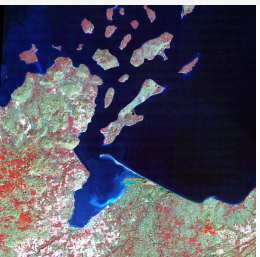
Scaling, propagating and mapping uncertainty in spectroscopy-derived foliar traits from the leaf to the image

Shawn Serbin[1], Aditya Singh[1], Clayton Kingdon[1], Brenden McNeil[2], Philip Townsend[1]

[1]University of Wisconsin – Madison
[2]West Virginia University



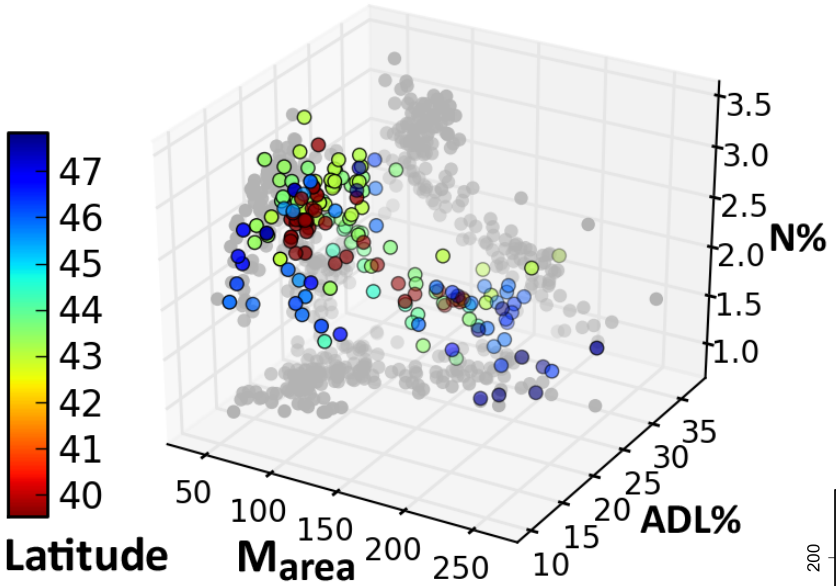
FERST

FOREST ECOSYSTEM REMOTE SENSING TEAM
DEPARTMENT OF FOREST AND WILDLIFE ECOLOGY
UNIVERSITY OF WISCONSIN - MADISON

Major Themes

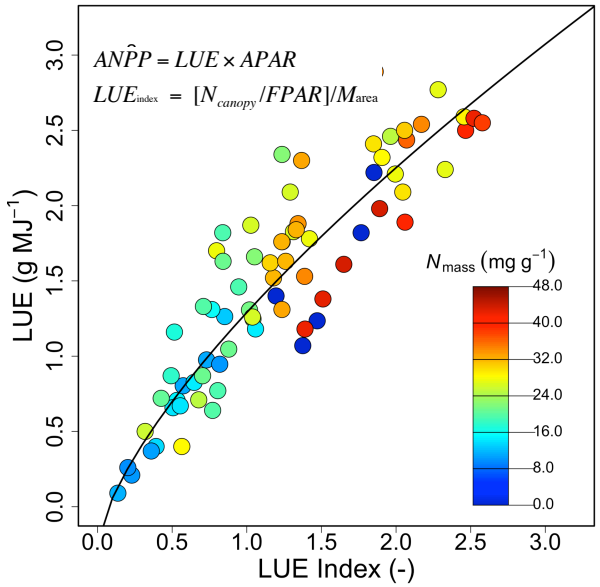
- Leaf traits & spectroscopy
- Image processing & scaling
- Spatial predictions
- Applications

Coachella Valley, California



Singh et al. [in prep] *Eco. Apps*

Data from Green et al., (2003). *Ag. For. Met.*



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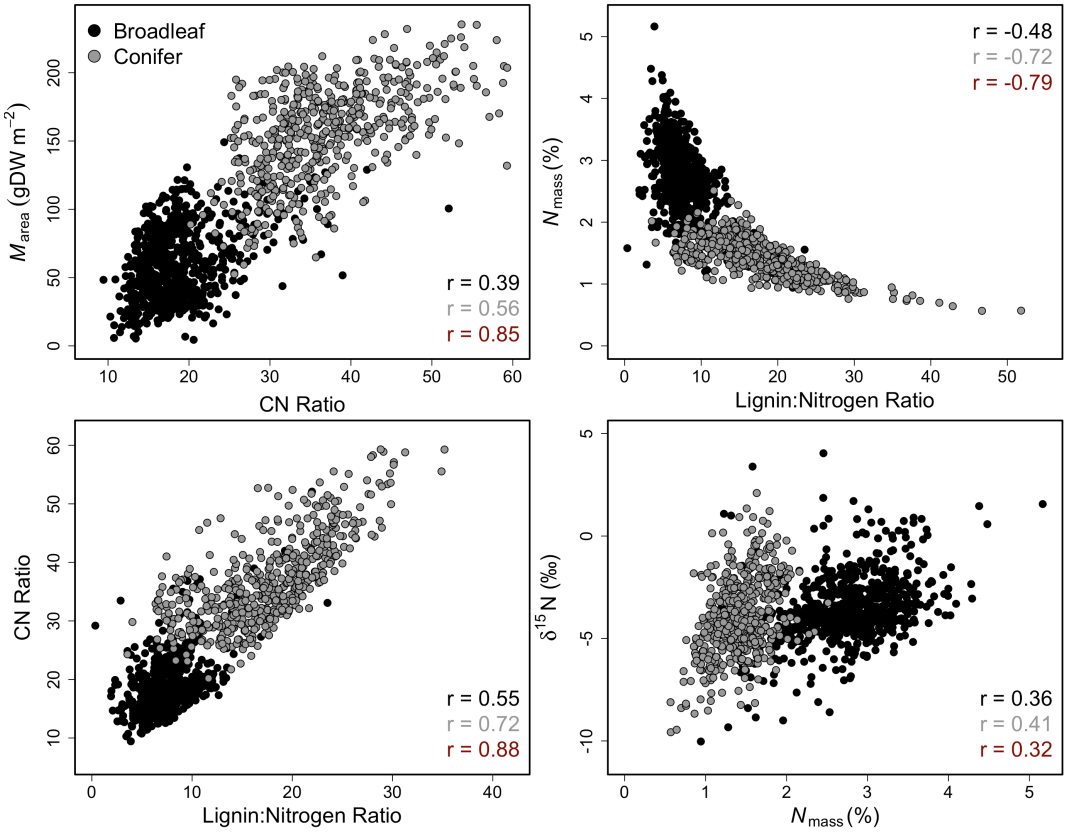
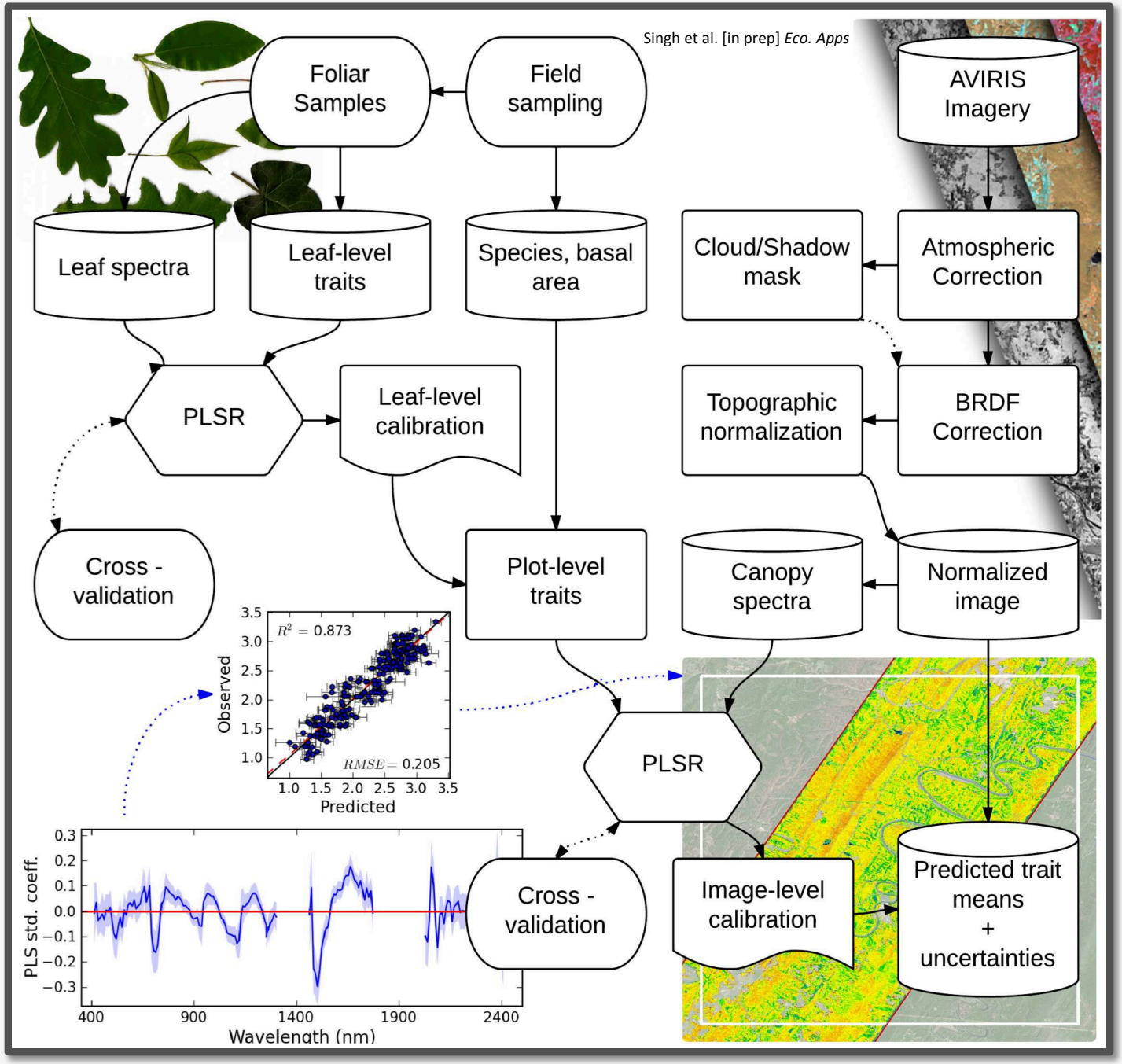
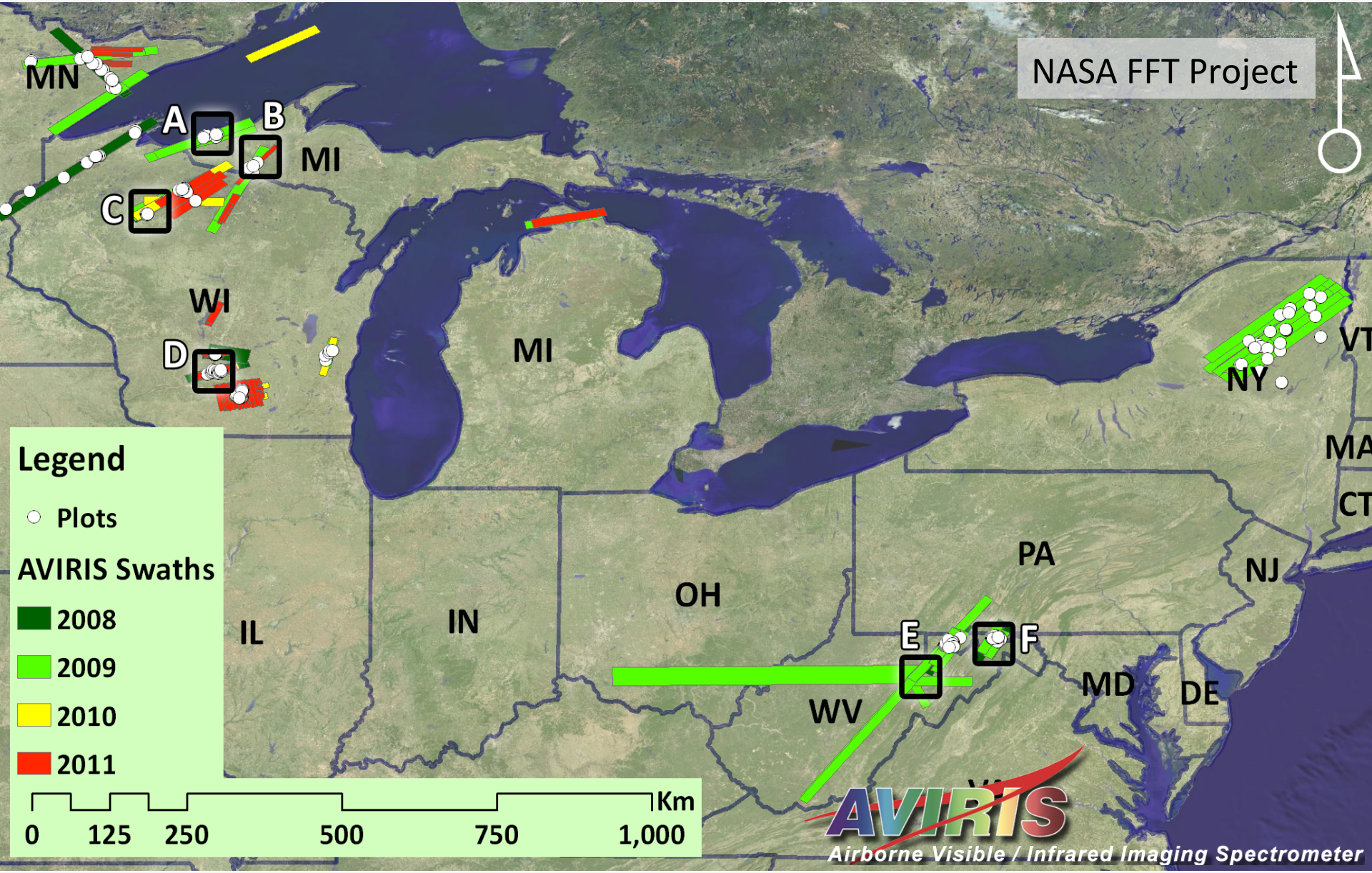
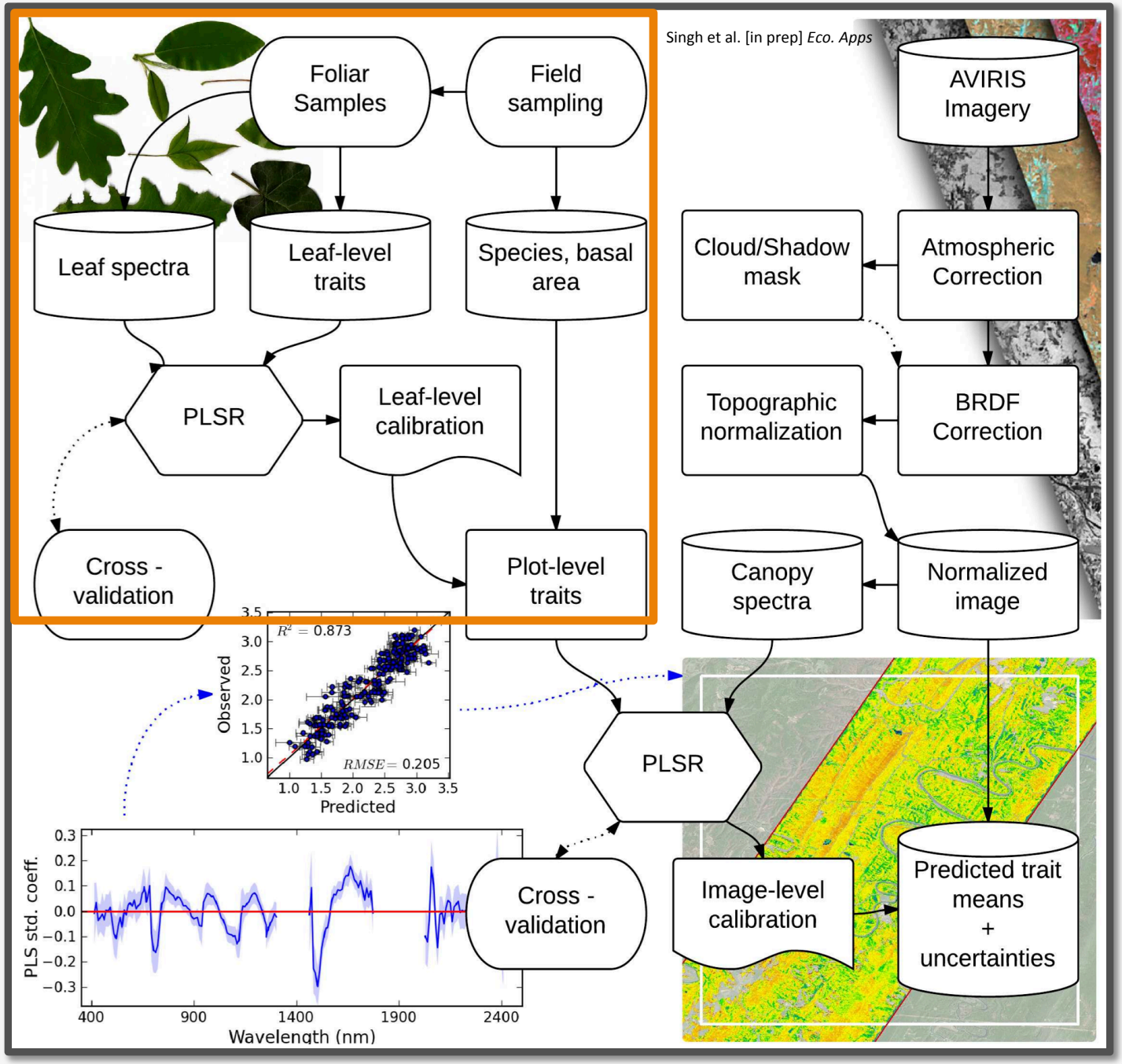



