Performing tower-based solar induced fluorescence retrievals in the context of physiological, environmental, and hardware-based sources of uncertainty

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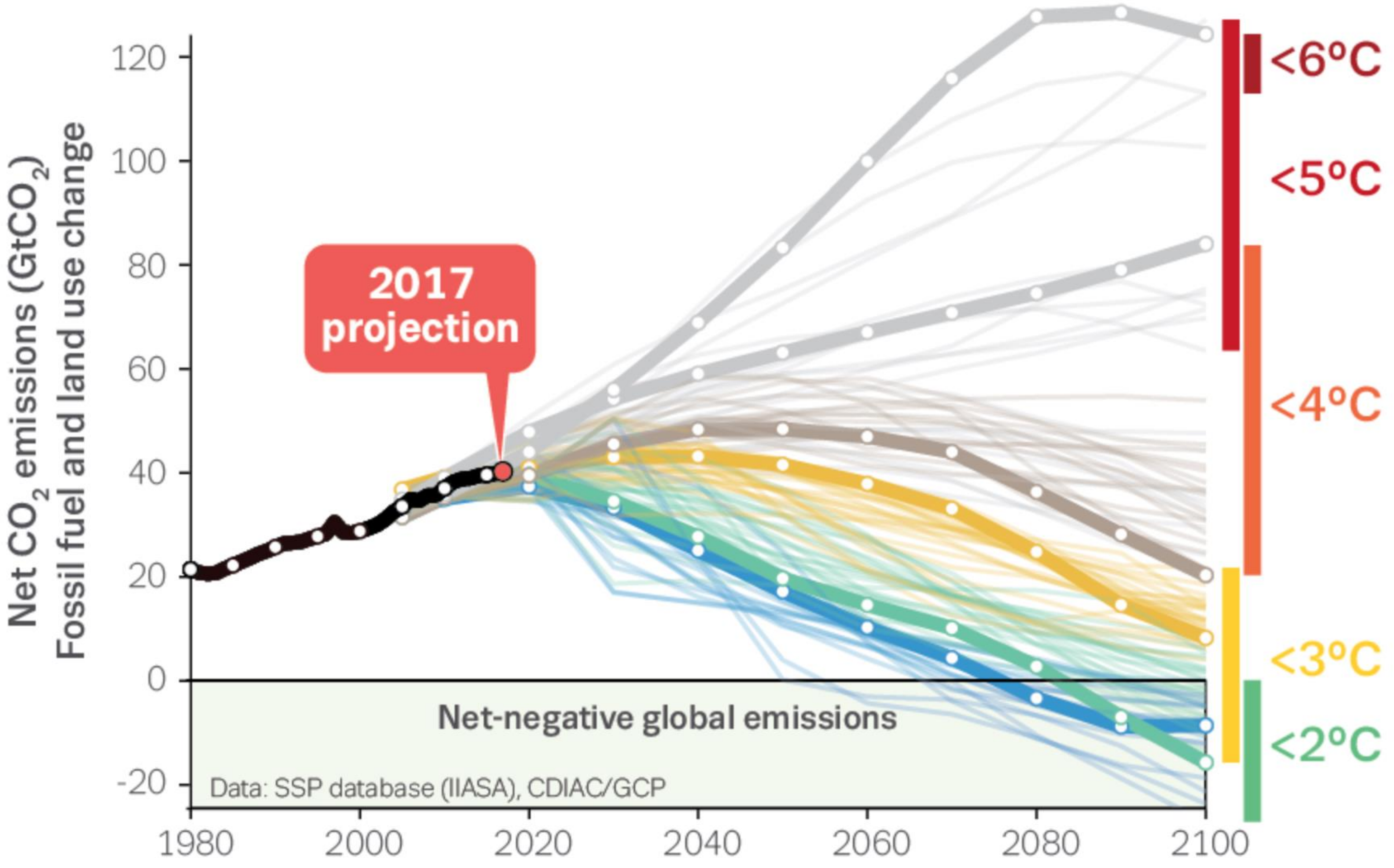
Large but Crucial Uncertainties in Terrestrial C Sink

Often estimated as residual of other terms in carbon budgets

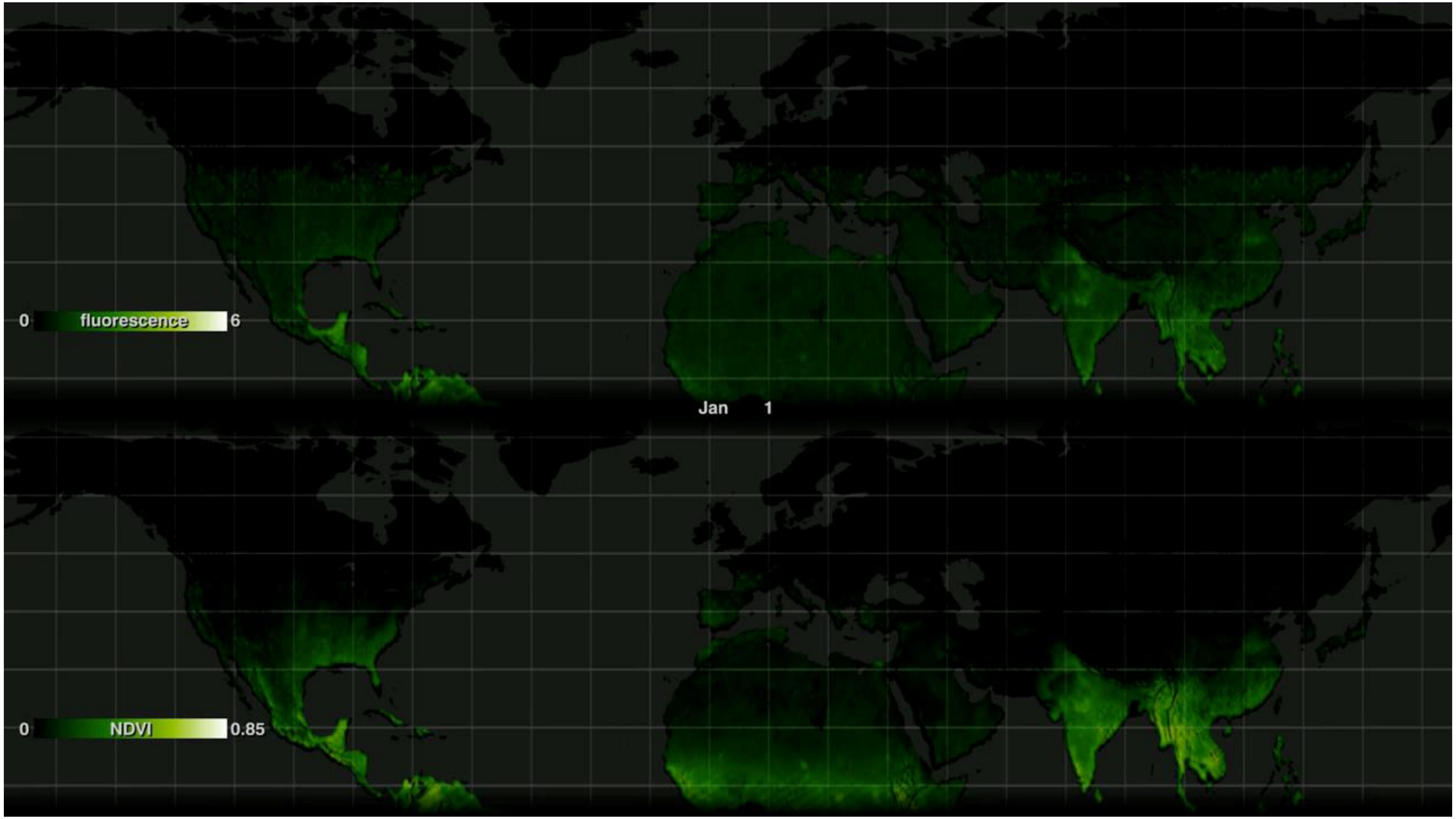
(Le Quéré *et al.* 2013, Peters *et al.* 2012)



Global Carbon Project 2017 Carbon Budget

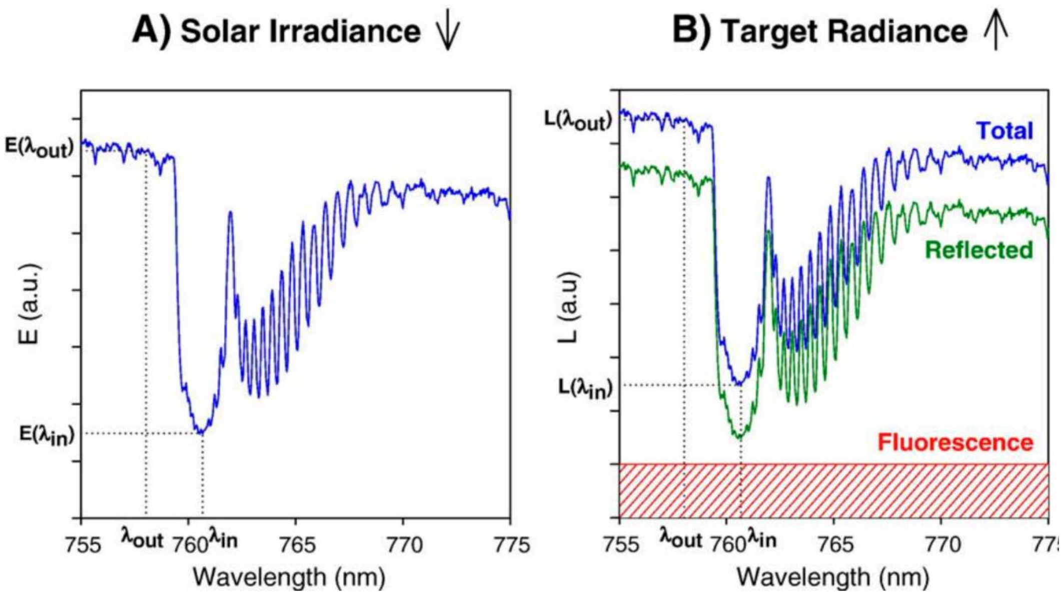
Solar-Induced Fluorescence (SIF)

