and other sensors, allows us to sort this out later.

Quick overview of Stray light problem

Int Cal Lamp w/ RH

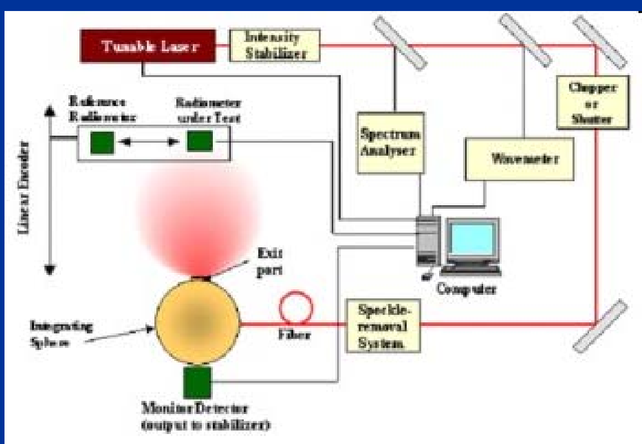
- During M232 the humidity in the MOS was abnormally high, and the lamp ratios changed.
- For the Odd buoys the picture is more complicated. The high RH was during M231 and 33.

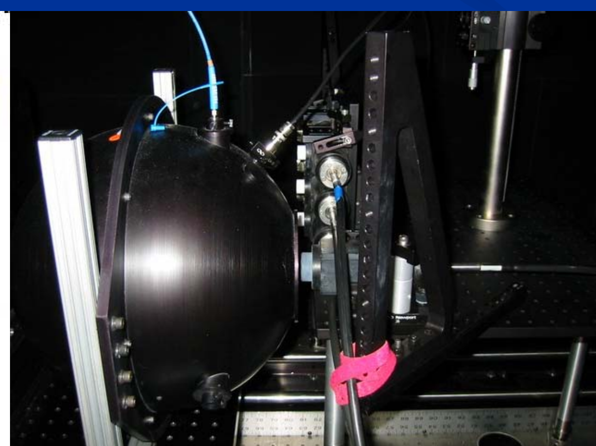


Green = lamp ratio, Blue = relative humidity

NIST 2008 SIRCUS data

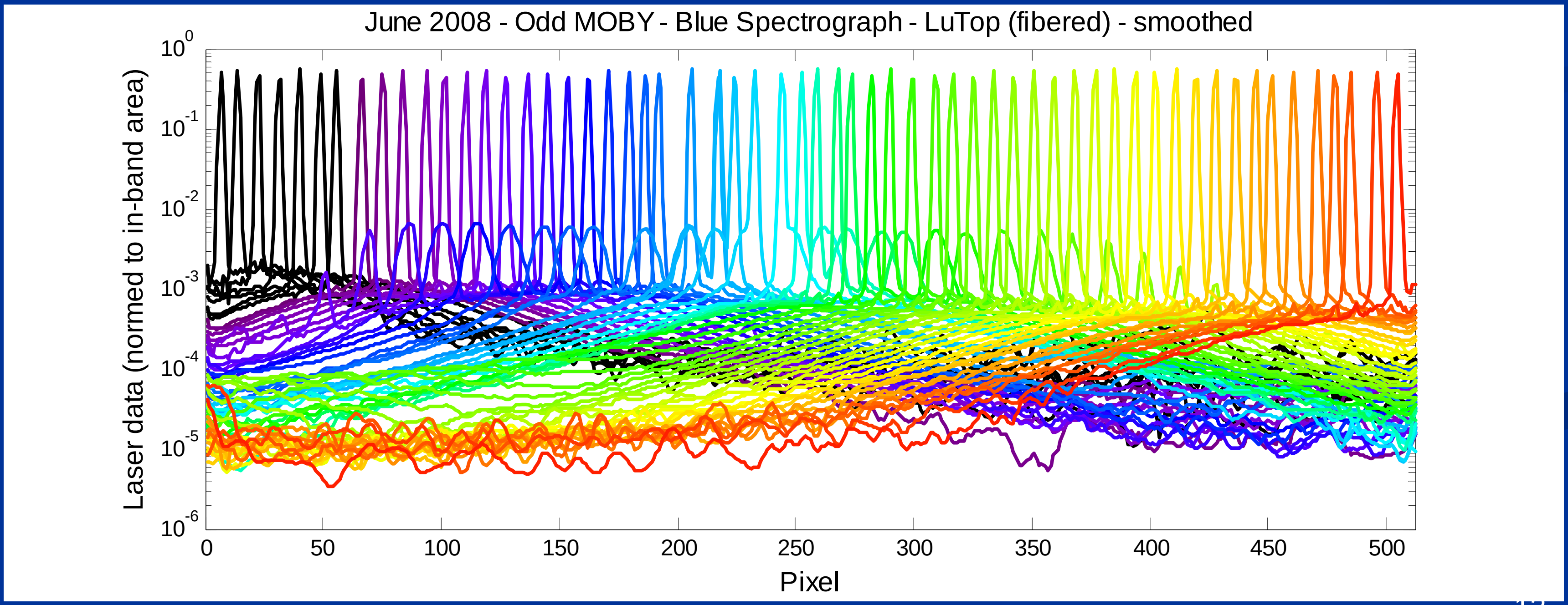
- New complete laser data take in 2008 in June and November at NIST (even and odd buoys)
- Data collected every ~5 nm for LuTop and LuMOS.
- Data collected every ~30 nm for LuMid and Bot, EdSfc, EdTop (Mid and Bot)