Singh et al. [in prep] *Eco. Apps*
Foliar Samples
Field sampling
AVIRIS Imagery
Leaf spectra
Leaf-level traits
Species, basal area
Cloud/Shadow mask
Atmospheric Correction
PLSR
Leaf-level calibration
Topographic normalization
BRDF Correction
Cross - validation
Plot-level traits
Canopy spectra
Normalized image
R^2 = 0.873
RMSE= 0.205
Observed
Predicted
PLSR
PLS std. coeff.
Wavelength (nm)
Cross - validation
Image-level calibration
Predicted trait means + uncertainties

165 Plots 120+ AVIRIS Scenes

Example Scenes

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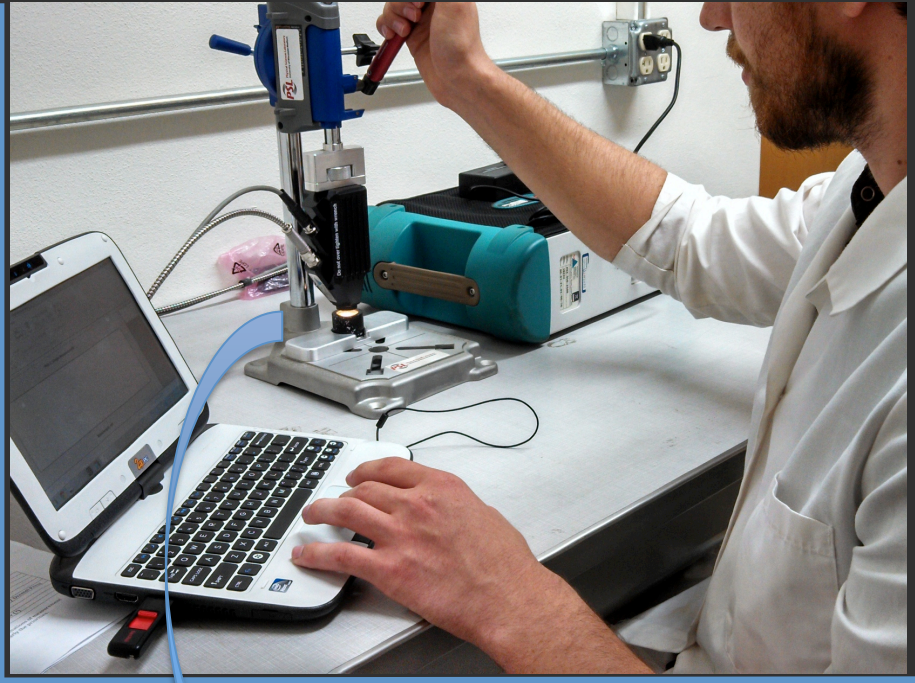
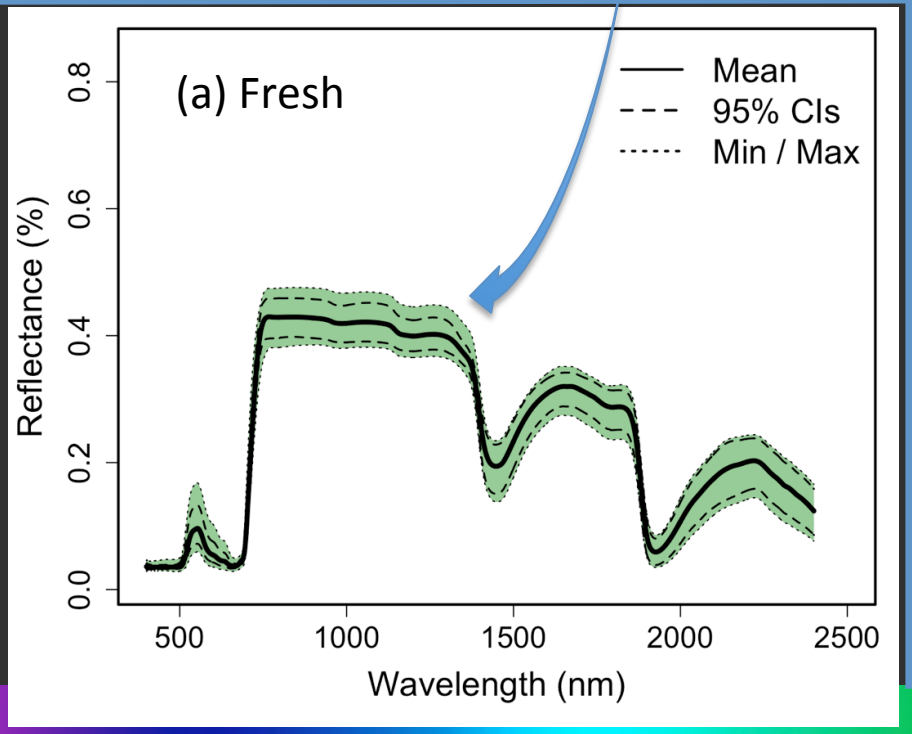
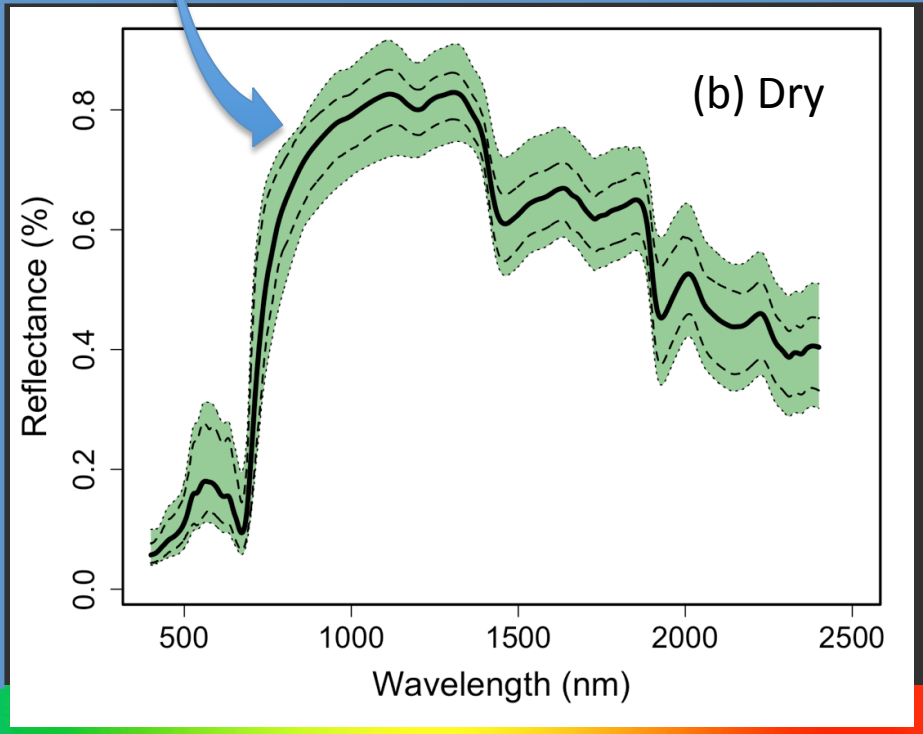
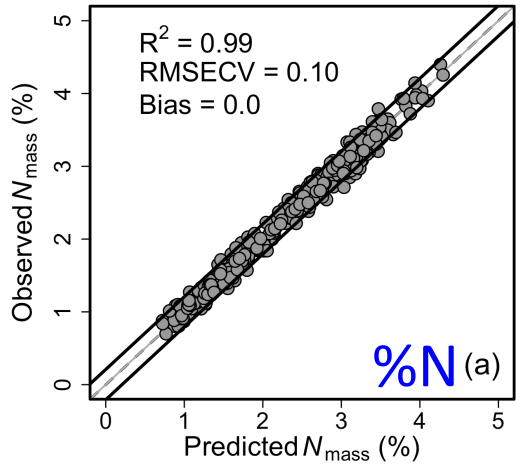
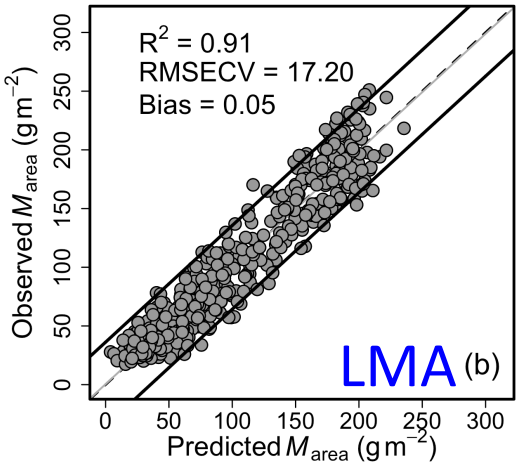


