Remote Sensing of Fluxes: *EO-1 Hyperion and Flux Towers*

Question: *Can we demonstrate robust algorithms driven by hyperspectral satellite data that can estimate carbon flux variables through the seasons and over a wide range of sites?*

- *How do spectral properties and temporal dynamics of different ecosystems compare?*
- *Are there common (global) spectral approaches to trace vegetation function?*

Petya Campbell
K. Fred Huemmrich
University of Maryland Baltimore County
May 16, 2012

Data Summary

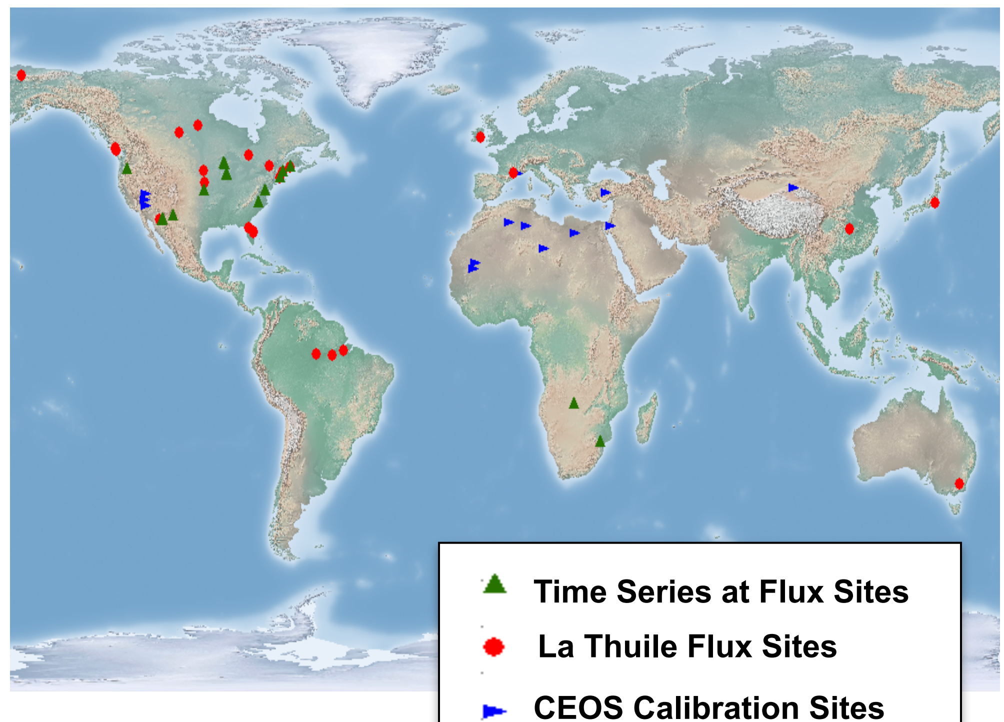
Preliminary results from studies matching Hyperion imagery to flux towers

Multi-site Historical study

- Match flux data from LaThuile Fluxnet Synthesis with Hyperion
  - 33 different flux tower sites during mid-growing season from 2001 to 2007

Time Series study

- Ongoing observations of 90 tower sites
  - Started 2008
  - Capture seasonal change
  - 20 sites processed



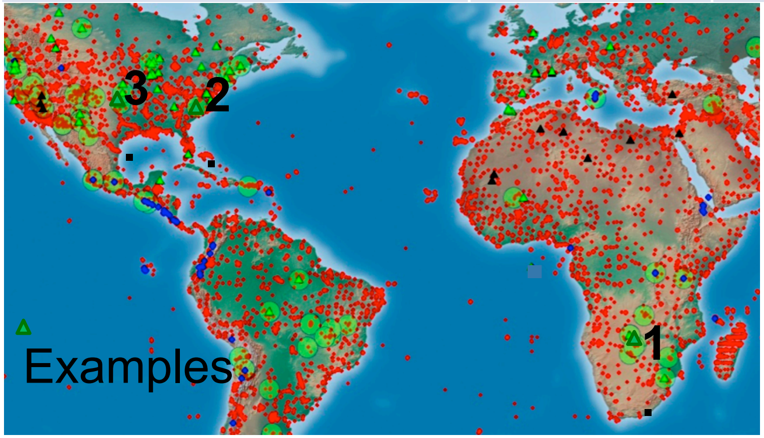
CO_2 Flux Data

Existing global network of flux towers measuring CO_2 flux using eddy covariance techniques provide a consistent ground dataset to work with

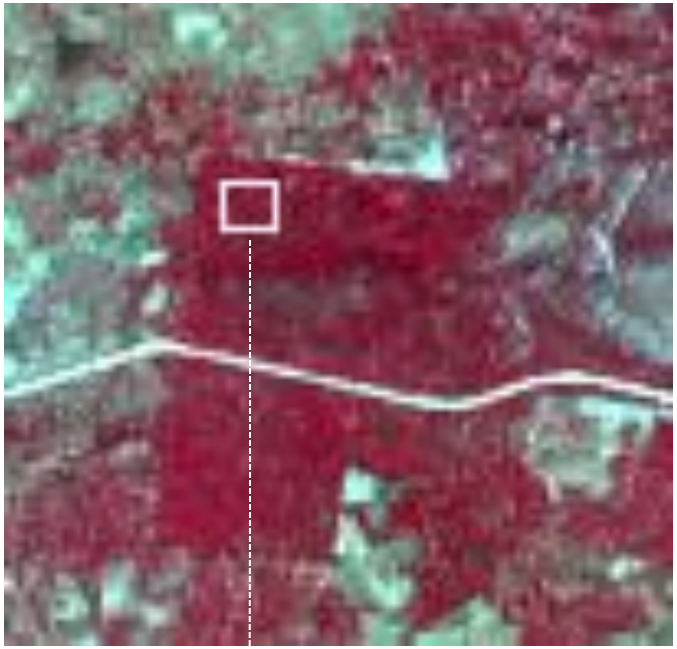
- Net Ecosystem Production (NEP, μmol m^{-2} s^{-1}) is the total CO_2 flux measured by flux towers.
- Ecosystem Respiration (Reco), the CO_2 flux from the ecosystem to the atmosphere, is calculated from relationships developed between nighttime NEP and temperature.
- Gross Ecosystem Production (GEP), the CO_2 uptake by vegetation, was calculated from the observed NEP and Reco.
- Light Use Efficiency (LUE), the ratio of GEP to photosynthetically active radiation absorbed by vegetation