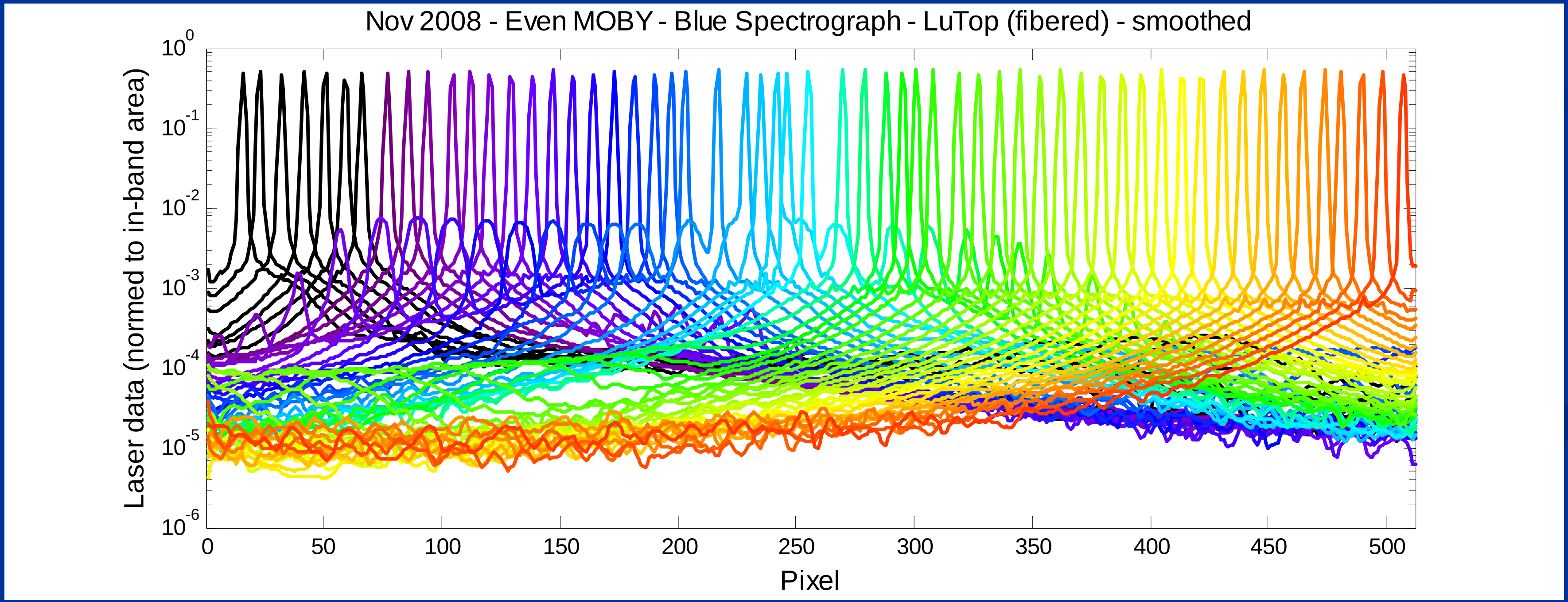
2008 SIRCUS data - Odd

- Odd buoy – June 2008 – MOBY241/243
- 386 laser data sets collected over 10 days
- Color source validation data also collected



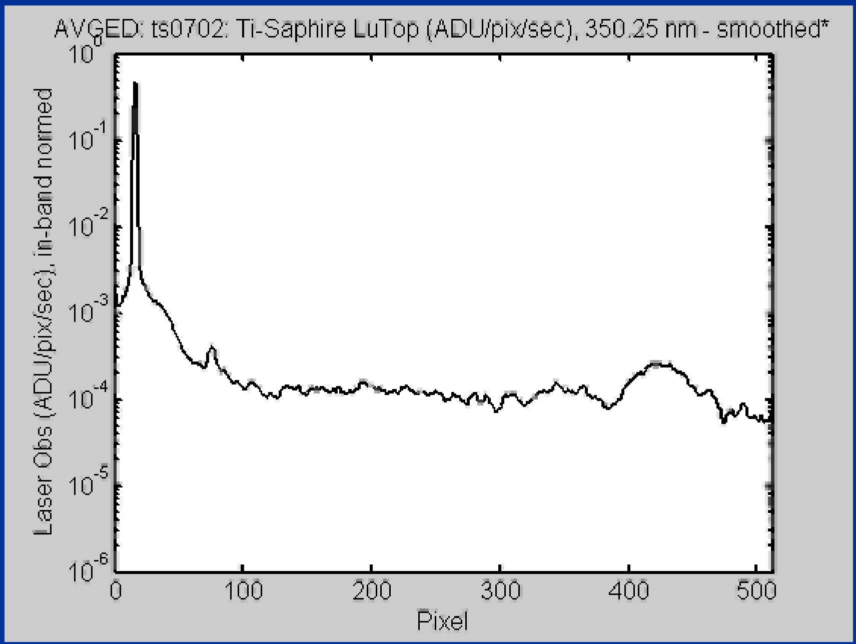
2008 SIRCUS data - Even

- Even buoy – Nov 2008 – MOBY242/244
- 372 laser data sets collected over 8 days
- Color source validation data also collected

