Laboratory and Field Calibration Methods for Solar-induced Fluorescence Monitoring Systems

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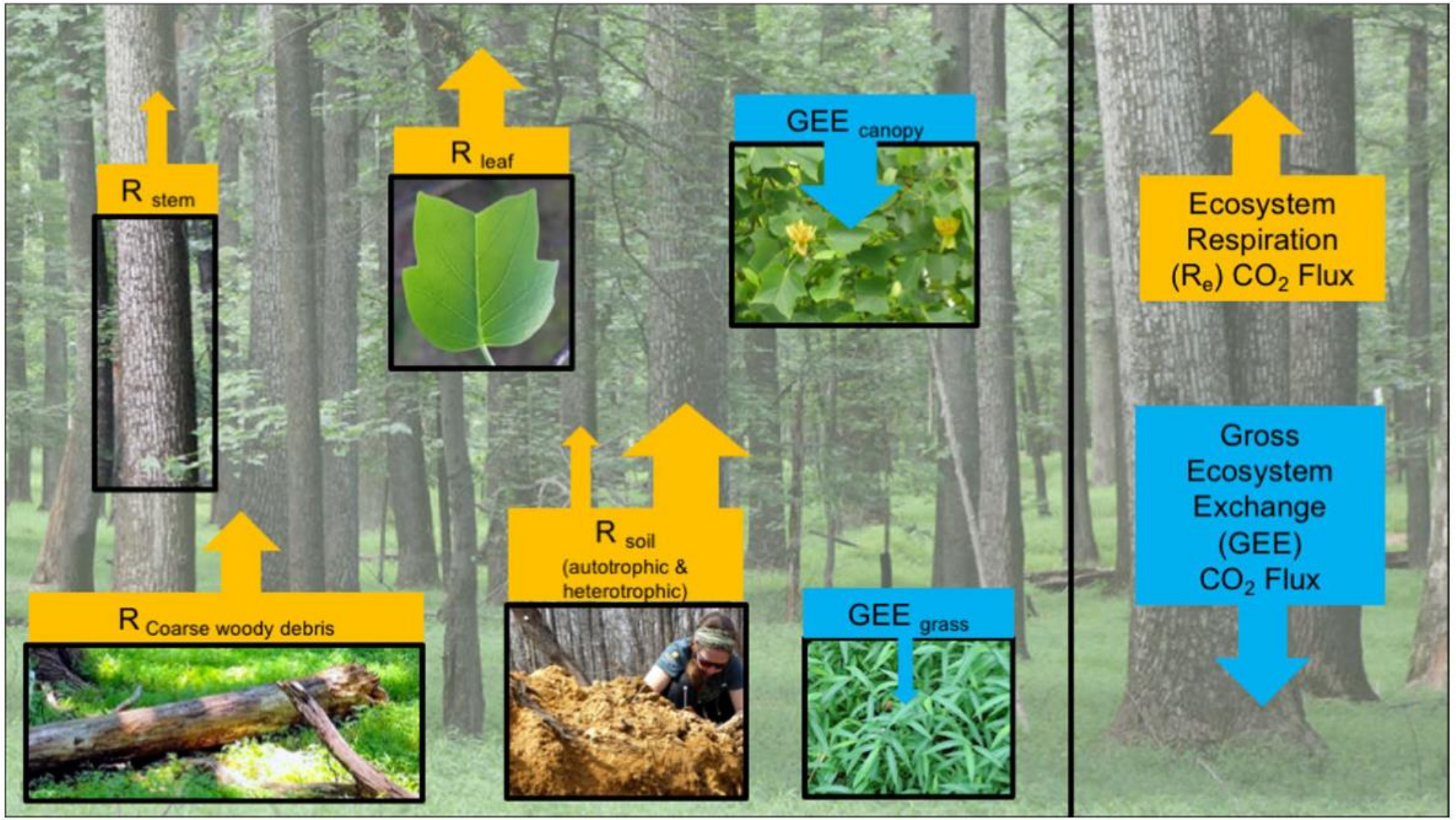
Forested Optical Reference for Evaluating Sensor Technology (FOREST)

