NIST Calibration Support for VIIRS Ocean Earth Data Records Products

PI: Carol Johnson

Presenter: David Allen

Sensor Science Division, NIST

August 10, 2016

cjohnson@nist.gov

National Institute of Standards and Technology
U.S. Department of Commerce

Topics

- SeaPRISM filter measurements
- NOAA's Spectral Radiance Standard
- Blue Tile

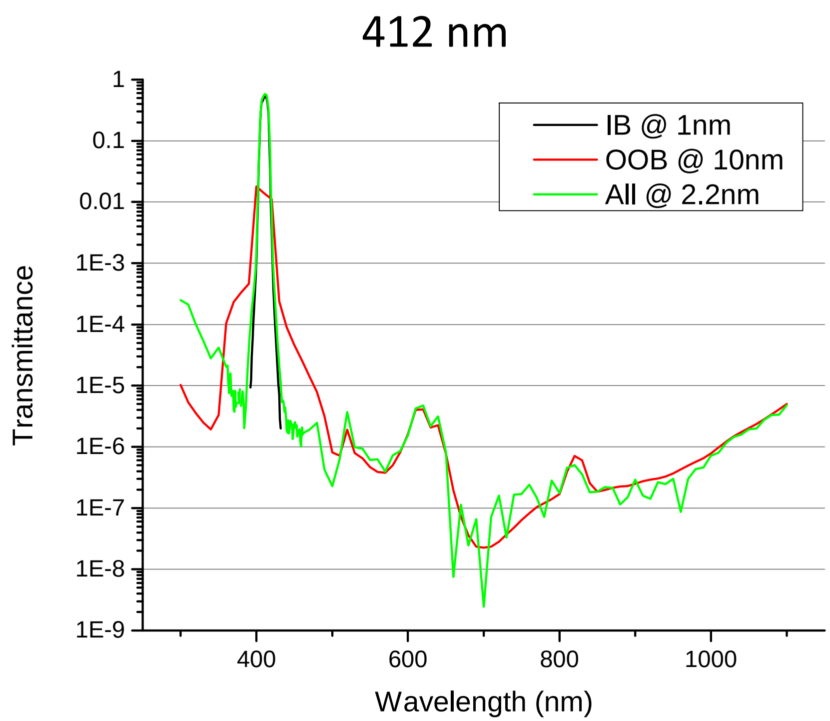
SeaPRISM Filters

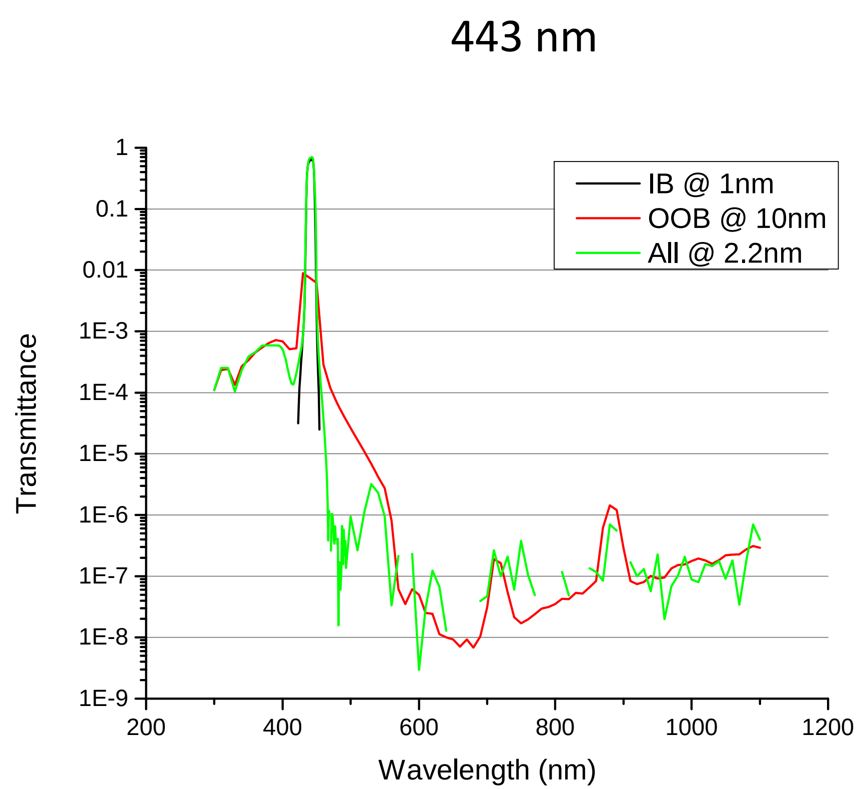
- The spectral out-of-band could not be measured for the SeaPRISM080 NIST that was characterized and calibrated on SIRCUS
- This is important because differences between the spectral distributions of the calibration and measured sources cause bias if there is spectral out of band in the filters
- A spare set of AERONET-OC SeaPRISM filters was measured twice for transmittance at NIST by Howard Yoon
- We present the final data and results of a sensitivity study

Specifications

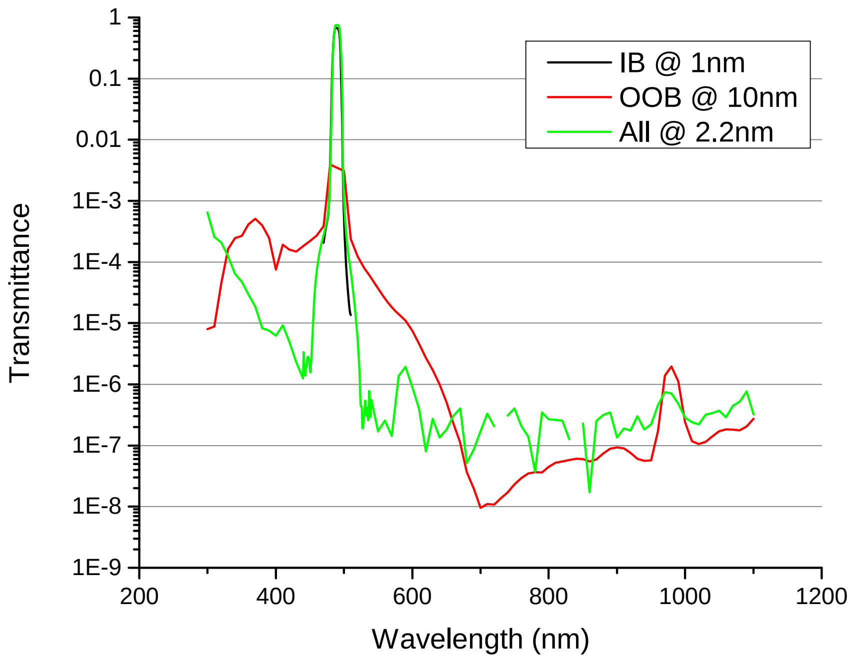
Nominal Wavelength (nm)	Nominal Bandpass (nm)	Designations
412	10	from #610 412/10nm #03 Lot 11087 Interferenzoptic GmbH
443		POC Part No.: 8746-801, Filter Ass'y 443nm, S/N 45, Test Lot# 3805, Made in USA
490	10	POC Part No.: 8746-805, Filter Ass'y 490/10nm, S/N 27, Test Lot# 4305, Made in USA
531	10	POC Part No.: 8746-807, Filter Ass'y 531/10nm, S/N 12, Test Lot# 3905, Made in USA
551	10	POC Part No.: 8746-809, Filter Ass'y 551/10nm, S/N 12, Test Lot# 1006, Made in USA
667	10	POC Part No.: 8746-803, Filter Ass'y 667/10nm, S/N 33, Test Lot# 4505, Made in USA

The first measurements were 1nm bandpass (in band) and 10nm bandpass (out of band). These data were presented on a TelCon. It was then recognized the measurements at 10nm bandpass gave incorrect results on the shoulders because of the stray light in the Cary 14 spectrophotometer. So, a second set of measurements was performed, and the results were re-analyzed.


