SpecNet Spectral Network

Linking optical sampling to flux measurements around the world.

http://specnet.info

SpecNet

- Overview
  - History
  - Current status
- Why combine optical & flux measurements?
- Tour of sites, methods, issues, results…
- Future directions

John Gamon, University of Alberta

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SpecNet History

SpecNet Spectral Network

Linking optical sampling to flux measurements around the world.

Formed in 2003 as a "Working Group" (National Center for Ecological Analysis & Synthesis, Santa Barbara, CA)

Meetings:

- Santa Barbara, California (2003, 2006 – NCEAS, with Faiz Rahman)
- Edmonton, Canada (2007 – iCORE, University of Alberta)
- Monte Bondone, Italy (2008 - COST)
- Lethbridge, Canada (2009, - Canadian Remote Sensing Society)
- Hyytiälä, Finland (2011, - COST)
- Berkeley, California (2011, - FLUXNET)

Additional SpecNet-themed meetings and sessions at ESA and AGU meetings

http://specnet.info

SpecNet Italy (COST) – Vescovo et al.

SpecNet Spectral Network

Linking optical sampling to flux measurements around the world.

SpecNet Special Issue - *Remote Sensing of Environment* (2006), volume 103 (11 papers)

Gamon JA, Rahman AF, Dungan JL, Schildhauer M, Huemmrich KF (2006) Spectral Network (SpecNet): what is it and why do we need it? *Remote Sensing of Environment*. 103: 227-235. (part of RSE Special Issue).

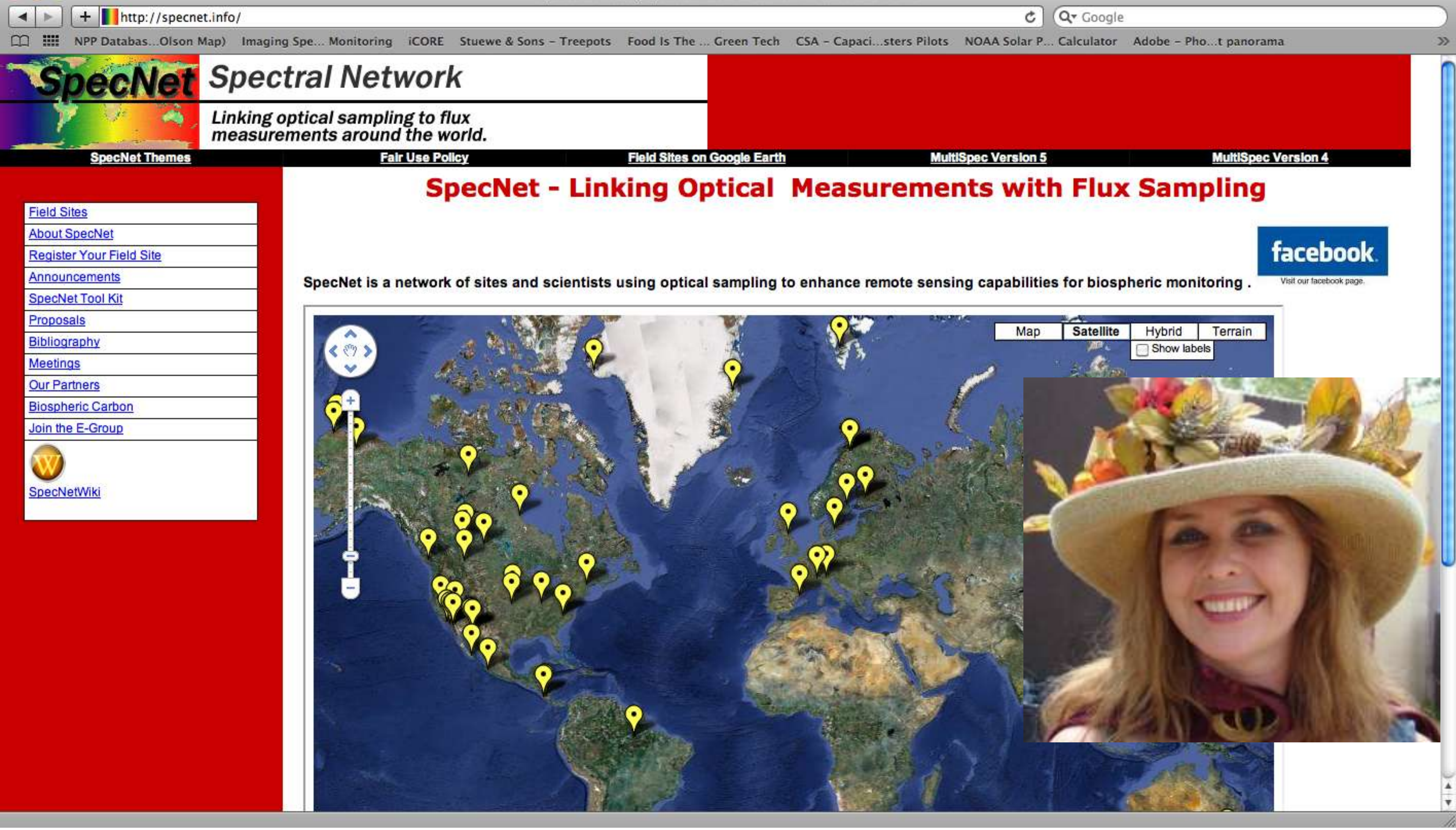
Gamon JA, Coburn C, Flanagan L, Huemmrich KF, Kiddle C, Sanchez-Azofeifa GA, Thayer D, Vescovo L, Gianelle D, Sims D, Rahman AF, Zonta Pastorella G (2010) SpecNet revisited: bridging flux and remote sensing communities. *Canadian Journal of Remote Sensing.* 36(Suppl. 2): S376–S390.

Gamon, J.A. (2010) Integrating Remote Sensing and Flux Measurements. Vol 3(1):7-10. *FluxLetter* (the newsletter of FLUXNET, available online at: http://bwc.berkeley.edu/FluxLetter/)

Gamon, J.A. (2011) Linking flux measurements and remote sensing with field optical sampling. *AsiaFlux Newsletter*, Issue No. 33: 8-15. (in press)

http://specnet.info

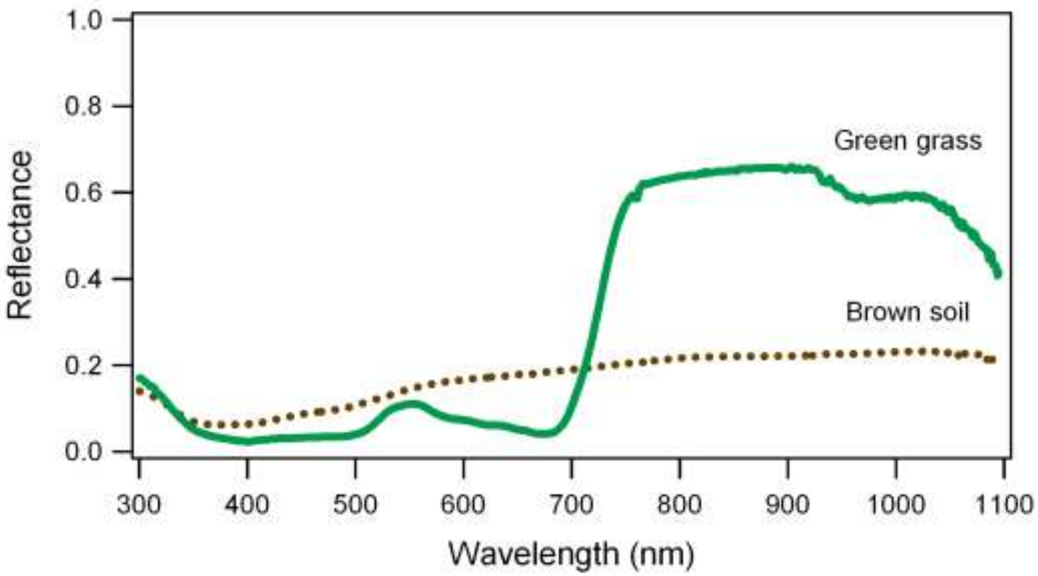
Current Status



SpecNet (Spectral Network), builds on the existing capabilities of the flux tower network FLUXNET) by adding spectral measurements to existing flux tower sites at a range of ecosystems around the world. SpecNet is envisioned as a data-sharing cooperative, and new investigators are welcome. The hope is that by standardizing sampling protocols and data structure across sites, we can facilitate an understanding of factors controlling terrestrial carbon flux and provide information useful for modeling and validating emerging satellite data products (e.g. MODIS).

http://specnet.info

Reflectance Spectra as "proxies"



"Spectral Libraries"

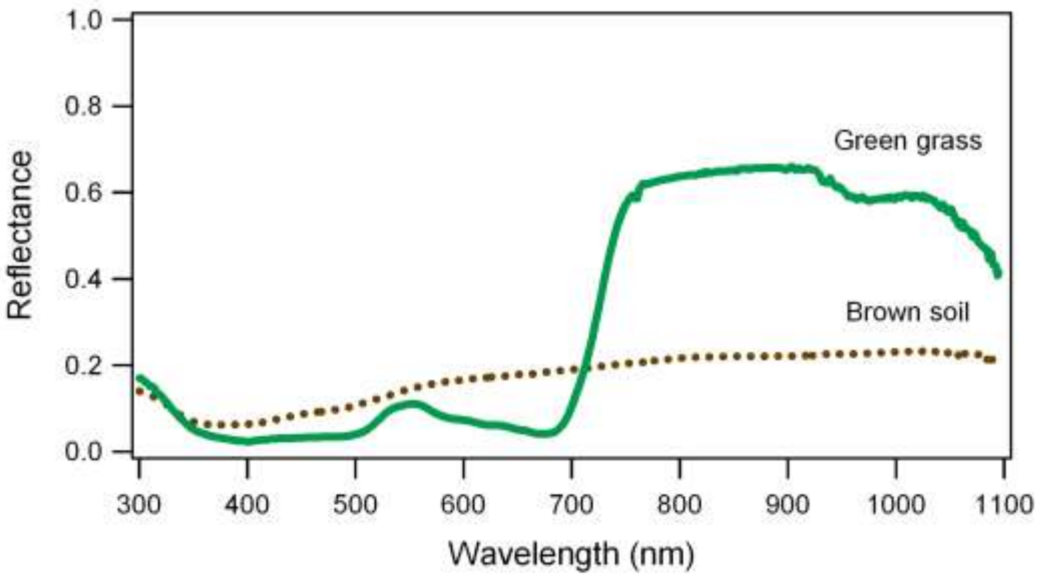
Surface cover
Surface albedo
Surface temperature
Species composition
Biodiversity
Pigment content
- Chlorophylls
- Carotenoids
- Flavonoids

Vegetation structure
- Radiation absorption
- Leaf area index
- Leaf angle distribution

Water status
Biochemical composition
- nitrogen
- lignin
- cellulose

Mineral absorption features

Reflectance Spectra as "proxies"



"Spectral Libraries"

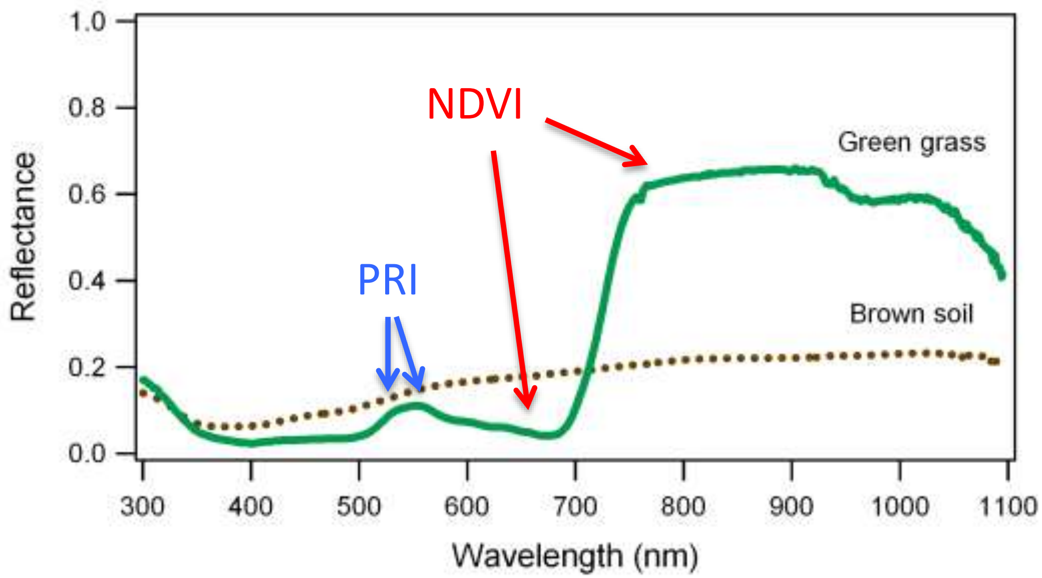
- Surface cover
- Surface albedo
- Surface temperature
- Species composition
- Biodiversity
- Pigment content
  - Chlorophylls
  - Carotenoids
  - Flavonoids
- Vegetation structure
  - Radiation absorption
  - Leaf area index
  - Leaf angle distribution
- Water status
- Biochemical composition
  - nitrogen
  - lignin
  - cellulose
- Mineral absorption features

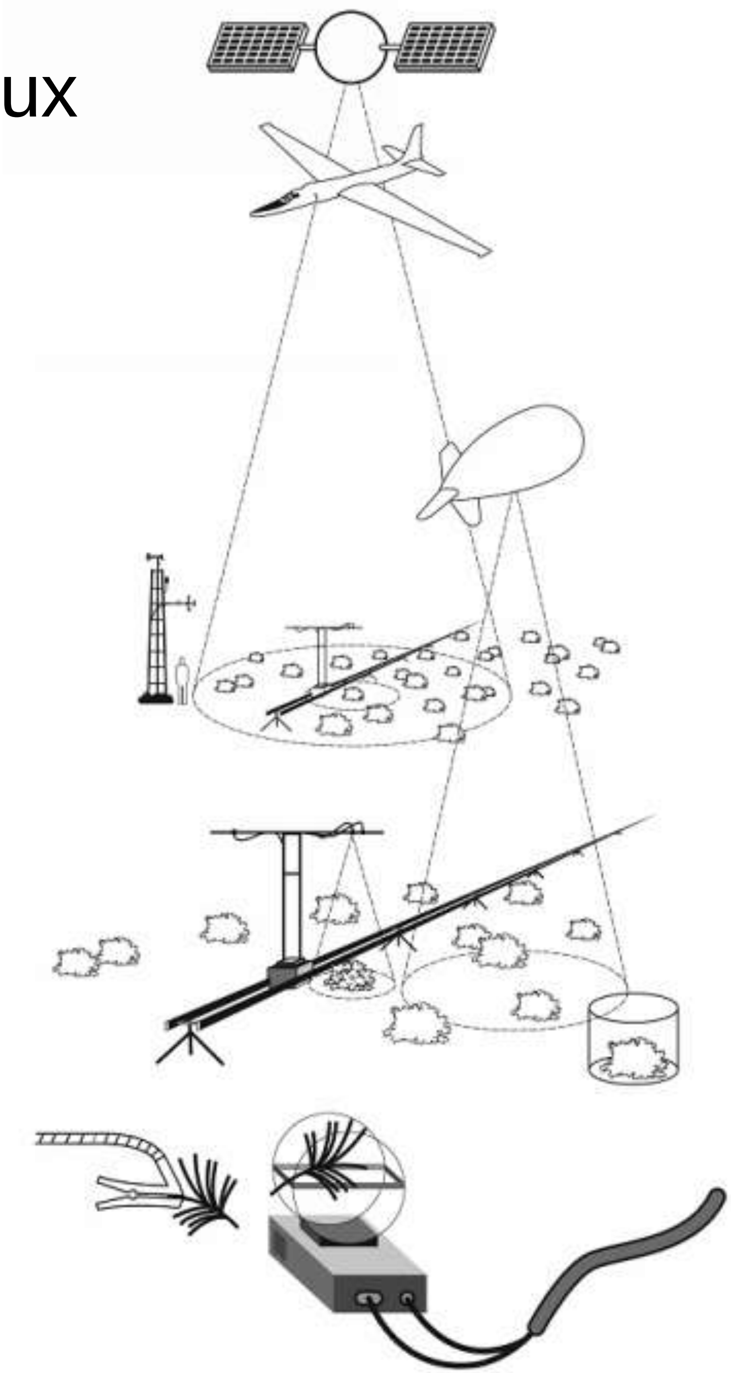
Tools & Methods

Monitoring Biospheric Carbon Flux

Normalized Difference Vegetation Index (NDVI)

Photochemical Reflectance Index (PRI)