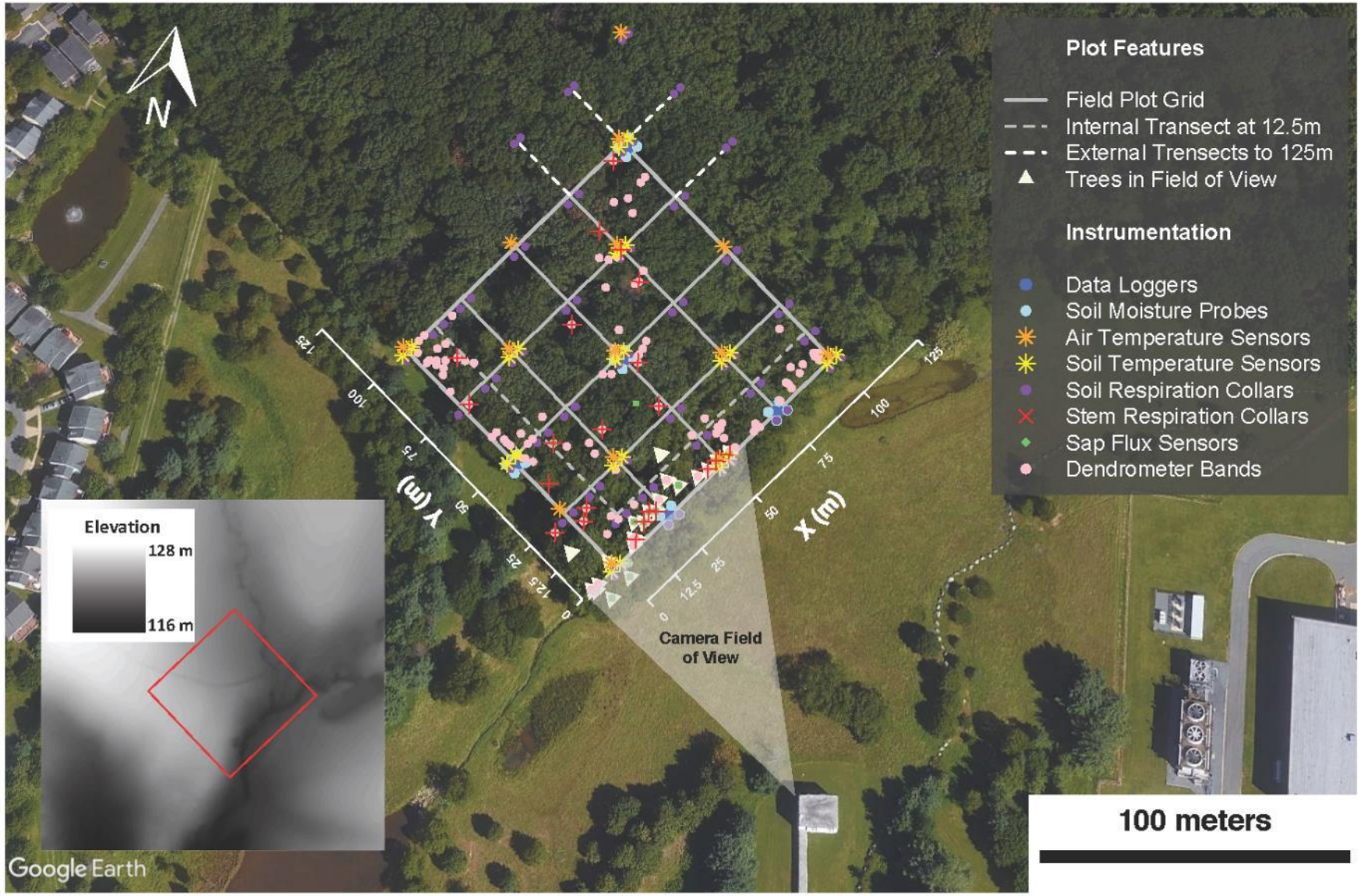
- Forested 1 hectare plot established on NIST Gaithersburg campus in summer 2017
- Carbon flux monitoring for comparison with optical remote sensing measurements
- FOREST reference site is more complicated than typical reference standards