412 nm
Transmittance
Wavelength (nm)
IB @ 1nm
OOB @ 10nm
All @ 2.2nm
1
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
400
600
800
1000

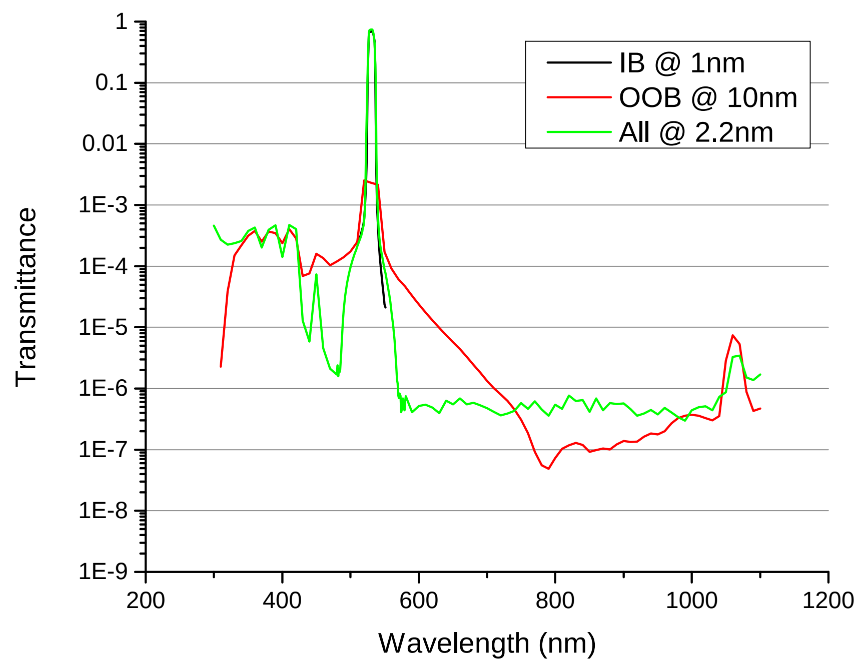

443 nm
Transmittance
Wavelength (nm)
IB @ 1nm
OOB @ 10nm
All @ 2.2nm
1
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
200
400
600
800
1000
1200

490 nm



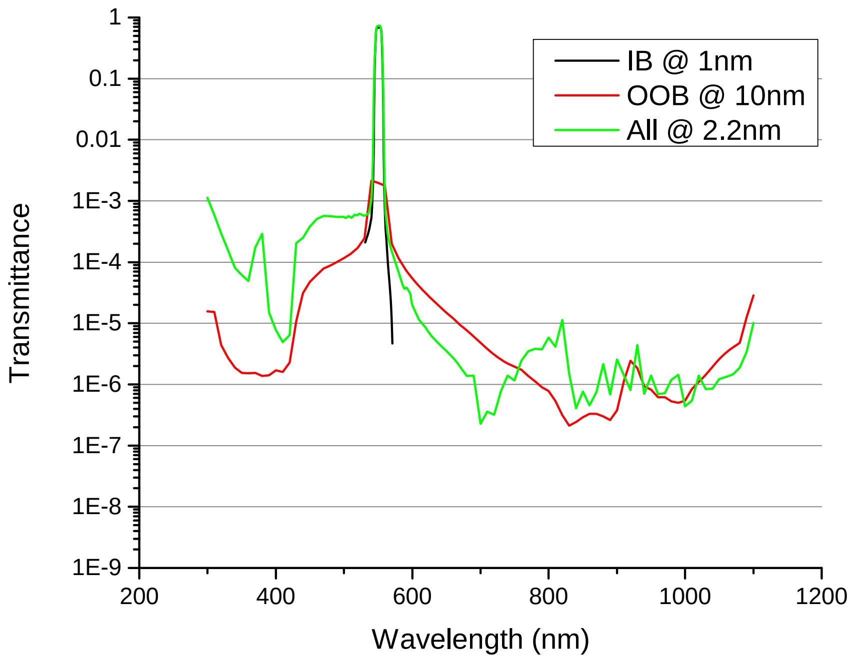
IB @ 1nm
OOB @ 10nm
All @ 2.2nm
Transmittance
1
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
200
400
600
800
1000
1200
Wavelength (nm)

531 nm

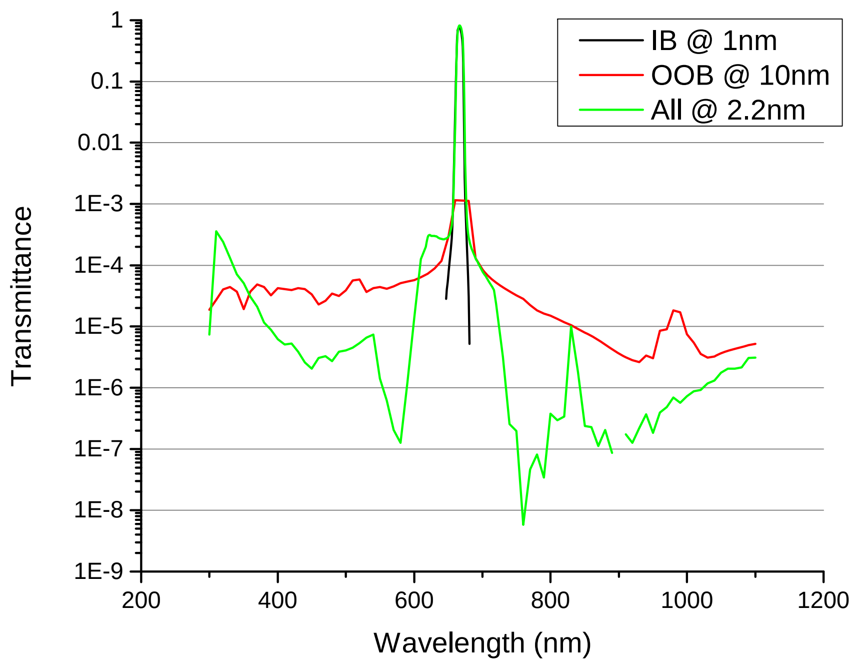


IB @ 1nm
OOB @ 10nm
All @ 2.2nm
Transmittance
1
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
200
400
600
800
1000
1200
Wavelength (nm)

551 nm

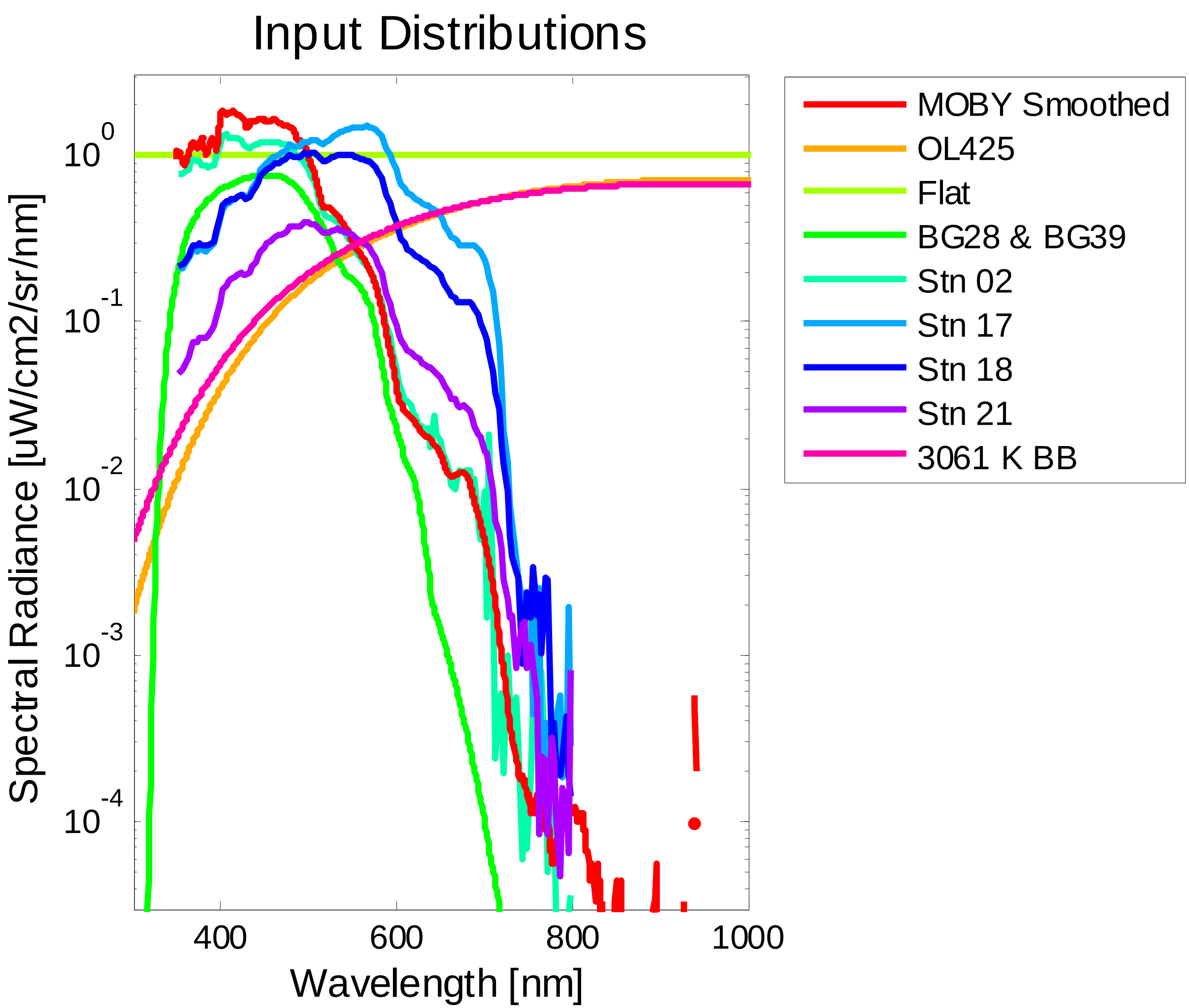

IB @ 1nm
OOB @ 10nm
All @ 2.2nm
Transmittance
1
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
200
400
600
800
1000
1200
Wavelength (nm)

