Mapping biochemistry and photosynthetic metabolism in ecosystems using imaging spectroscopy

Imaging spectroscopy in California and the Midwest

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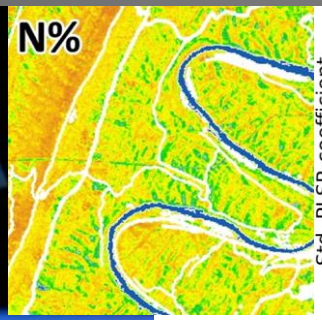

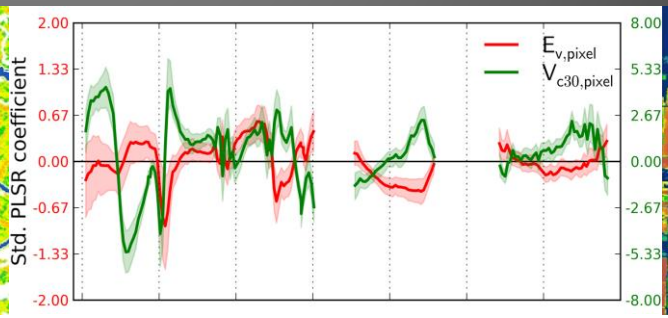

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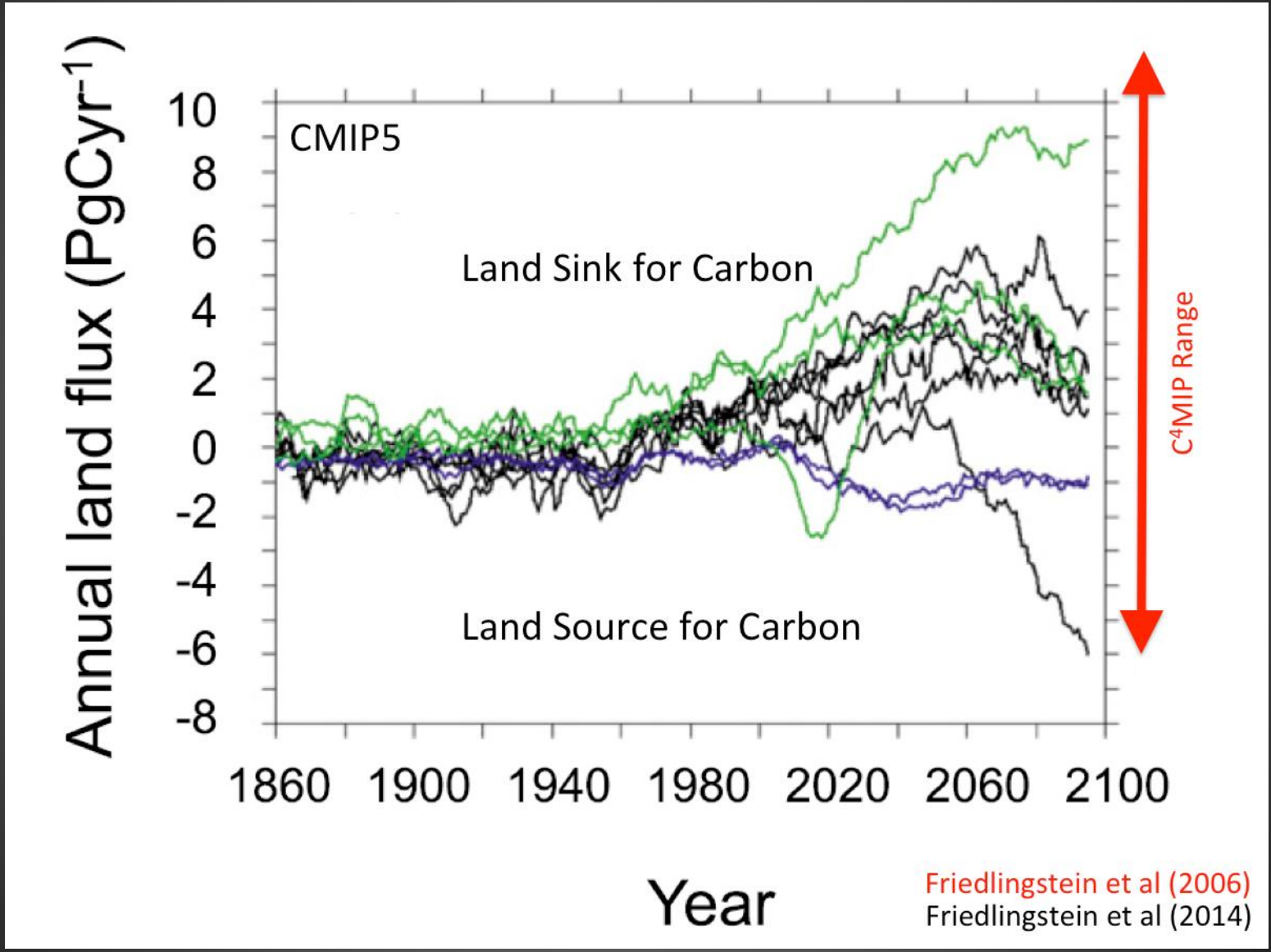
Background


Annual land flux (PgCyr-1)
10
8
6
4
2
0
-2
-4
-6
-8
CMIP5
Land Sink for Carbon
Land Source for Carbon
C4MIP Range
1860
1900
1940
1980
2020
2060
2100
Year
Friedlingstein et al (2006)
Friedlingstein et al (2014)