Major Ecosystem Carbon Fluxes



Winbourne et al. 2022

FOREST Sensor Suite



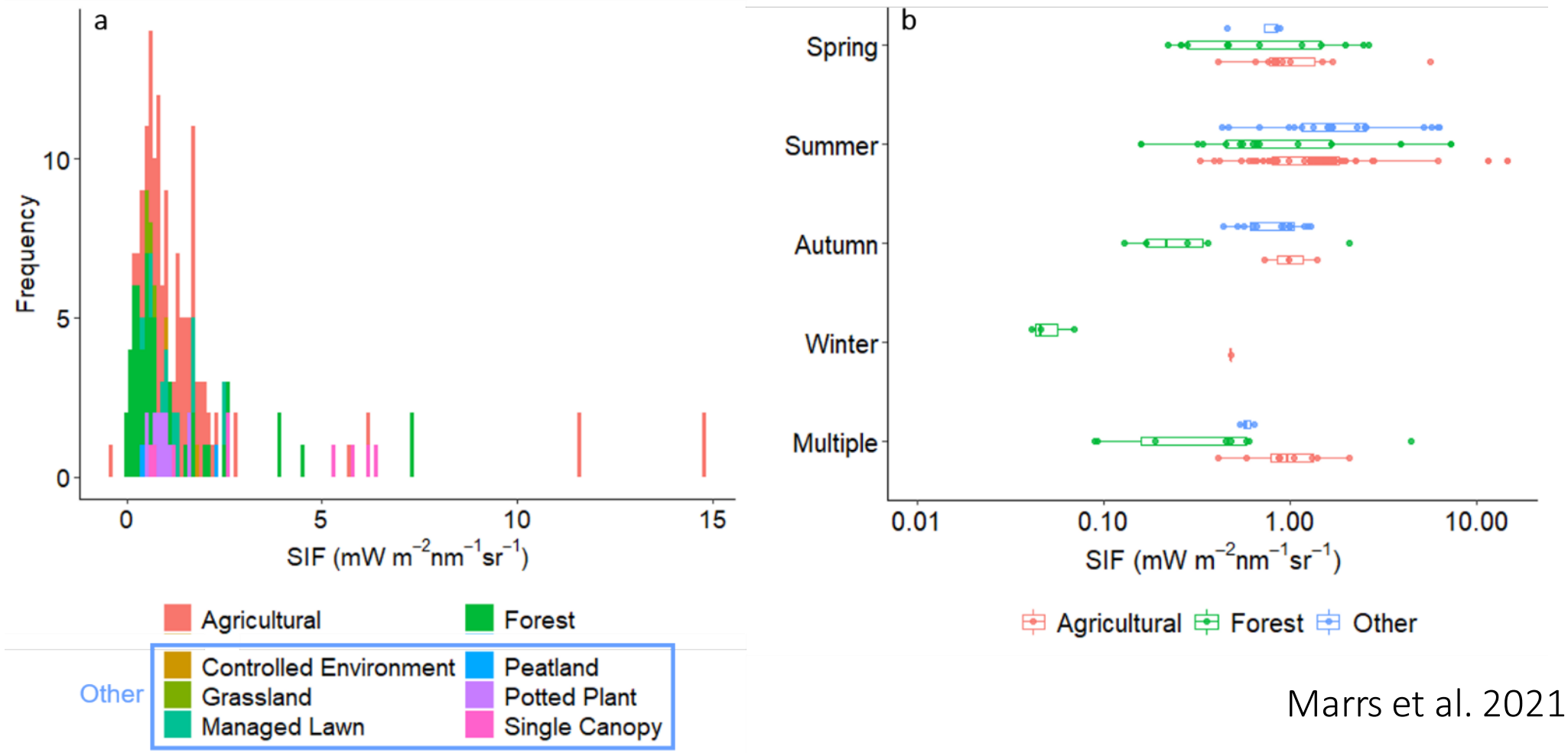
Map: Ian Smith

Cameron Solar-Induced Fluorescence (SIF) System

- Remotely sensed chlorophyll fluorescence can track plant productivity
- Co-registered spectrometers, 3-channel optical camera, and thermal imager with programmable targeting

Lack of consensus on field-measured SIF signals

Published mean SIF retrievals span three orders of magnitude

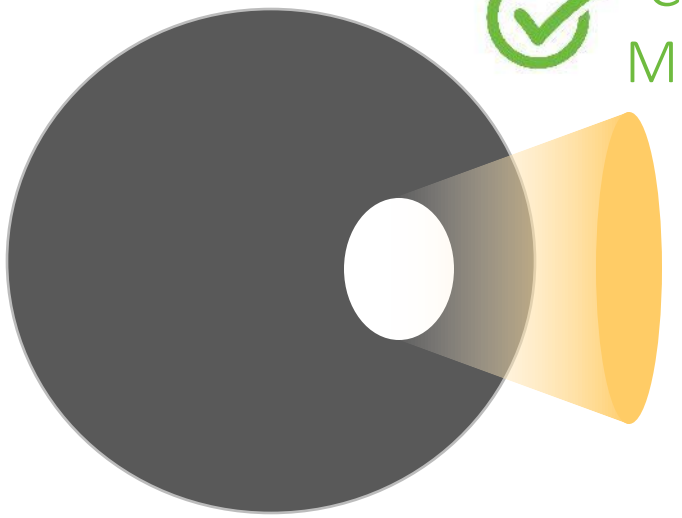


Marrs et al. 2021

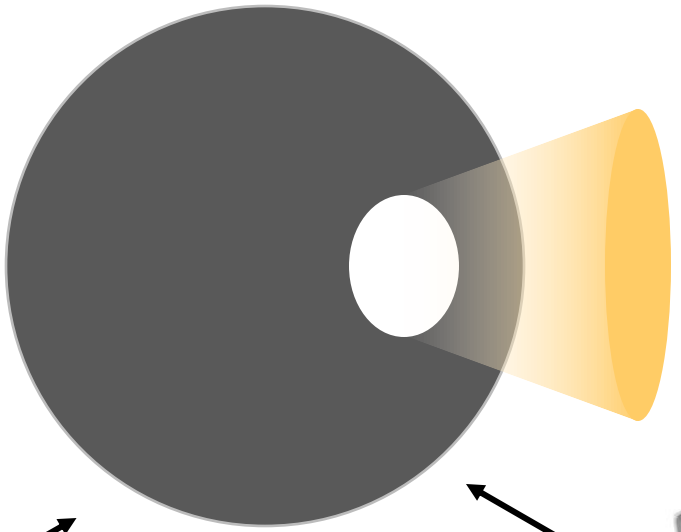
Laboratory Instrument Characterizations

Integrating Sphere
Source (NPR)

Calibrated
March 2023



Integrating Sphere
Source (OL455)