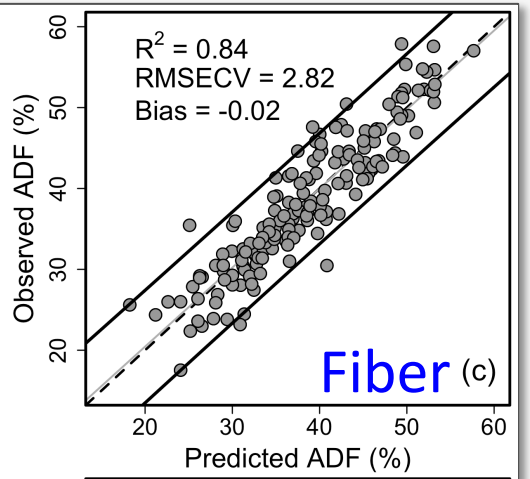

(a) Fresh
Mean
95% CIs
Min / Max
Reflectance (%)
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength (nm)

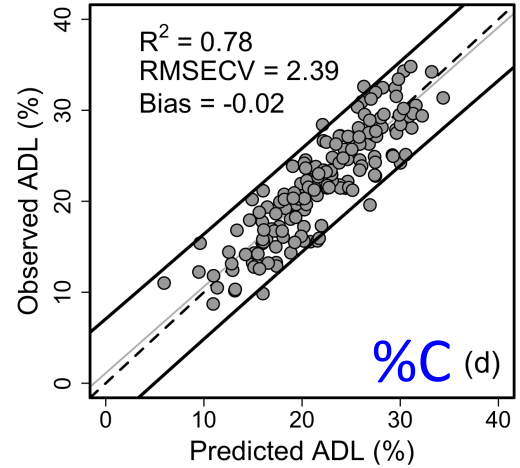

(b) Dry
Reflectance (%)
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
Wavelength (nm)

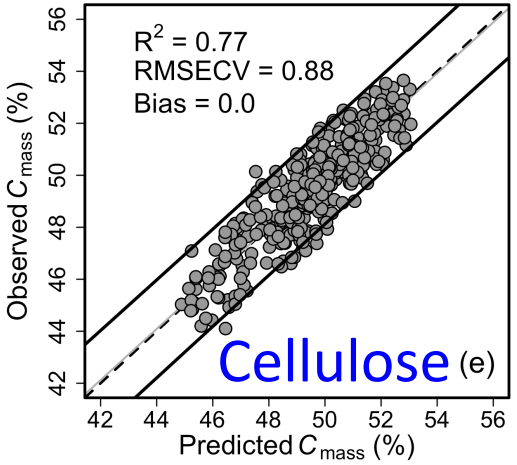
Cal.

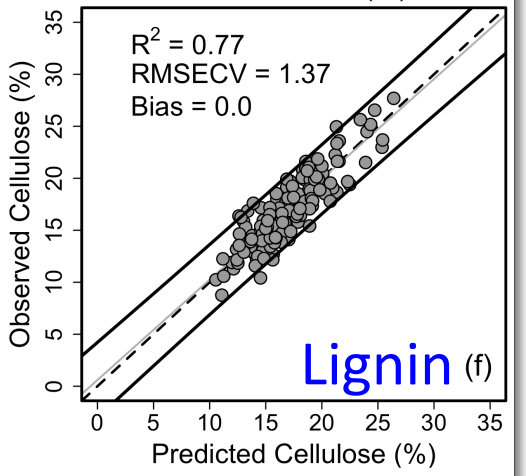


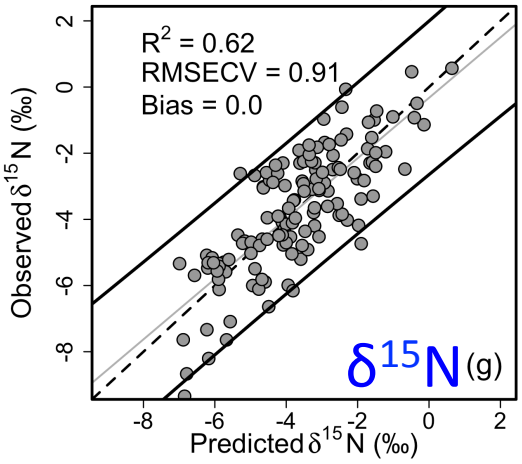












Where we are today:

Standardized equations to predict foliar constituents using leaf-level spectroscopy.

Also: cardenolides, condensed tannins, phenolic glycocides

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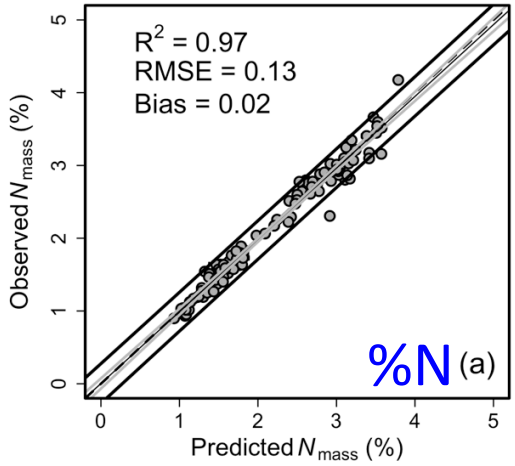
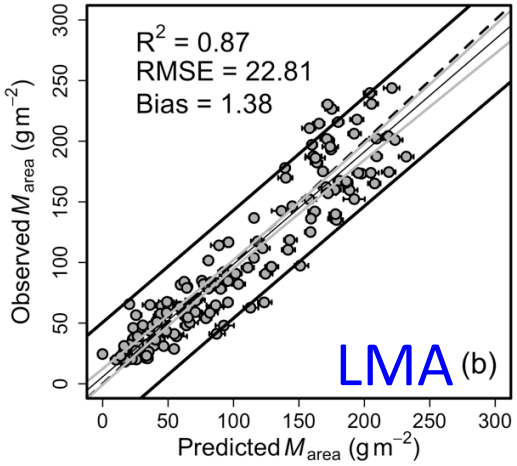
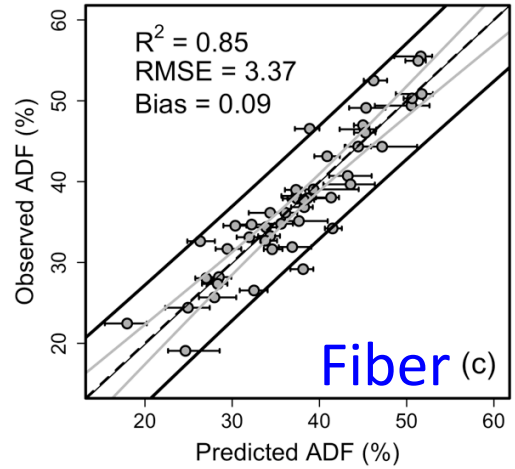
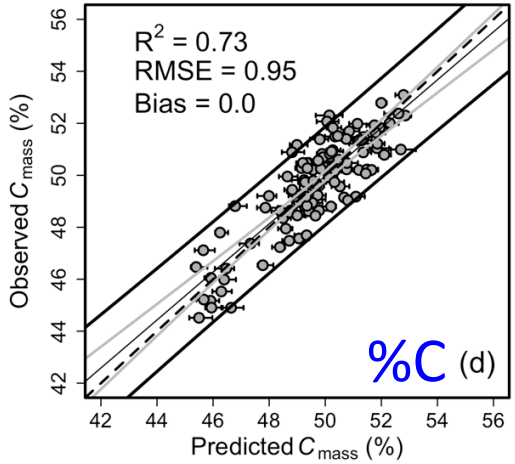
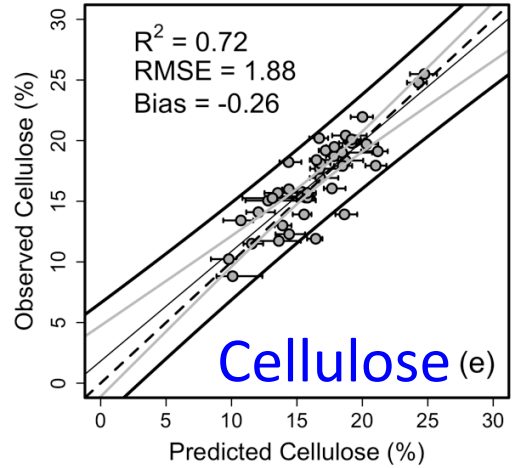
Val.

