

Validation of the dissemination of spectral irradiance values using FEL lamps

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Outline

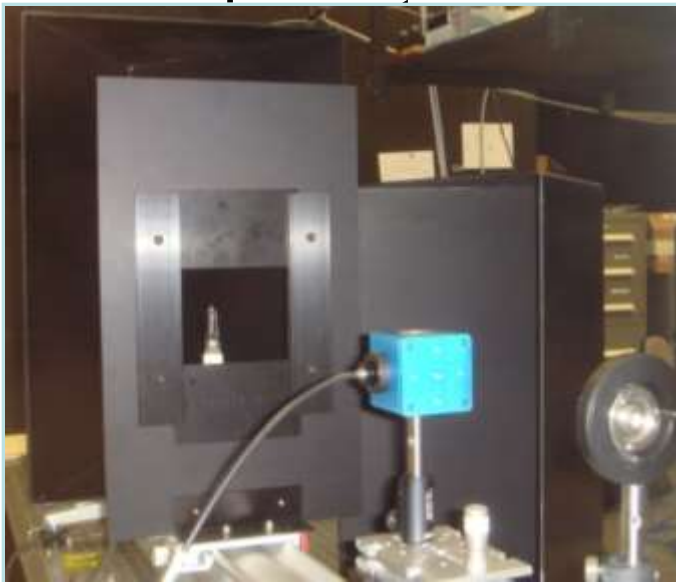
- Motivation
- Experimental Configuration
- Comparison Uncertainties
- Results
- Conclusions

Motivation

- FEL – type tungsten quartz halogen lamps
 - disseminate NIST scales of spectral irradiance
 - and radiance (with diffuse reflectance standard)
 - are valuable artifacts; defined protocol
 - irradiance scales are subject to biases
- Independent validation
 - assessment of traceability claims
 - required as part of the Statement of Work for the Advanced Baseline Imager (ABI) by NASA, under direction by NOAA

NIST Irradiance Bench

- Portable, kinematic, X95 structural rail
 - reference lamps, alignment laser, pinhole aperture, FEL kinematic mount, non-limiting apertures, back light trap, on-axis baffle, two optical-fiber coupled spectroradiometers, photometer, control and DAQ

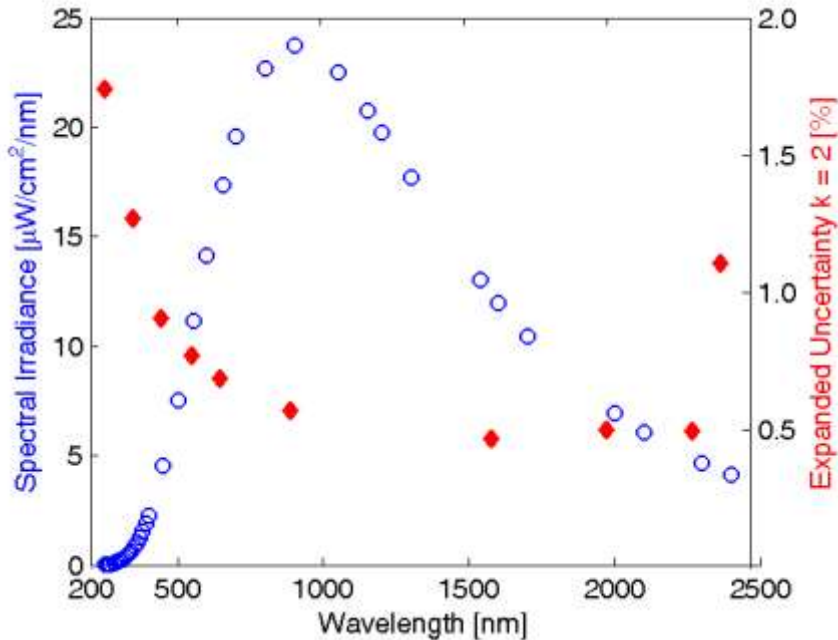


Experimental Procedure

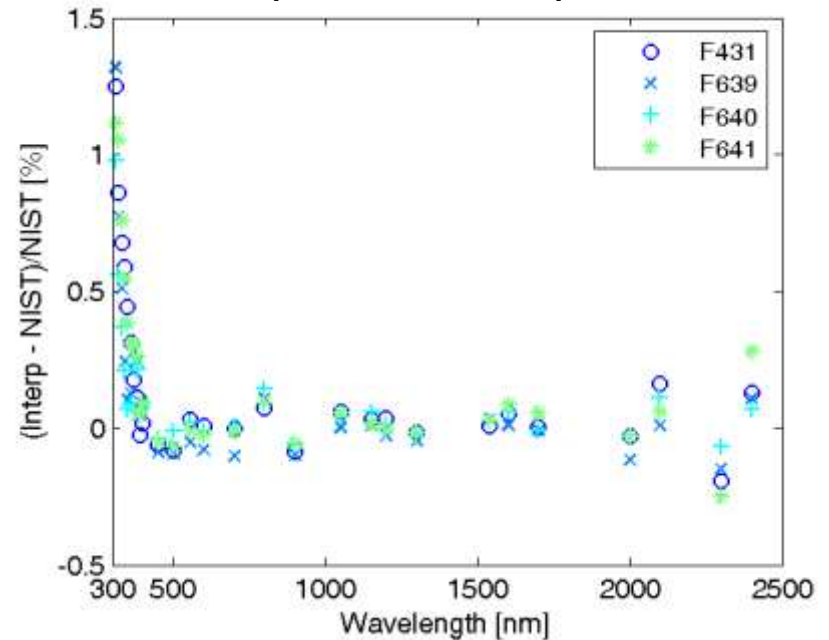
- Assign irradiance values from the reference to the working standard FEL lamp
 - Calibrate either the FieldSpec 3 or the SR-3500
 - Reference lamp on; photometer (blocked and un-blocked); spectroradiometer (blocked and un-blocked); photometer (blocked and unblocked); reference lamp off
 - Calibrate the test FEL lamp
 - Test lamp on; photometer (blocked and un-blocked); spectroradiometer (blocked and un-blocked); photometer (blocked and unblocked); test lamp off
 - Repeat FieldSpec 3 or SR-3500 calibration
 - Reference lamp on; photometer (blocked and unblocked): spectroradiometer (blocked and unblocked); photometer (blocked and unblocked); reference lamp off