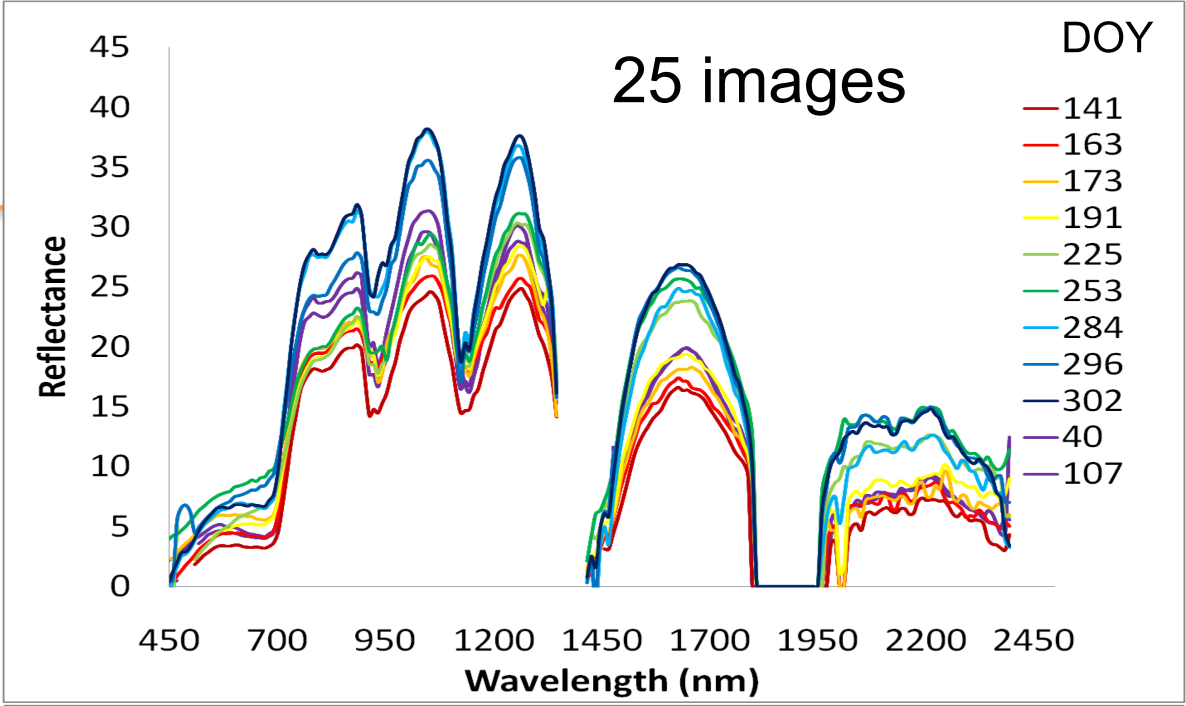
Time Series at Flux Sites
(examples from 3, 20 being processed)