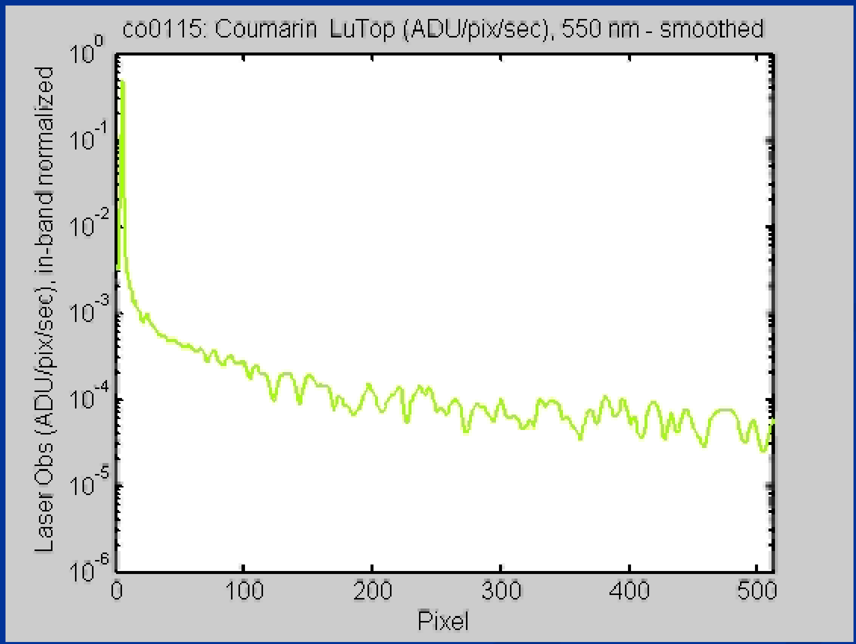


Movie of Laser data

Even buoy BSG Fibered
Laser data - smoothed



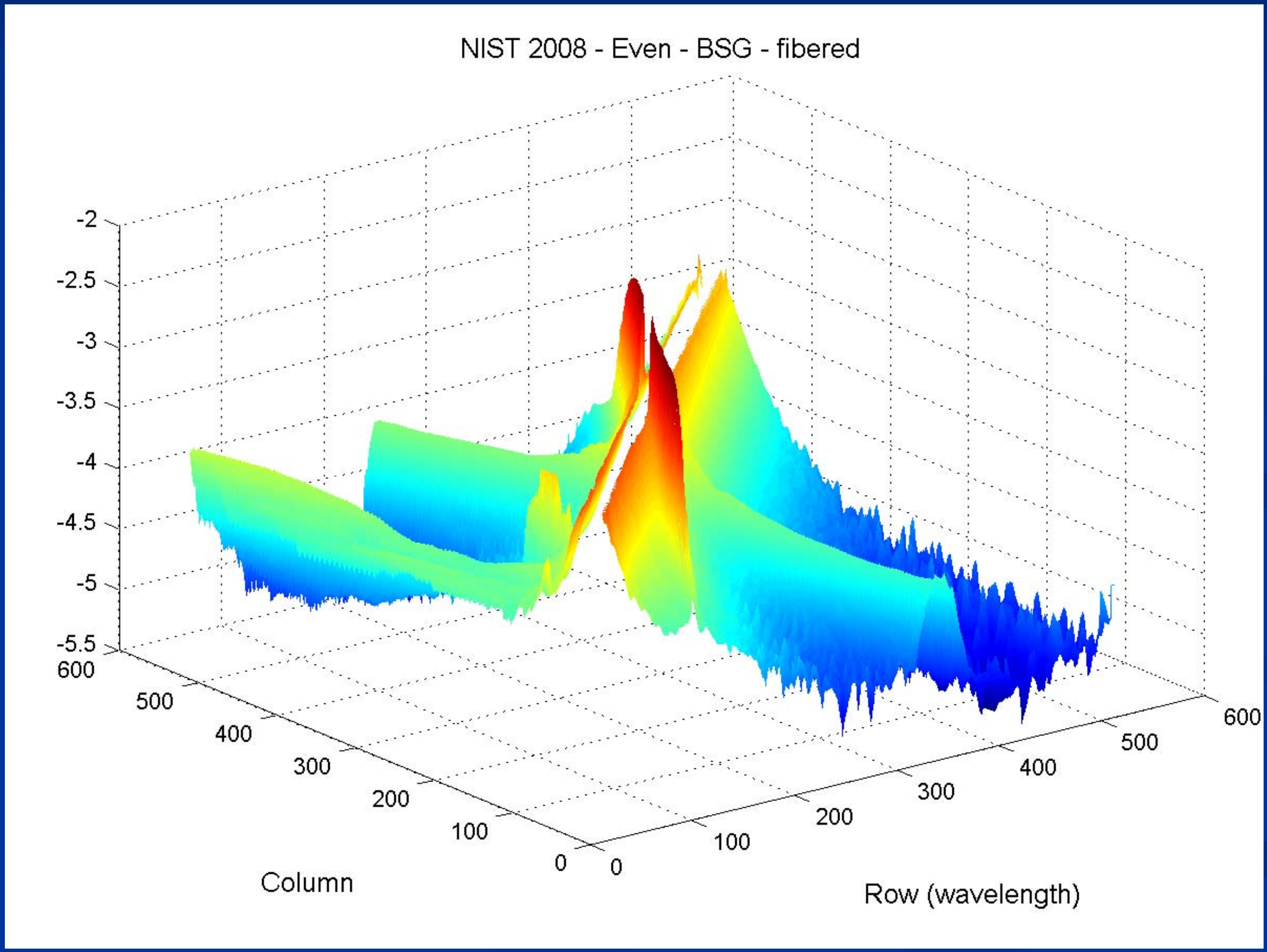
Even buoy RSG Fibered
Laser data - smoothed



Processing laser data

- Quality checking is applied (spikes and suspect scans are removed, if possible)
- Data is adjusted by darks, integration time and bin factor - ADU/pix/sec
- Problem data are fixed (oscillations, noise in scans, out-of-band noise/level)
- Single spectrum analysis used to smooth data
- Divide by in-band area and interpolate to fill in the missing laser data (started with 58 need 512 one for each CCD column pixel).

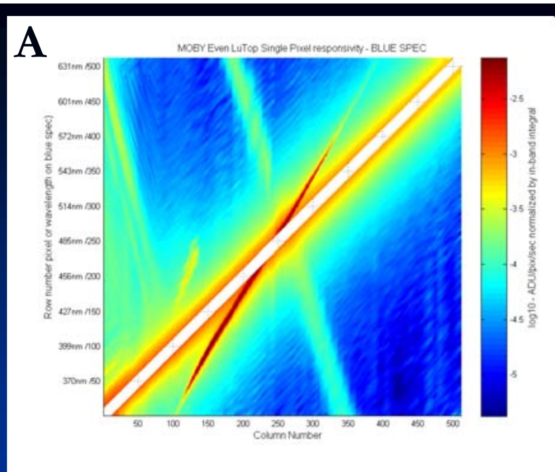
Matrix for BSG Even Fibered



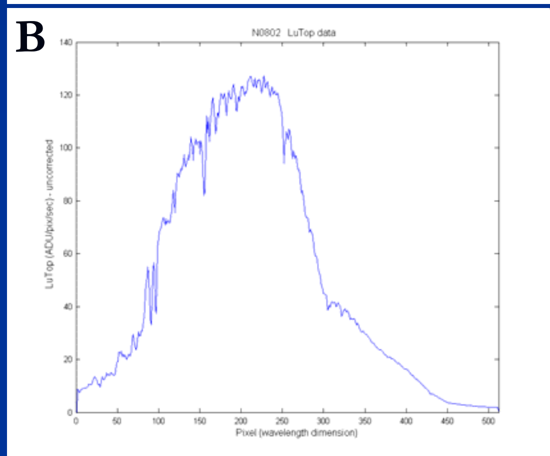
Applying the Matrix

- A = the SLC matrix, B = in-water Lu data (ADU/pix/sec)
- Pixel 1 (B) is multiplied by row 1 (A) , then pixel 2/row 2 up to pixel/row 512.
- Matrix C is the result. Summing the rows in C produce the green/red line in D
- This must be done for in-water and system response data.
- E shows Matrix C with the in-band removed and normalized to the total out-of-band