Reference Lamps

F-640 FASCAL II Calibration



Interpolation Comparison



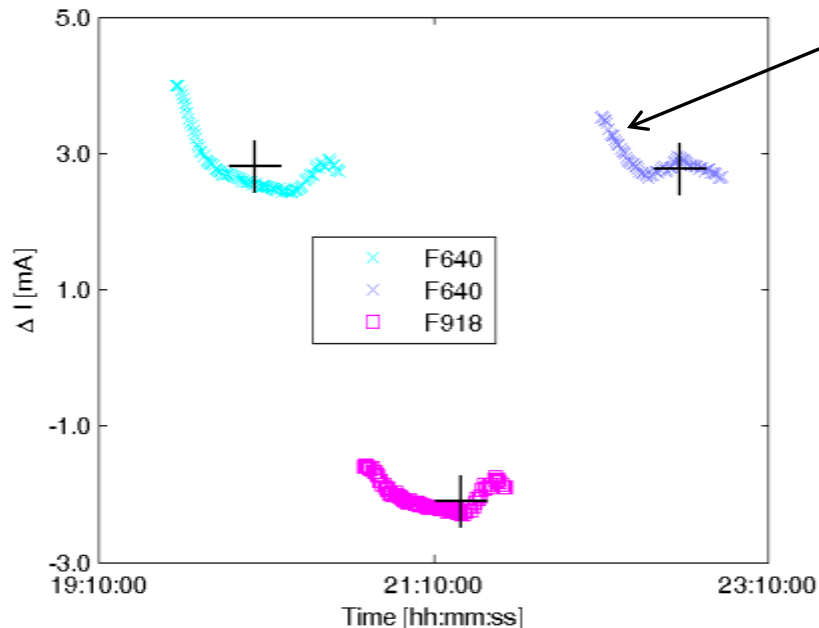
Uncertainty Components

- *FASCAL II Calibration;*
- *Interpolation in λ to FieldSpec 3 or SR-3500 wavelength grid*

Other lamps calibrated: F-639, F-641, F-431, and F-646; served as reference lamps or checks.

Lamp Housekeeping

Differences from Calibration Current



Warm-up; Large crosses are the mean values

The lamps were aligned using a laser, pinhole, and the glass alignment jig;
The distance to the collecting aperture was measured with a calibrated electronic ruler;
The lamp current was monitored as the voltage drop across a calibrated 0.1Ω resistor; and
The voltage drop across the lamp filament was monitored at the bi-post.

Uncertainty Components

- *Incorrect current settings (references @ 8.200 A; Tests @ 8.000 A;*
- *Drift during operation or anomalous voltage readings (not observed)*

Lamp Currents

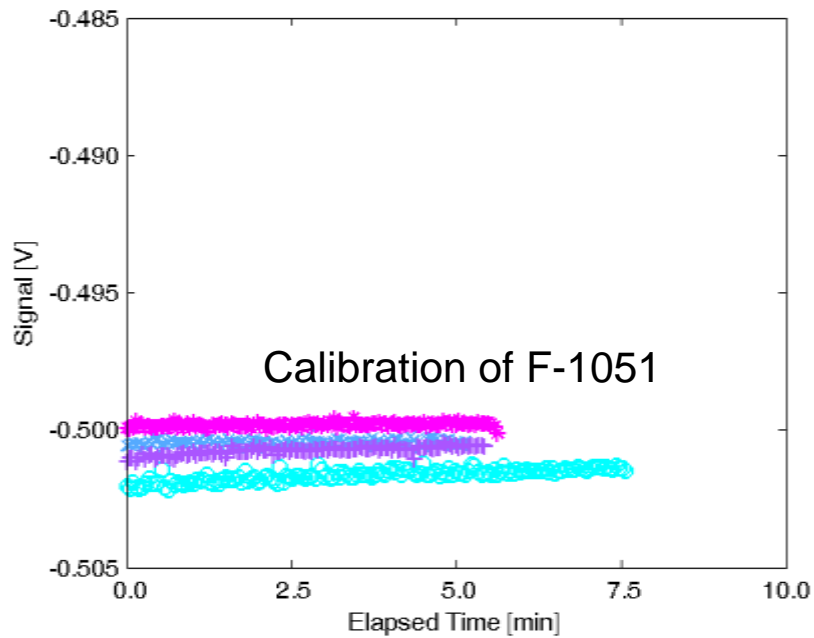
Lamp	Date Time	ΔI mA	$u(I)$ mA
F640	11/08/2010 20:01	10.802	0.0126
F918	11/08/2010 21:12	10.285	0.0112
F640	11/08/2010 22:05	10.632	0.0093
F640	11/09/2010 16:22	11.337	0.0108
F1051	11/09/2010 18:00	10.950	0.0092
F640	11/09/2010 19:23	11.363	0.0112
F639	11/10/2010 15:01	2.651	0.0199
F829	11/10/2010 17:09	2.683	0.0269
F639	11/10/2010 18:08	-1.386	0.0233
F640	11/10/2010 19:37	2.804	0.0398
F918	11/10/2010 20:44	-2.104	0.0239
F640	11/10/2010 22:09	2.774	0.0141
F640	11/19/2010 14:00	-1.736	0.0099
F641	11/19/2010 15:11	-1.808	0.0093
F640	11/19/2010 16:16	-1.762	0.0093
F640	11/10/2010 22:57	19.556	0.0115
F640	11/10/2010 23:14	-18.416	0.0090

Lamp currents as determined from the voltage of the calibrated shunt resistor. The differences are from the calibration currents. On November 8 and 9, the currents were set too high for the entire sequence of ref/test/ref. Later, sensitivity tests were performed with the photometer and the SR-3500.

