Spectral time series for the study of ecosystem function, using EO-1 Hyperion

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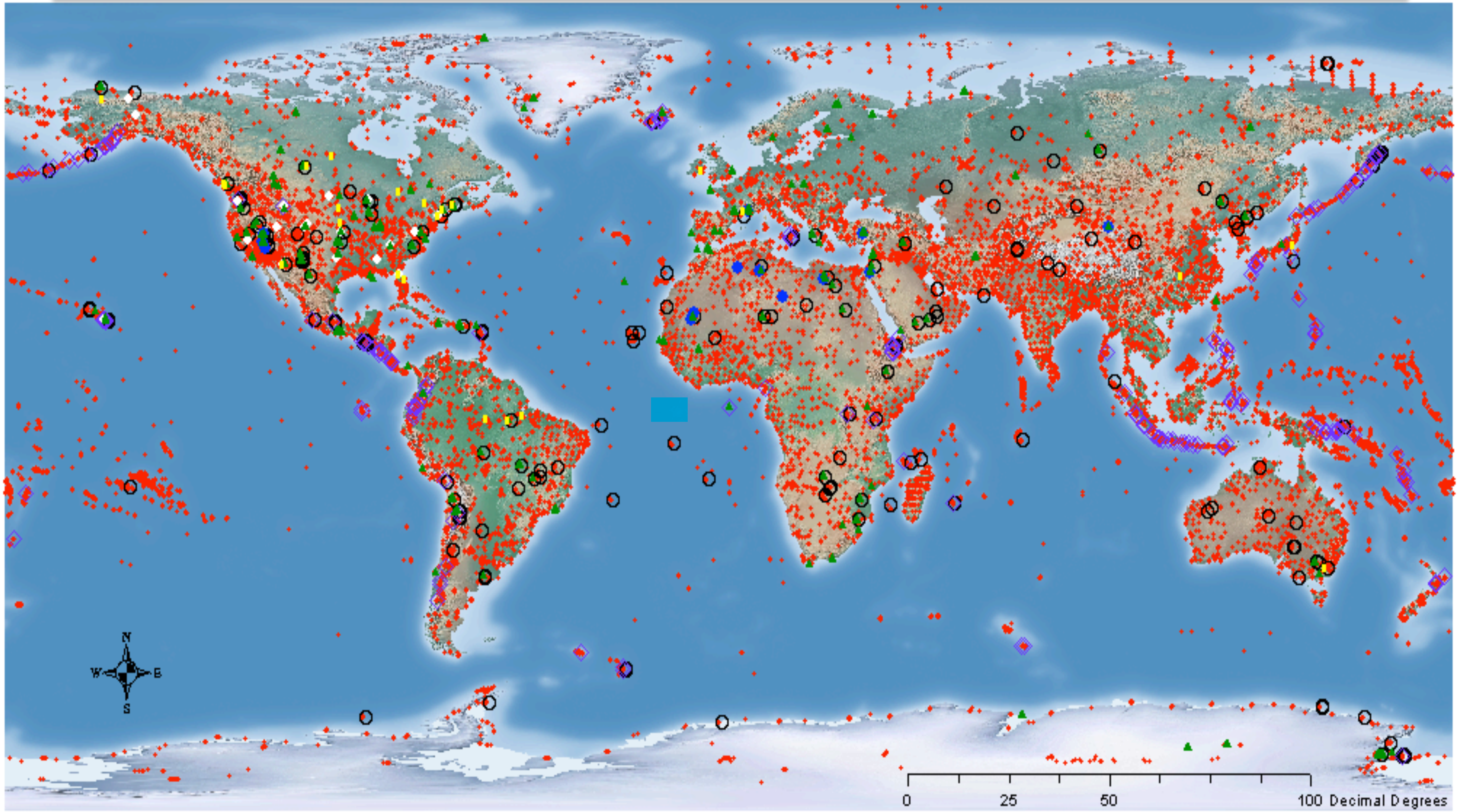
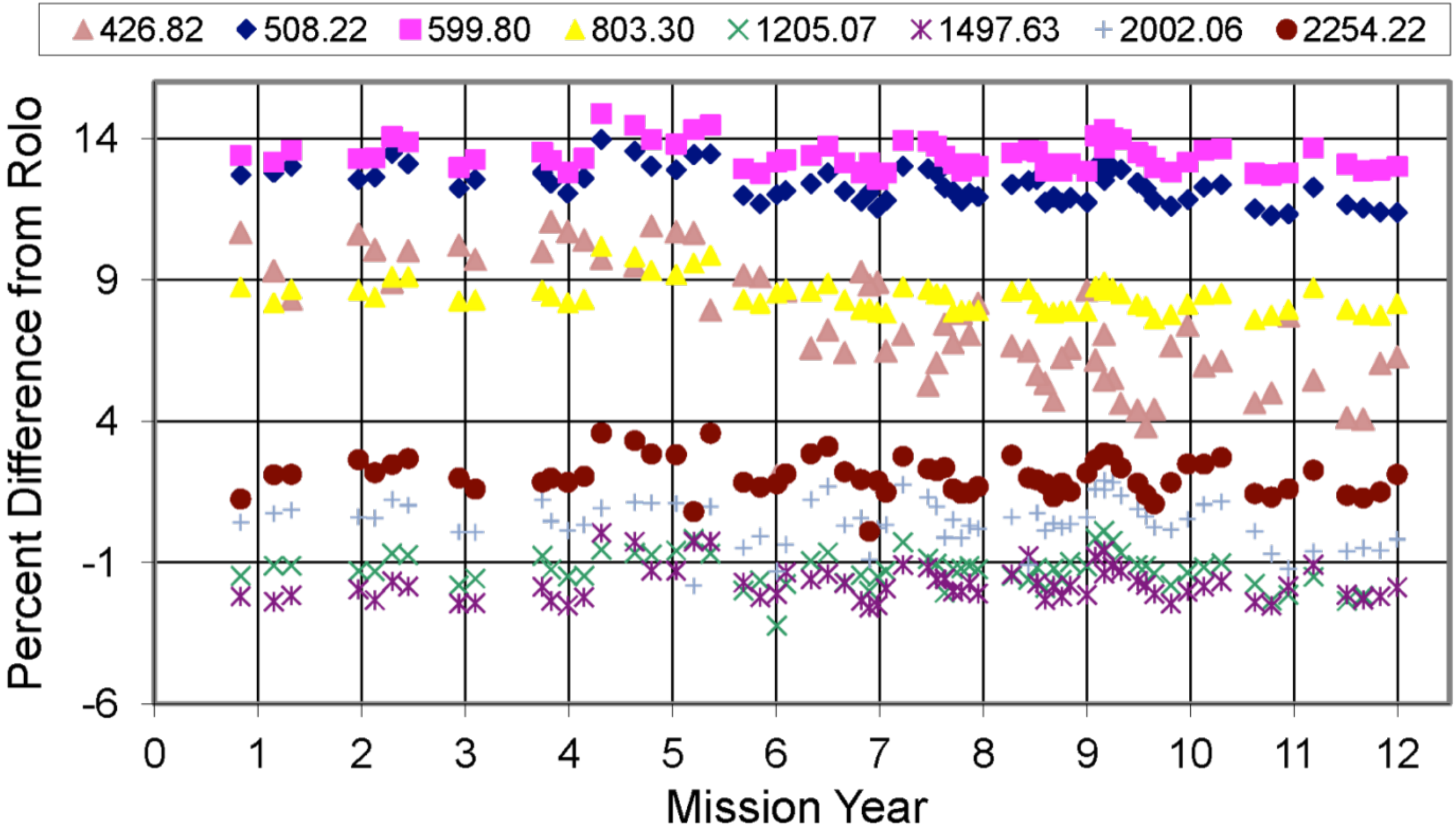
EO-1 Acquisitions, Dec 2000 – Current

> 70,000 Hyperion scenes have been collected



CEOS 14 Cal/Val	NEON 20 core	>10 images
EO-1 MSO Sites	La Thuile Flux Sites	Volcanoes

