# Linking Seasonal Foliar Chemistry to VSWIR-TIR Spectroscopy Across California Ecosystems

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# Acknowledgements


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# Foliar Chemistry

Foliar chemistry provides an insight into the quality of vegetation and nutrient cycles

- Chlorophyll –> Levels of productivity
- Nitrogen -> Indicator of photosynthetic and growth rates
- Lignin -> Rate of litter decomposition

Conventional Methods are time consuming and expensive

Spectroscopy can address these issues through faster analytical speed and minimal sample preparation (Lawler et al., 2006)

# VSWIR Spectroscopy

- Most spectroscopy studies use the Visible Near Infrared/Short Wave Infrared (VSWIR) spectrum
- Plant Biochemical:
  - Nitrogen (Bolster et al. 1996; Doughty et al 2009; Ferwerda et al., 2005; Martin et al. 2008)
  - Lignin and Cellulose (Kokaly and Clark, 1992; Asner et al., 2011; Kokaly et al., 2009)
  - Chlorophyll (Ustin et al., 2009; Doughty et al 2009; Martin et al.,2007; Asner et al., 2011 )
- Plant Biophysical: Specific Leaf Area, Water Content
  - (Ceccato et al., 2001; Doughty et al., 2009; Martin et al., 2007; Asner et al., 2011)
- However, dominated by water and pigment absorption (Ribeiro da Luz and Crowley, 2010)

# Spectroscopy using TIR

- Thermal Infrared (TIR) spectrum (2.5 to 15.4 µm) can answer some questions about plant characteristics
- Plants show spectral diversity in TIR
  - (Ullah et al., 2012; Ribeiro da Luz and Crowley 2010; Salisbury and Milton, 1988)
- Spectra features of cellulose, cutin, xylan, silica, and oleanolic acid present (Ribeiro da Luz and Crowley 2007)
- Increased resolution is increasing possibilities

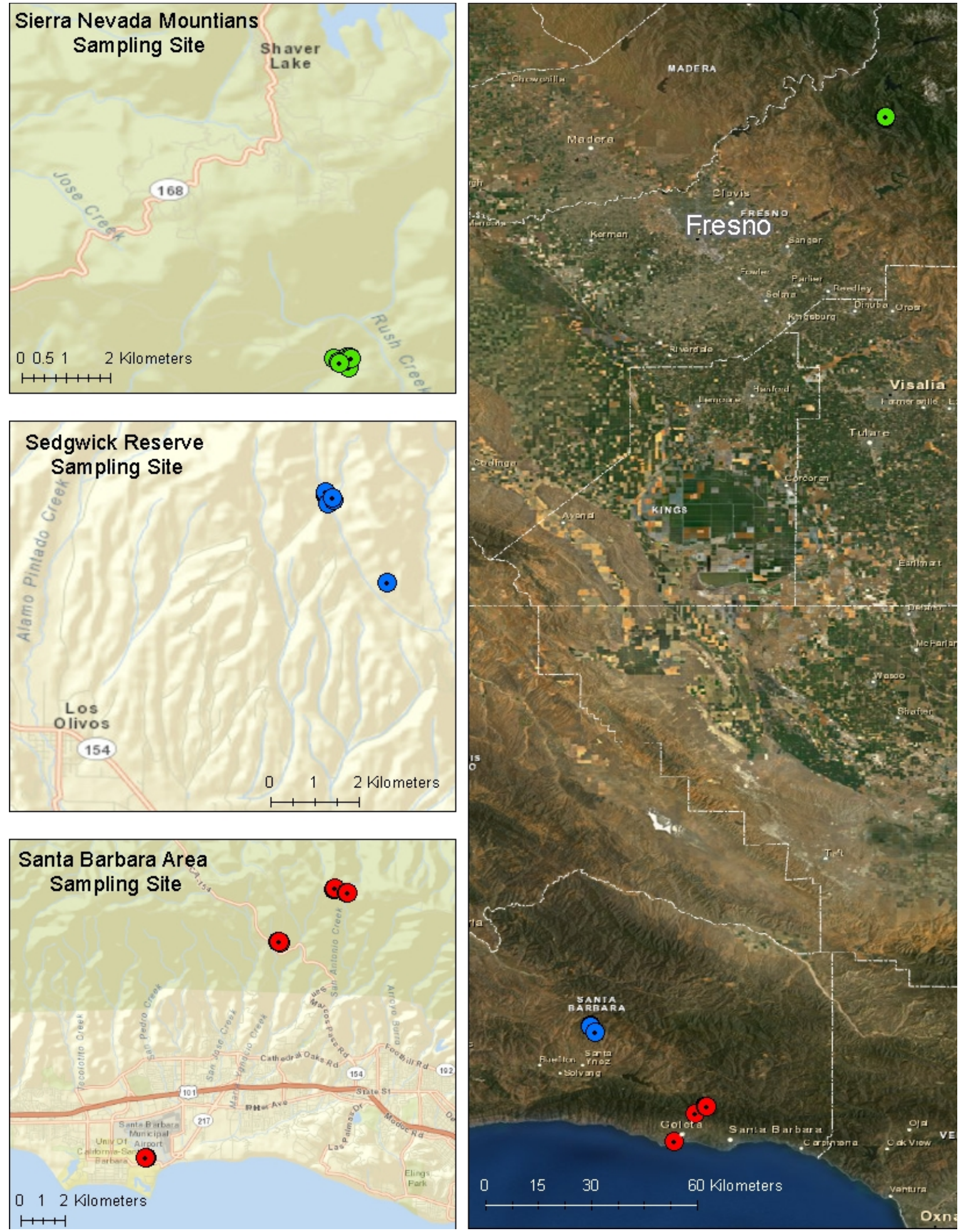
- Integrating VSWIR and TIR
  - Limited knowledge on synergies
  - HyspIRI Preparatory Flights with AVIRIS and MASTER

# Research Questions:

- Are biochemical properties of plant species distinguishable in the TIR spectrum?
- Do synergies between VSWIR and the TIR spectrum improve analysis of biochemical properties?

# Study Sites:

- **Sierra Nevada Mountains:**
  - Elevation: 1400 m
- **Sedgwick Reserve:**
  - Elevation: 400 m
- **Santa Barbara Area:**
  - Elevation: 5 to 1080 m



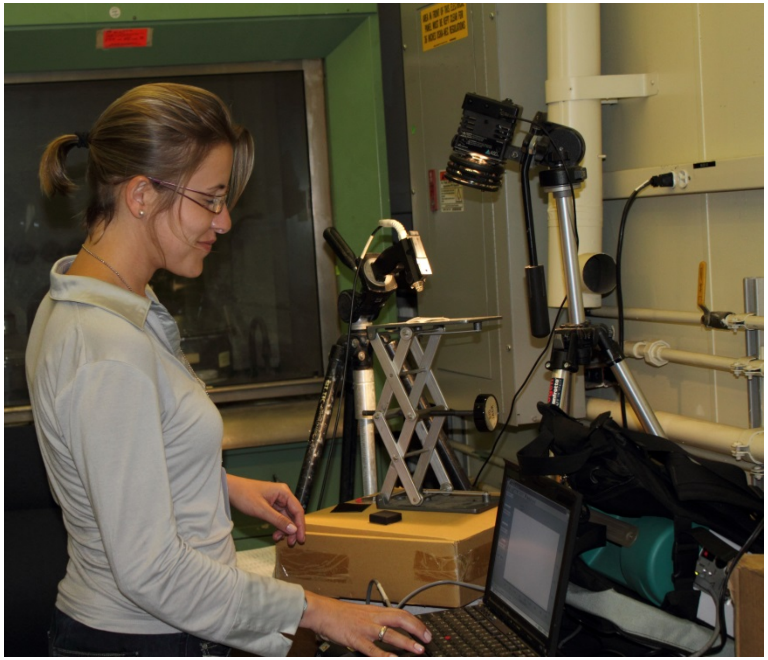
# Sampling:

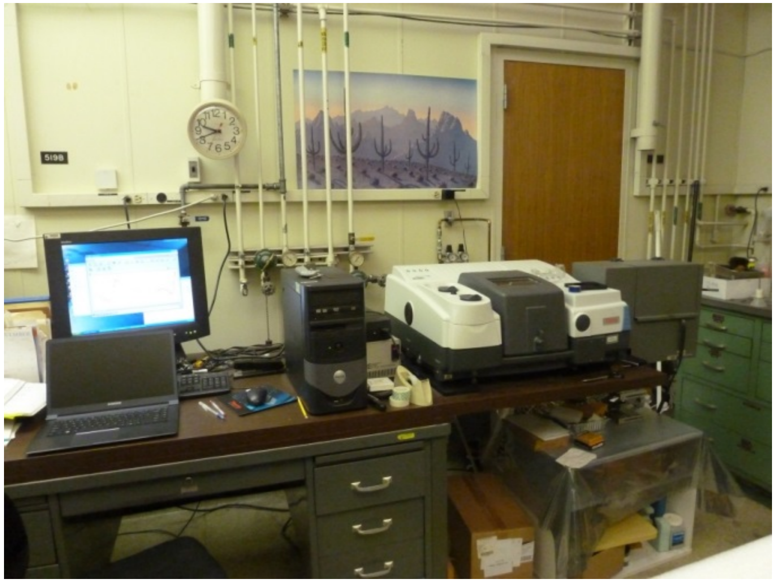
- 16 Species
- 3 Replications
- Young and Old Leaf Sample
- Spring:
  - Santa Barbara: 4/1/13
  - Sierra Nevada: 4/20/13
  - Sedgwick Reserve: 4/21/13
- Summer:
  - Santa Barbara: 6/3/13
  - Sierra Nevada: 6/8/13
  - Sedgwick Reserve: 6/9/13

| Species | Common Name | Abb. |
|---|---|---|
| *Adenostoma fasciculatum* | Chamise | ADFA |
| *Arctostaphylos glandulosa* | Manzanita | ARGL |
| *Baccharis pilularis* | Coyote brush | BAPI |
| *Ceanothus cuneatus* | Buck-brush Ceanothus | CECU |
| *Ceanothus megacarpus* | Big-pod Ceanothus | CEME |
| *Ceanothus spinosus* | Green-bark Ceanothus | CESP |
| *Heteromeles arbutifolia* | Toyon | HEAR |
| *Umbellularia californica* | Bay laurel | UMCA |
| *Abies concolor* | White Fir | ABCO |
| *Pinus lambertiana* | Sugar Pine | PILA |
| *Pinus ponderosa* | Ponderosa Pine | PIPO |
| *Calocedrus decurrens* | Incense cedar | CADE |
| *Quercus agrifolia* | Coast live oak | QUAG |
| *Quercus douglasii* | Blue Oak | QUDO |
| *Quercus lobata* | Valley Oak | QULO |
| *Salvia leucophylla* | Purple Sage | SALE |

# Spectroscopy

- NASA Jet Propulsion Lab
- Thermal Spectrum
  - Nicolet
  - 2.5 µm to 15.4 µm
- VSWIR
  - Analytical Spectra Devices
  - 0.35 µm to 2.5 µm





# Data Collected

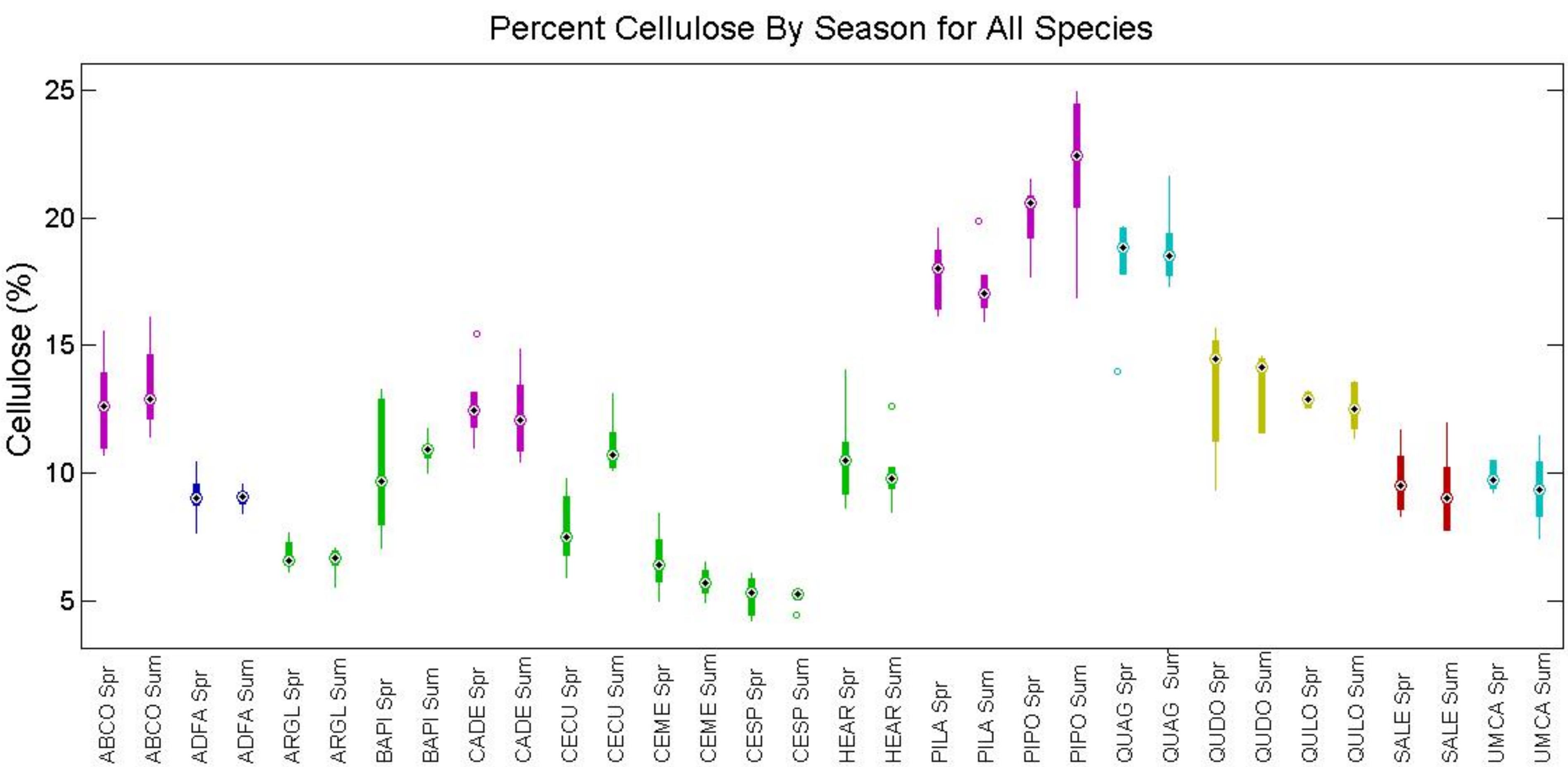
- Lignin and Cellulose: Ankom Fiber Analyzer
- Nitrogen: Combustion Method using NA 1500 Nitrogen and Carbon analyzer
- Pigments: Processed by UC Davis*
- Specific Leaf Area*
- Leaf Thickness*
- Relative Water Content*