667 nm


IB @ 1nm
OOB @ 10nm
All @ 2.2nm
Transmittance
1
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
200
400
600
800
1000
1200
Wavelength (nm)

Sensitivity Analysis

- Approach
  - Multiply all transmittance values by the flux responsivity of a silicon photodiode
  - Set the transmittance to zero in the out-of-band regions for the comparison case (“In-Band”)
  - Select spectral distributions to represent Lw
  - Use measurement equations to find the sensitivity to In-band vs Total-Band


Input Distributions
Spectral Radiance [uW/cm2/sr/nm]
Wavelength [nm]
10^0
10^-1
10^-2
10^-3
10^-4
400
600
800
1000
MOBY Smoothed
OL425
Flat
BG28 & BG39
Stn 02
Stn 17
Stn 18
Stn 21
3061 K BB

Measurement Equations

$$\lambda_{\mathrm{c,w}} = \frac{\int \lambda L_{\mathrm{c,w}}(\lambda)\tau(\lambda)r(\lambda)d\lambda}{\int L_{\mathrm{c,w}}(\lambda)\tau(\lambda)r(\lambda)d\lambda}$$

Channel wavelength depends on the spectral distribution of the source measured: c = calibration; w = water

$$D_{\mathrm{c,w}} = \frac{S_{\mathrm{c,w}}}{L_{\mathrm{c,w}}(\lambda_{\mathrm{c,w}})}$$

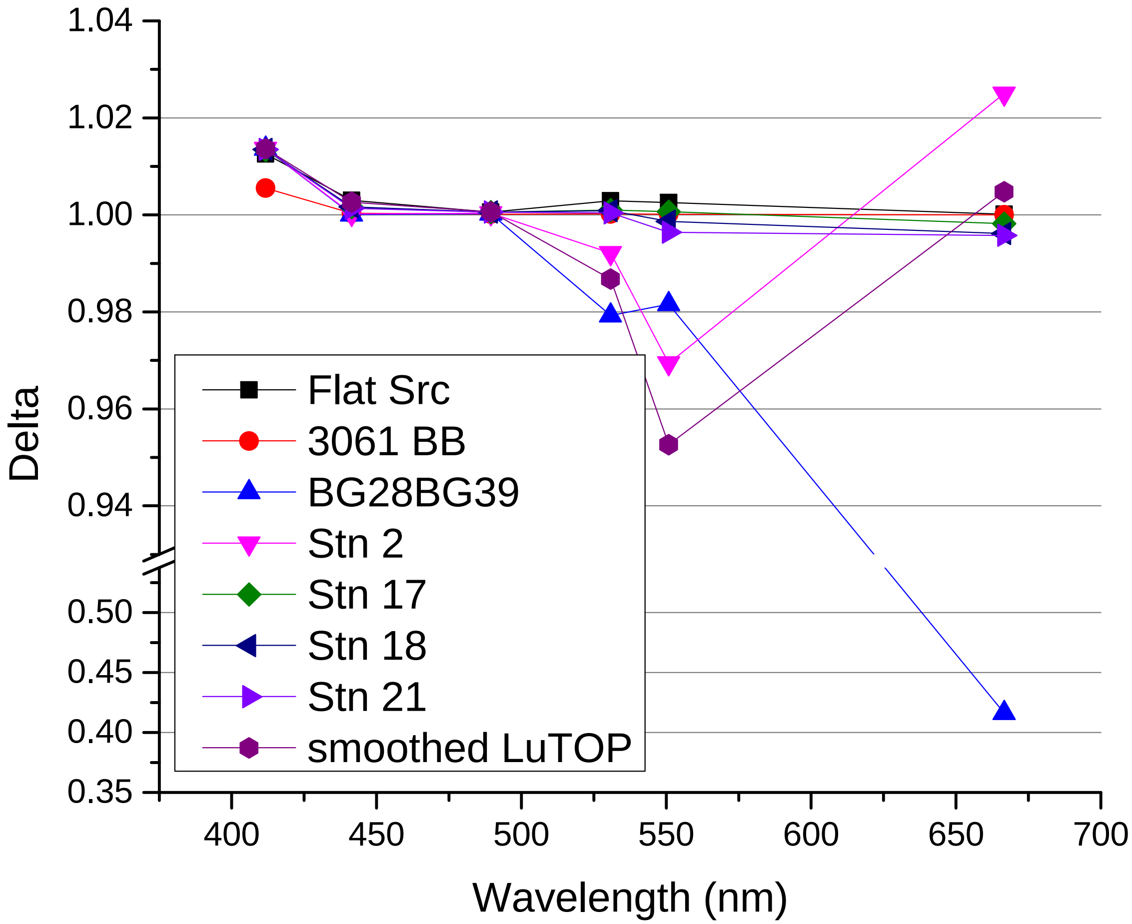
Using the calculated signals, a calibration coefficient is defined given the calibration and water spectral distributions. They will differ because of spectral out of band.

$$\delta = \frac{\left(\frac{D_{\mathrm{c}}}{D_{\mathrm{w}}}\right)_{\mathrm{IB}}}{\left(\frac{D_{\mathrm{c}}}{D_{\mathrm{w}}}\right)_{\mathrm{Total}}} = \frac{L_{\mathrm{w}}(\lambda_{\mathrm{w,IB}})}{L_{\mathrm{c}}(\lambda_{\mathrm{c,IB}})}\frac{L_{\mathrm{c}}(\lambda_{\mathrm{c,TOT}})}{L_{\mathrm{w}}(\lambda_{\mathrm{w,TOT}})}$$

The bias is found by comparing the calibration coefficient ratios calculated with only the in band data or with full, total band data.

Parr and Johnson, J Res NIST, 116(5), p751-760 (2011)