Fluorescence units: W m^{-2} nm^{-1} sr^{-1}

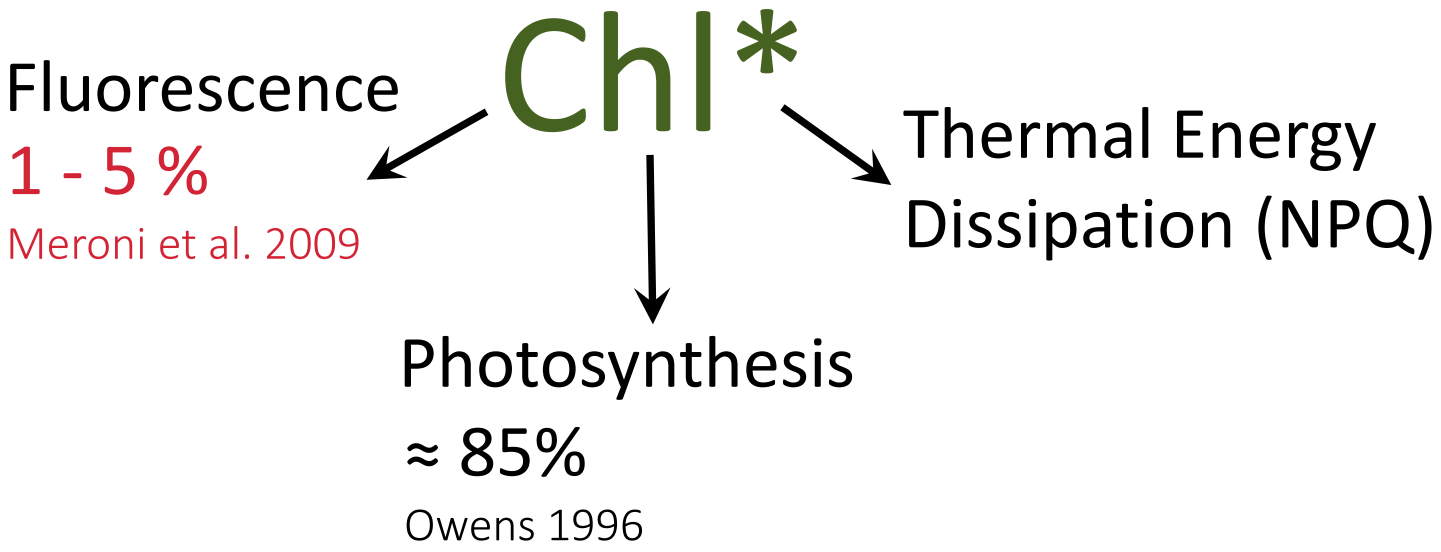


NASA's Goddard Space Flight Center Scientific Visualization Studio

How can we go from the leaf to the satellite?



$$F = \frac{E(\lambda_{out}) \cdot L(\lambda_{in}) - L(\lambda_{out}) \cdot E(\lambda_{in})}{E(\lambda_{out}) - E(\lambda_{in})}$$



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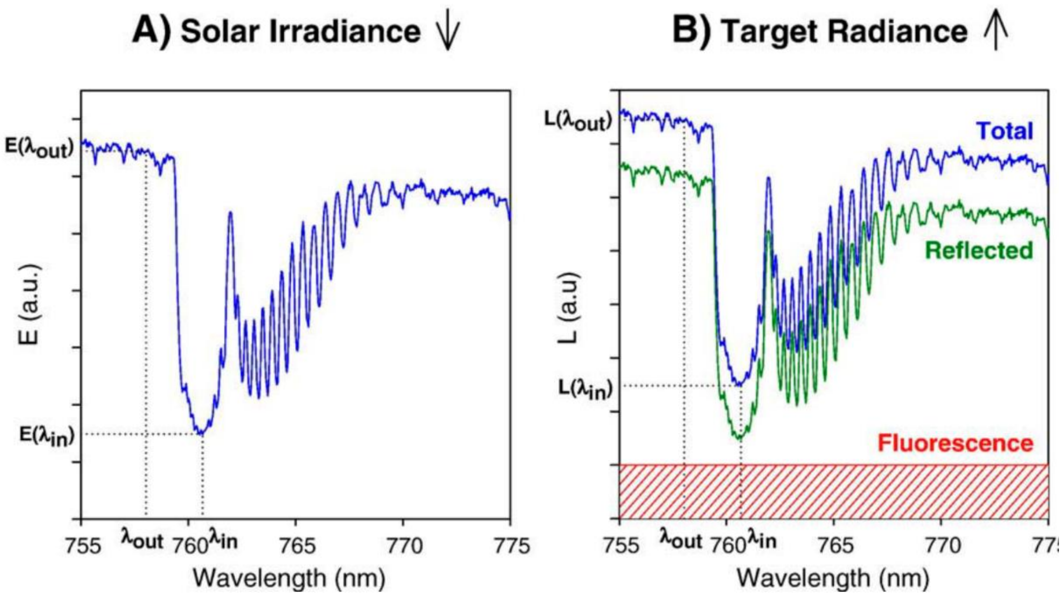


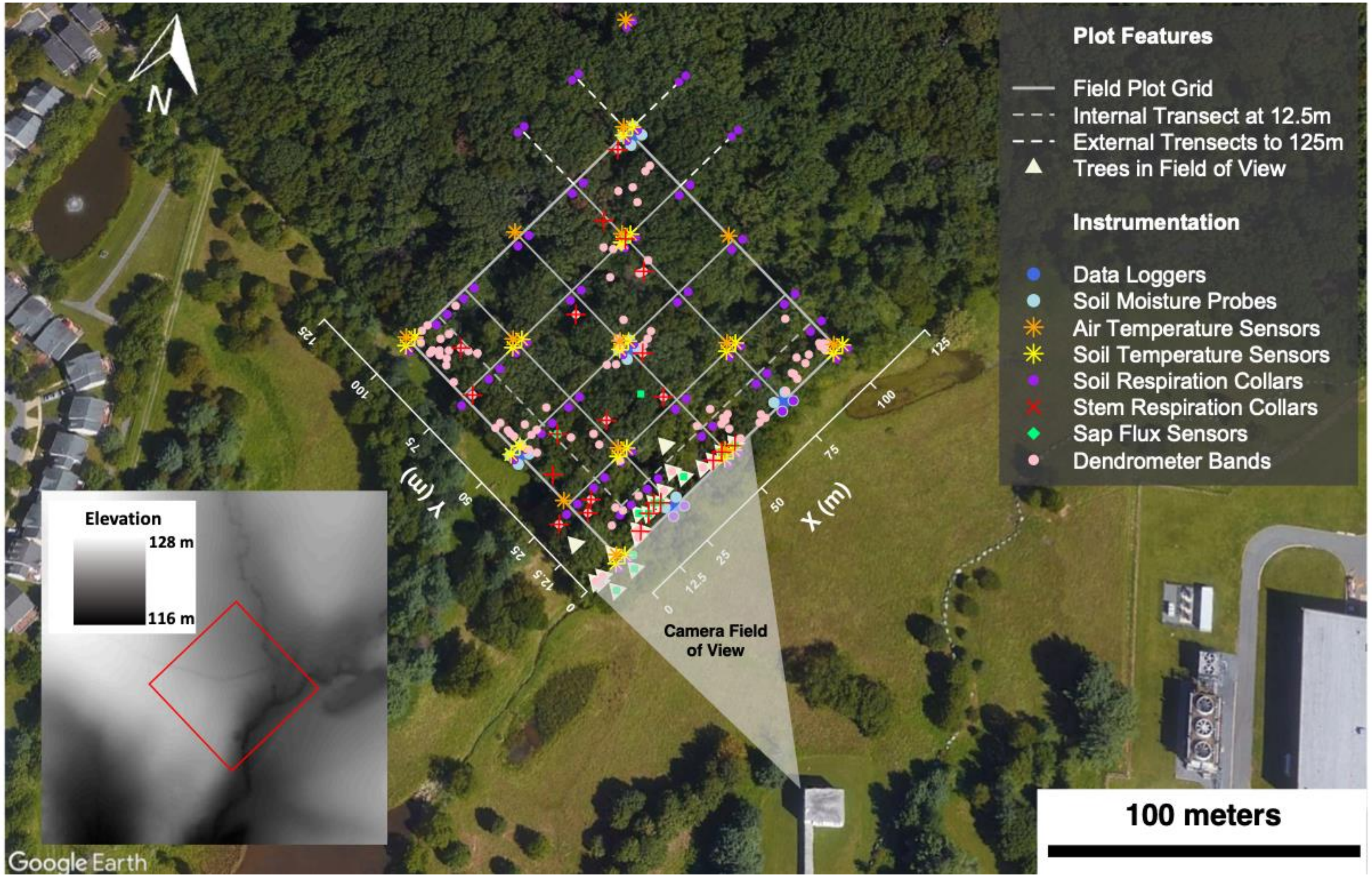
$$F = \frac{E(\lambda_{\text{out}}) \cdot L(\lambda_{\text{in}}) - L(\lambda_{\text{out}}) \cdot E(\lambda_{\text{in}})}{E(\lambda_{\text{out}}) - E(\lambda_{\text{in}})}$$

What are our instrumentation and hardware limitations?