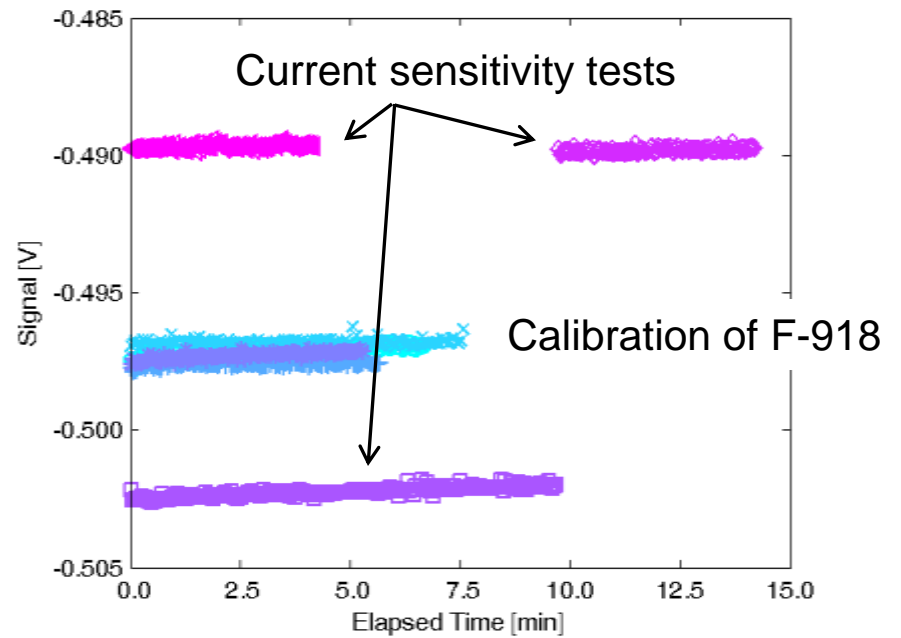
} Photometer only

Photometer Results

F640 on November 9

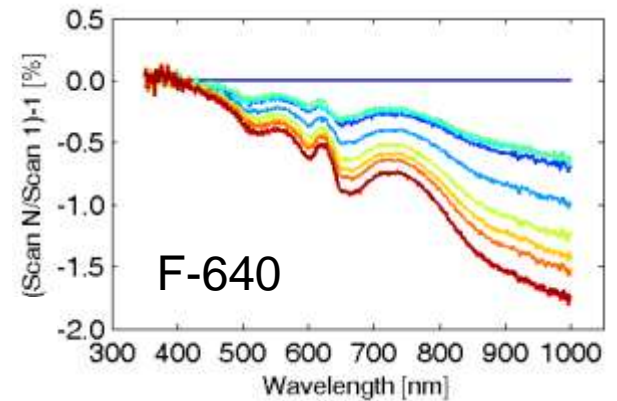
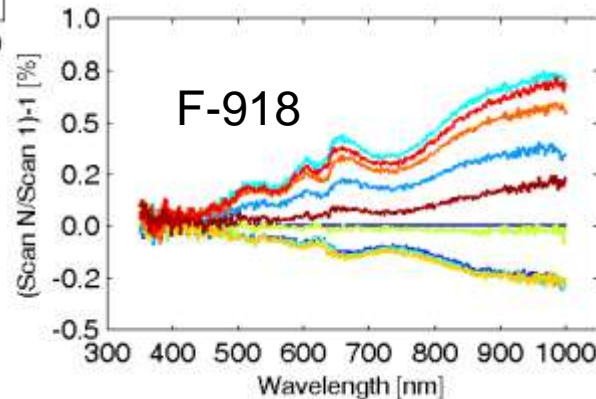
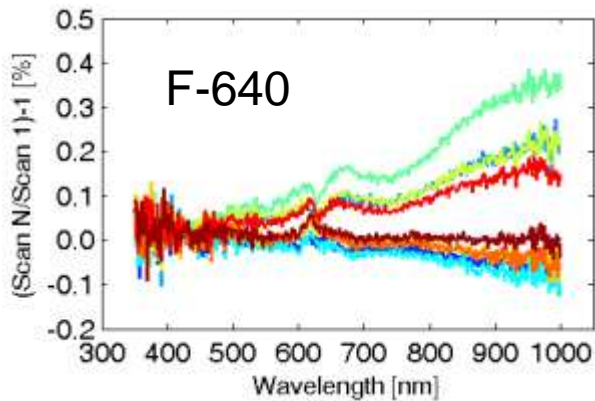