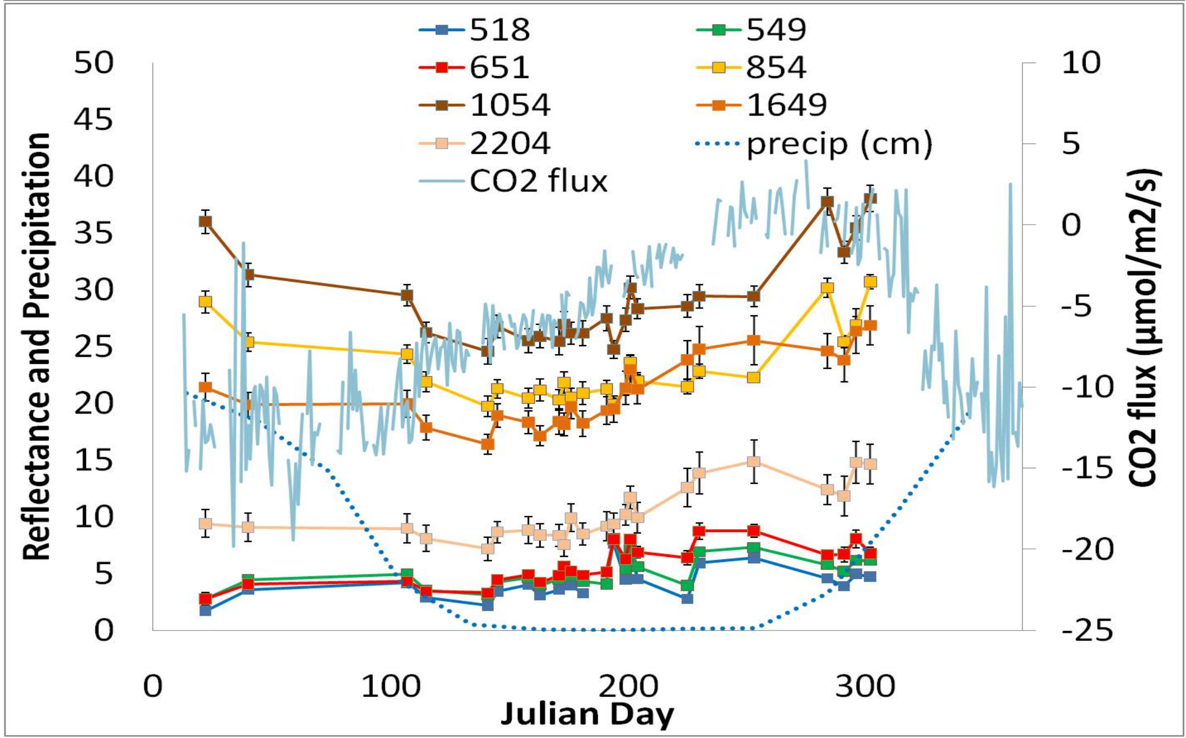
FLUX Site Name	Location	Climate	Vegetation
1. Mongu lat: -15.4377778, lon: 23.252778 25 images	Zambia, Africa	Tropical/ dry vs. wet seasons/ hot	Kalahari/ Miombo woodland
2. Duke Loblolly Pine, lat: 35.977130, lon: -79.095240 7 images	North Carolina, US	Temperate/ no dry season/ hot summer	Mixed forest/ Hardwoods/ Evergreen
3. Konza Prairie lat: 39.0823925 lon: -96.560277 7 images	Kansas, US	Continental/ cold winter/ hot summer	Grassland/ C4 tall grass prairie



Mongu, Zambia





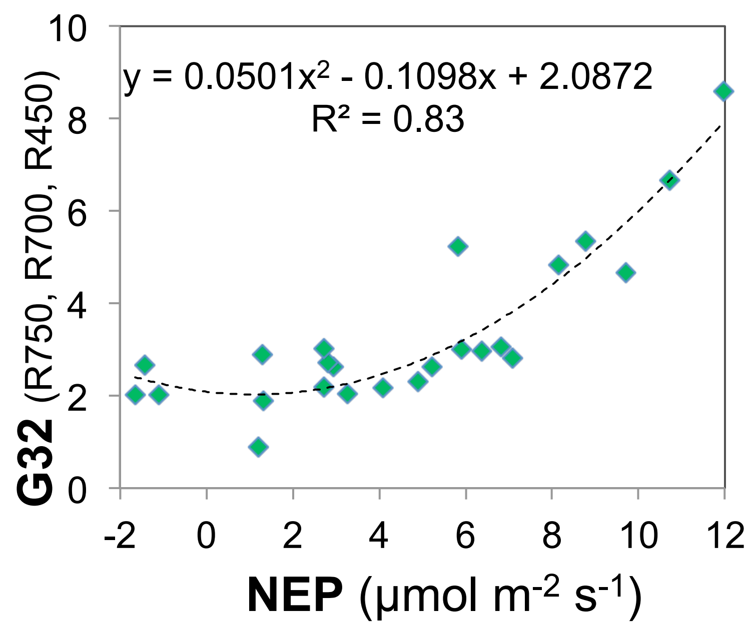


Bio-indicator	Bands (nm)	R^2 [NEP (GEP)]
G32	R750, 700, 450	0.83 (0.81) NL
Dmax	D max (650…750 nm)	0.77 (0.87) NL
Dmax / D704	D(690-730)	0.79 (0.80) NL
mND705	R750, 704, 450	0.75 (0.79) NL
RE1	Av. R 675…705	0.71 (0.56) NL
EVI	R (NIR, Red, Blue)	0.73 (0.88) L
NDVI	Av. R760-900, R620-690	0.52 (0.60) NL