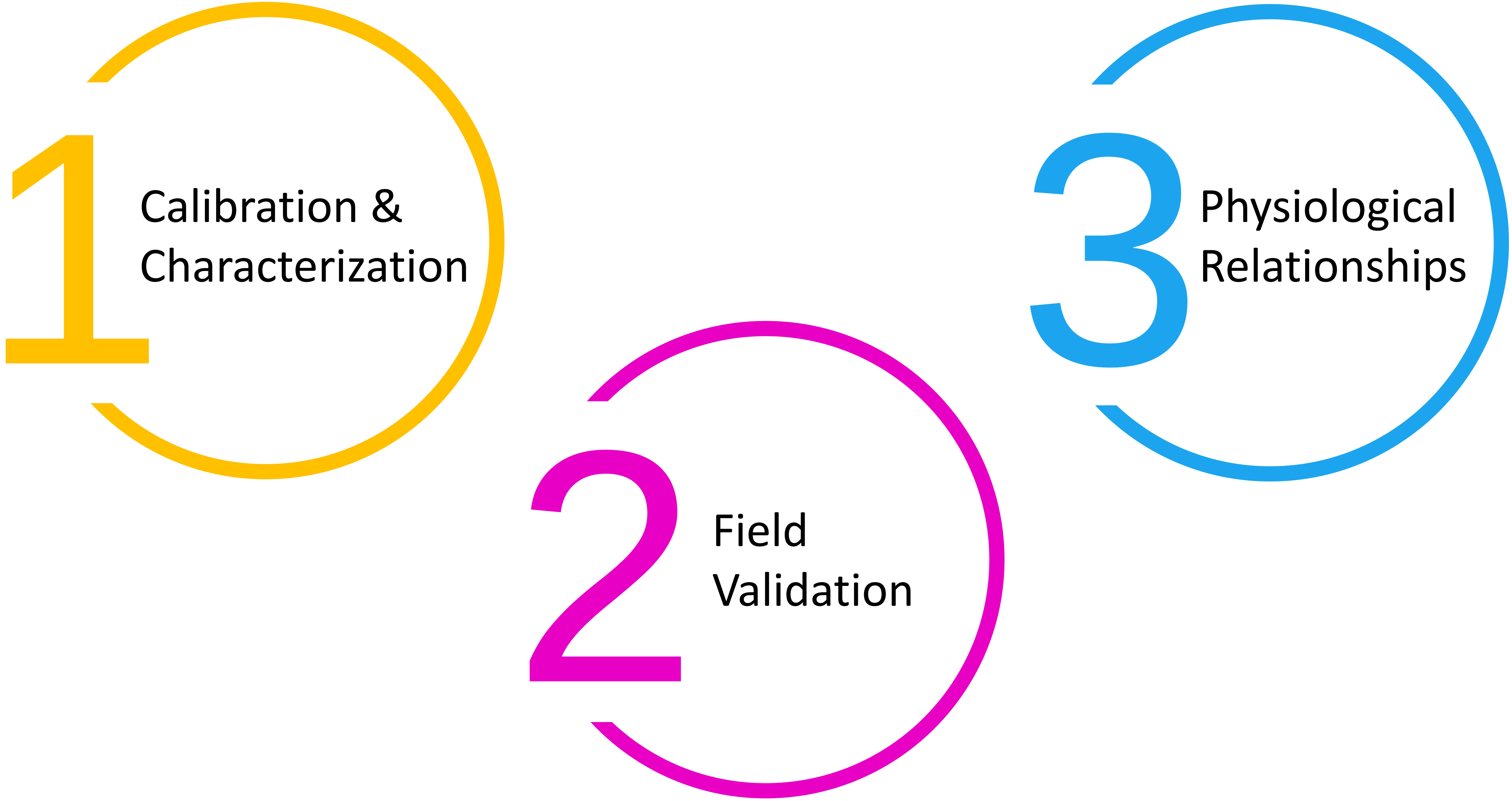
- Detector characterization
- Effects of fore-optics
- Atmospheric corrections
- Measuring physiological signals

Instrumentation & Methods Testbed

Forested
Optical
Reference for
Evaluating
Sensor
Technology



Map: Ian Smith
Imagery: Google Earth


1
Calibration & Characterization
2
Field Validation
3
Physiological Relationships

1 Calibration & Characterization

2 Field Validation

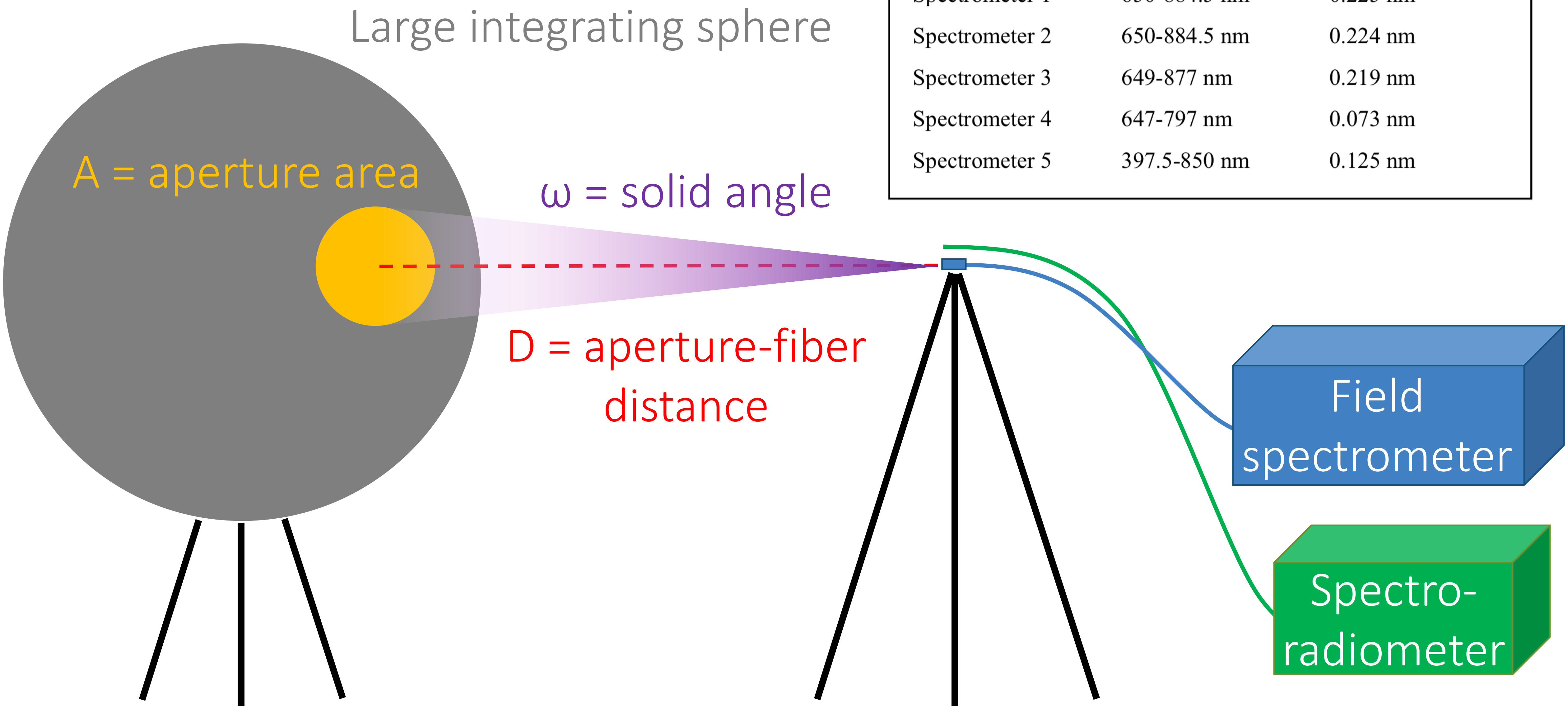
3 Physiological Relationships

Instrument Responsivity

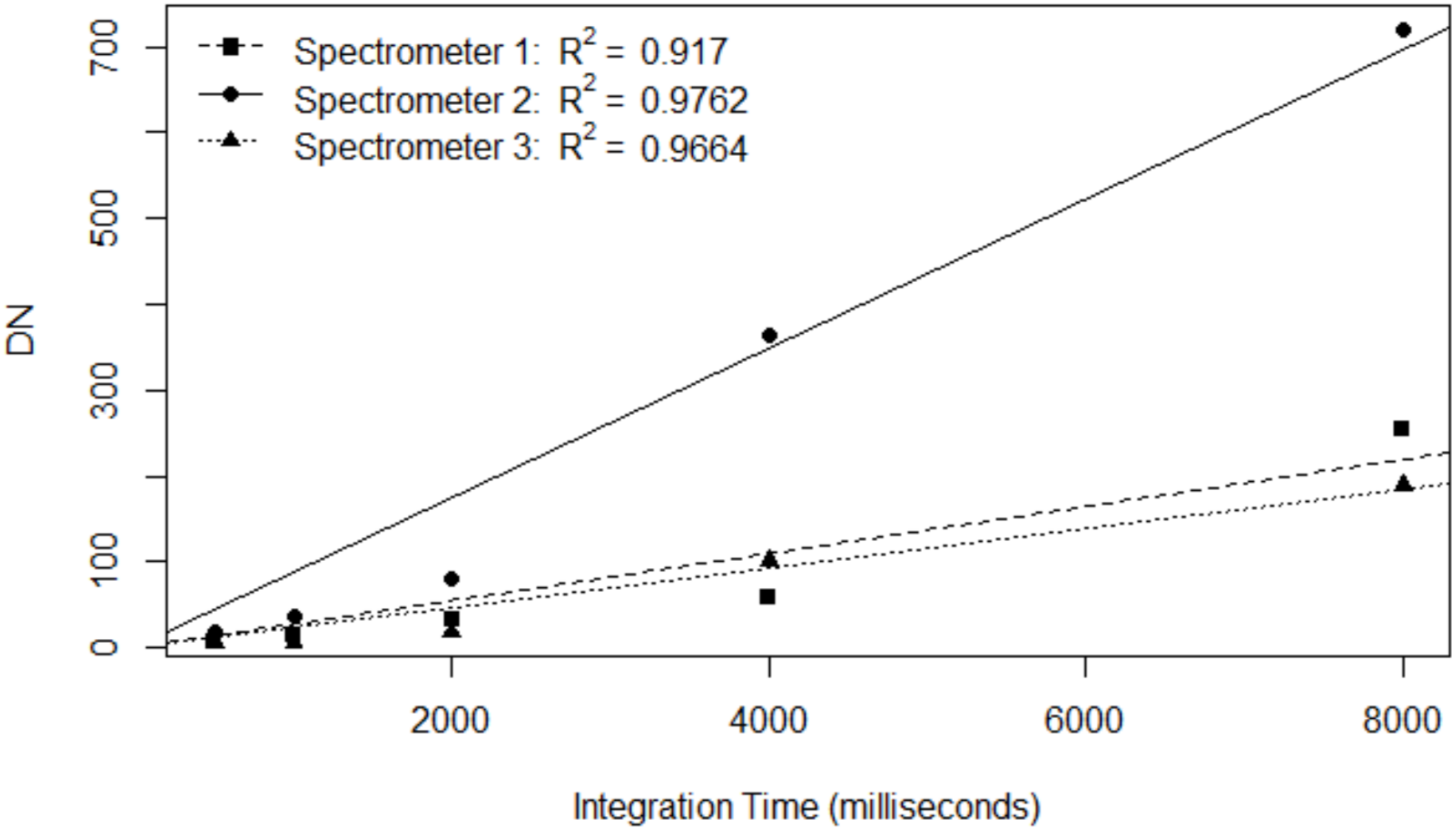
Determine radiometric responsivity by transferring scale from a calibrated spectroradiometer