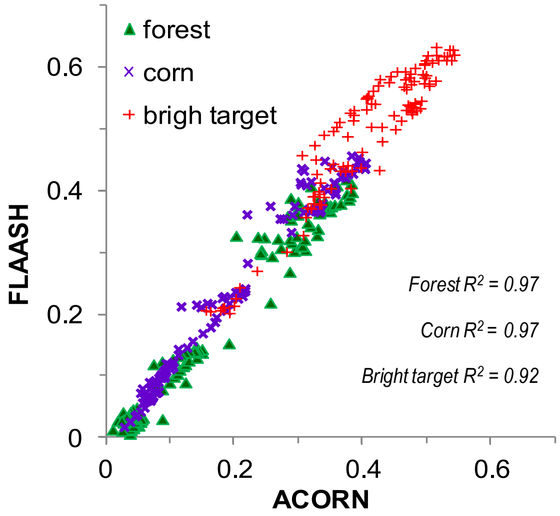
Hyperion Lunar Calibration Trends

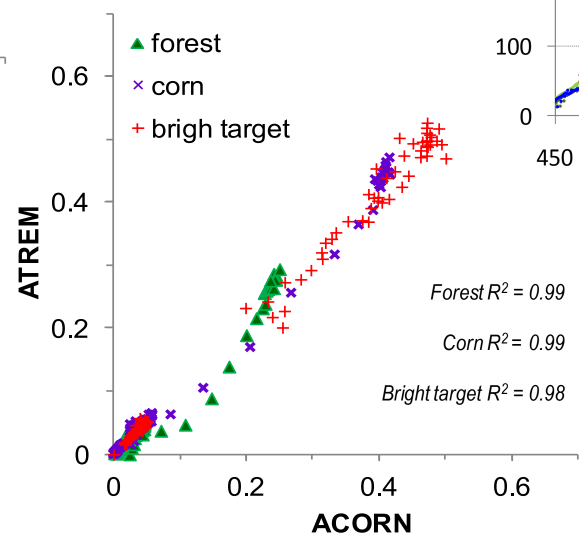


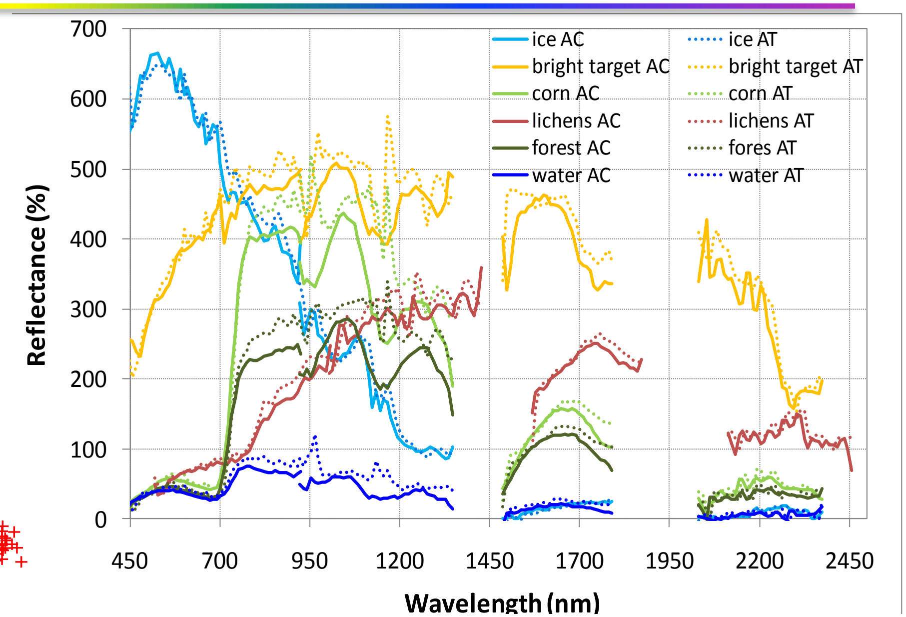
<u>Differences</u> *between Rolo model and Hyperion measurements remain stable (within 5%) over time*

Lawrence Ong 2013

EO-1 Hyperion Image Processing

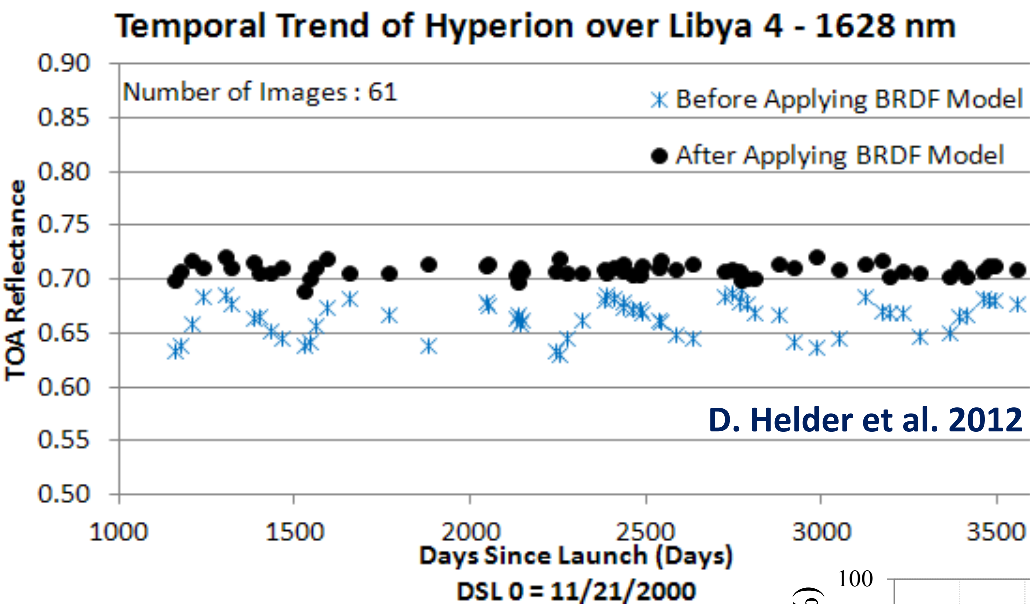






- Level 1R Hyperion data were atmospherically corrected using the Atmosphere CORrection Now (ACORN) model.
- Reflectance spectra were extracted in the vicinity of the existing flux towers, from 30-50 pixels depending on the site size.

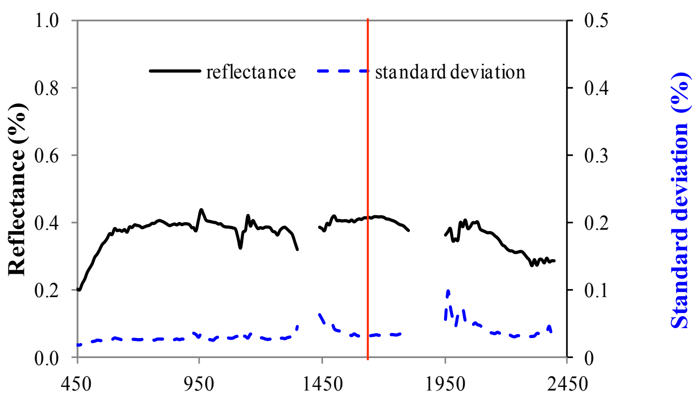
Spectral Time Series at CEOS Cal/Val Sites

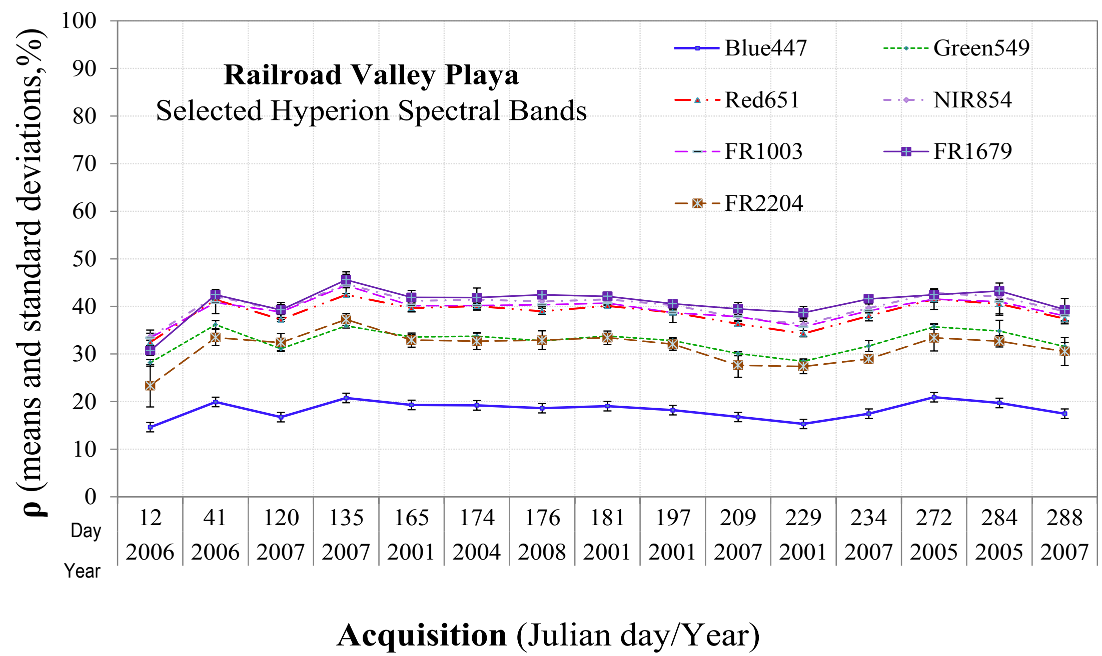


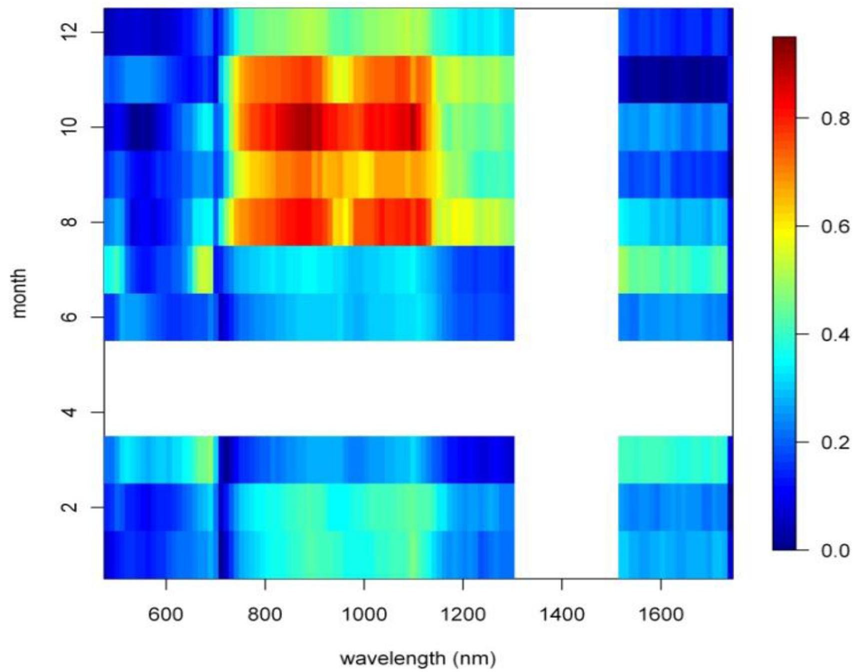
Temporal Profile of Selected Hyperion Bands