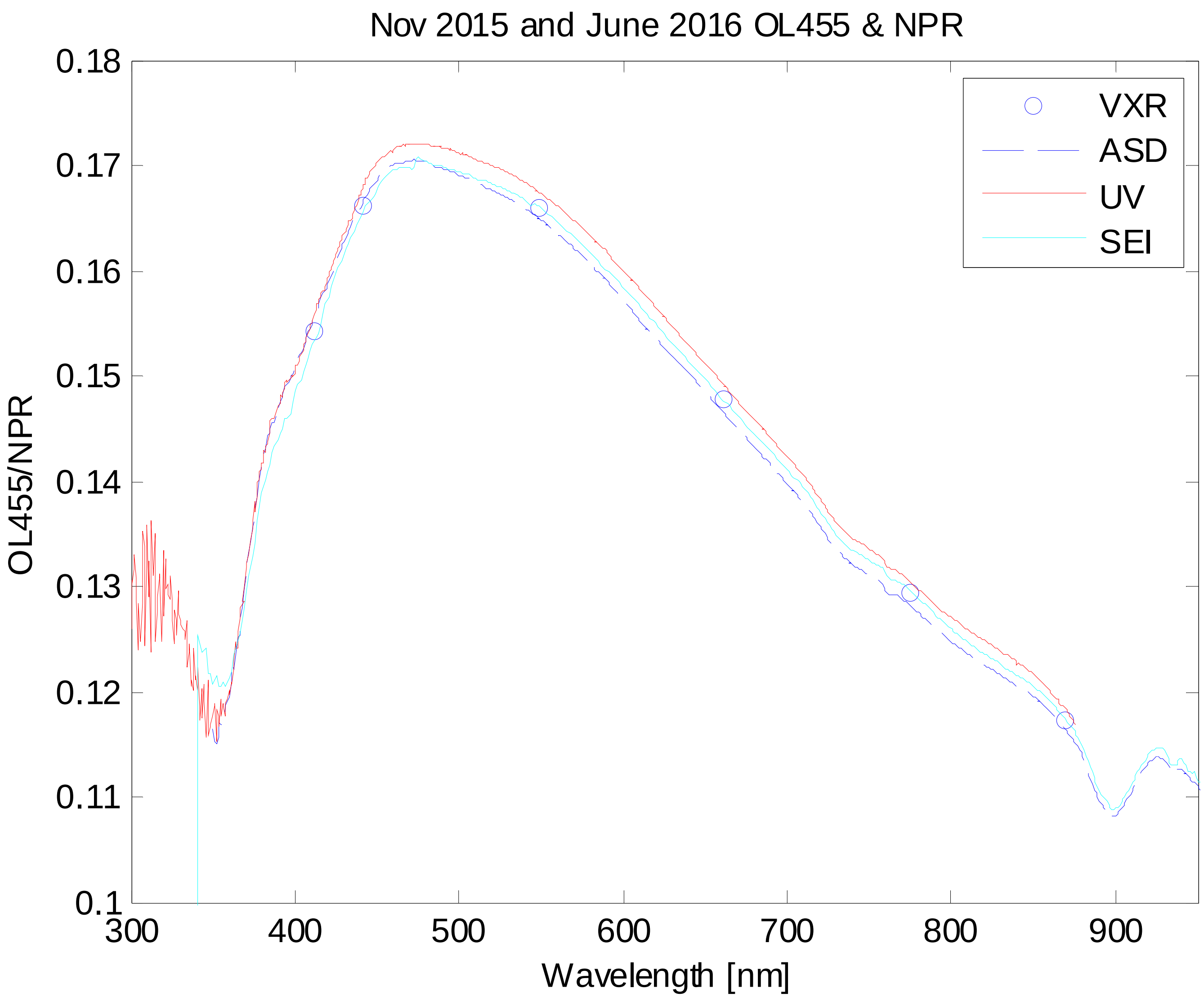
Results



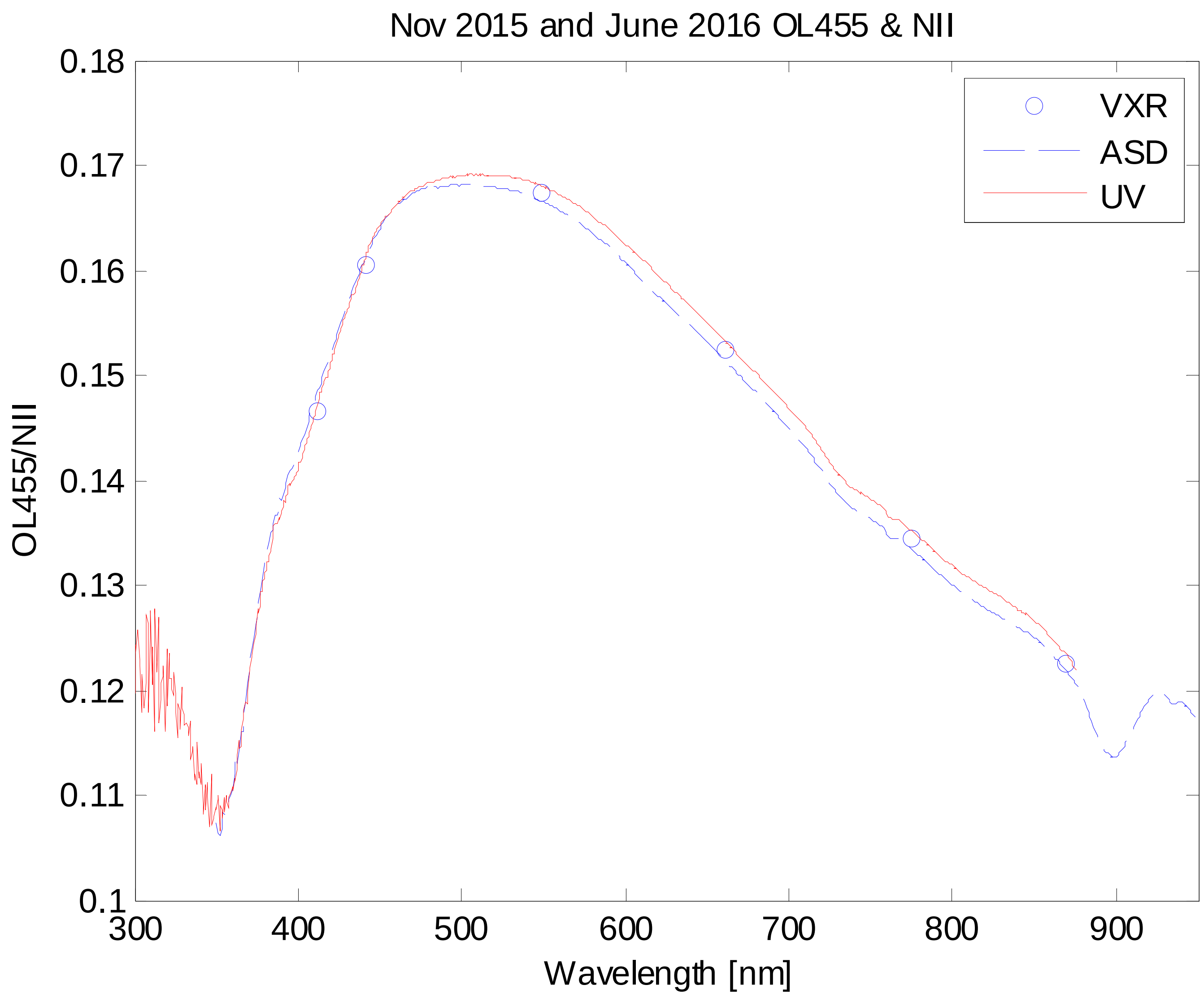
Delta is referenced to the spectral radiance standard, the OL425 spectrum in this case.

NOAA Spectral Radiance Validation

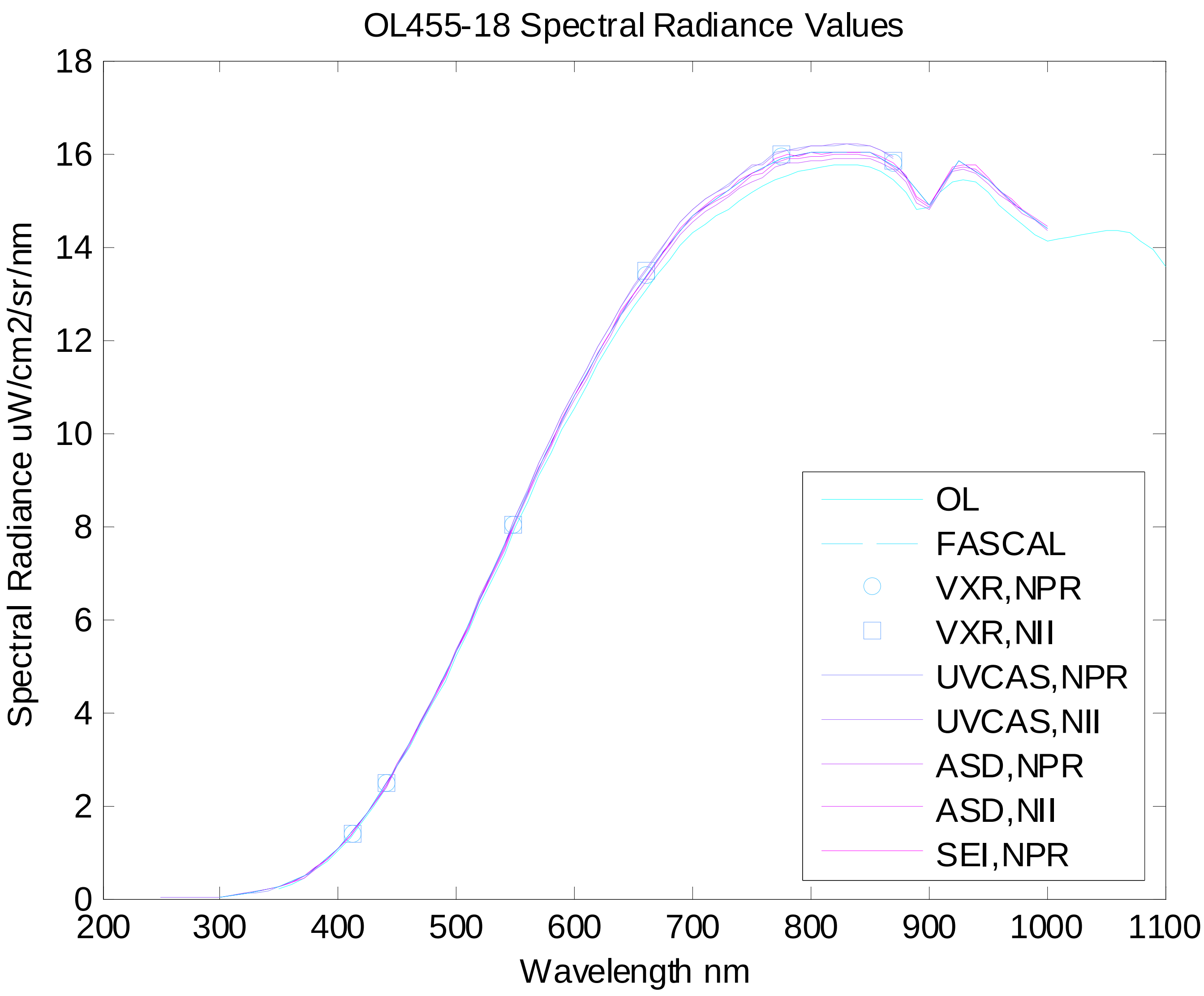
- OL455-18 is the spectral radiance standard in the NOAA/STAR calibration laboratory
- Externally-illuminated 18” sphere with monitor photodiode
  - Aug 2013 calibration by Optronic Labs
  - Nov 2015 & Jun 2016 validation in Remote Sensing Lab (RSL) at NIST
  - Apr 2016 NIST FASCAL calibration
- User adjusts an iris between the lamp and sphere to maintain calibration value of the monitor photodiode