10 light levels

Spectrometer 1

Spectrometer 2

Radiometer

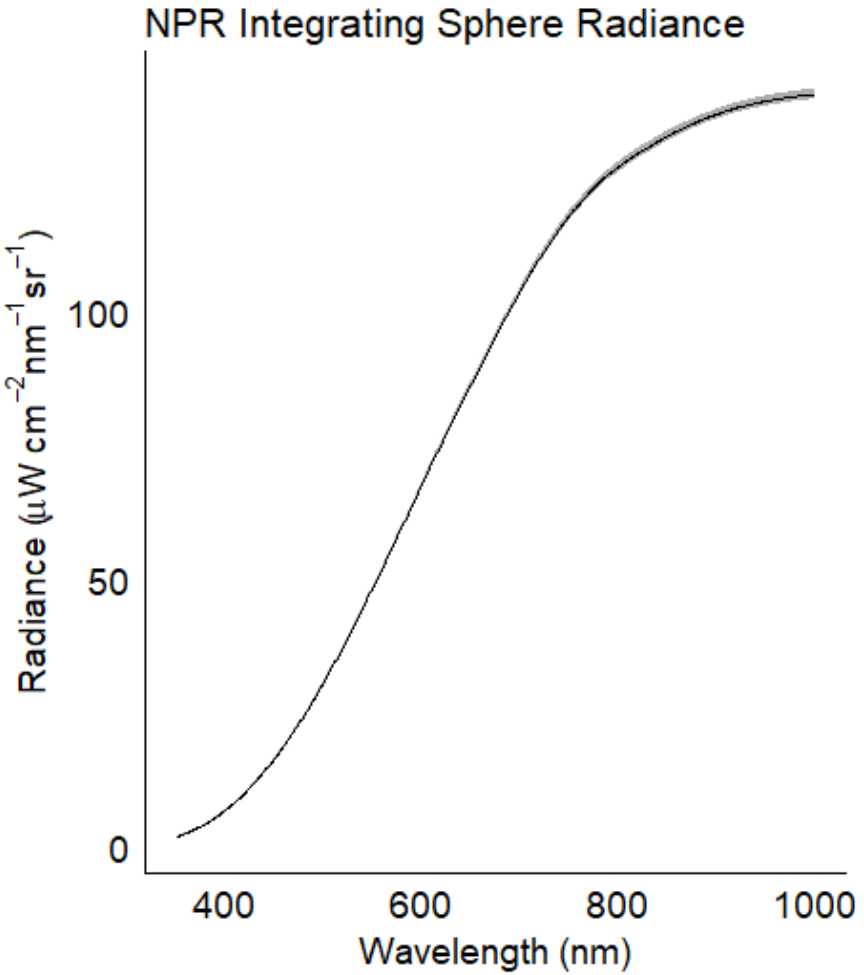
Cameron
SIF System
x2

Laboratory Instrumentation Characteristics

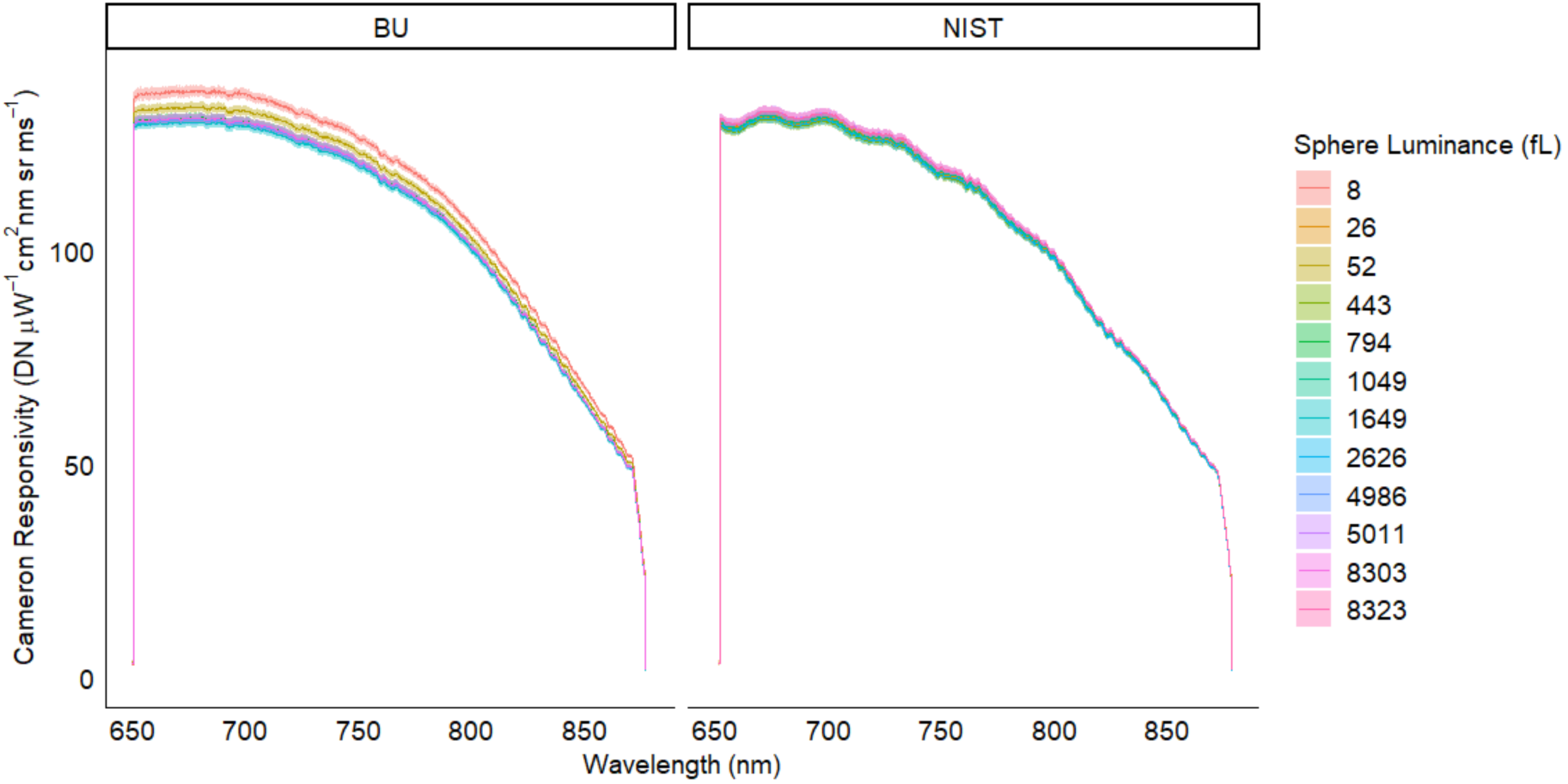
Spectrometer	Spectral Range	Spectral Resolution
Transfer Spectrometer 1	350.0 nm – 2500.0 nm	1.0 nm
Transfer Spectrometer 2	339.2 nm – 2502.2 nm	2.1 nm
SIF Spectrometer (NIST)	651.0 nm – 878.8 nm	0.22 nm
SIF Spectrometer (BU)	649.2 nm – 877.3 nm	0.22 nm