* Future Topics



# PLS Regression

- Used in many spectroscopy studies
  - Nitrogen, Lignin, and Cellulose in the NIR (Bolster et al. 1996)
  - Leaf Mass Area, Nitrogen, Pigments, and Carotenoids in the VSWIR (Doughty et al., 2010)
  - Pigments, Carotenoids, LMA, Water, Nitrogen, Cellulose, Lignin, Tannins, Phosphorous, Potassium, and Zinc (Asner et al., 2011)
- Models a response variable when there are a large number of predictor variables
- Creates components as linear combinations of predictors
- Unique because response variables are taken into account
- Determine Number of Components:
  - Smallest RMSE
  - Highest Percent Variation Explained
  - Smallest Number of Components

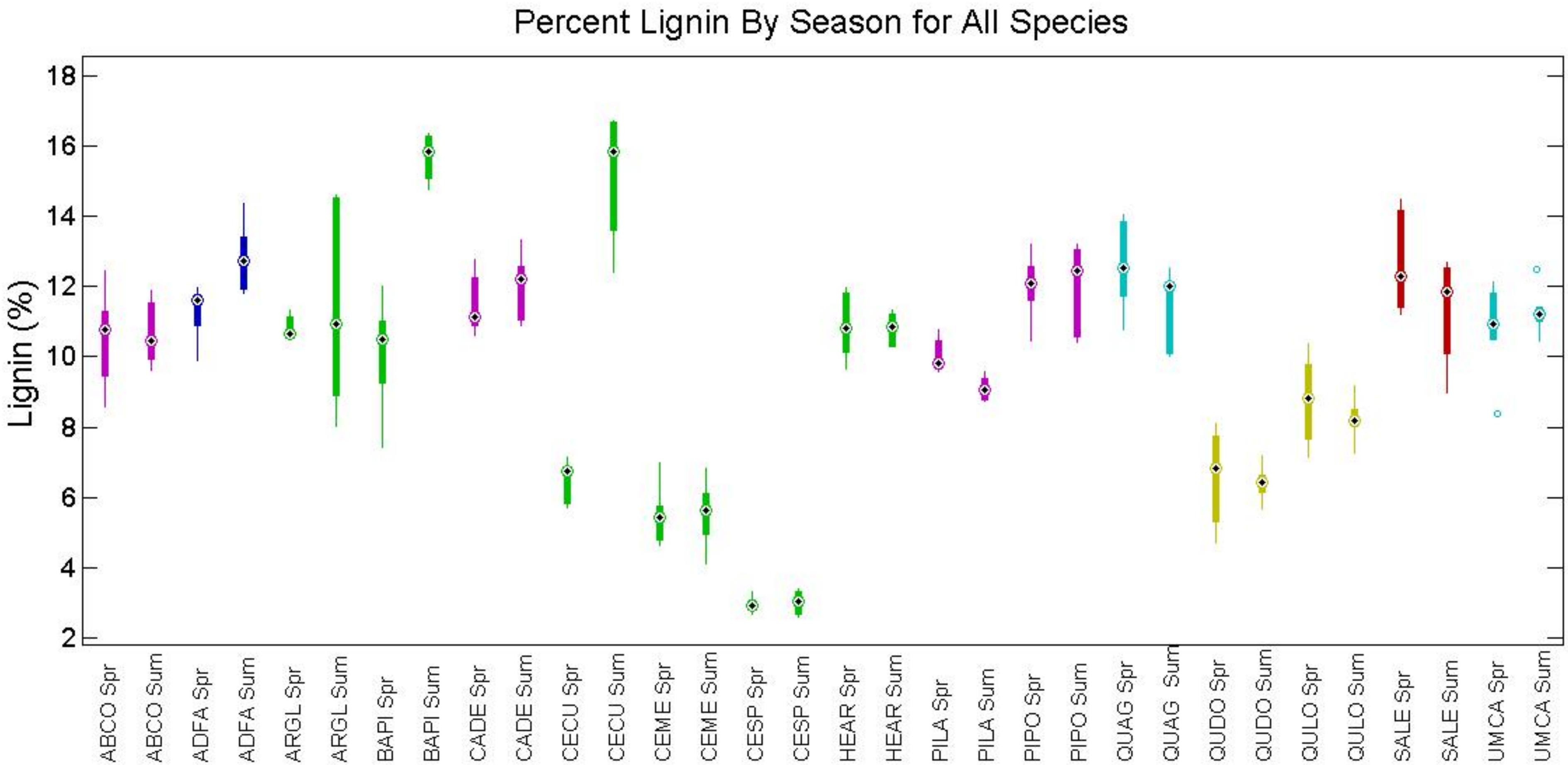