Examined multiple Spectral Indices at each site

- Best for NEP at Mongu was G32
- Associated with Chlorophyll

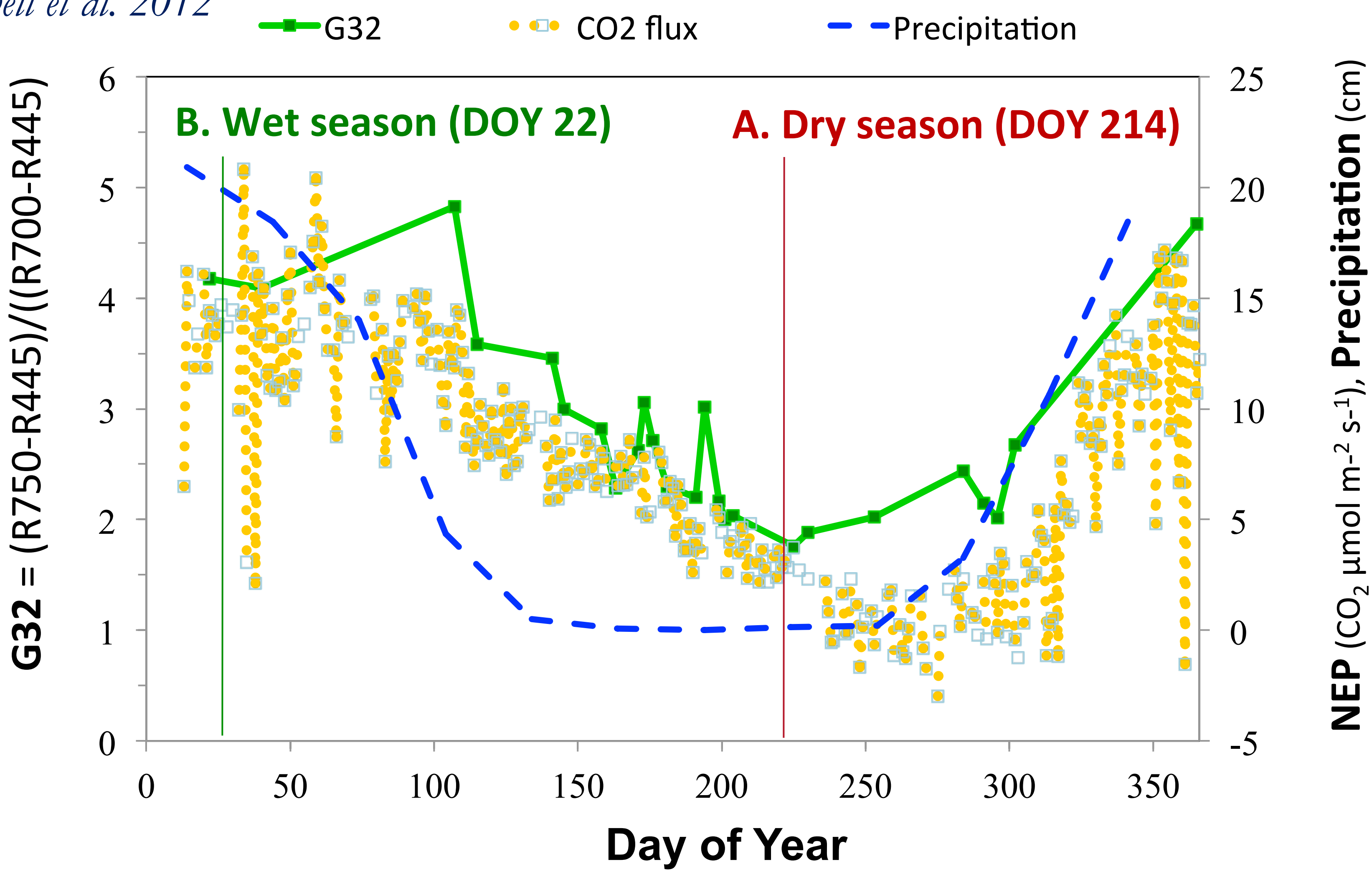
(Gitelson et al. 2003)



Campbell et al. 2012

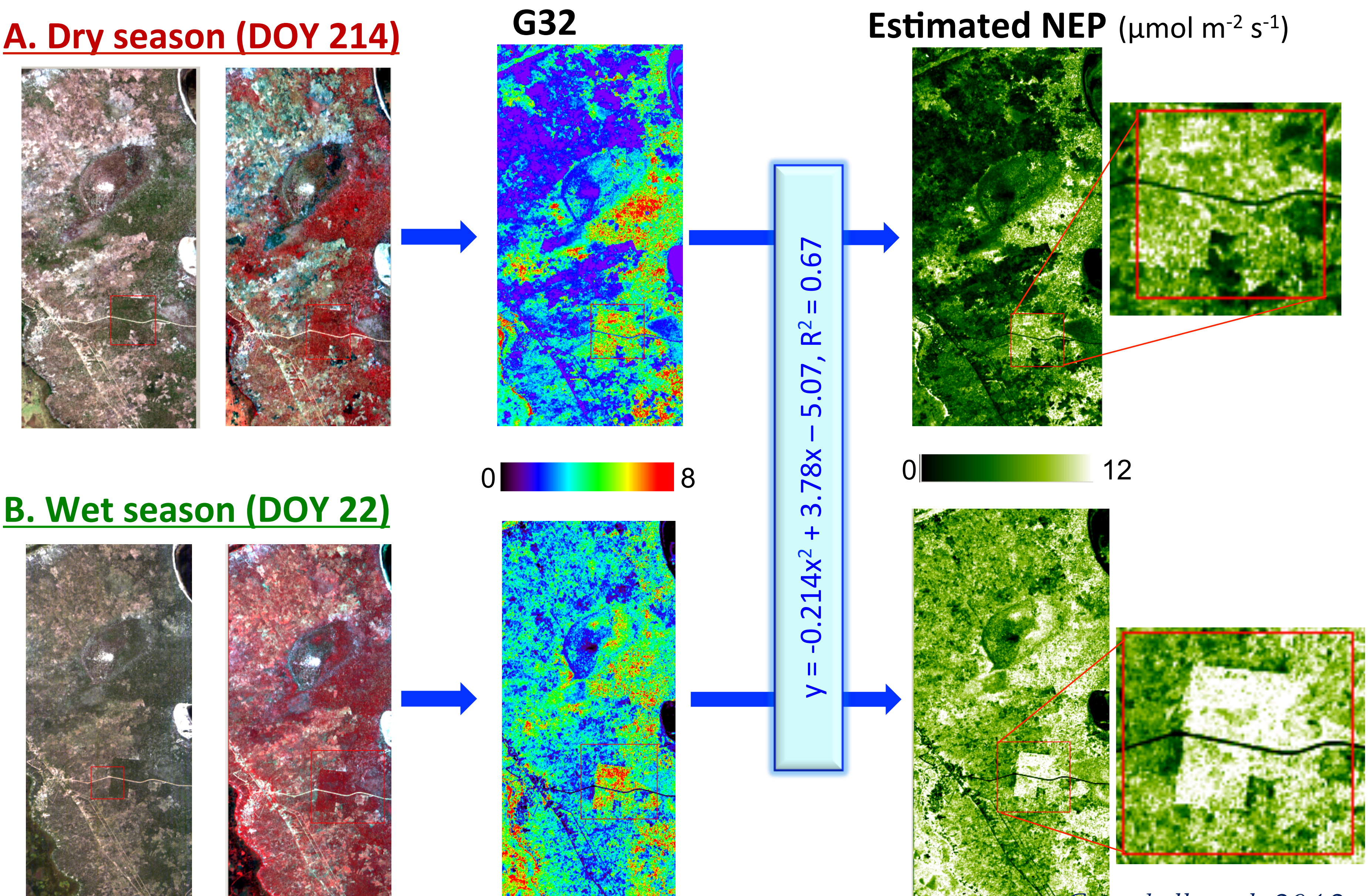
Mongu – Hyperion Spectral Indices and NEP

