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CALCON 2019

Experiences learned in the acquisition, processing, and assessment of in-situ point spectroscopy measurements supporting airborne hyperspectral cal/val activities

Raymond Soffer, Gabriela Ifimov

Outline

- Objectives/Context
- Laboratory Reference Panel Characterization/Calibration
- Field Reference Panel Cross Calibration
- Field Spectrometry – Quality Assessment
- Next steps

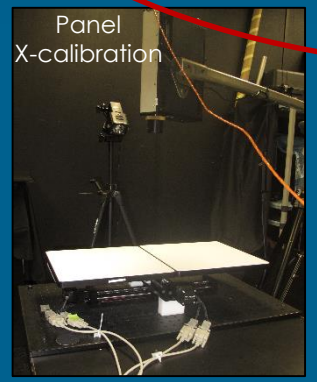
Objectives

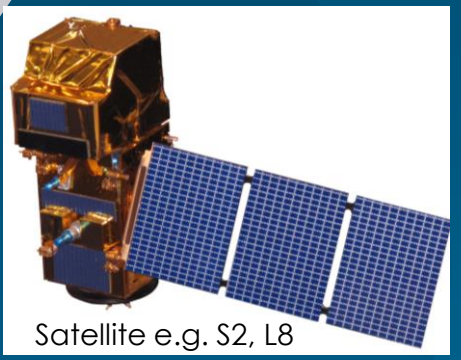
Laboratory and Field Panel Calibration

Field Spectroscopy

Airborne Hyperspectral Imagery

Satellite Multispectral Imagery





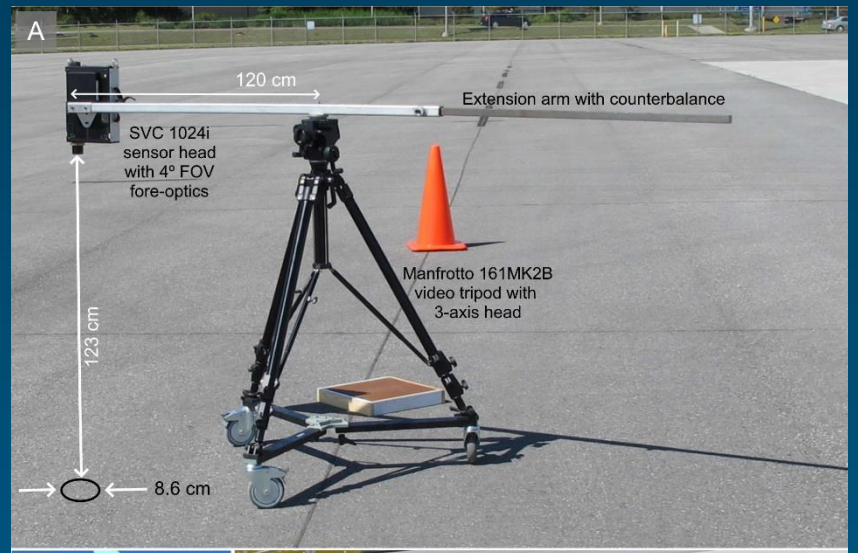
Bottom-Up validation study in support of multixspectral satellite imagery derived data product validation

Context

- NRC Flight Research Laboratory Airborne Hyperspectral Program
  - CASI/SASI operations (Twin Otter)
  - µCASI (Rotary UAV) – in development
- Various applications
  - Peatlands, Above Ground Biomass Mapping, Forensic Remote Sensing, Hydrocarbon Detection, Species Enumeration, Illegal Crop Detection
- Emphasis on Cal/Val
  - Supporting ground measurements acquired whenever possible.
- Challenges related to the implementation of a rigorous field spectroscopy methodology
- Sites are often less than ideal
  - Difficult to access,
  - Atmospherically challenging – variable cloud conditions, aerosols ….

Objectives

- **Reference panel calibration to a common reflectance reference**
  - X-Calibration of multiple field reference panels against common lab standard using available measurement equipment
  - Calibration of the lab reference panel against a NIST standard
  - Understanding the uncertainties inherent in the derived methodology
- **QA assessment of field spectrometry data sets**
  - Downwelling irradiance stability
  - Illumination angle correction
  - Impact of variable atmospheric conditions

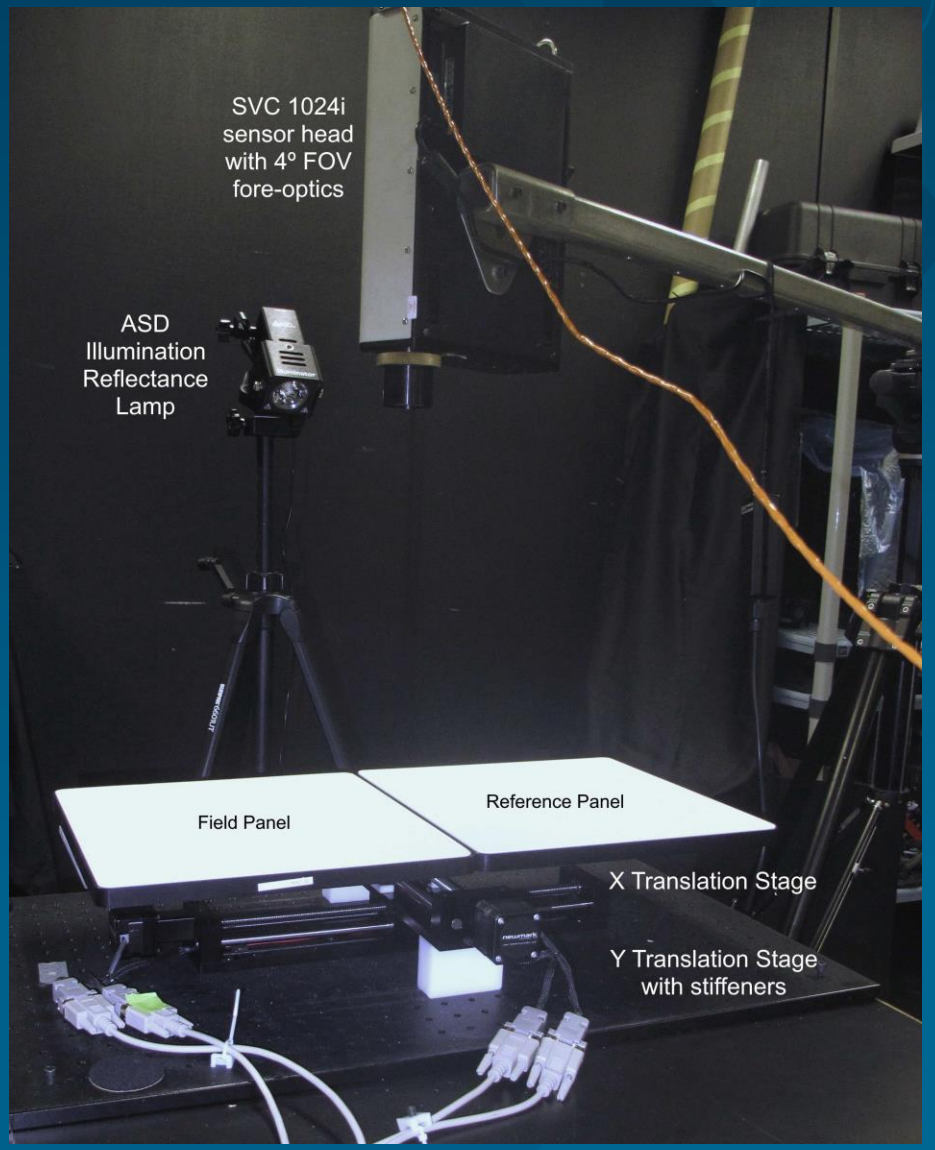


Field Configuration

- SVC HR1024i
- Video Tripod with 3-axis head
- Solar diffusor
- Digital Hemispherical Camera
- SPN1 Solar Pyranometer

Panel X-Calibration Lab Configuration

- SVC HR1024
- XY Translation Table



Field Spectroscopy Approach

Panel Substitution Methodology (PSM)

$$HCRF_{tar}(\theta_{vref}:\theta_{itar},\lambda) = \frac{S_{tar}(\theta_v:\theta_{itar},\lambda)}{S_{ref}(\theta_v:\theta_{iref},\lambda)} \times BCRF_{ref}(\theta_{vref}:\theta_{iref},\lambda) \times IACF(\theta_{iref},\theta_{itar})$$

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tar - Measurement of the target surface
ref - Reference surface (reference panel)
θ_v - View angle
θ_i - Illumination angle
IACF - Incidence Angle Correction Factor

$$IACF = COS(\theta_{itar}) / COS(\theta_{iref})$$

BCRF - Biconical reflectance factor of the reference panel

$$BCRF_{ref}(0°:\theta_{iref}) = BCRF_{ref}(0°:45°) \times nBCRF(\theta_{iref})$$

$nBCRF(\theta_{iref})$ - normalized BCRF of 99% Spectralon™ for nadir view & a given illumination angle normalized to R_{ref}(0°:45°)

Field Spectrometry QA: Issues to be addressed

- Spectral reflectance of the reference
- Radiometric System Linearity
- Instrument Stability
- Stability of Illumination conditions between reference and target scans
- Field-of-View Issues
  - homogeneity cal/val target

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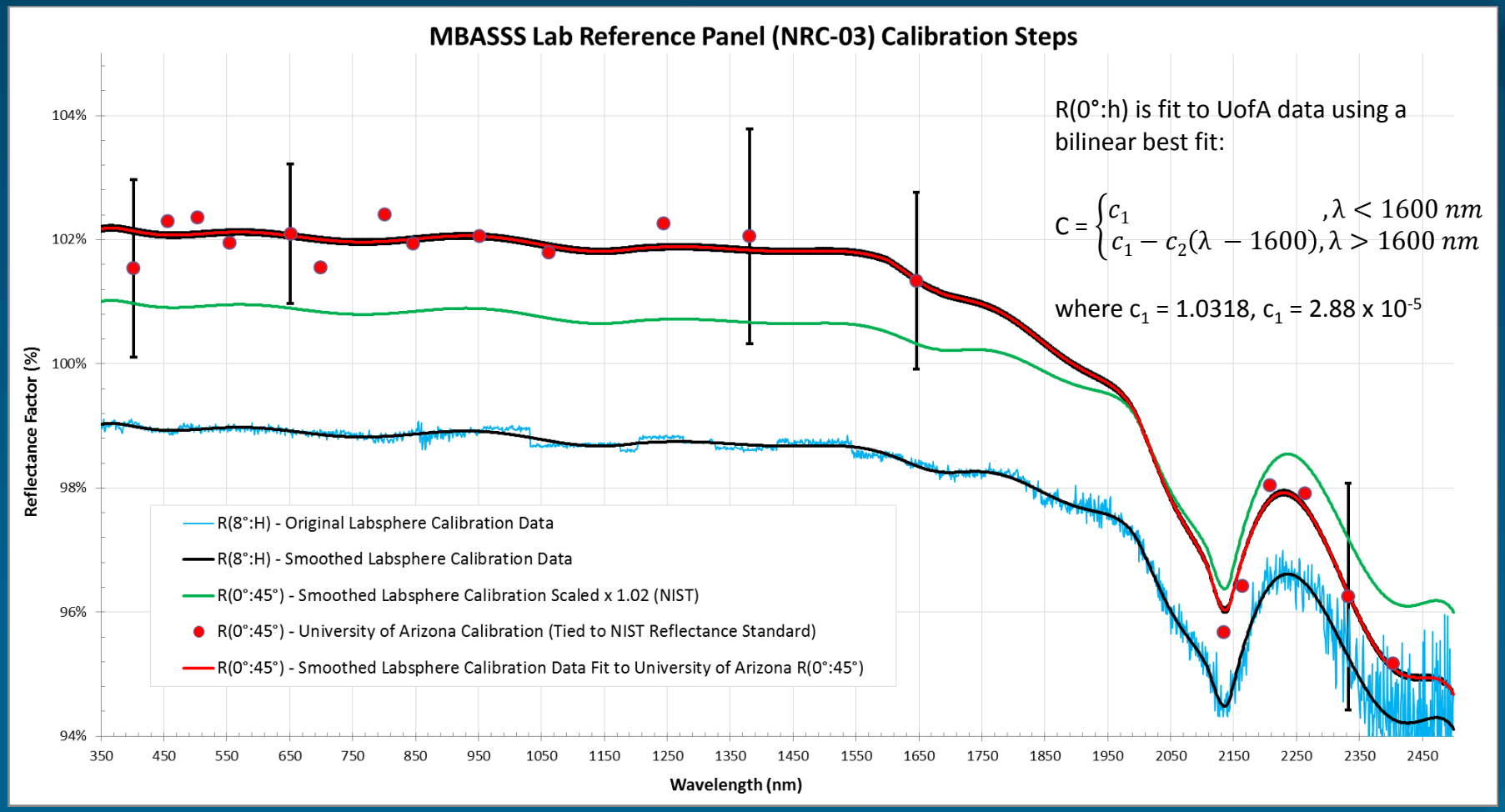
Lab Reference Panel Calibration – R(0°:45°)

Panel calibration performed at University of Arizona Calibration facility – tied to NIST reflectance standard



Cooksey, C.C., Allen, D.W., Tsai, B.K., & Yoon, H.W. (2015). Establishment and application of the 0/45 reflectance factor scale over the shortwave infrared. Applied Optics, 54, 3064-3071.

Georgiev, G.T., Butler, J.J., Cooksey, C., Ding, L., & Thome, K.J. (2011). SWIR calibration of Spectralon reflectance factor. In R. Meynart, S.P. Neeck, & H. Shimoda (Eds.), Proc. SPIE 8176, Sensors, Systems, and Next-Generation Satellites XV (p. 81760W). Prague, Czech Republic.