**Broadleaf Deciduous Shrub** **Broadleaf Evergreen Tree**

**Broadleaf Deciduous Tree** **Needleleaf Evergreen Shrub**

**Broadleaf Evergreen Shrub** **Needleleaf Evergreen Tree**

Statistically Significant ($p<0.05$) between Seasons: CECU

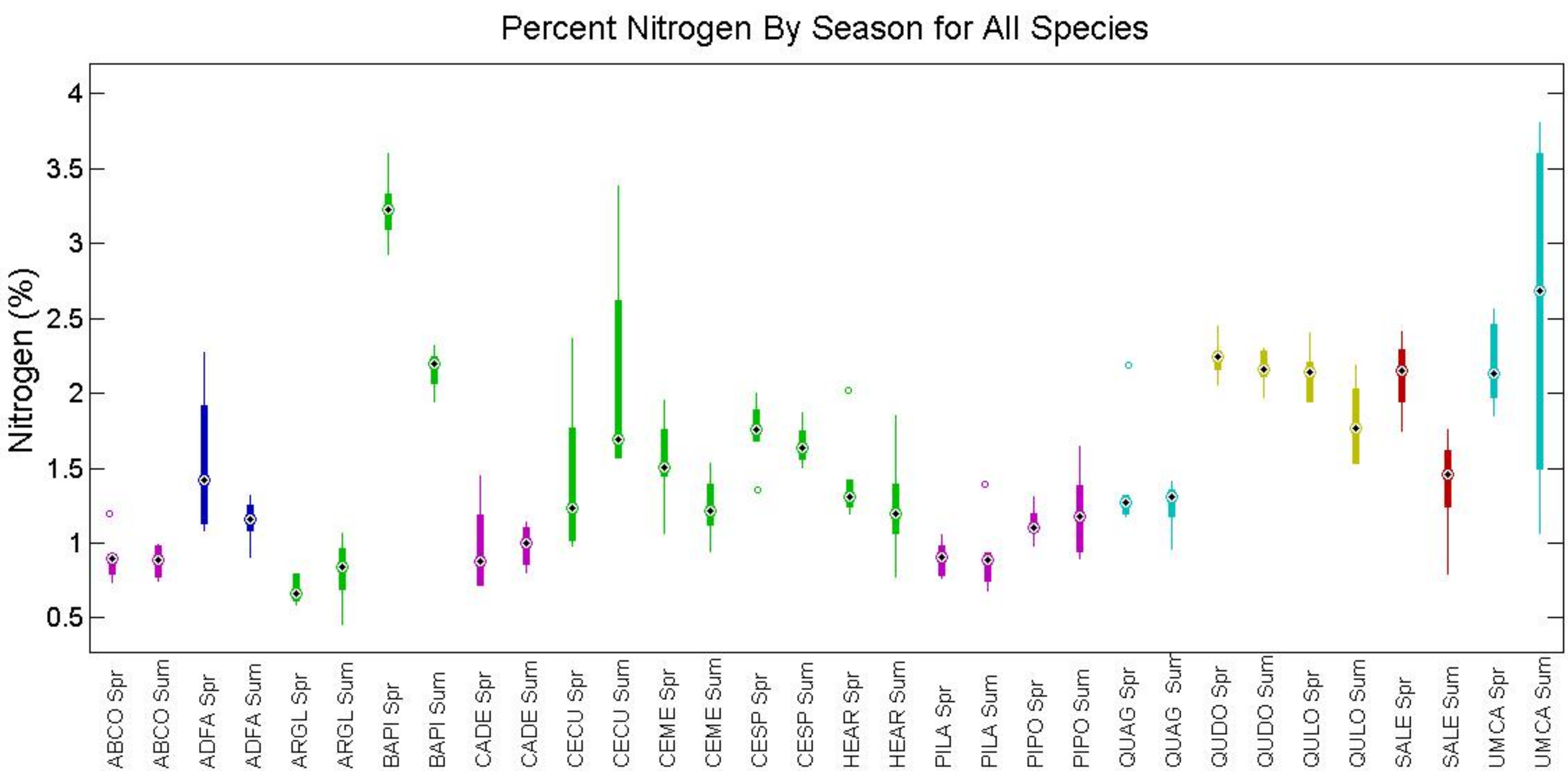



**Broadleaf Deciduous Shrub** **Broadleaf Evergreen Tree**

**Broadleaf Deciduous Tree** **Needleleaf Evergreen Shrub**

**Broadleaf Evergreen Shrub** **Needleleaf Evergreen Tree**

Statistically Significant ($p < 0.05$) between Seasons: ADFA, BAPI, CECU,PILA



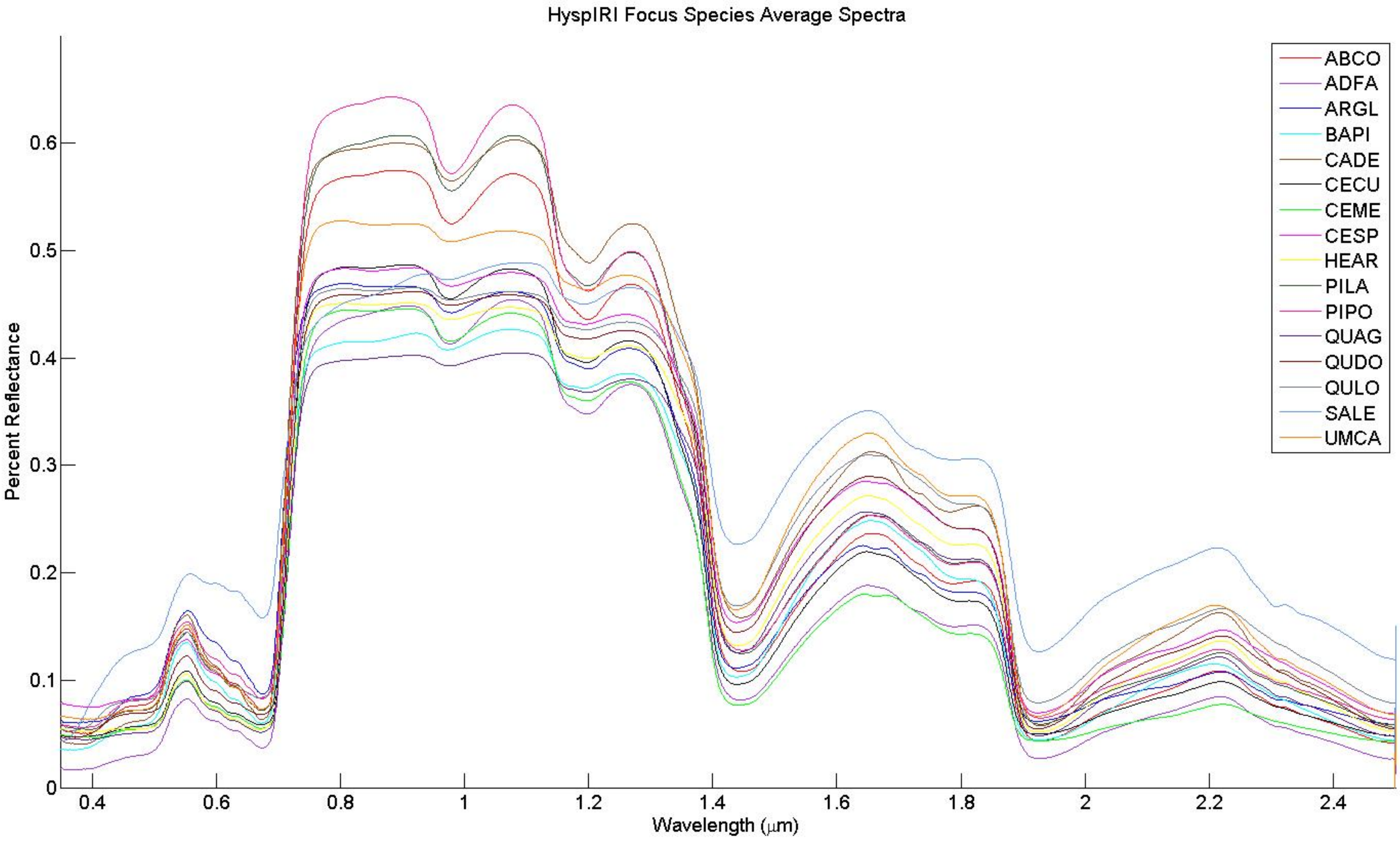

**Broadleaf Deciduous Shrub** | **Broadleaf Evergreen Tree**

**Broadleaf Deciduous Tree** | **Needleleaf Evergreen Shrub**

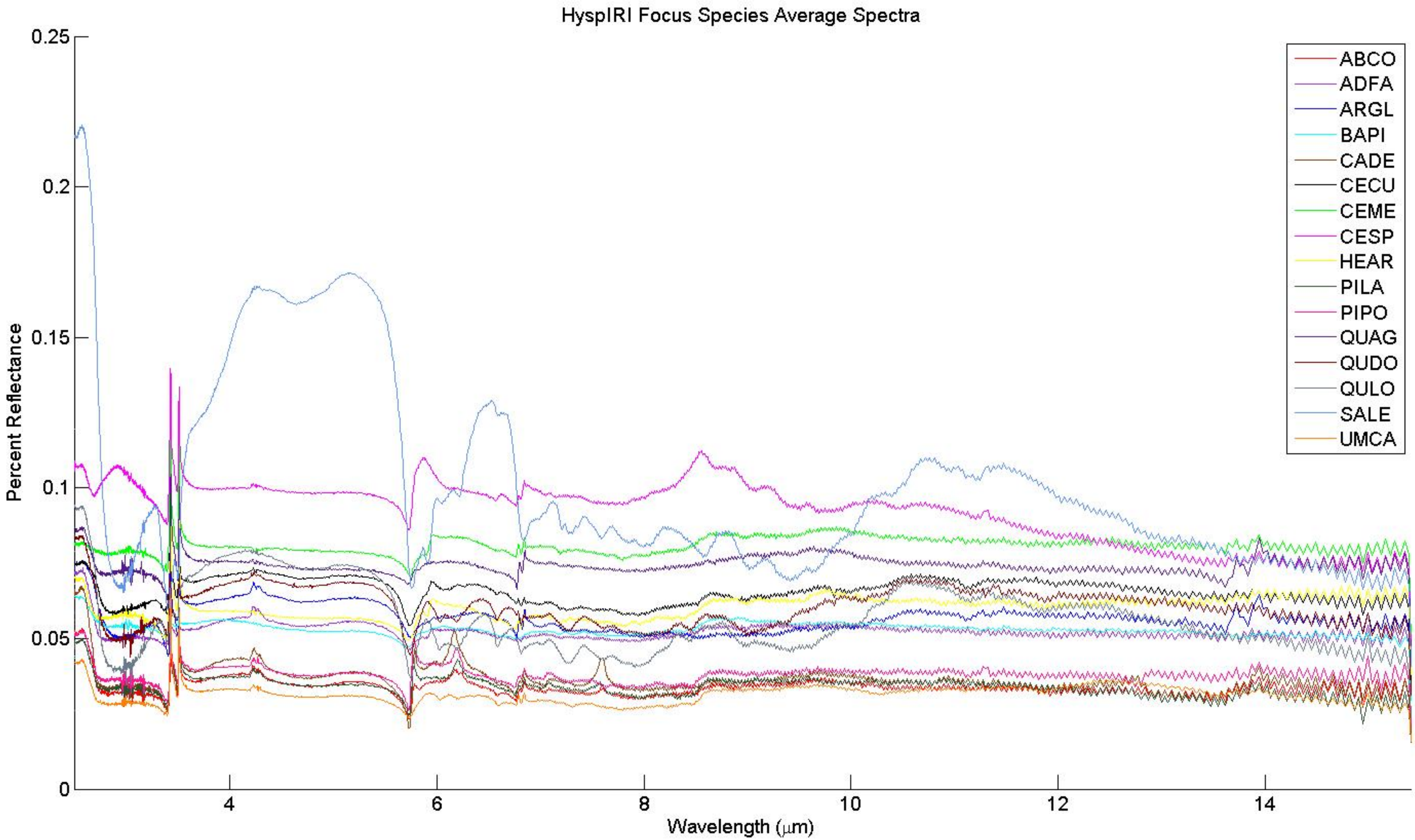
**Broadleaf Evergreen Shrub** | **Needleleaf Evergreen Tree**