Instrument Responsivity

Instrument	Spectral Range	Spectral Resolution
Spectrometer 1	650-884.5 nm	0.225 nm
Spectrometer 2	650-884.5 nm	0.224 nm
Spectrometer 3	649-877 nm	0.219 nm
Spectrometer 4	647-797 nm	0.073 nm
Spectrometer 5	397.5-850 nm	0.125 nm

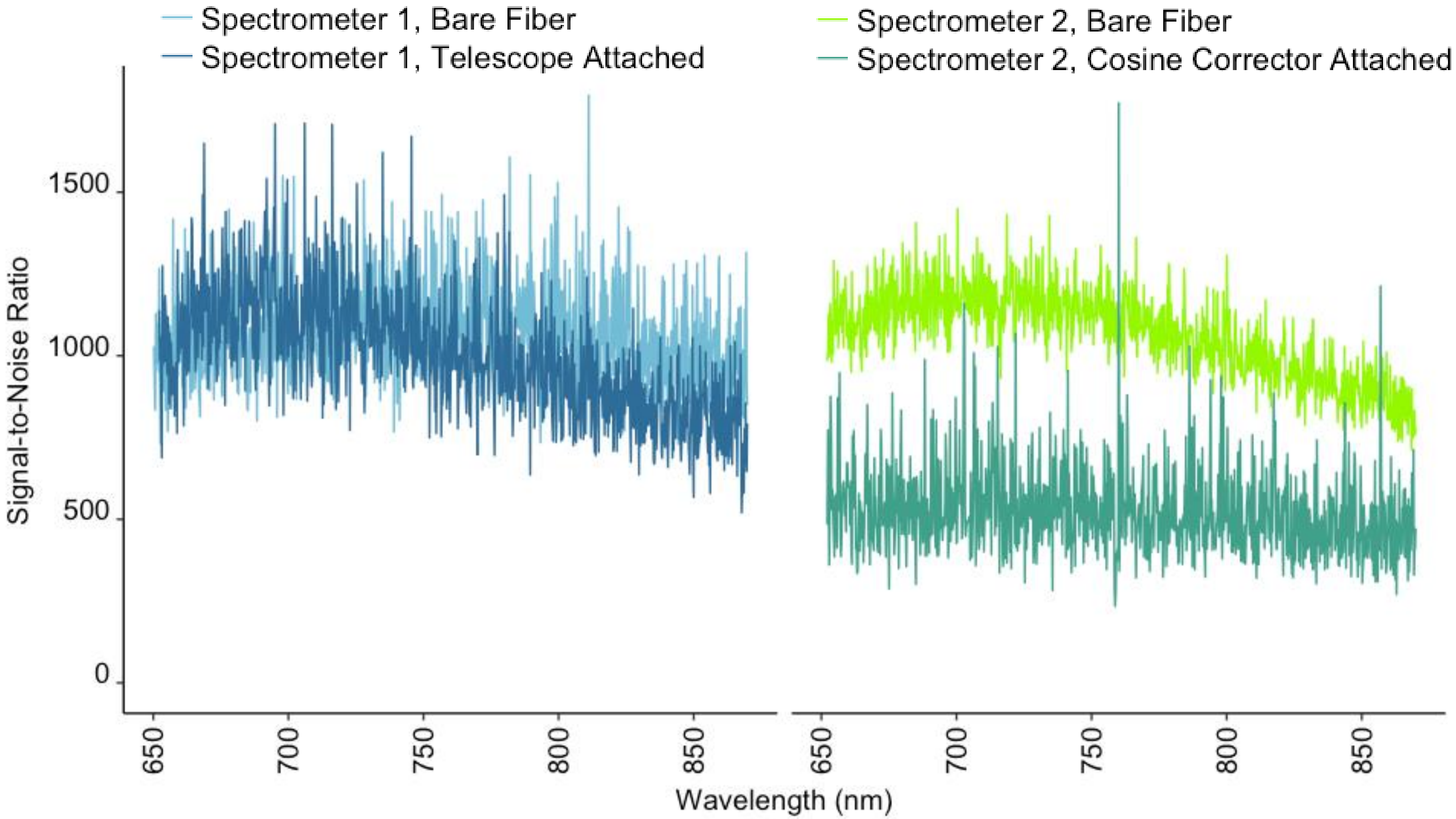