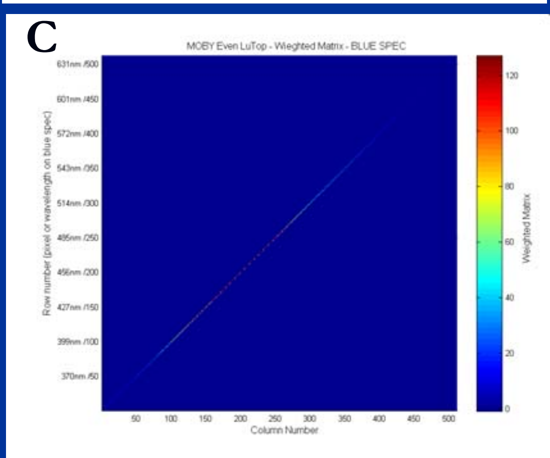
A



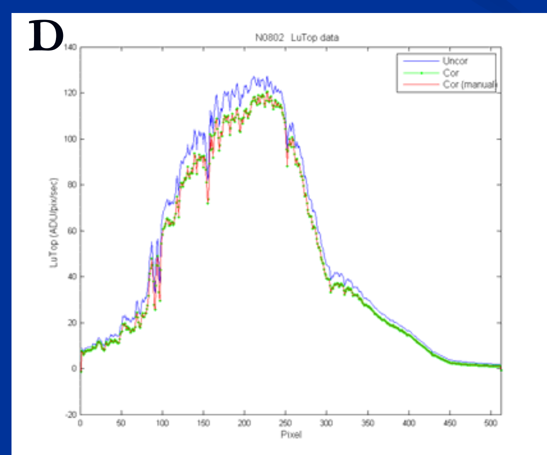
B



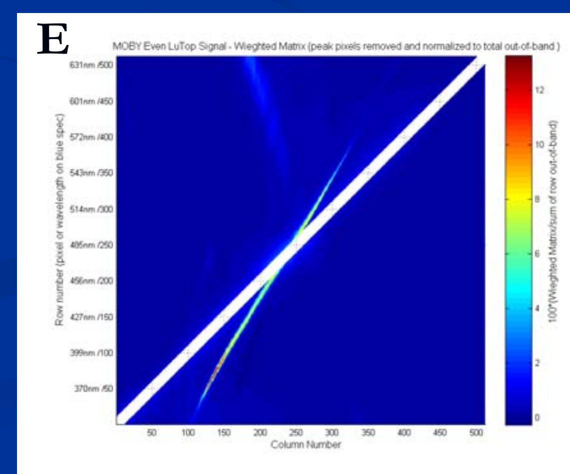
C



D



E



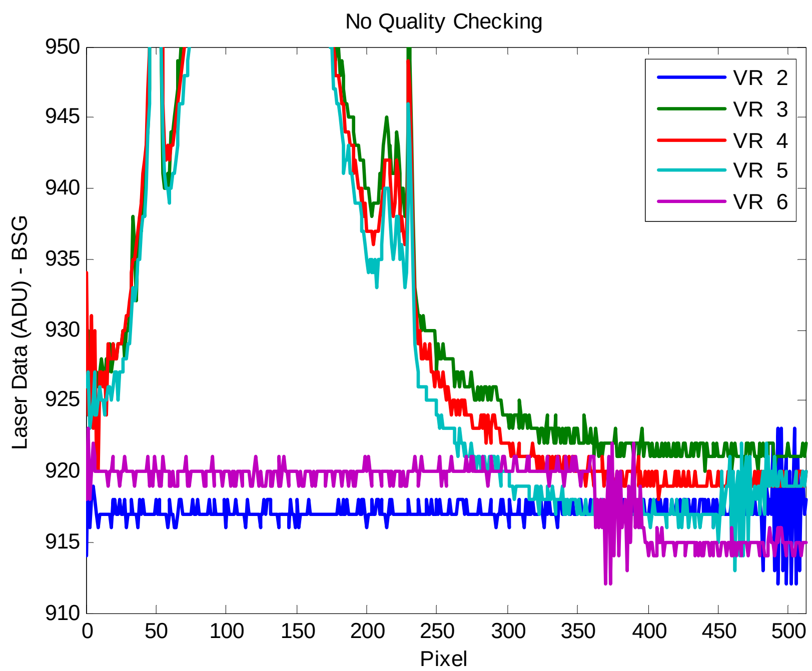
Raw Data problems

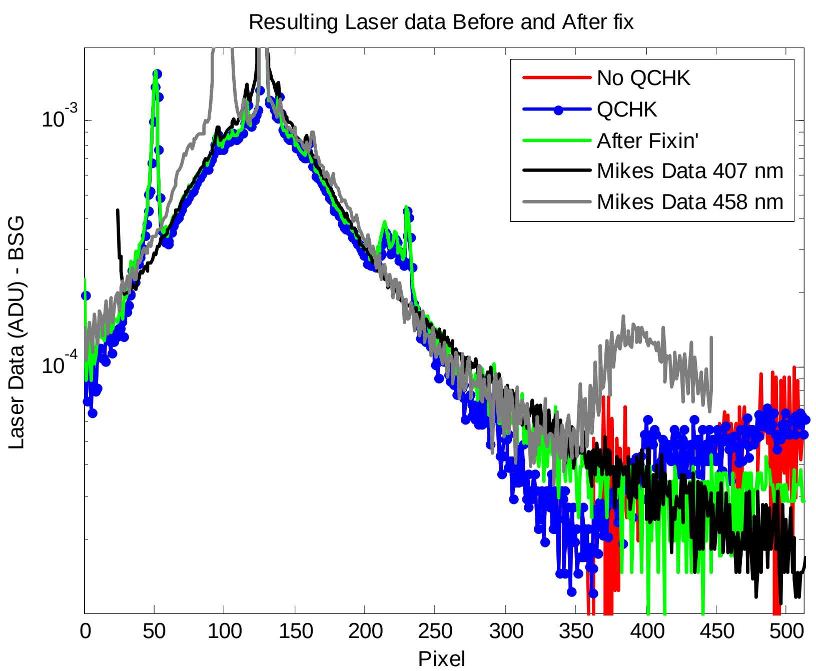
- First all spikes and suspect scans (which can be removed) are removed
- Sine waves are removed using single spectrum analysis (Nov 2008 data)
- Low laser power data must be fixed (both)
- Noise and step changes in spectral laser data fixed (June 2008 data)