Background

Multiple sources of uncertainties

- Model formulation
- **Model data**

- **Models use simplified representations of the land surface,**
- **Ecosystems classified by plant functional types (or species),**
- **Critical functional traits from look-up-tables.**

Functional traits vary across space (and time)

- **Imaging spectroscopy has the potential to better describe spatio-temporal variations in critical ecosystem traits across large regions.**

Foliar biochemistry from imaging spectroscopy

4 years (2008-2011), 145 AVIRIS scenes, 237 plots, 6 states, 36 species
N%, LMA, C%, Lignin%, Cellulose% , Fiber%, $\delta^{15}N$

Methods

Leaf level

Foliar Samples

Field sampling

Leaf spectra

Leaf-level traits

Species, basal area

PLSR

Leaf-level calibration

Image level

AVIRIS Imagery

Cloud/Shadow mask

Atmospheric Correction

Topographic normalization

BRDF Correction

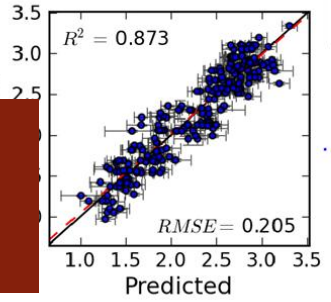
Analysis & prediction

Cross - validation

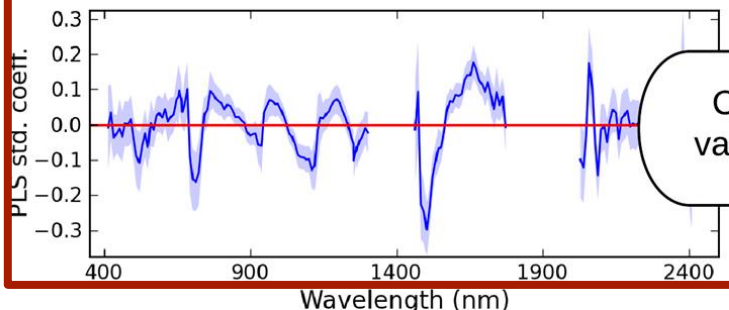
Plot-level traits

Canopy spectra

Normalized image



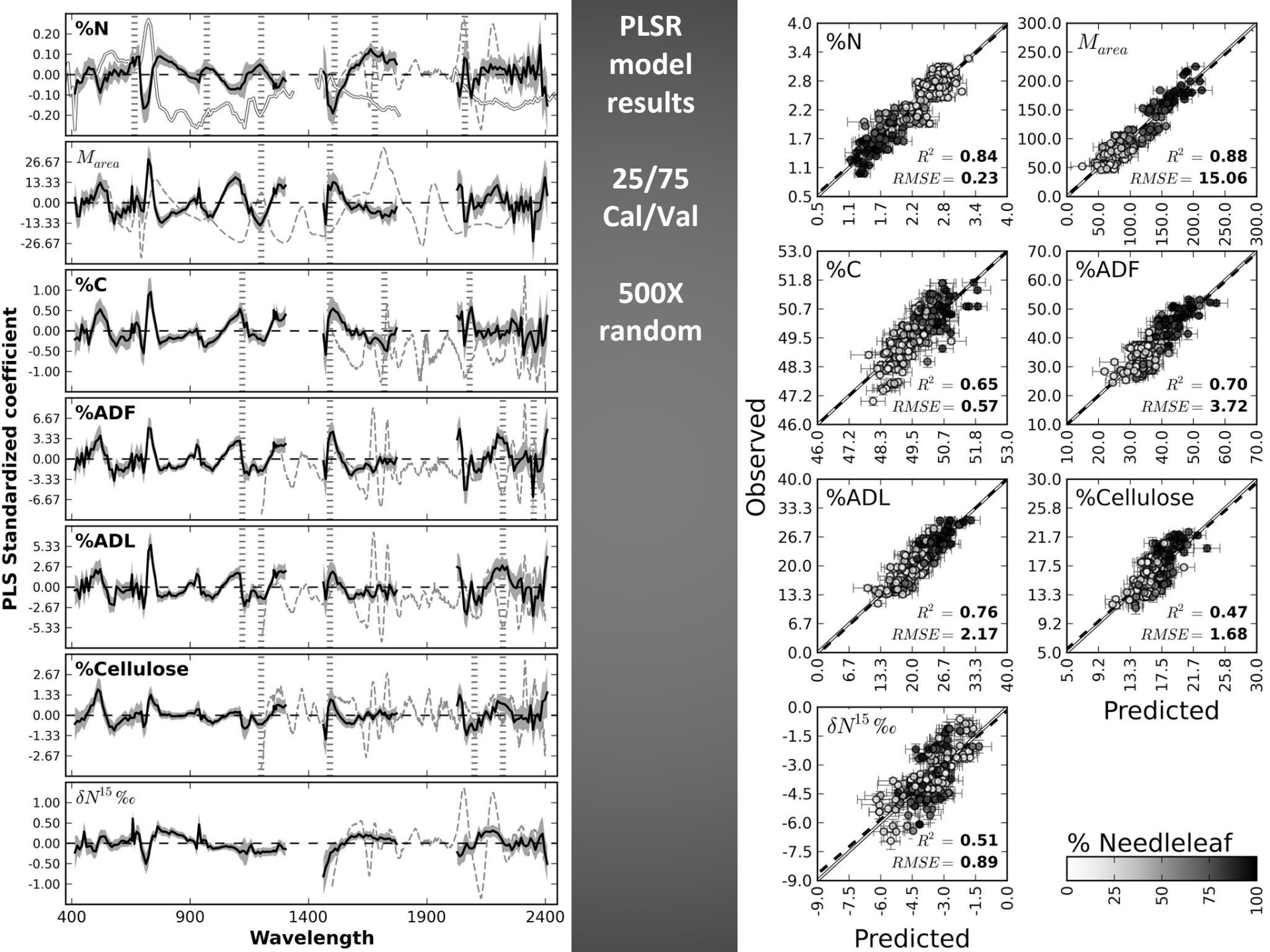
PLSR



Cross - validation

Image-level calibration

Predicted trait means + uncertainties

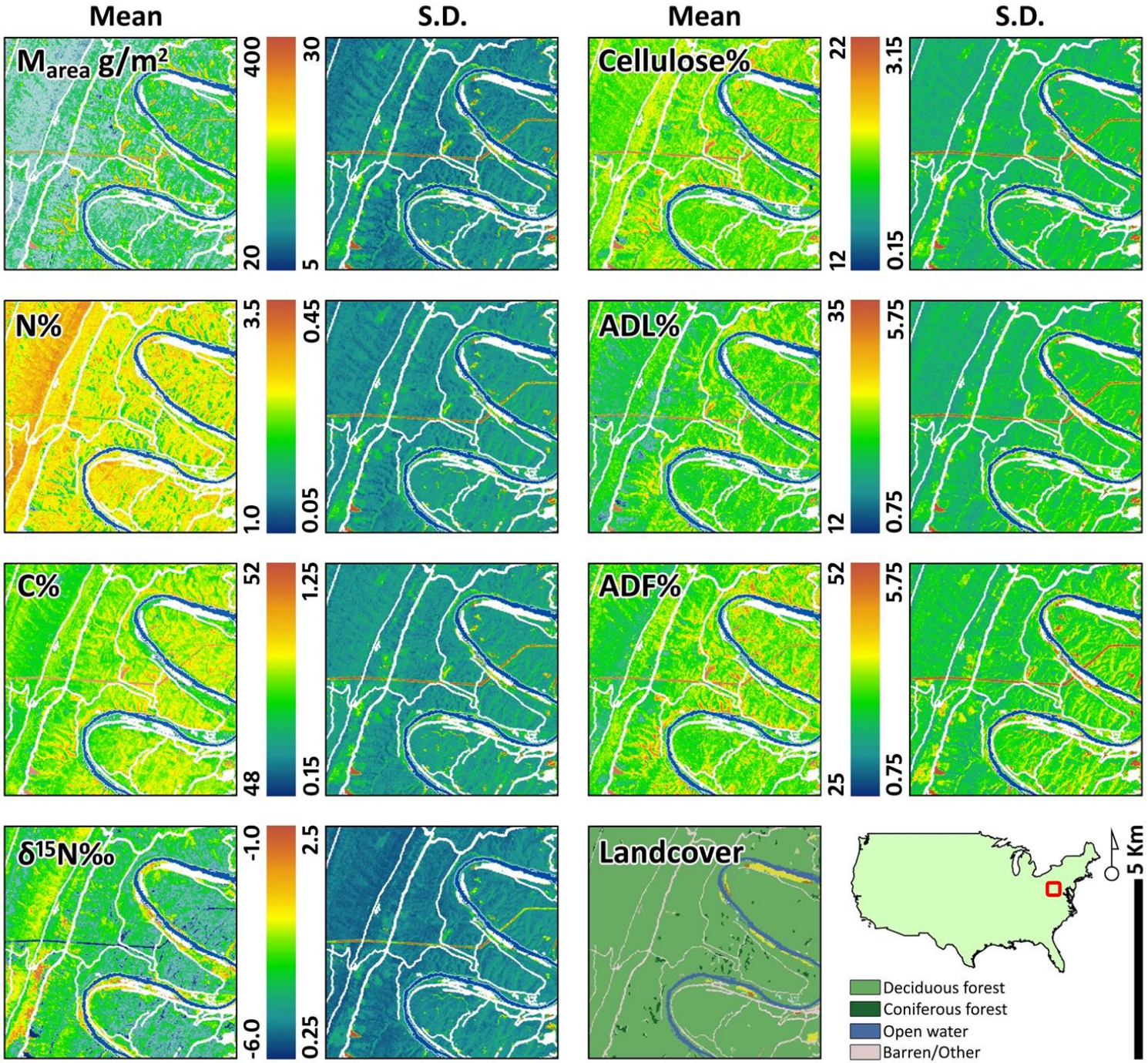

PLSR model results
25/75 Cal/Val
500X random
PLS Standardized coefficient
Wavelength
%N
M_{area}
%C
%ADF
%ADL
%Cellulose
δN^{15} ‰
Observed
Predicted
R^2 = 0.84
RMSE = 0.23
R^2 = 0.88
RMSE = 15.06
R^2 = 0.65
RMSE = 0.57
R^2 = 0.70
RMSE = 3.72
R^2 = 0.76
RMSE = 2.17
R^2 = 0.47
RMSE = 1.68
R^2 = 0.51
RMSE = 0.89
% Needleleaf