Transfer Radiometer

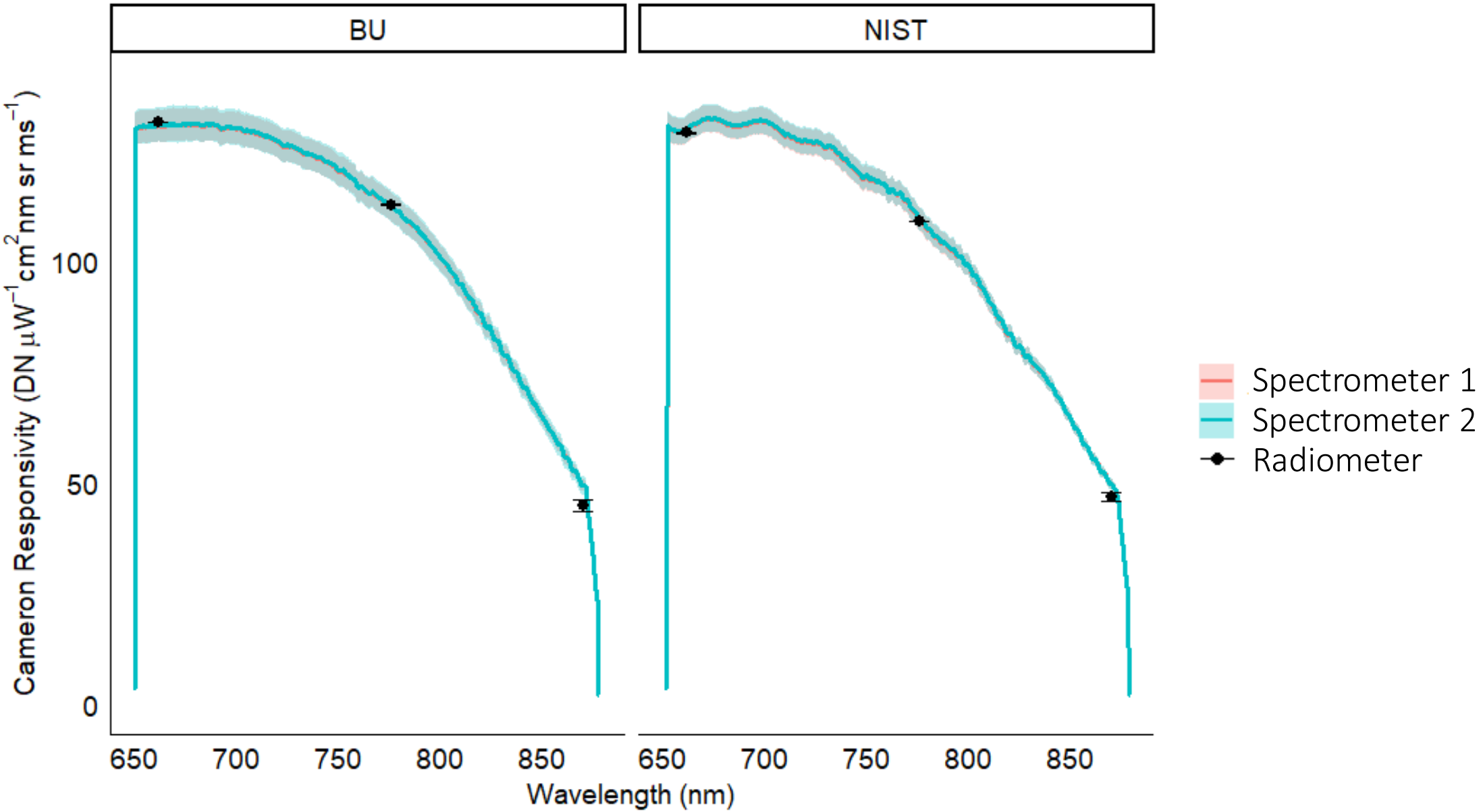
Channel	Center Wavelength	Bandwidth
1	411.8 nm	10.8 nm
2	441.0 nm	10.5 nm
3	548.4 nm	10.2 nm
4	661.4 nm	9.5 nm
5	775.5 nm	11.1 nm
6	870.0 nm	13.4 nm