NDVI

PRI

$$GPP = (PAR \times F_{PAR}) \times \varepsilon$$

Pigments
Moisture
Temperature

GPP = Gross Primary Production (photosynthesis)

PAR = Photosynthetically active radiation

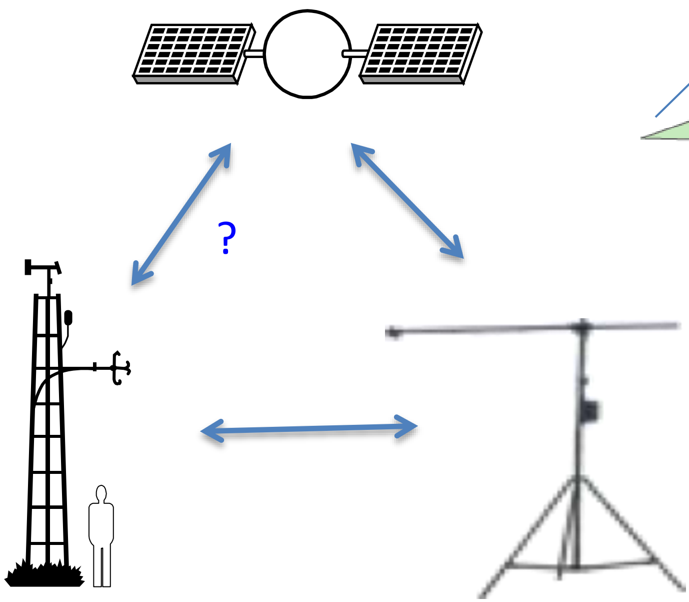
F_{PAR} = Fraction of PAR absorbed

ε = Radiation-use efficiency

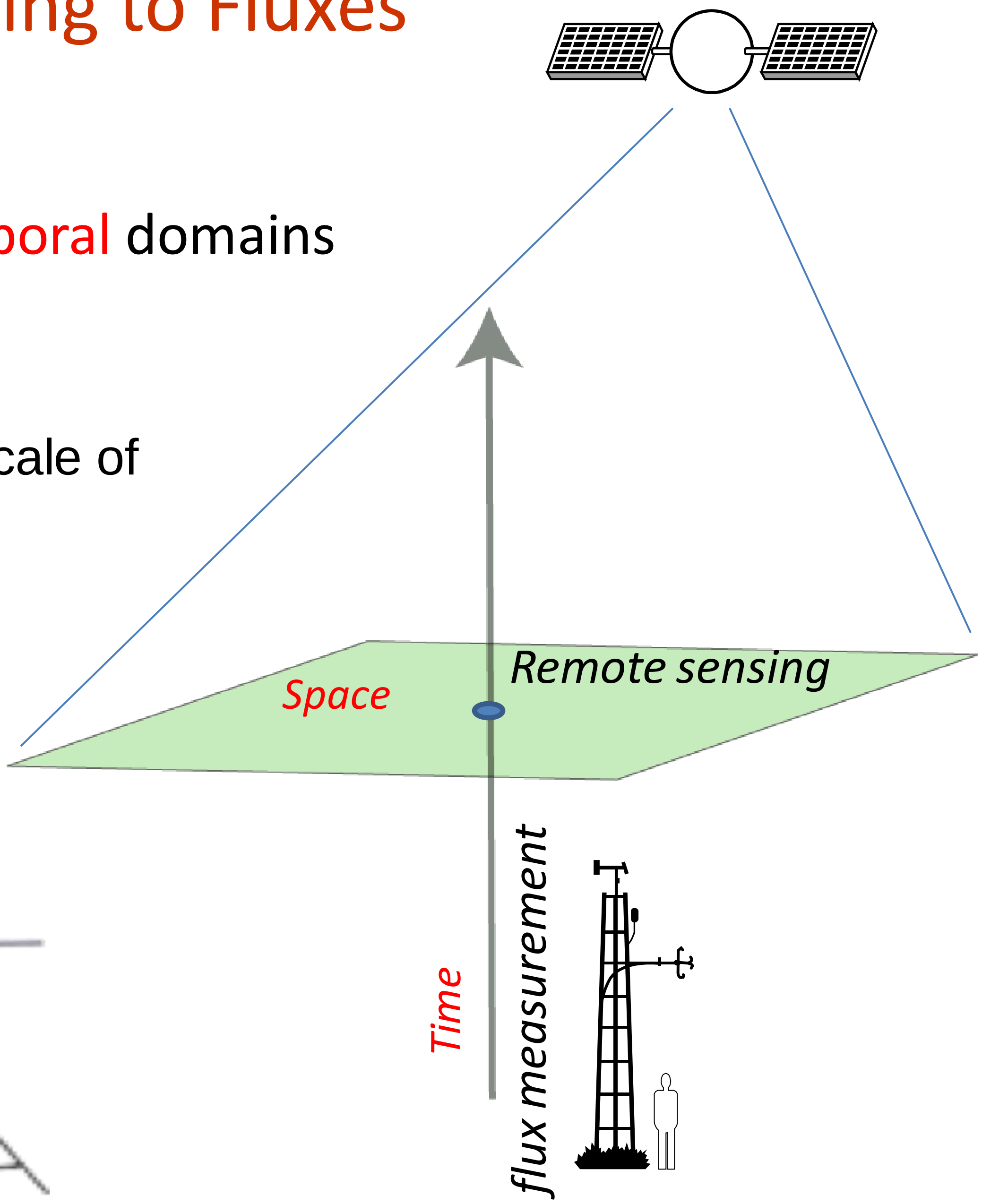
Linking Remote Sensing to Fluxes

<u>Challenge</u>:
Integrating spatial and temporal domains

<u>Solution</u>:
Field optical sampling at the scale of the flux tower footprint.

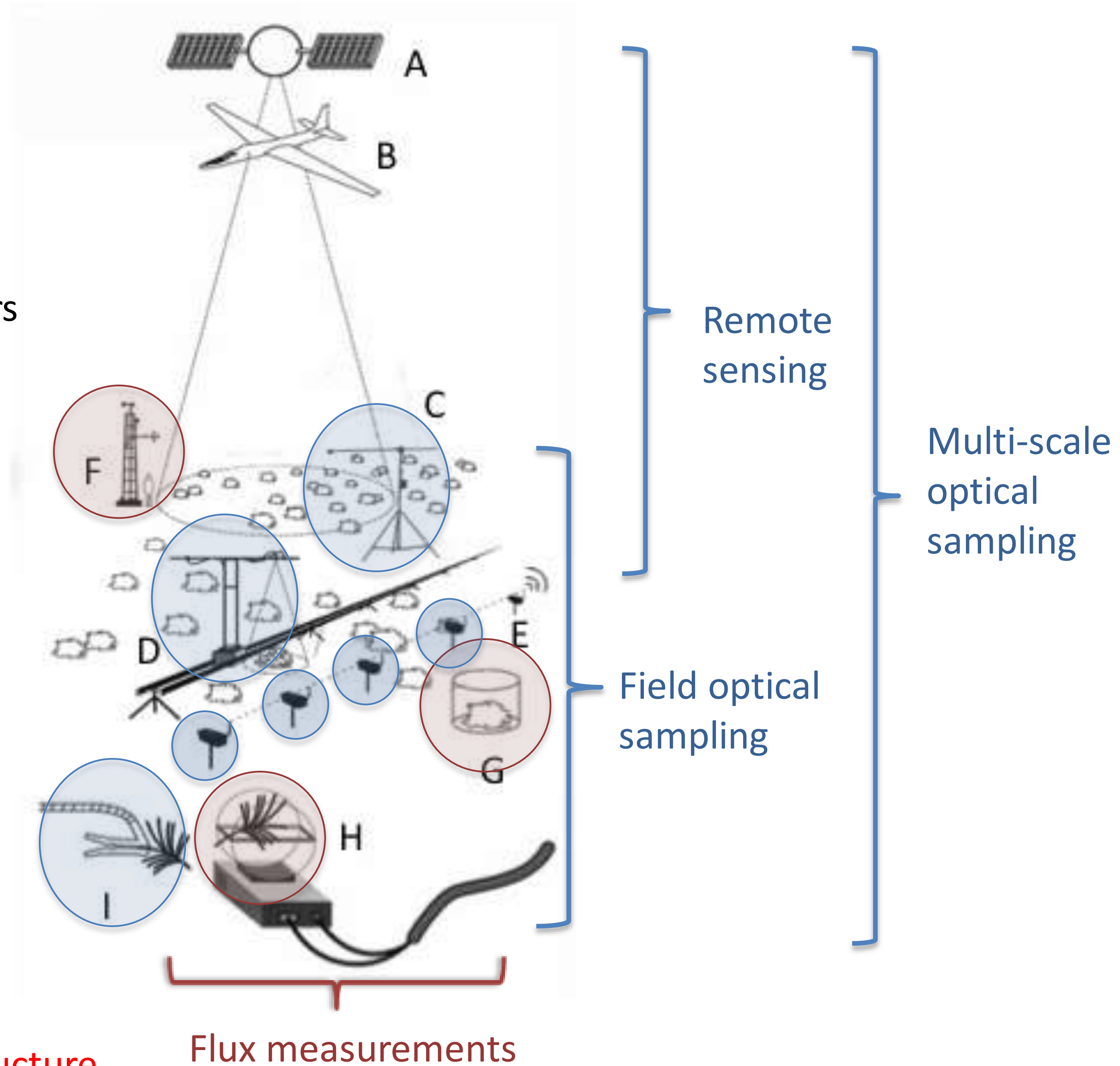


Optical sampling



Multiscale Sampling of Fluxes and Optical Properties

A) Satellites
B) Airborne sensors
C) Tower-mounted sensors
D) Mobile optical sensors
E) Sensor networks
F) Flux tower
G) Chamber gas exchange
H) Leaf gas exchange
I) Leaf reflectance



Additional challenges:
Integrating spectral domain
& Informatics/Cyberinfrastructure

Array of Technologies

Photo: Martin van Leeuwen.

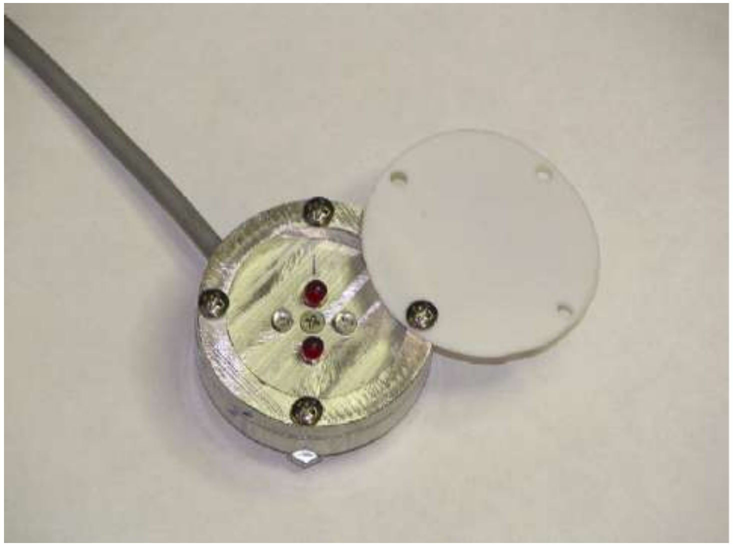


Photo: Youngyrel Ryu

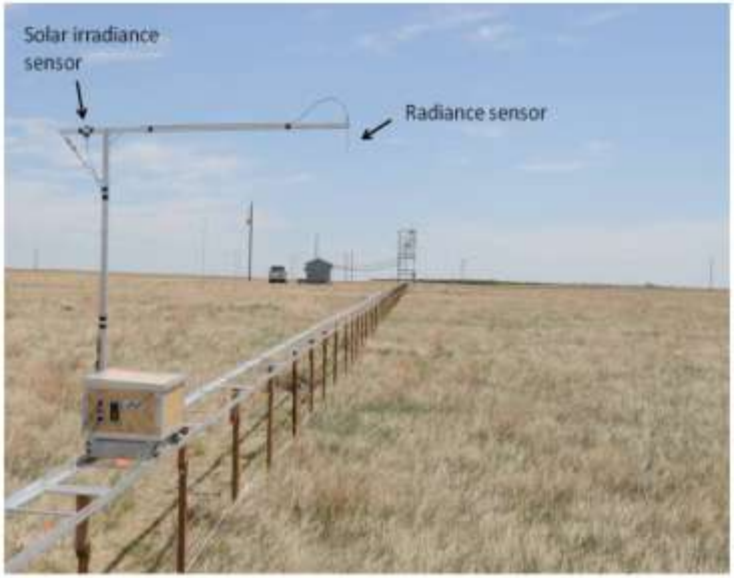


Photo: John Gamon

Photo: Thomas Hiler

Imaging Spectrometers

Pre-flight calibration

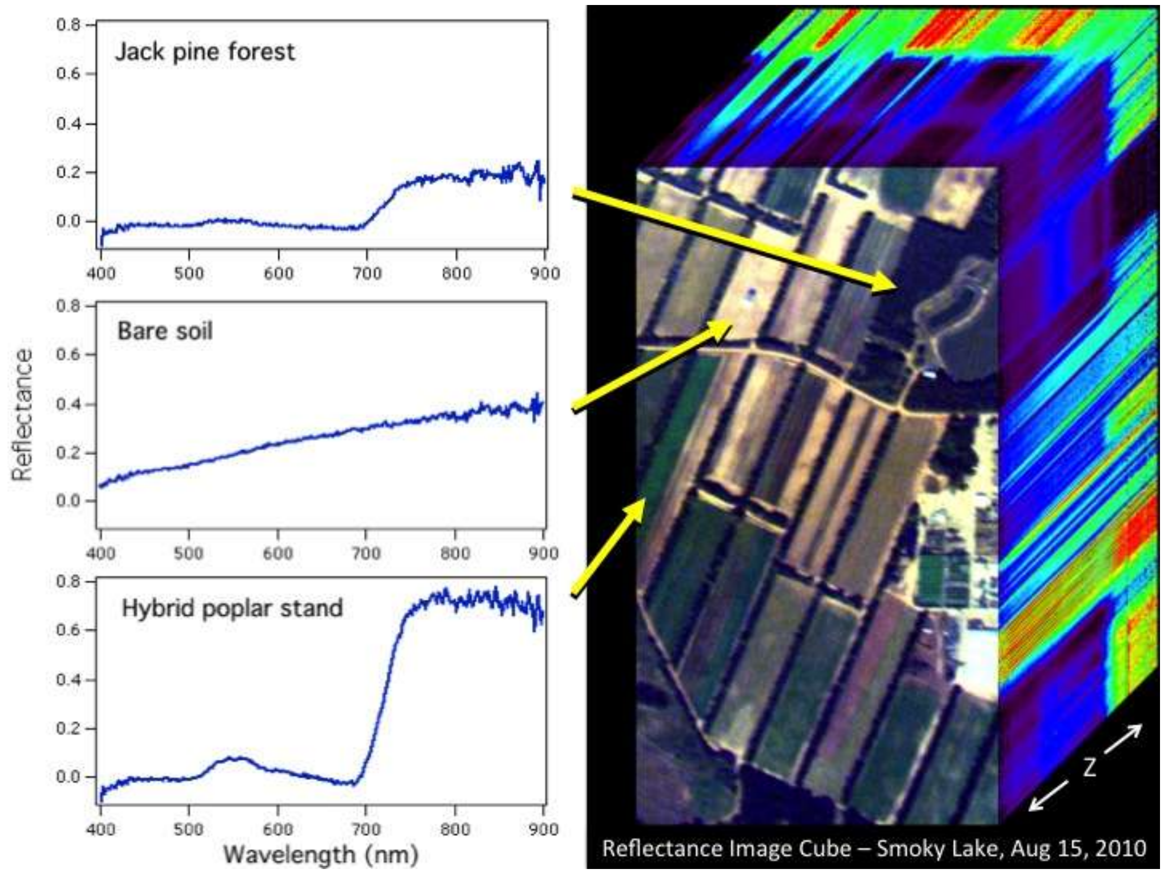
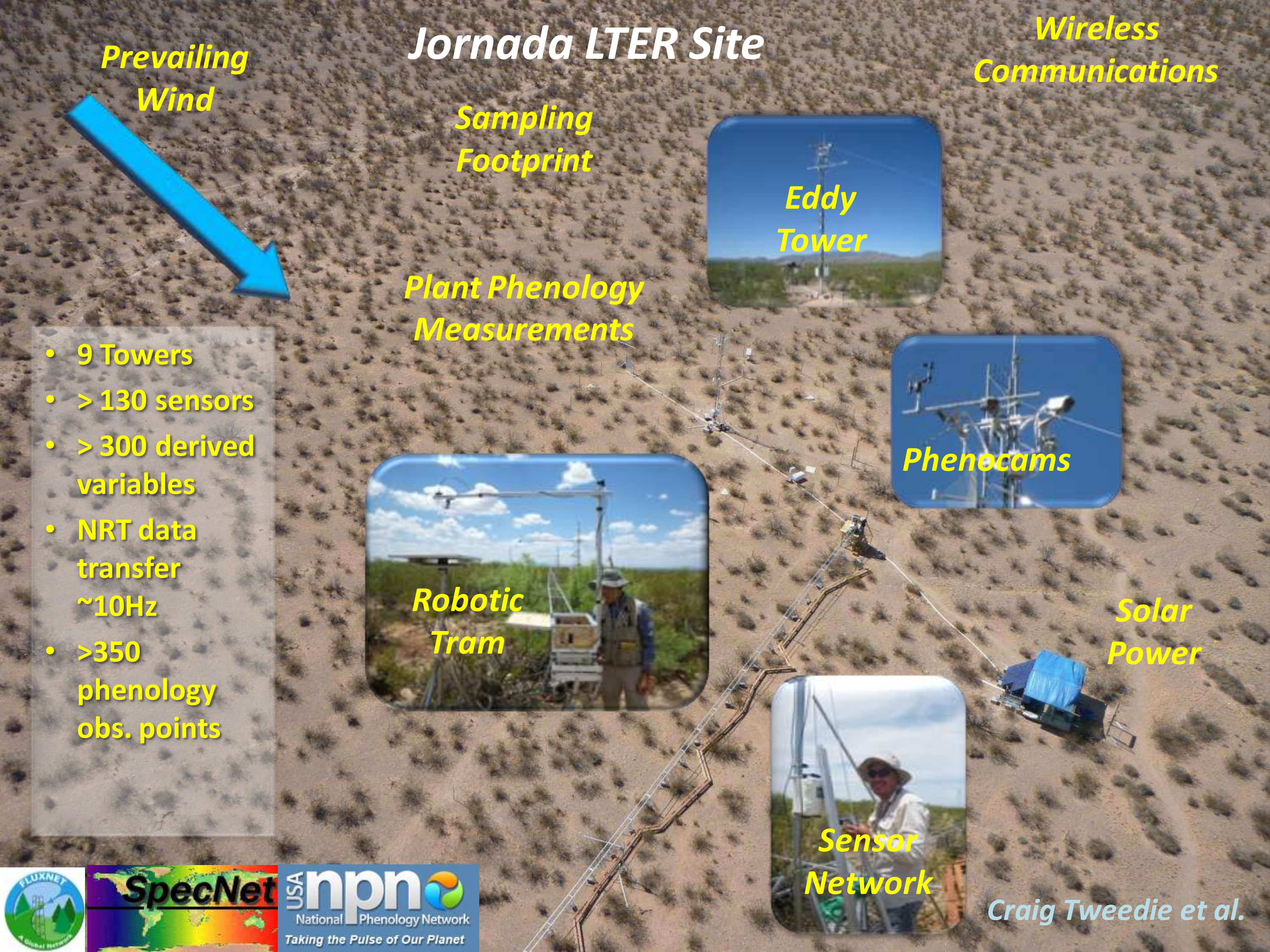