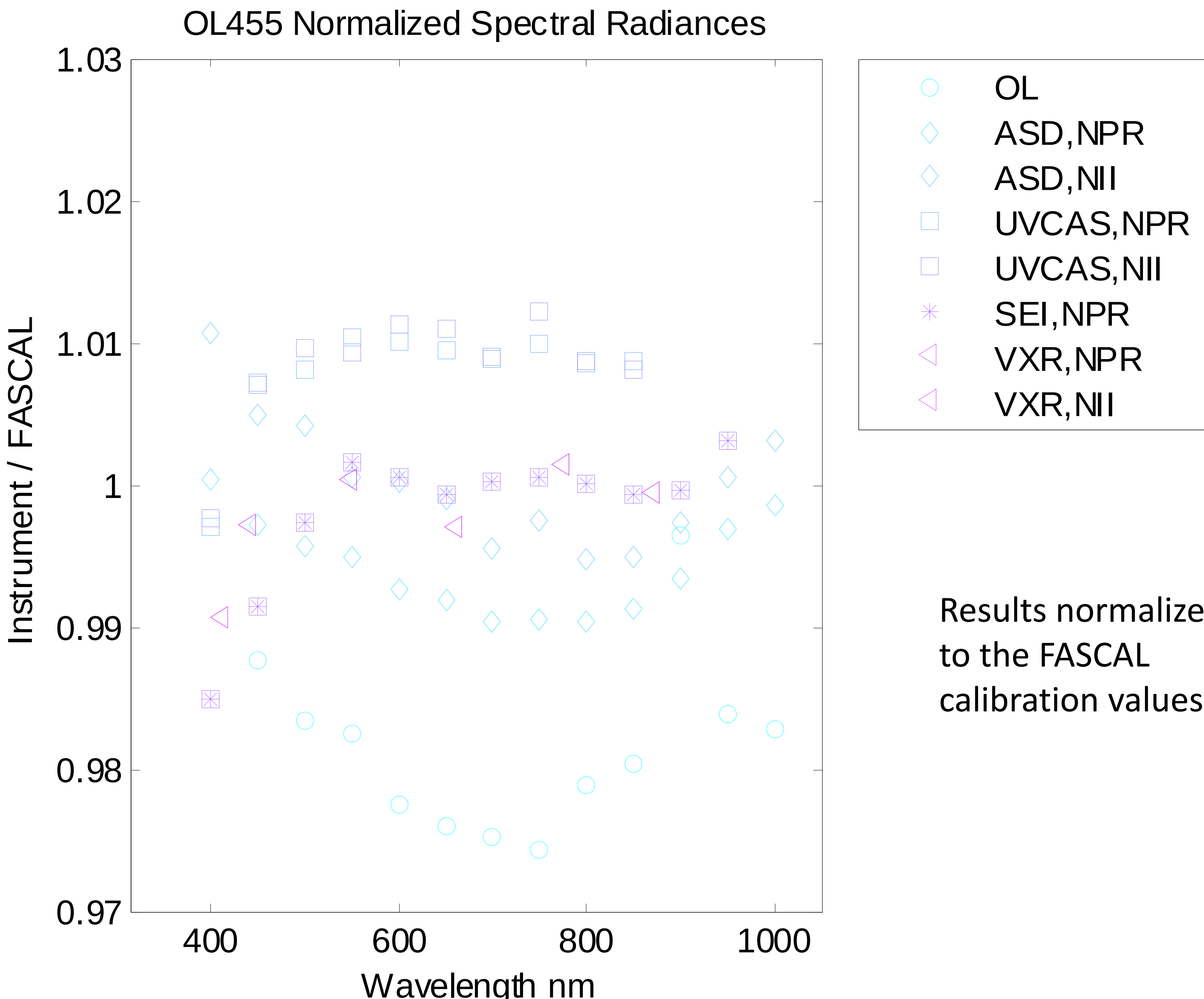
Signal ratios of the OL455 to the RSL NIST Portable Radiance (NPR) sphere source for four transfer radiometers (one filter, three spectrographs).



Signal ratios of the OL455 to the RSL NIST Portable Radiance II (NII) sphere source for three transfer radiometers (one filter, two spectrographs).



Spectral radiances from OL, FASCAL, and the validation in RSL.

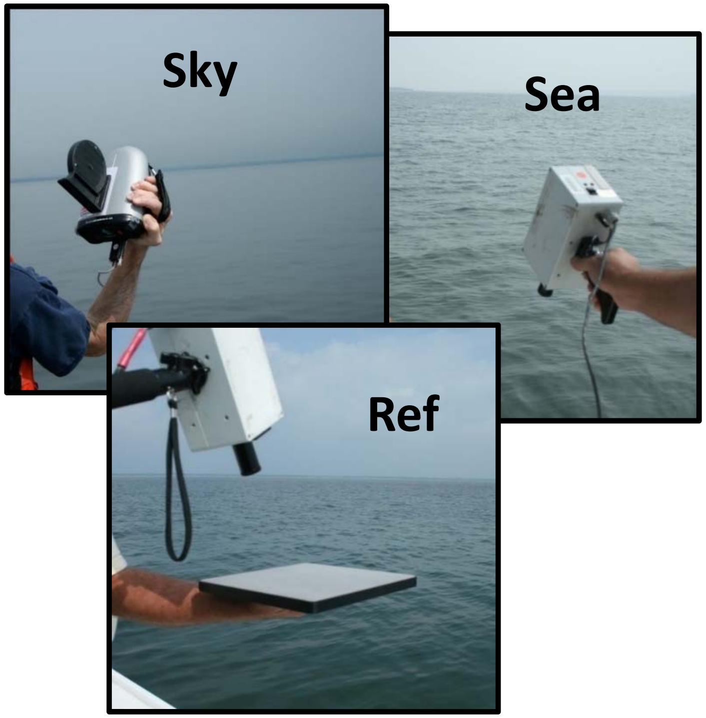


Results normalized to the FASCAL calibration values

Blue Tile

- Validation of hand-held radiance radiometers and the in-air technique during cruises to determine remote sensing reflectance
- Tasks
  - Measure a reflectance target that differs in BRDF and spectral parameters from the white or gray Spectralon reflectance standard targets
  - Measure the BRDF of this blue tile in NIST and GSFC facilities
  - Independently reduce the Nancy Foster blue tile date

R_{rs} using Reflectance Standards



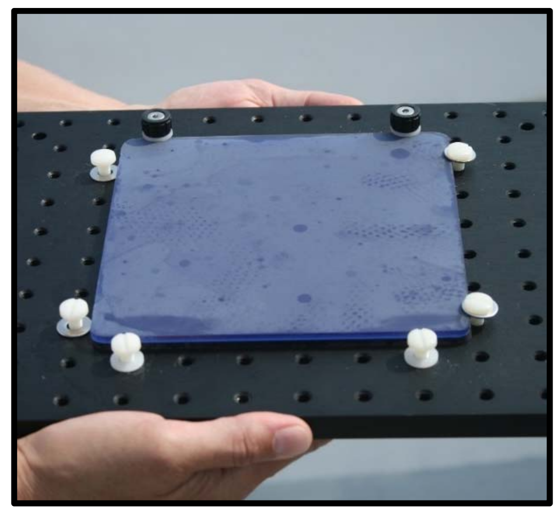
Hand-held, in-air method

Blue Tile measurement equation

$$\rho_{\text{tile}} = \frac{S_{\text{tile}}}{S_{\text{std}}} \frac{E_i(t_{\text{std}})}{E_i(t_{\text{tile}})} \rho_{\text{std}}$$