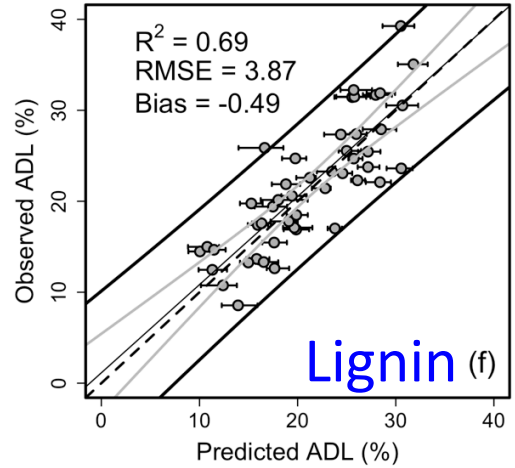


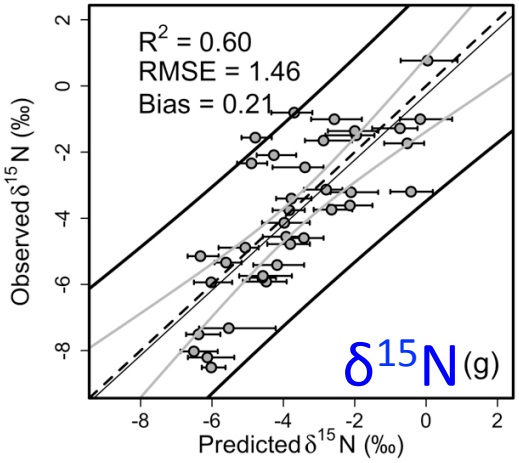












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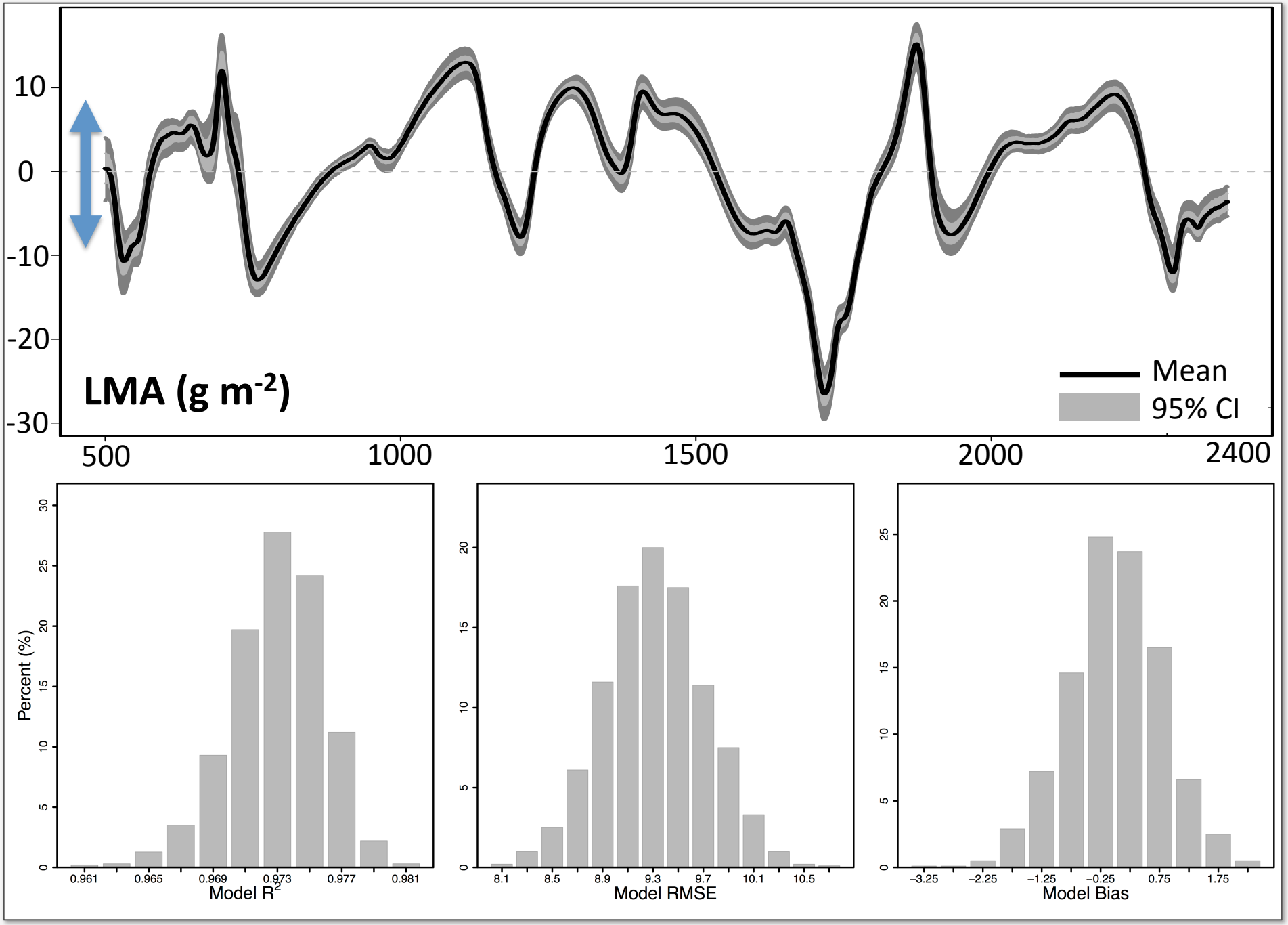
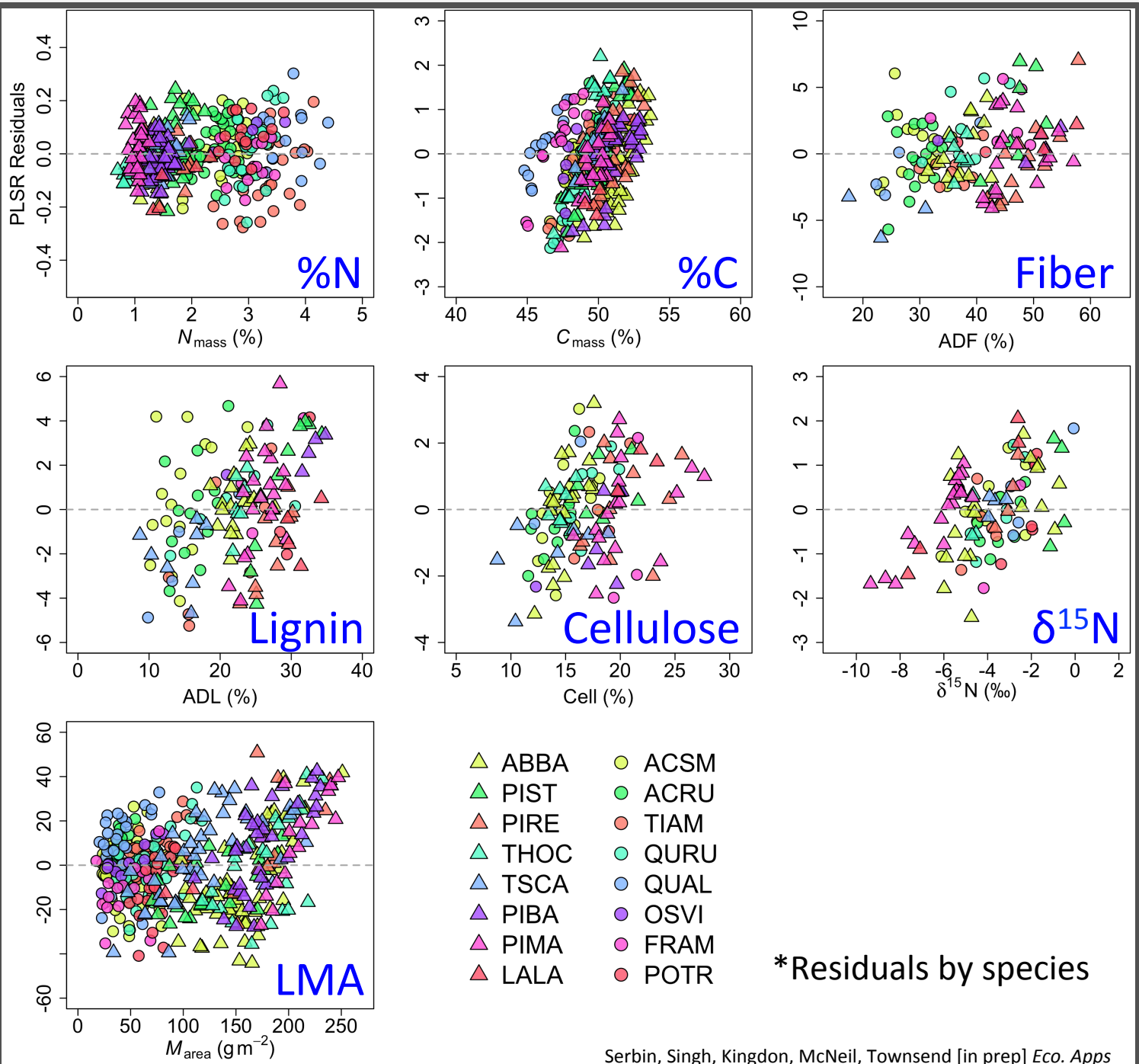
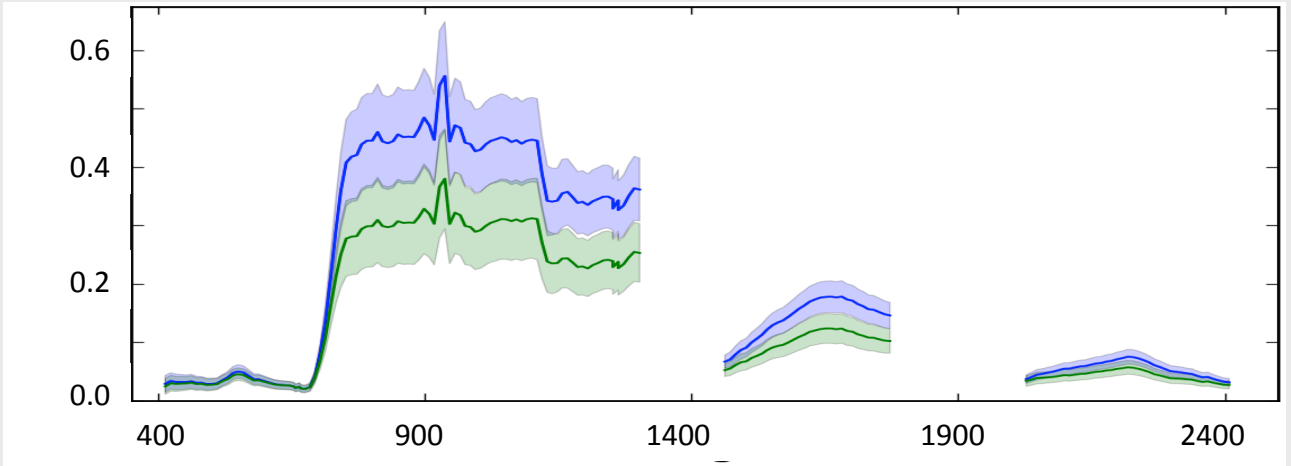
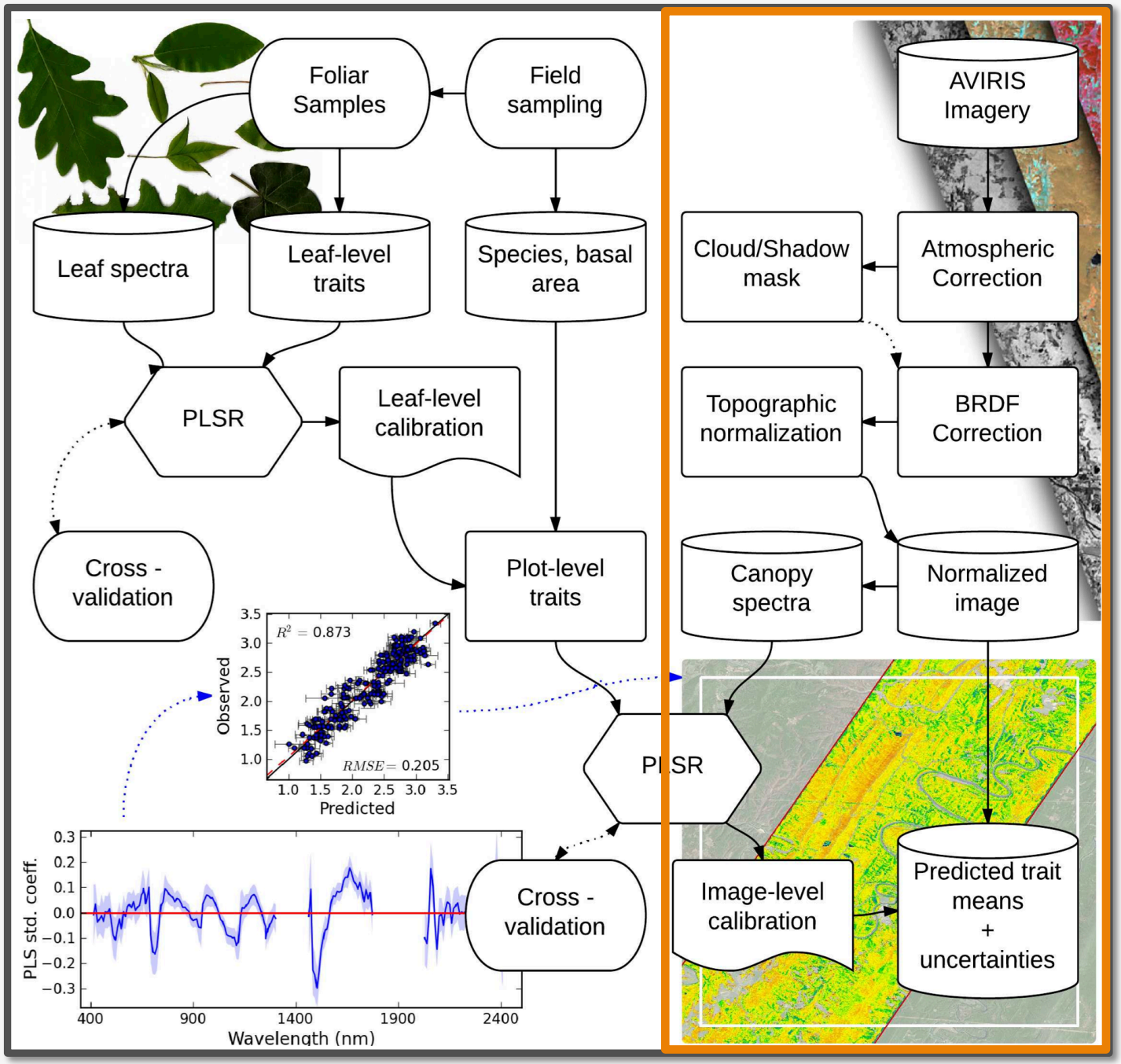

10
0
-10
-20
-30
LMA (g m-2)
Mean
95% CI
500
1000
1500
2000
2400
Percent (%)
0
5
10
15
20
25
30
0.961
0.965
0.969
0.973
0.977
0.981
Model R2
8.1
8.5
8.9
9.3
9.7
10.1
10.5
Model RMSE
−3.25
−2.25
−1.25
−0.25
0.75
1.75
Model Bias