Figure: J. Gamon & L. Hitao


Site Tour

Jornada LTER Site

- 9 Towers
- > 130 sensors
- > 300 derived variables
- NRT data transfer ~10Hz
- >350 phenology obs. points



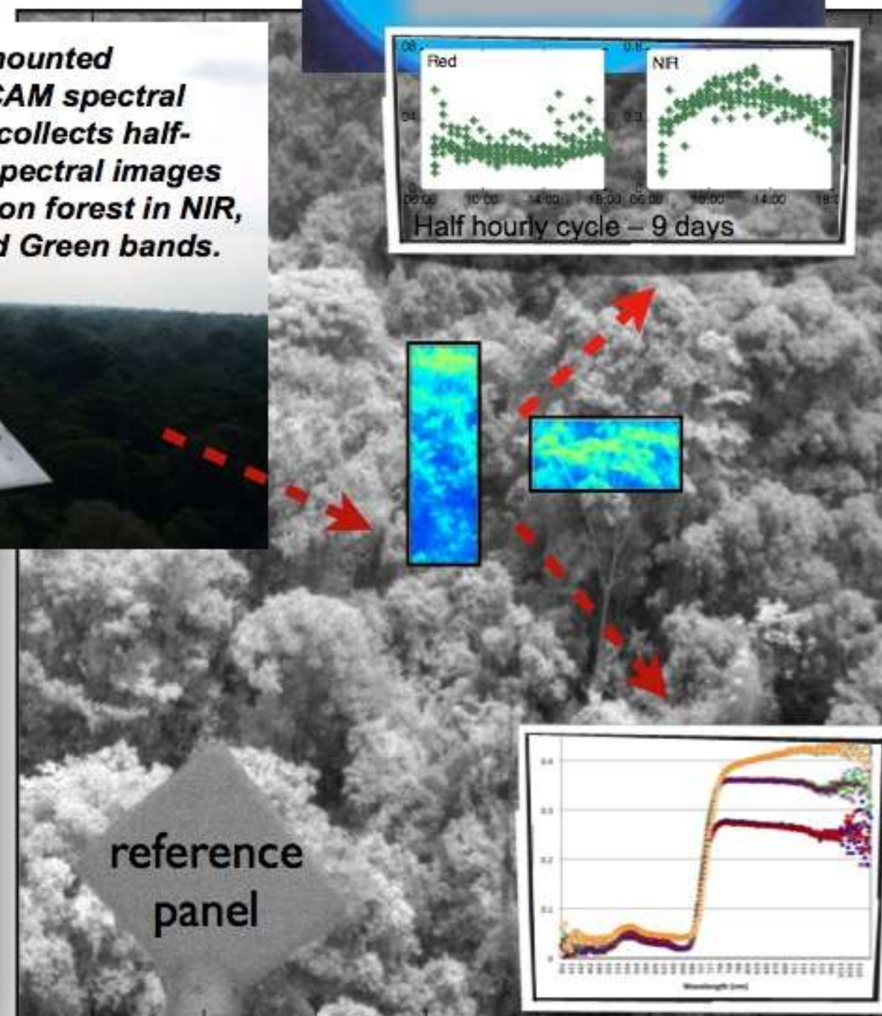
SpecNet

USA npn National Phenology Network
Taking the Pulse of Our Planet

Craig Tweedie et al.

Spectral sampling in the Amazon (from above)

Canopy-, Satellite- Scale Phenology, Photosynthesis, and Optical Variations

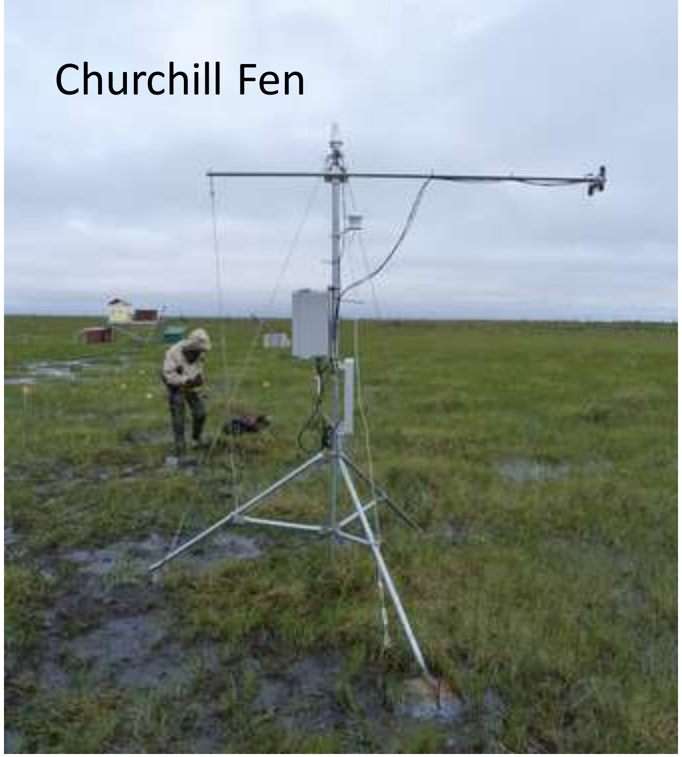


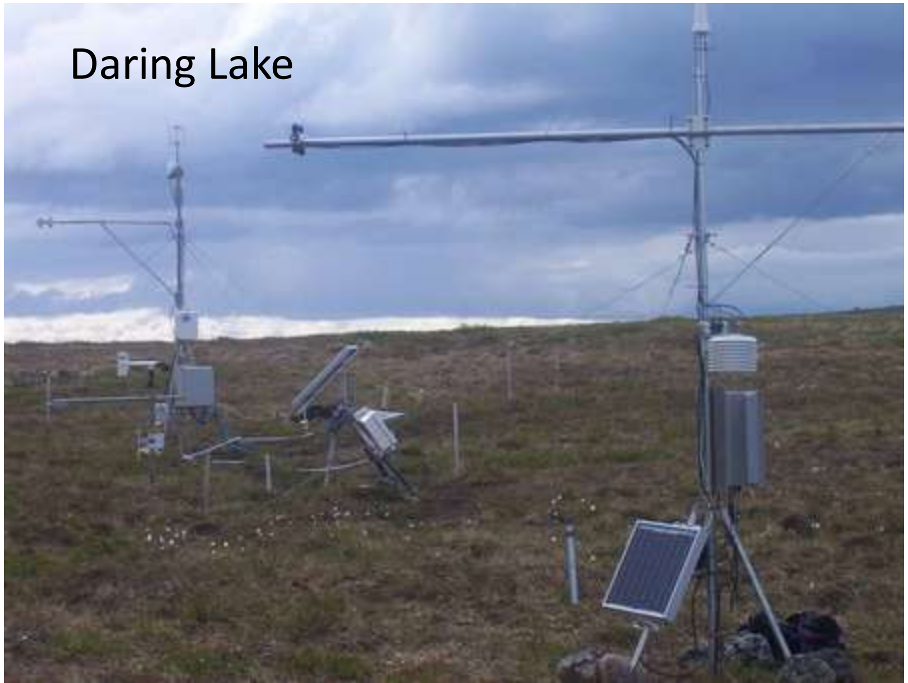
NorthSTAR sites

Churchill – Mario Tenuta, Krista Hanis

Daring Lake – Peter Lafleur, Elyn Humphreys

Imnavait – Gus Shaver, Adrian Rocha,
Donie Bret-Harte, Eugenie Euskirchen





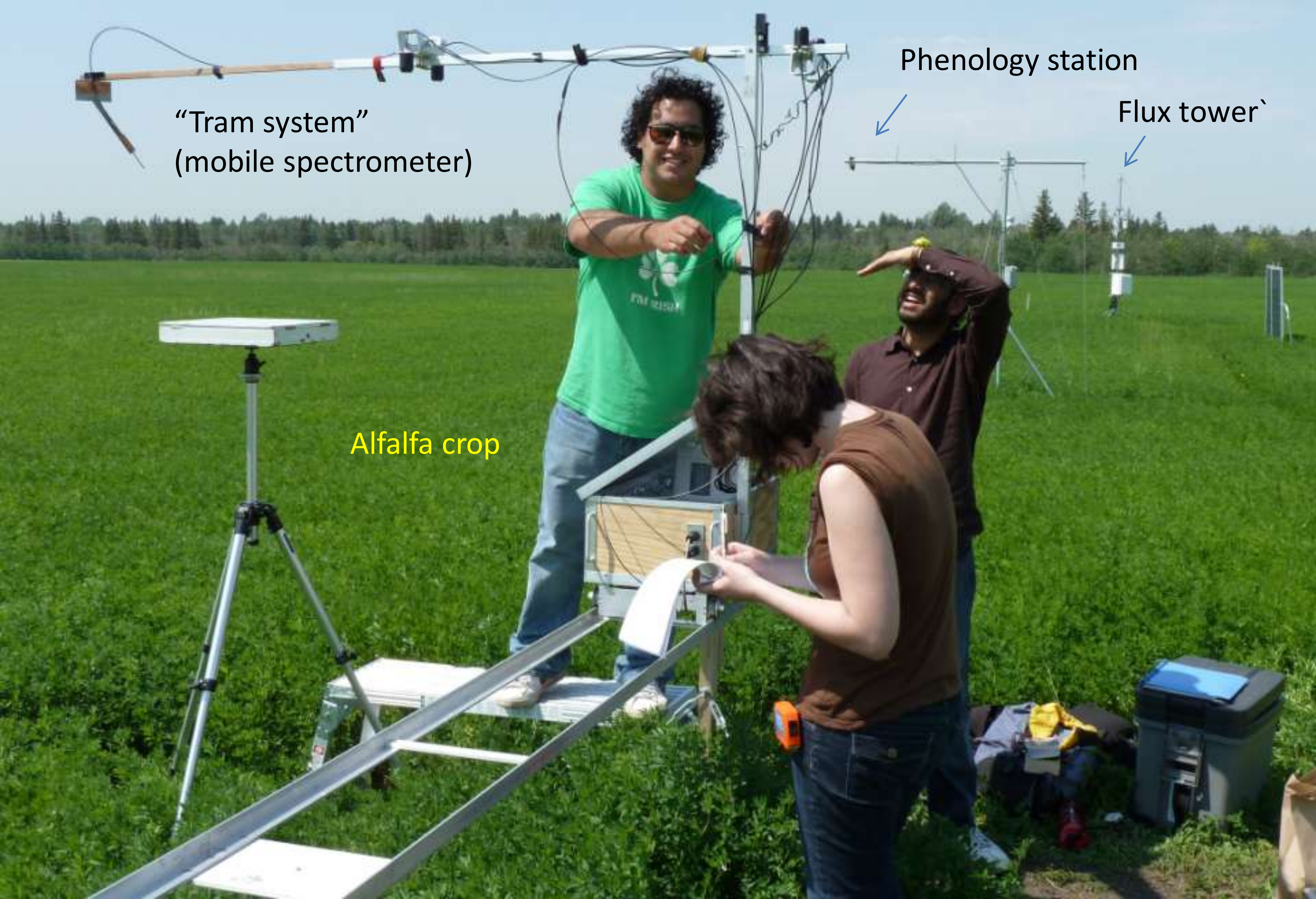
Why combine optical & flux measurements?

- Adds to our understanding of fluxes
  - Matches the flux footprint
  - Gap filling
  - Linking respiration to recently fixed carbon
- Connects fluxes to remote sensing – helps with "scaling"
  - Upscaling – extrapolating from points to regions
  - Downscaling – calibration/validation of satellite models (e.g. MODIS products)
- Improves understanding of flux controls & dynamics
  - Phenology
  - Disturbance
  - Identifies factors controlling fluxes
- Needed to "quantify carbon, water and energy fluxes *Everywhere, and All of the Time*."