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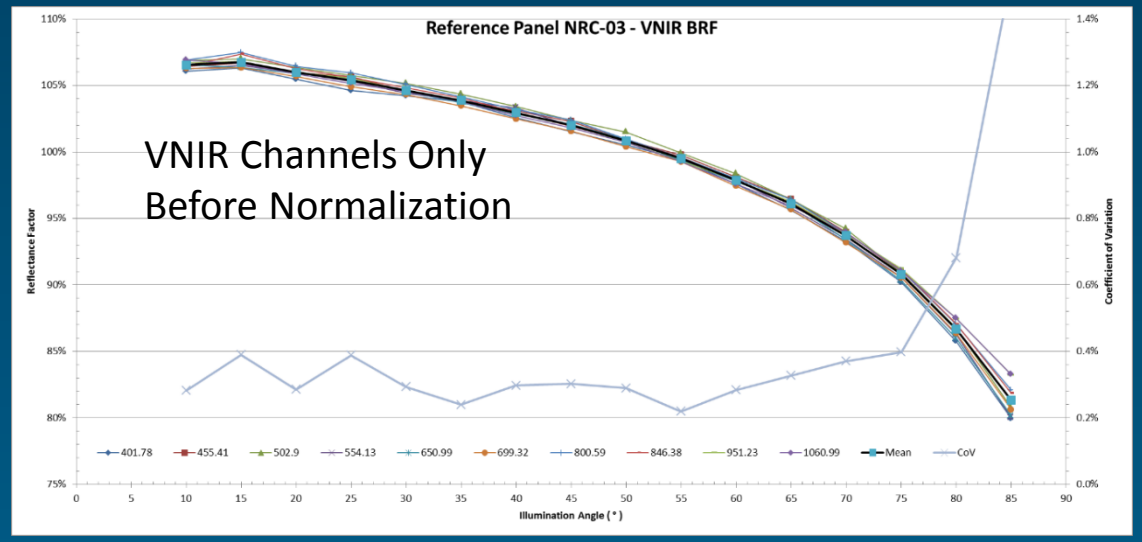
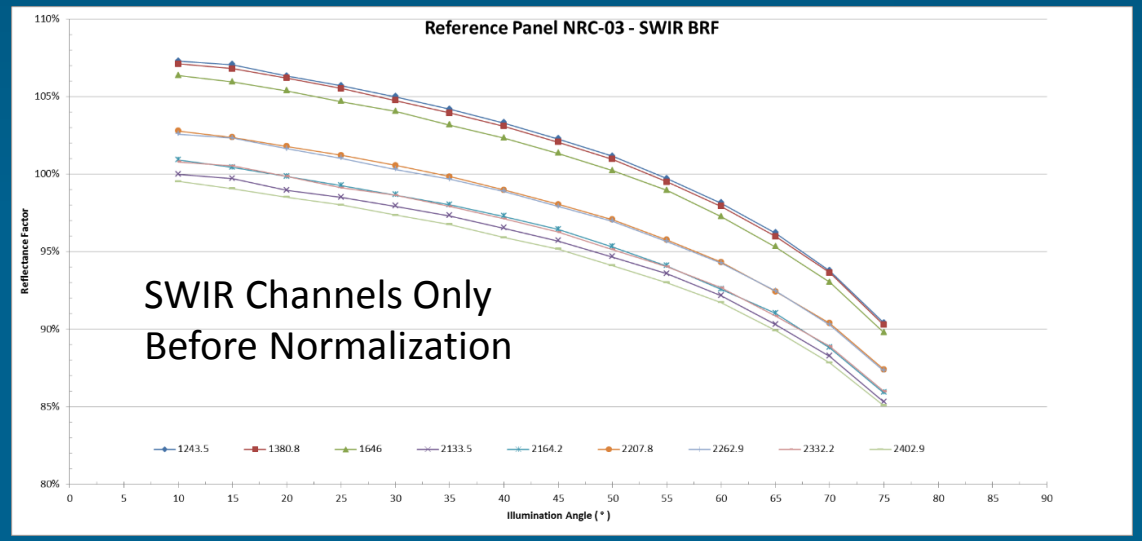
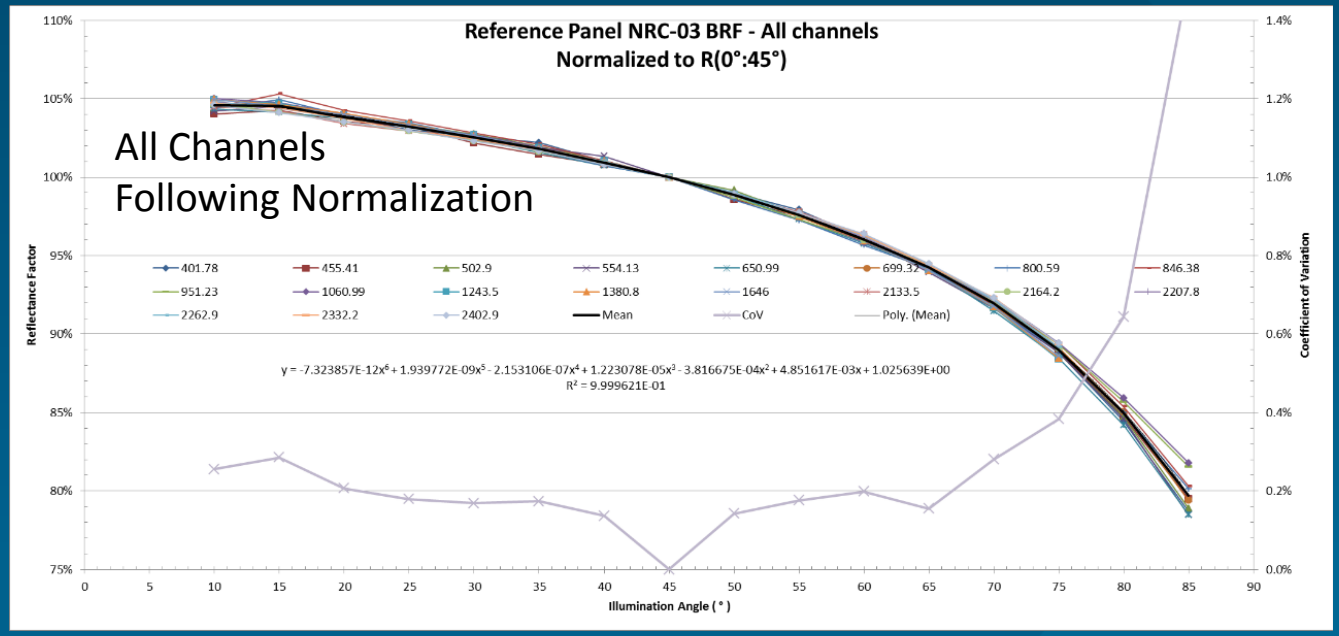
Lab Reference Panel Calibration – nBCRF

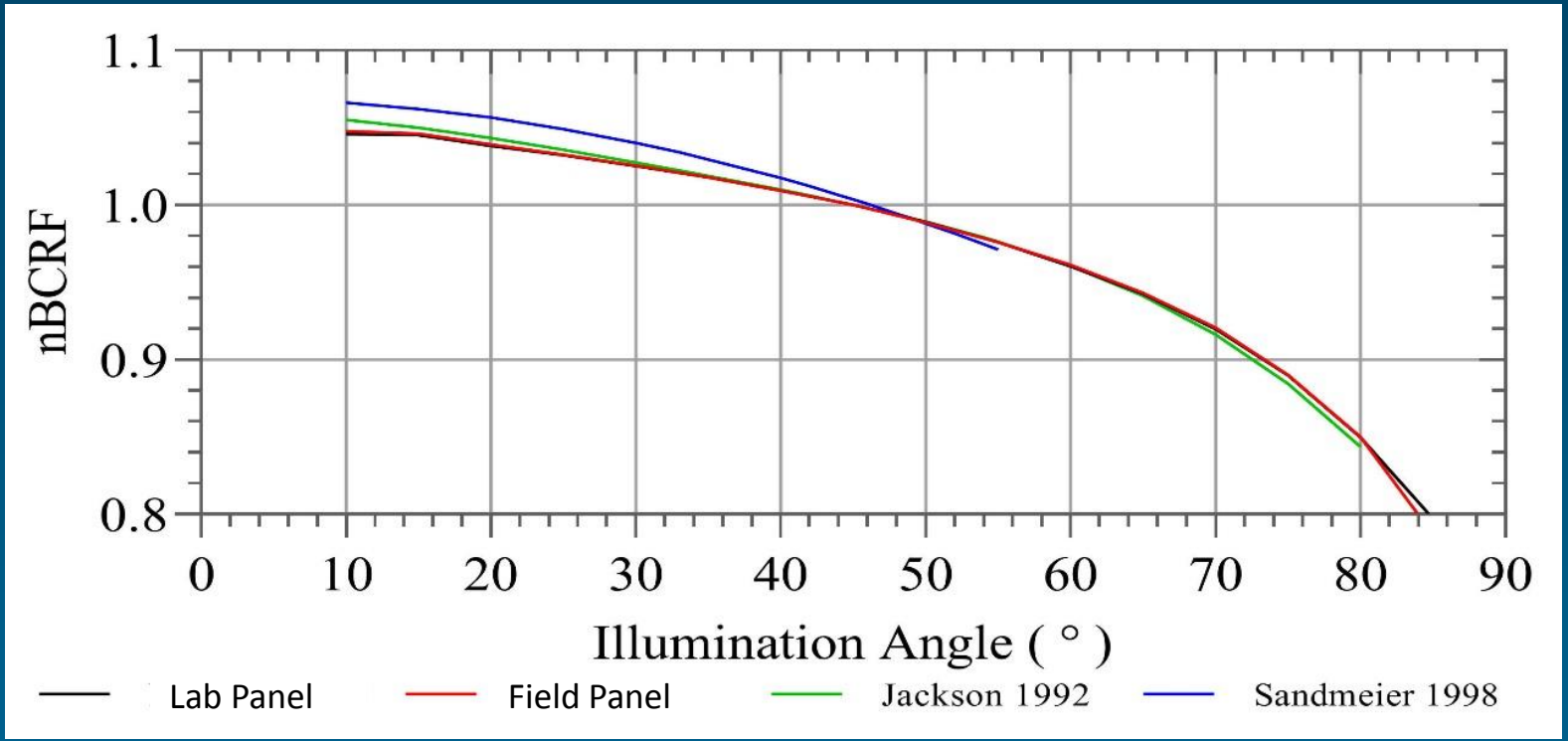






Validation that our results perform as described by Jackson et. al. (1992)

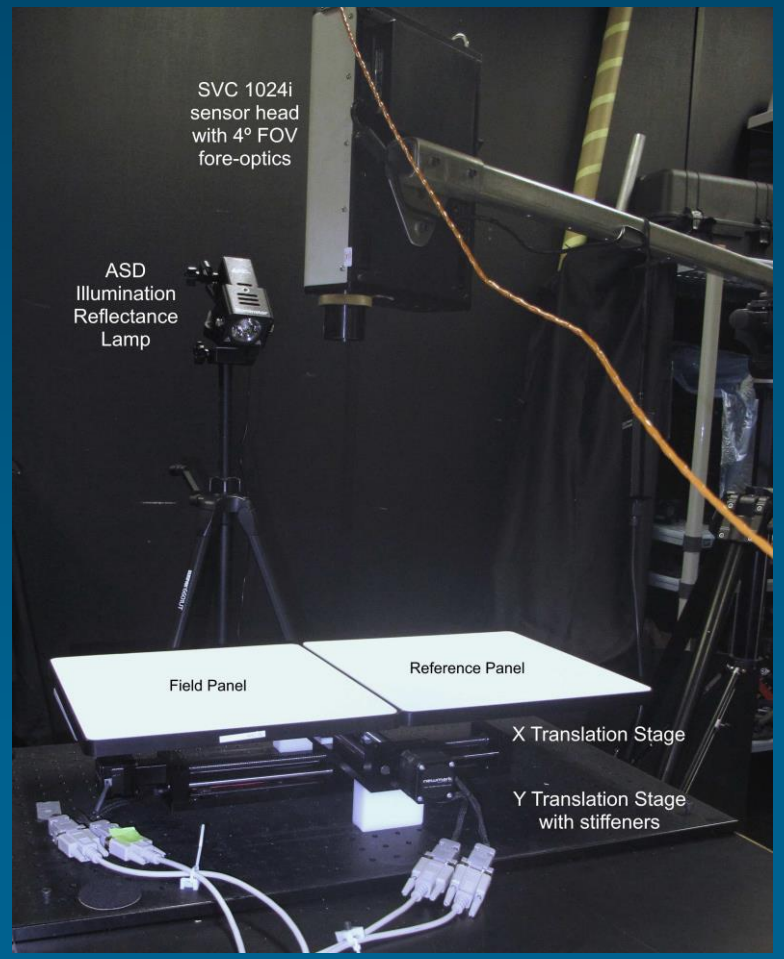
Reference Panel nBCRF Calibration



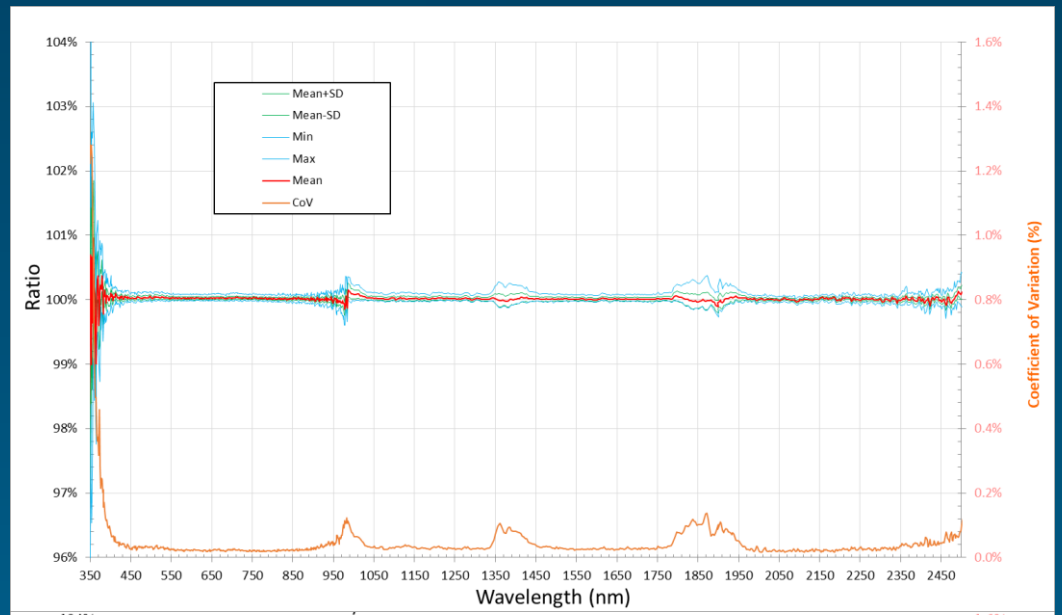
- Wavelength independent nBCRF Function
- Easily defined as a polynomial
- Consistent findings for two panels
  - Lab panel
  - Lightly use field panel
- Results confirmed with respect to other similar published results

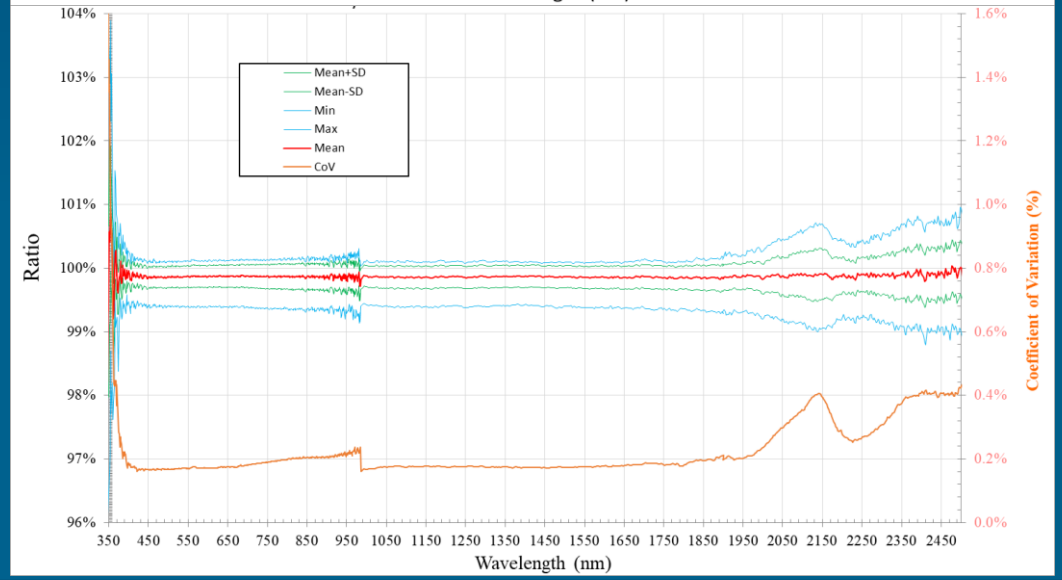
- Jackson, R.D., Clarke, T.R., & Susan Moran, M. (1992). Bidirectional calibration results for 11 spectralon and 16 BaSO4 reference reflectance panels. *Remote Sensing of Environment, 40*, 231-239
- Sandmeier, S.R. (2000). Acquisition of Bidirectional Reflectance Factor Data with Field Goniometers. Remote Sensing of Environment, 73, 257-269