F640 on November 10



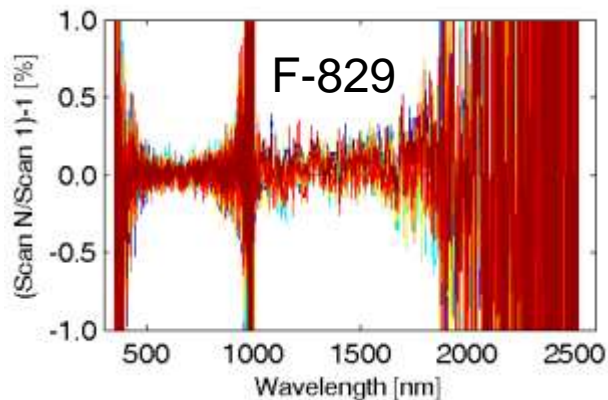
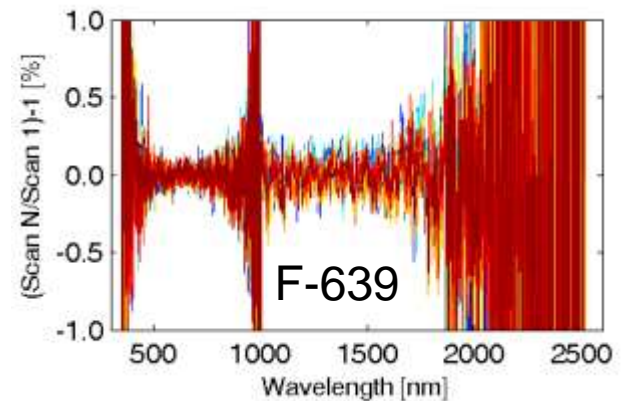
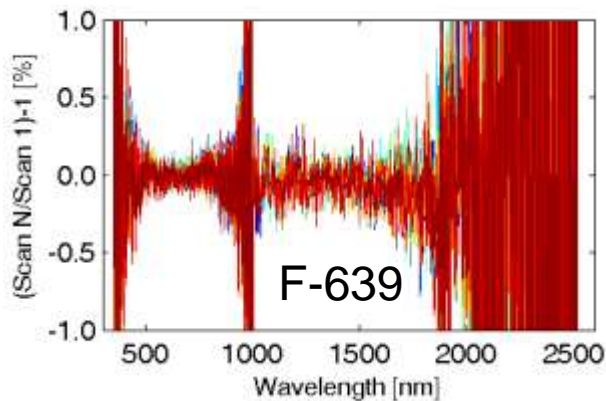
FieldSpec 3 –VNIR Issues

On November 8, the ten sequential scans, normalized to initial scan did not agree in magnitude at 1000 nm for the two reference scans, and the temporal behavior for the second reference set showed a 2% change. The lamp housekeeping and the photometer indicated stable conditions, & the SWIR1 and SWIR2 were ok. The remainder of comparison data acquired using the SR-3500. Afterwards, the FieldSpec 3 was sent to ASD for repairs.

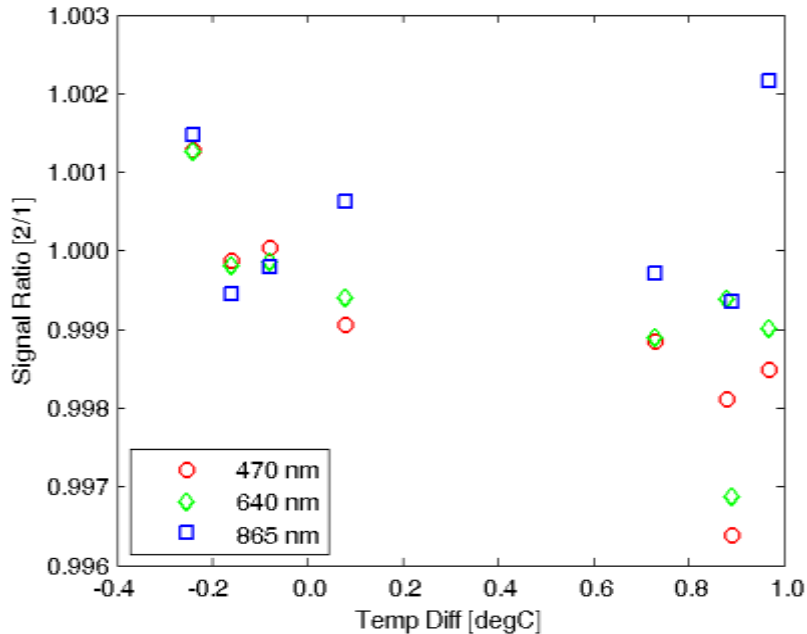


SR-3500

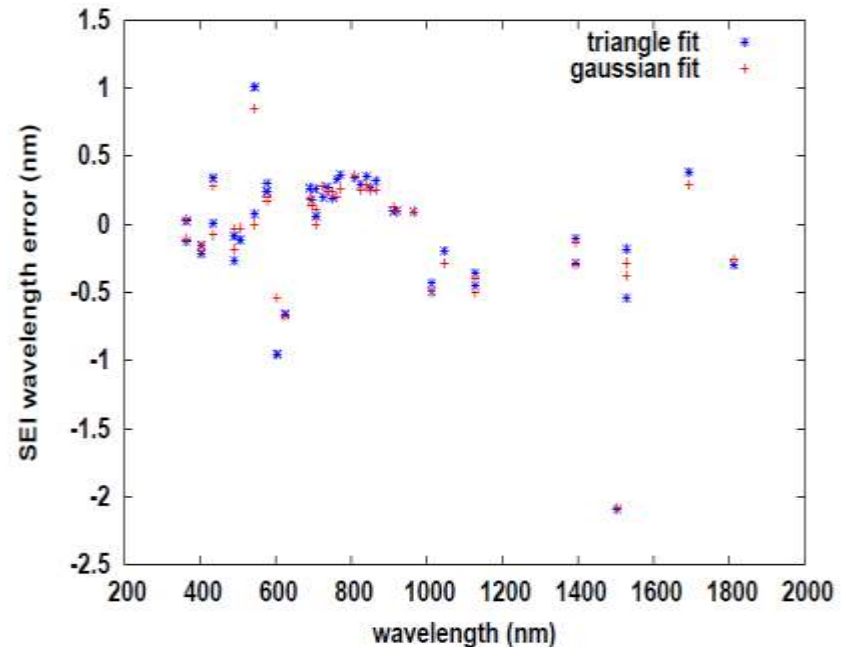
On November 9, 10, and back at NIST on November 19, the twenty sequential scans, shown normalized to initial scan, agreed well over the entire spectral range. The noise is greater at the ends of the arrays and in the SWIR2 spectrograph, but even there the uncertainty in the mean is $\sim 0.3\%$ at 2250 nm.