Noise and Step Changes

(June 2008 data only)

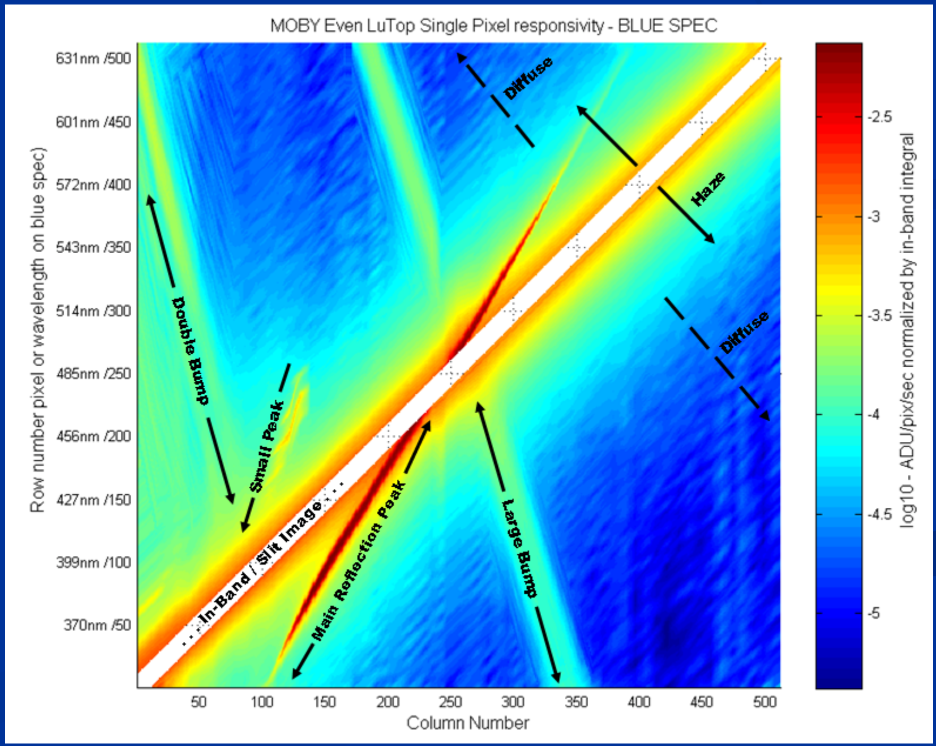
- Affects 375 – 450 and 635 nm data
- Steps removed by shifting data up or down





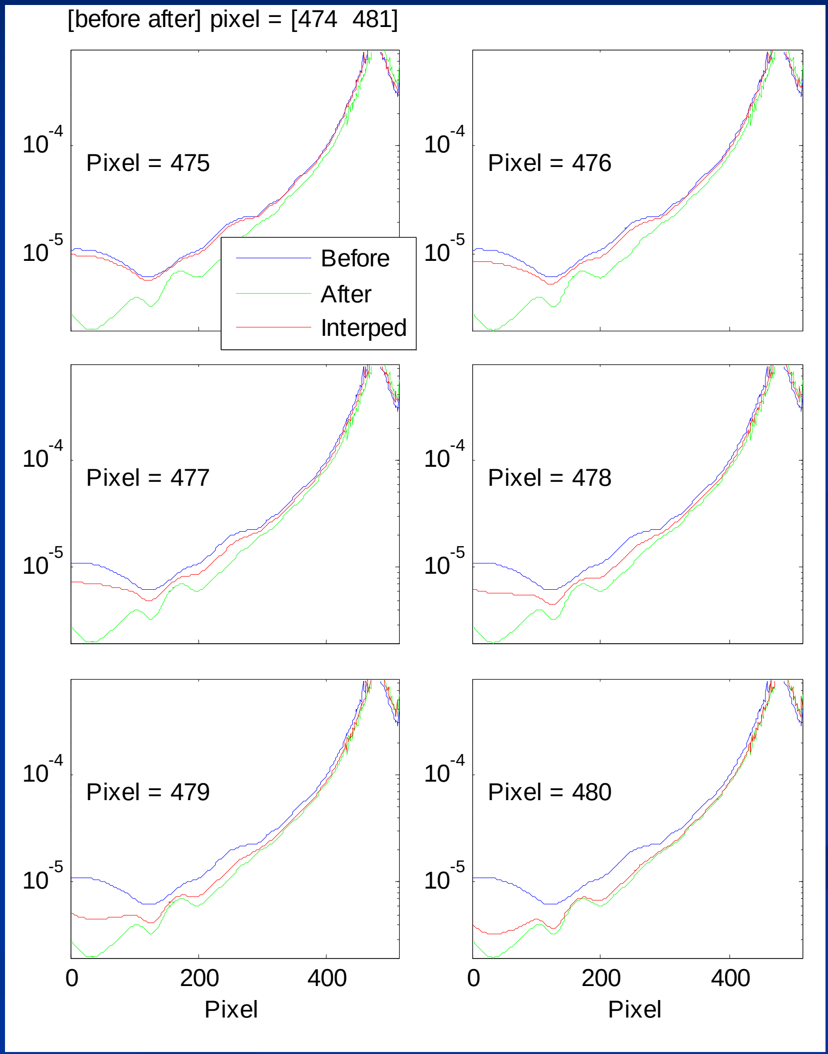
Interpolation

- Edges copied (left and right side of array)
- Linear regression used to interpolate the …
  - Diffuse and haze out-of-band
  - Double bump
  - Main Reflection peak
  - Large bump
  - Small peak
- Multiple peaks required separate analysis and interpolation for each feature