Calibration converts those images from pretty pictures to accurate data sets that can be used for a variety of scientific purposes such as …

D. Helder





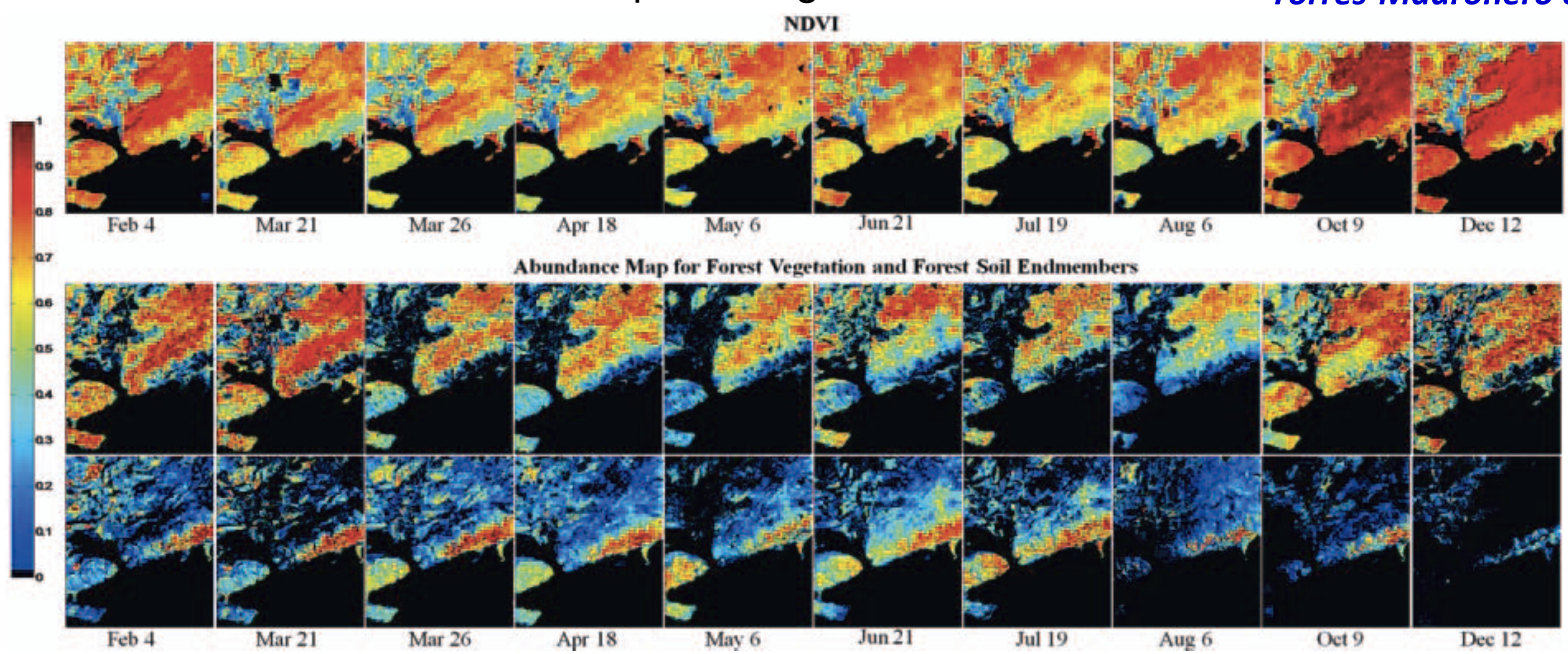


Reflectance spectro-temporal Separability Index comparing native *vs*. invasive tree species in Hawaii, demonstrating that phenology is a key to spectral separability analysis.

Somers & Asner, 2013

NDVI and Endmember abundance maps for vegetation and soil

Torres-Madronero et al. 2012



Science Questions

- Is there a common (global) spectral approach to trace vegetation function, and it's CO_2 sequestration ability?

- How do species and biodiversity composition within ecosystems respond spectrally to the seasonal environmental changes?

- How do spectral properties and temporal dynamics of vastly different ecosystems compare?

Flux Tower Data

FLUXNET Integrating Worldwide CO_2, Water and Energy Flux Measurements

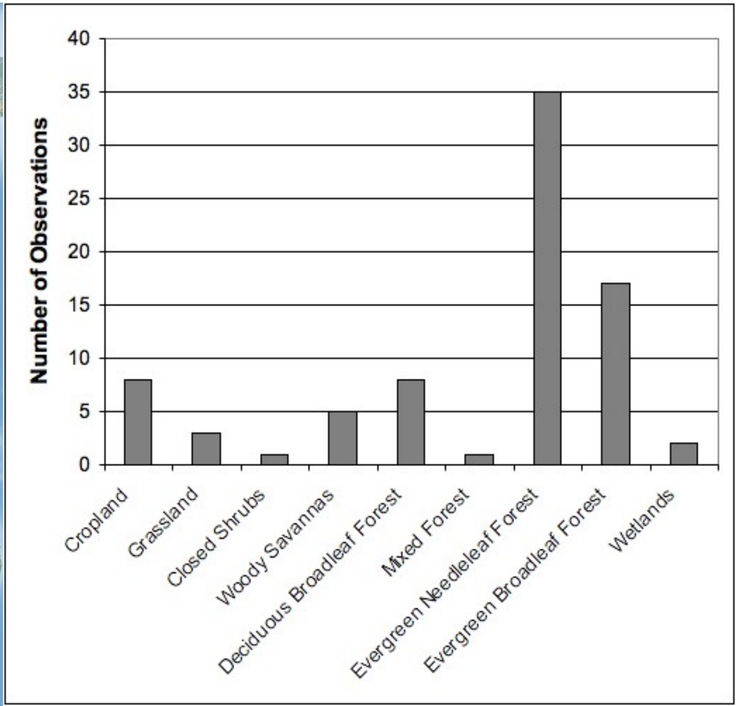
FLUXNET is a "network of regional networks" for regional and global analysis of observations from micrometeorological tower sites. The flux tower sites about 545 (~410 active) use eddy covariance methods to measure the exchanges of carbon dioxide (CO_2), water vapor, and energy between terrestrial ecosystems and the atmosphere.

LaThuile Fluxnet Synthesis: A global network of about 250 flux sites with standardized flux calculations and gap filling for all sites (data 1982-2008)

Hyperion & Fluxnet

The time series include more than 90 sites globally, with >40 sites providing observations over flux tower sites

- PLS: 79 images of 33 different LaThuile flux tower sites, data from 2001 to 2007, matched flux data with available Hyperion imagery
- Spectral time series and VIs, 450+ images, 15 flux tower sites



CO_2 Flux Data Processing

- Net Ecosystem Production (NEP, µmol m^{-2} s^{-1}) is the CO_2 absorbed by the vegetation, measured by the flux tower.
- Ecosystem Respiration (Re) was calculated from relationships developed between nighttime Net Ecosystem Exchange (NEE) and air temperature.
  - When available, soil moisture was also used to determine Re
- Gross Ecosystem Production (GEP) is calculated from the observed NEE and Re.

Carbon Flux Variables

We looked at Light Use Efficiency (LUE, ε) derived from the tower data

$$\varepsilon = GEP/(f_{APAR}\ PAR_{in})$$

Where:

GEP is the gross ecosystem production (calculated from tower data)

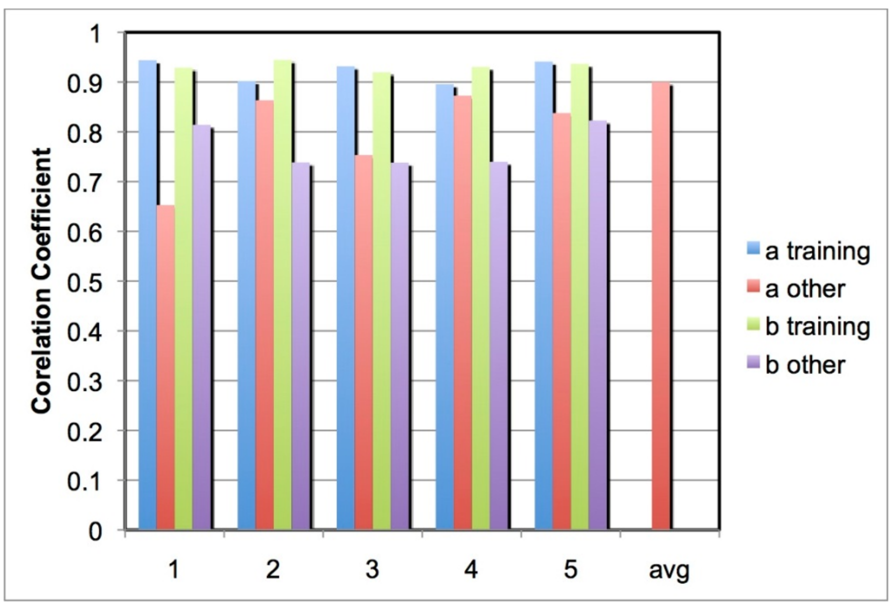
PAR_{in} is the incident Photosynthetically Active Radiation (measured at tower)