Serbin, Singh, Kingdon, McNeil, Townsend [in prep] *Eco. Apps*

Scaling: Imaging Spectroscopy

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Predicted
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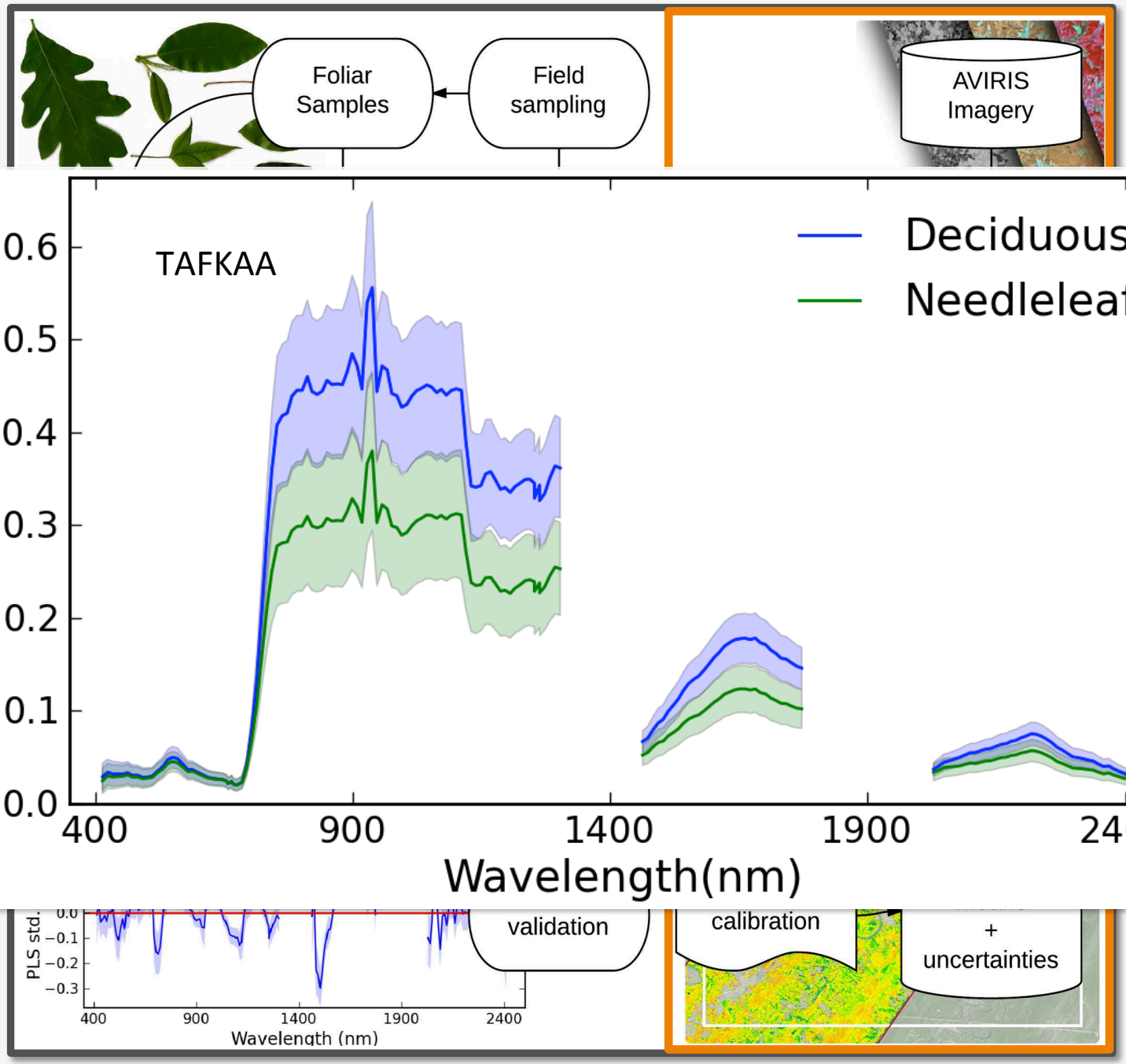
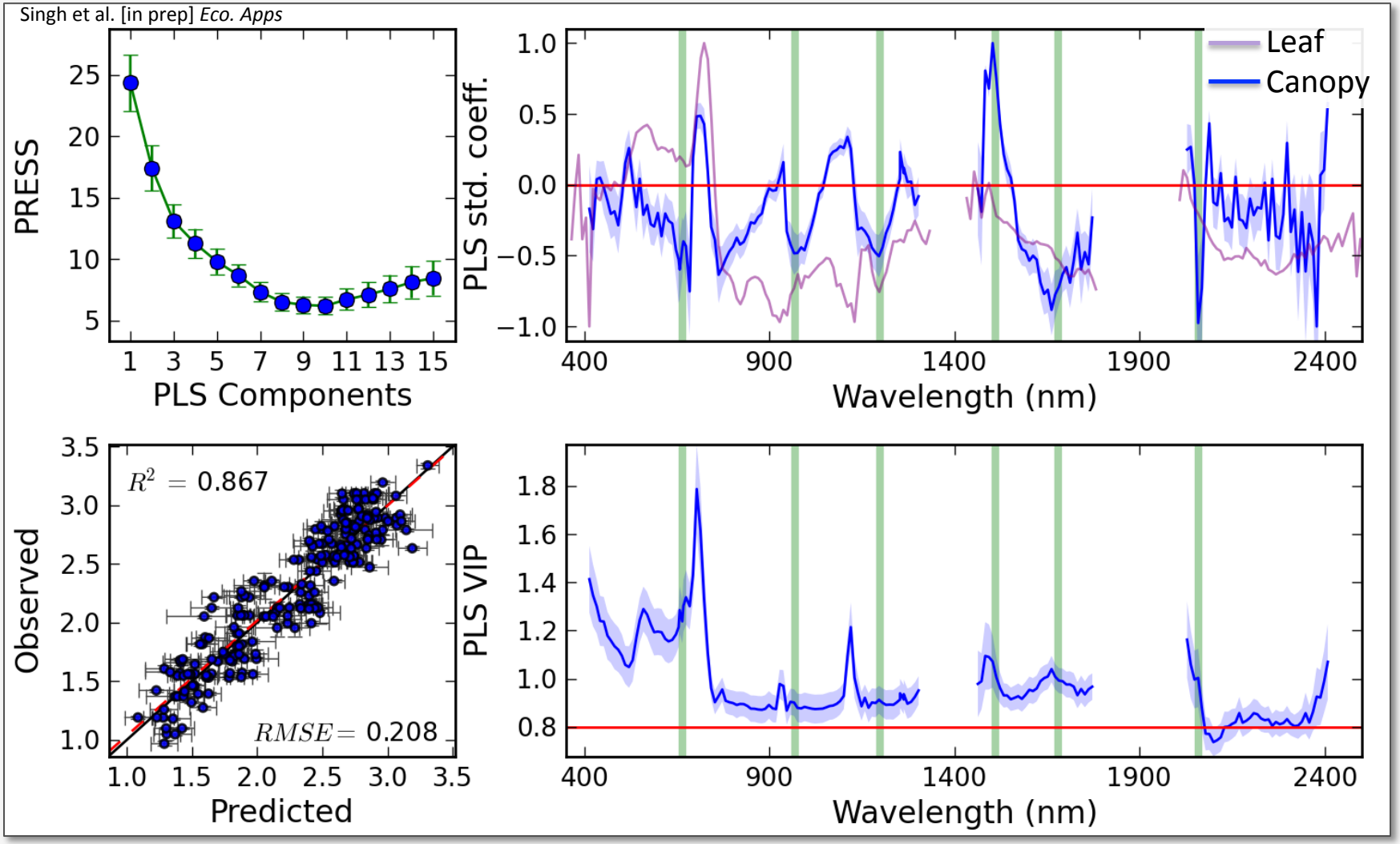
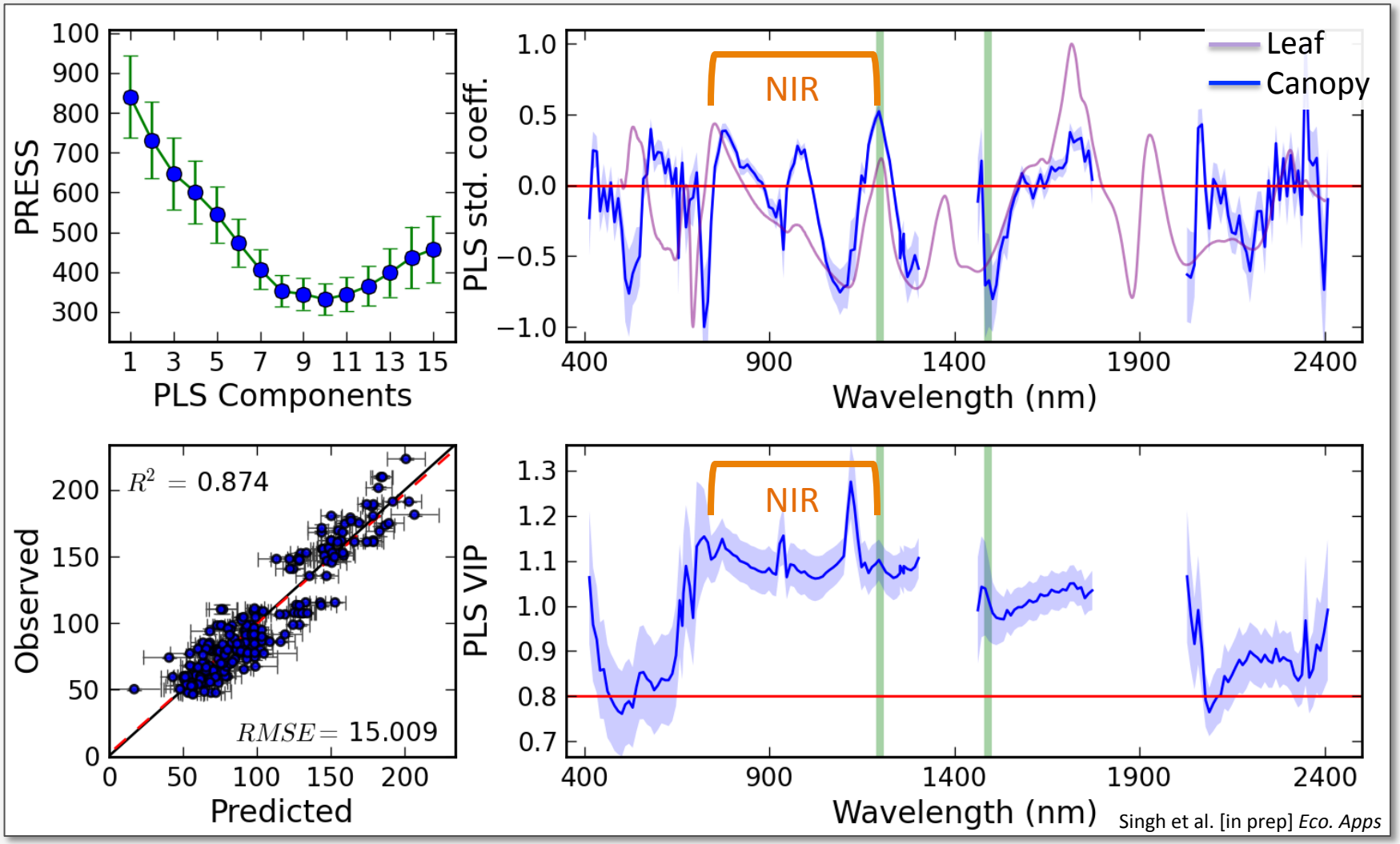

Foliar Samples
Field sampling
AVIRIS Imagery
TAFKAA
Deciduous
Needleleaf
Reflectance
0.0
0.1
0.2
0.3
0.4
0.5
0.6
400
900
1400
1900
2400
Wavelength(nm)
validation
calibration
+
uncertainties
PLS std.
−0.3
−0.2
−0.1
0.0
400
900
1400
1900
2400
Wavelength (nm)

Leaf Nitrogen Conc. (%)



Leaf Mass per Area (LMA, g m^{-2})



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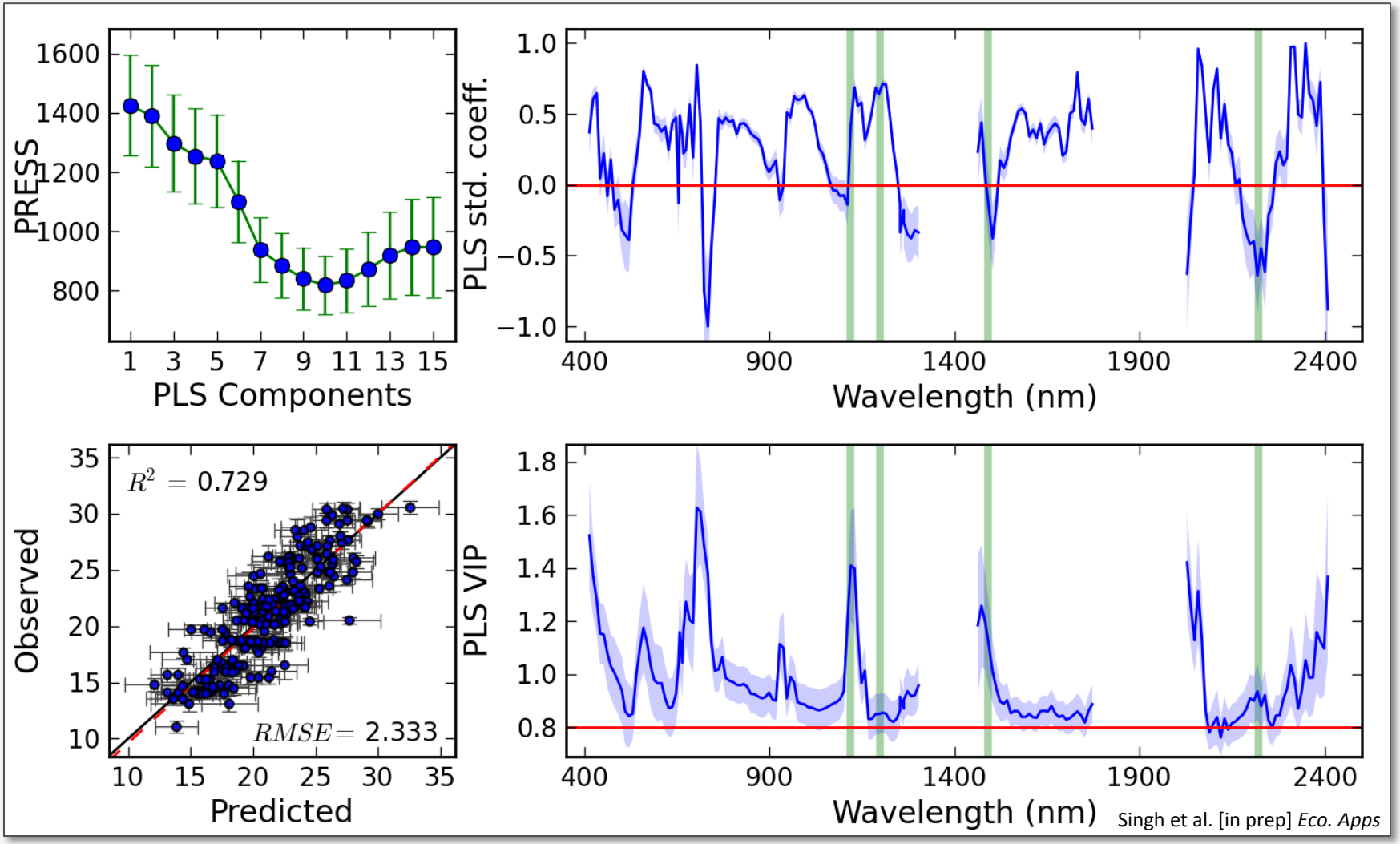
Lignin (% DW)