Linear Interpolation

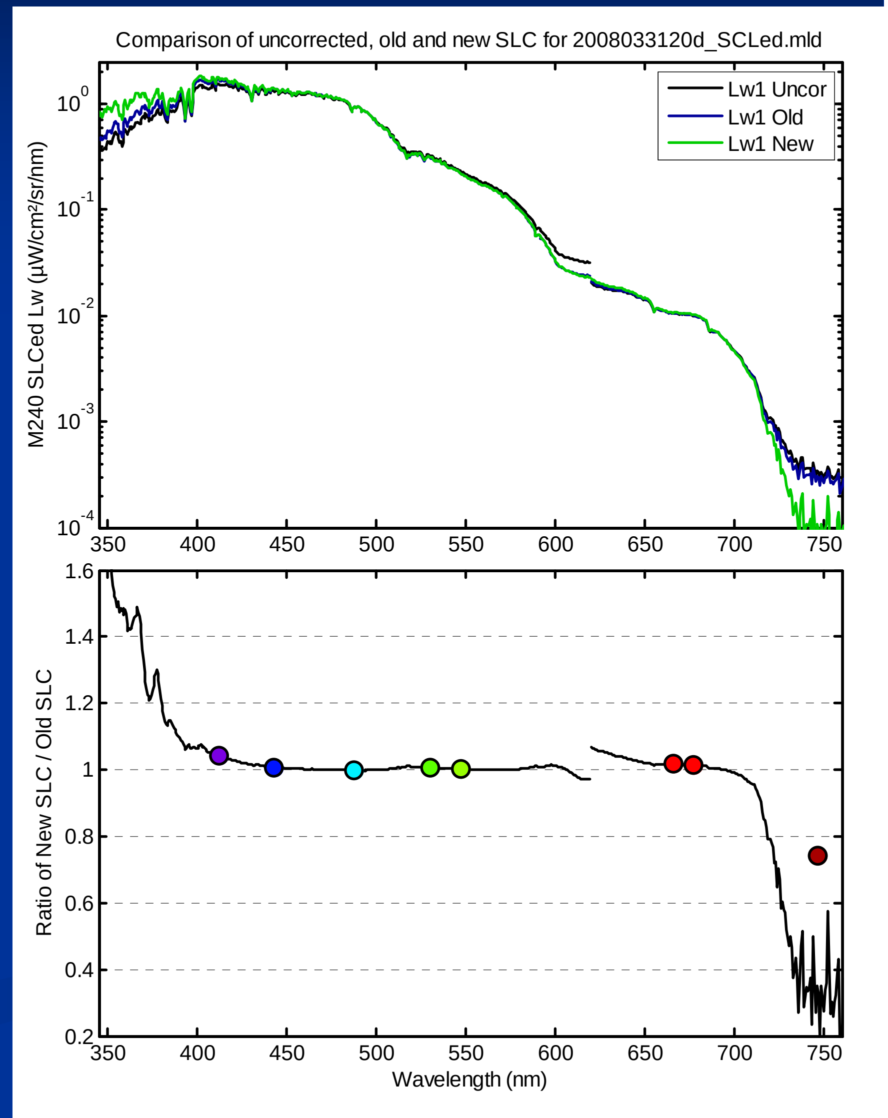
- Align peaks of adjacent laser observations
- Linearly weight the aligned laser data
- Add the two weighted laser observations to create the new laser data



2008 vs Existing SLC - Even

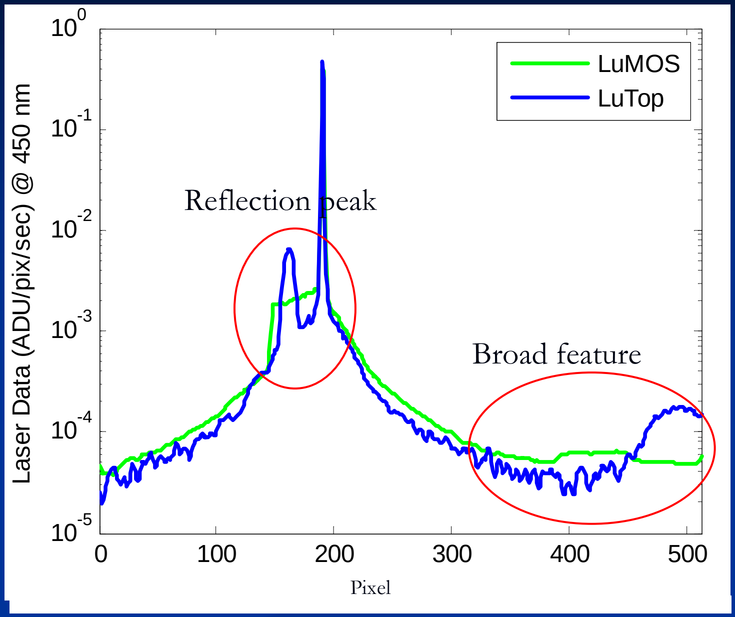
- Largest change in the UV and red spectrograph
- Only run on a few examples
- The lower panels shows a 4.3% increase in MODIS-Terra band 8 (411.8) nm.

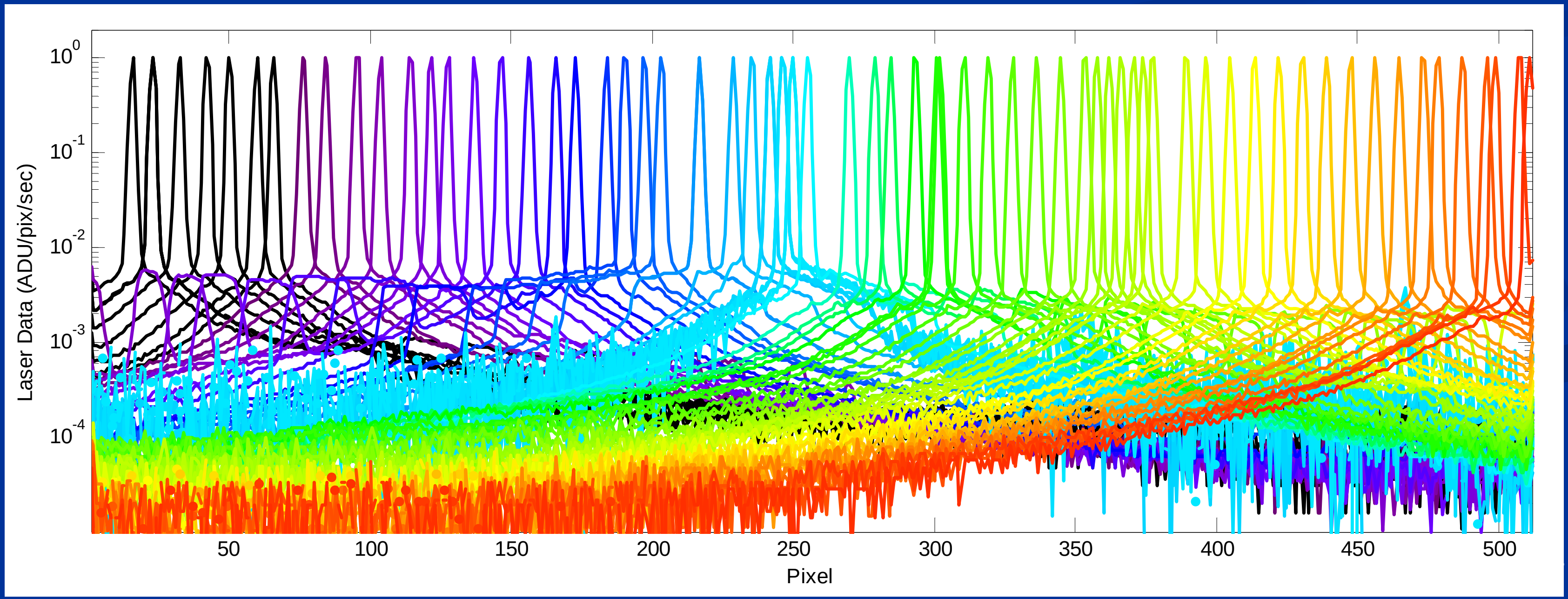
Preliminary Changes to some MODIS-Terra Bands (one example)				
8	9	10	14	15
411	442	486	676	746
4.3	1.0	-0.2	1.7	-25.4