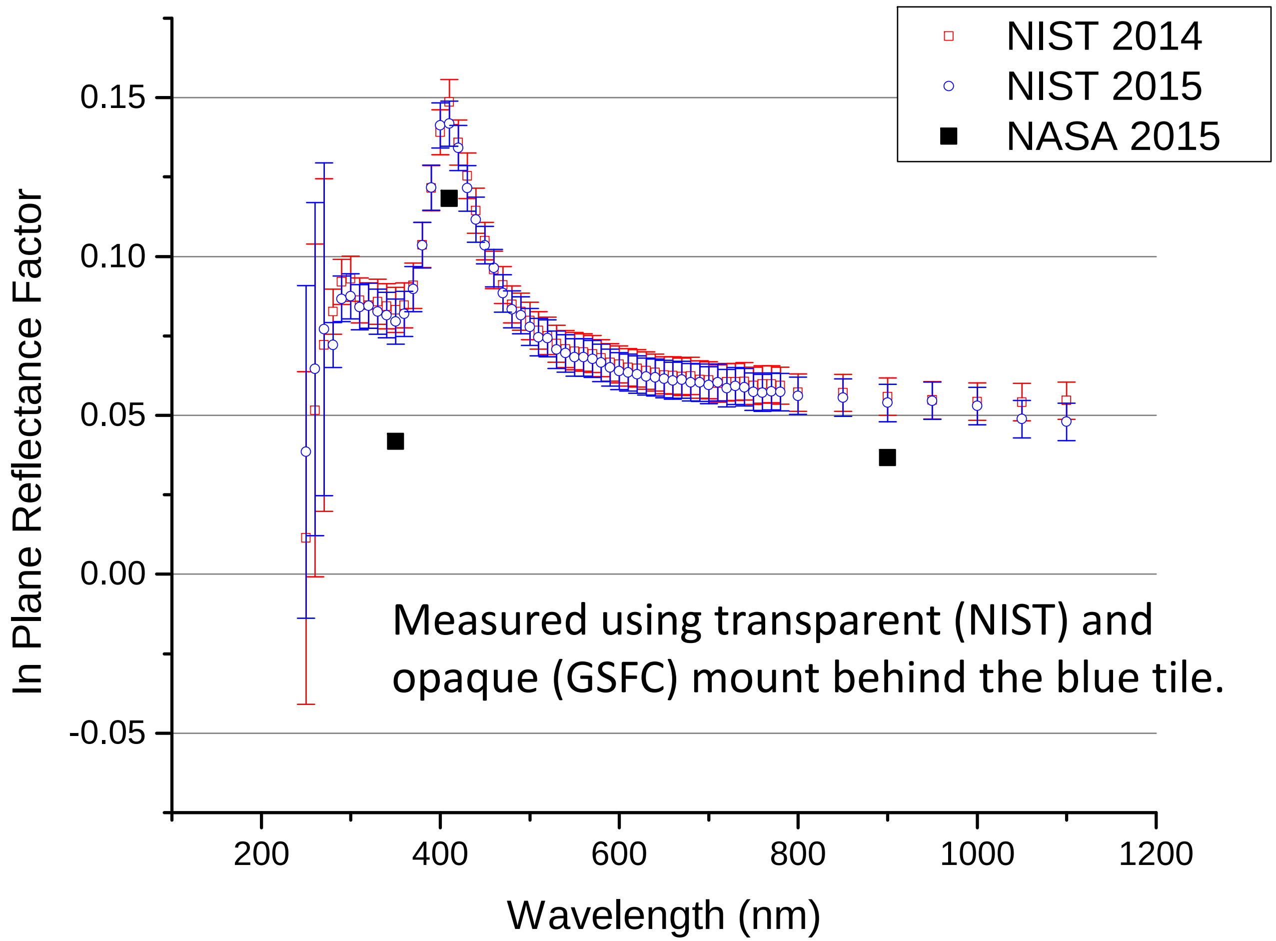
If reference standard is Lambertian, then

$$\rho_{\text{std}} = \rho_{\text{d,std}}(8^\circ, \phi_{\text{i}}; 2\pi)$$



Blue Tile Target: ground blue glass, shown here at the Long Island Workshop

Blue Tile 0/45 Reflectance Factor



Independent Analysis

- Status
  - Tested reader for binary files from ASD
  - Automated programs being written to ingest all the raw files and produce tables of header data as an aid to organization
- 2014 Cruise had 1 station, 2015 Cruise has 4 stations
- Poster submitted to OOXXIII

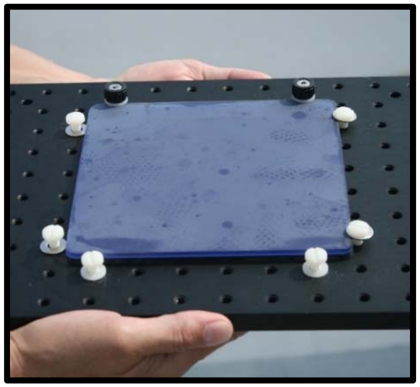
Upcoming Work

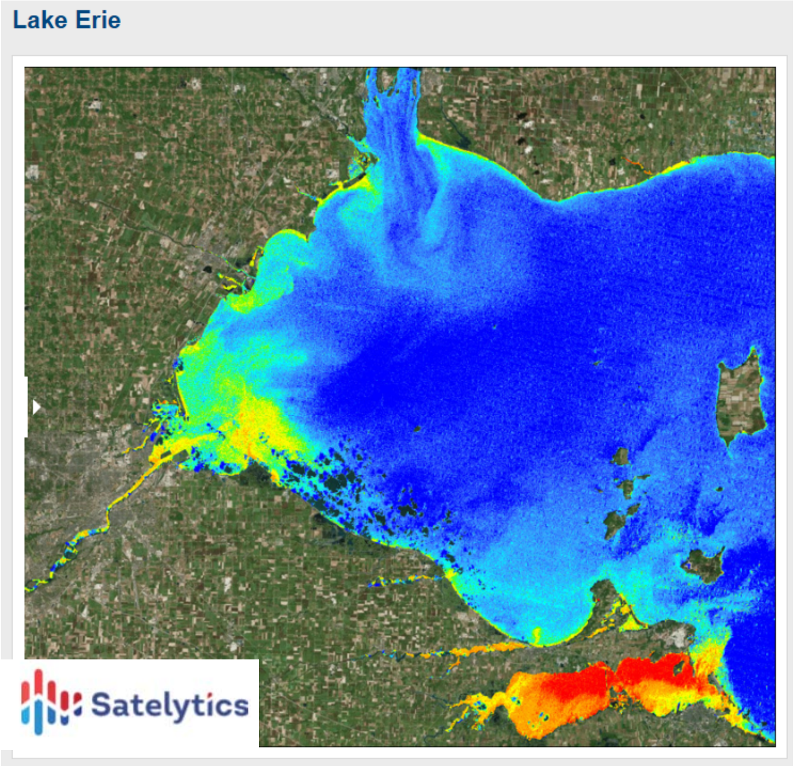
- Archival paper on SeaPRISM080
- Analysis of blue tile for 2014, 2015 cruises
- Validation of NOAA's irradiance bench
- BRDF measurements of blue tile
- Controlled field experiments with the blue tile

Other Activities

Emerging Applications of Spectral Remote Sensing

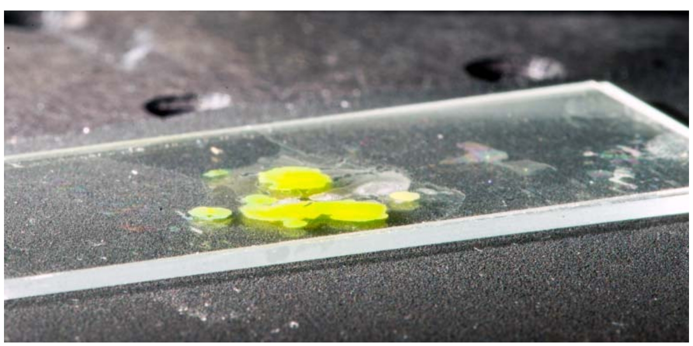
- Custom Data Products (inland bodies of water)
- Need for validation
- End-to-end analysis

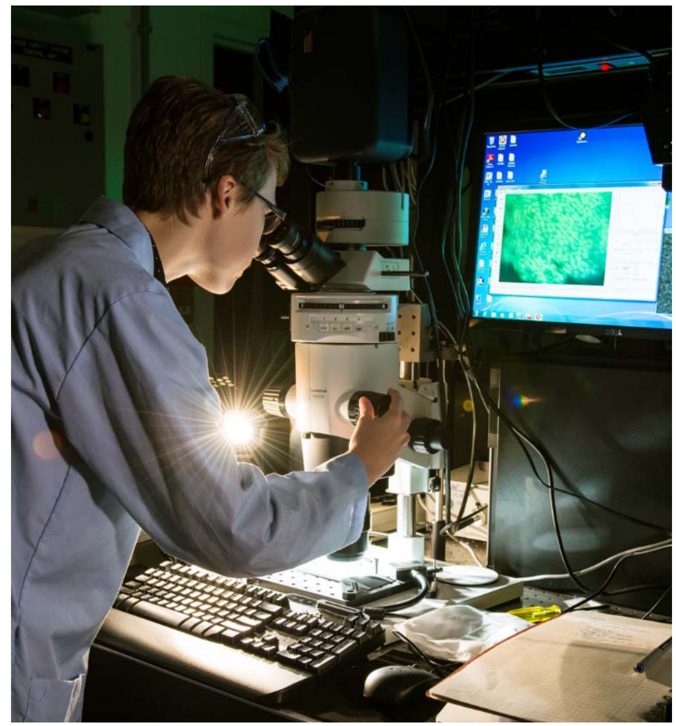




Remote Sensing of Harmful Algal Blooms (HABs)

- Cyanobacterial blooms have the potential to release harmful toxins into the water
  - Not all species release toxins, and some toxic species do not always produce toxins.
- **Objective**: to determine if there is a way to use hyperspectral remote sensing to identify toxic blooms without physical sampling
- This will be done in part through analysis of algal samples with a hyperspectral microscope.