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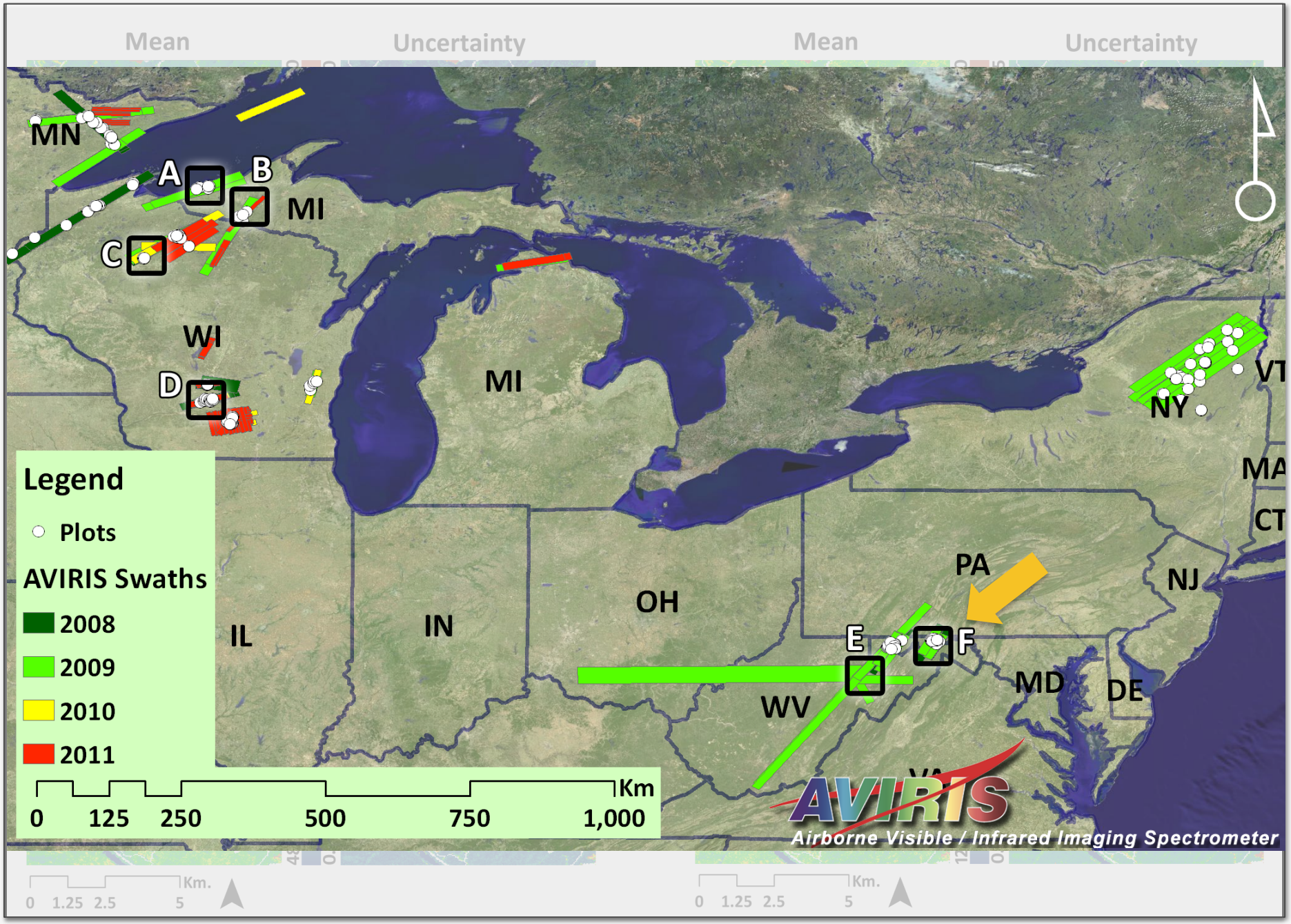
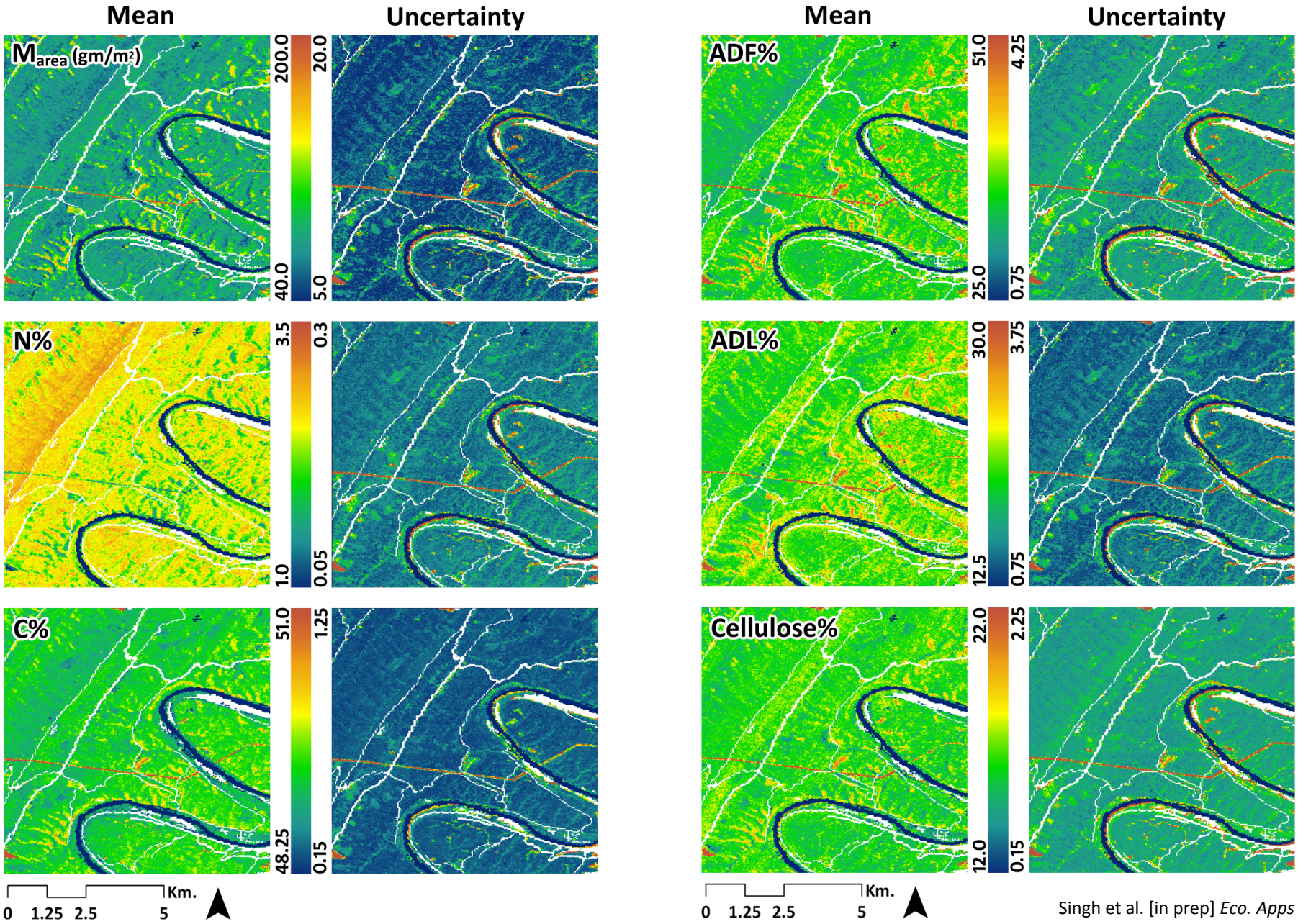

Mean
Uncertainty
Mean
Uncertainty
MN
A
B
MI
C
WI
D
MI
VT
NY
MA
CT
PA
NJ
OH
IN
IL
E
F
MD
DE
WV
Legend
Plots
AVIRIS Swaths
2008
2009
2010
2011
Km
0
125
250
500
750
1,000
AVIRIS
Airborne Visible / Infrared Imaging Spectrometer
Km.
0 1.25 2.5 5
Km.
0 1.25 2.5 5



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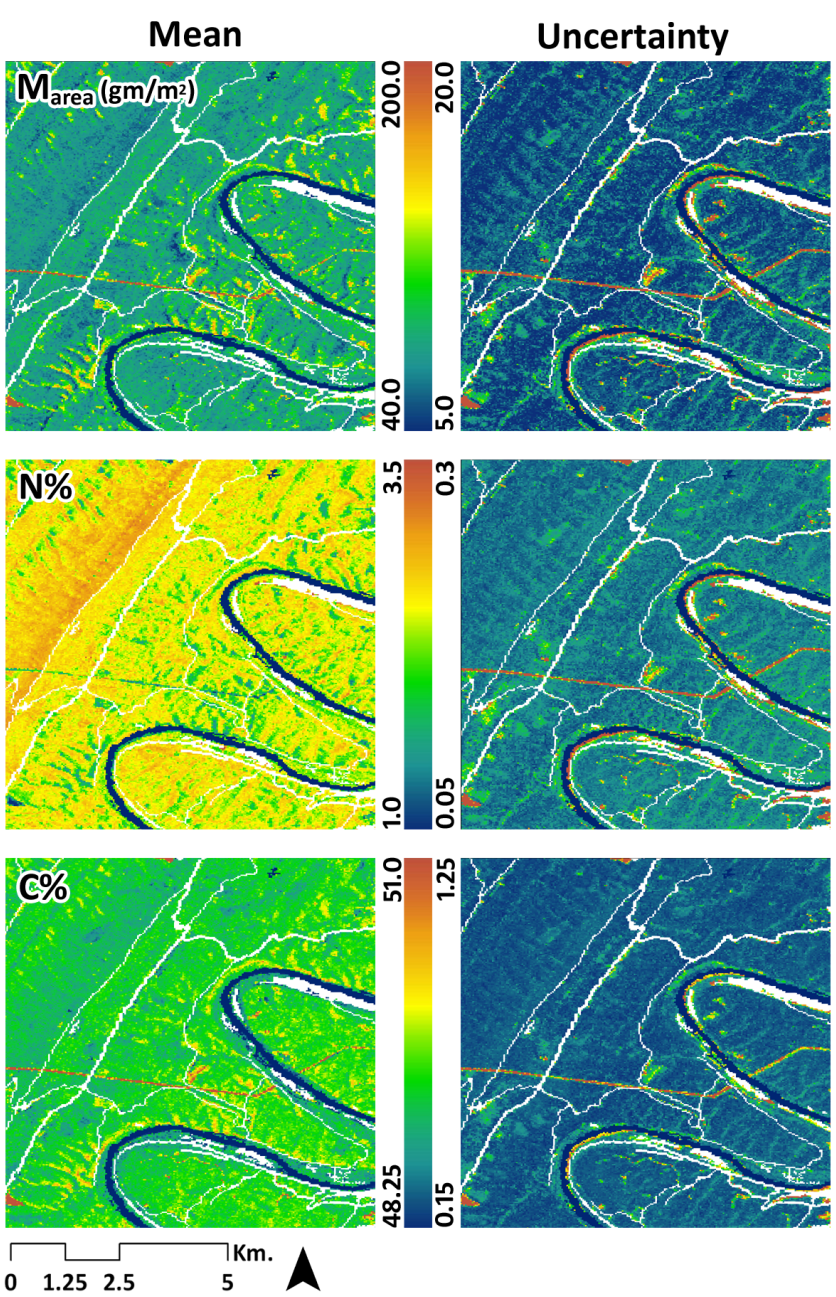
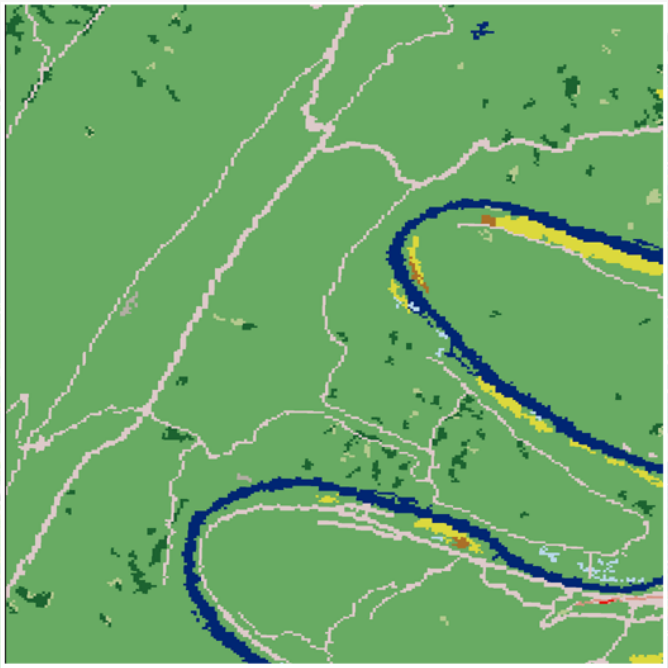
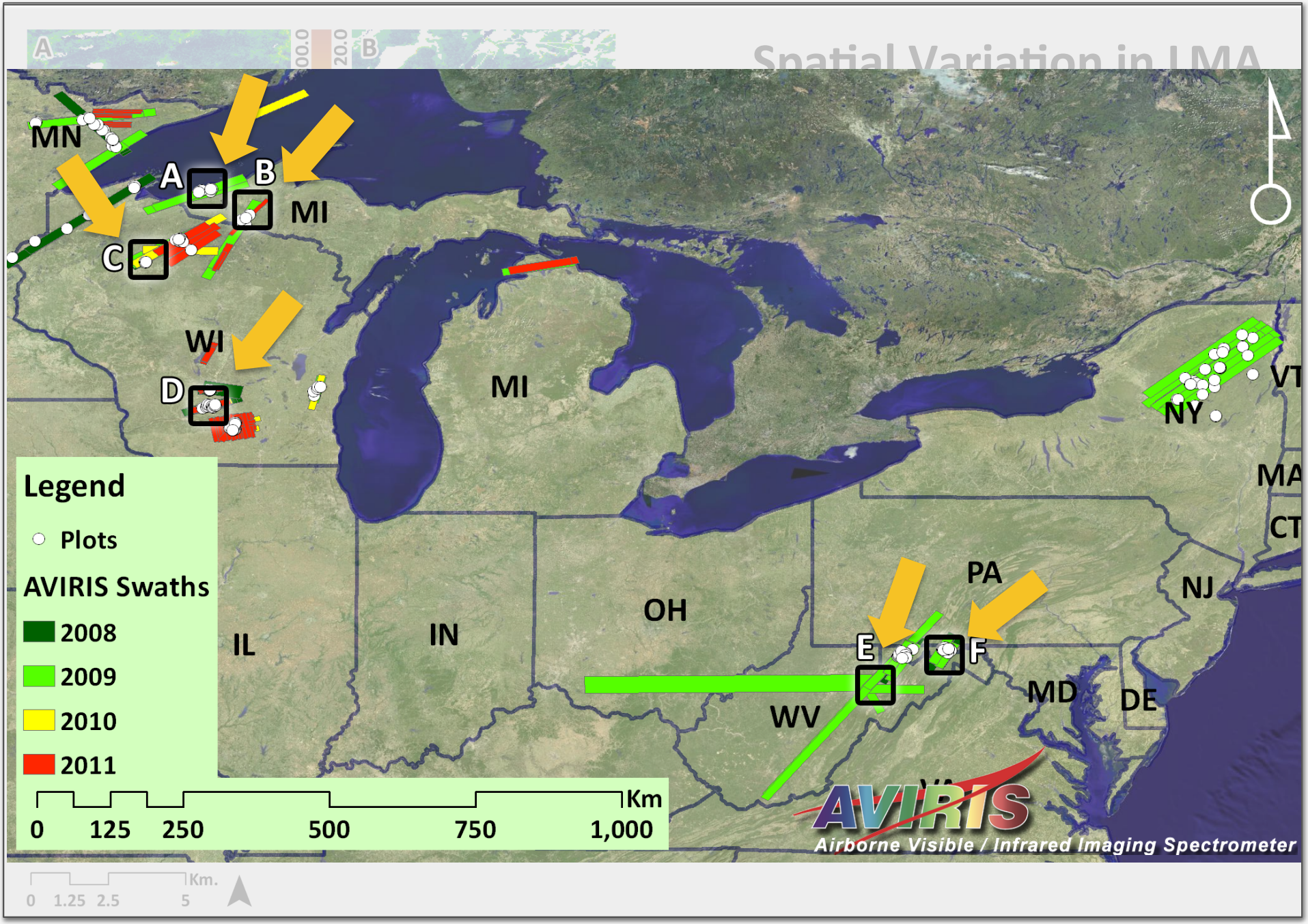