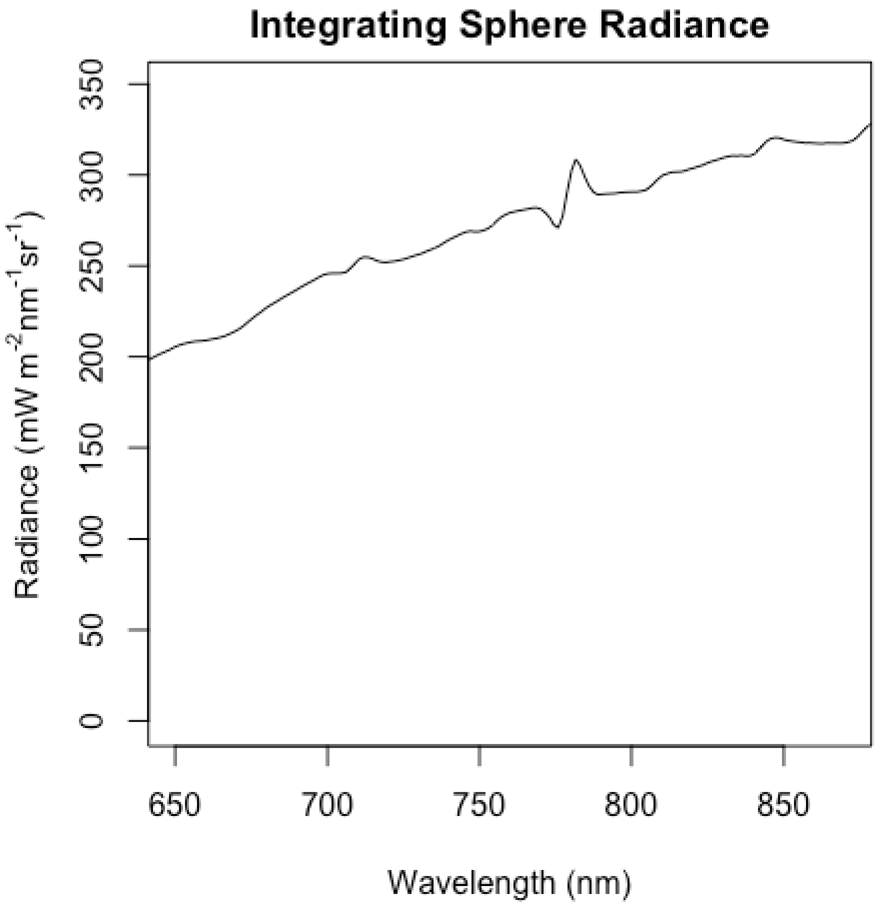
Electronic Dark Current



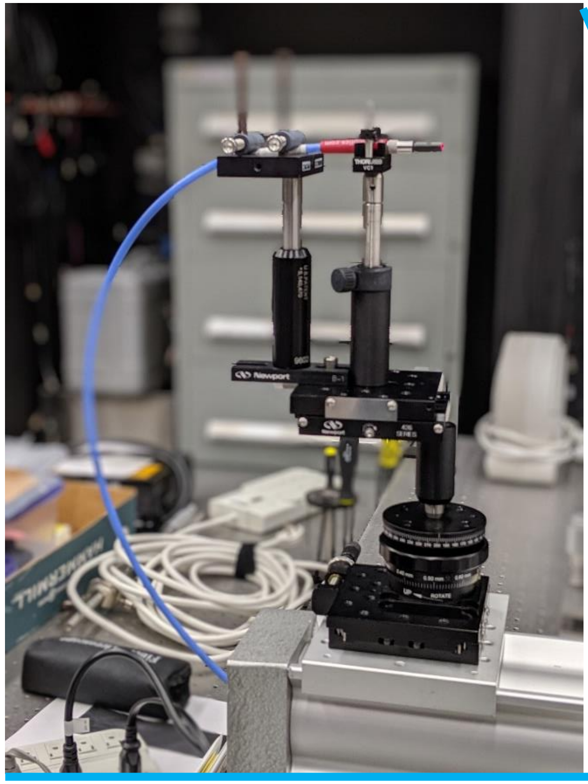
0.1 - 0.4 % change

Signal-to-Noise Ratios: Laboratory

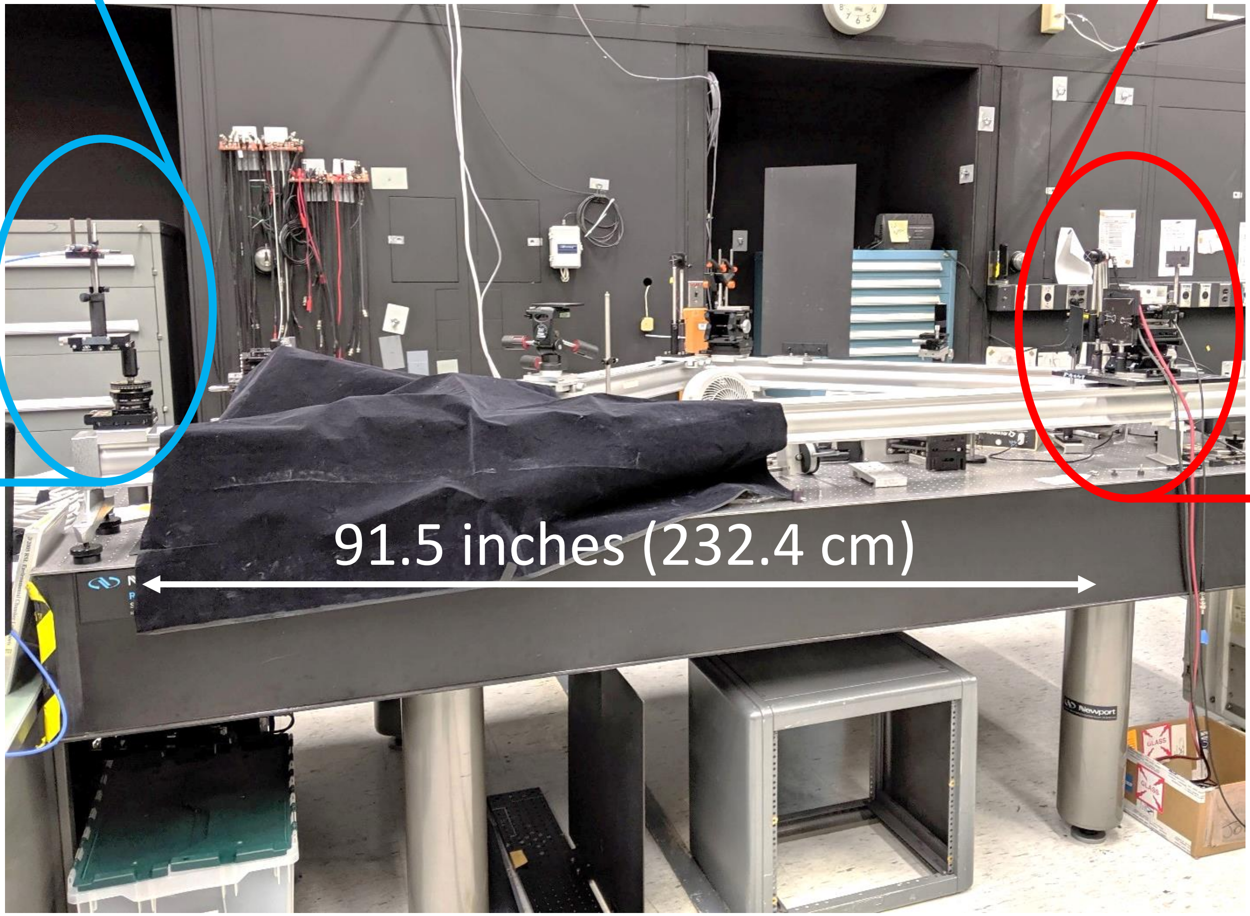


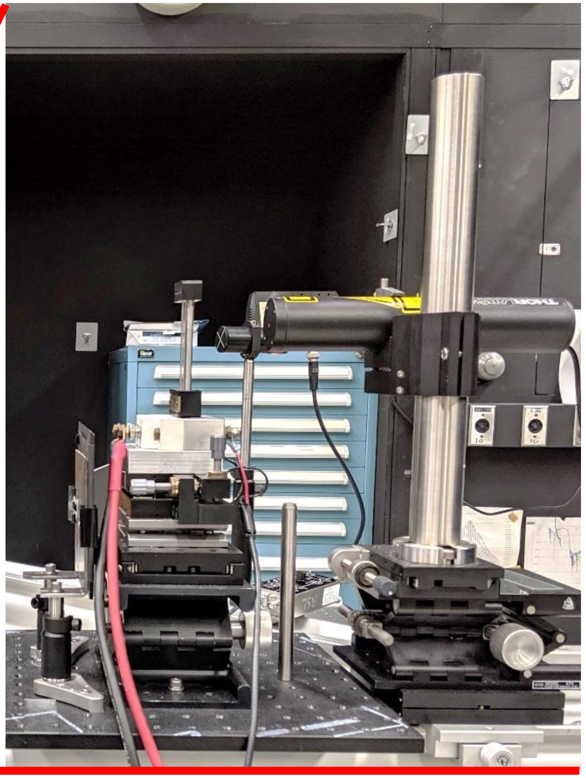


Cosine Corrector Characterization Setup



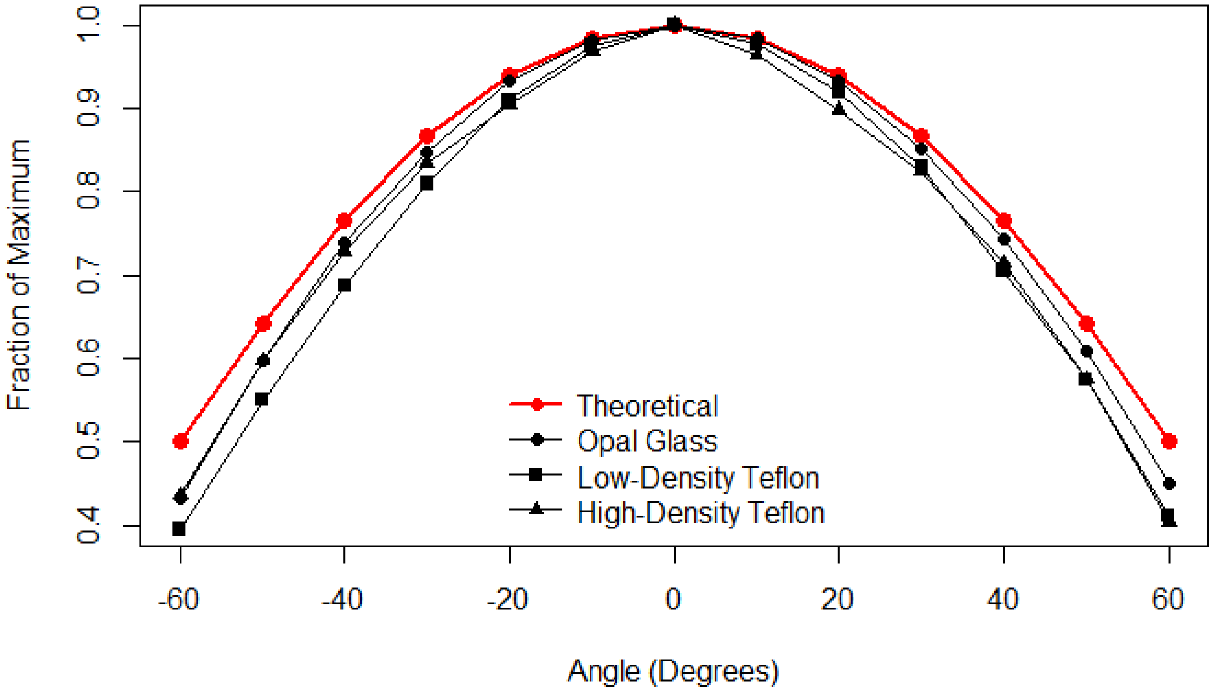