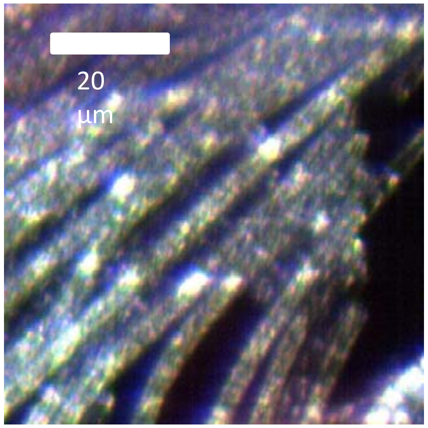
Emily Paine
USGS/NAGT Intern, NIST Guest Researcher

USGS science for a changing world

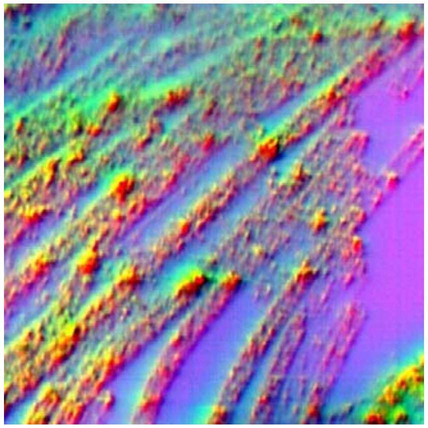
Remote Sensing of HABs

- The resolution of a HS microscope can be used to identify small-scale variations within cells.
- Ideally, this could be used to identify more informative spectral features that could be used to locate blooms that are producing toxins.

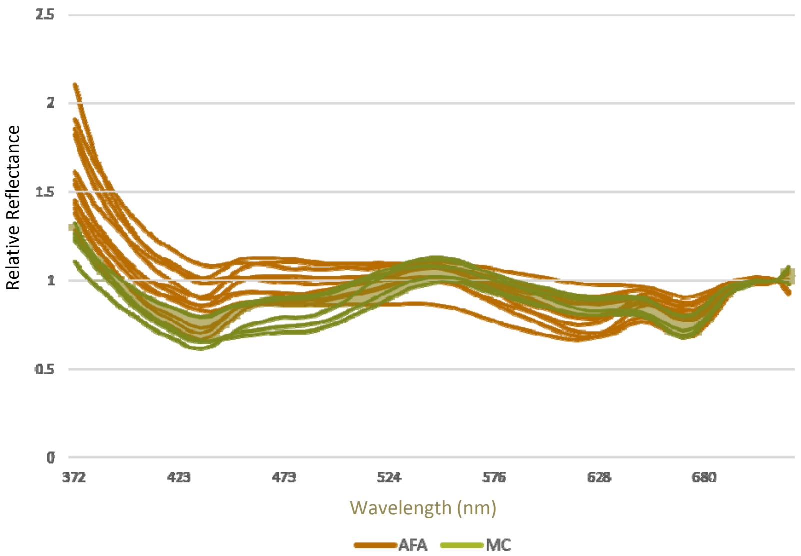
Aphanizomenon flos-aquae



True color



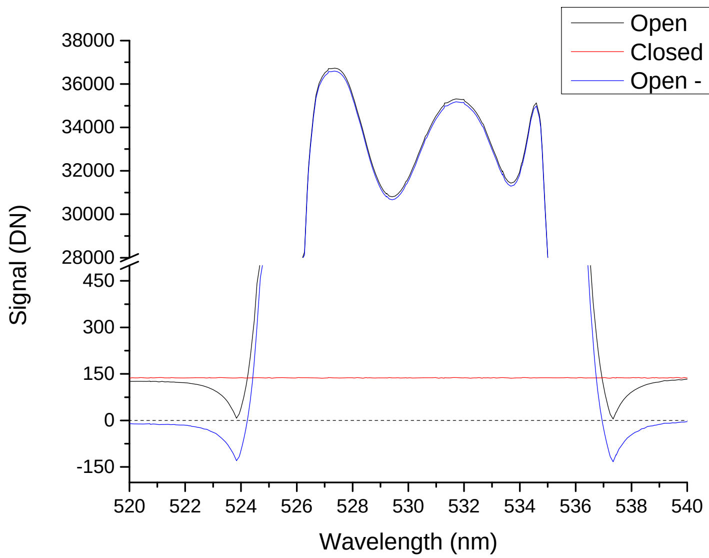
PCA Bands 1,2, and 3



Emily Paine
USGS/NAGT Intern, NIST Guest Researcher

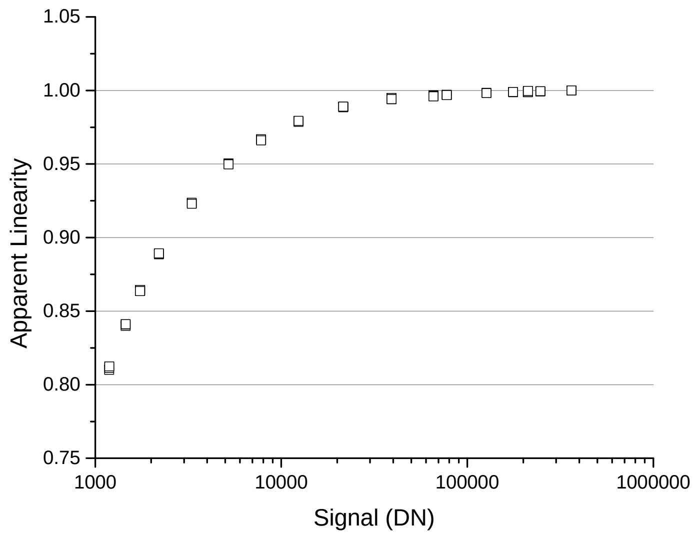
Back Up Slides

SeaPRISM Program vs RS232 Commands



Normalized by the SIRCUS sphere monitor photodiode, SeaPRISM signals from 364k DN to 1.2k DN demonstrated a 20% nonlinearity – something never observed during GSFC or JRC characterizations.

SIRCUS laser blocked gave an offset; laser open gave signals that decreased to zero and then increased; hence nets were negative – not physical behavior. The PRS mode on a broadband source gave 0 DN with the source blocked.

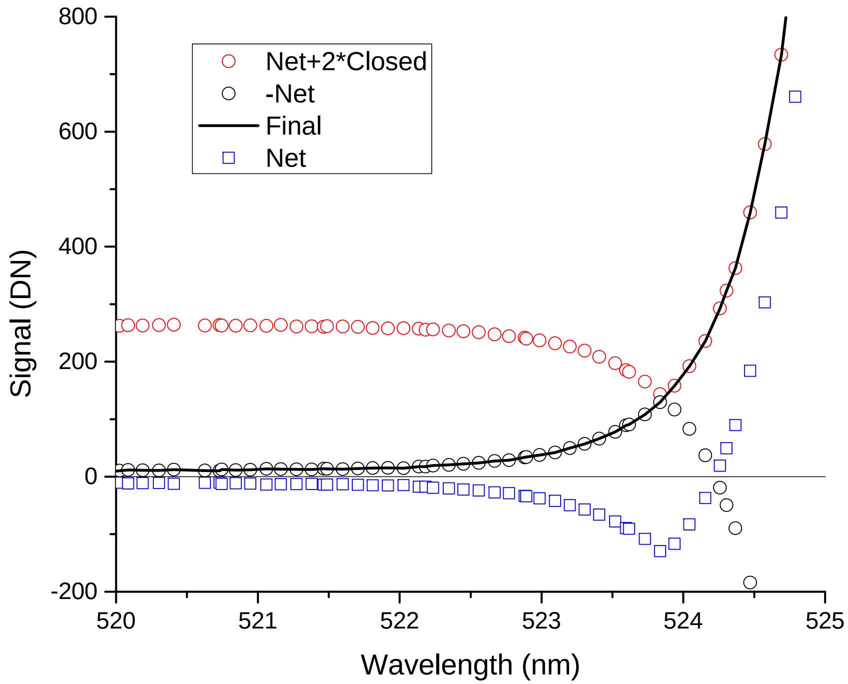


Measurement sequence: @, G, *i* then [Open, C, Close, C, step laser] x *N* times/band