Results

Trait maps

Means and uncertainties obtained by applying 500 models to each image spectra

Savage River State Forest MD



Results

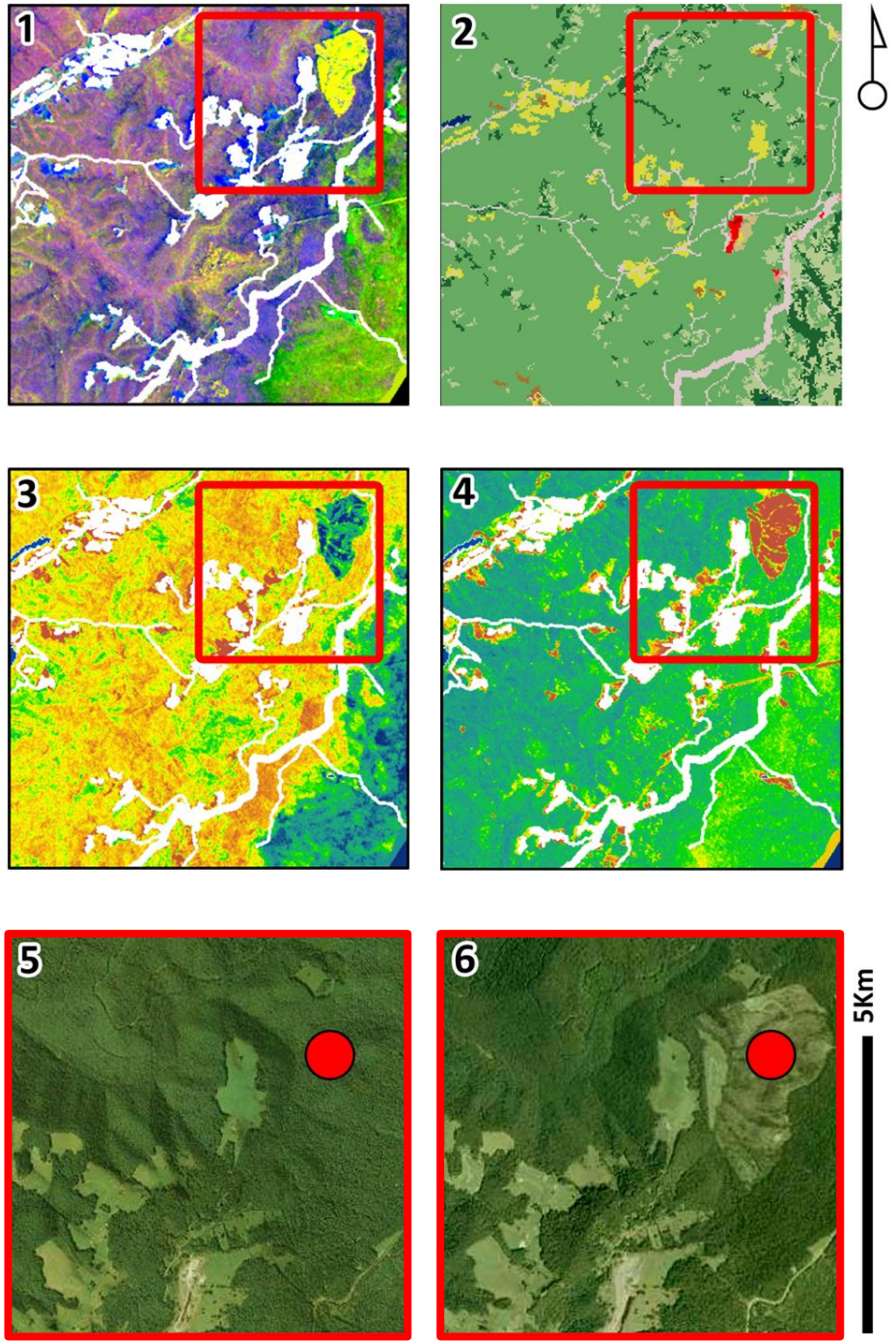
Emergent patterns

- Spatial variations in foliar traits are not captured in landcover maps.

- Disturbances show up as high uncertainties

Uncertainties can be utilized for:

- Detecting changes in FTs,
- Constraining ecosystem models (bayesian updating)...