Panel X-Calibration Methodolgy



Illumination Angle = 45°
Panel surfaces vertically aligned

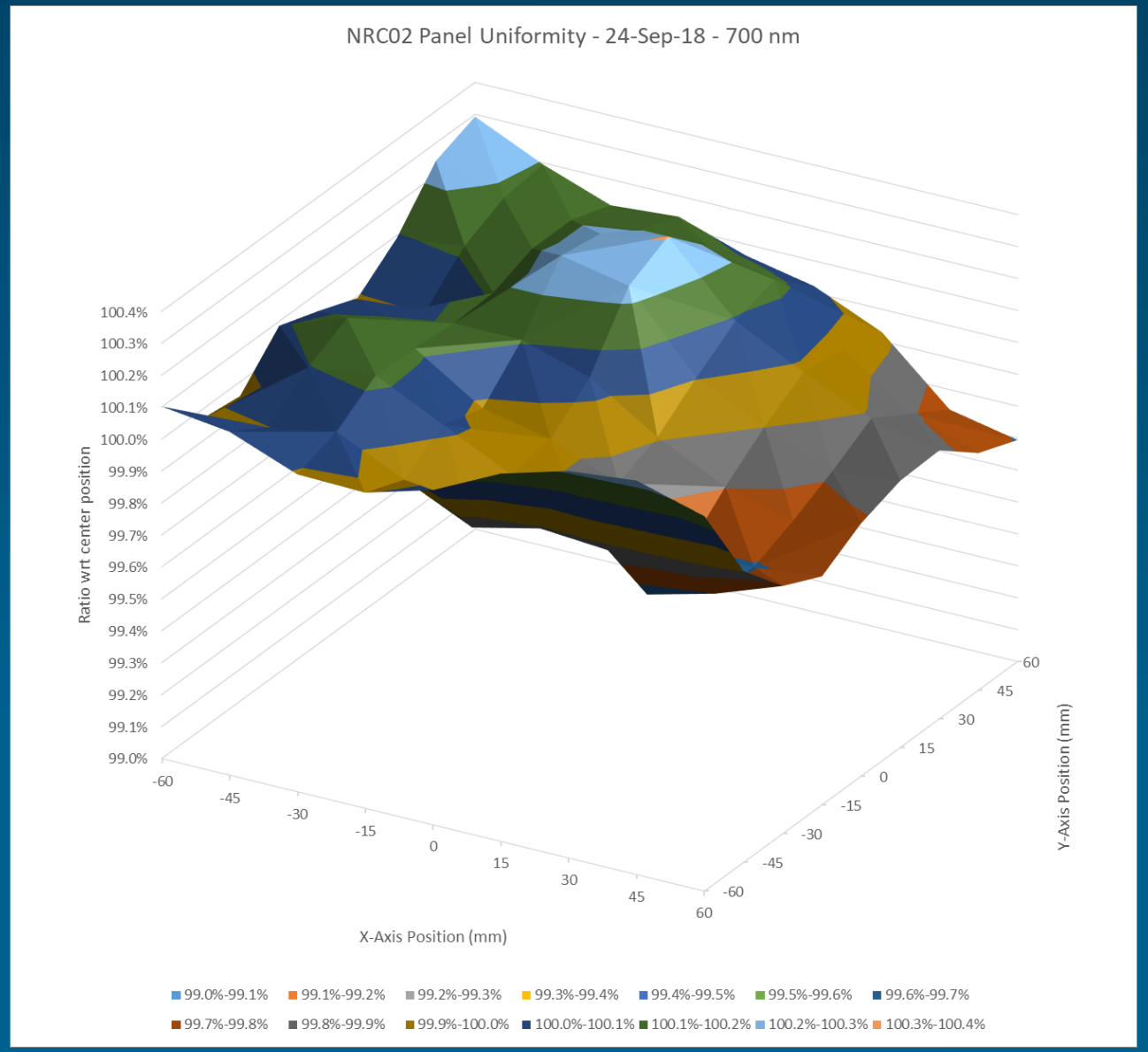




Step 1
System Stability Check
81 measurements
Static configuration
- Source Stability
- System stability

Step 2
Panel Uniformity Check
9 x 9 grid
2.5 cm FOV, 2.5 cm step
- Source Stability
- System Stability

Panel X-Calibration Methodolgy



- How much uncertainty does imprecise positioning of the field spectrometer fov on the field reference panel contribute to the overall uncertainty?
- How does this uncertainty change with use?

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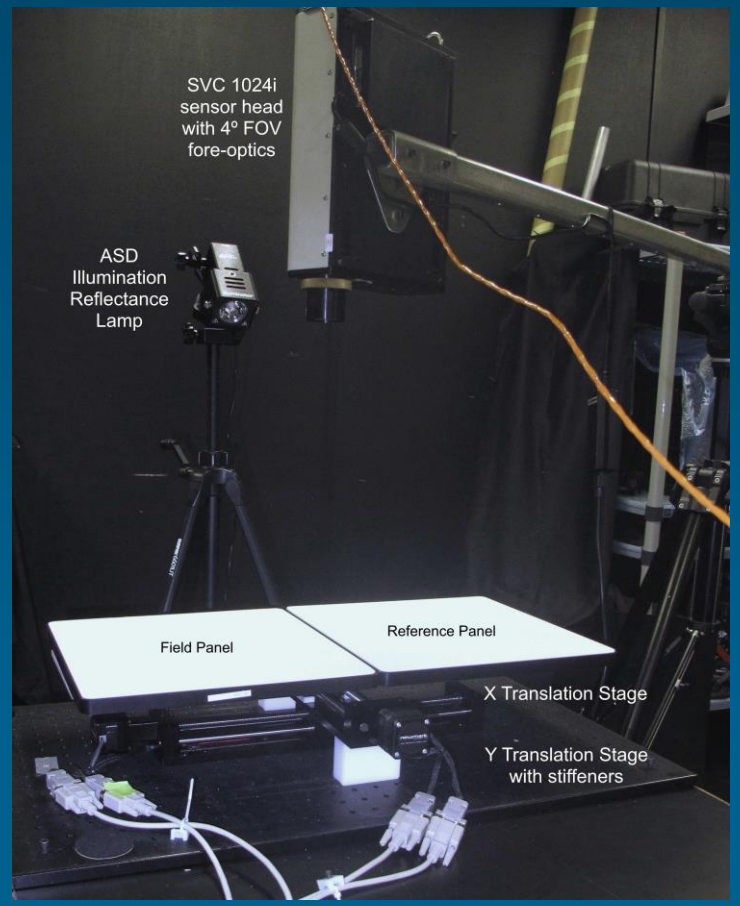
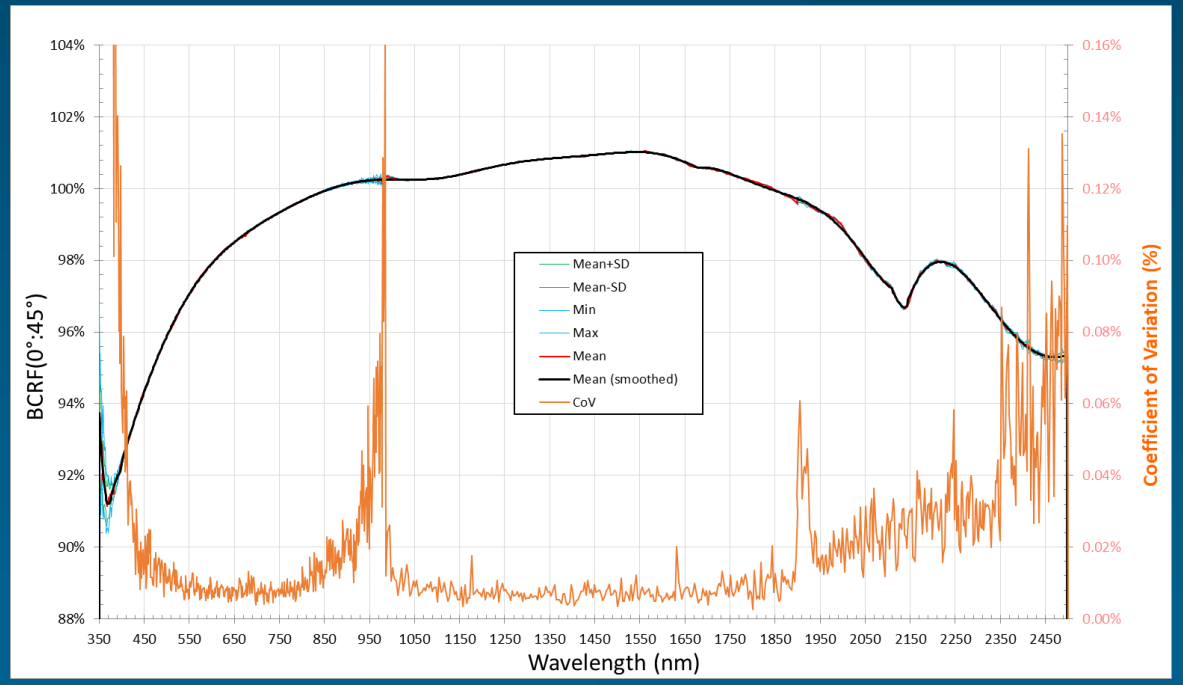
Panel X-Calibration Methodolgy