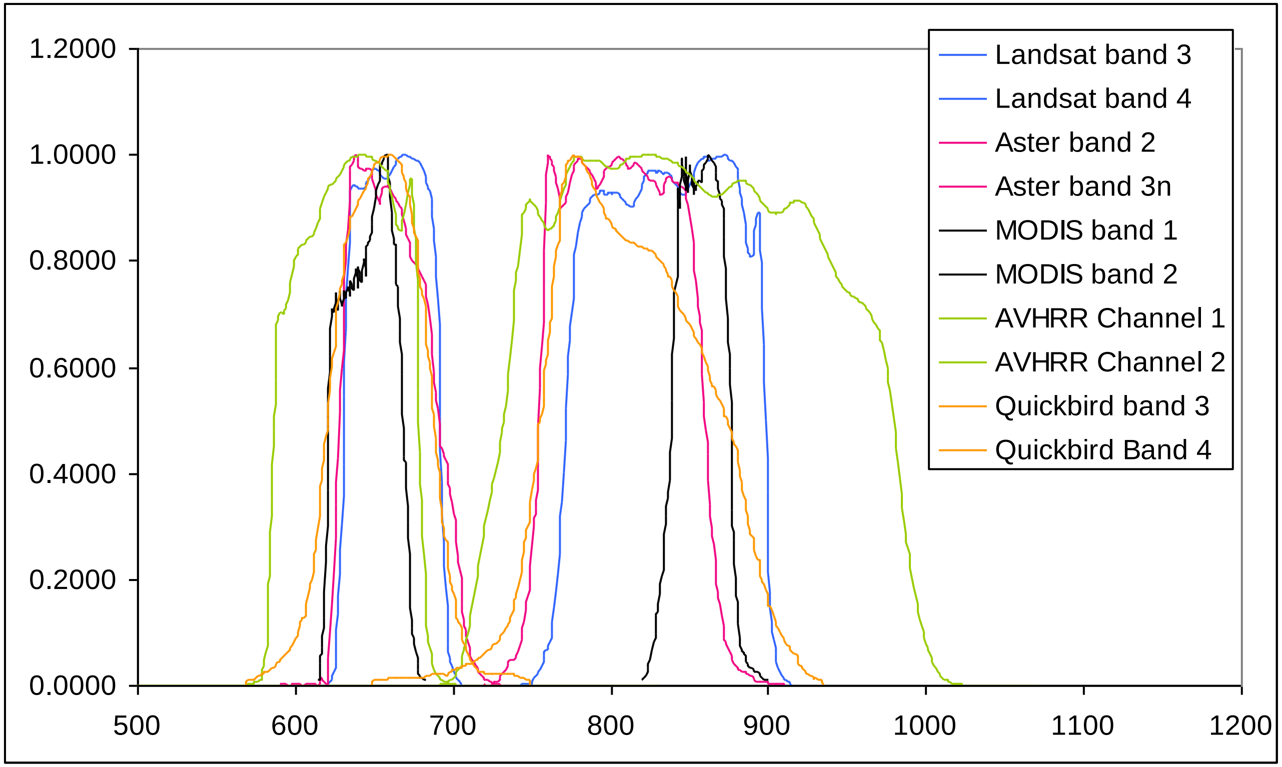
- Addresses policy and carbon market needs

Technical Details:
“Do’s & Don’ts”

Linking fluxes to optical sampling

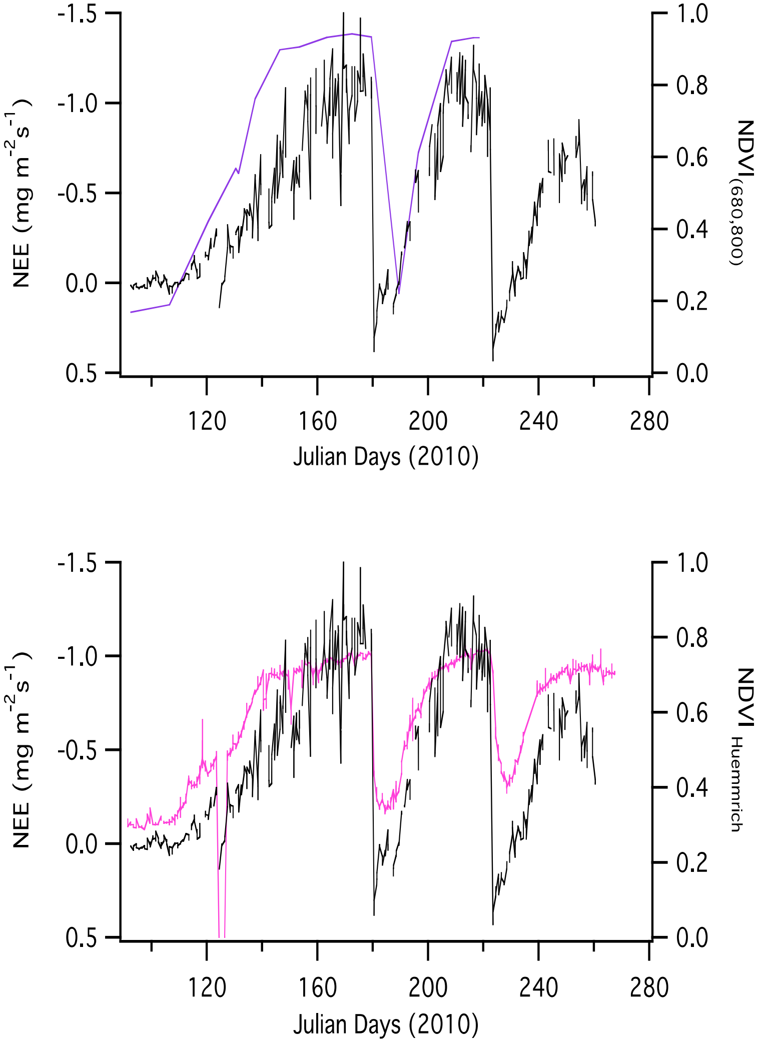


Band Considerations – Many NDVIs!



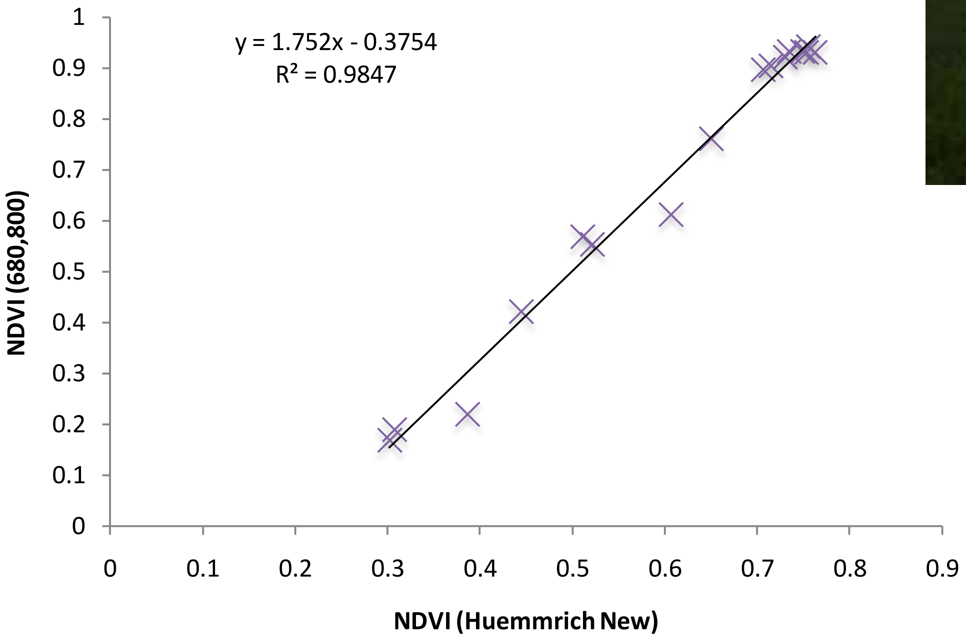
Satellite wavebands used for NDVI … there is *NO single standard!*

Does it matter?



Data: Saulo Castro

Comparison of phenology station NDVI to tram NDVI



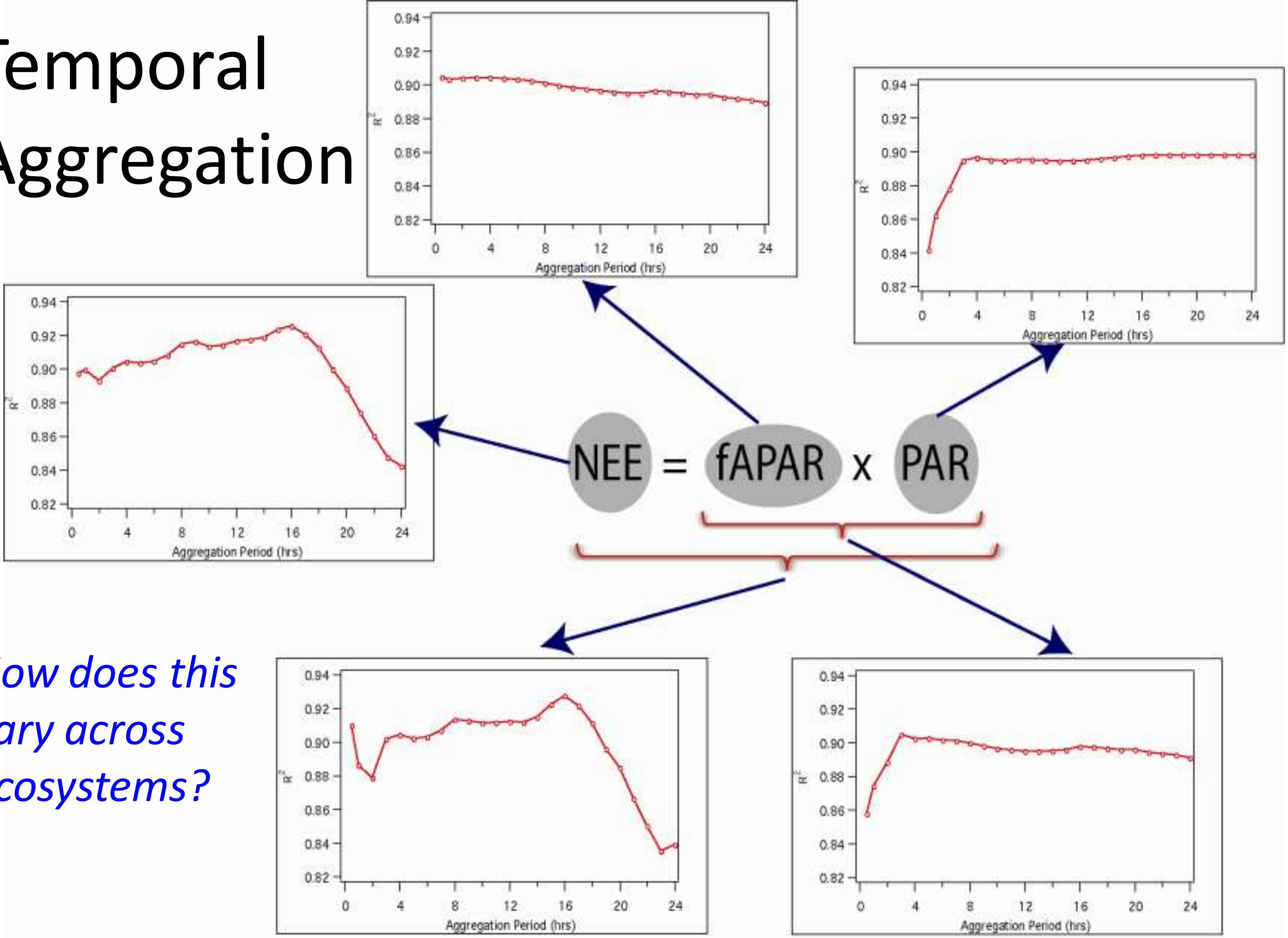
Standardization

vs.

Calibration & metadata

Data: Saulo Castro

Temporal Aggregation



How does this vary across ecosystems?

Figure 5: r^2 patterns resulting from various temporal aggregations of a) fAPAR, b) PAR c) APAR, d) NEE + APAR, e) NEE. In all cases, values were aggregated around midday, and r^2 values represent a correlation between optical variables and NEE.

Data: Saulo Castro

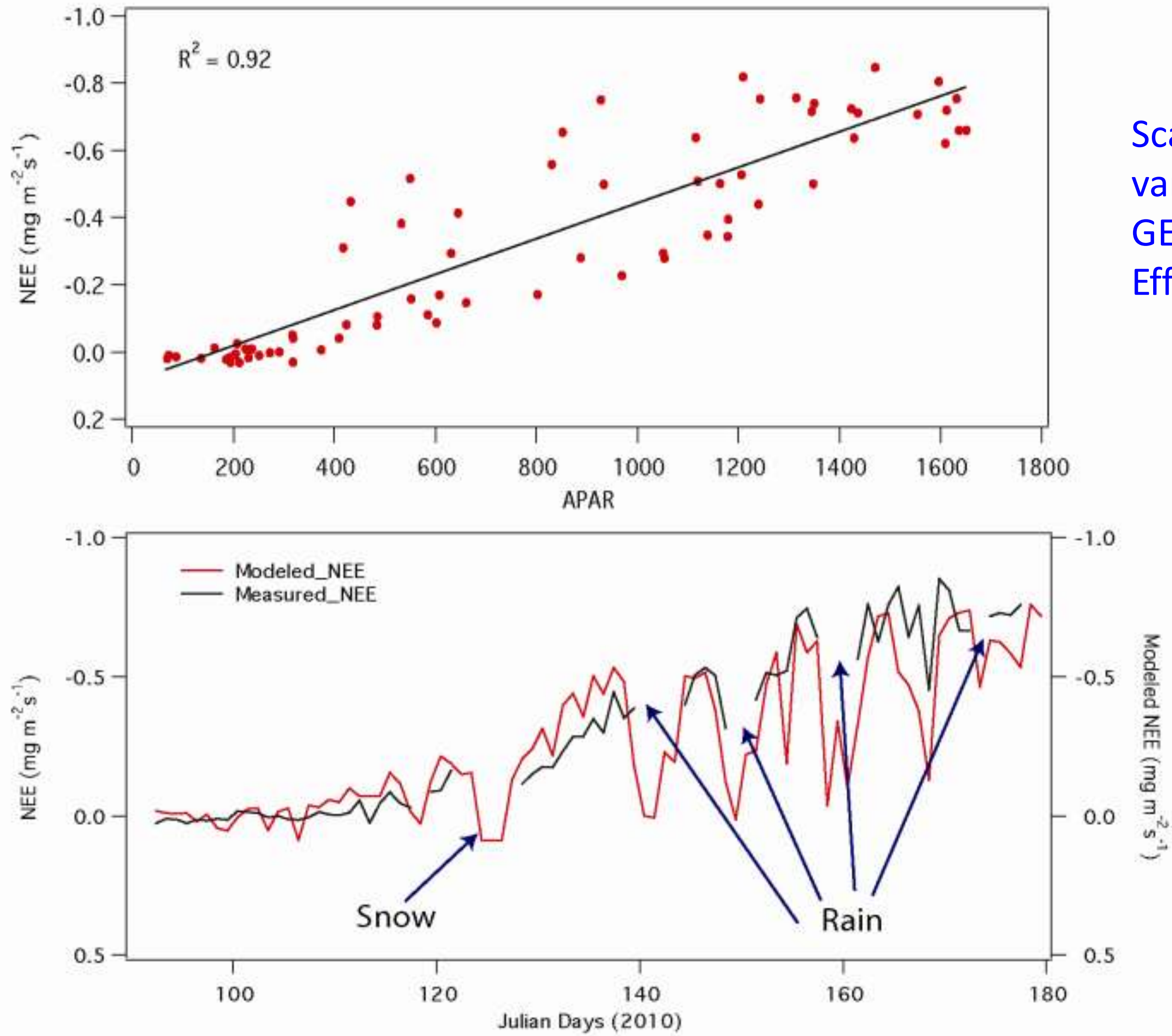


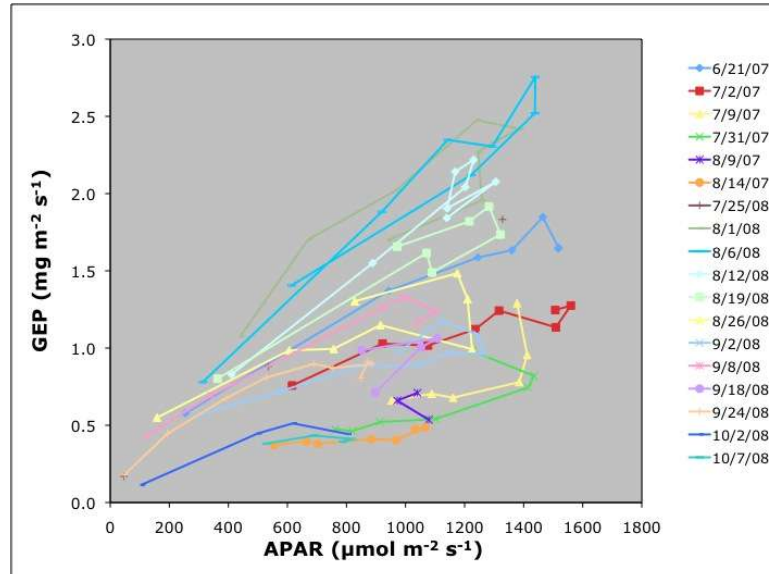
Figure 6: a) Measured NEE as a function of APAR. b) Comparison of the seasonal dynamics from the modeled NEE (red line) and measured NEE (black line). Data gaps within the measured NEE were due to precipitation.