Statistically Significant ($p < 0.05$) between Seasons: BAPI, QULO, SALE

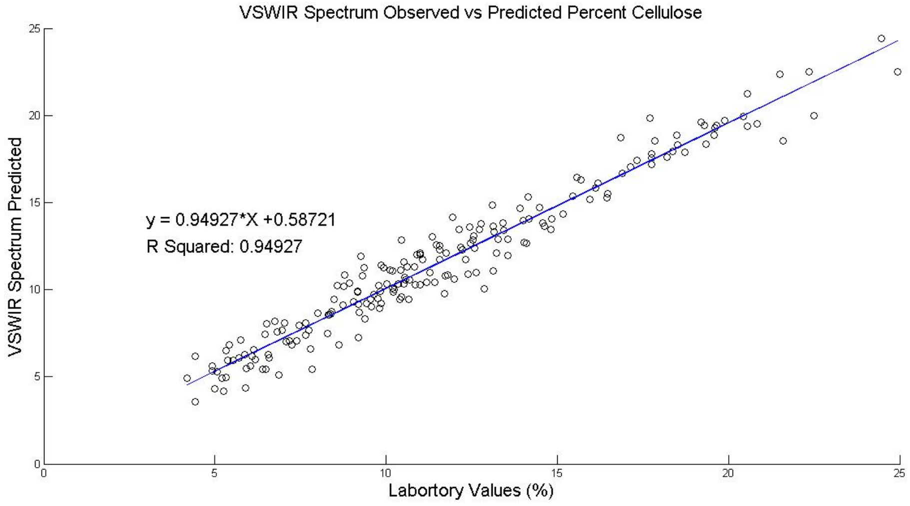
# Spectra: VSWIR

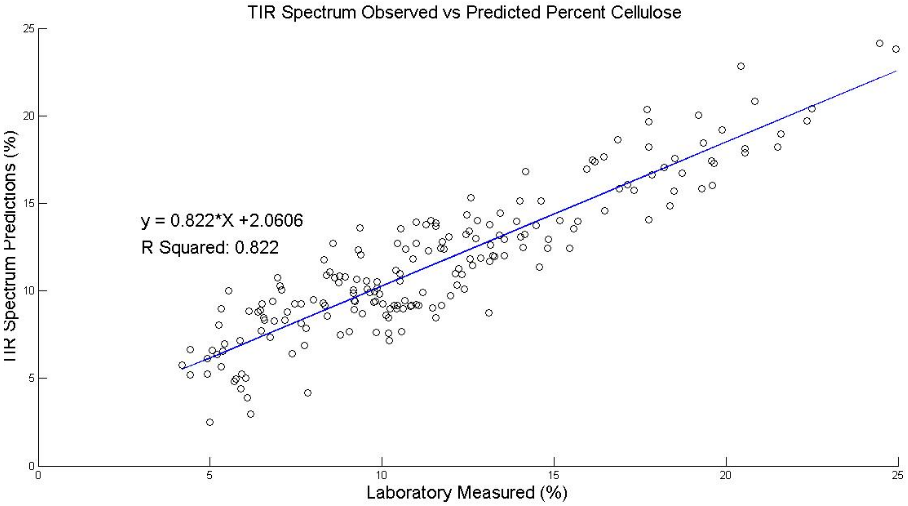


# Spectra: TIR


HyspIRI Focus Species Average Spectra
Percent Reflectance
Wavelength (μm)
0.25
0.2
0.15
0.1
0.05
0
4
6
8
10
12
14
ABCO
ADFA
ARGL
BAPI
CADE
CECU
CEME
CESP
HEAR
PILA
PIPO
QUAG
QUDO
QULO
SALE
UMCA

# PLS Regression: Cellulose




Full Spectrum:

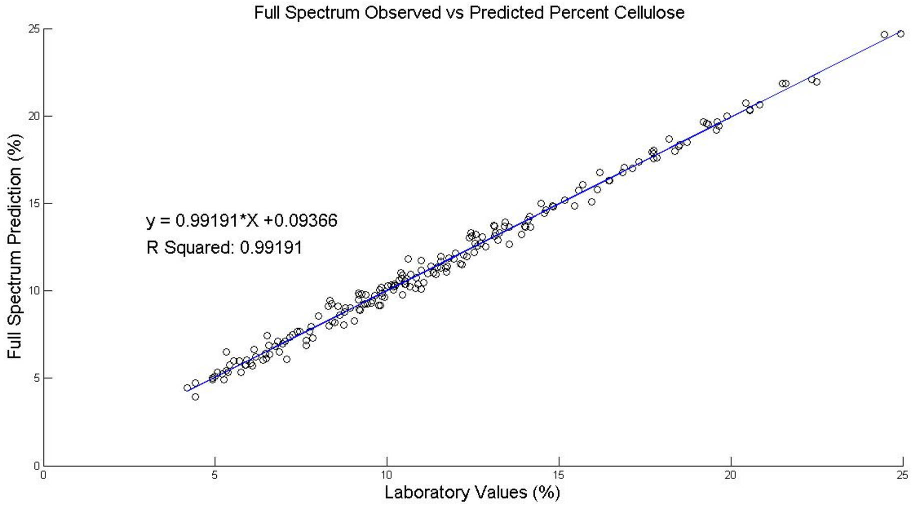
- 29 Components
- 99.1909 % Variance Explained

VSWIR:

- 27 Components
- 94.9274 % Variance Explained

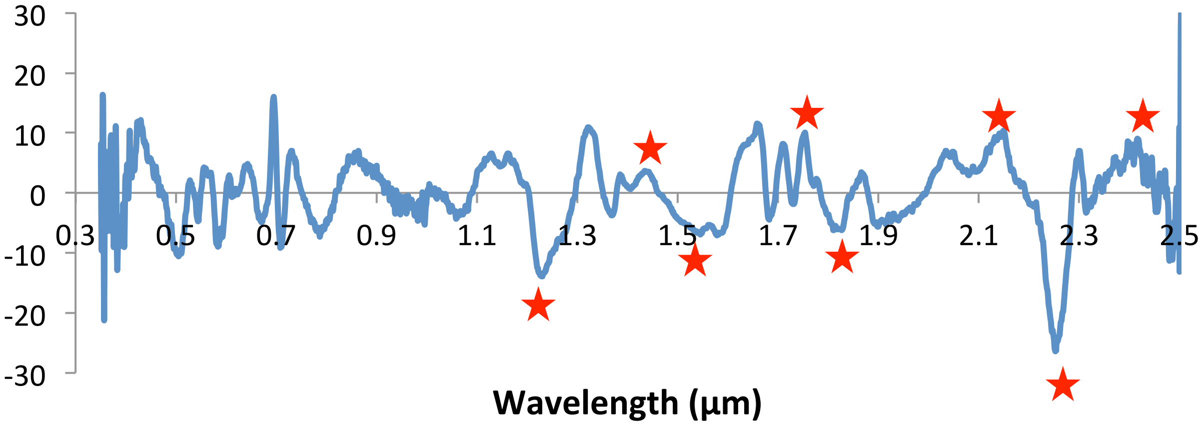
TIR:

- 11 Components
- 82.1996 % Variance Explained

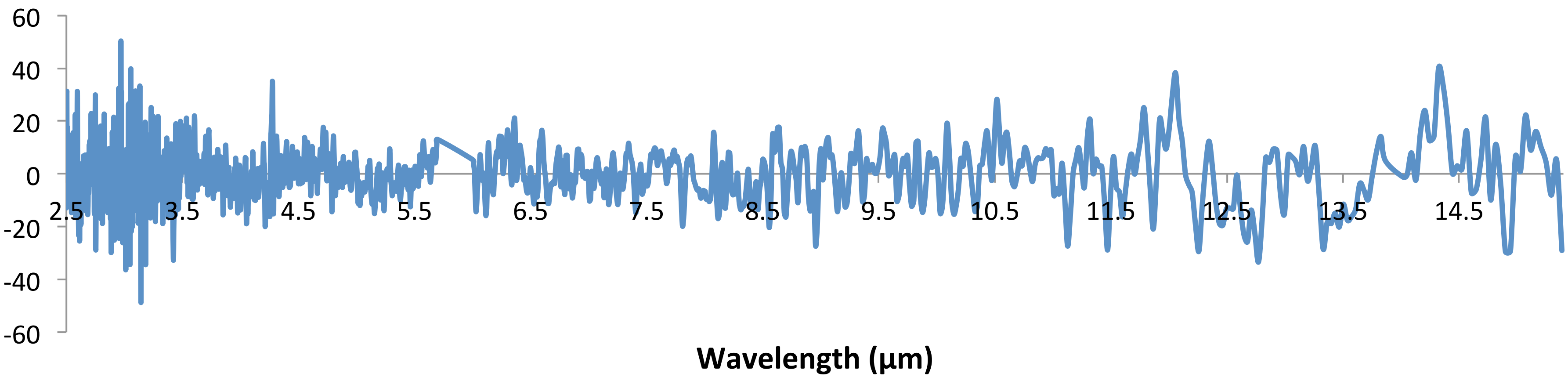


# PLS Regression: Cellulose

### Cellulose Regression Coefficients for VSWIR




### Cellulose Regression Coefficients for TIR

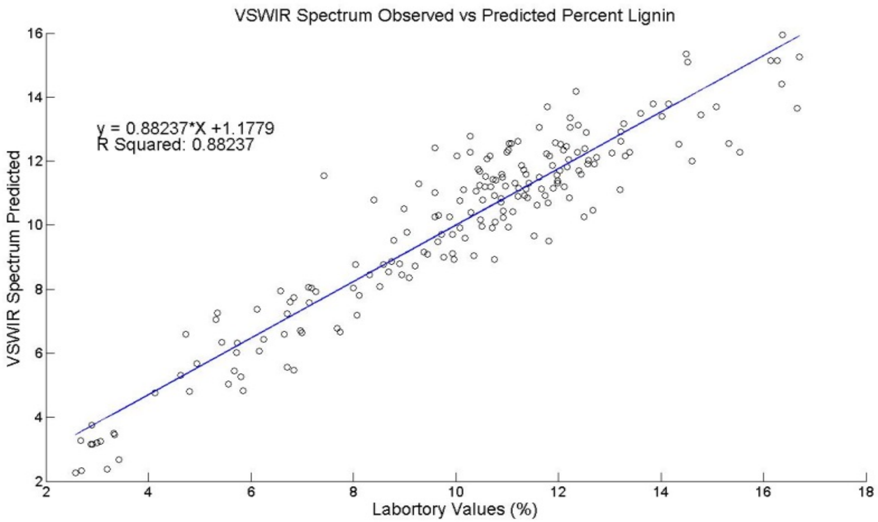


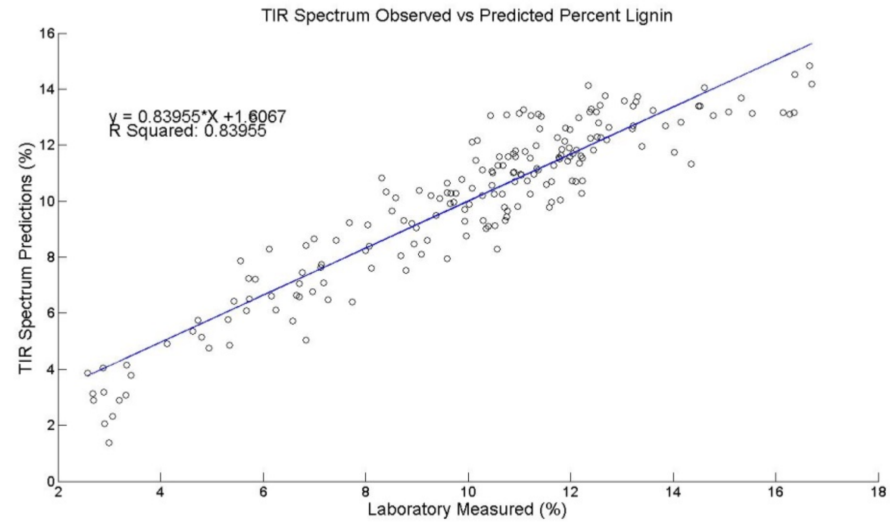

Wavelengths with
<u>Highest Coefficients</u>

| | |
|---|---|
| 0.35 | 3.14 |
| 0.70 | 4.27 |
| 1.23 | 12.06 |
| 1.32 | 12.77 |
| 1.66 | 14.32 |
| 2.25 | 14.9 |
| 2.97 | |

★ Known Absorption

# PLS Regression: Lignin




Full Spectrum:

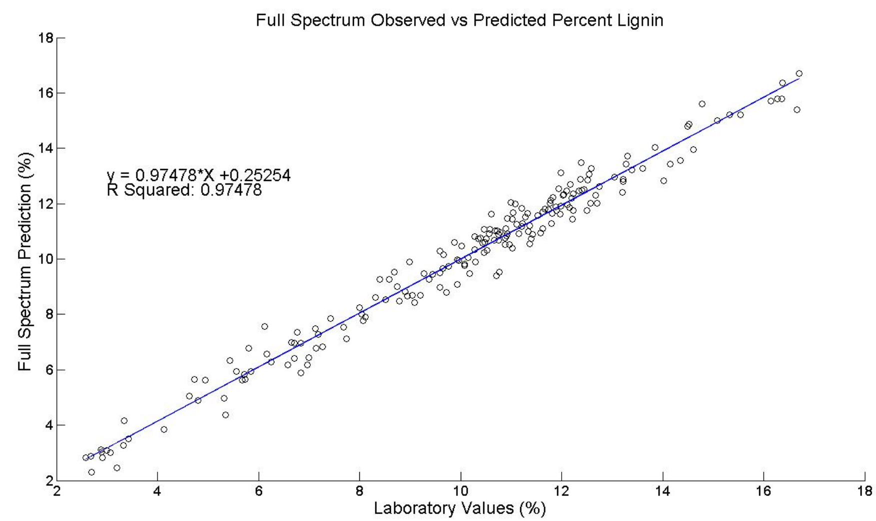
- 27 Components
- 97.4780 % Variance Explained