SR-3500 Characterization

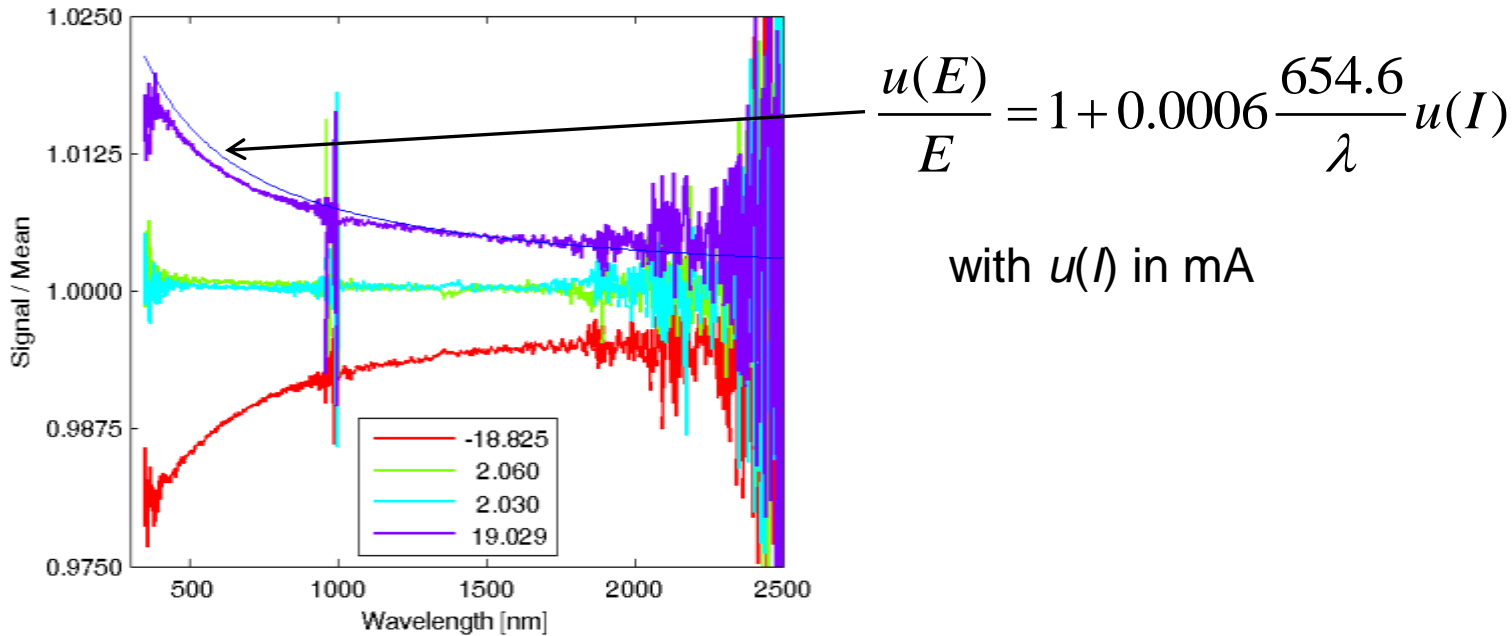


The ratios of reference lamp signals before and after the test lamp are correlated with VNIR temperature. No correction was applied but an uncertainty component was included. Fitted slope = $-0.23\%/^{\circ}\text{C}$ at 470nm.



The wavelength accuracy of the FieldSpec 3 and the SR-3500 was assessed using Hg and Ar emission lamps. The uncertainties are 0.59nm and 0.45nm, respectively.