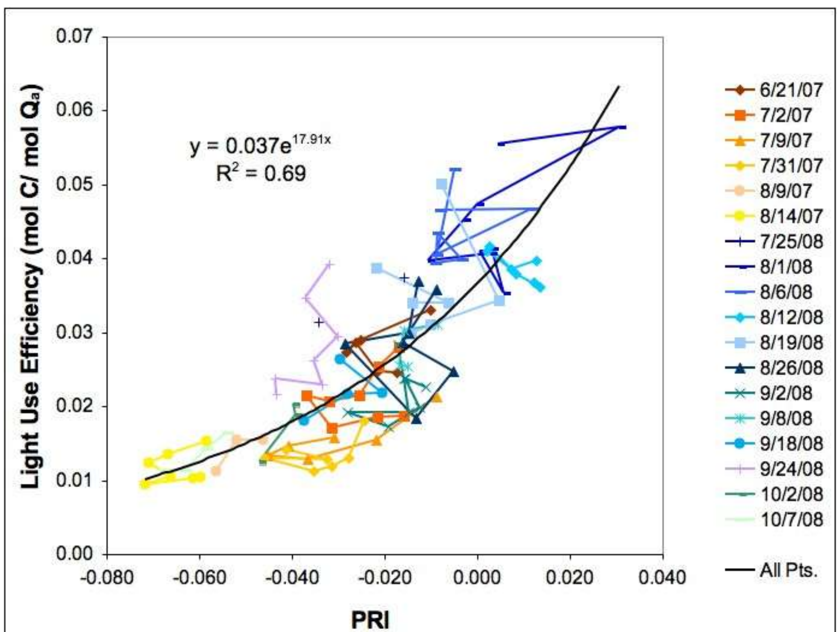
Scatter due to variation in GEE/NEE and Efficiency (ε)

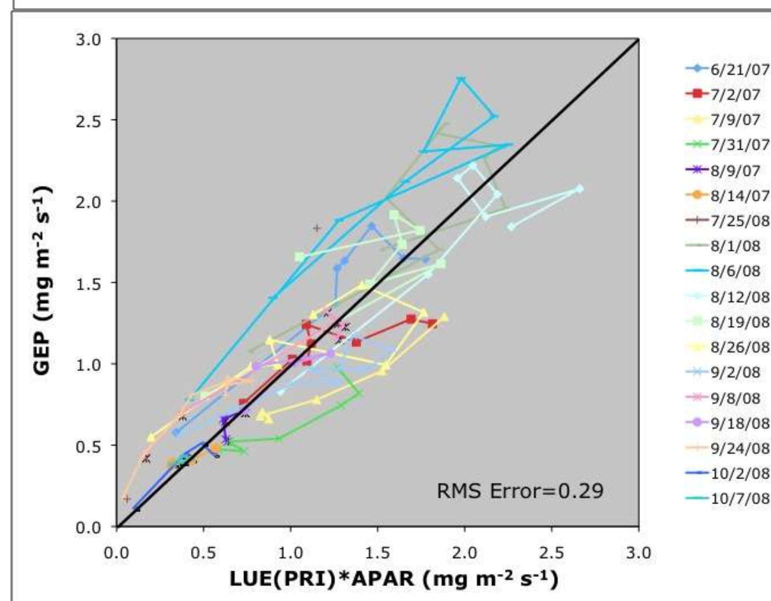
LUE model can be used for gap-filling

Data: Saulo Castro

Adding PRI to the LUE model



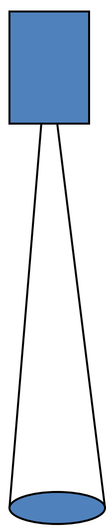




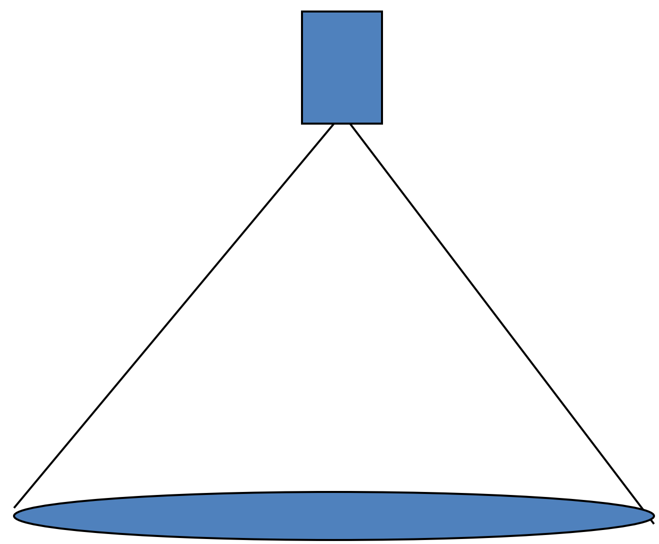
Figures courtesy Fred Huemmrich

Field-of-view considerations

Small field-of-view
-Well-defined target
-Well-defined look angle
-Lots of sensors needed
(or mobile sensors)
-Expensive!



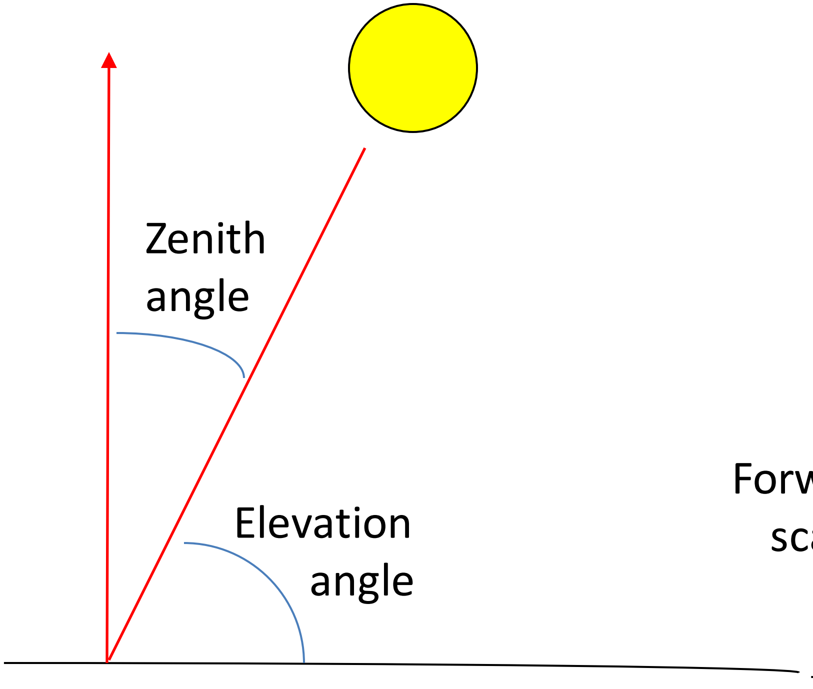
Large field-of-view
-Ill-defined target
-Ill-defined look angle
-Covers larger area (more representative?)
-Fewer sensors needed
-Lowers cost

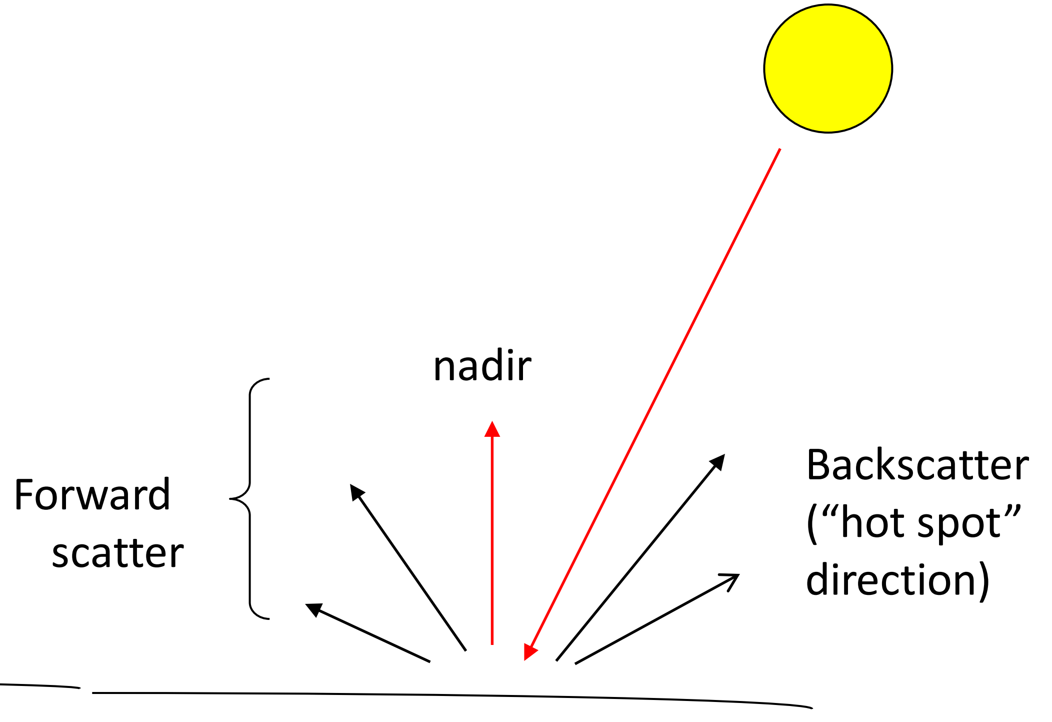


Angular considerations

Sun angle:
Varies diurnally,
seasonally and latitudinally

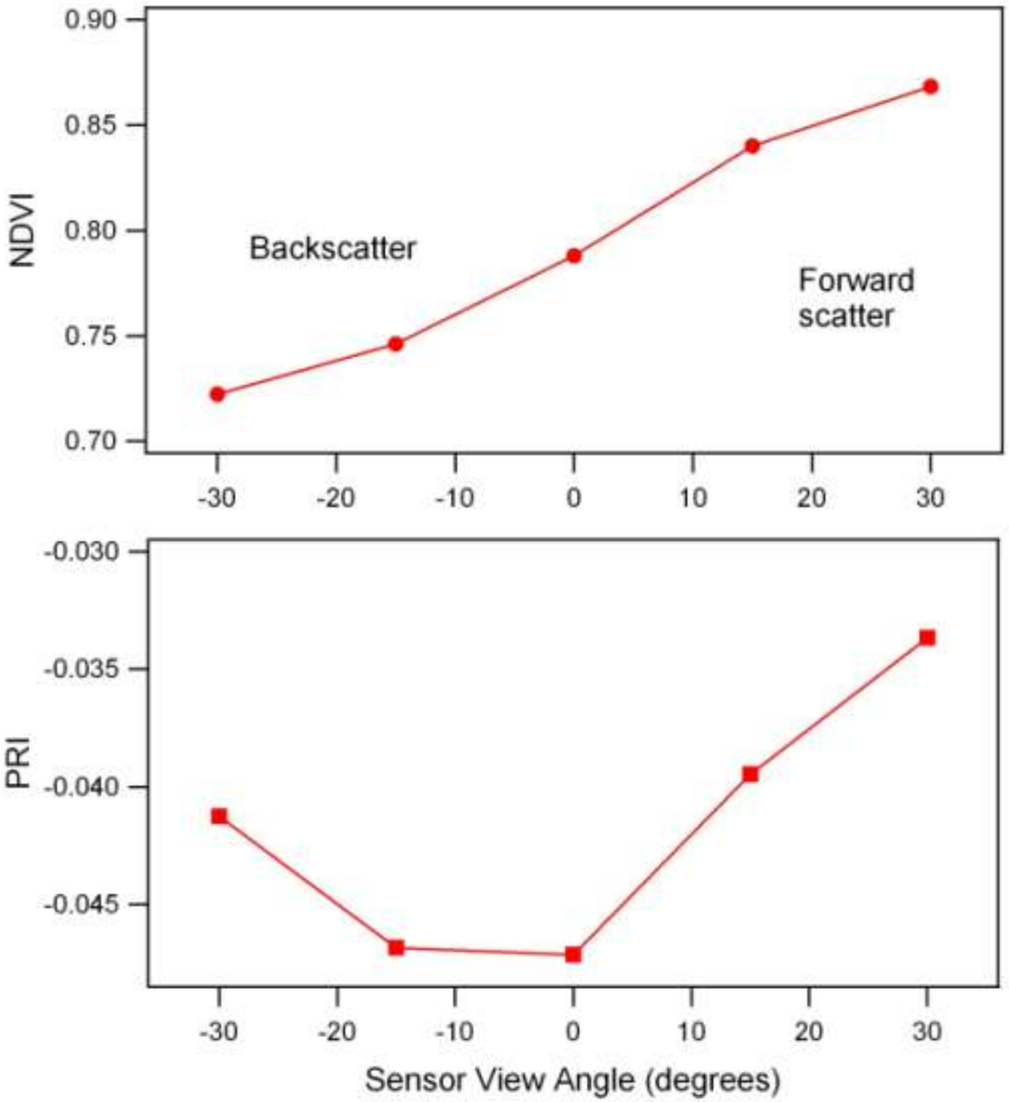
View angle:
varies with sensor look angle





Target (vegetation, ground, water, etc.)

Effect of View Angle – Barley Field



NDVI and PRI have different view angle responses

PRI tends to be lower towards backscatter direction (near hot spot)