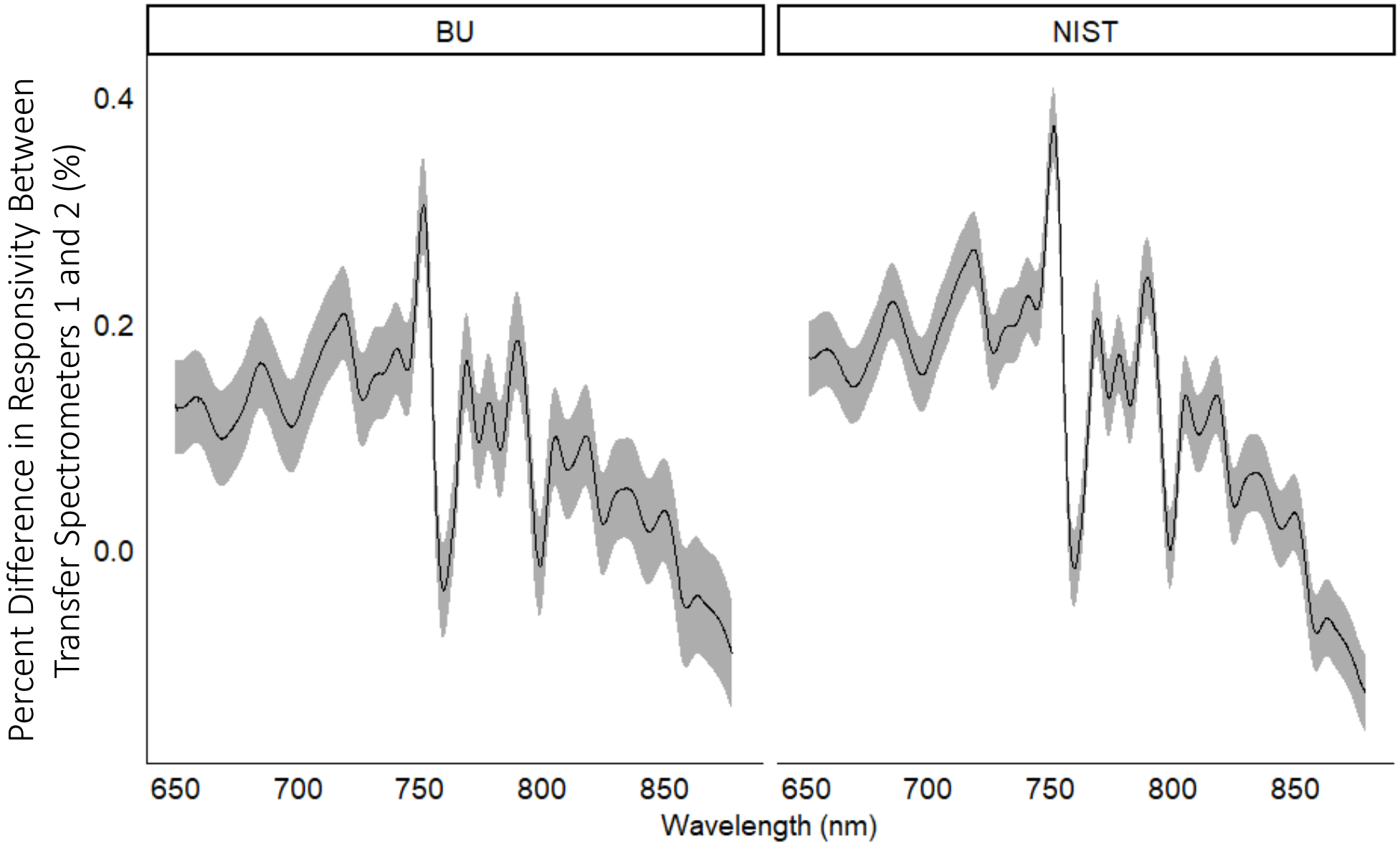
Radiometric Responsivity Values



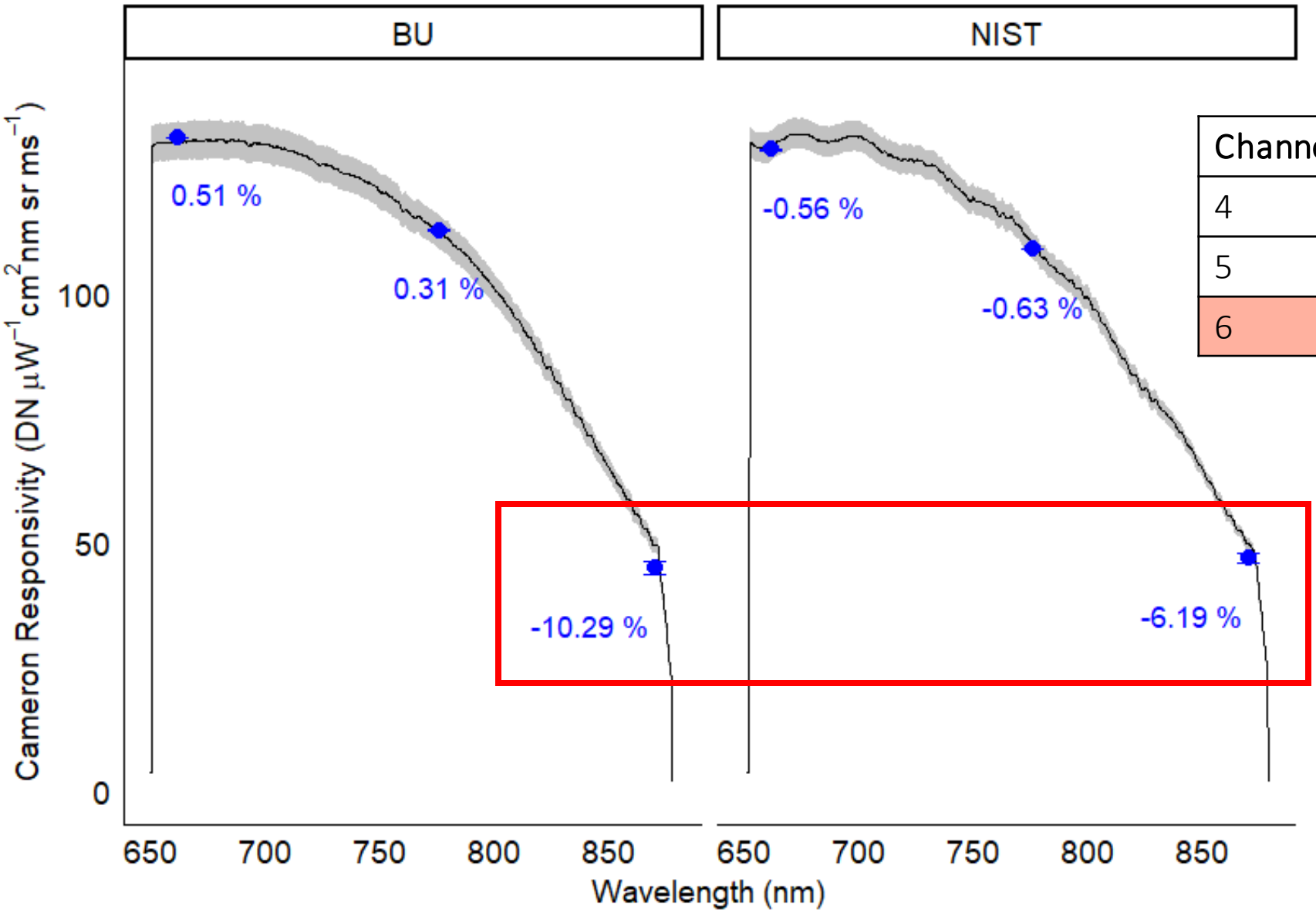
Responsivity Values Across Transfer Instruments