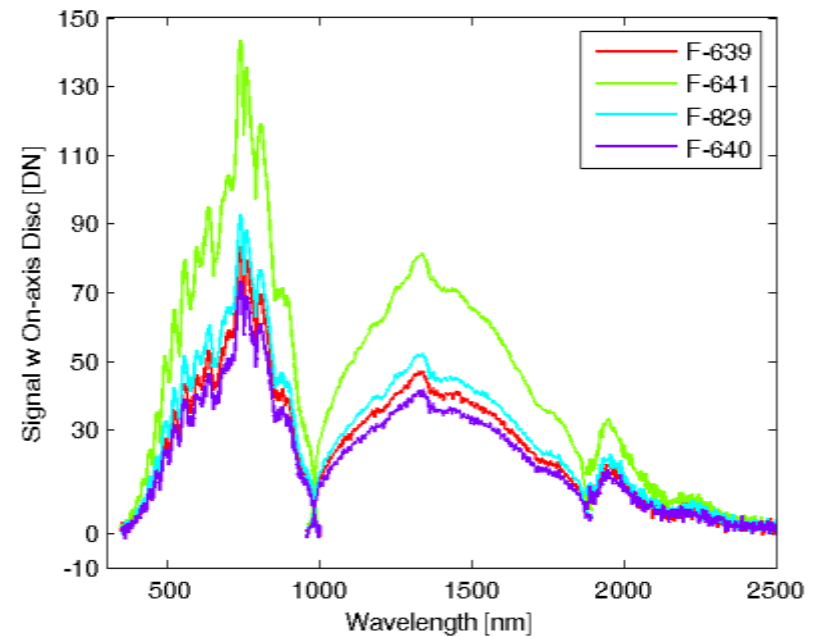
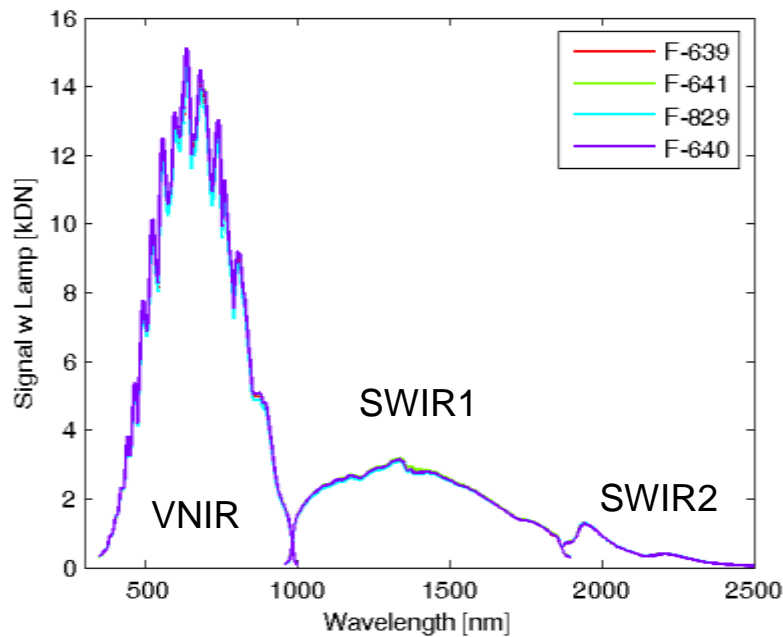
Current Sensitivity SR-3500



To assess the uncertainty in lamp current, the sensitivity coefficients were determined experimentally using the SR-3500 and lamp F-647 operated at ± 20 mA. Linear interpolation in this data set at each wavelength for a specified uncertainty in milliamps (Type B, uniform) gave the relative standard uncertainty in spectral irradiance. The thin blue line is from a published scaling law evaluated at 19mA.

Ambient Signal & Scattered Light Uncertainty

SR-3500 output in kDN (Lamp) and DN (Lamp & on-axis blocking disc)

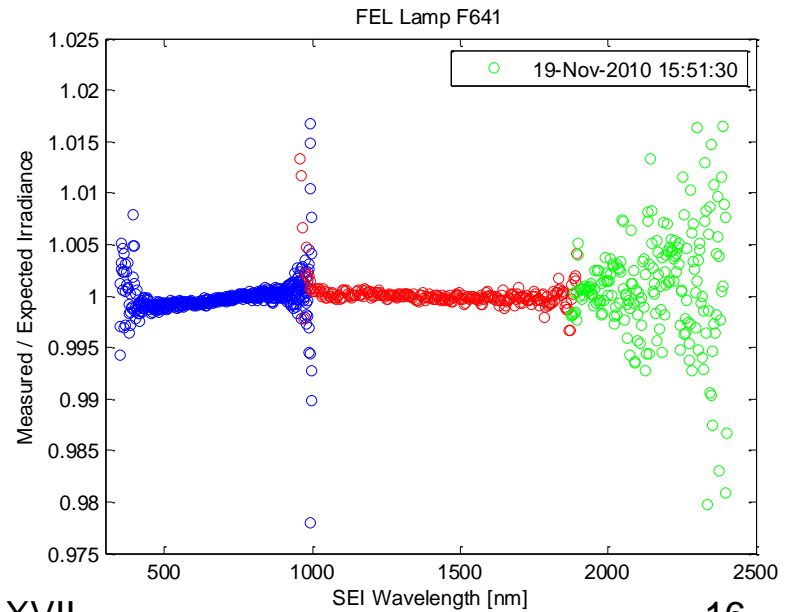
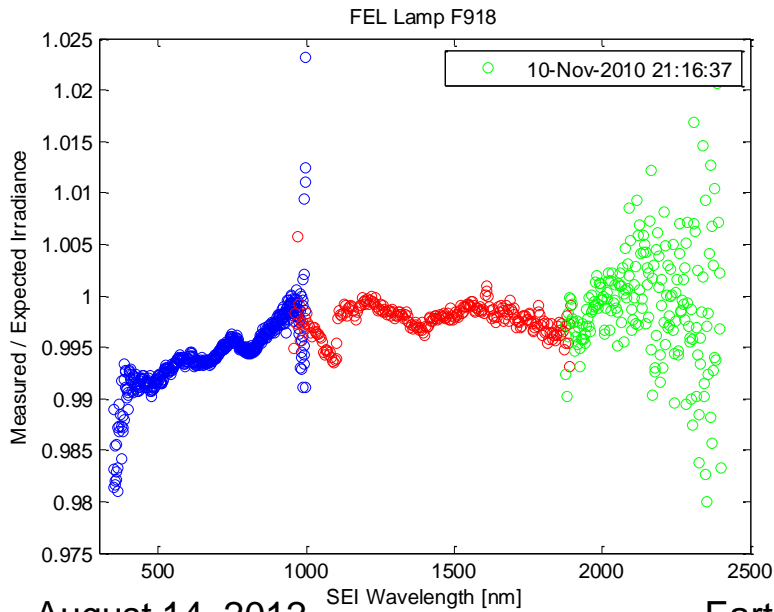
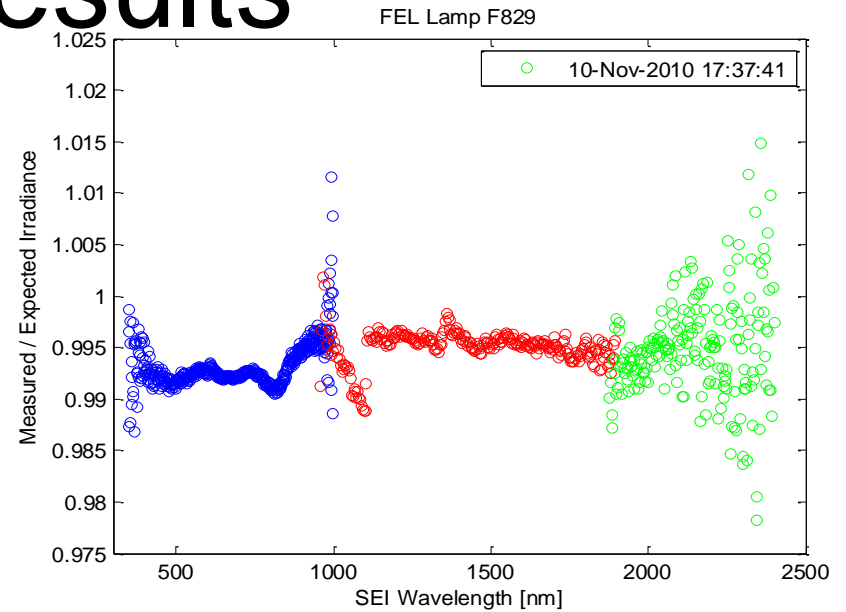
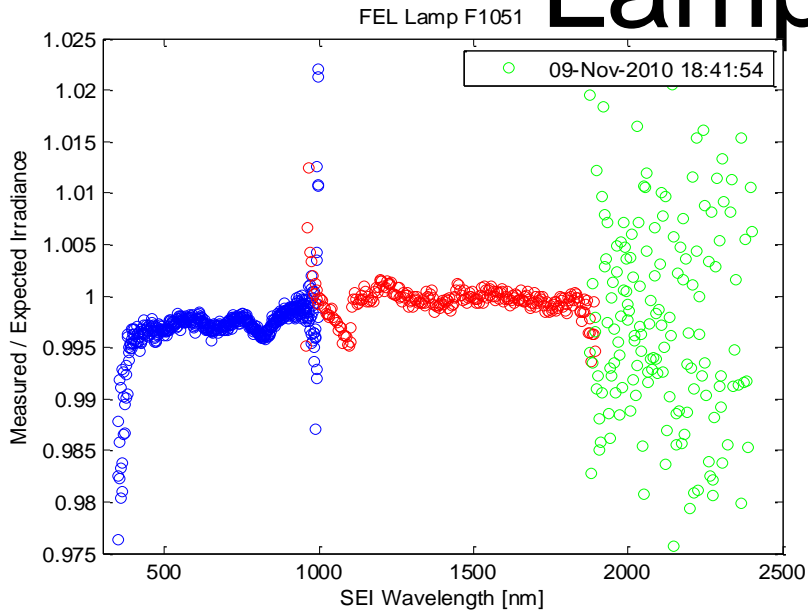