Campbell et al. 2012



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

Mongu – Mapping Seasonal Change in NEP



Campbell et al. 2012

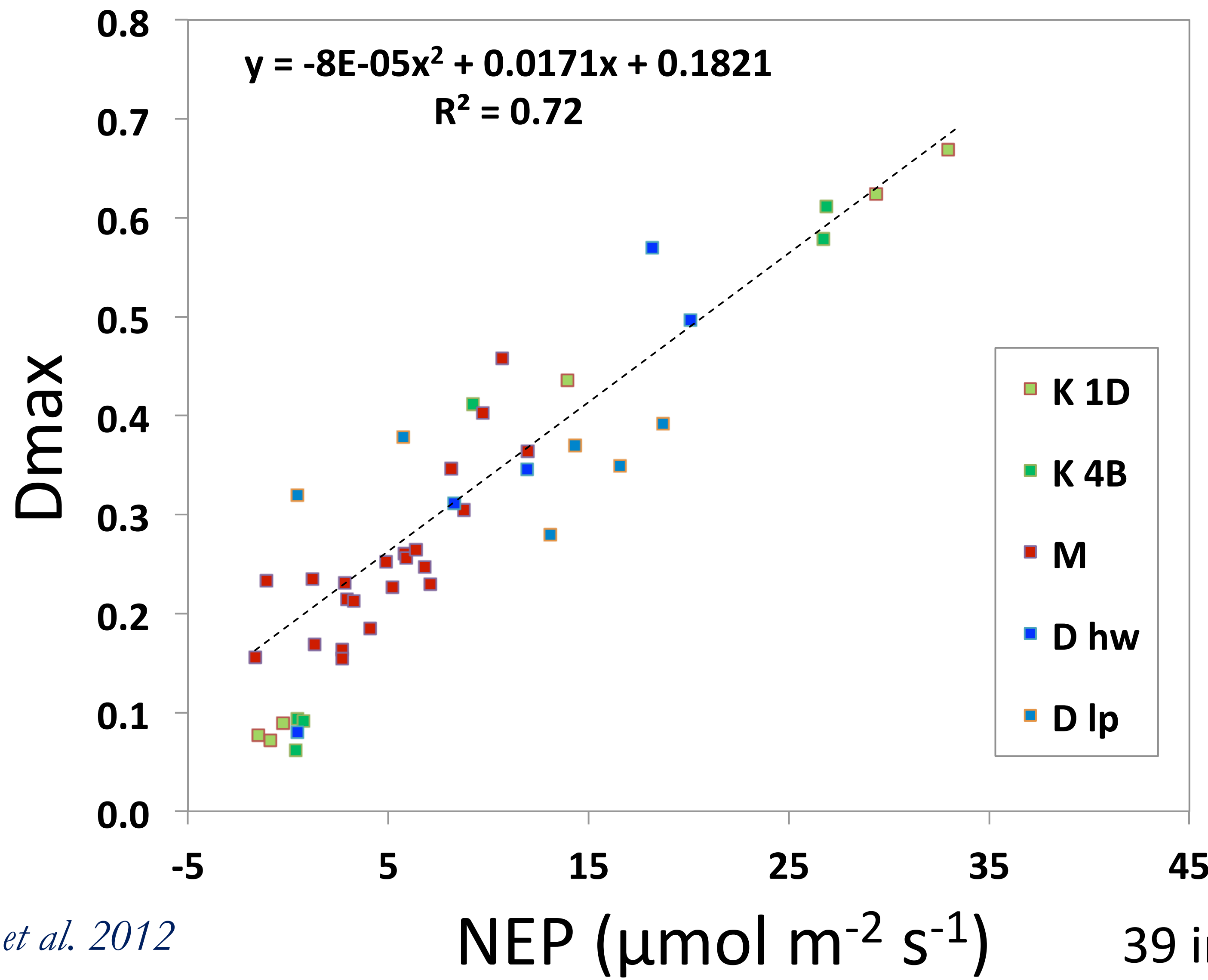
Top Performing Vegetation Indices (R^2 values) – Three Seasonal Sites Combined

Spectral indicator	Formula	NEP	GEP	LUE
Dmax	Max D in the 650-750 nm	**0.73 L+**	**0.77** L+	0.75 L+
DP22	Dmax/D(max + 12)	0.65 L+	0.74 NL+	0.71 L+
NDWI	R(870-1240)/R(870-1240)	**0.74** NL +	0.67 NL+	0.63 L+
MCARIa	Chlorophyll, R bands at 700, 670, and 550	0.41 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+