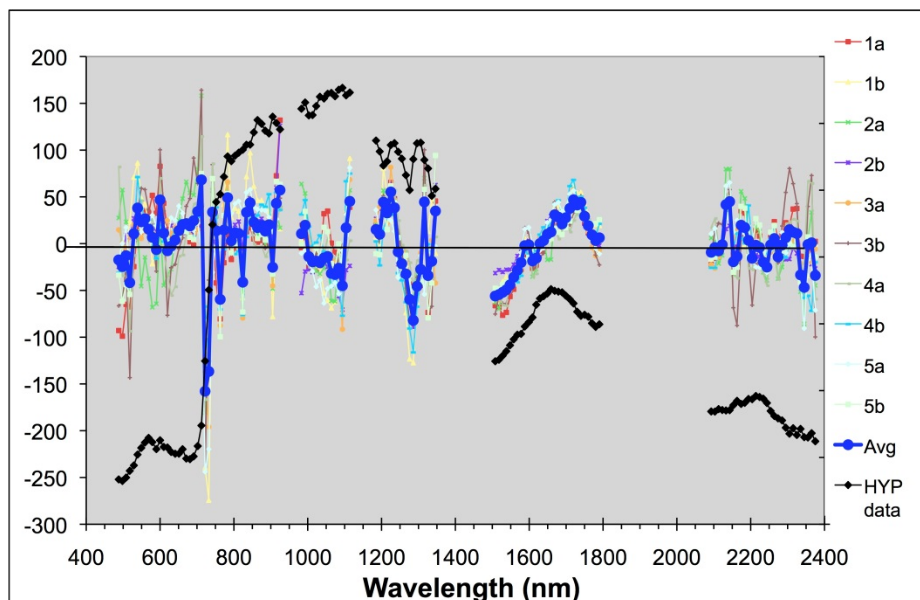
f_{APAR} is the fraction of PAR absorbed by vegetation (used MODIS f_{APAR} values)

Partial Least Squares –LUE

Partial Least Squares is an approach that utilizes all of the spectral information

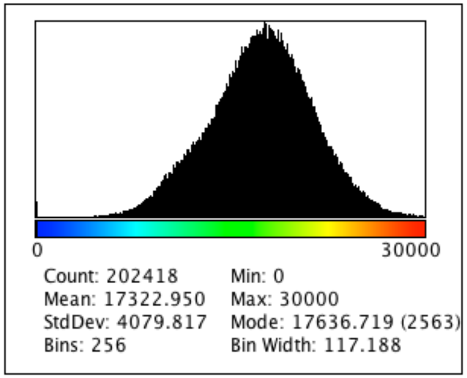
PLS regressions against daily LUE were calculated for all spectral bands for random subsets of half of the data (n=39) – resulted in similar weighting factors for the spectral bands



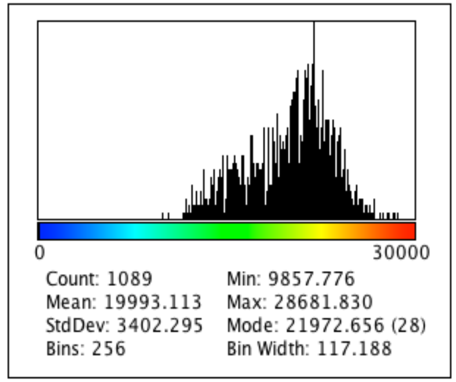


Remote Sensing of Fluxes: Hyperion and Fluxnet

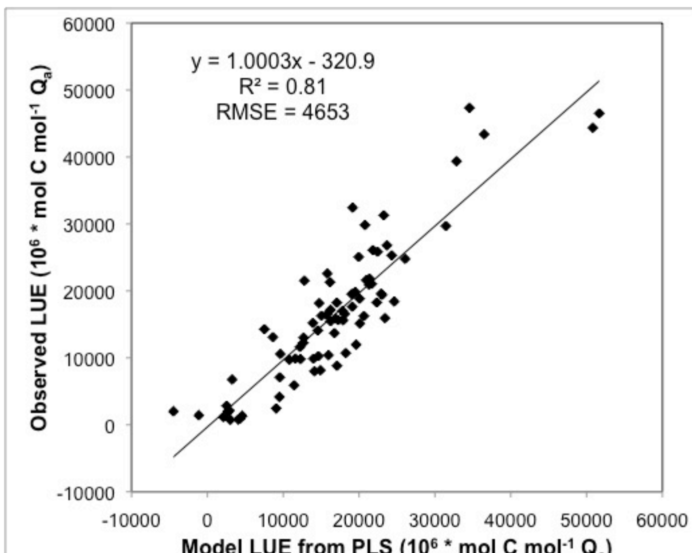
Using matched flux data from LaThuile Fluxnet Synthesis with Hyperion imagery for 33 globally distributed flux tower sites



LUE Histogram for full scene



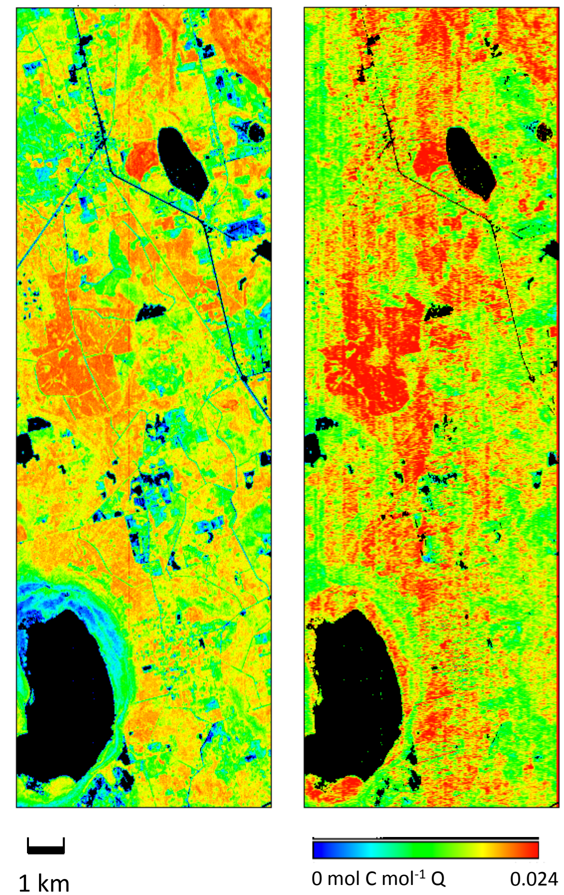
LUE Histogram for km^2 around tower



Light Use Efficiency (LUE) estimated from reflectance using PLS regression of spectra to observed LUE from flux towers

Florida Slashpine

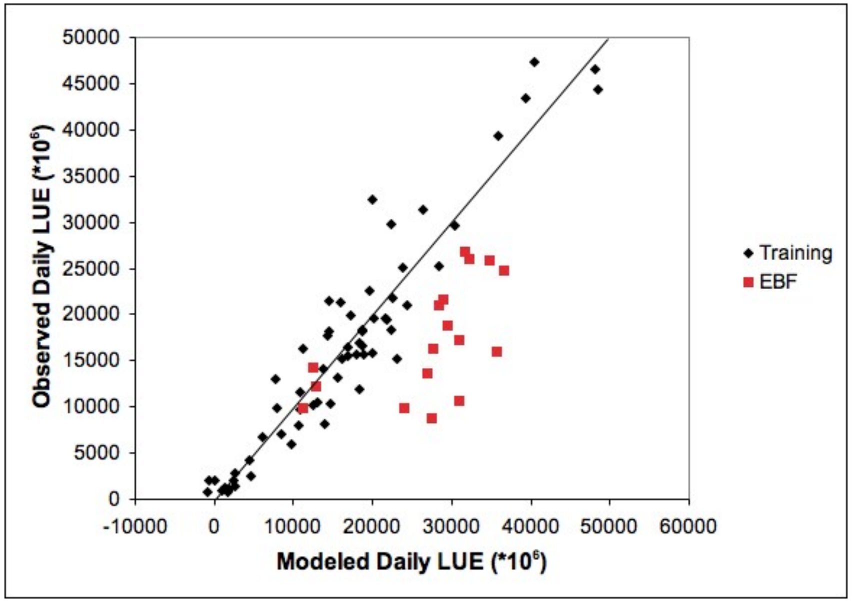
NDVI LUE

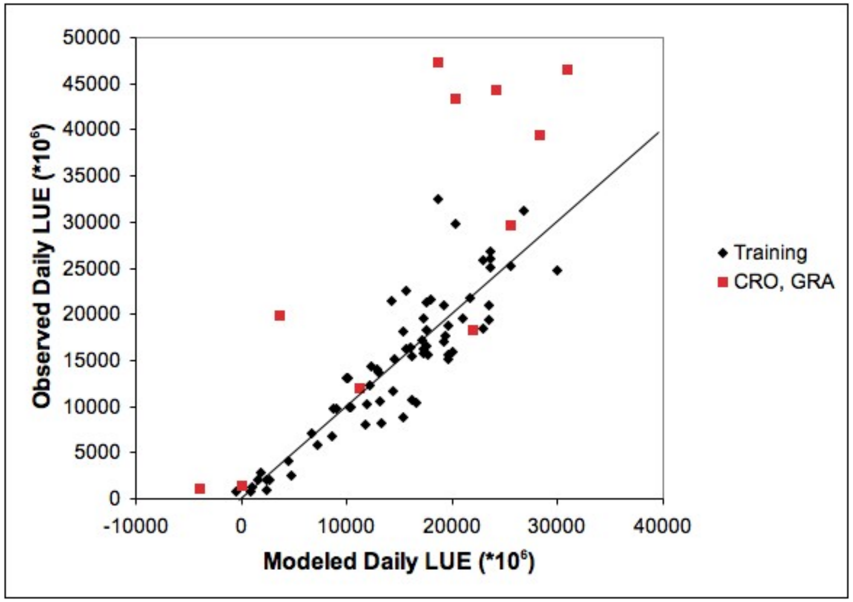


Huemmrich, Campbell & Middleton

Partial Least Squares – LUE

Tests where specific vegetation types were removed from training datasets often performed poorly when applied to the test data