The ambient signal (right panel) was at most 2% of the total signal (left panel). It is a measure of scattered light detected by the cosine collector on the spectroradiometer; the uncertainty (Type B) was set to be 20% of the fraction measured.

Comparison Uncertainty

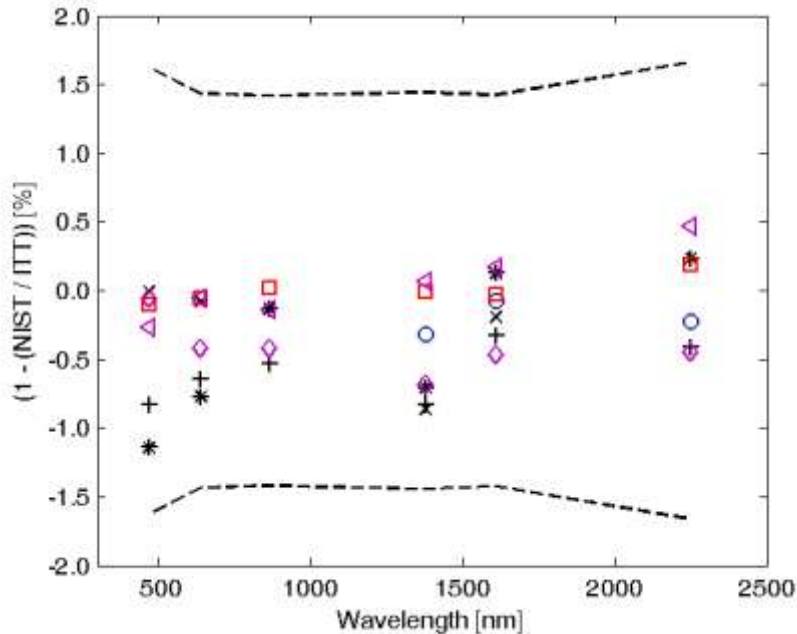
Component	Type	Value [%]					
ABI Bands	CWL [nm]	470	640	865	1378	1610	2250
	BP [nm]	40	100	39	15	60	50
Interp. in $E_R(\lambda)$	B	0.0911	0.0911	0.0911	0.0911	0.0911	0.0911
F-829, F-918, F-1051 Xfer	B	0.749	0.691	0.689	0.690	0.692	0.692
Interp. in $E_U(\lambda)$	B	0.0782	0.0782	0.0782	0.0782	0.0782	0.0782
Signal meas., ref. lamp							
FieldSpec 3, Nov 8	A				0.0219	0.0305	0.275
SR-3500, Nov 10, 19	A						0.267
SR-3500, Nov 9	A	0.110	0.0788	0.0949	0.162	0.102	1.32
Signal meas., test lamp							
FieldSpec 3, Nov 8	A				0.0255	0.0363	0.313
SR-3500, Nov 10, 19	A						0.349
SR-3500, Nov 9	A	0.0257	0.0100	0.0252	0.0209	0.0301	2.10
Wavelength, FieldSpec 3	B				0.0255	0.0363	0.313
Wavelength, SR-3500	B	0.234	0.0801	0.0063	0.0261	0.0297	0.349
VNIR Si PDA temp.	B	0.0807	0.0586	0.0311			
Lamp current	B	0.0908	0.0669	0.0505	0.0351	0.0307	0.0319
Perpendicular	B	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310
Centered	B	0.0310	0.0310	0.0310	0.0310	0.0310	0.0310
Total, FieldSpec 3, Nov 8	B				0.704	0.707	0.819
Total, SR-3500, Nov 10, 19	B	0.812	0.717	0.710	0.722	0.712	0.830
Total, SR-3500, Nov 9	B						2.58