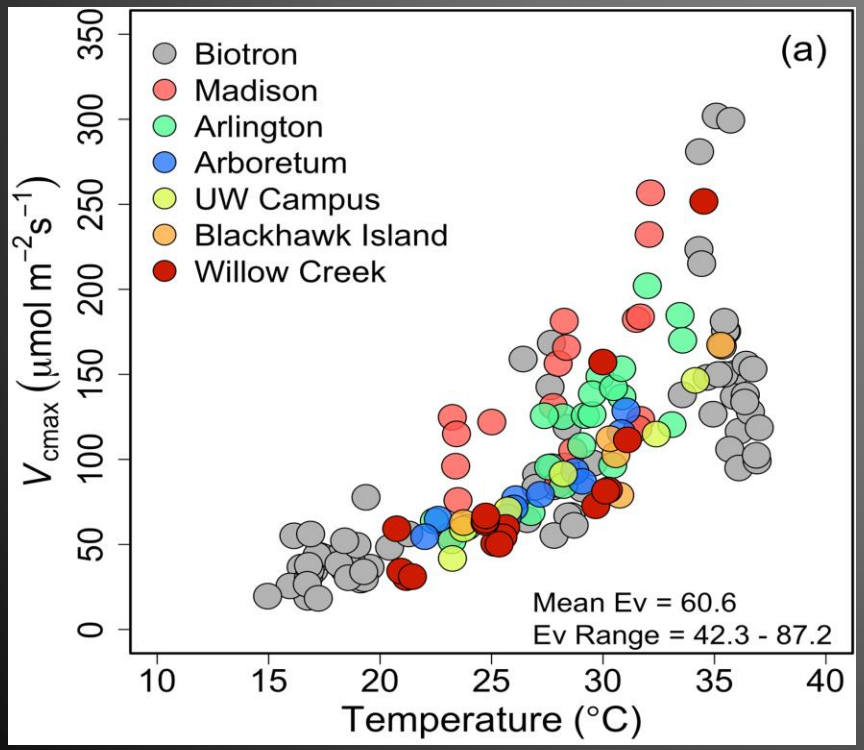


Foliar metabolism from imaging spectroscopy

Modeling photosynthesis in ecosystem process models:

- **Enzyme Kinetic (EK)**
- **Light Use Efficiency (LUE)**

- **For EK models, FT-specific rates of maximal carbon uptake (V_{cmax}) are needed**
- *Note that: Photosynthesis is strongly influenced by temperature (E_v).*



-118.0 °E
Fresno
KARE
36.0°N
CALIFORNIA
Santa Barbara
Los Angeles
Riverside
Palm Springs
34.0°N
SCREC
CVARS
San Diego
0 30 60 120 Kilometers
Sources: Esri, USGS, NOAA
-118.0 °E
-116.0 °E

Foliar metabolism from imaging spectroscopy

Leaf spectra have been shown to be sensitive to foliar metabolism (Serbin et al. 2012)

Objective: to develop general models for estimating Vcmax, Ev using imaging spectroscopy.

Methods:

Conducted gas-exchange measurements on 9 crops in 2011-2012:

- Kearney Agricultural Research and Extension center (KARE)
- Coachella Valley Agricultural Research Station (CVARS)
- South Coast Research and Extension Center (SCREC)

Crops:

- Lemon, Peach, Pomegranate, Palm, Grape, Avocado, Pistachio, Oat and Red peppers

Fitted A-Ci curves on gas-exchange data to obtain Vcmax, fit Arrhenius curves to get Ev

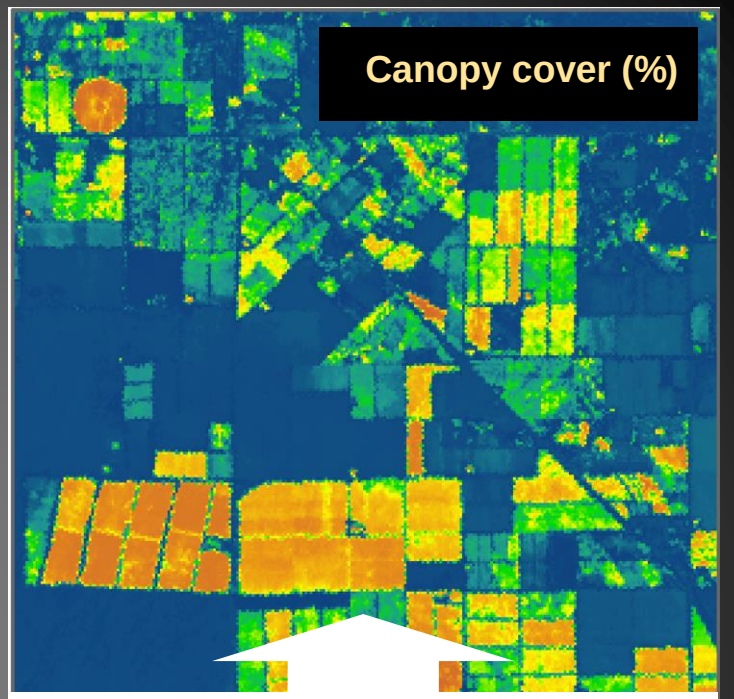
Methods

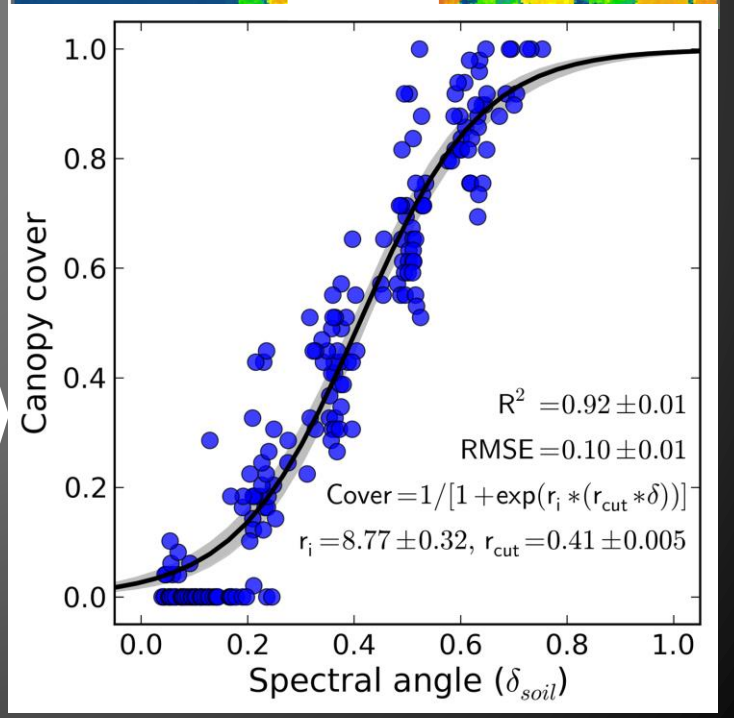
Issue: Reconciling plants with pixels

- Vctemp and Ev are measured at plant scale,
- ...predictions needed at pixel scale.