LuMOS data

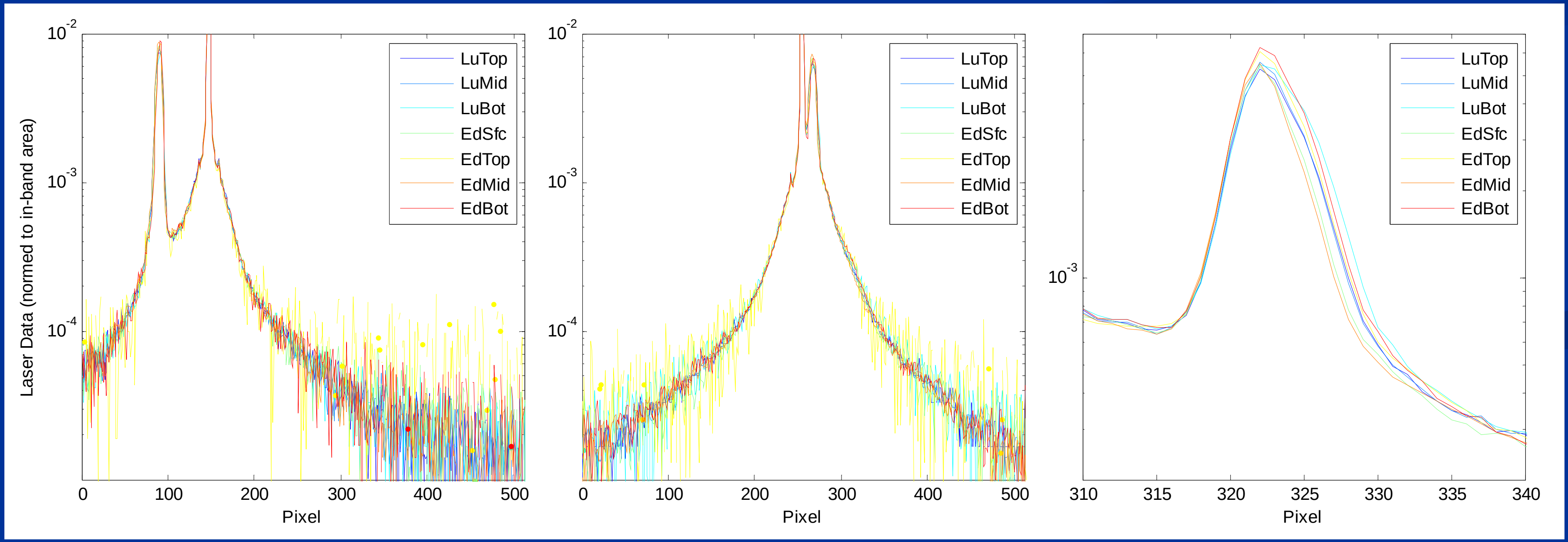
- No optical fibers, which causes square peaks
- Data was processed and smoothed.
- Interpolation not started. Need a slightly different algorithm for the square reflection peaks and broad feature.





Extension to Other Collectors

- Preliminary analysis shows the other fibered inputs are very similar to the LuTop data
- Only significant variation is around the reflection peaks
- Highly likely the LuTop matrix will work for other fibered sensors.



Summary

- All laser data were processed and all LuTop and LuMOS are smoothed
- Some problems with the data are still pending
- Progress has been made on finishing the 8 matrices needed