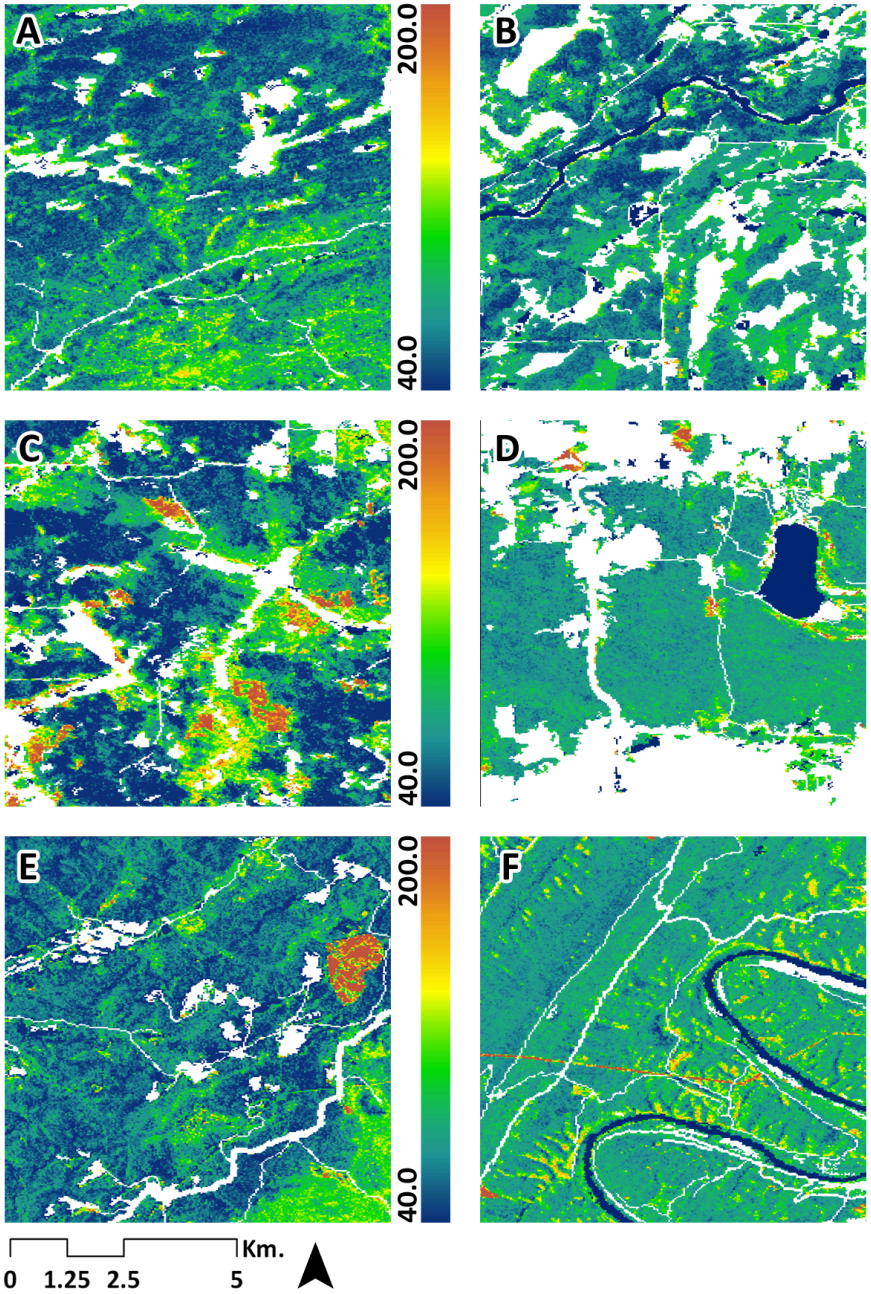
NLCD Land Cover Classification Legend

- 11 Open Water
- 12 Perennial Ice/ Snow
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land (Rock/Sand/Clay)
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 51 Dwarf Scrub*
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 72 Sedge/Herbaceous*
- 73 Lichens*
- 74 Moss*
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

* Alaska only


A
00.0
20.0
B
Spatial Variation in LMA
MN
A
B
MI
C
WI
D
MI
VT
NY
MA
CT
PA
NJ
OH
IN
IL
E
F
MD
DE
WV
Legend
Plots
AVIRIS Swaths
2008
2009
2010
2011
Km
0
125
250
500
750
1,000
AVIRIS
Airborne Visible / Infrared Imaging Spectrometer
Km.
0
1.25
2.5
5

Spatial Variation in LMA



A: Porcupine Mountains, MI (OG Hem/Hdw)

B: Ottawa NF, MI (OG Hem/Hardwood)

C: Flambeau River SF, WI (N. Hardwood)

D: Baraboo Hills, WI (Hickory/Oak/Pine)

E: Fernow Exp. Forest, WV (Mixed Hdw)

F: Green Ridge SF, MD (Mixed Oak)

Missing (urban/cloud)

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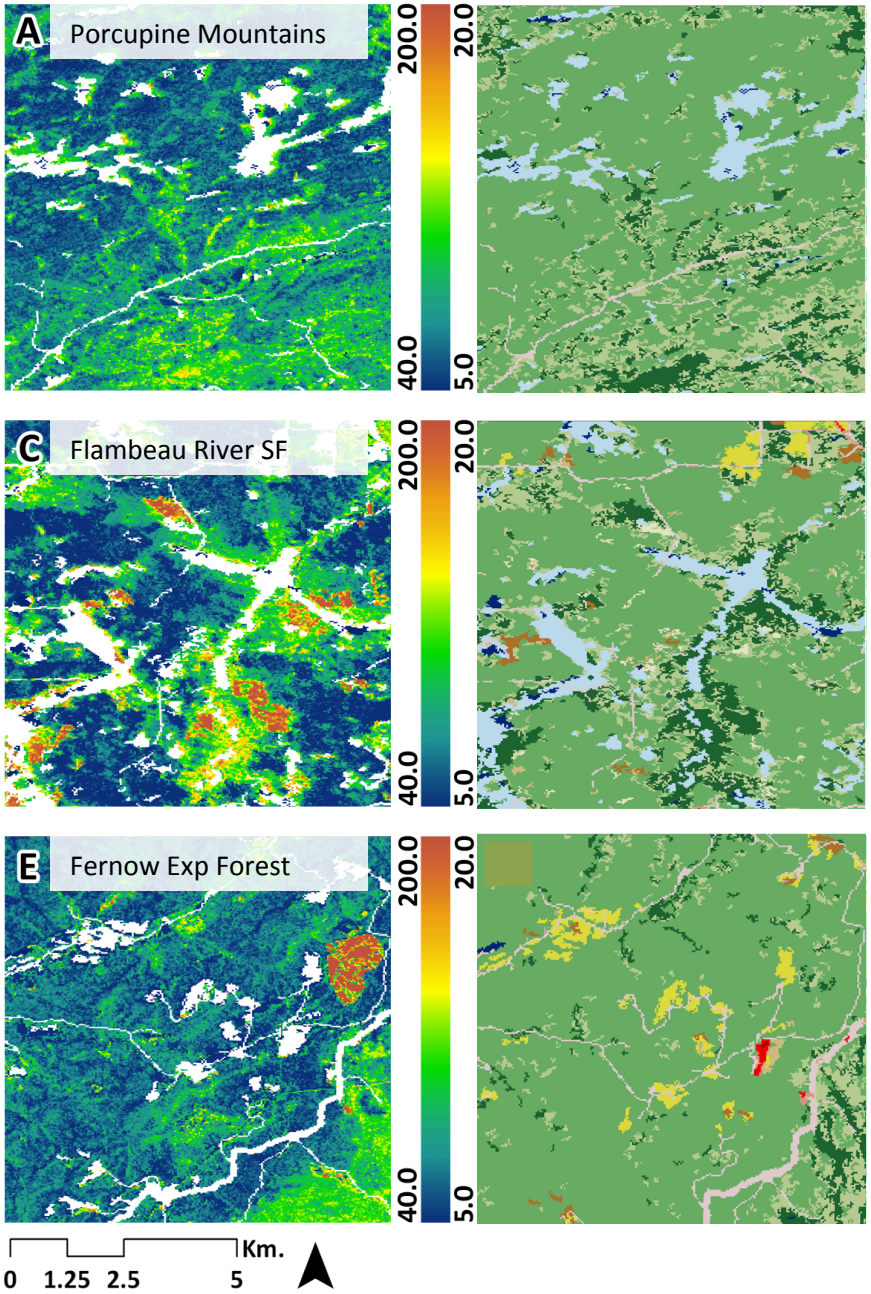
Spatial Variation in LMA