VSWIR:

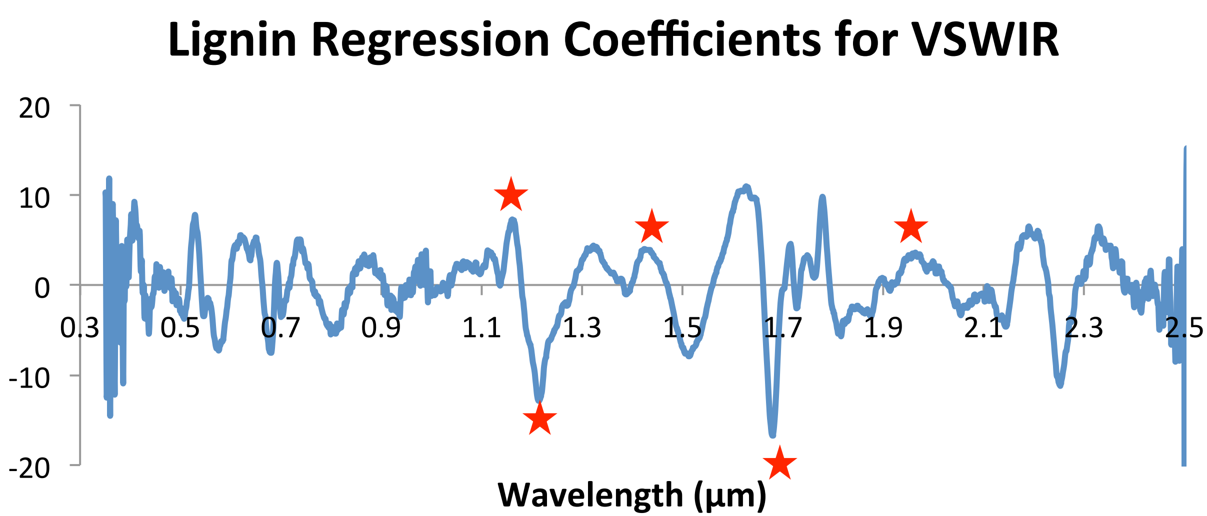
- 25 Components
- 88.2368 % Variance Explained

TIR:

- 13 Components
- 83.9547 % Variance Explained



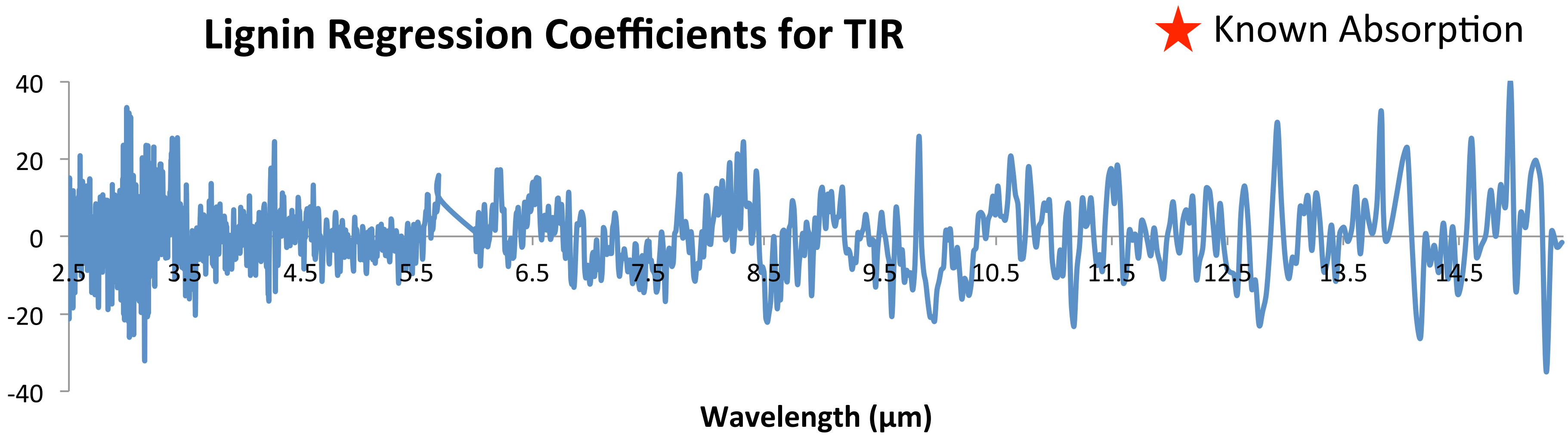
# PLS Regression: Lignin



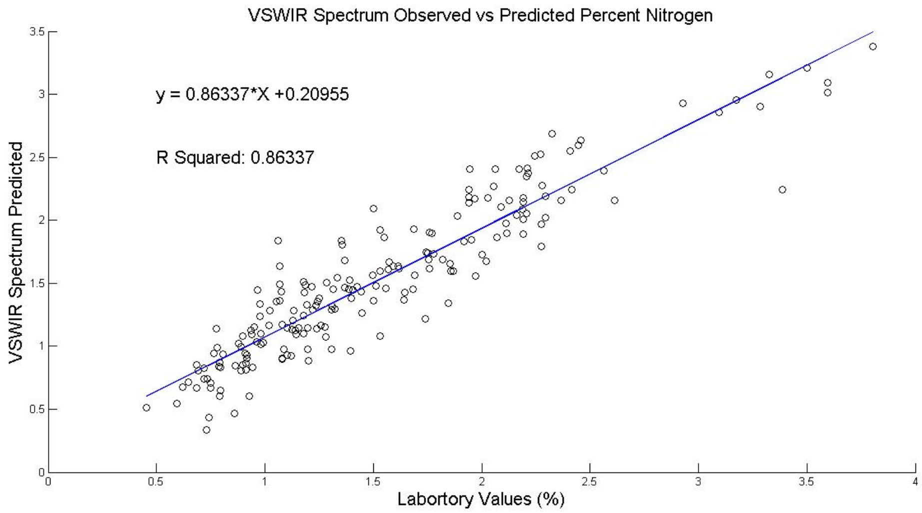

Wavelengths with Highest Coefficients

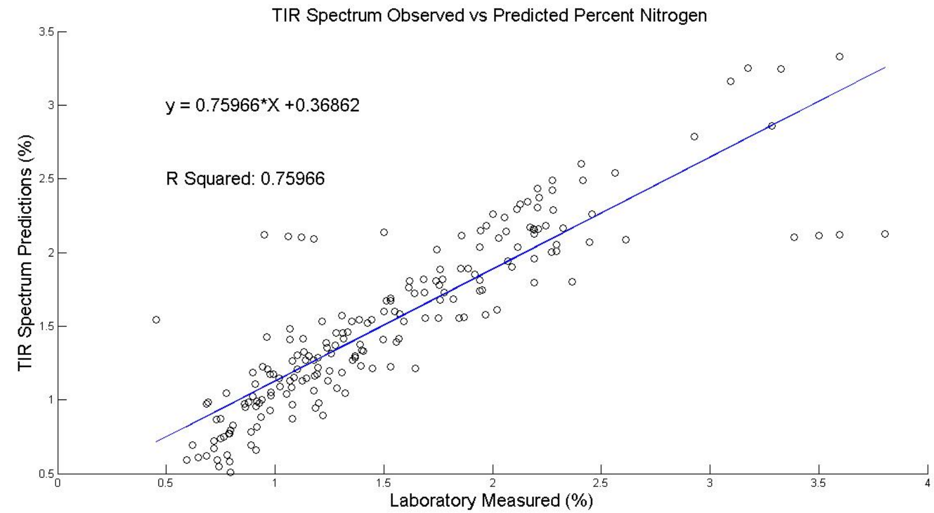
| | |
|---|---|
| 0.35 | 3.15 |
| 0.36 | 11.18 |
| 1.21 | 12.93 |
| 1.62 | 13.83 |
| 1.68 | 14.17 |
| 1.78 | 14.94 |
| 3.00 | 15.25 |