Black points – training data
Red points – Evergreen Broadleaf Forests

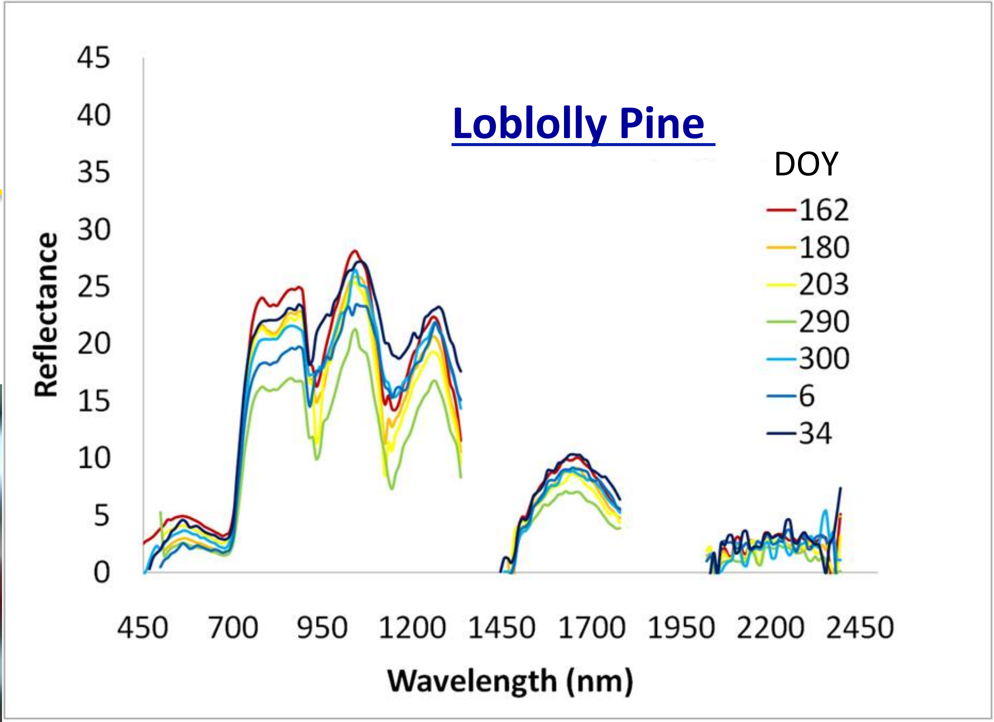
Black points – training data
Red points – Crops and Grasslands

Spectral Time series -- Regression Coefficients for the Top Performing Spectral Bio-indicators (R^2 values)

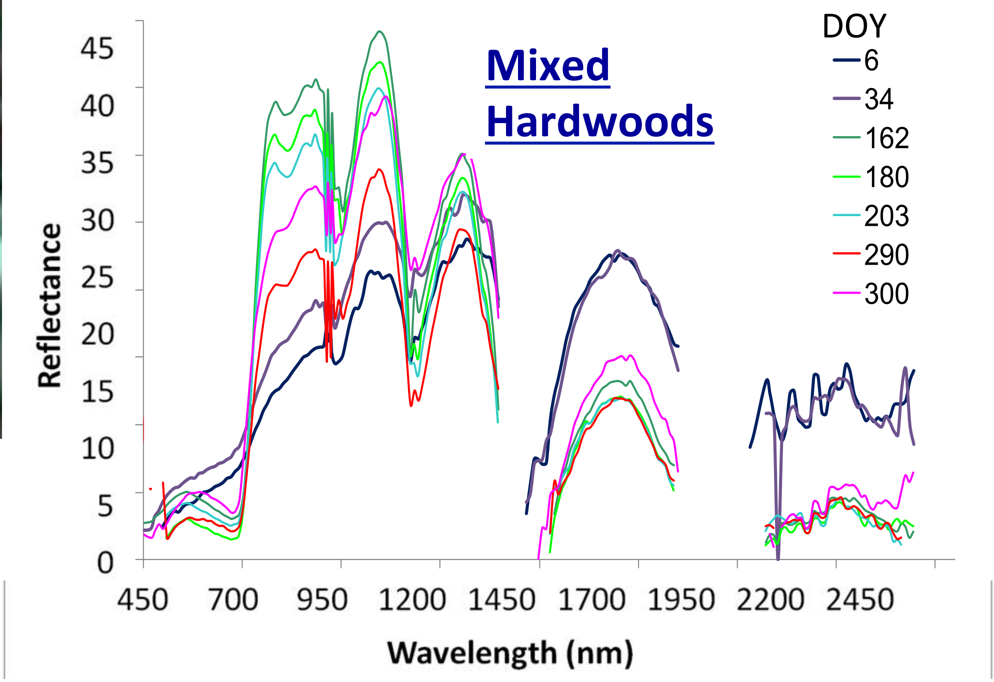
Spectral indicator	Formula	NEP	GEP	LUE
Dmax	Max D in the 650-750 nm	**0.72 L+**	**0.77** L+	0.76 L+
DP22	Dmax/D(max + 12)	0.64 L+	0.73 NL+	0.70 L+
NDWI	R(870-1240)/R(870-1240)	**0.75** NL +	0.66 NL+	0.62L+
MCARIa	Chlorophyll, R bands at 700, 670, and 550	0.42 L+	0.75 L+	**0.77** L+
PRI4	(R531-R670)/(R531-R670)	0.66 NL+	0.62 NL+	0.49 NL+
NDVI	(NIR-R)/(NIR+R) NIR= Av. 760..900, R=Av. 620..690	0.56 NL+	0.59 NL+	0.44 NL+

Duke, NC

Pine site
Hardwood site



Loblolly Pine
DOY
162
180
203
290
300
6
34
Reflectance
Wavelength (nm)
45
40
35
30
25
20
15
10
5
0
450
700
950
1200
1450
1700
1950
2200
2450



Mixed Hardwoods
DOY
6
34
162
180
203
290
300
Reflectance
Wavelength (nm)
45
40
35
30
25
20
15
10
5
0
450
700
950
1200
1450
1700
1950
2200
2450

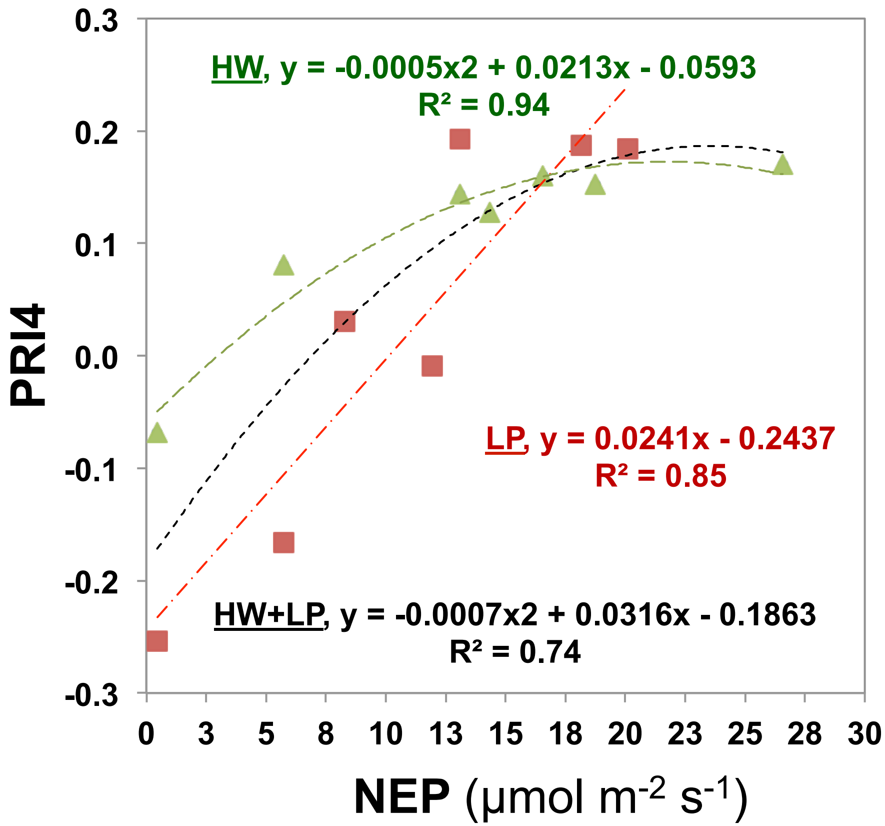
Bio- indicators of *Photosynthetic Function*

Loblolly Pine (LP)

Index	Bands (nm)	R^2 [NEP (GEP) *LUE*]
PRI1	531, 570	0.84 (0.73) L
PRI4	531, 670	0.75 (0.63) *0.73* L
DPI	D 680, 710, 690	0.91 (0.44) NL
NDWI	870, 1240	0.76 (0.60) L
NDVI	NIR, Red	0.19 (0.48) L

Hardwoods (HW)