Agreement Across Transfer Instruments



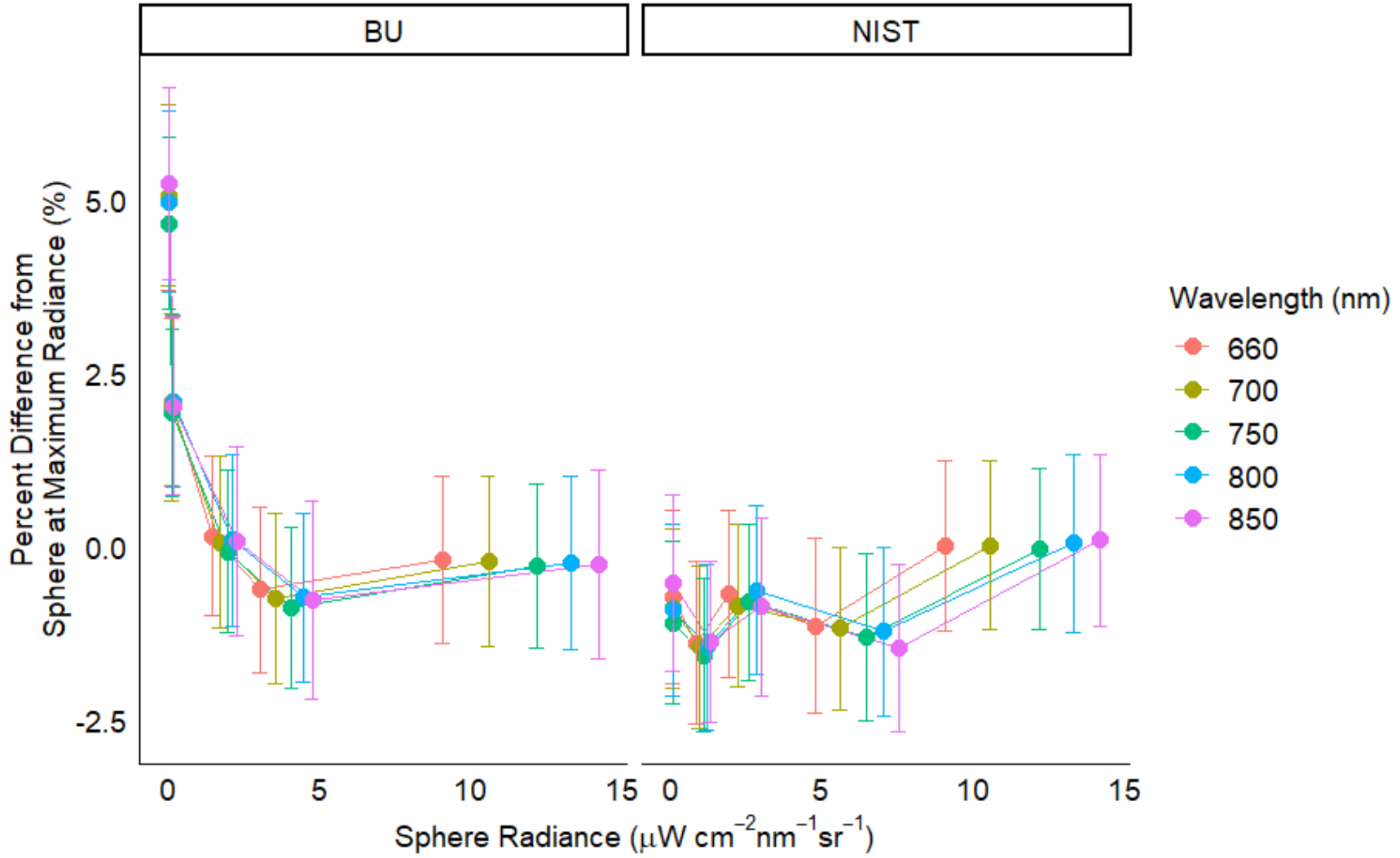
Agreement Across Transfer Instruments



Channel	Center Wavelength	Bandwidth
4	661.4 nm	9.5 nm
5	775.5 nm	11.1 nm
6	870.0 nm	13.4 nm