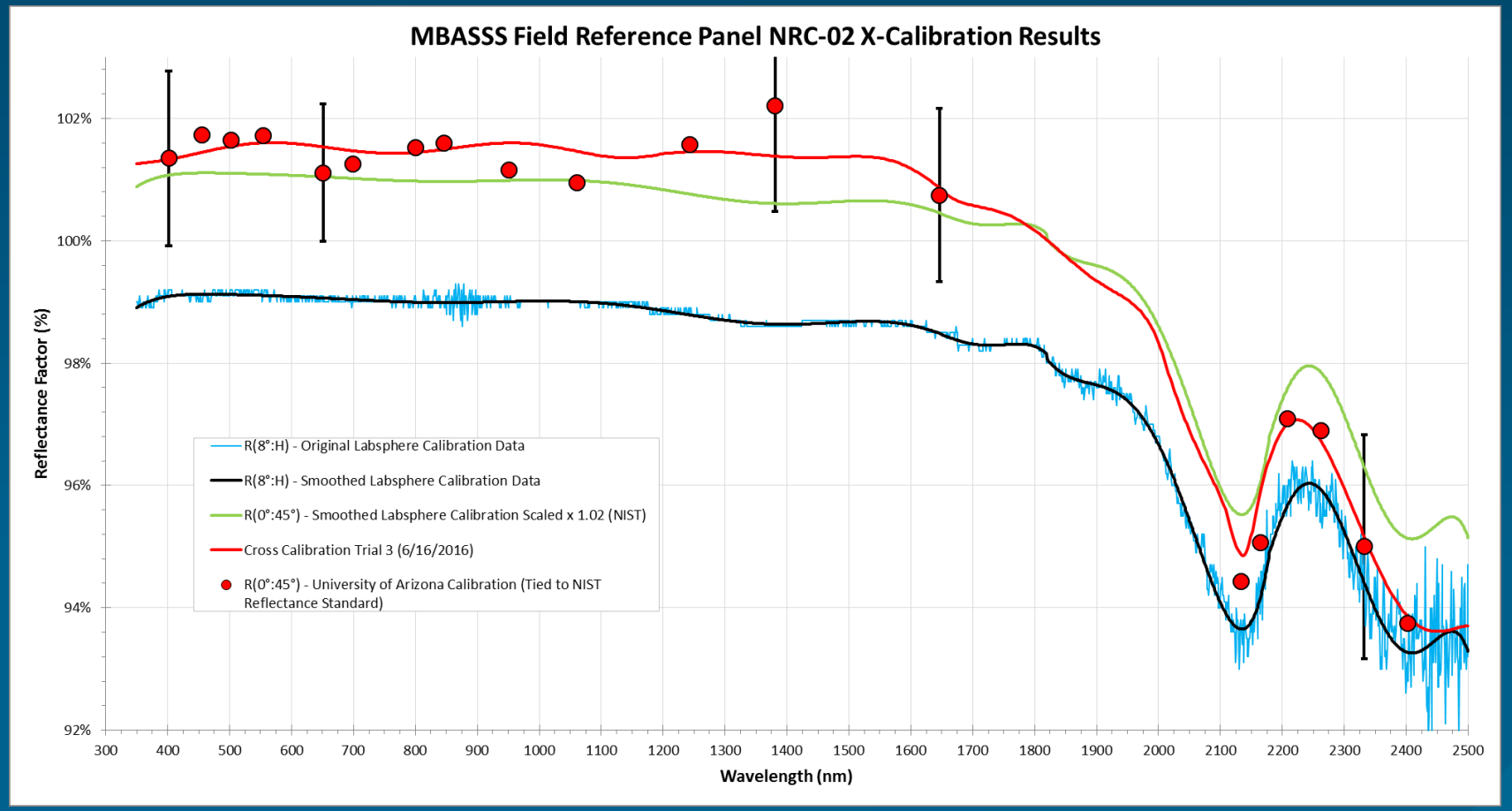




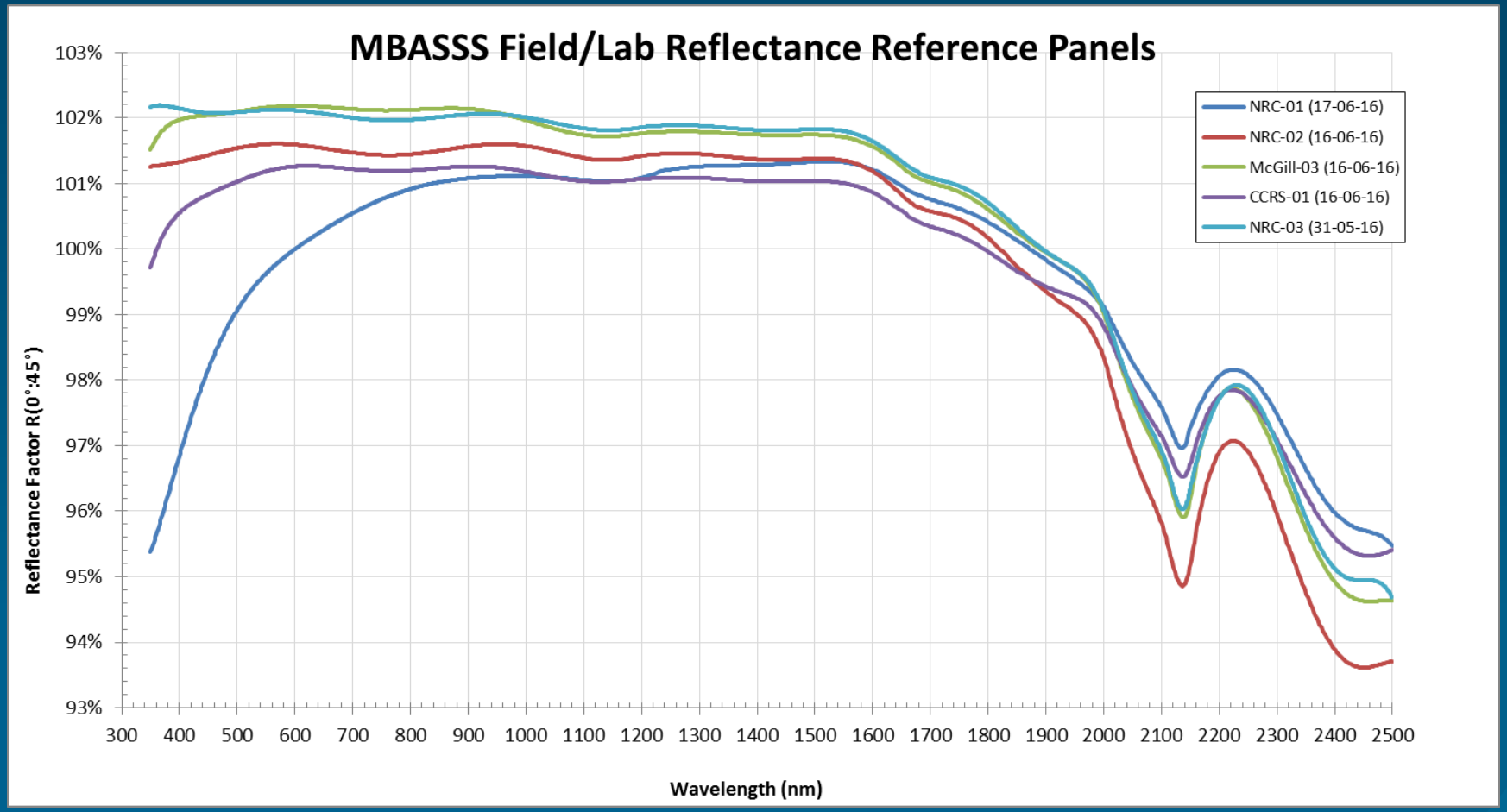
Step 3
X-Calibration
9 measurements

Repeat scan of reference panel for each measurement

Validation of NRC Panel X-Calibration Methodolgy



Reference Panels X-Calibration Results



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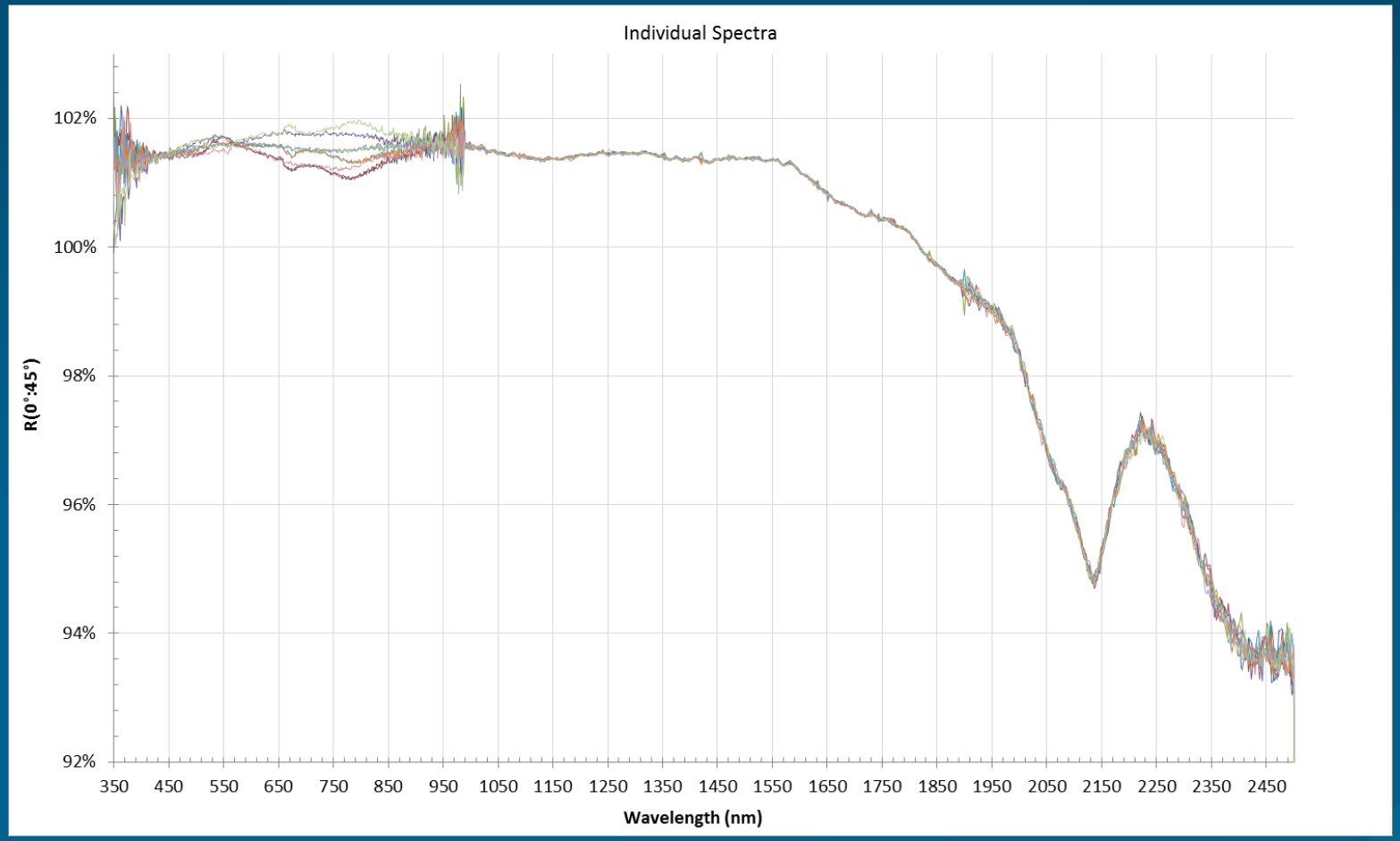
Non-linearity identified in SVC HR1024i Results

- Observed when integration time changed between reference and target scan
- Auto integration feature generated different settings for almost identical surfaces for unknown reason



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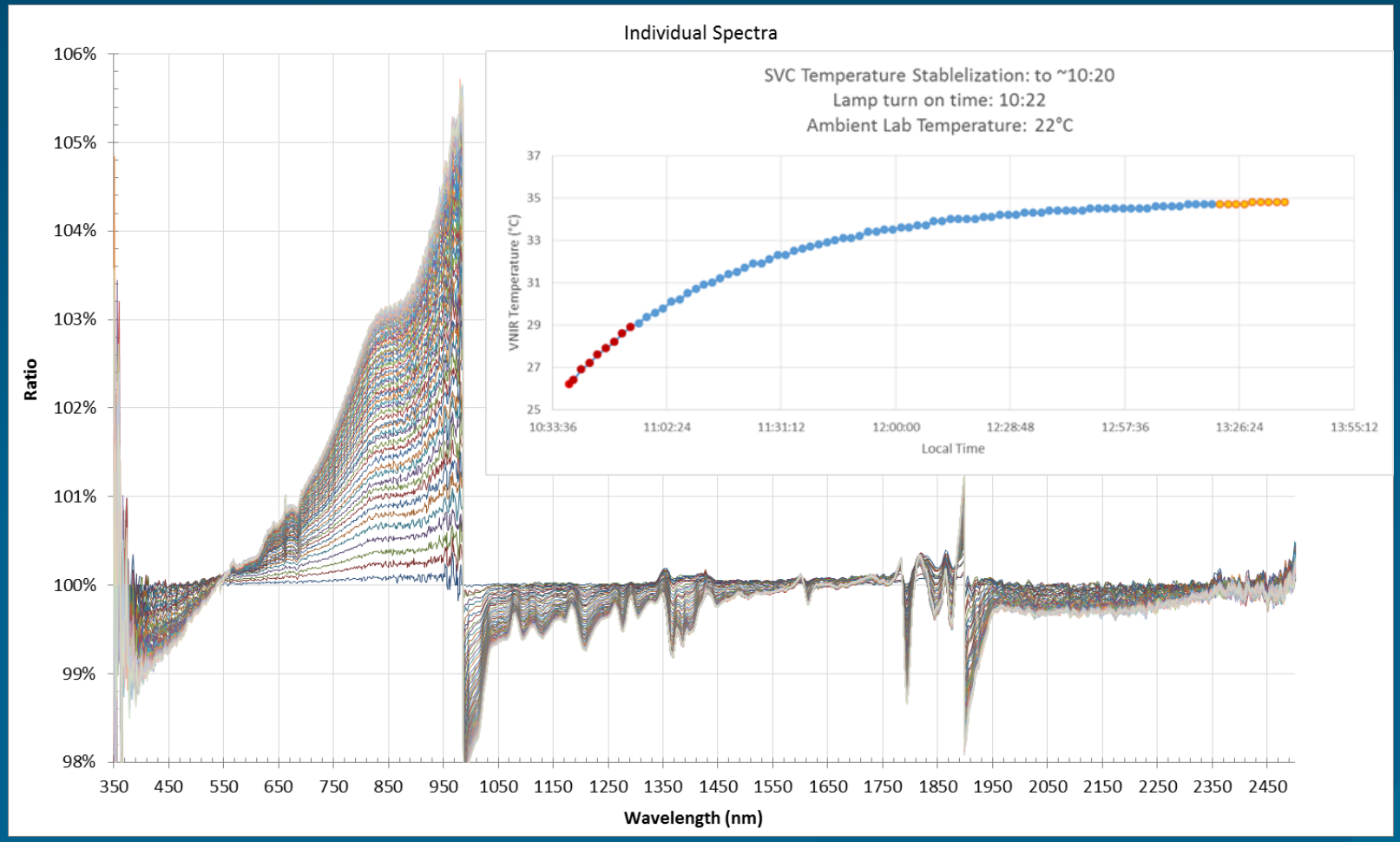
System stability issues related to VNIR detector temperature

- VNIR reported temperatures still stabelizing after 3 hours
- Despite stable reported SWIR detector temperatures, SWIR results also required time to stabilize.



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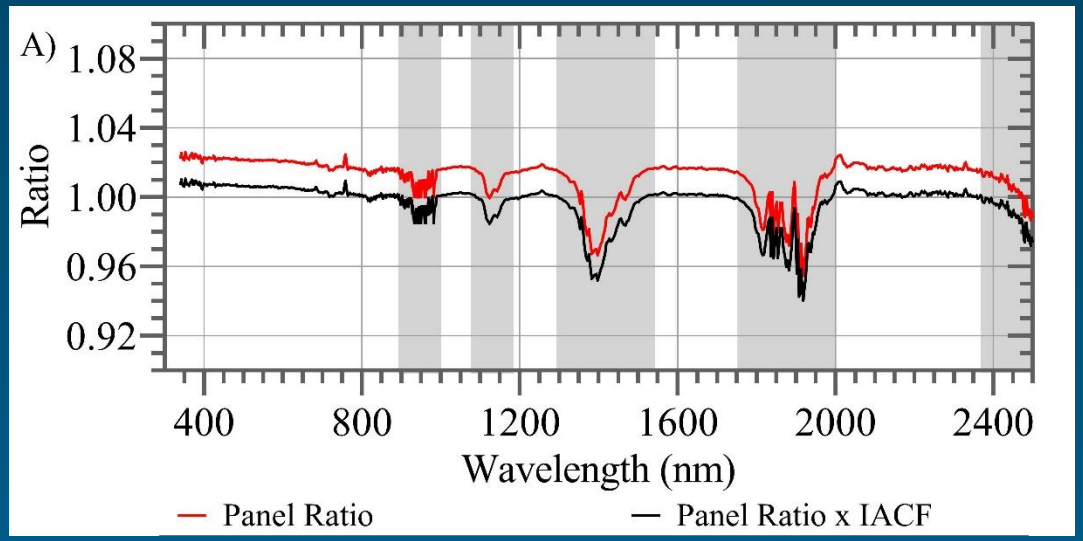
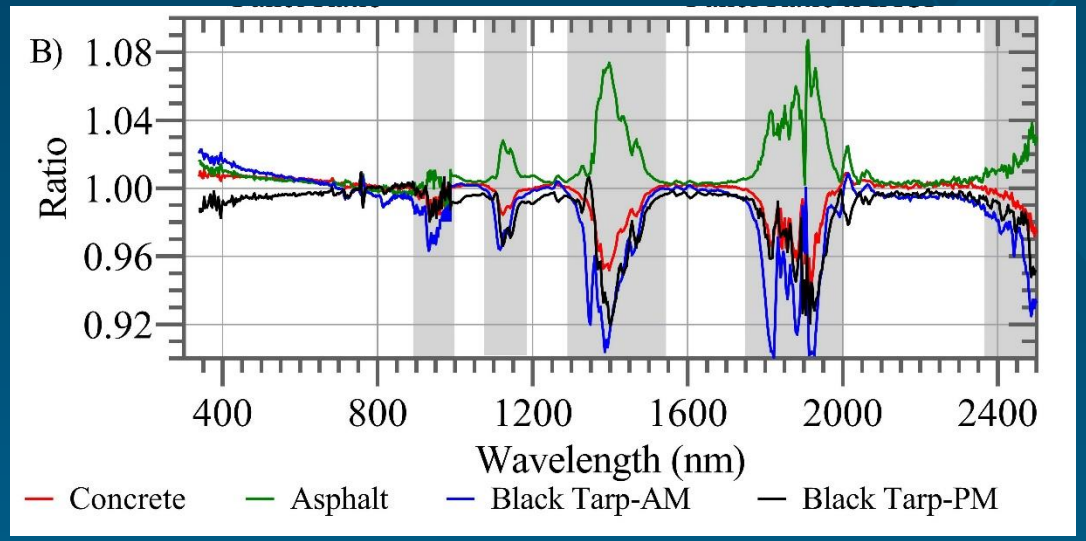
Measurement Sequence for Field

- Panel reference scan
- Shadowed panel target scan
- Illuminated panel target scan with shadow adjacent to panel
- Multiple (n) target surface scan Shadowed panel target scan
- Shadowed panel target scan
- Illuminated panel target scan with shadow adjacent to panel
- End of Sequence (EOS) Panel target scan