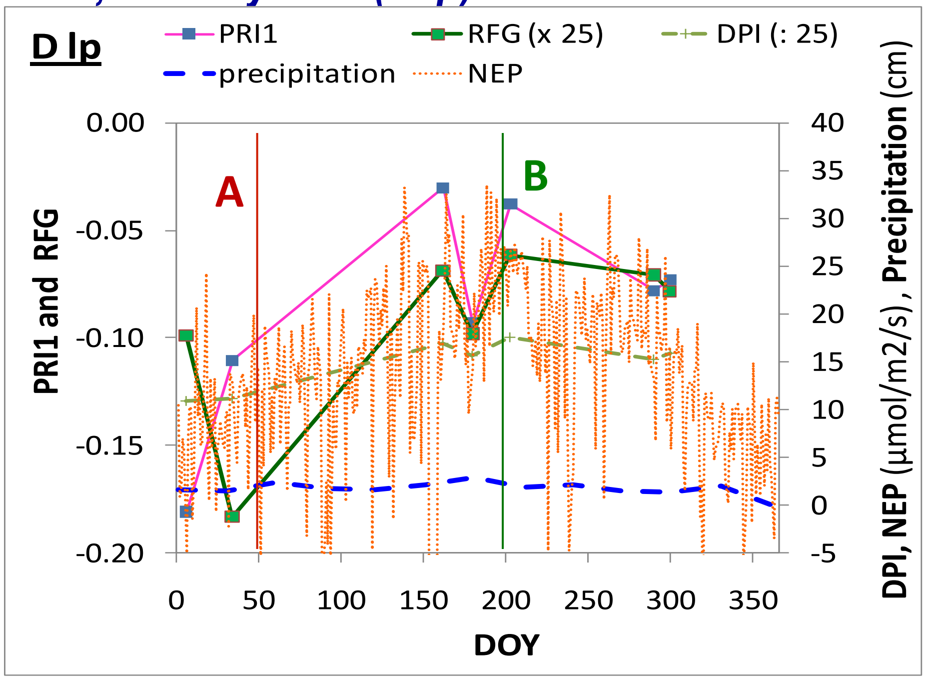
Index	Bands (nm)	R^2 [NEP (GEP) *LUE*]
PRI4	531, 670	0.84 (0.48) NL
Dmax	D max (650…750 nm)	0.83 (0.40) NL
NDII	820, 1650	0.79 (0.34) L
EVI	NIR, Red, Blue	0.84 (0.41) L
NDVI	NIR, Red	0.63 (0.19) L



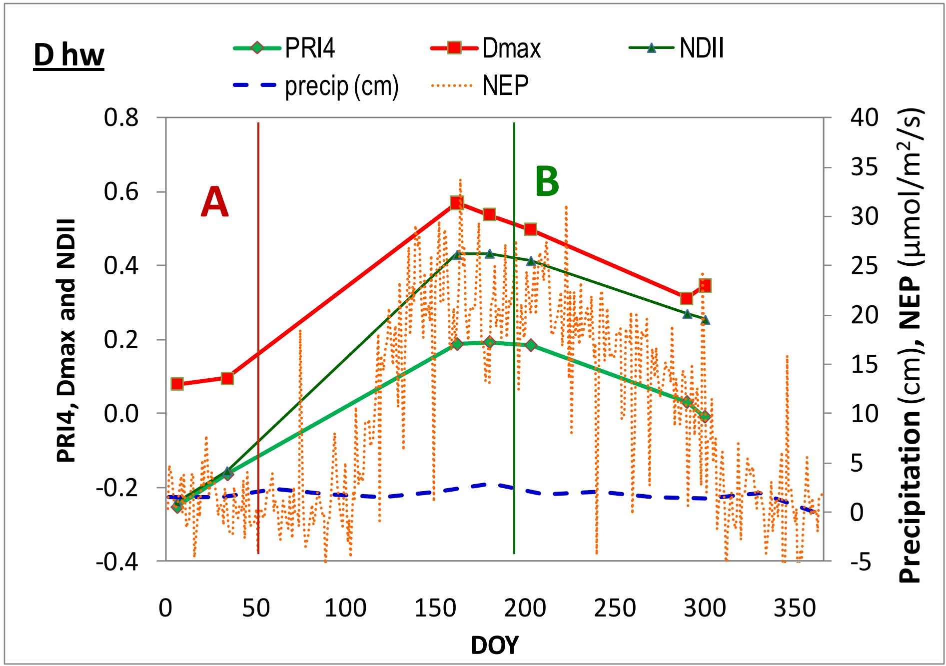
Campbell et al. 2012

Seasonal dynamics in PRI

Duke, Loblolly Pine (D lp)

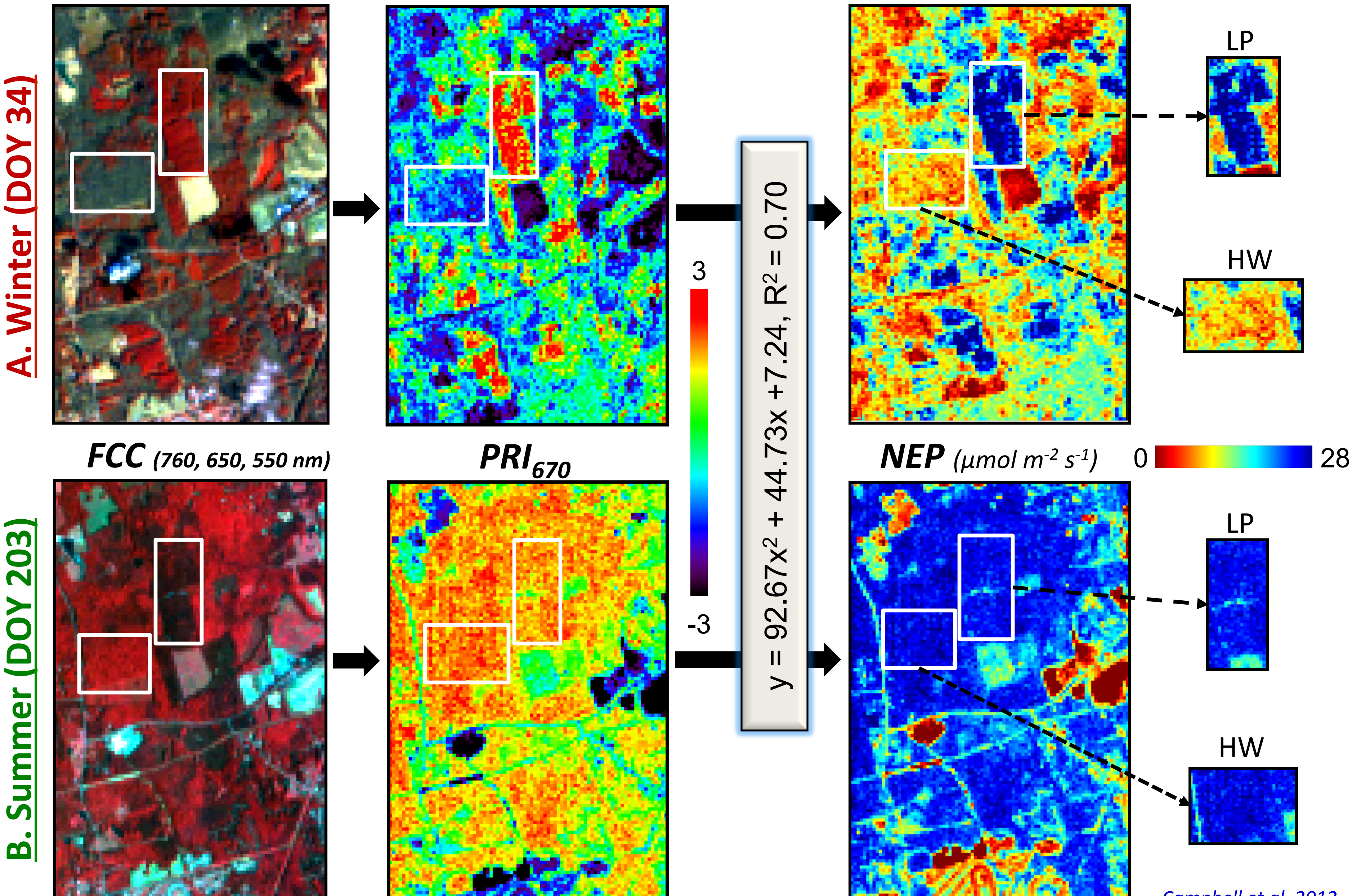


Duke, Hardwoods (D hw)