Cross-site comparisons
& upscaling

NorthSTAR sites

Churchill – Mario Tenuta, Krista Hanis

Daring Lake – Peter Lafleur, Elyn Humphreys

Imnavait – Gus Shaver, Adrian Rocha,
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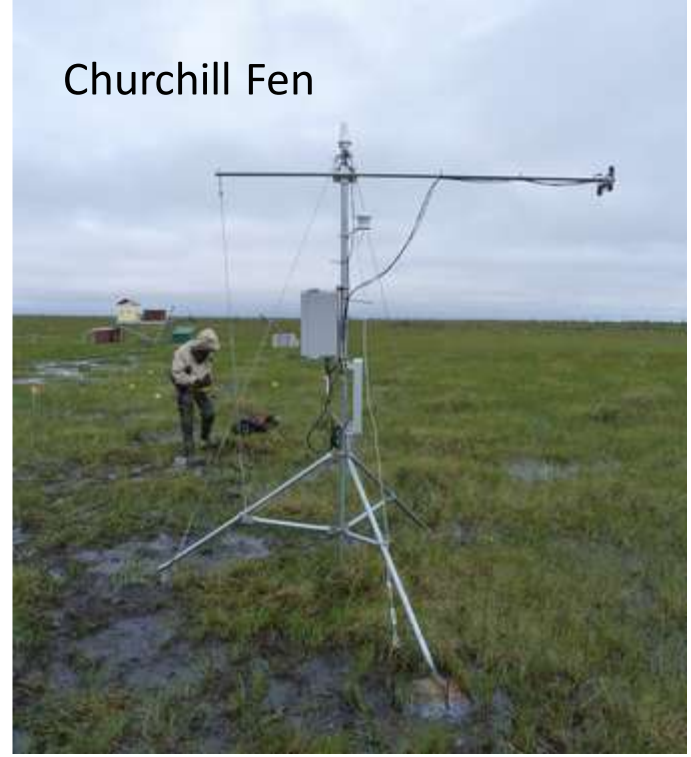
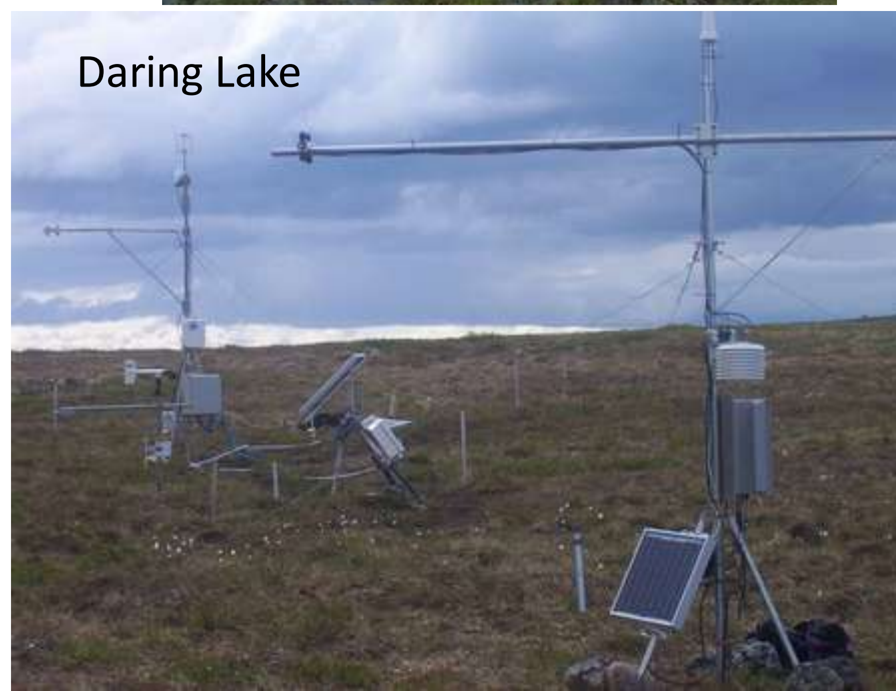
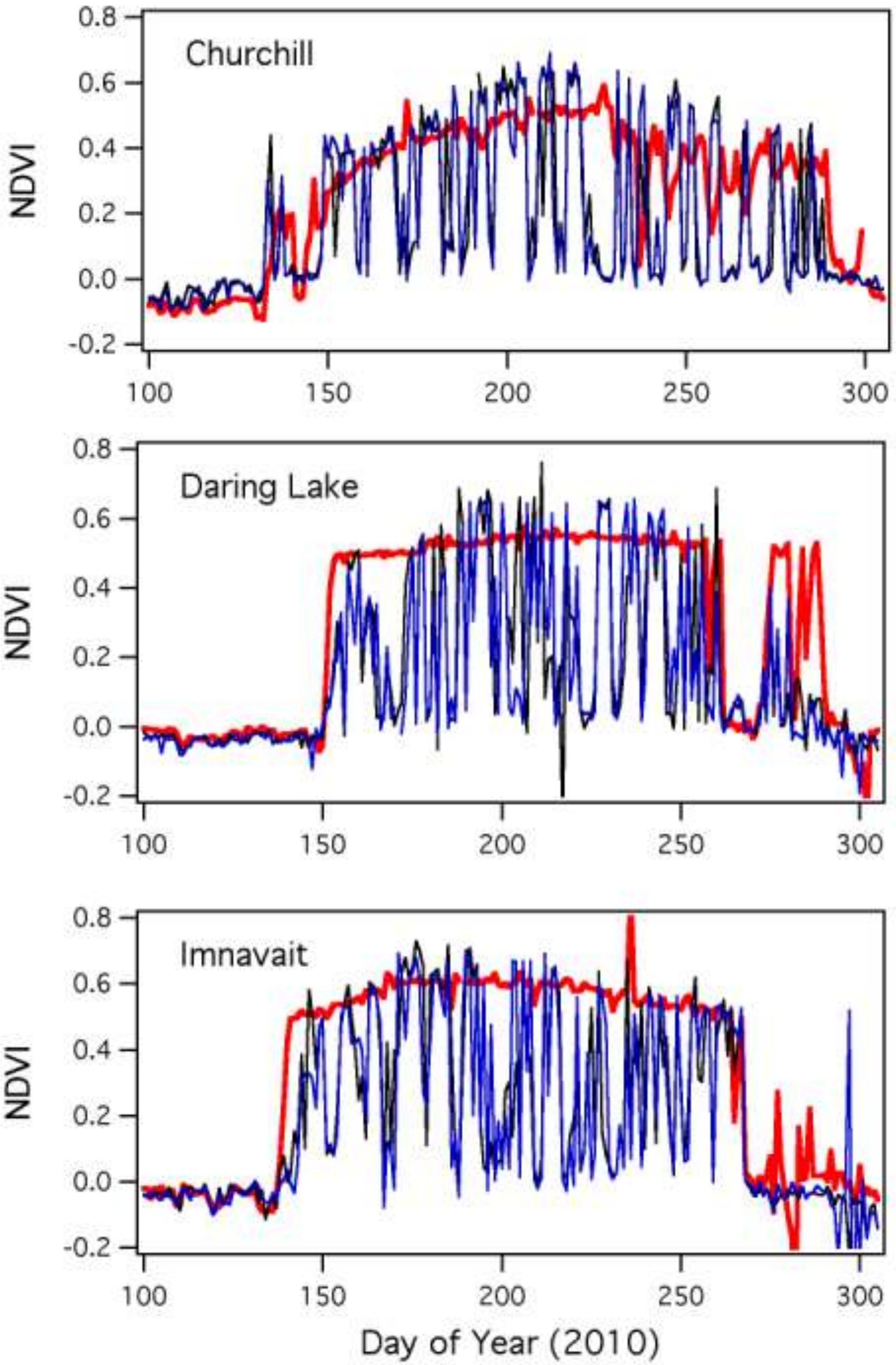
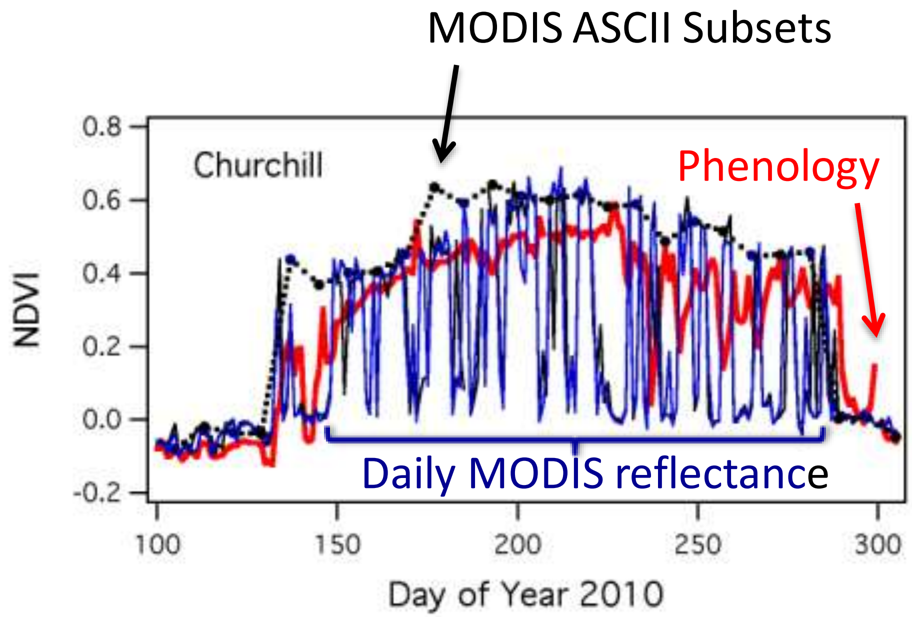




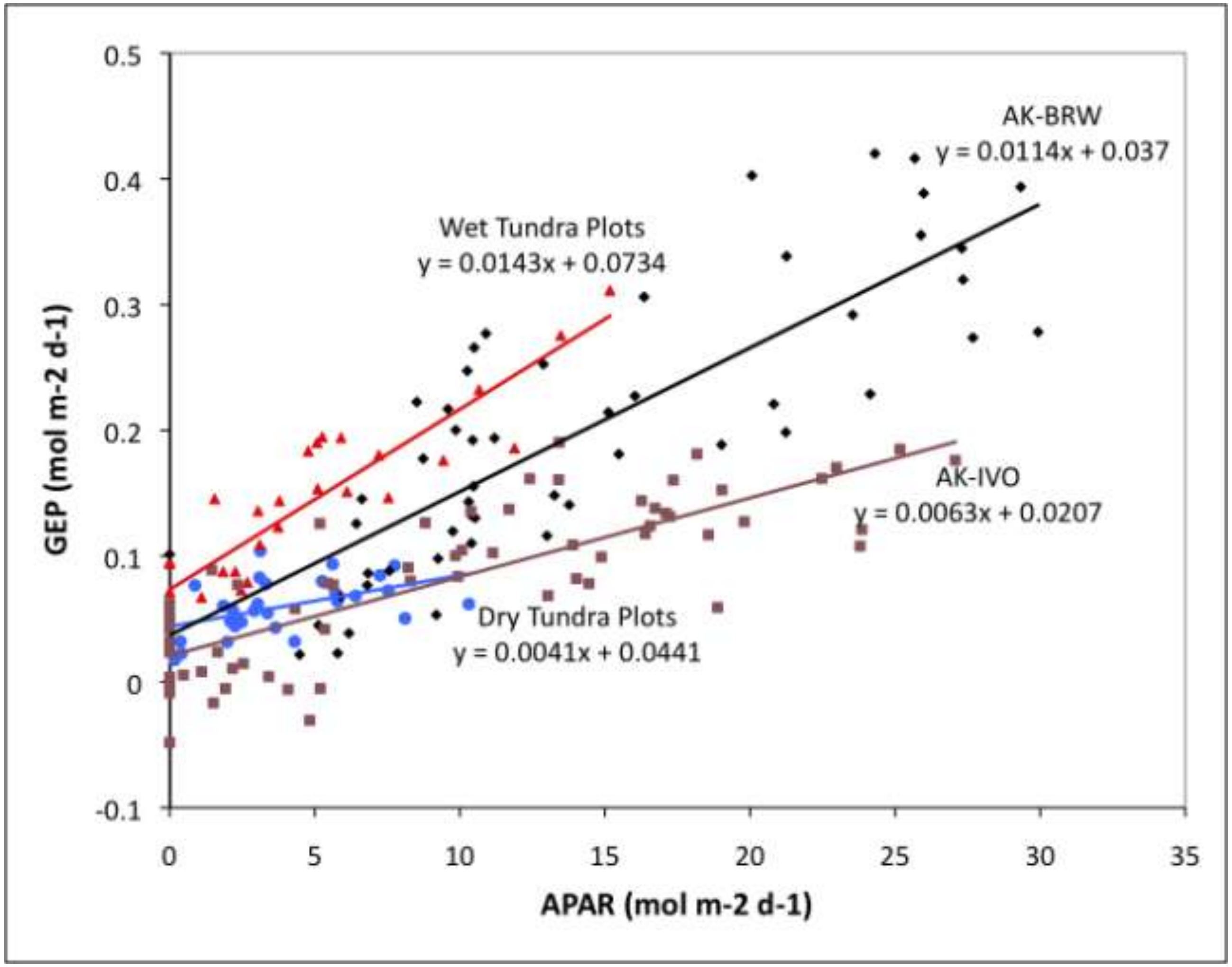
Phenology Station NDVI vs. MODIS NDVI

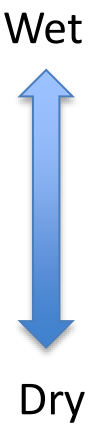




MODIS data courtesy Scott Williamson

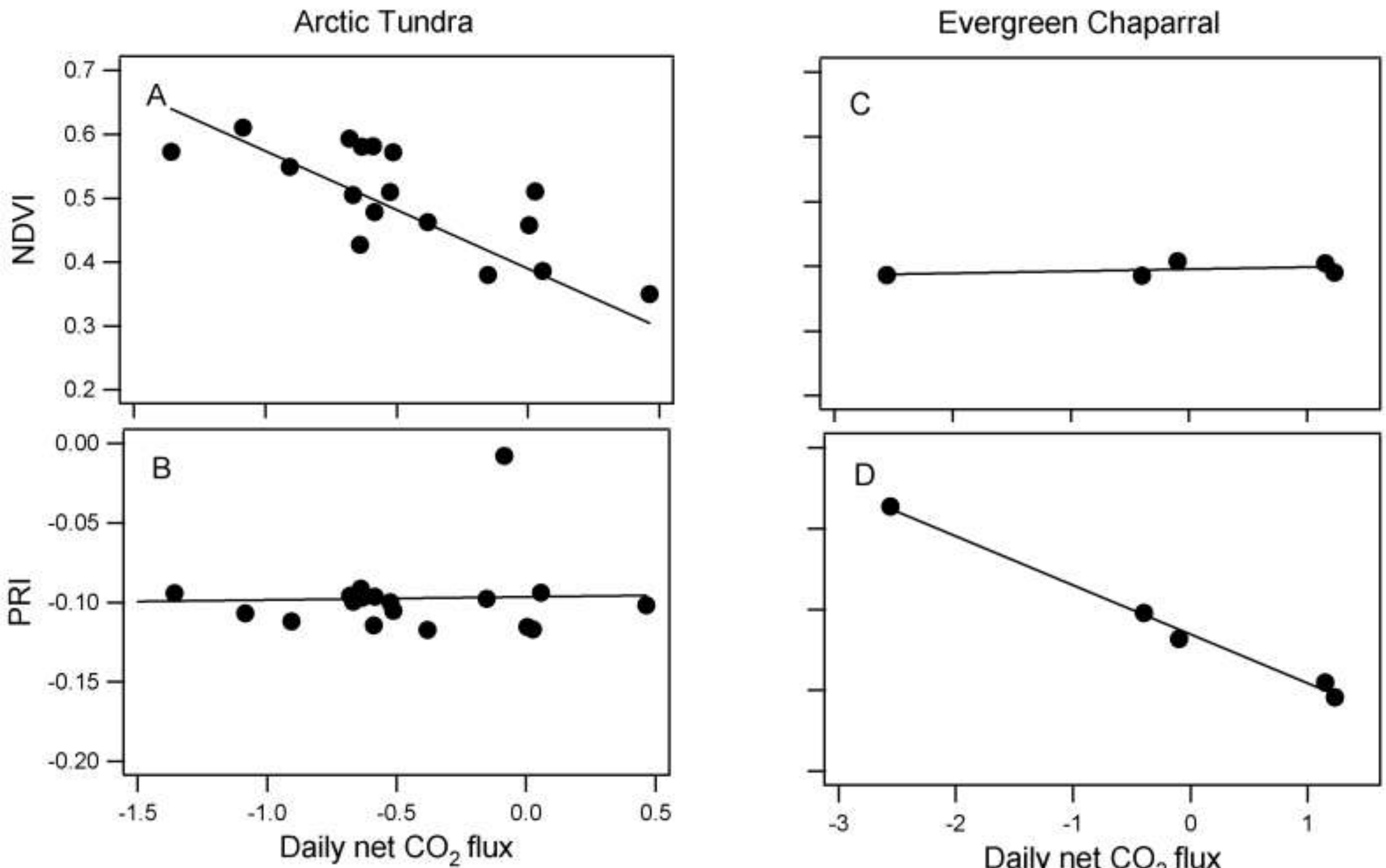
APAR-GEP plots reveal different slopes (seasonal LUE values) related to moisture constraints on productivity.





Data: Fred Huemmrich

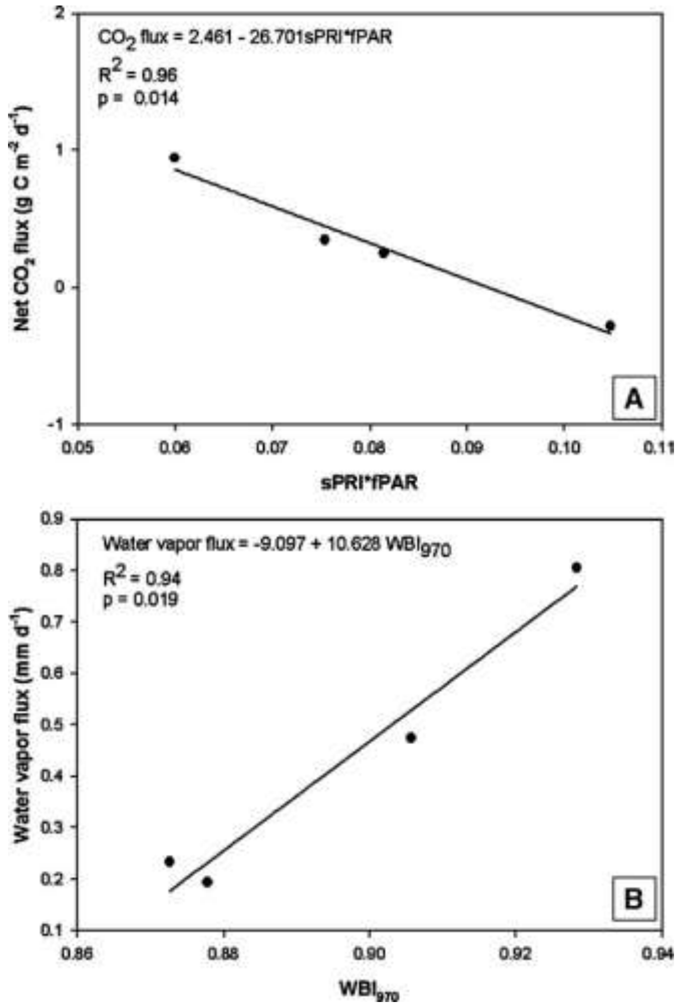
Contrasting controls on carbon flux revealed through combined optical and flux sampling.