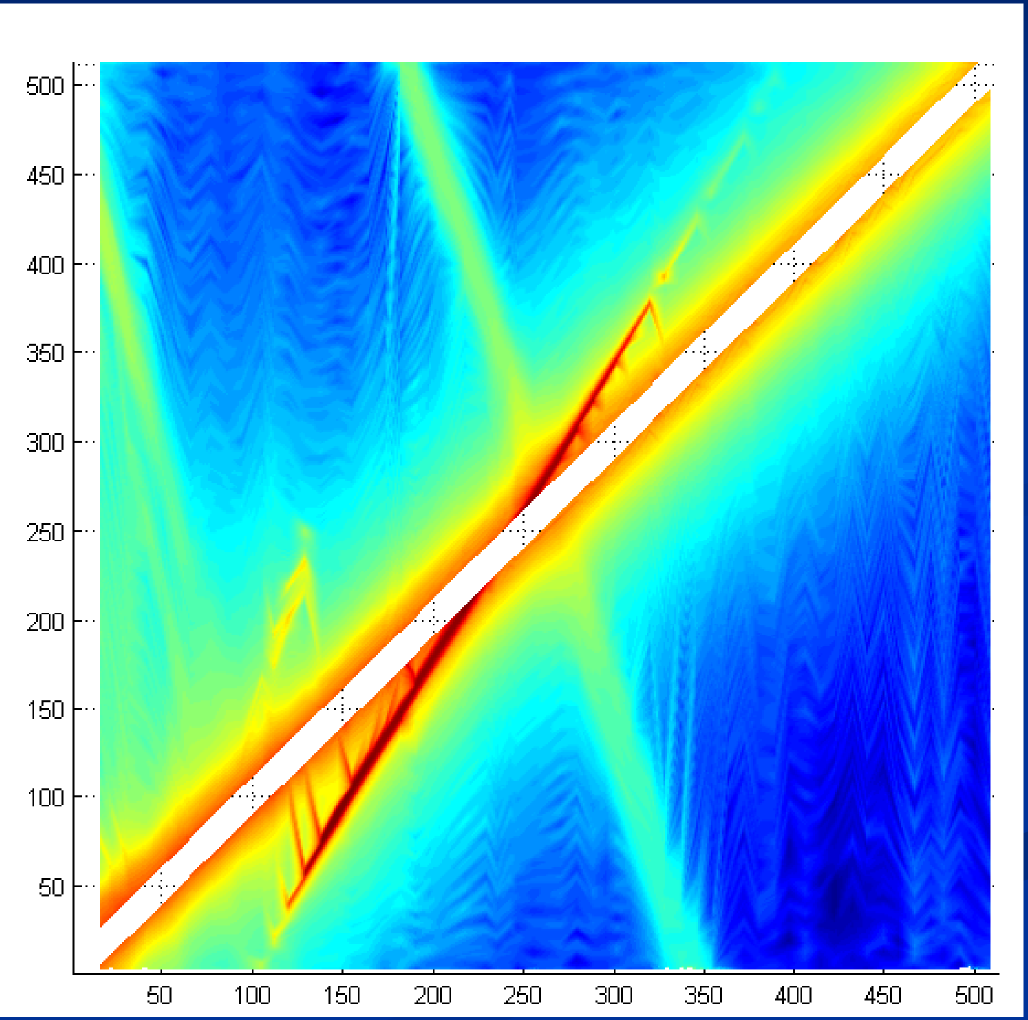
Buoy	Sensor	Blue Spectrograph	Red Spectrograph
Even	Fibered	Done	Close (3 lasers need attention)
Odd	Fibered	Close (fix UV data)	Preliminary only (basic matrix)
Even	LuMOS	Not started	Not started
Odd	LuMOS	Not started	Not started

Alternate SLC Algorithm
David Harris, NIST

- Maximizes a likelihood function
  - No separation of in-band from out-of-band
  - Laser observations modeled analytically
  - Solution from optimization using quadratic programming
  - Bayesian inference – negative results non physical
  - Advantages and disadvantages still need to be sorted out.
- Technique may be appropriate for other systems

Cumulative summation interpolation

- Eric Shirley – NIST
- Uses cumulative summation and interpolation to create matrix
- Feathering on the reflection peak is the primary problem.
- Source of feathering identified
- Likely solution identified
- Advantages: Totally independent method and great potential for future work

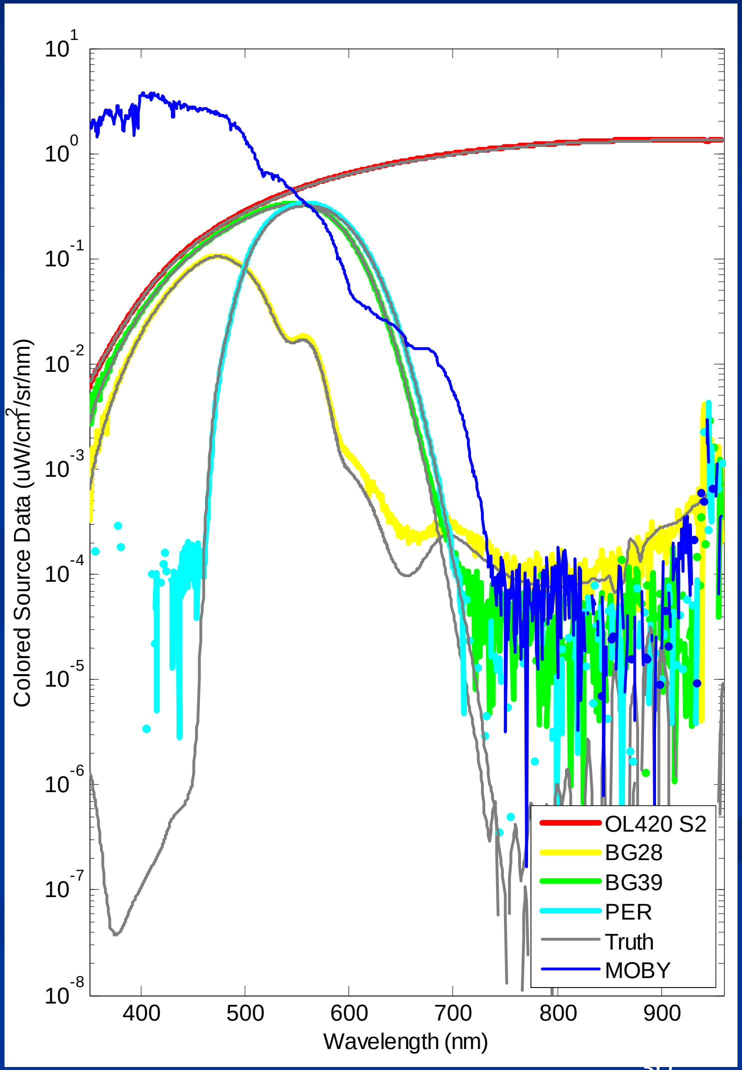


Testing on MOBY data

- Limited (a few files) have been used to test matrix during developments 40-43 (around when laser data was collected)
- Still needs to be applied to deployment 42 and 43.
- This study of 2008 MOBY data will be begin once the stray light matrices are finalized.

Validating method

- Still need to acquire a high accuracy validation data set.
- Need comparable spectral distribution to the Lu spectra
- Need to improve on the current measurements by use of alternative sources such as LEDs
- Sources must be calibrated w/ low uncertainties ~ 1-2 %
- Measurements must occur at time of MOBY cals



Generating Report

- We will publish this work, consisting of description of MOBY SIRCUS measurements, analysis of these data, description of validation data, estimation of the uncertainties, and impact on the MOBY deployments 241 and 242.
- Current work is being posted to the web at the following addresses (for group discussions).
  - http://data.moby.mlml.calstate.edu/slc_nist200801/straylight.html
  - http://data.moby.mlml.calstate.edu/slc_nist200802/straylight.html

The End