Detector Nonlinearity

An uncorrected 0.1 % nonlinearity over the saturation range of the detector can translate to an error of 3 % to 10 % in the SIF signal (Grossmann et al. 2018)

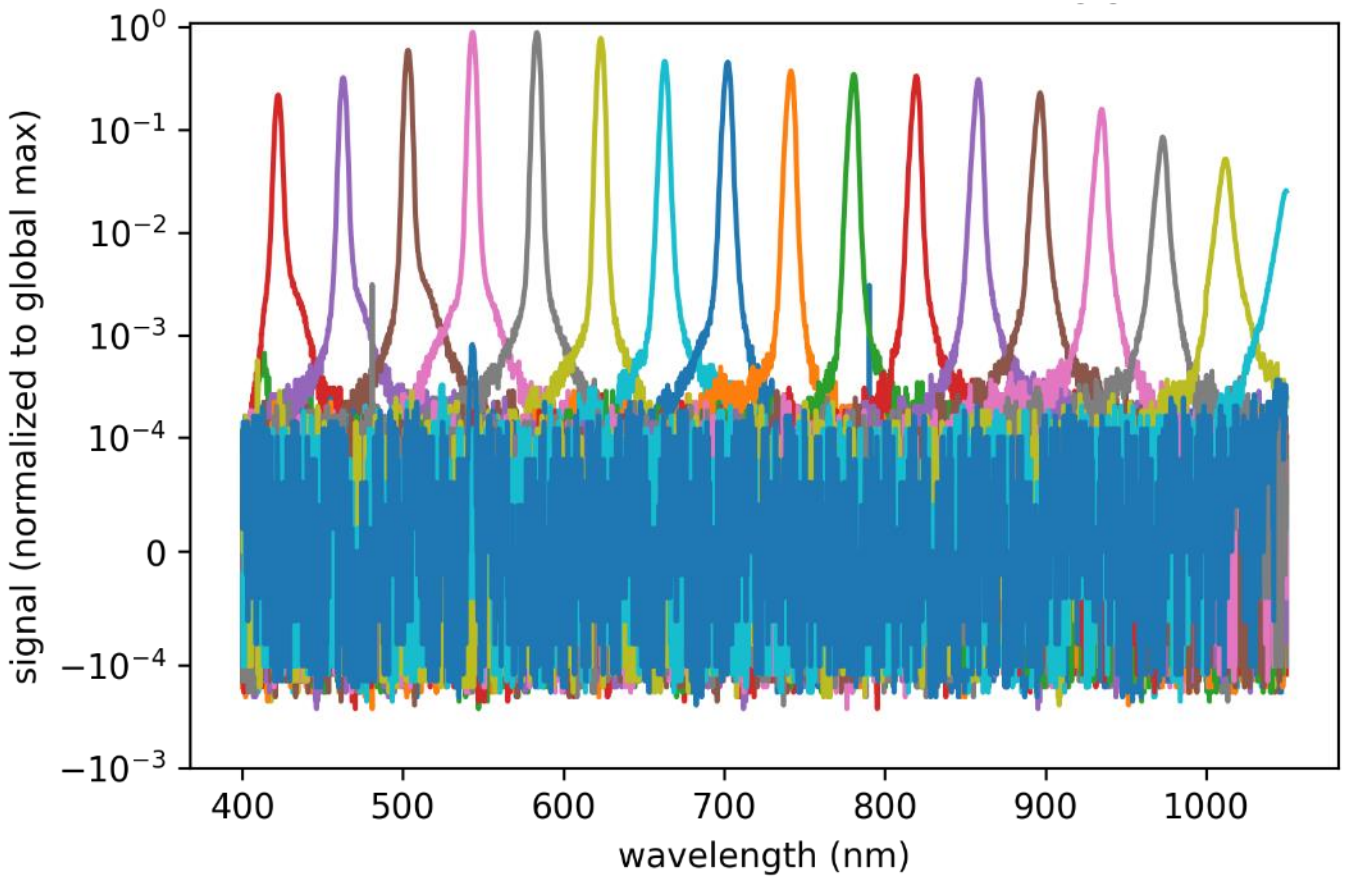


Conclusions

- Radiance responsivities for SIF-measuring instrumentation calculated using a calibrated sphere source and multiple transfer instruments agreed to within < 1 %
- This represents a significant improvement over existing calibration methods and will help to address crucial sources of uncertainty in SIF retrievals, which limit data intercomparison and ground validation of satellite data
- Differences in detector nonlinearity across instruments are still under study and highlight the need for calibration & characterization of all field instrumentation

Future Directions

- Assessment of laser line tuneable filter (LLTF) system for radiance calibrations is in progress
- Creation of field-portable LLTF system
- More linearity testing
- Wavelength calibration
- Stray light characterization



Acknowledgements

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Questions?