Radiation-limited

Water-limited

Mapping disturbance impacts on carbon and water vapor fluxes



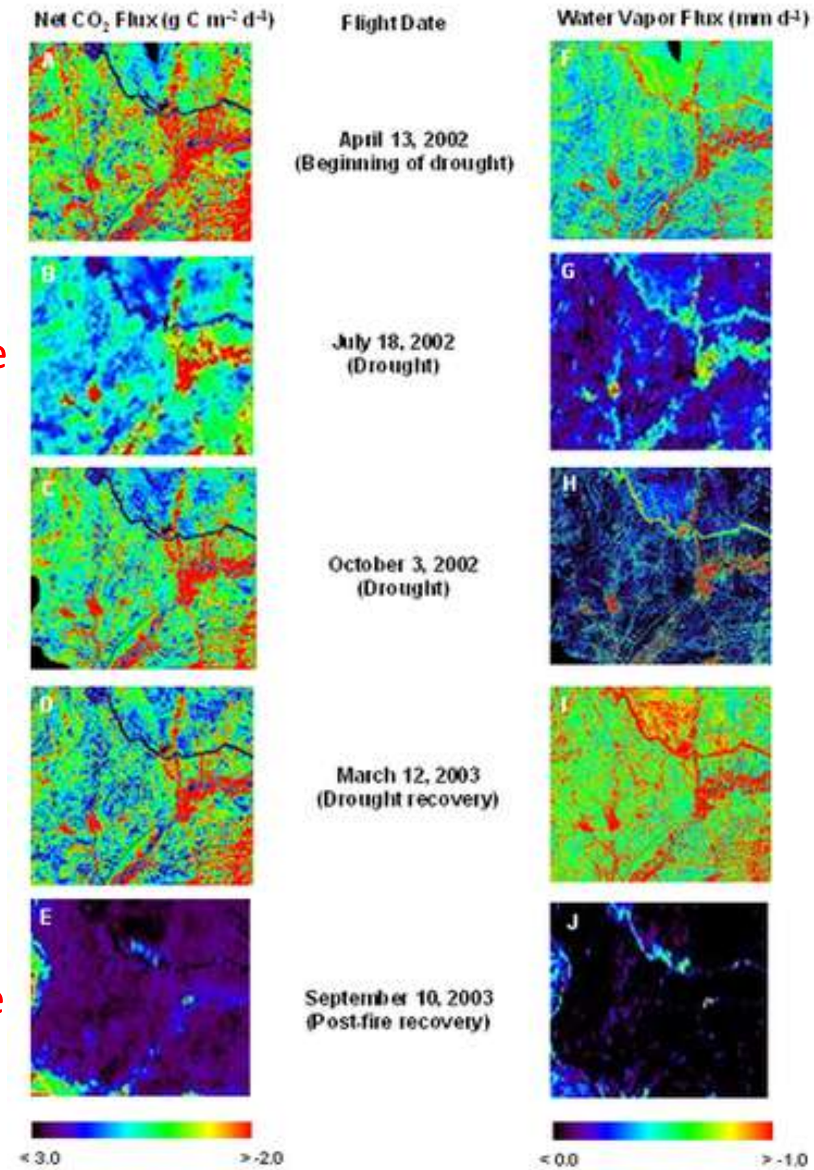
sink

source

sink

sink

source



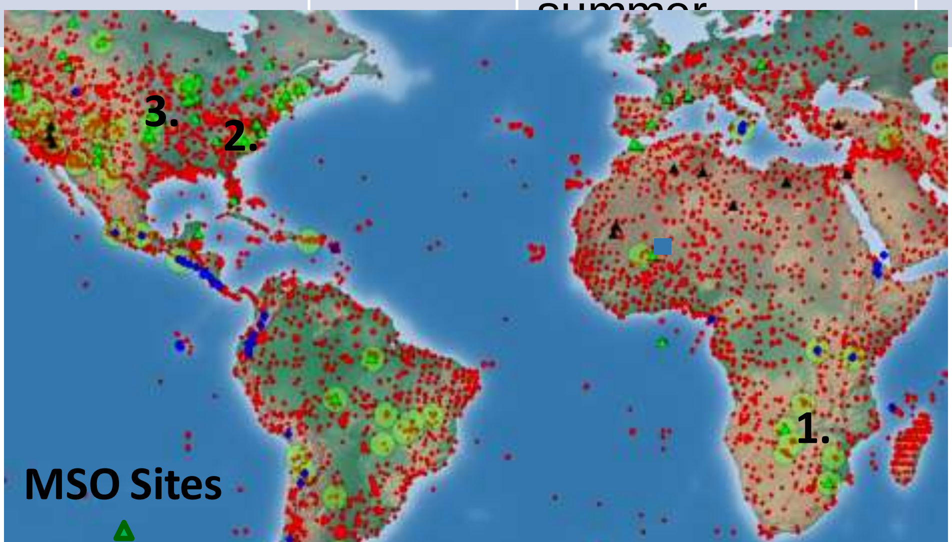
Fuentes et al. 2006

EO-1 Hyperion: 3 Ecosystem Studies

Time Series

FLUX Site Name	Locati on	Climate	Vegetation
1. Mongu	Zambia	Temperate/ warm summer	Kalahari/ Miombo Woodland
2. Duke	North Carolin a USA	Temperate/ no dry season/ hot summer	Hardwood forest/ Loblolly pine
3. Konza Prairie	Kansas USA	Cold/ no dry season/ hot summer	Grassland

Mongu



Slide: Betsy MIddleton

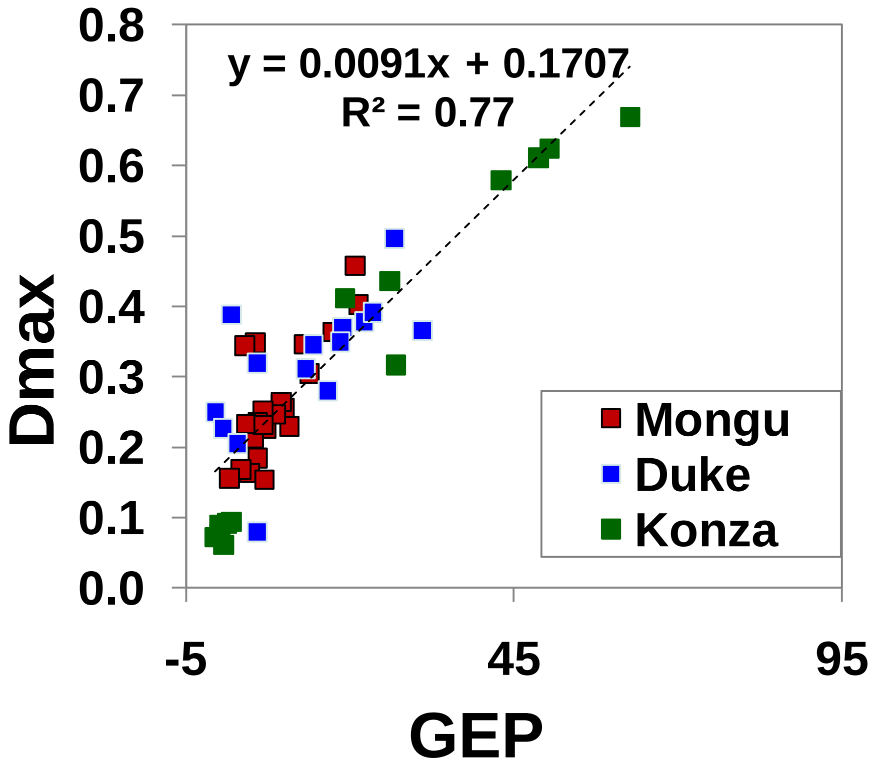
All Flux Sites -- Regression Coefficients for the Top Performing Spectral Bio-indicators (R^2 values)

Spectral indicator	Formula	NEP	GEP	LUE
Dmax	Max D in the 650-750 nm	0.73 L+	**0.77** L+	0.75 L+
DP22	Dmax/D(max + 12)	0.65 L+	0.74 NL+	0.71 L+
G34	Chlorophyll, R bands at 750, 800, 520, and 450 nm	0.55 NL-	0.52 NL-	-0.65 NL-
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+
EVI2	2 bands (NIR and Red)	0.55 L+	0.60 NL+	0.73 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+

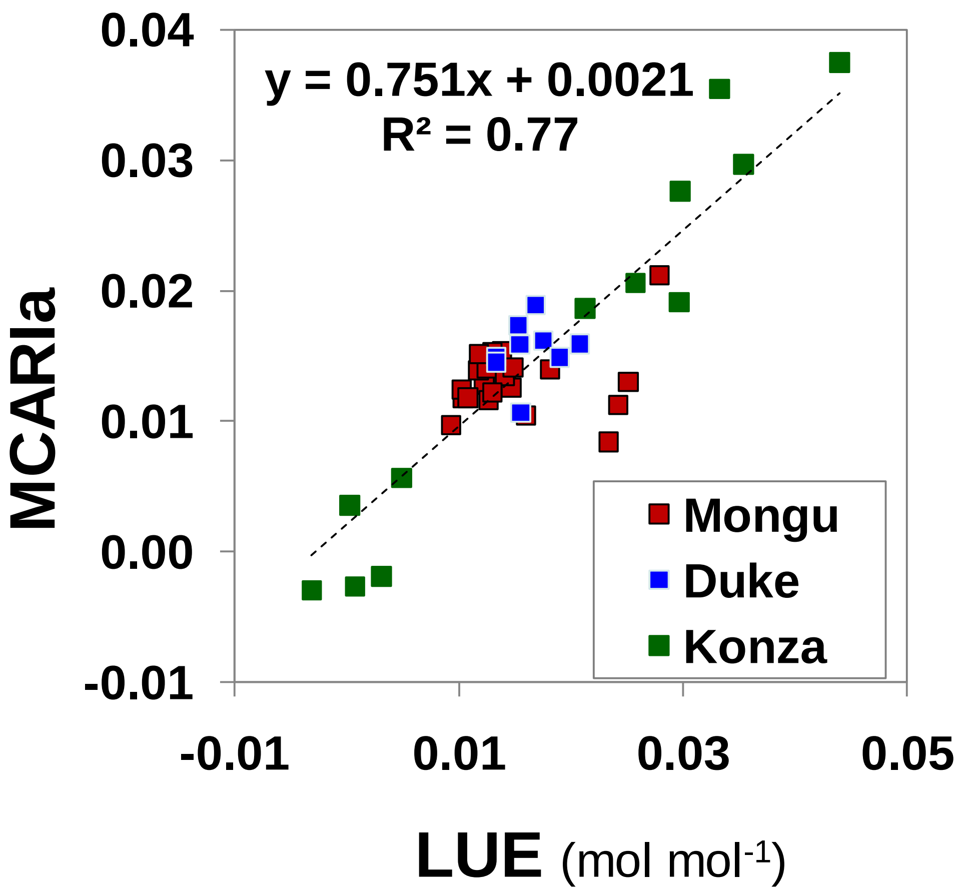
Slide: Betsy MIddleton

Multiple Flux Sites

Konza (K), Mongu (M), Duke (D)



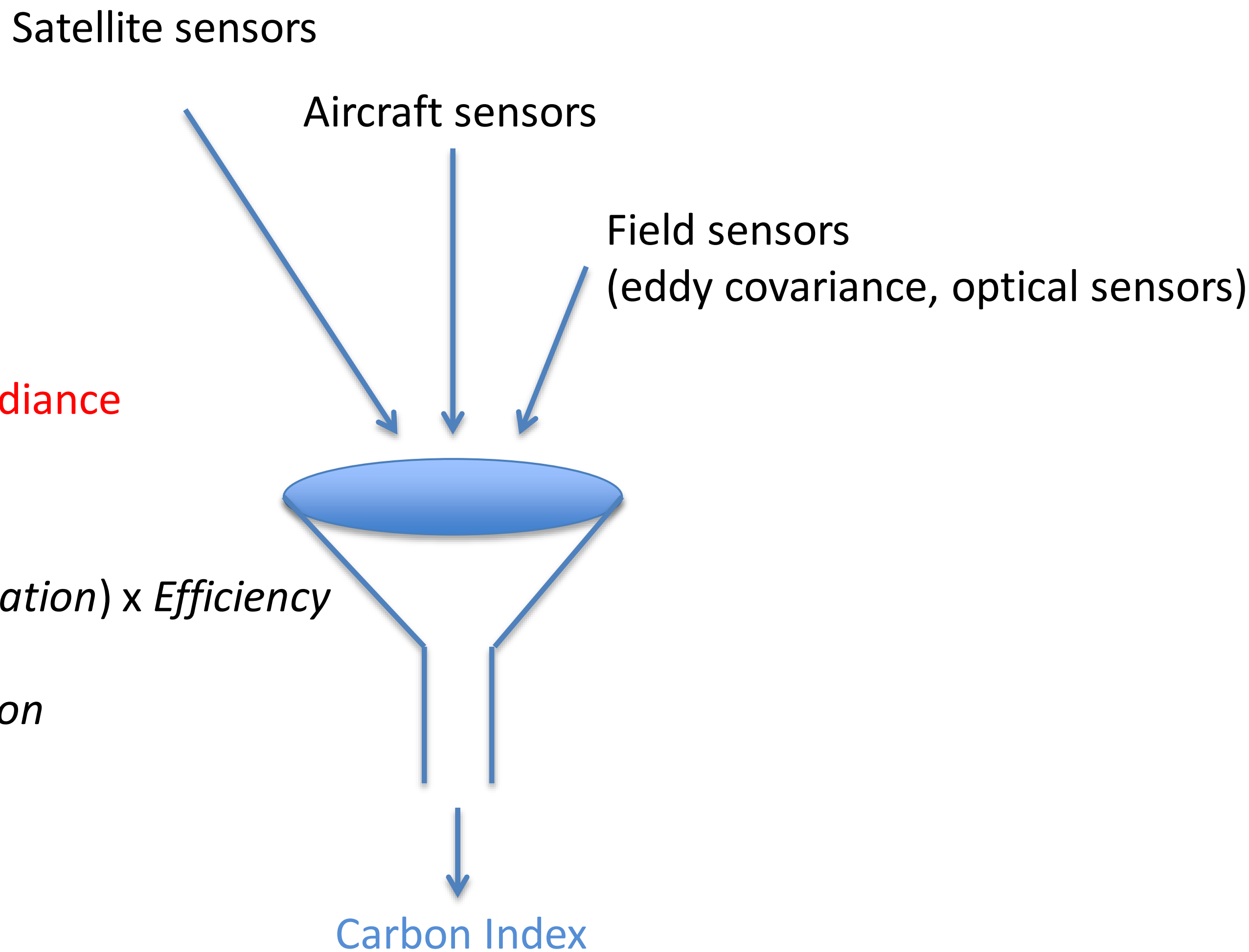
Optical data offer a rich set of tools
For understanding and scaling fluxes