Fiber on stand & rotating stage

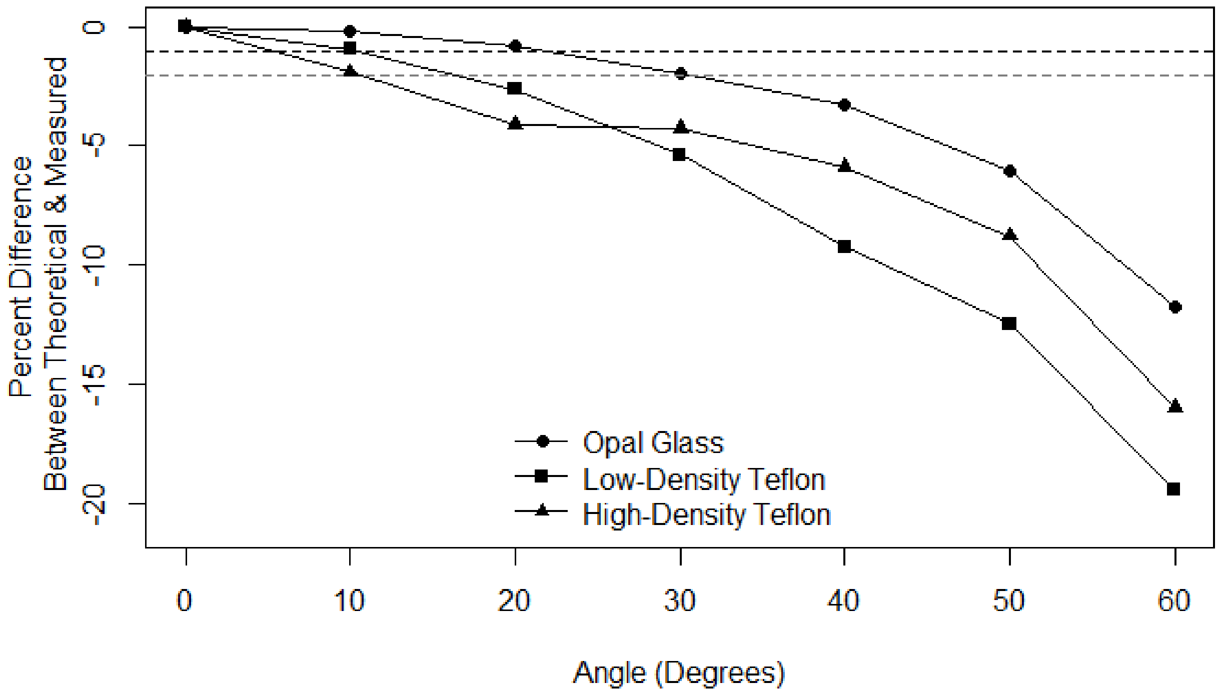




FEL lamp & alignment laser

Cosine Corrector Characterization





1. Calibration & Characterization
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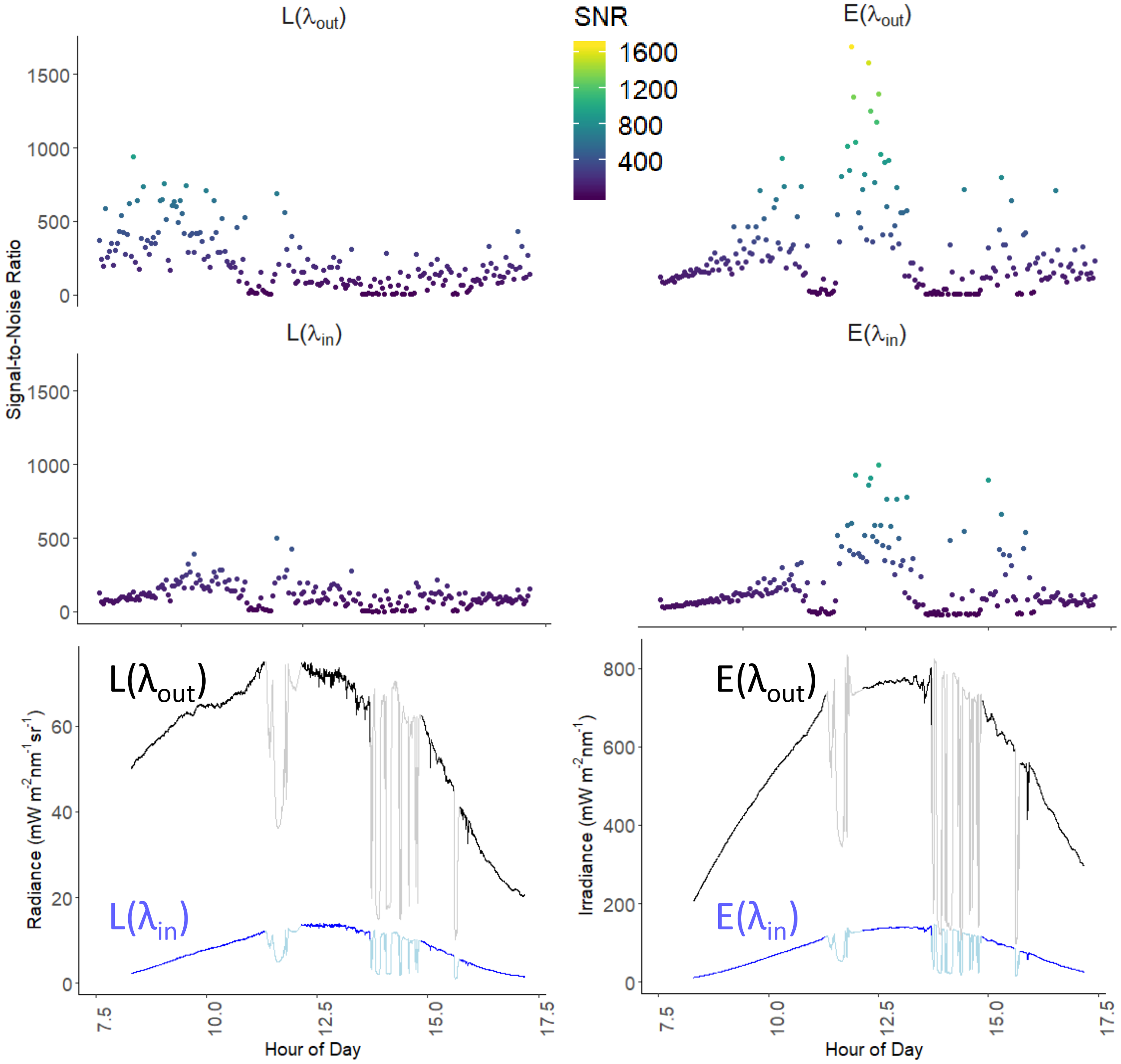
Field SNR / Observed Variability