Campbell et al. 2012

39 images

Combined Seasonal Sites – Derivative Maximum

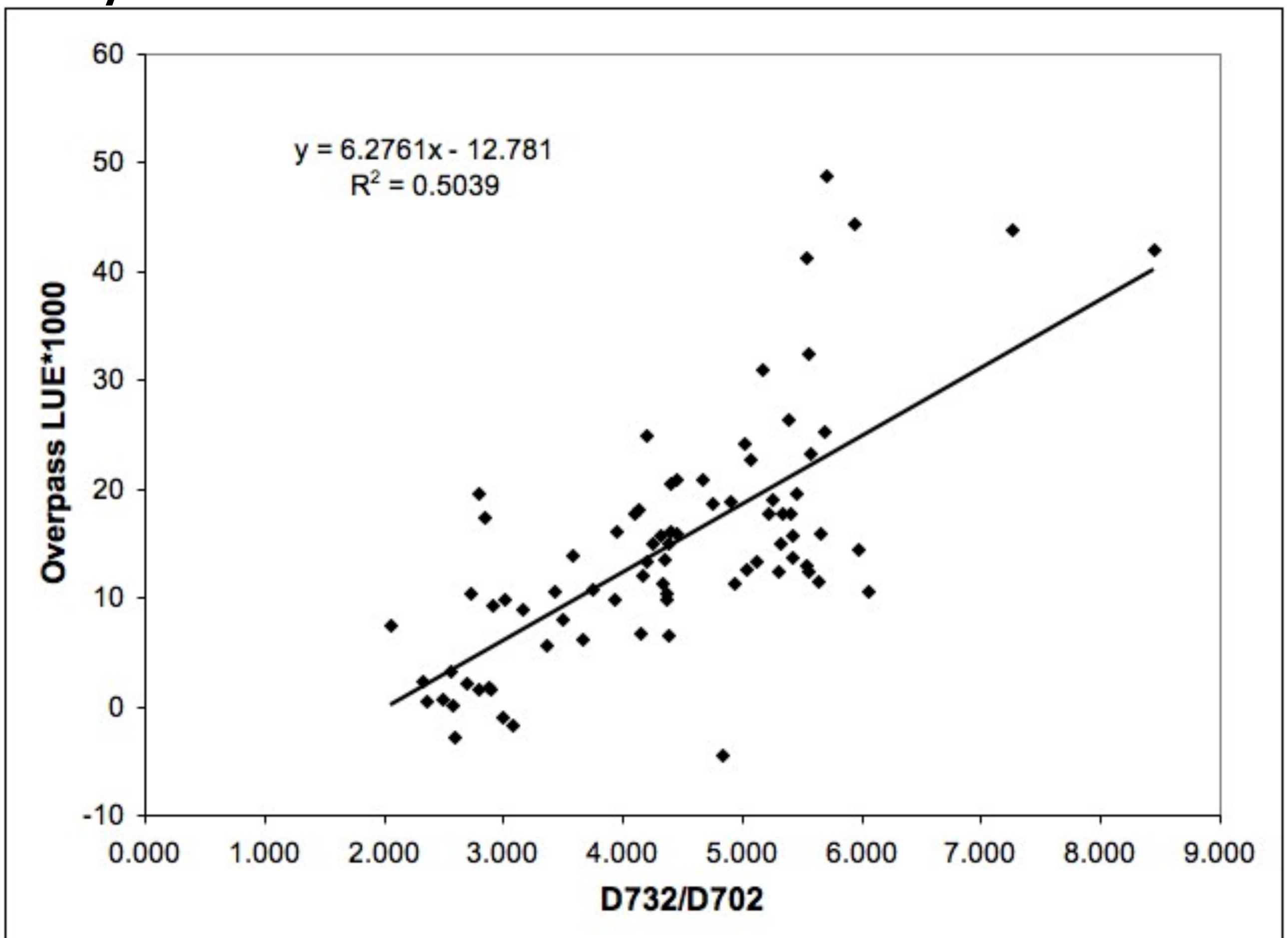


Campbell et al. 2012

39 images

Multi-site – Vegetation Index and LUE

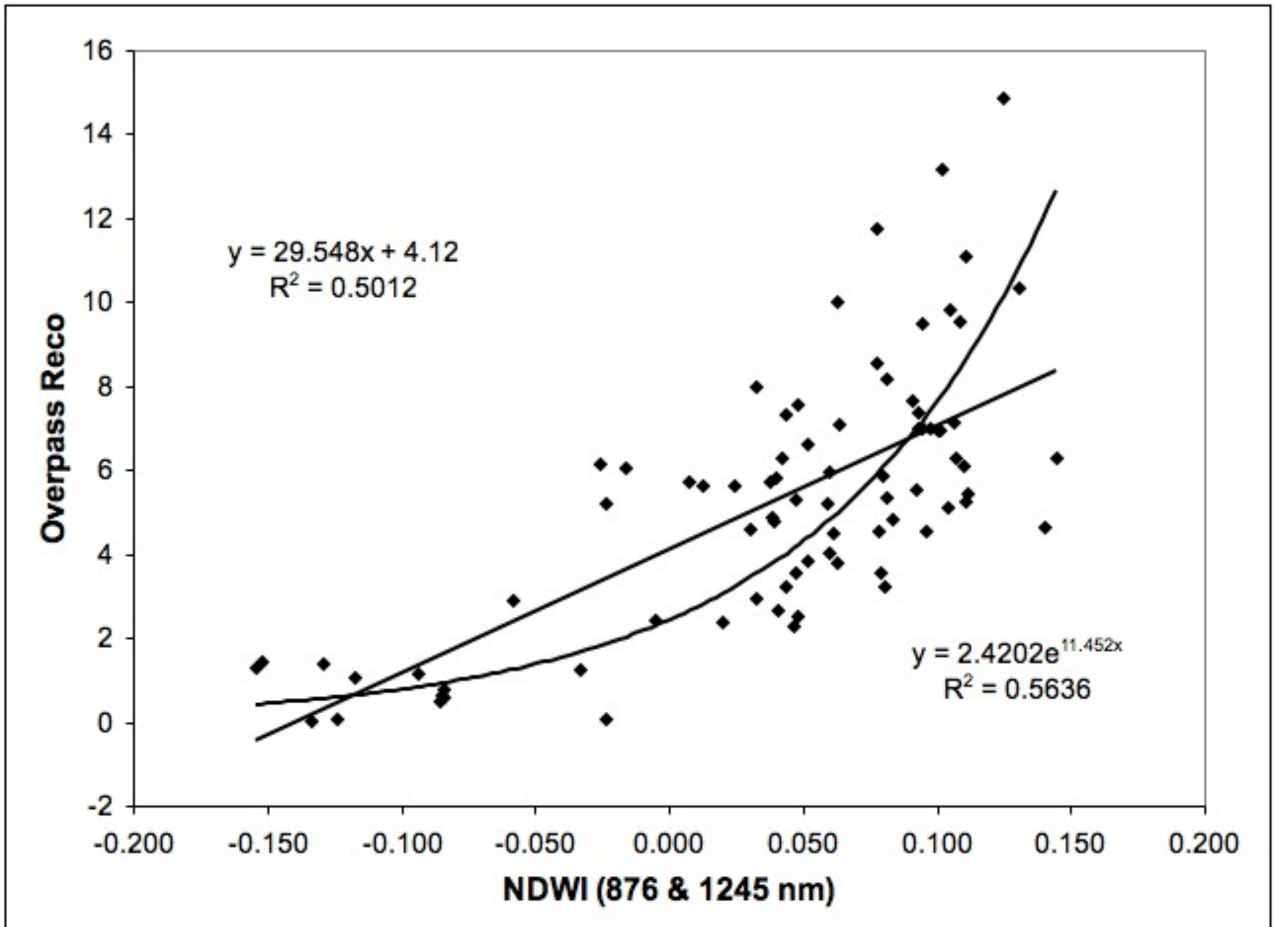
- Best index (out of 107 tried) for LUE at overpass time for 33 different sites