→ Adjust plot-averaged, plant-scale measurements by vegetation cover fraction.

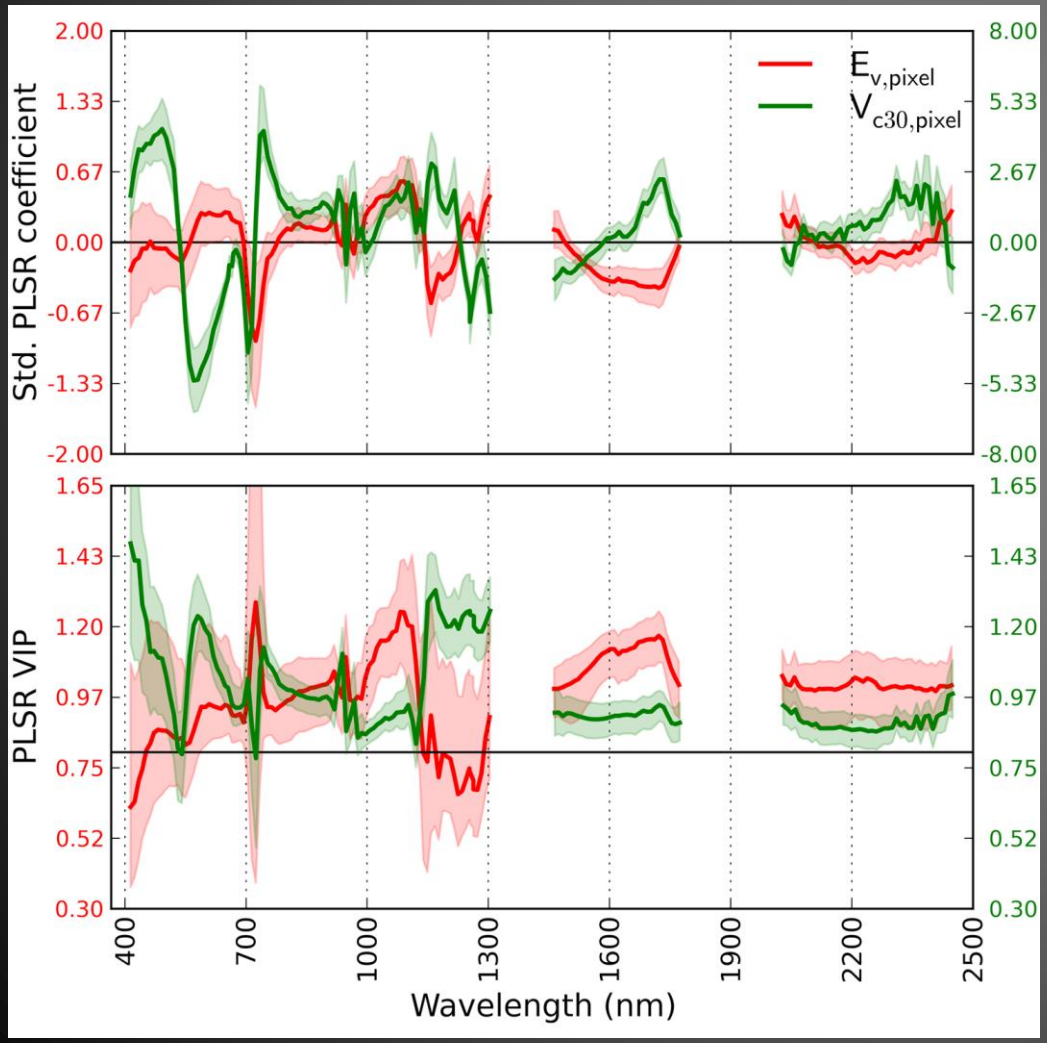
- Use GoogleEarth and Field data to estimate vegetated fraction in pixel,
- Use spectral angles to develop cover models,
- Adjust field-measured Vctemp, Ev by fraction.