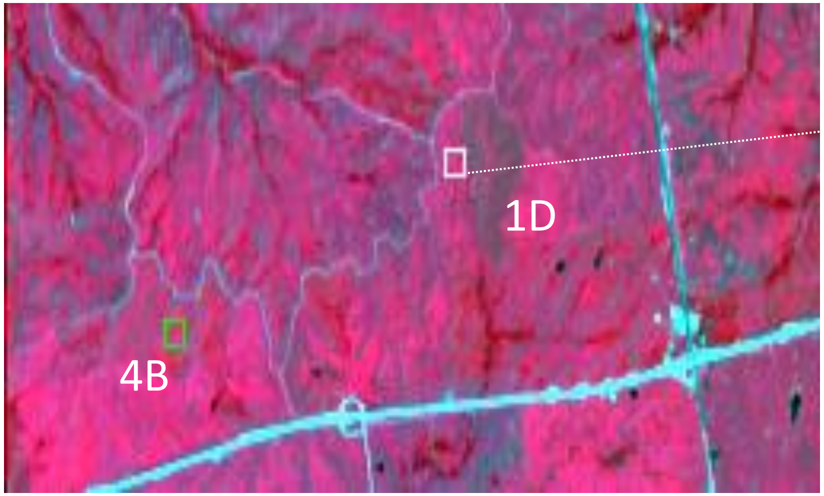
Campbell et al. 2012

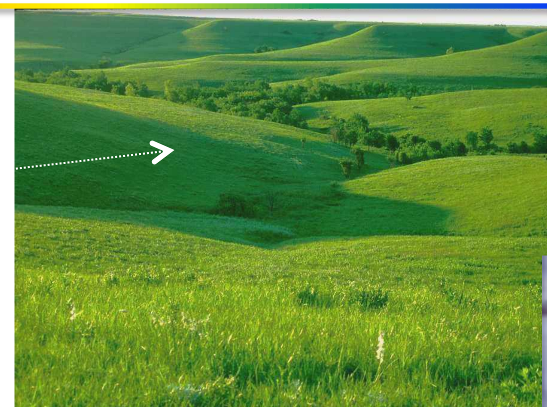
Duke Forest : PRI_{670} & NEP

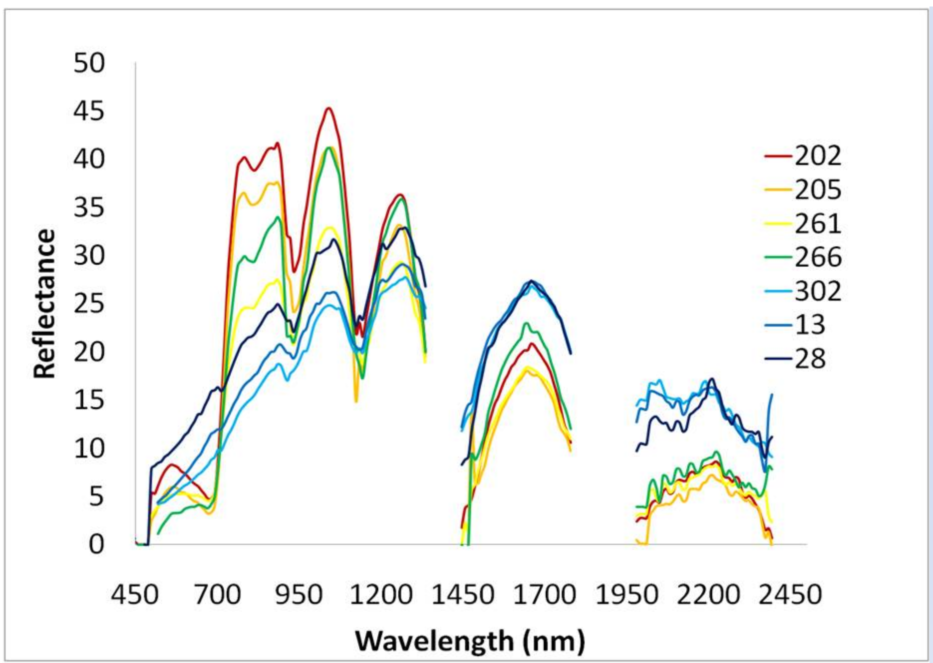


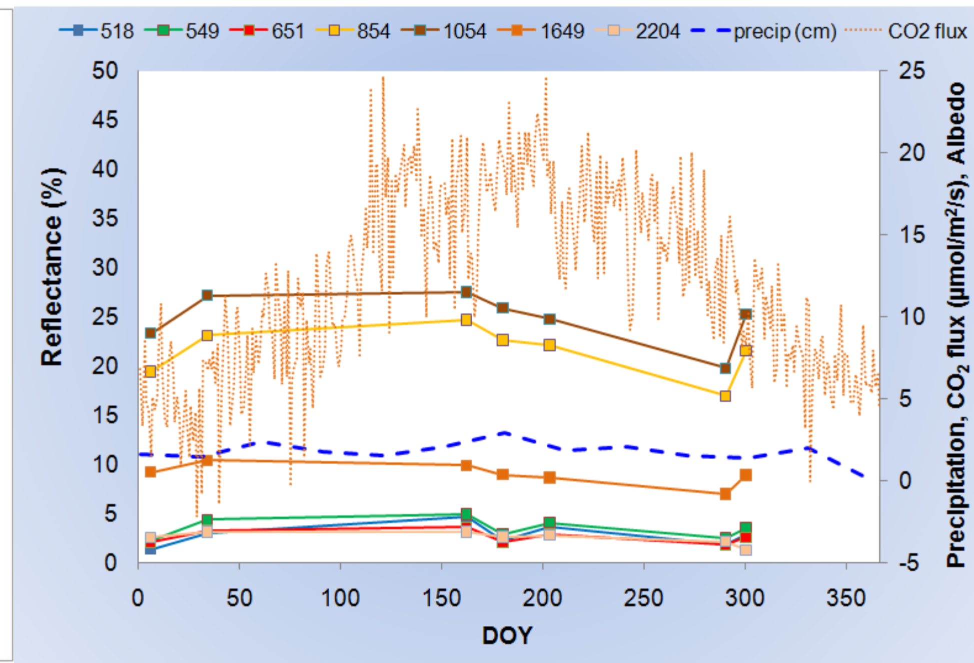
Campbell et al. 2012

Seasonal Spectral Dynamics at Konza

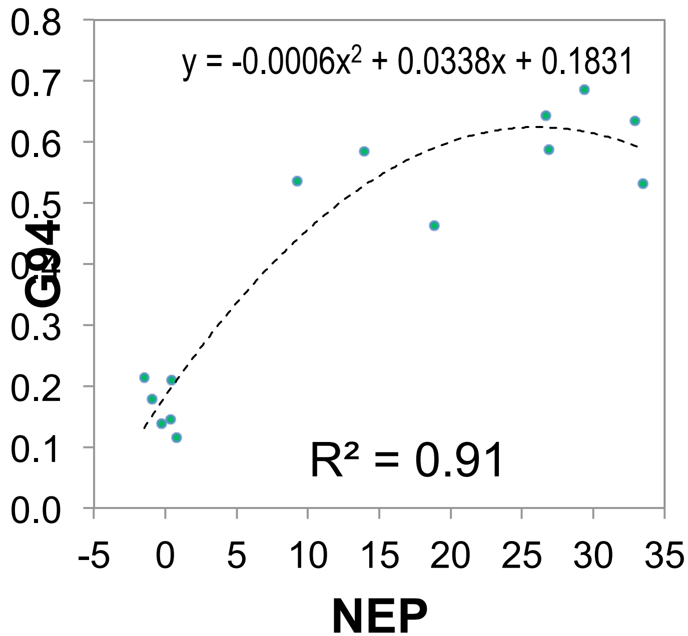


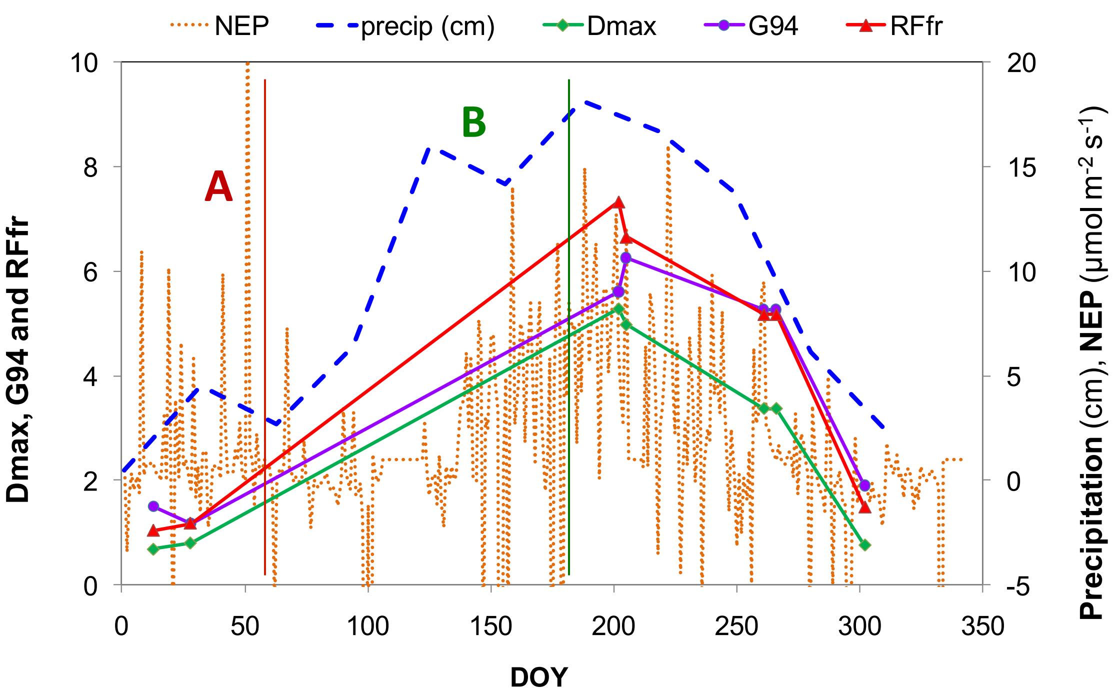




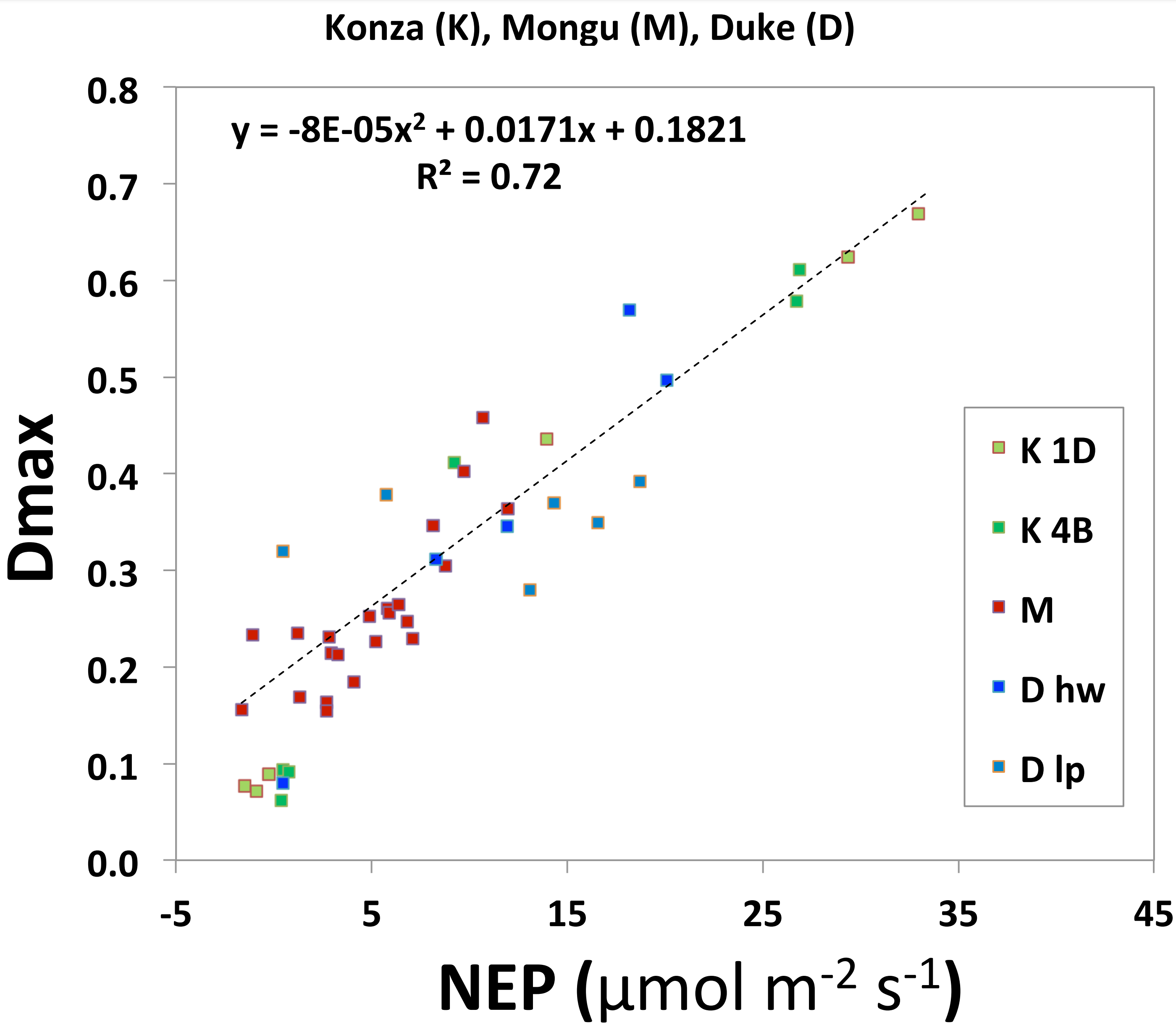


Index	Bands (nm)	R^2 [NEP (GEP) *LUE*]
G94	R 800, 700	0.95 (0.90) *0.75* NL
Dmax	D max	0.93 (0.95) *0.94* L
EVI	NIR, Red, Blue	0.83 (0.92) *0.88* NL
NDWI	R 870, 1240	0.86 (0.91) *0.85* NL
NDVI	Av. R760-900, Av. R620-690	0.63 (0.67) *0.68* L





Derivative Maximum



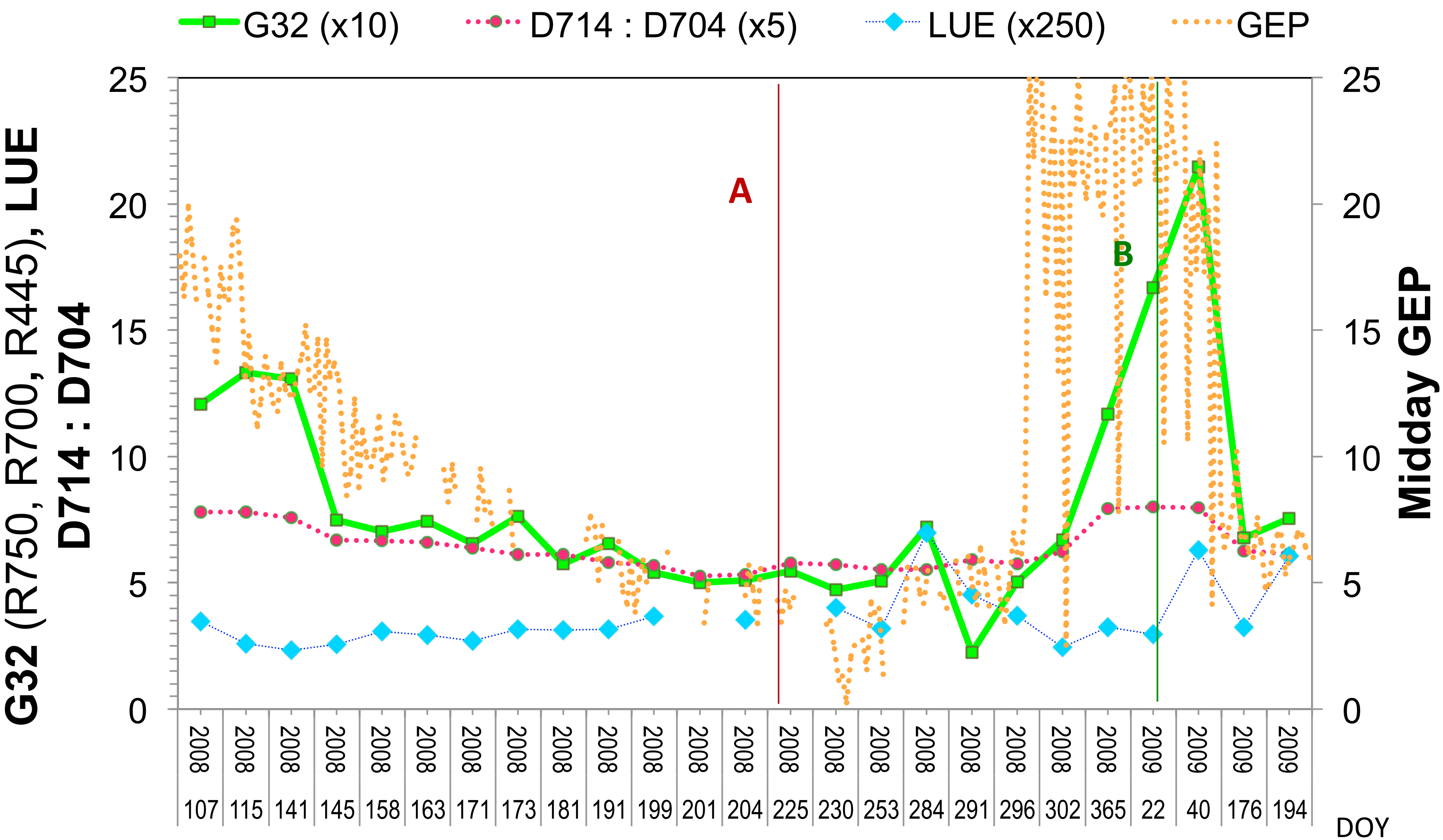
Conclusions

- In different ecosystems, continuous reflectance data and a variety of spectral bio-indicators had strong correlation to CO_2 flux parameters (e.g. NEP, GEE, etc.).
- The PLS regression provides a consistent global approach for estimating CO2 fluxes
- The bio-indicators with strongest relationships were calculated using continuous spectra, using numerous wavelengths associated with chlorophyll content and/or derivative parameters.