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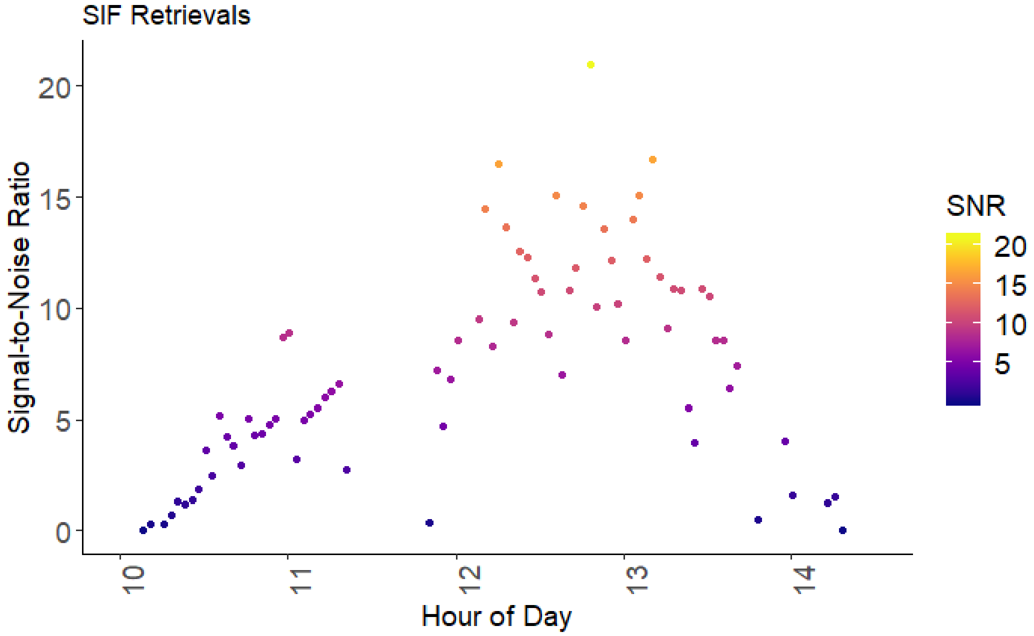
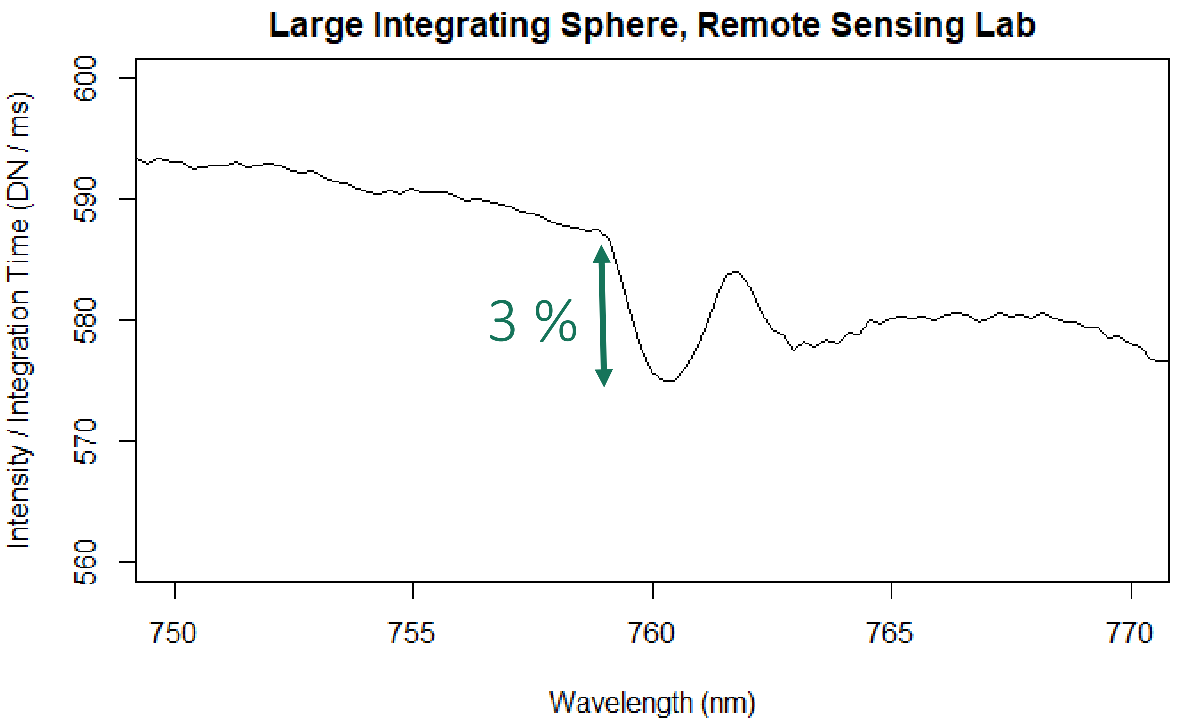
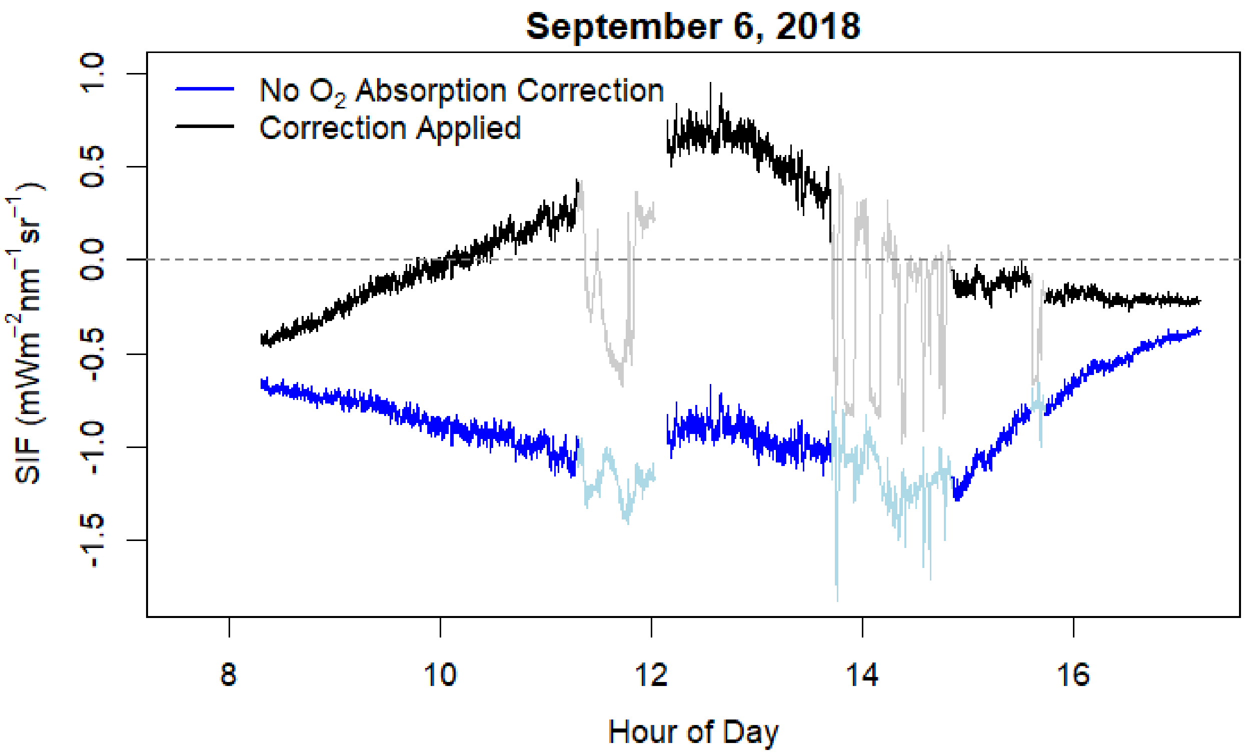
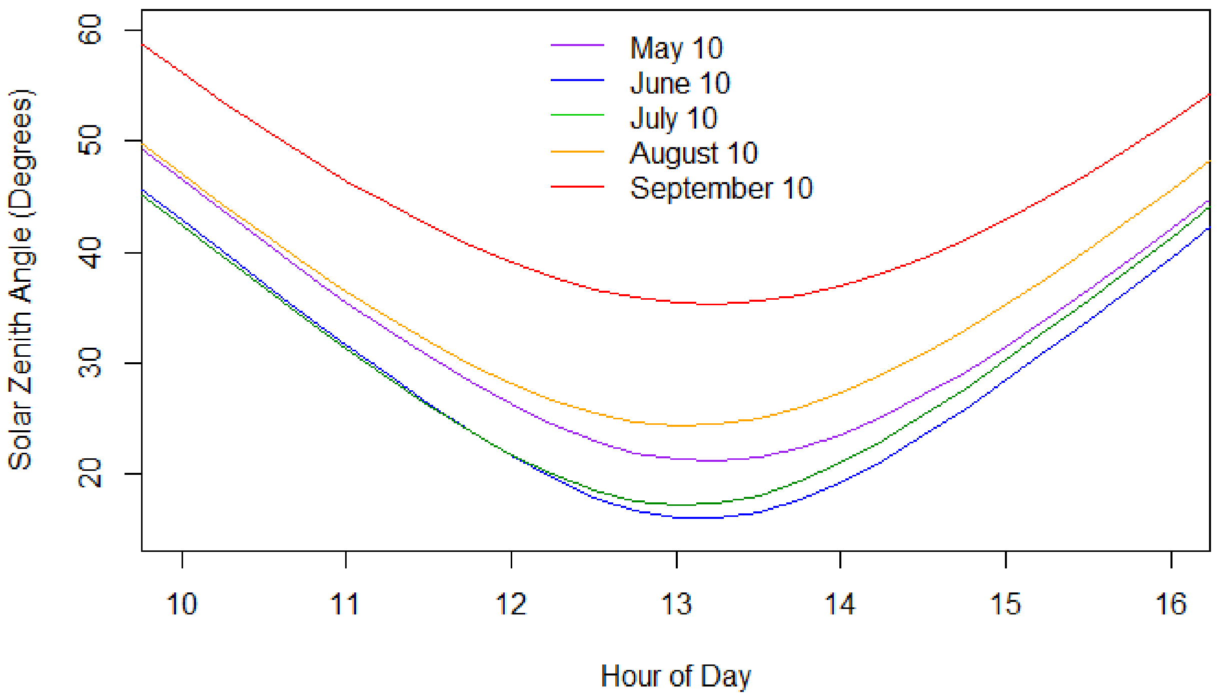