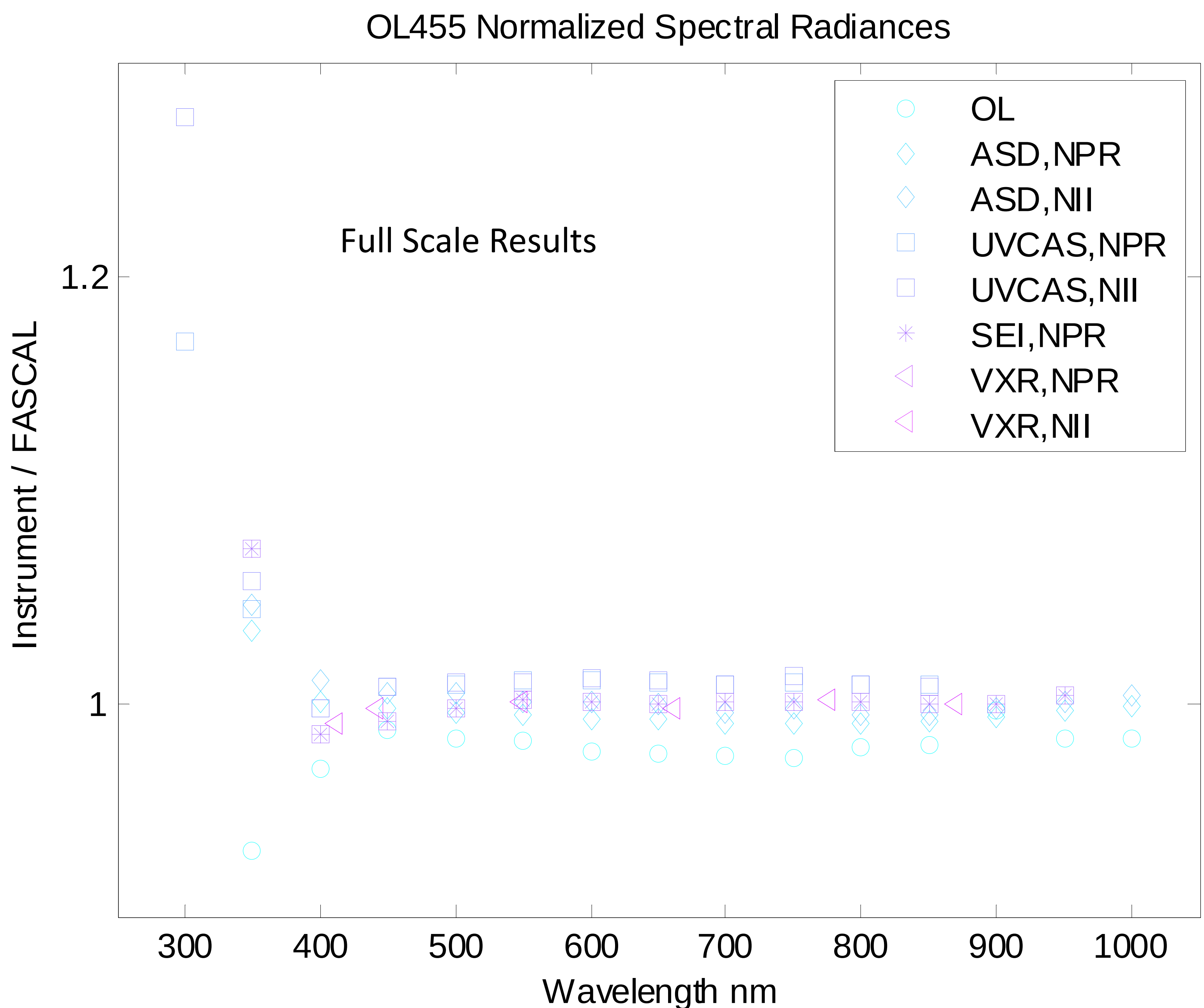
Correction Model

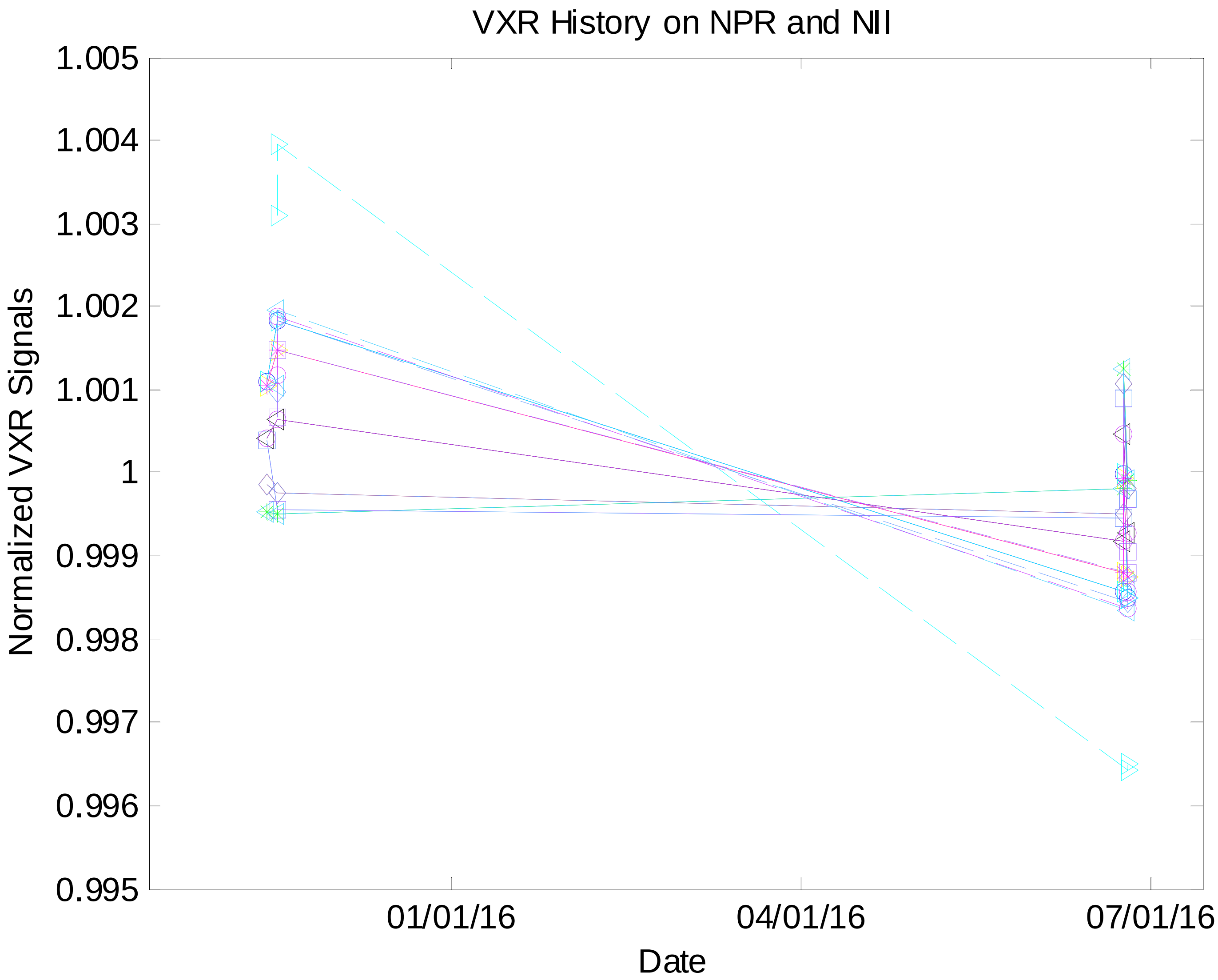
- What if
  - *There is an internal offset B_{int}, a positive value in units of DN, that is always subtracted prior to outputting the measurement result; and*
  - *if the result of this internal subtraction is negative, the sign is reversed so that only positive values are output.*
- Identifying S_{closed} with B_{int} allowed us to correct the SIRCUS data

Ambiguity Exists for Low DN Output



The ambiguity affects the spectral characterization: example: B_{int} = 138 DN, then an output of 2 DN means the signal was either 140 DN or 136 DN due to the internal subtraction and sign reversal. The relative error depends on the signal level – worse case is for zero or 2*B_{int}. This limits the dynamic range, and measurements of the out-of-band at the system level are not possible.


OL455 Normalized Spectral Radiances
Full Scale Results
Instrument / FASCAL
Wavelength nm
1.2
1
300
400
500
600
700
800
900
1000
OL
ASD,NPR
ASD,NII
UVCAS,NPR
UVCAS,NII
SEI,NPR
VXR,NPR
VXR,NII



Normalized ratios of the VXR net signals indicate the stability of the VXR/NPR and VXR/NII systems before and after the FASCAL calibration of the OL455-18.