★ Known Absorption



# PLS Regression: Nitrogen




Full Spectrum:

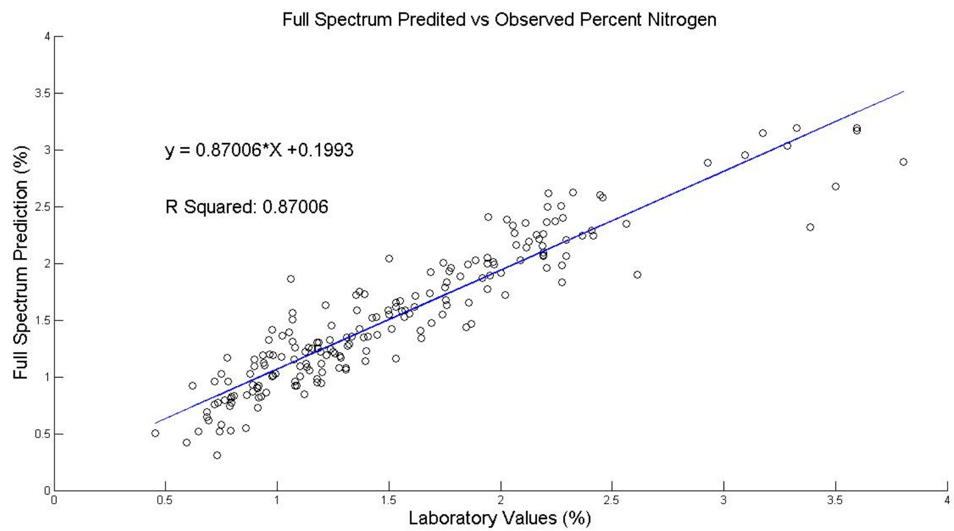
- 17 Components
- 87.01 % Variance Explained

VSWIR:

- 19 Components
- 86.34 % Variance Explained

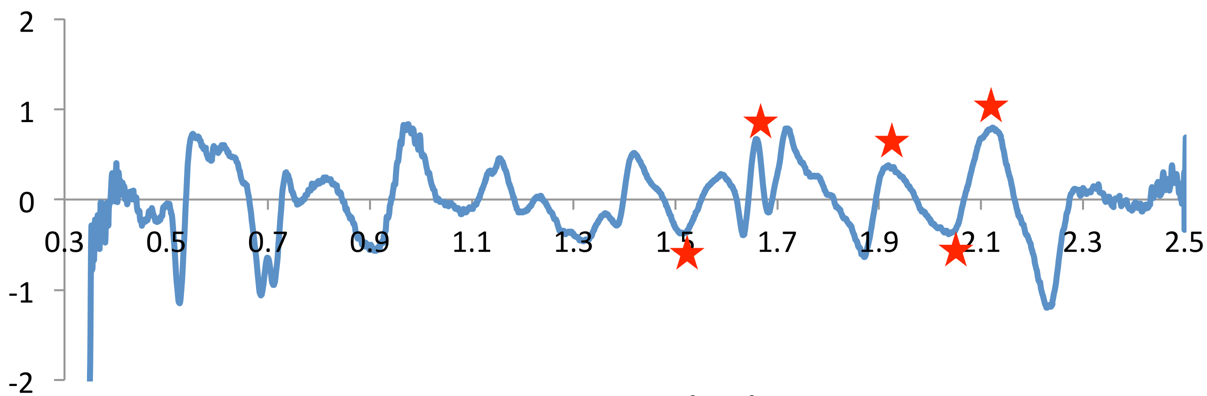
TIR:

- 13 Components
- 75.97 % Variance Explained

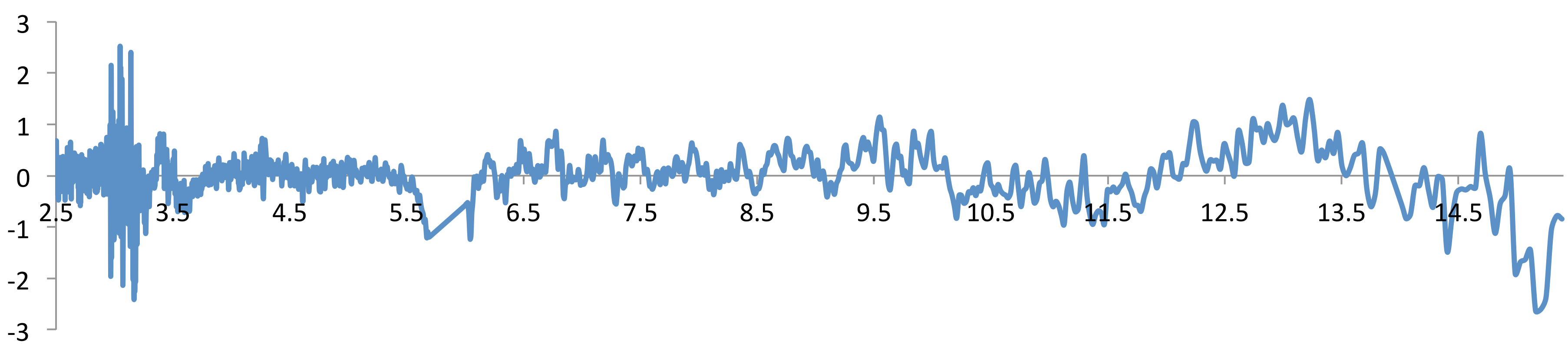


# PLS Regression: Nitrogen

## Nitrogen Regression Coefficients for VSWIR




## Nitrogen Regression Coefficients for TIR




Wavelengths with
<u>Highest Coefficients</u>

| | |
|---|---|
| 0.53 | 3.05 |
| 0.69 | 3.17 |
| 0.97 | 9.55 |
| 1.71 | 13.23 |
| 2.18 | 15.16 |
| 2.23 | |

★ Known Absorption

# Foliar Chemistry

- Seasonality changes in chemical components limited to only a few species
  - Different trend when Fall samples are collected?
  - Potentially use one regression equation for multiple seasons?
- Wide Range of Foliar Chemistry
  - Lignin: 2.6% to 16.7%
  - Cellulose: 4.2% to 24.9%
  - Nitrogen: 0.45% to 3.8%

# PLS Regression

- Are biochemical properties of plant species distinguishable in the TIR spectrum?
  - Regressions were able to key into known absorption features of biochemicals in the VSWIR
  - TIR regression results had high $R^2$, but not higher than VSWIR
- Do synergies between VSWIR and the TIR spectrum improve analysis of biochemical properties?
  - For all biochemicals the addition of TIR and VSWIR spectrum increased $R^2$

# Summary

- Preliminary results from UCSB HyspIRI field campaign
- The incorporation of the TIR spectrum looks promising for foliar chemistry spectroscopy studies
- In the process of collecting Fall samples now
- In the future we will be looking at pigments, water content, specific leaf area, and leaf thickness

## Questions?

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