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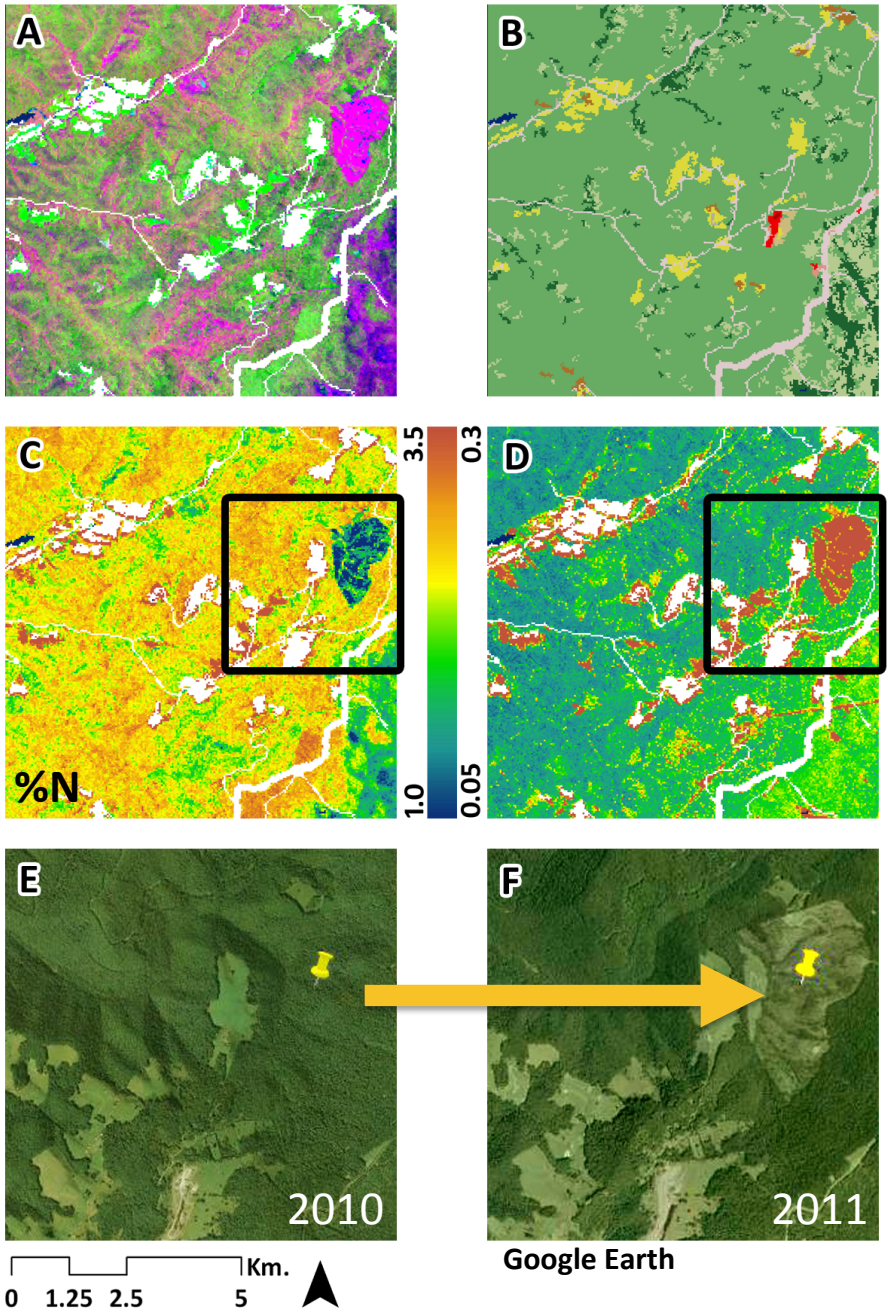
* Alaska only

Fernow Exp. Forest Logging Disturbance



R: ADL

G: Nitrogen

B: LMA

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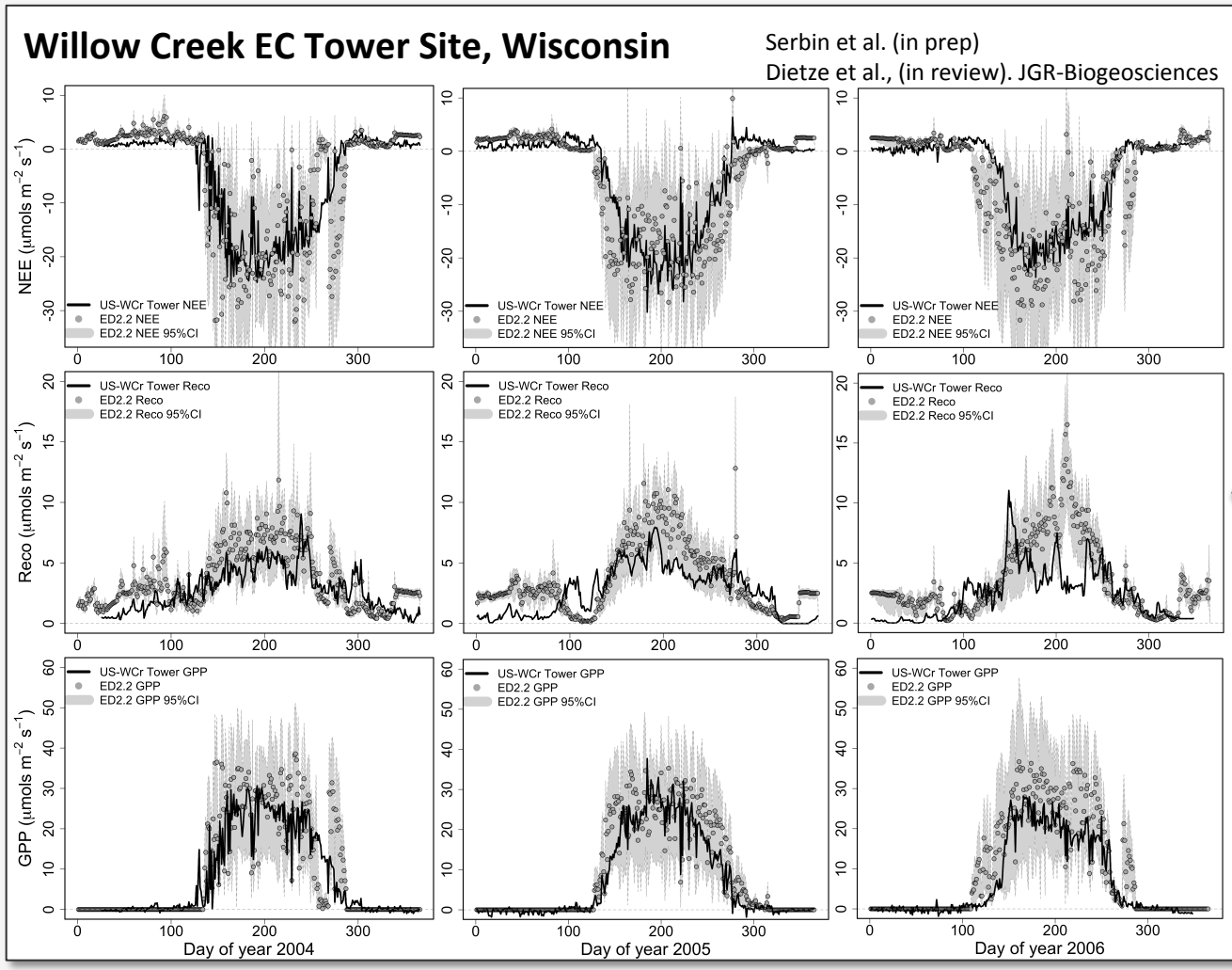
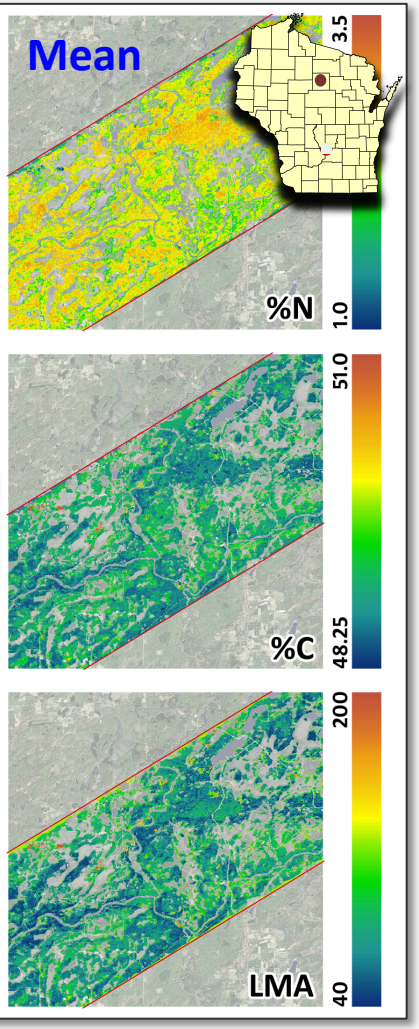
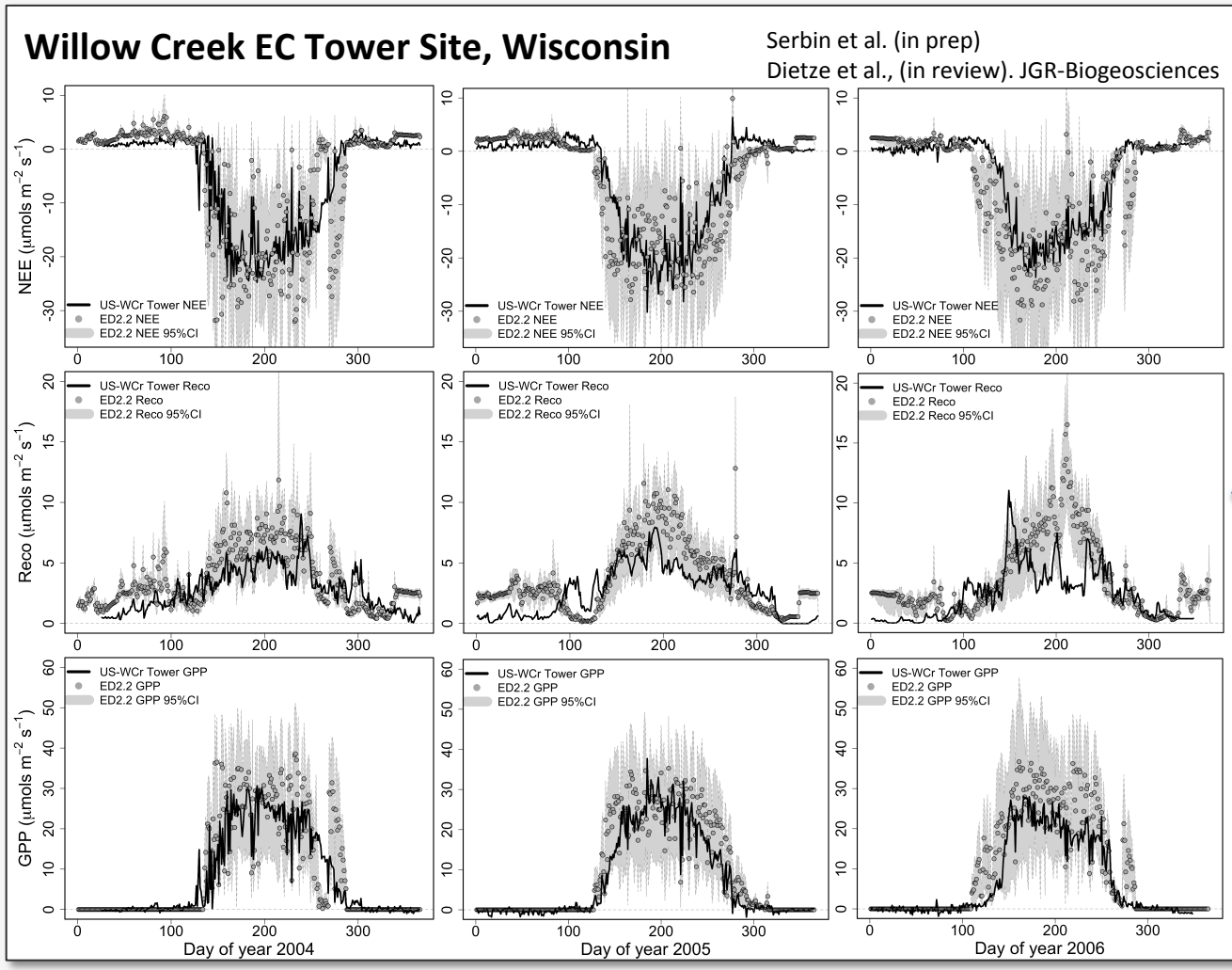
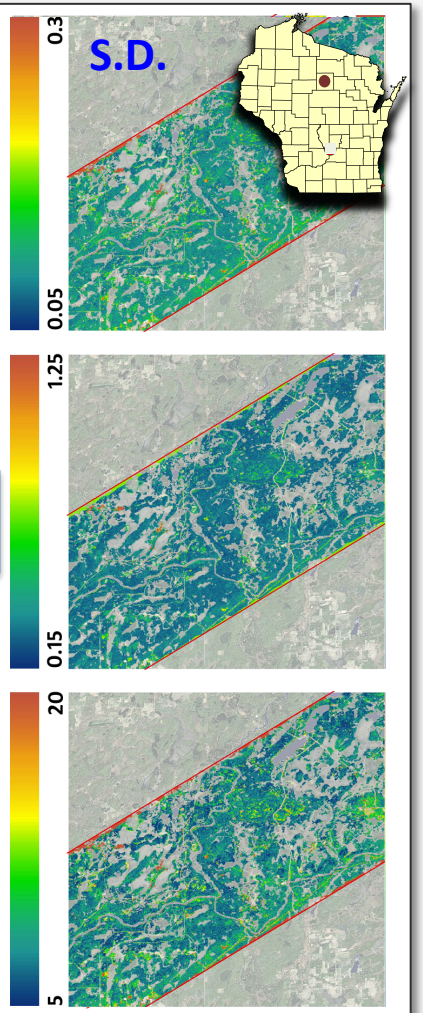
Model-data Assimilation: AVIRIS





Model-data Assimilation: AVIRIS





Next Steps

- Application of PLSR algorithms to new sites
  - Eastern US; NEON
  - HyspIRI California Campaign (cal/val)
- Synthesize spatial predictions within ecosystem models
  - Upper Midwest, HyspIRI California Campaign Leaf morphology, phenology, chemistry, etc

AVIRIS

Airborne Visible / Infrared Imaging Spectrometer

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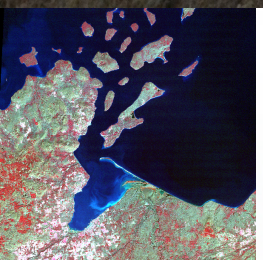
San Joaquin Exp. Range, California



FERST

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