was the first derivative at 732 nm divided by the derivative at 712 nm



79 Points

Multi-site – Vegetation Index and Reco

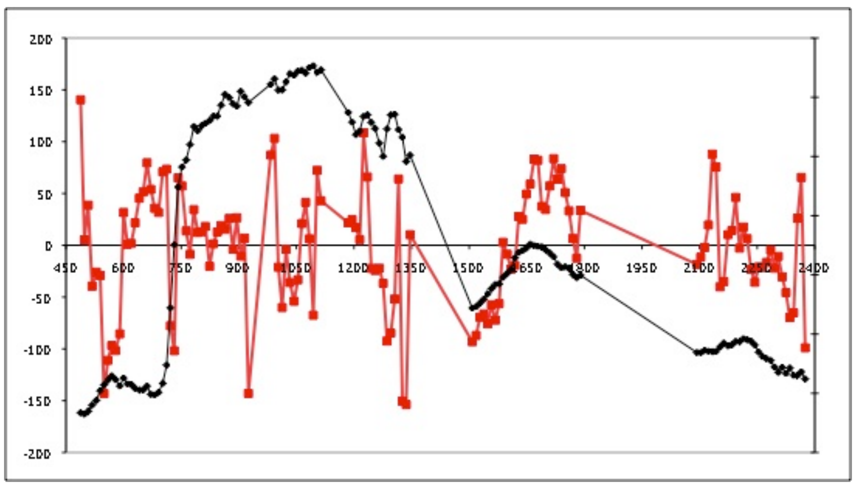
- Best index (out of 107 tried) for Reco at overpass time was the Normalized Difference Water Index (NDWI), using reflectances at 876 and 1245 nm