Lamp Results

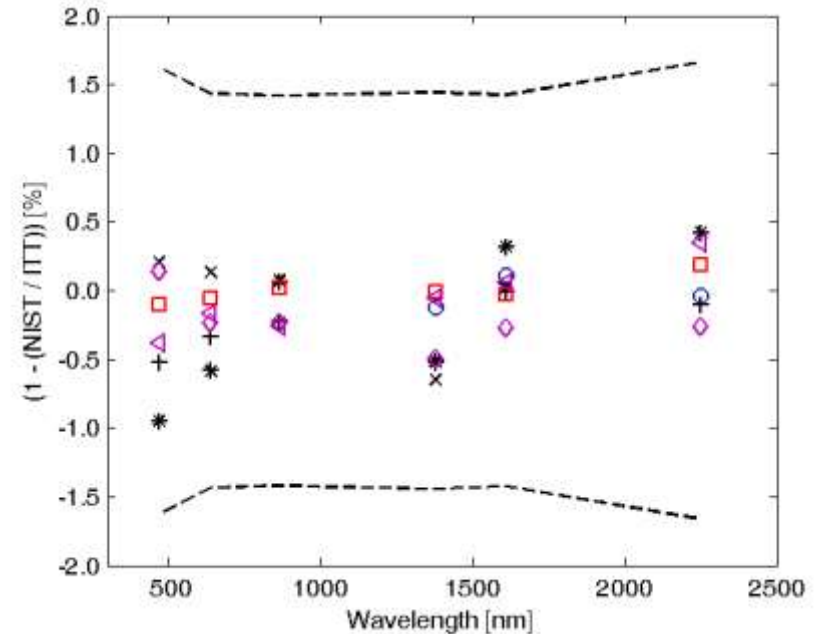


Comparison Results

With Correction



Without Correction



- $k = 2$
- F-918 FS3
- × F-1051 SR
- + F-829 SR
- * F-918 SR
- F-641 SR
- ◇ F-431 OL
- △ F-646 OL

The ITT realization of spectral irradiance includes a correction based on measurements with a NIST-calibrated photometer (Left Panel). The overall agreement appears better when this correction is not applied (Right Panel), but the difference is well within the comparison uncertainty. This uncertainty appears to be overestimated given these results.

Observations & Conclusions

- ITT procedure validated
 - Agreement within comparison uncertainty
 - Comparison uncertainty overestimated?
 - Recommend ITT to re-evaluate photometer role
- Interpolation matters
 - Evaluate multiple methods
 - Break up spectral regions and test
- Irradiance bench performance
 - Temperature stabilize all detectors
 - Include self-validation steps

Acknowledgements

- Memorandum of Understanding with NOAA
 - NA10AANEG0045 and NA10AANEG0174
- Thanks to Heather Patrick, Zhigang Li, Stephen Maxwell, Stephanie Flora

Backup Slides

Core and ancillary measurements

Date	Place	Inst.	Lamps	Goal	Notes
Nov 6, 2010	NIST	FieldSpec 3	F-639	Test	No photometer
Nov 8, 2010	ITT	FieldSpec 3	Hg, Ar	Wavelength	
Nov 8, 2010	ITT	FieldSpec 3	F-640/F-918/F-640	Calibration	
Nov 9, 2010	ITT	FieldSpec 3	Hg, Ar	Wavelength	
Nov 9, 2010	ITT	SR-3500	F-640/F-1051/F-640	Calibration	τ on SWIR2
Nov 9, 2010	ITT	OL 750	ITT RS & F-431	Validation	
Nov 10, 2010	ITT	SR-3500	F-639/F-829/F-639	Calibration	
Nov 10, 2010	ITT	SR-3500	F-640/F-918/F-640	Calibration	
Nov 10, 2010	ITT	photometer	F-640	Sensitivity	To current
Nov 11, 2010	ITT	SR-3500	Hg, Ar	Wavelength	
Nov 18, 2010	NIST	SR-3500	Hg	Wavelength	
Nov 18, 2010	NIST	SR-3500	F-647	Stability	w/ time
Nov 18, 2010	NIST	SR-3500	F-647	Stability	w/ position
Nov 18, 2010	NIST	SR-3500 & photometer	F-647	Sensitivity	To current
Nov 19, 2010	NIST	SR-3500	F-640/F-641/F-640	Calibration	
Nov 19, 2010	ITT	OL 750	ITT RS & F-646	Validation	
Mar 22, 2011	NIST	FASCAL	F-646	Calibration	