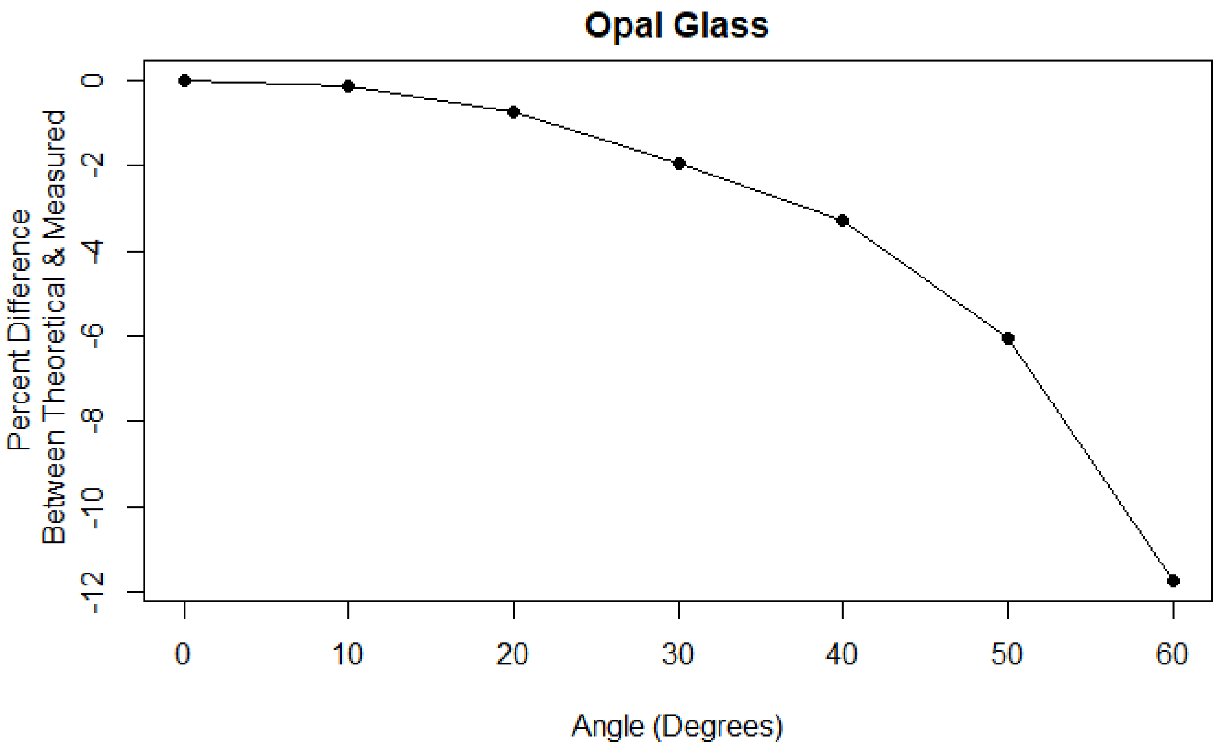
Oxygen Absorption Correction



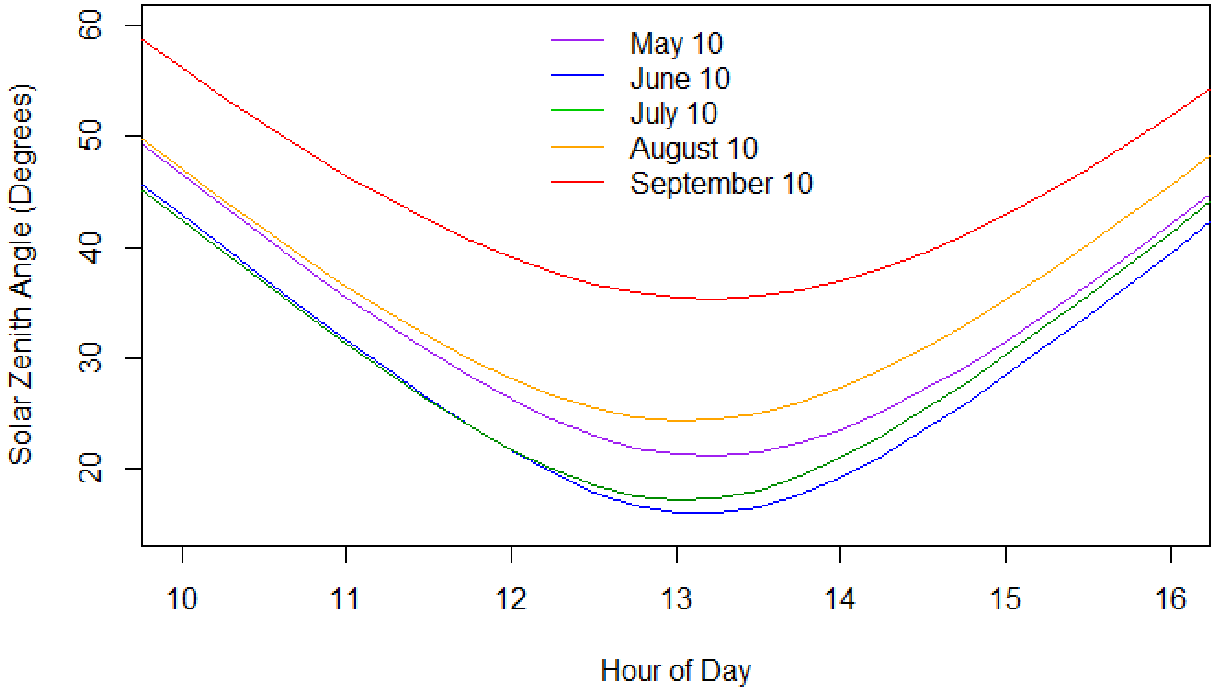


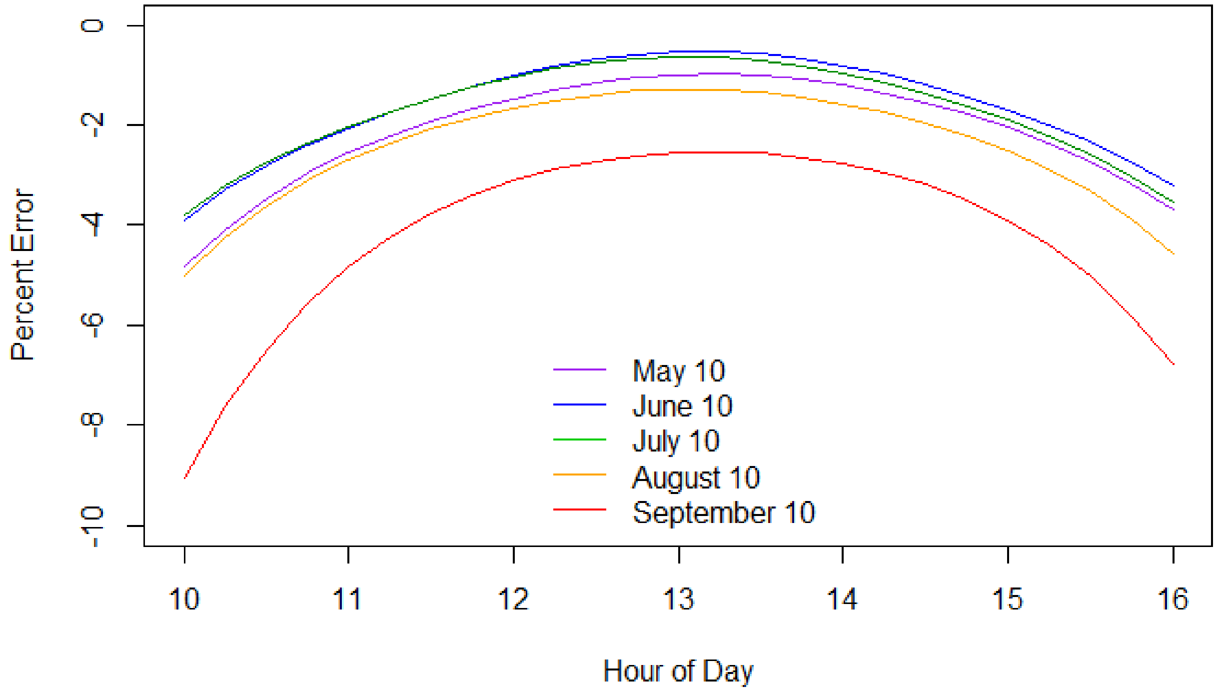
Cosine Corrector Effects in the Field





Cosine Corrector Effects in the Field





1 Calibration & Characterization

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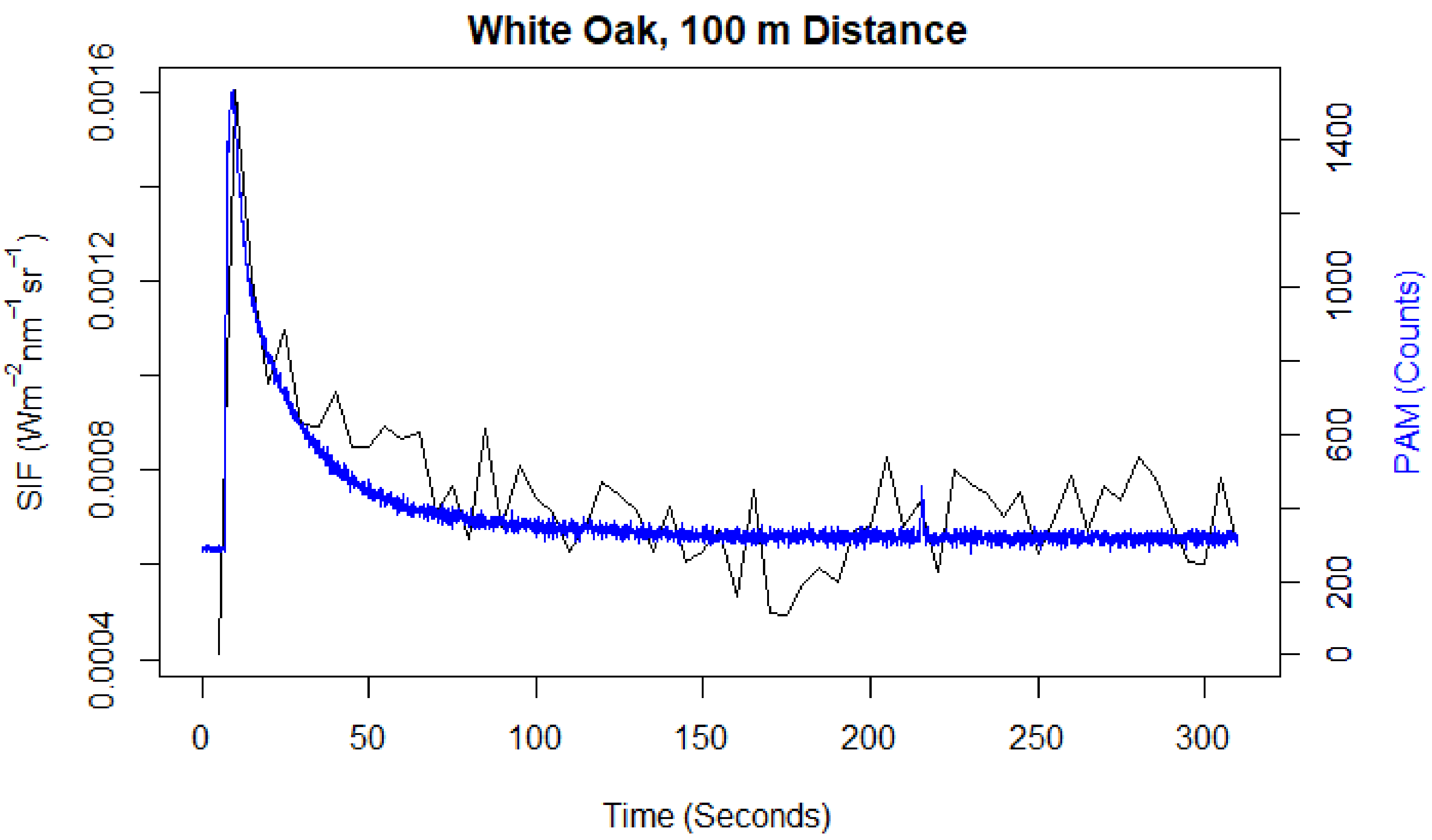
Physiologically Meaningful Signal

- Kautsky effect: spike in fluorescence when dark-acclimated vegetation is exposed to light

- Good agreement between SIF retrievals and pulse-amplitude modulated (PAM) fluorescence at leaf level



Conclusions

1

Variability among instruments, even of the same model, requires characterization

Harmonization among SIF-measuring instruments across scales is crucial

2

Atmospheric O_2 absorption correction has the largest single effect

Special attention needs to be given to SNR in field conditions in order to make robust measurements

3

SIF is a challenging measurement, due to low signal intensity ($\sim 1\ mWm^{-2}nm^{-1}sr^{-1}$)

However, we can successfully measure fluorescence from 100 m distance

Thank you!

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Barry Logan
Jaret Reblin
Carol Johnson
Matthew Boyd
Brian Dougherty

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NIST