End of Sequence (EOS) Stability Check



EOS illumination level compared to start of sequence



IACF corrected ratio for asphalt, concrete, and black tarp data sets

SZA at Beginning of sequence (BOS) → 33.2°
SZA at End of Sequence (EOS) → 32.0°

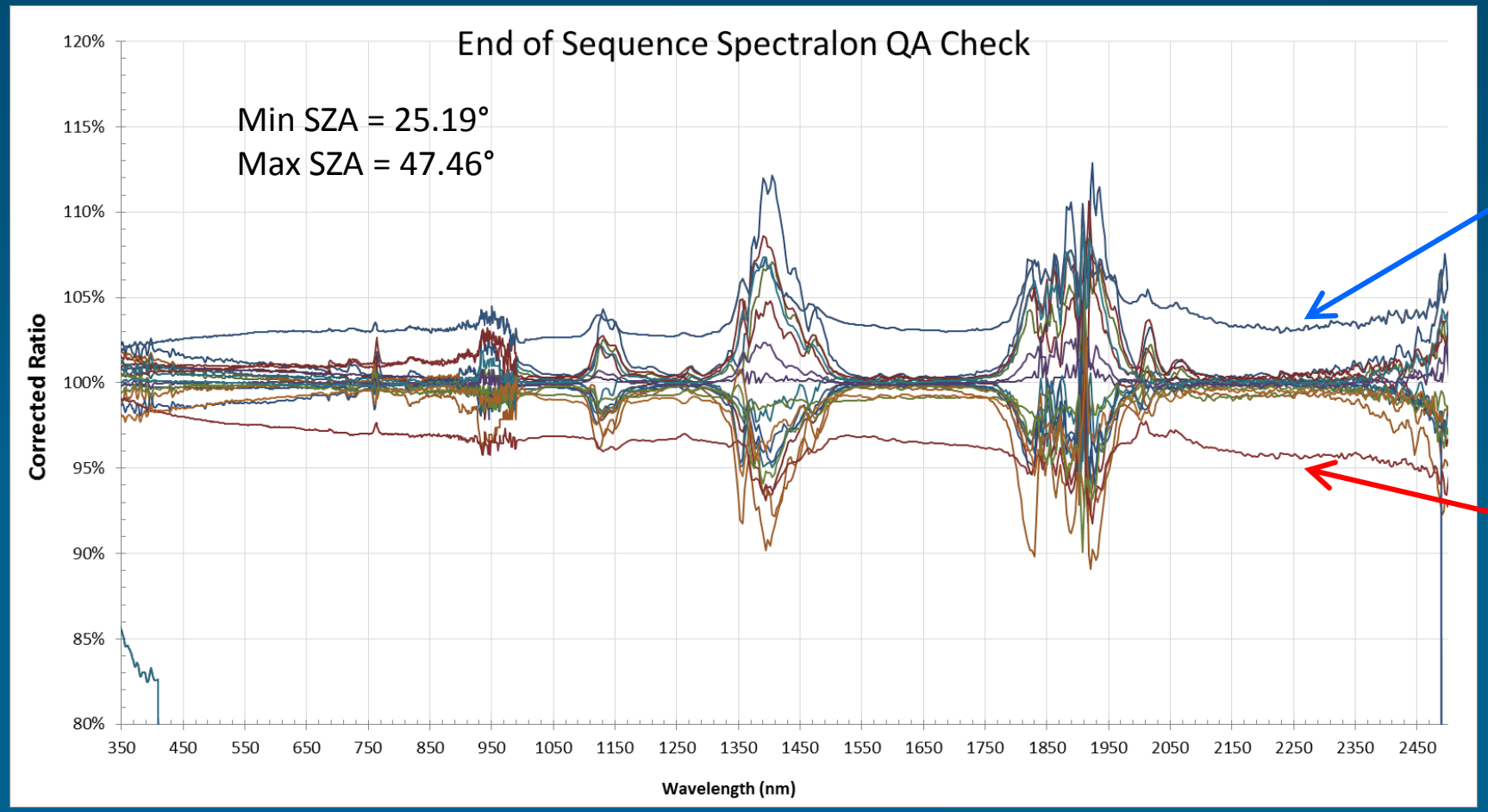
IACF = Cos(33.2°)/Cos (32.0°) = 0.9851

Changes in the Spectralon nBCRF also to be accommodated

nBCRF(33.2°)/nBCRF(32.0°) = 0.9980

EOS Irradiance Stability Check

- 18 Measurement sequences



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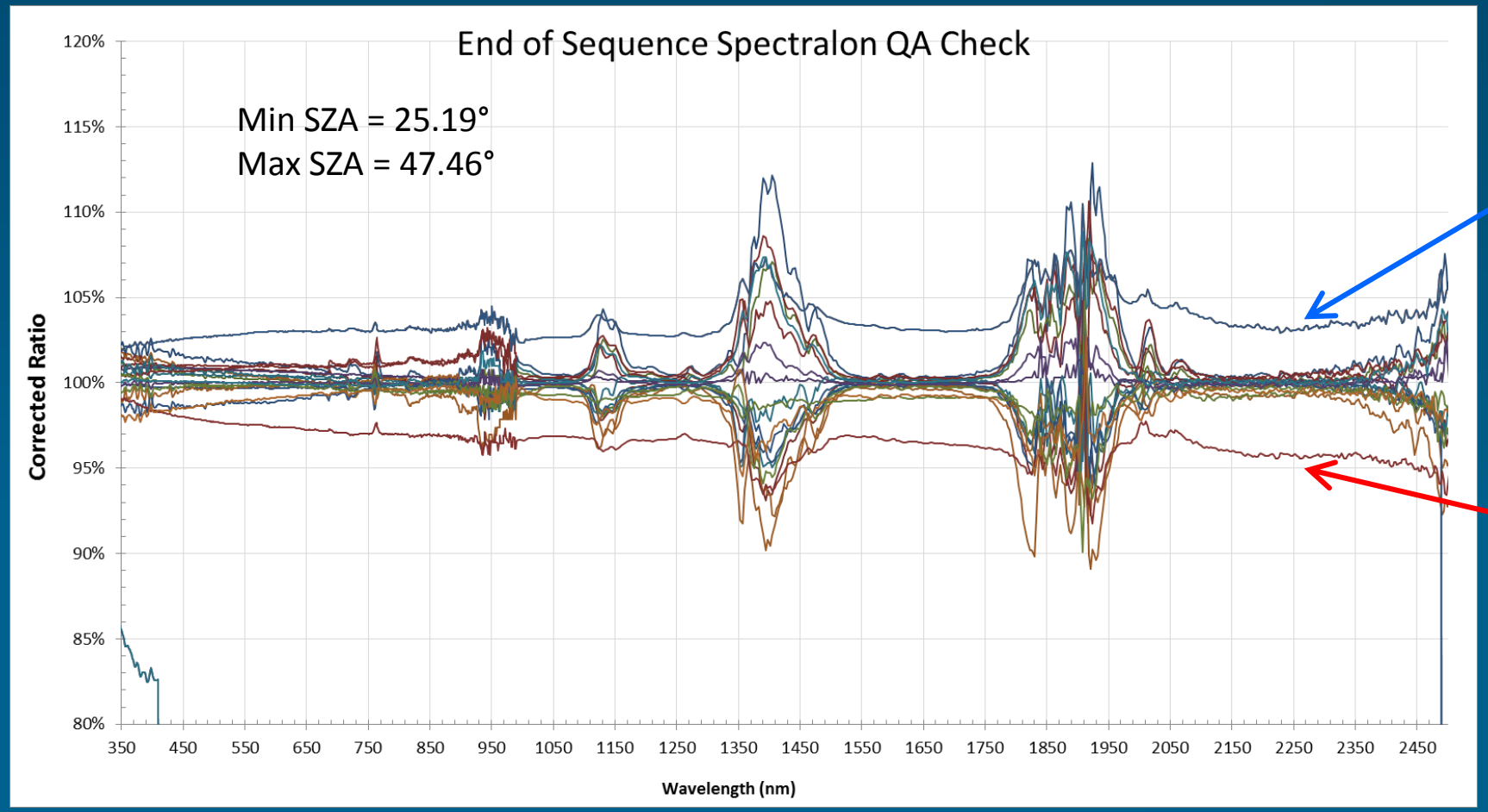
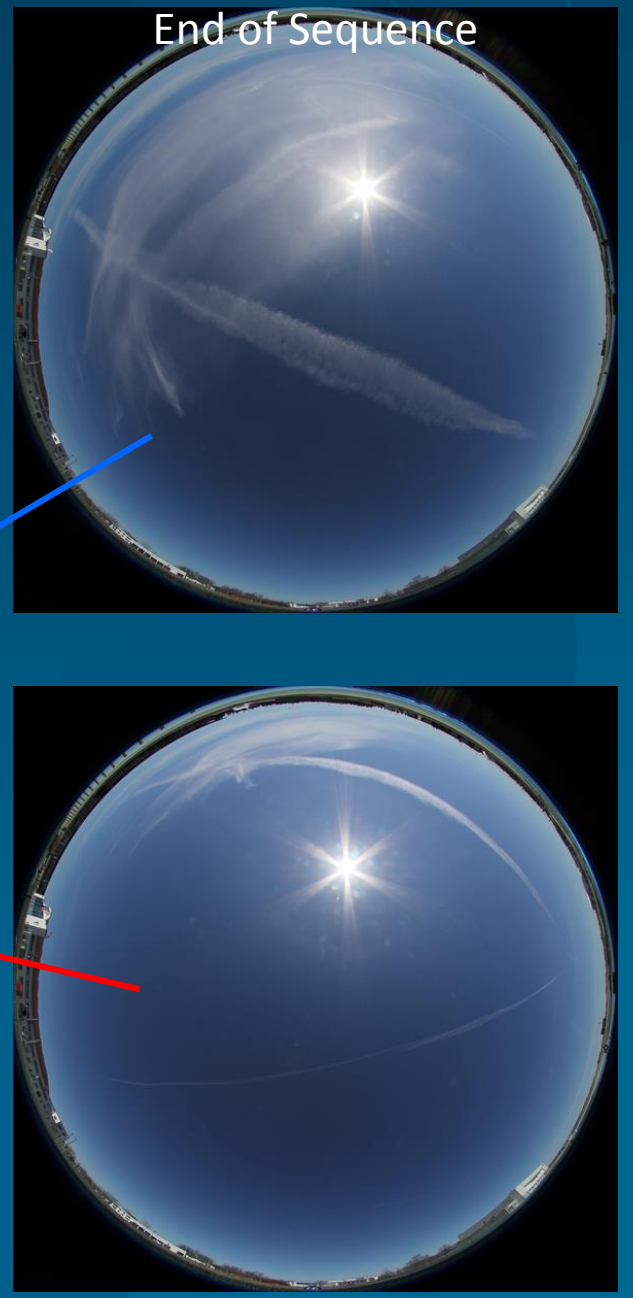




SPN1 Sunshine Pyranometer

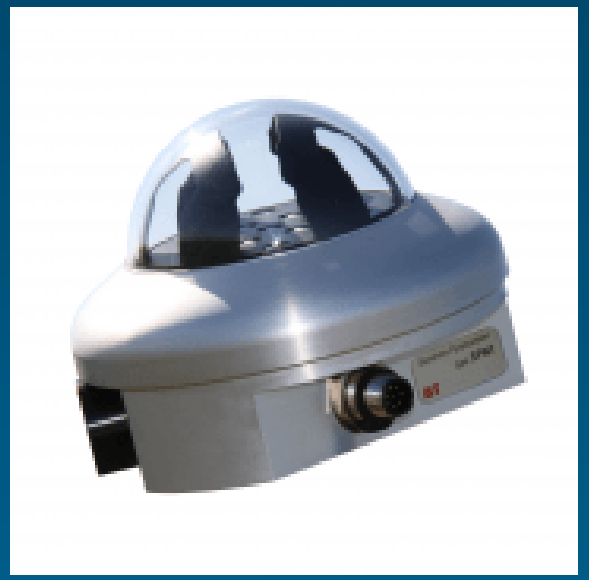
Irradiance stability and Diffuse:Global Ratio

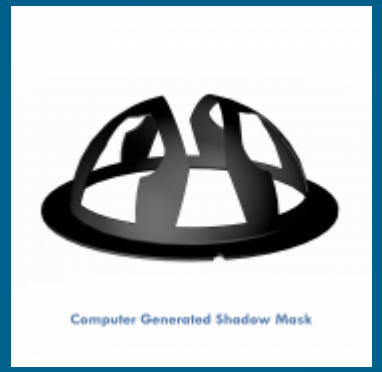
That provides an indication of the stability of the downwelling illumination conditions but **only for an instant in time.**

What happens in between?

Ideally we would have a dual spectrometer setup, one acquiring spectra of the target and one monitoring the downwelling irradiance in close proximity to each other

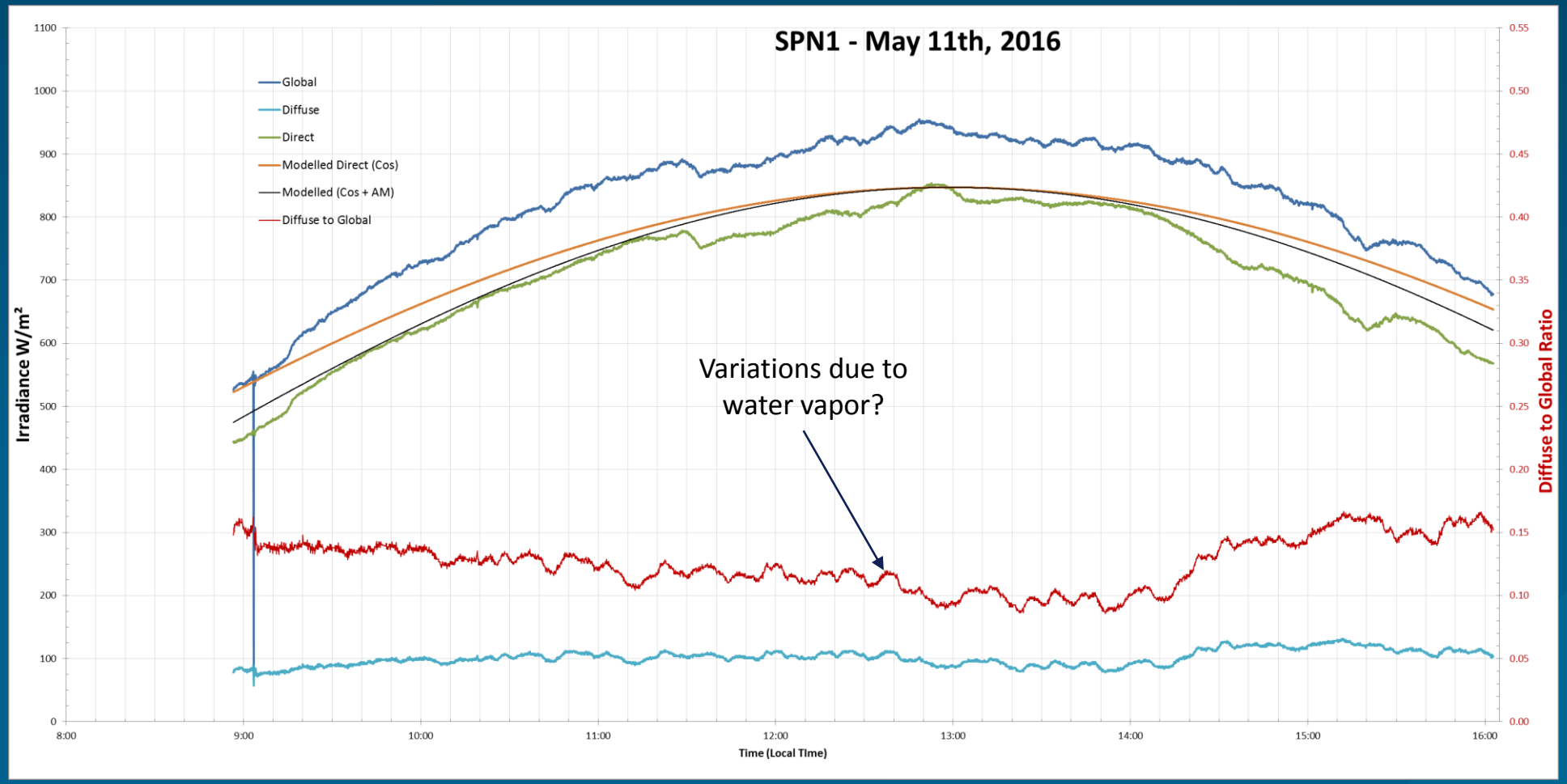
We didn't have that luxury. What we did have is SPN1 sunshine pyranomter (Delta-T) that acquired diffuse and global irradiance levels with the results integrated into the HR1024i (SVC) field spectrometry data files.