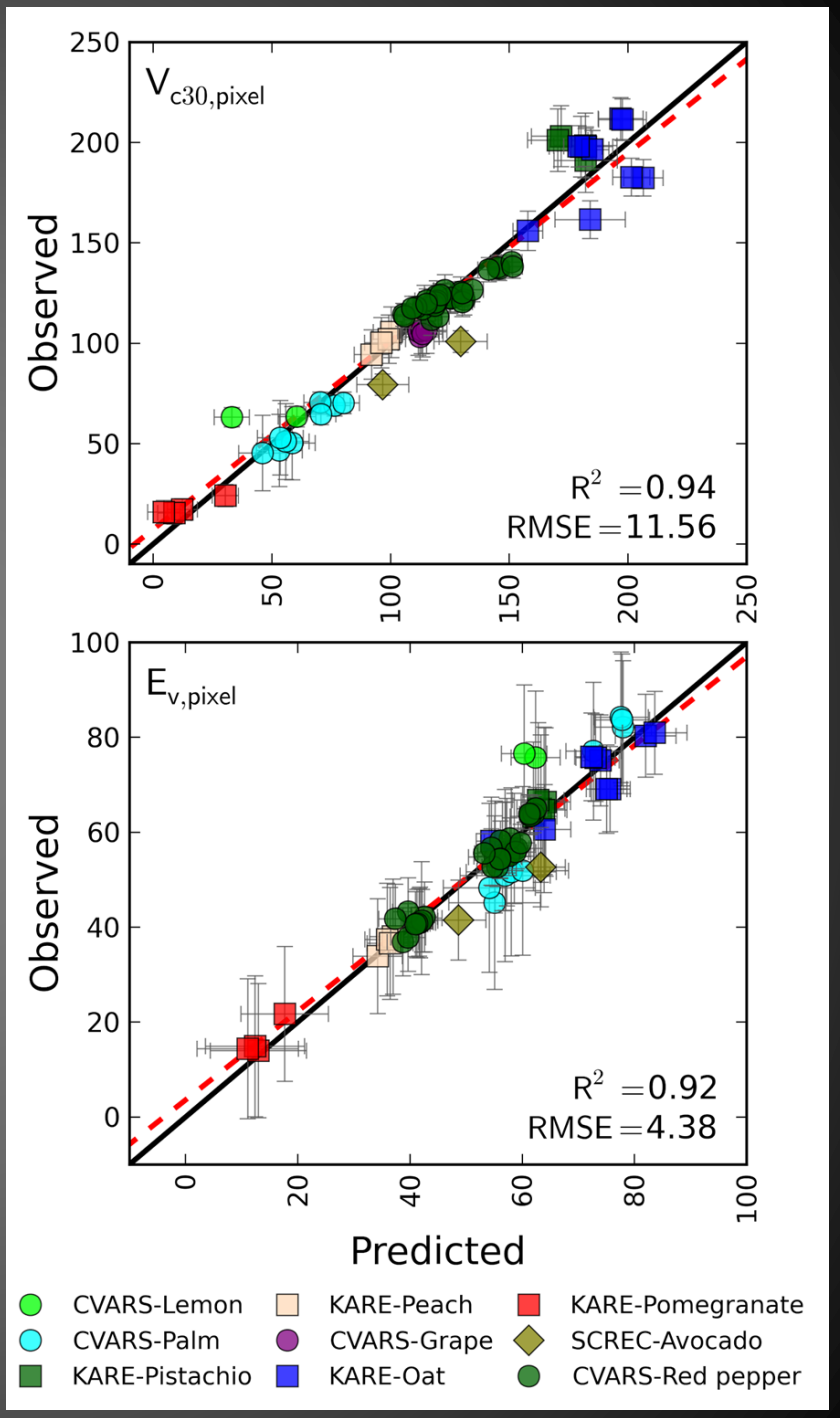




Results

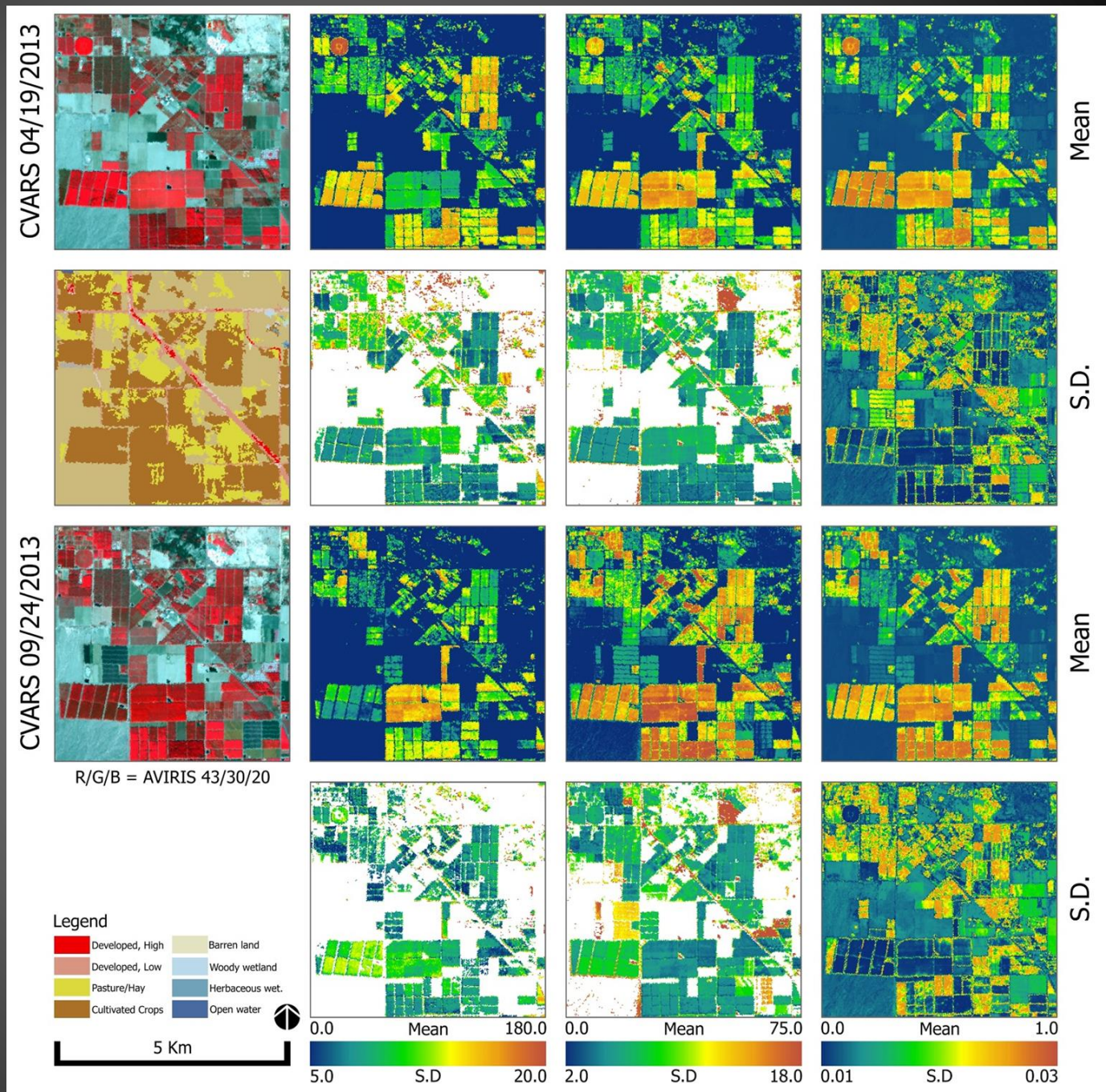
- PLSR models, 66/33% Calibration/Validation
- 500 randomized replications
- Error propagated through V_{c30}, E_v & Cover