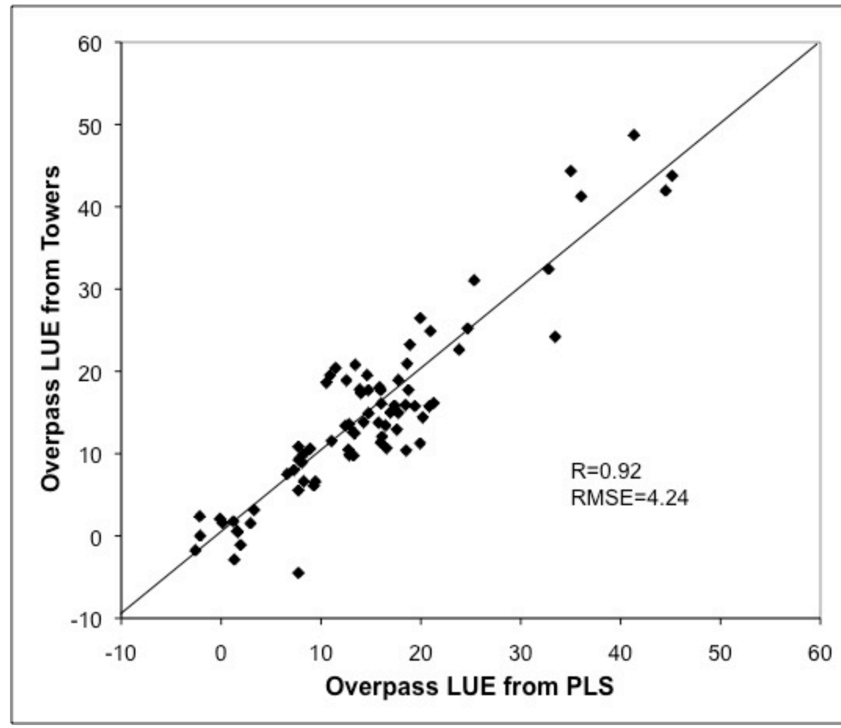


80 Points

Multi-site – Partial Least Squares Overpass LUE

- An example of an approach that utilizes all of the spectral information

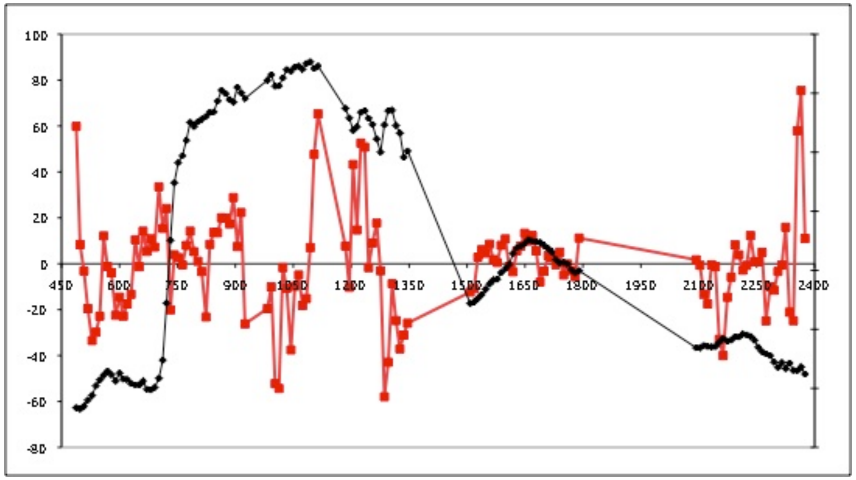


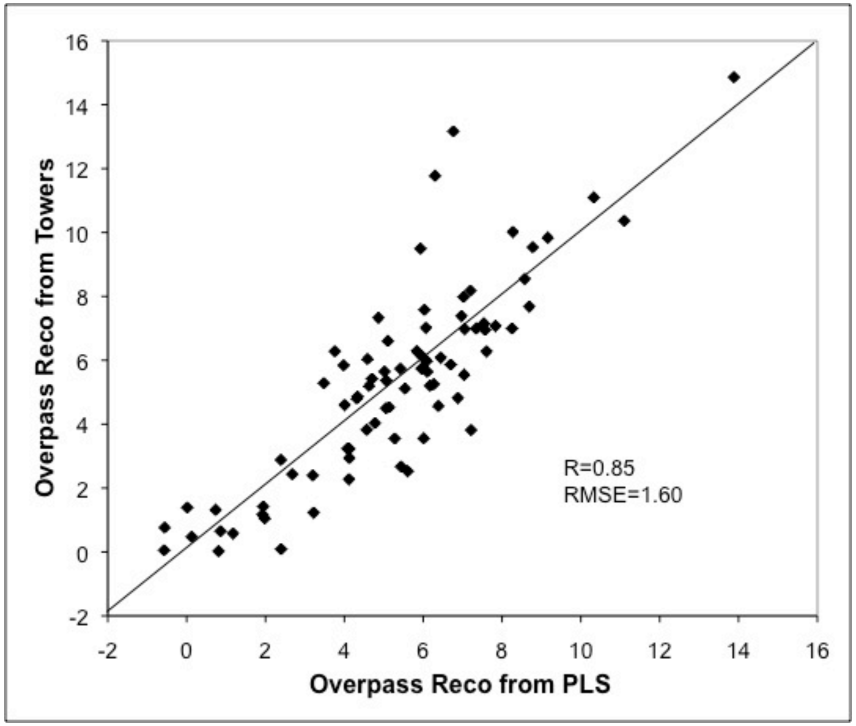


red - PLS coefficients
black - sample reflectance spectra

79 Points

Multi-site – Partial Least Squares Overpass Reco





red - PLS coefficients
black - sample reflectance spectra

79 Points

Remote Sensing of Fluxes
Hyperion and Flux Towers

- Hyperion on EO-1 provides us with two important capabilities:
  - the capability of collecting hyperspectral observations of globally-distributed sites, and
  - the ability to make repeated measurements of a site
- Provides a dataset for testing and developing algorithms for global data products
- The strongest relationships with carbon uptake parameters used continuous spectra, numerous wavelengths associated with chlorophyll content, and/or derivative parameters.
- A common (global) spectral approach appears feasible. To derive it will require:
  - Diverse coverage, representing major ecosystem types, and
  - time series, to cover the dynamics within a cover type.

Recommendations

These studies utilize data from the existing flux tower network

For many HyspIRI products we will need more studies applying algorithms for a number of different landcover types

- Use ground, aircraft, and satellite spectral reflectance data
- Need to develop protocols for ground measurements of potential HyspIRI products
- Need to establish network of sites measuring these products
- These sites can grow into a HyspIRI cal/val network