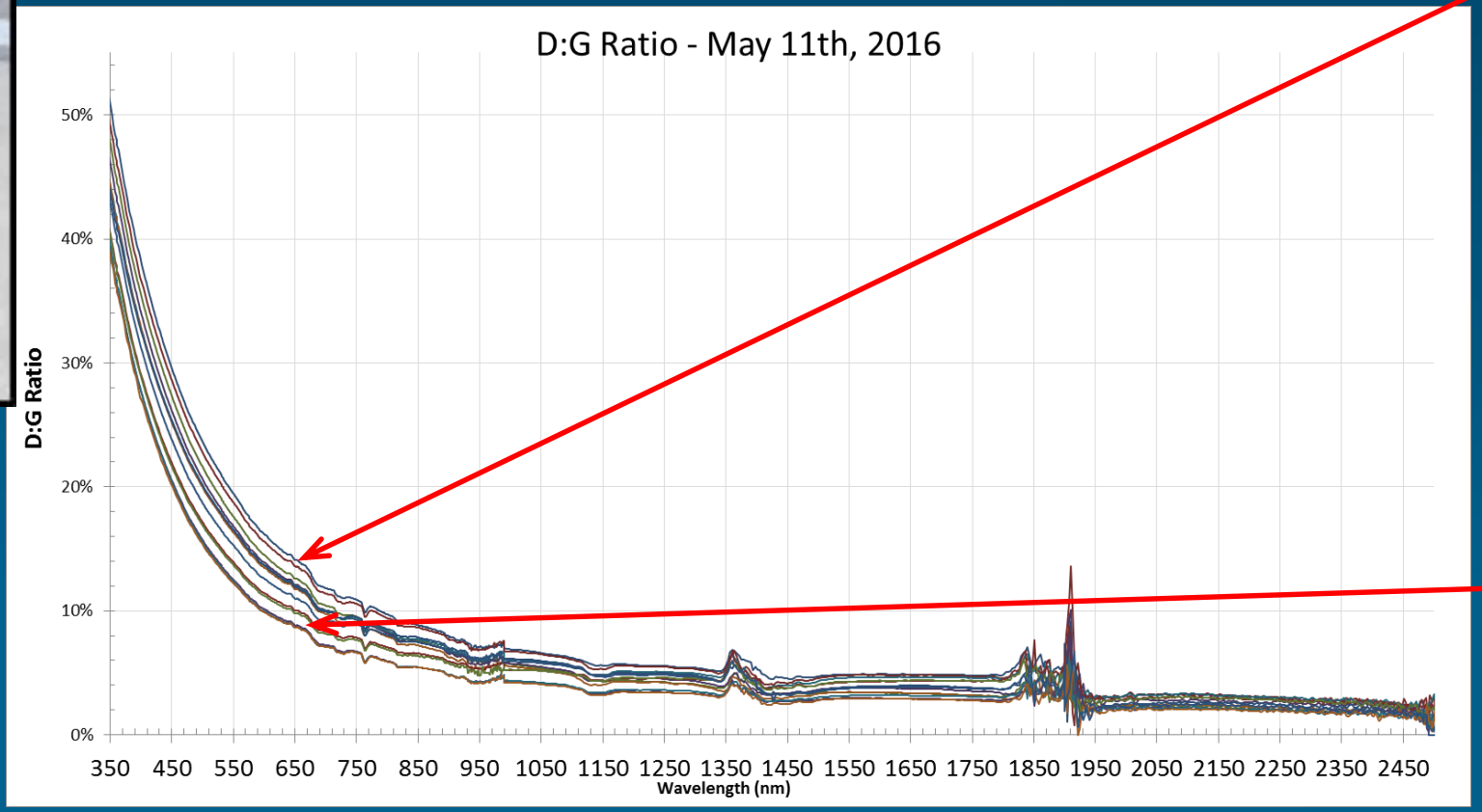


SPN1 Irradiance Data – May 11th, 2016

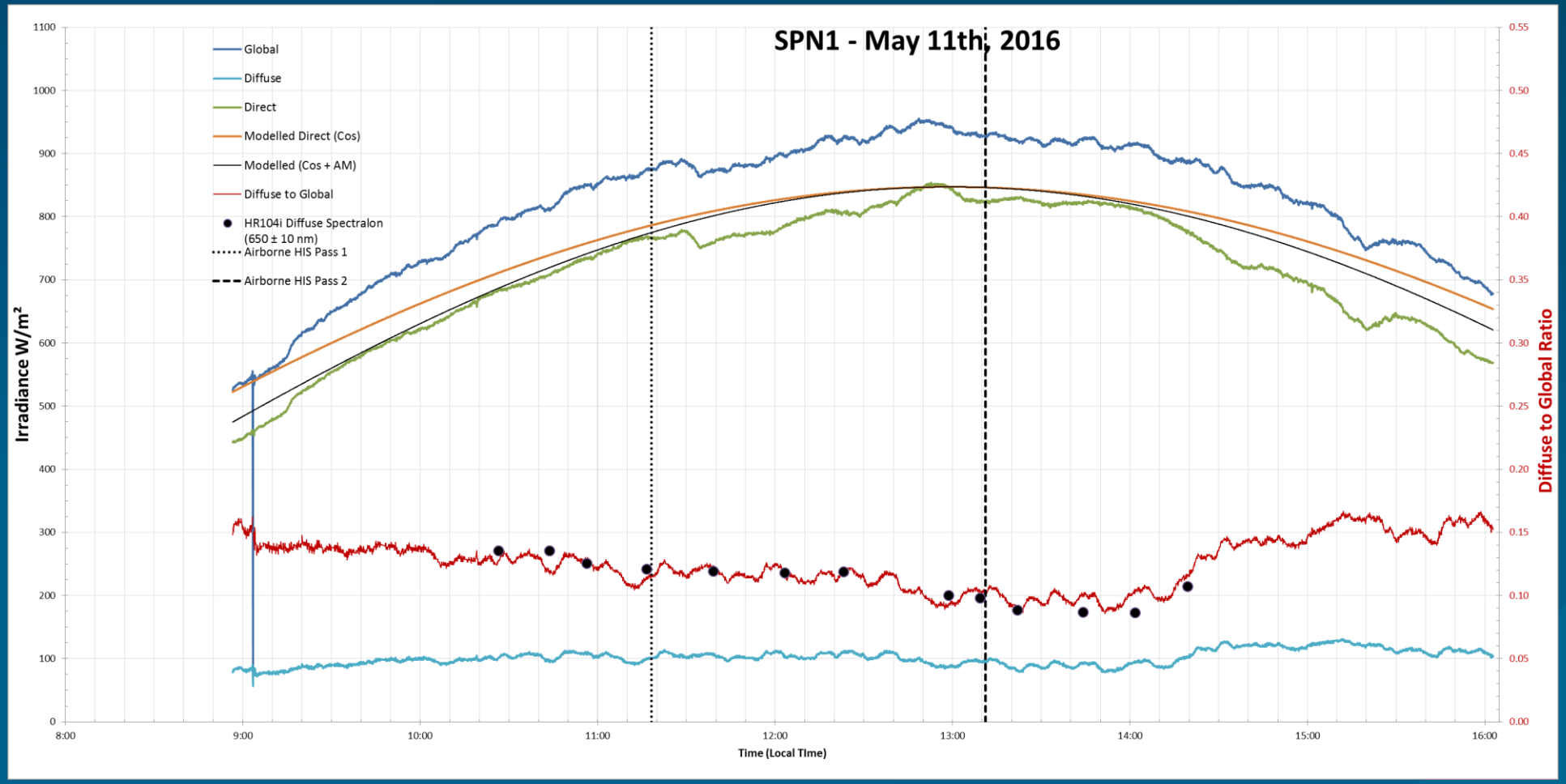
- 5 sec intervals

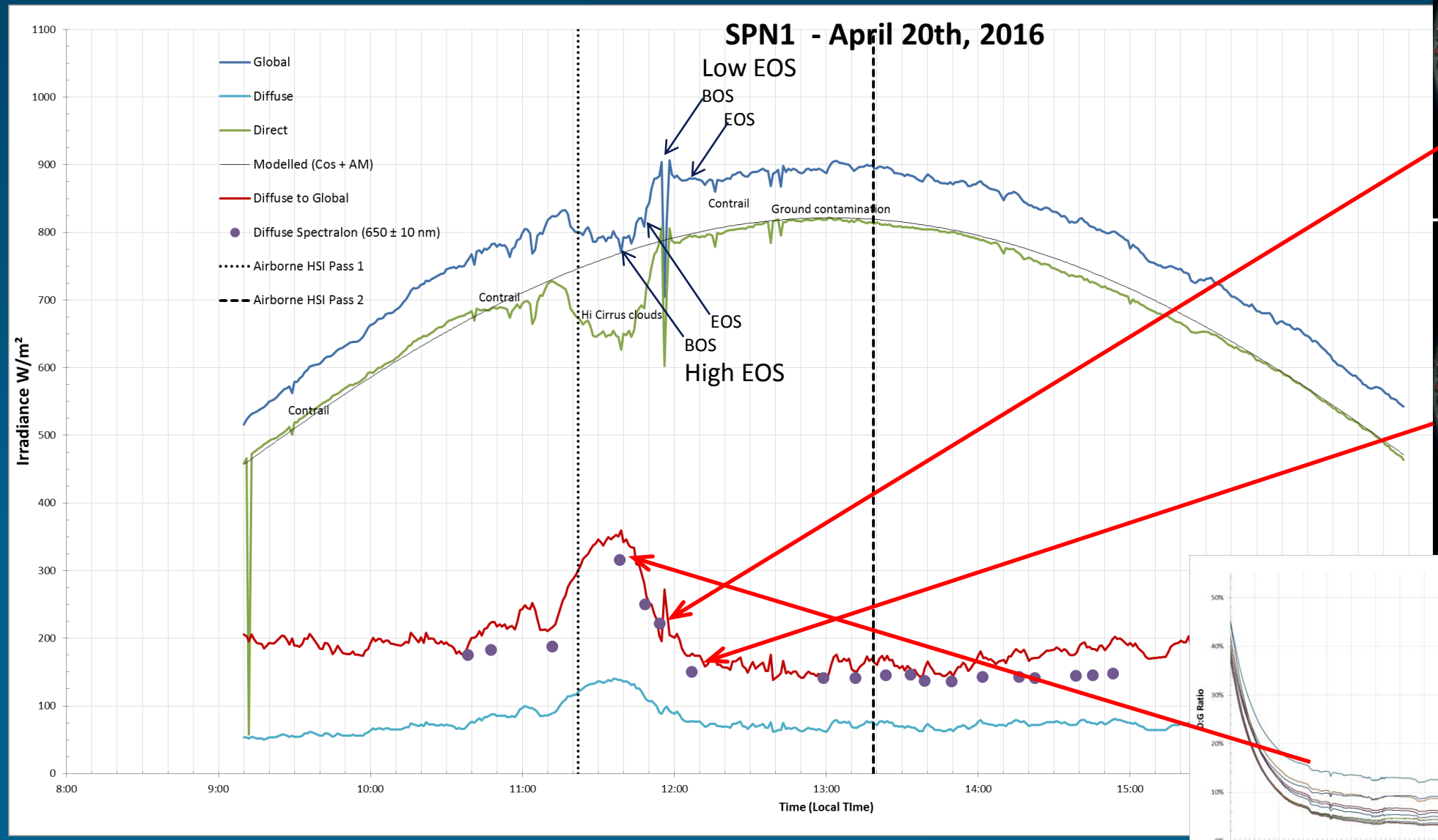


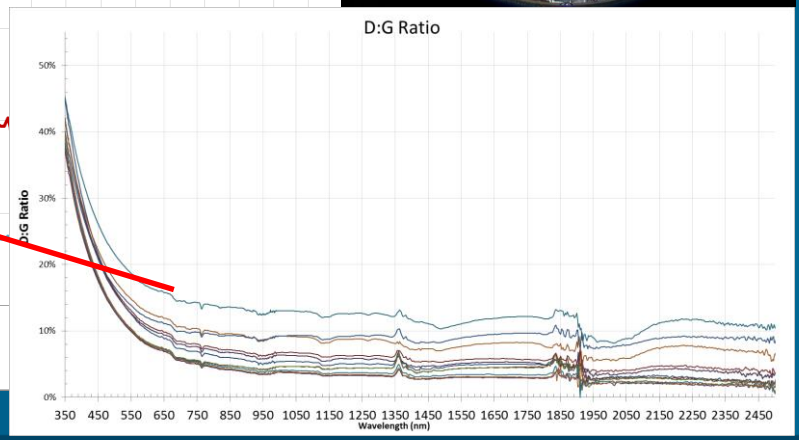
HR1024i Diffuse:Global Spectra

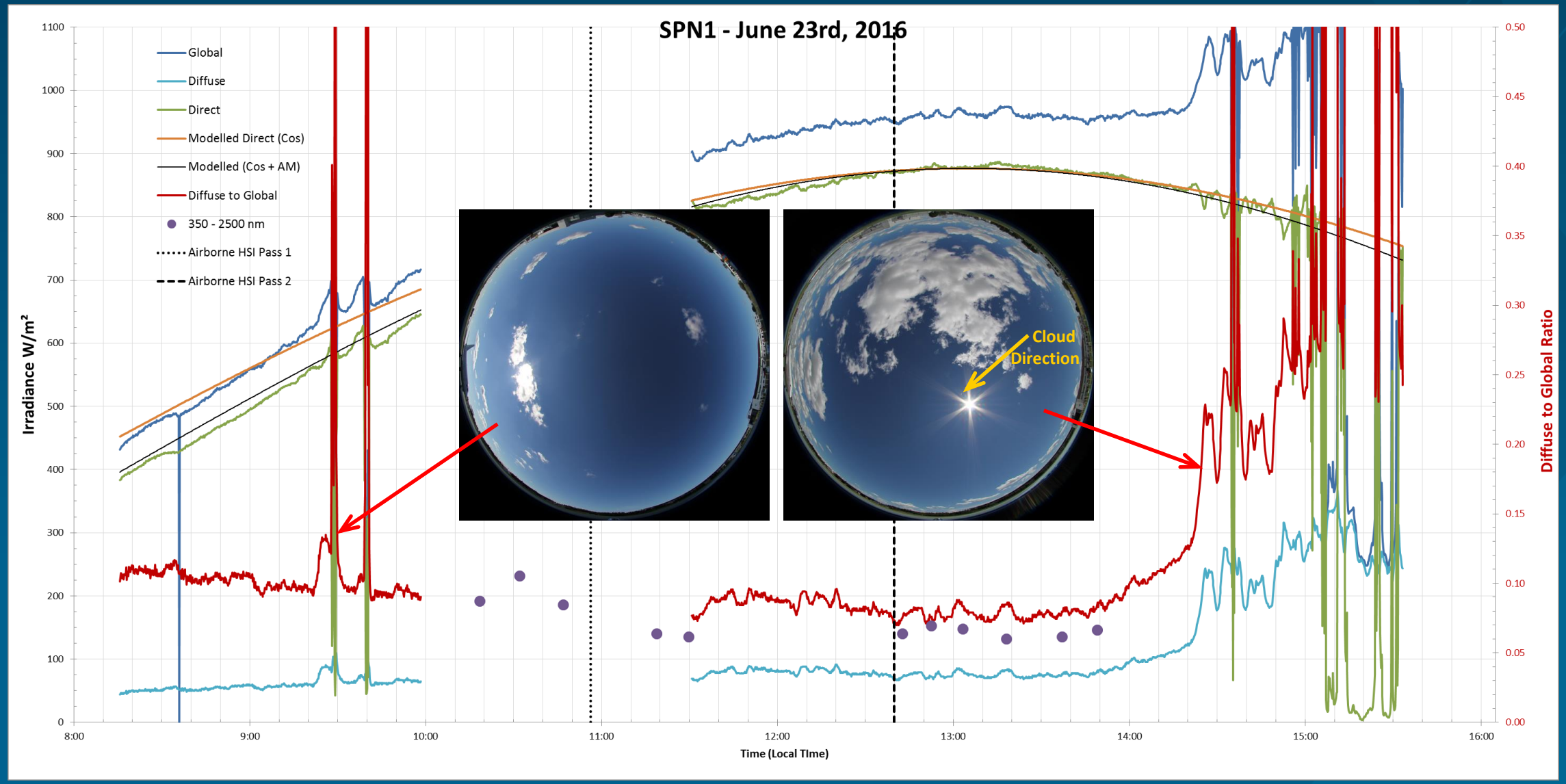


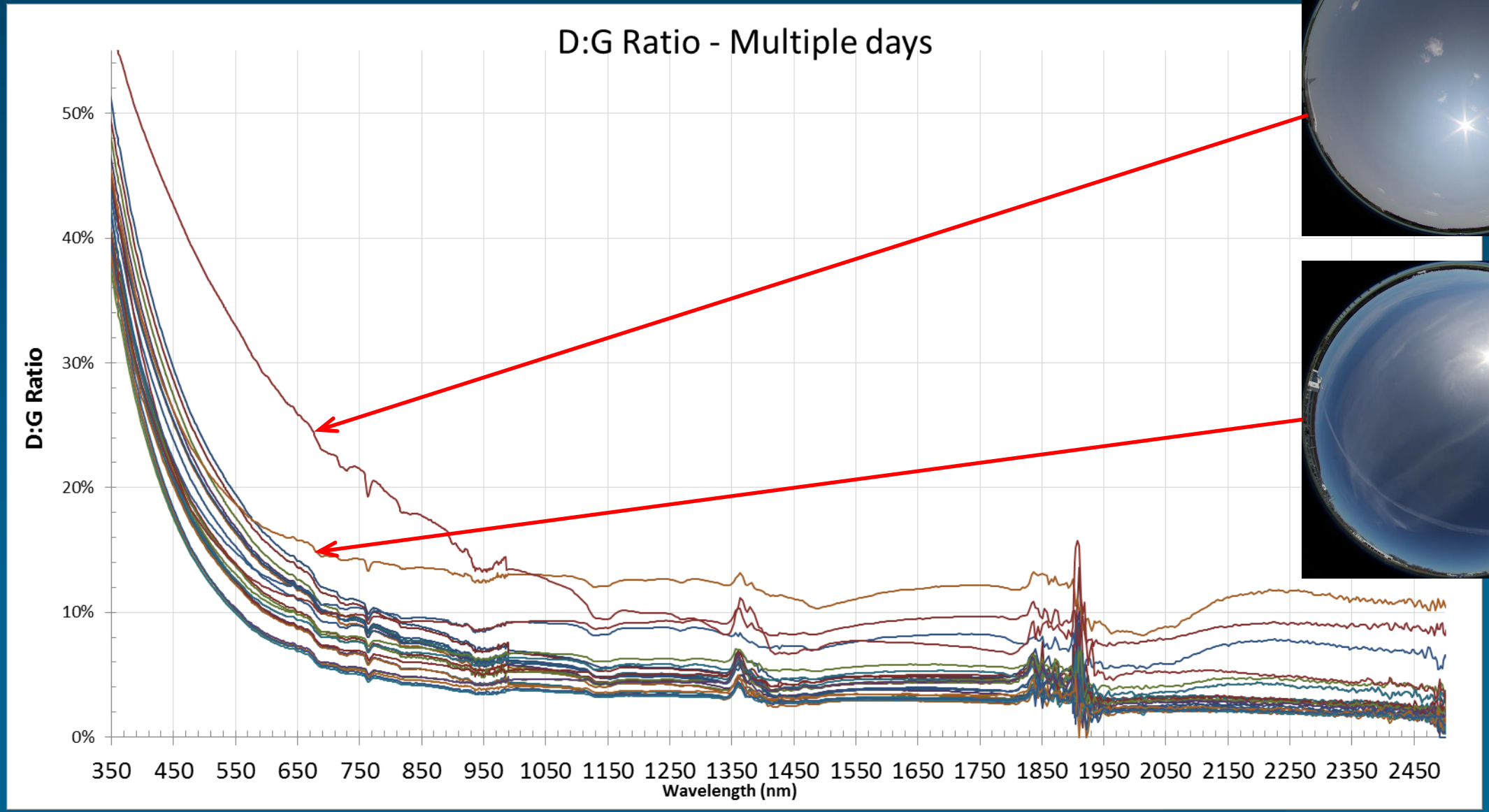
D:G Ratios: HR1024i (650 ± 10 nm) vs SPN1



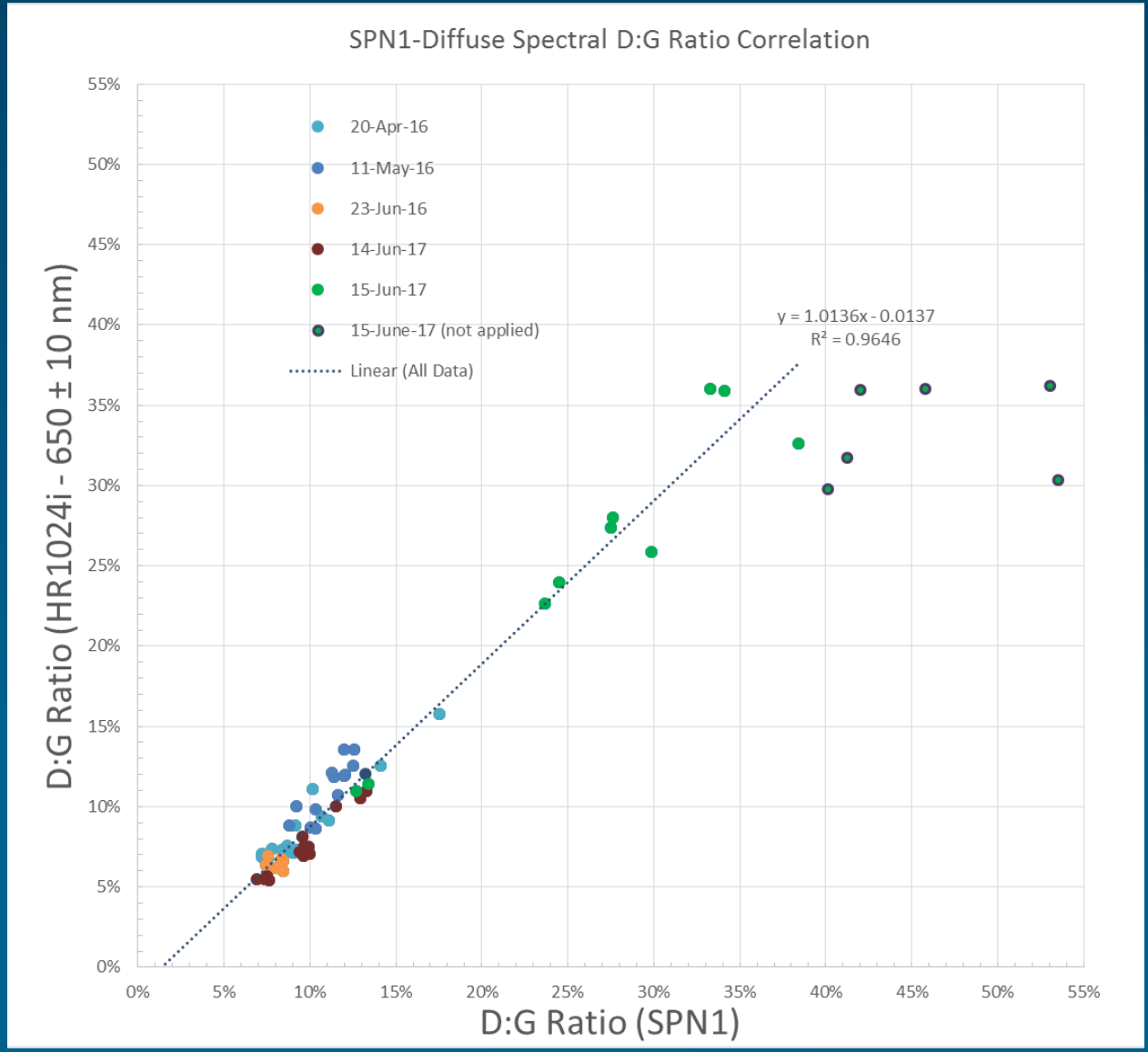

SPN1 - April 20th, 2016
Global
Diffuse
Direct
Modelled (Cos + AM)
Diffuse to Global
Diffuse Spectralon (650 ± 10 nm)
Airborne HSI Pass 1
Airborne HSI Pass 2
Low EOS
BOS
EOS
Contrail
Ground contamination
Contrail
Hi Cirrus clouds
EOS
BOS
High EOS
Contrail
Irradiance W/m²
Time (Local TIme)
1100
1000
900
800
700
600
500
400
300
200
100
0
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00


D:G Ratio
D:G Ratio
50%
40%
30%
20%
10%
0%
350 450 550 650 750 850 950 1050 1150 1250 1350 1450 1550 1650 1750 1850 1950 2050 2150 2250 2350 2450
Wavelength (nm)

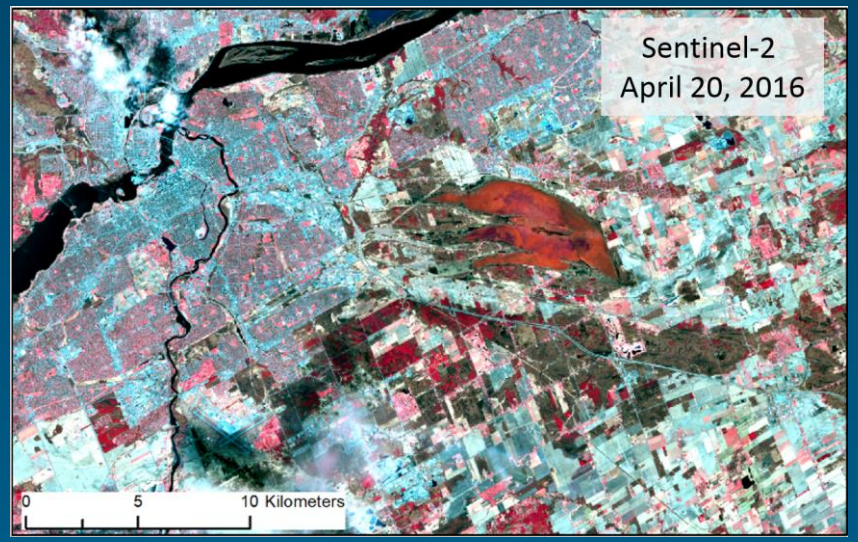

SPN1 - June 23rd, 2016
Global
Diffuse
Direct
Modelled Direct (Cos)
Modelled (Cos + AM)