Results

- Seasonal changes and spatial variation in Vc30 and Ev at CVARS
- Availability of uncertainties a plus for ecosystem process models.



Conclusion

- Spatial estimates of plant nutrient status = finer-scale understanding of nutrient cycling rates
- Availability of uncertainty estimates = identification of data gaps, (...or disturbances)

- Fine-scale spatial and temporal estimation of V_{cmax} and E_v could be used to inform ecosystem process modeling activities
- Concurrent availability of thermal data will allow us to more accurately scale Vcmax with temperature,
- Spatio-temporal estimates of Vcmax will allow finer-scale assessment of ecosystem productivity.

Research in progress:

- Expansion to newer agricultural sites,
- Expansion of study sites to include natural landscapes (forest, chaparral, scrub),
- Investigation of controls on Vcmax and Ev (soil moisture, vapor pressure deficit...)
- Use of spatial and temporal maps for PFT parameterization and modeling

Manuscripts

Leaf-level:

S.P. Serbin, A. Singh, B.E. McNeil, C.C. Kingdon, P.A. Townsend (2014) **Spectroscopic determination of leaf morphological and biochemical traits for northern temperate and boreal tree species.** *Ecological Applications*. DOI: 10.1890/13-2110.1

Canopy-level:

A. Singh, S.P. Serbin, B.E. McNeil, C.C. Kingdon, P.A. Townsend (2015) **Imaging spectroscopy algorithms for mapping canopy foliar chemical and morphological traits and their uncertainties.** *Ecological Applications*. DOI: 10.1890/14-2098.1

Metabolism:

S.P. Serbin, A. Singh, A.R. Desai, S.G. Dubois, A.D. Jablonski, C.C. Kingdon, E.L. Kruger, P.A. Townsend (*in review*) **Remotely estimating photosynthetic capacity, and its response to temperature, in vegetation canopies using imaging spectroscopy**. *Remote Sensing of Environment*.

Ainsworth, E.A., Serbin, S.P., Skoneczka, J.A., & Townsend, P.A. (2014). **Using leaf optical properties to detect ozone effects on foliar biochemistry.** *Photosynthesis Research*. 119, 65-76

S.P. Serbin, D.N. Dillaway, E.L. Kruger, P.A. Townsend (2012) **Leaf optical properties reflect variation in photosynthetic metabolism and its sensitivity to temperature.** *Journal of Experimental Botany.* 63(1) 489-502.

Thank you!

Questions?

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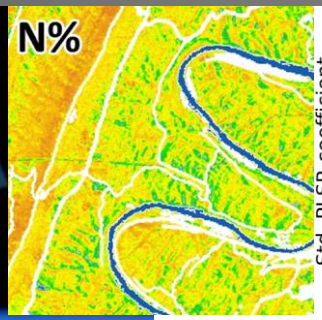

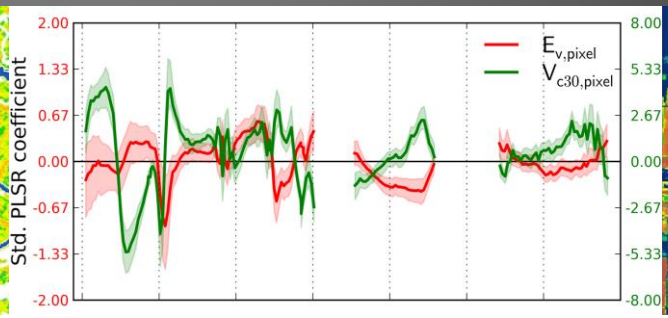

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