- Common (global) spectral approach to trace vegetation function and estimate it's CO_2 sequestration ability is feasible. It requires:
  - a diverse spectral coverage, representative of the major ecosystem types,
  - spectral time series, to cover the dynamics within a cover type.

Future Work

- Expand the tests over additional ecosystem types, including rain forest, temperate and sub-arctic vegetation types.
- Test the importance of specific phenologic periods (or times of year) for systematic estimation of ecosystem functional potential and productivity.
- Test the ability of additional spectral approaches to trace the dynamics in vegetation condition.
- Strategy to assess/confirm the accuracy of the produced maps.

Hyperion Spectral Indices and GEP at Mongu



The spectral bio-indicator associated with chlorophyll content (G32, green line) best captured the CO_2 dynamics related to vegetation phenology.

Bio-indicator	Bands (nm)	R^2 [NEP (GEP)]
G32	R750, 700, 450	0.83 (0.81) NL
Dmax	D max (650…750 nm)	0.77 (0.87) NL
Dmax / D704	D(690-730)	0.79 (0.80) NL
mND705	R750, 704, 450	0.75 (0.79) NL
RE1	Av. R 675…705	0.71 (0.56) NL
EVI	R (NIR, Red, Blue)	0.73 (0.88) L
NDVI	Av. R760-900, R620-690	0.52 (0.60) NL

G32, Associated with *Chlorophyll*

(Gitelson et al. 2003)