Diffuse to Global
350 - 2500 nm
Airborne HSI Pass 1
Airborne HSI Pass 2
Cloud Direction
Irradiance W/m²
Diffuse to Global Ratio
Time (Local TIme)
1100
1000
900
800
700
600
500
400
300
200
100
0
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00

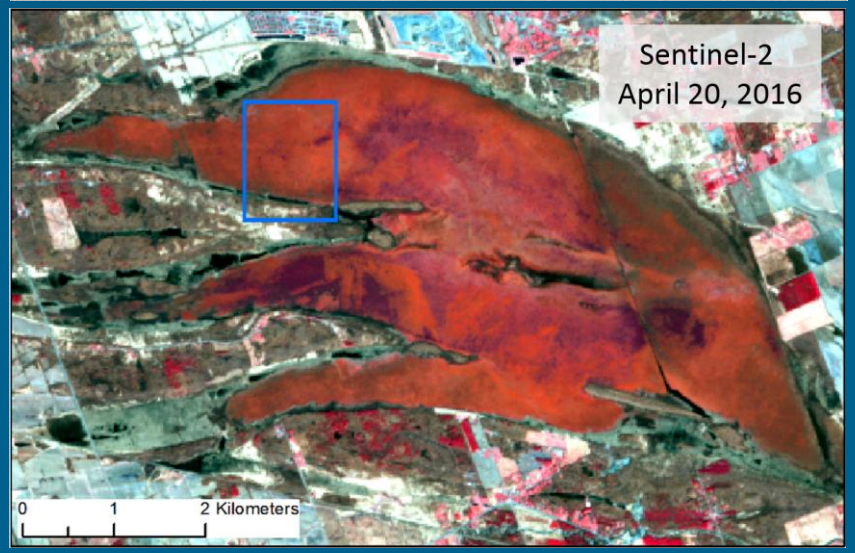

D:G Ratio - Multiple days
D:G Ratio
50%
40%
30%
20%
10%
0%
350 450 550 650 750 850 950 1050 1150 1250 1350 1450 1550 1650 1750 1850 1950 2050 2150 2250 2350 2450
Wavelength (nm)

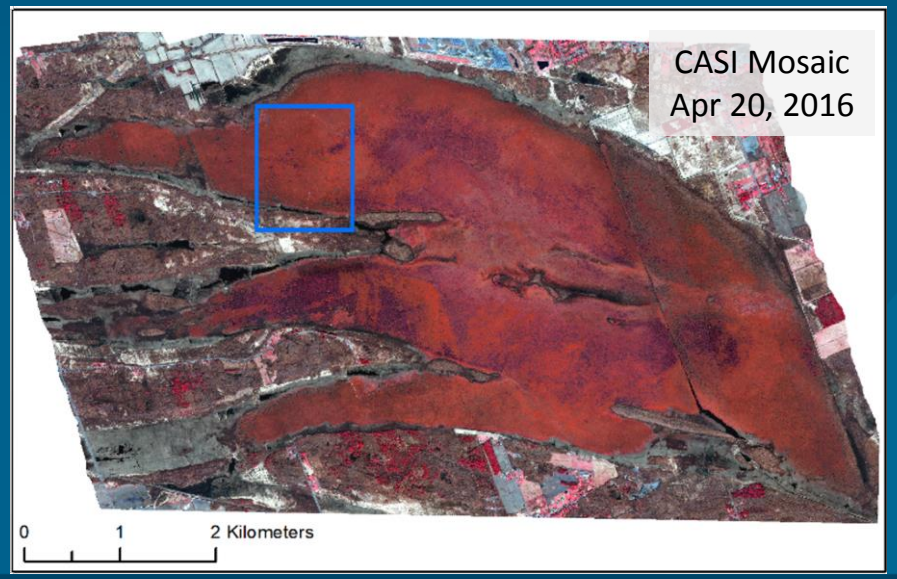
D:G Ratios: HR1024i (650 ± 10 nm) vs SPN1



Mer Bleue Arctic Simulation Study Site (MBASSS) Sentinel-2 Data Product Validation Project

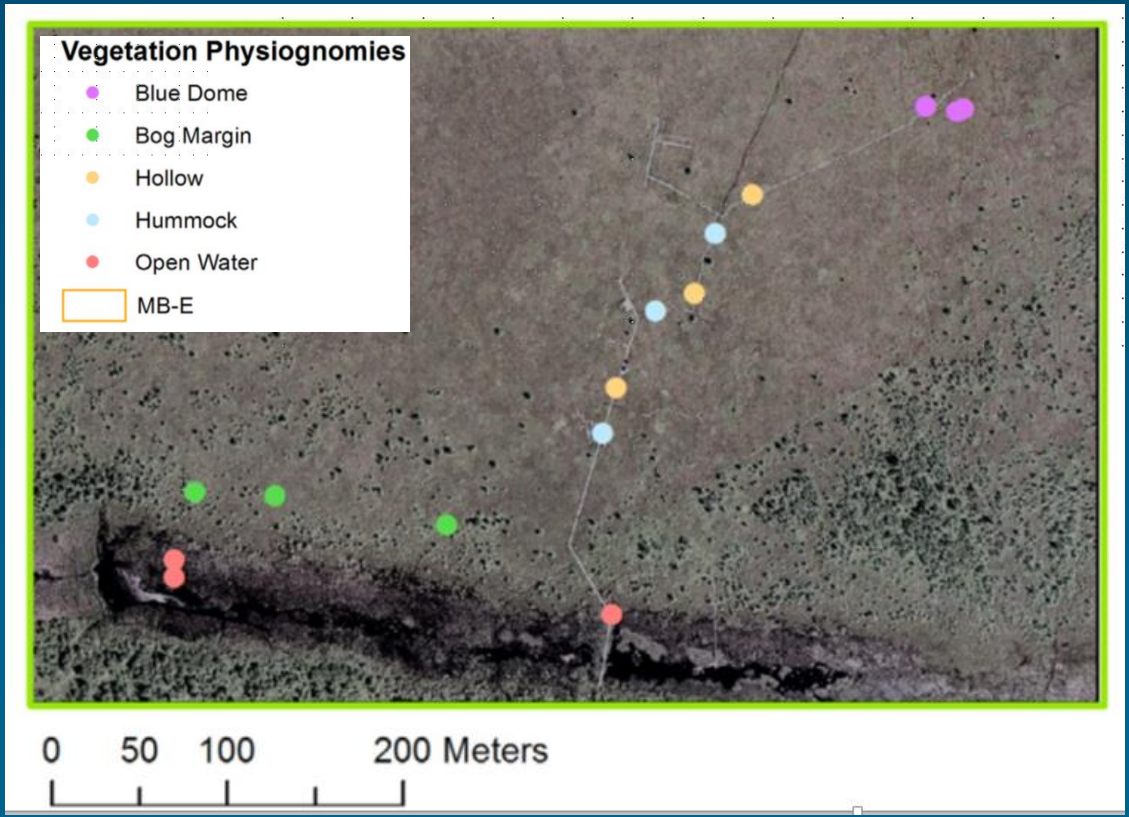






Mer Bleue Peatland

- 14 sampling plots covering 6 Physiognomies
- 3 Spectra / plot



Field Spectroscopy issues at Mer Blue

- Difficult/limited access Leading to inadequate spatial sampling
- Limited time to acquire 'coordinated' field spectra
- Lack cal/val target(s)
  - No suitable natural target
  - No convenient location for artificial target
- Difficulty logistics
  - Panel leveling
  - Operator location

Moving Forward - Bridging the Gap

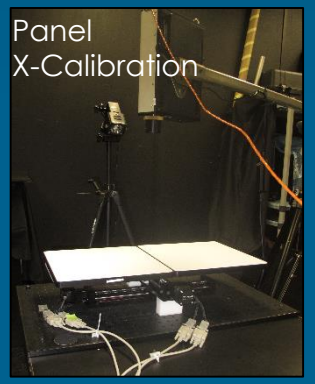
Laboratory and Field Panel Calibration

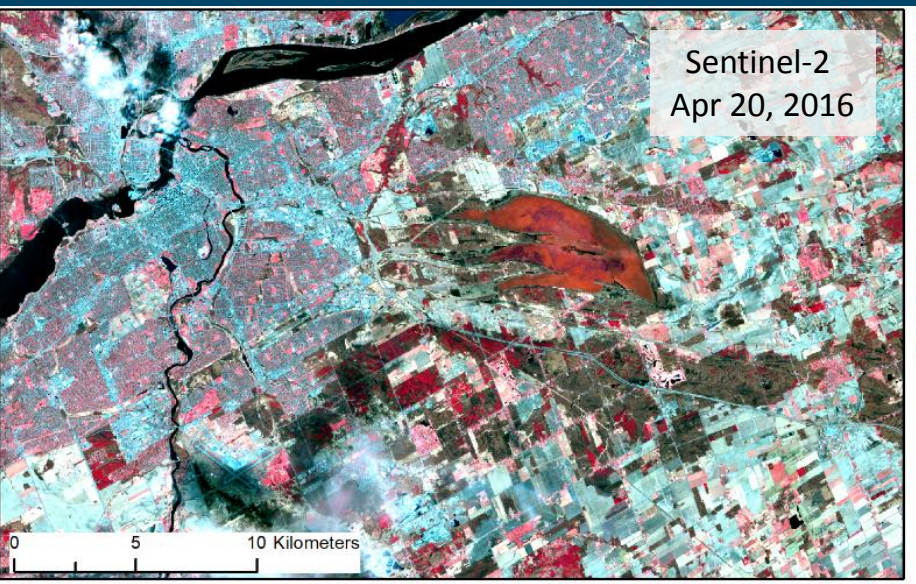
Field Spectroscopy

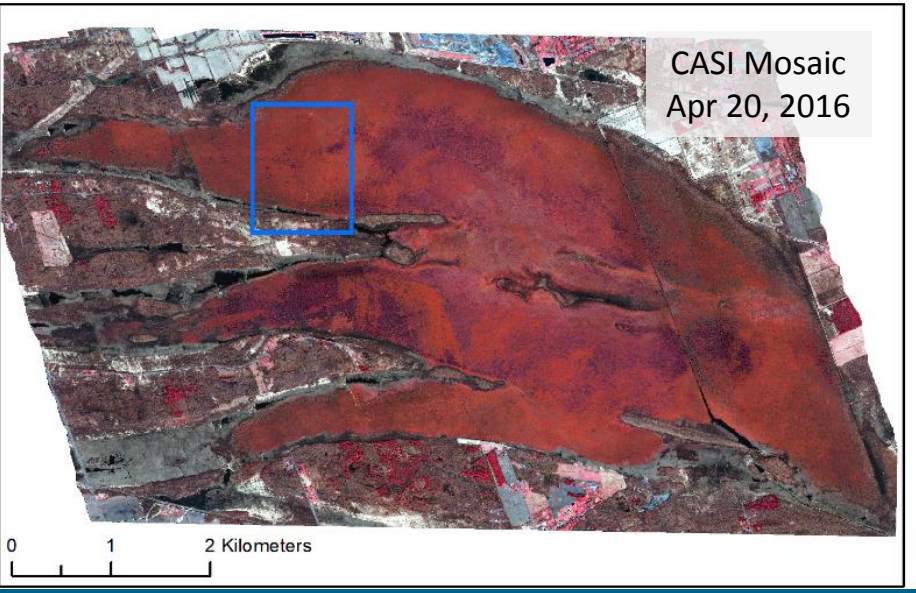
UAV Hyperspectral

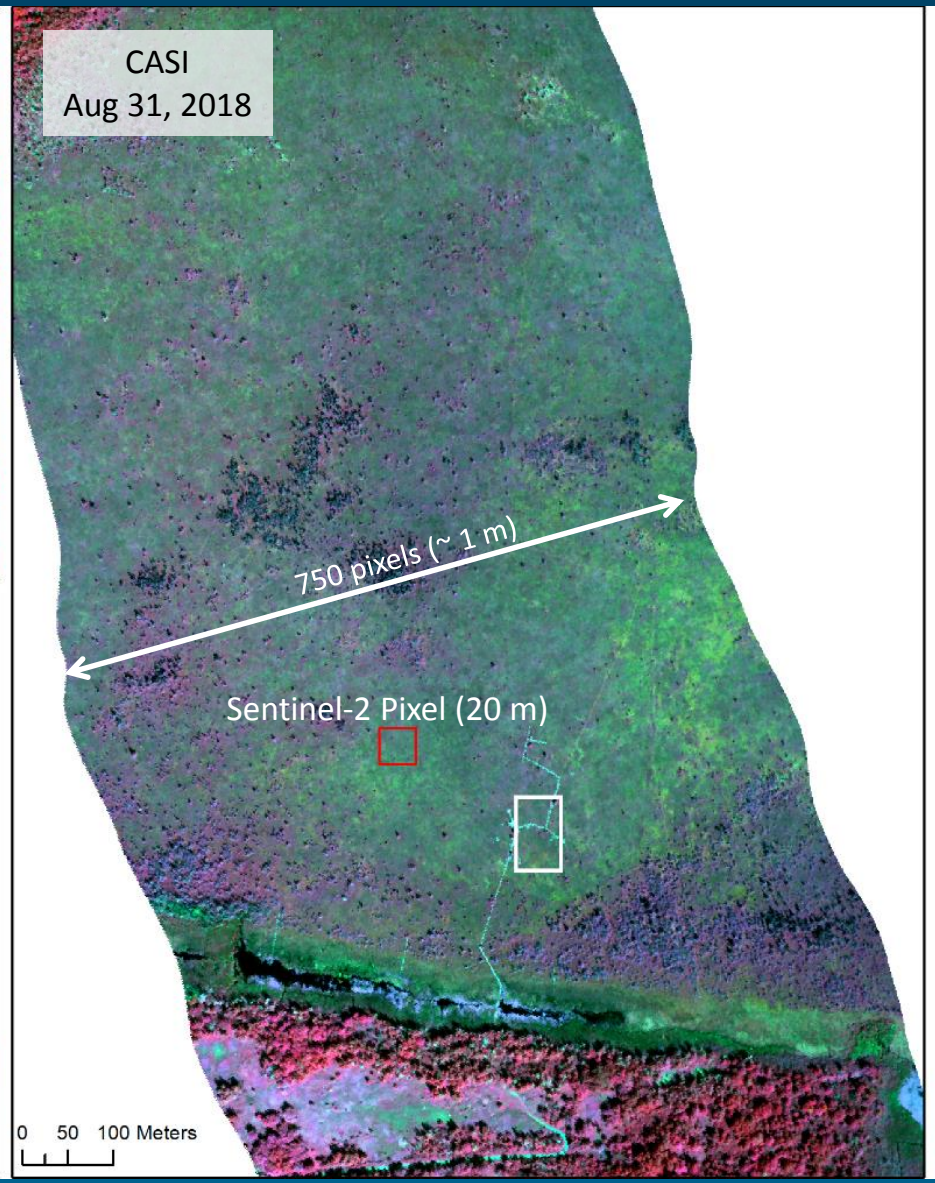
Airborne Hyperspectral

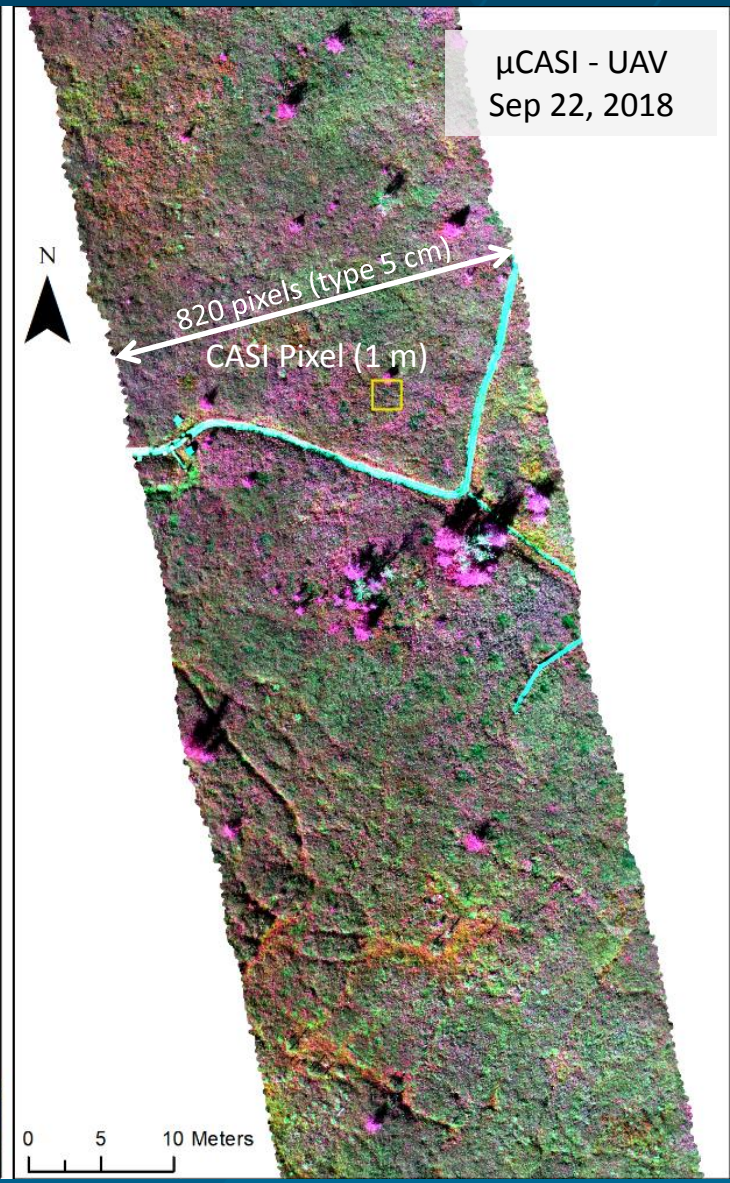
Satellite Multispectral

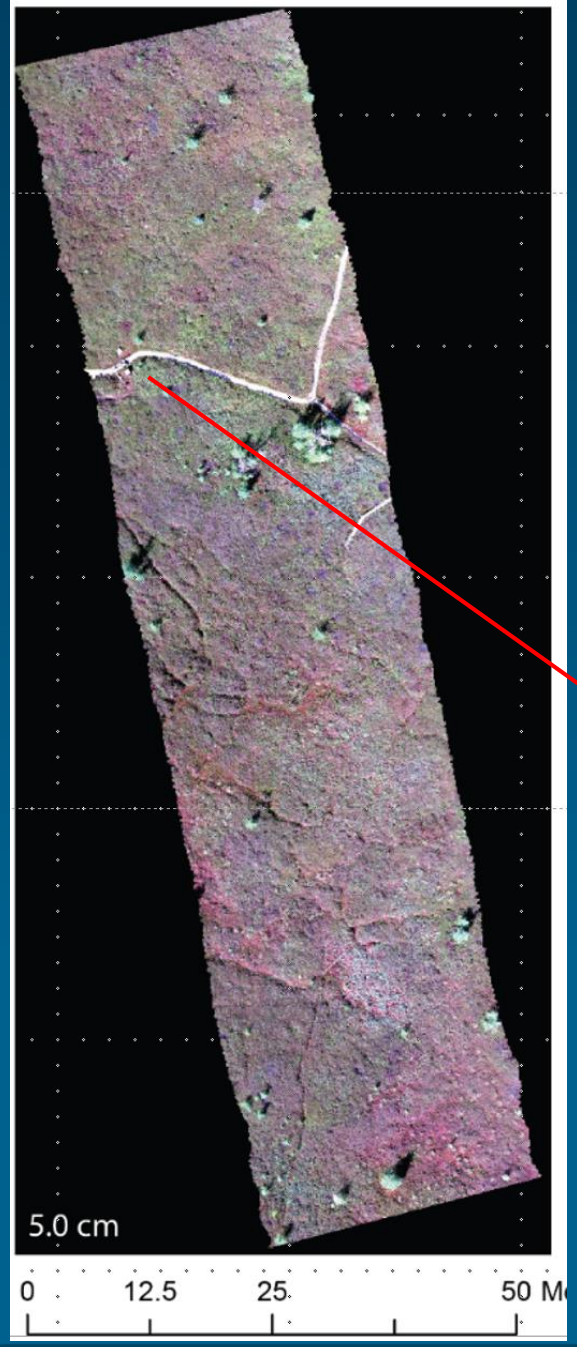



Sentinel-2
Apr 20, 2016
0 5 10 Kilometers


CASI Mosaic
Apr 20, 2016
0 1 2 Kilometers


CASI
Aug 31, 2018
750 pixels (~ 1 m)
Sentinel-2 Pixel (20 m)
0 50 100 Meters


µCASI - UAV
Sep 22, 2018
N
820 pixels (type 5 cm)
CASI Pixel (1 m)
0 5 10 Meters



UAV HSI

- replace field spectroscopy?
- 400 UAV HSI spectra (5 cm x 5 cm) within one 1 Airborne HSI Pixel (1 m x 1 m)
- Provides sub-pixel spatial composition so upscaling can properly be assessed

Field Spectroscopy

- Hi quality measurement of reference targets within UAV HSI field of view
- Use for validation or vicarious calibration under similar atmospheric conditions
- Manageable 30 cm (12”) panels should be adequate?

Summary – Panel Calibration

- Successfully calibrated panels to a common reflectance standard
  - Uncertainty in methodology results has been evaluated
- Common standard calibrated against NIST Reflectance standard
- Allows for monitoring of:
  - Degradation of panel reflectance levels
  - Degradation of panel uniformity
- Lab work under controlled conditions provided an environment to identify operational characteristics of the SVC HR1024i instrument likely to go unnoticed in the field.

Summary – Field Spectrometry QA

- A detailed appreciation of the downwelling irradiance environment is required to understand the quality of the resulting field spectra.
- A method to assess the data quality will help to develop an appreciation of what conditions can or cannot be tolerated for various field spectrometer applications.
- The importance the hemispherical sky photos in providing contextual awareness of the various data sets cannot be understated.

Summary – Next Steps

- Enhancement of Field Spectra through the use of UAV Hyperspectral
- Collating the uncertainty information described here into an overall uncertainty budget for the field spectra
  - Uncertainty in the panel reflectancy
    - Are we using the correct value for the reference panel reflectance?
    - What impact does the D:G ratio have on the identification of the appropriate reference panel reflectance?
  - Uncertainty due to variable atmospheric conditions
- Identification of acceptable/unacceptable atmospheric conditions?
  - When to postpone/cancel field work and/or aiborne acuisitions.
  - Removal of unacceptable data points/sequences.

Work funded and supported by:

Thank you

CONTACT
Raymond Soffer

Research Council Officer, Aerospace
1920 Research Rd
Ottawa ON
K1A 0R7