Data: Betsy Middleton

Future: tackling data challenges for science and policy needs

Integrating carbon data from multiple sources



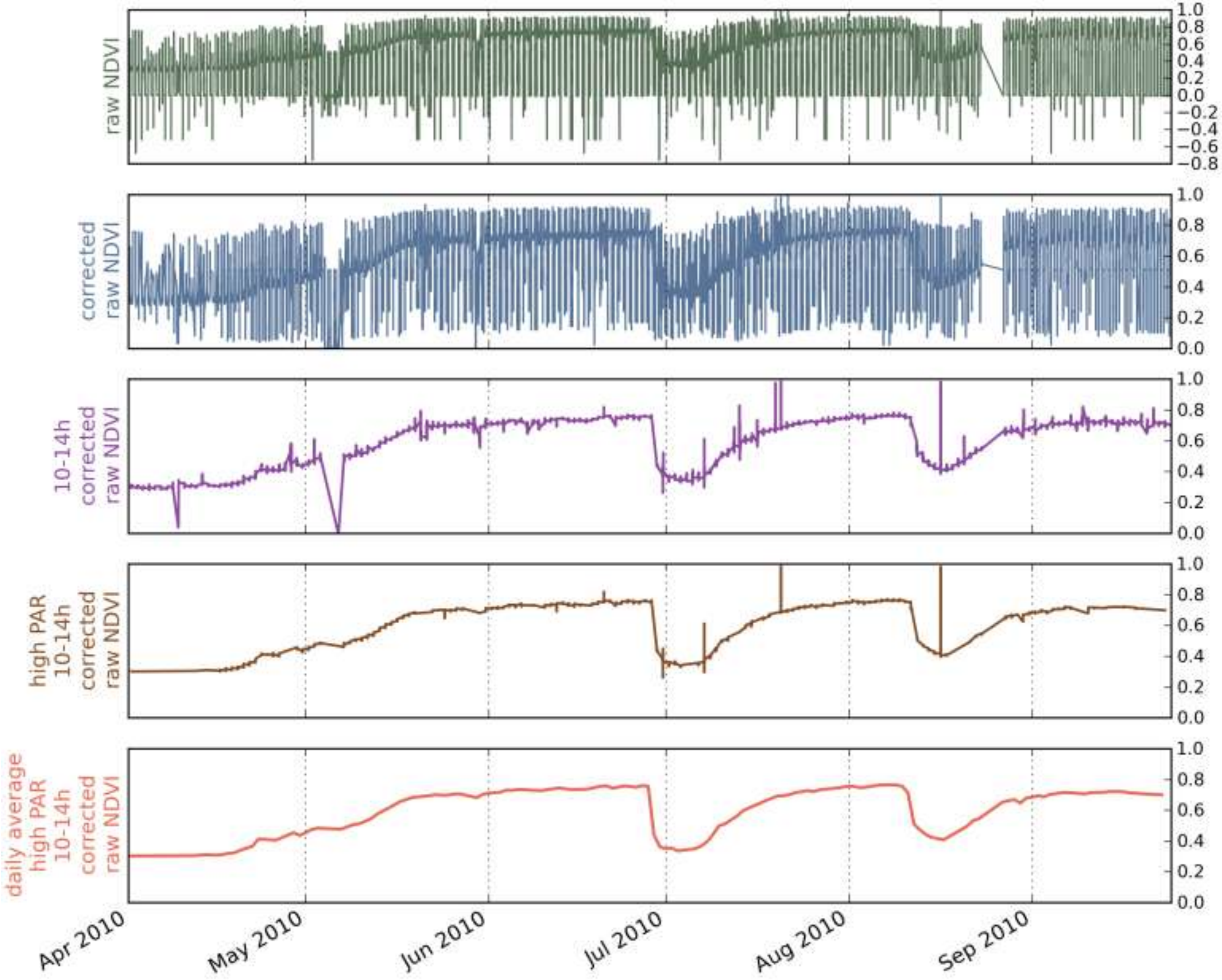
NDVI Irradiance

GEE = (*Absorbed radiation*) x *Efficiency*

NEE = *GEE - Respiration*

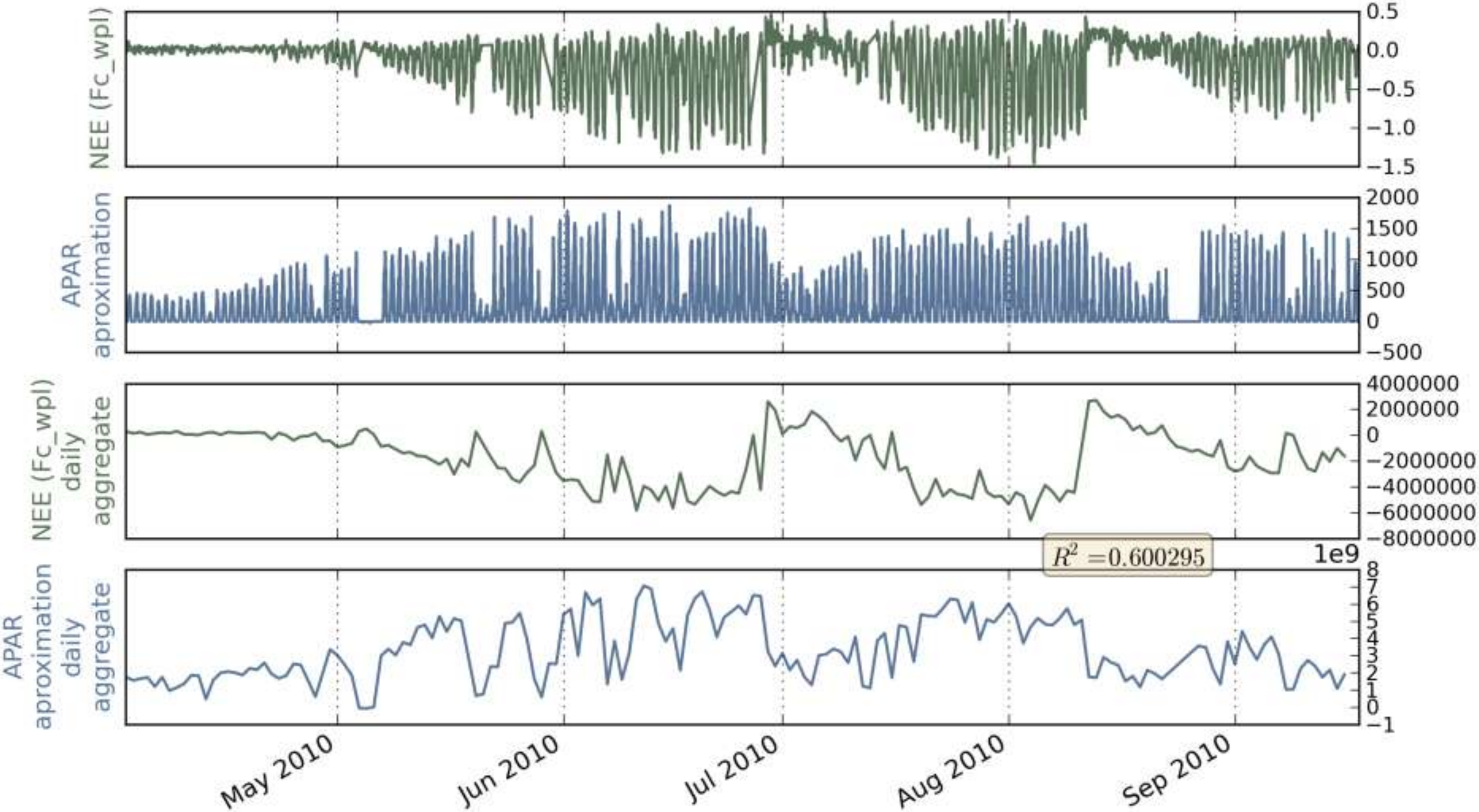
http://biosphericcarbonnetwork.org

Informatics & Cyberinfrastructure - Automating Data Processing



Gilberto Zonta Pastorello

Informatics & Cyberinfrastructure – Integrating flux & optical data



Gilberto Zonta Pastorello

GCI

the global carbon index

- Home
- Our Mission
- Our Data
- Field Sites
- Our Economics
- Contact Us
- Wiki
- Your Land's Value

Data-Derived Global Vegetation Values

Placing a dollar value on biospheric carbon sequestration.

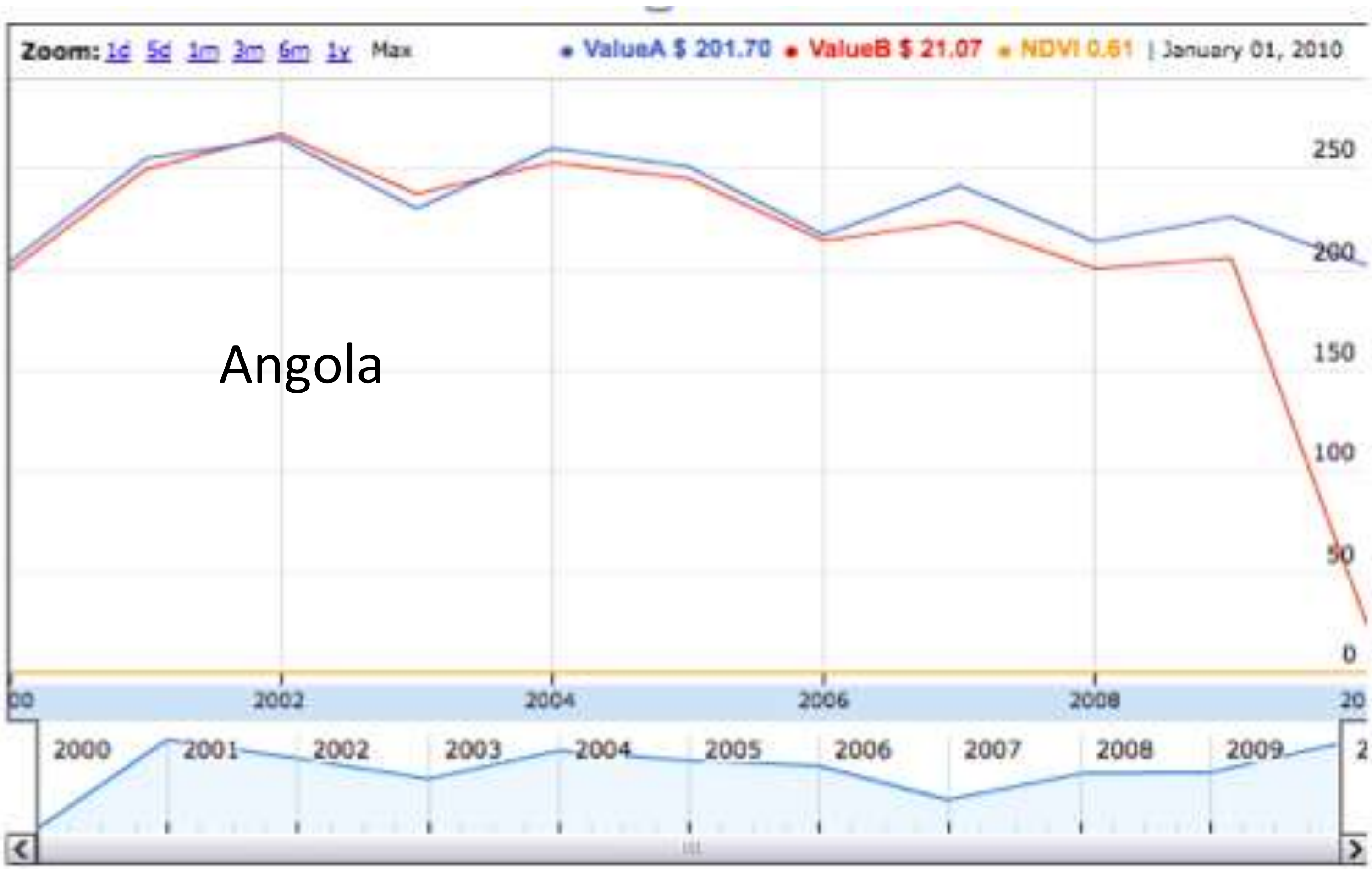
Go to first site

View field sites in tabular format

Donnette Thayer

http://globalcarbonindex.org

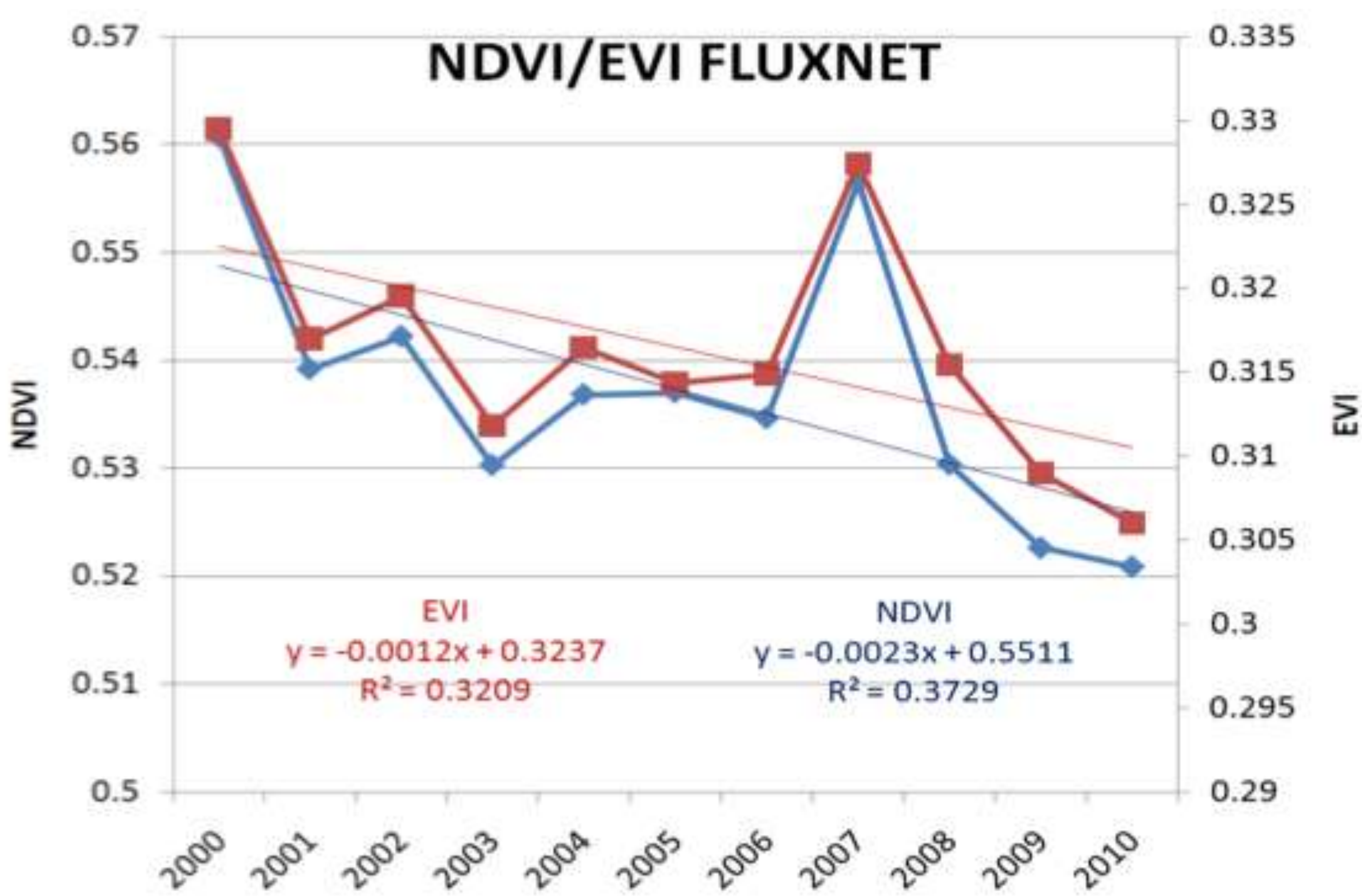
Carbon Stock Charts based on NPP (MOD17)



Angola

Donnette Thayer: http://globalcarbonindex.org

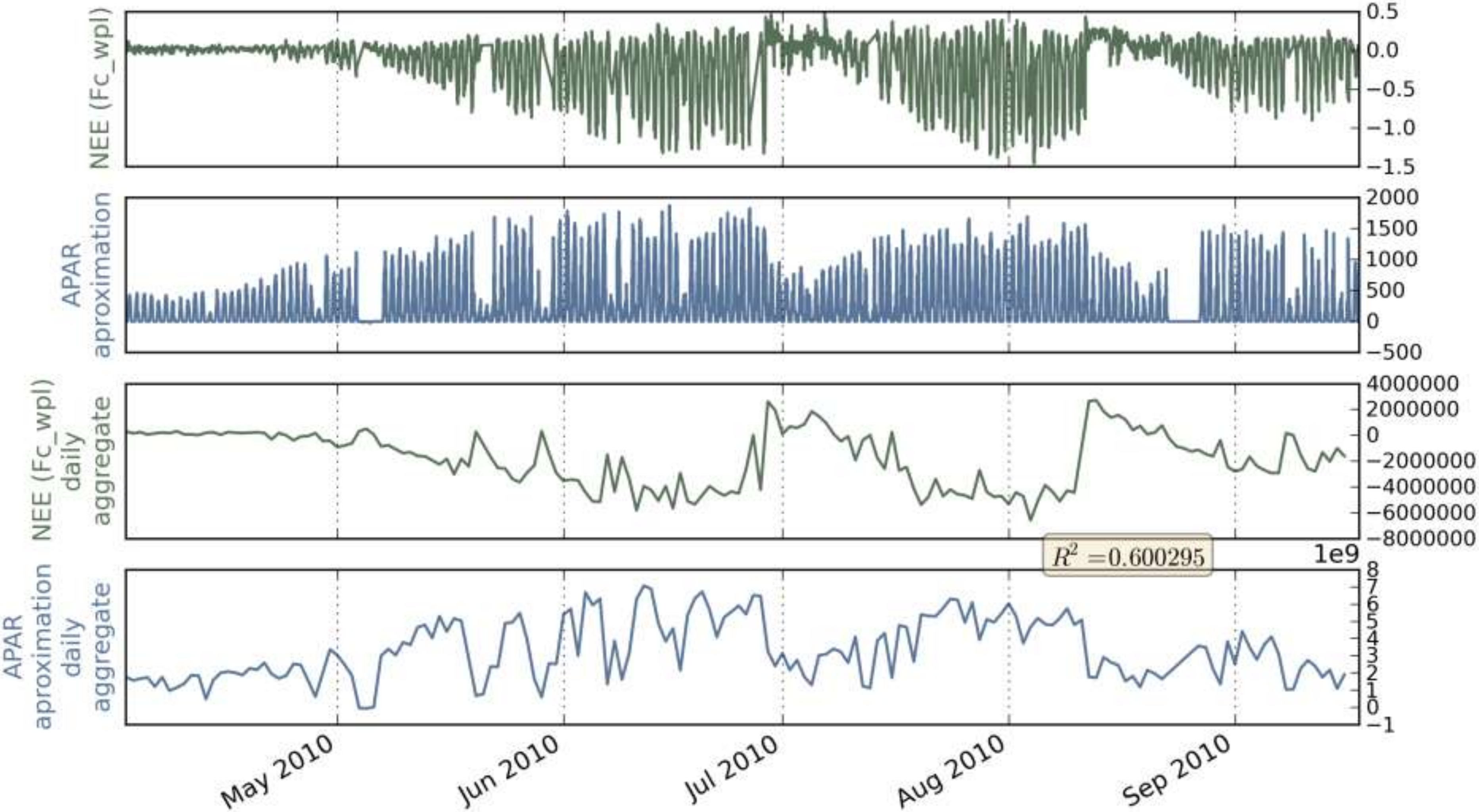
Declining NDVI & EVI for all FLUXNET sites



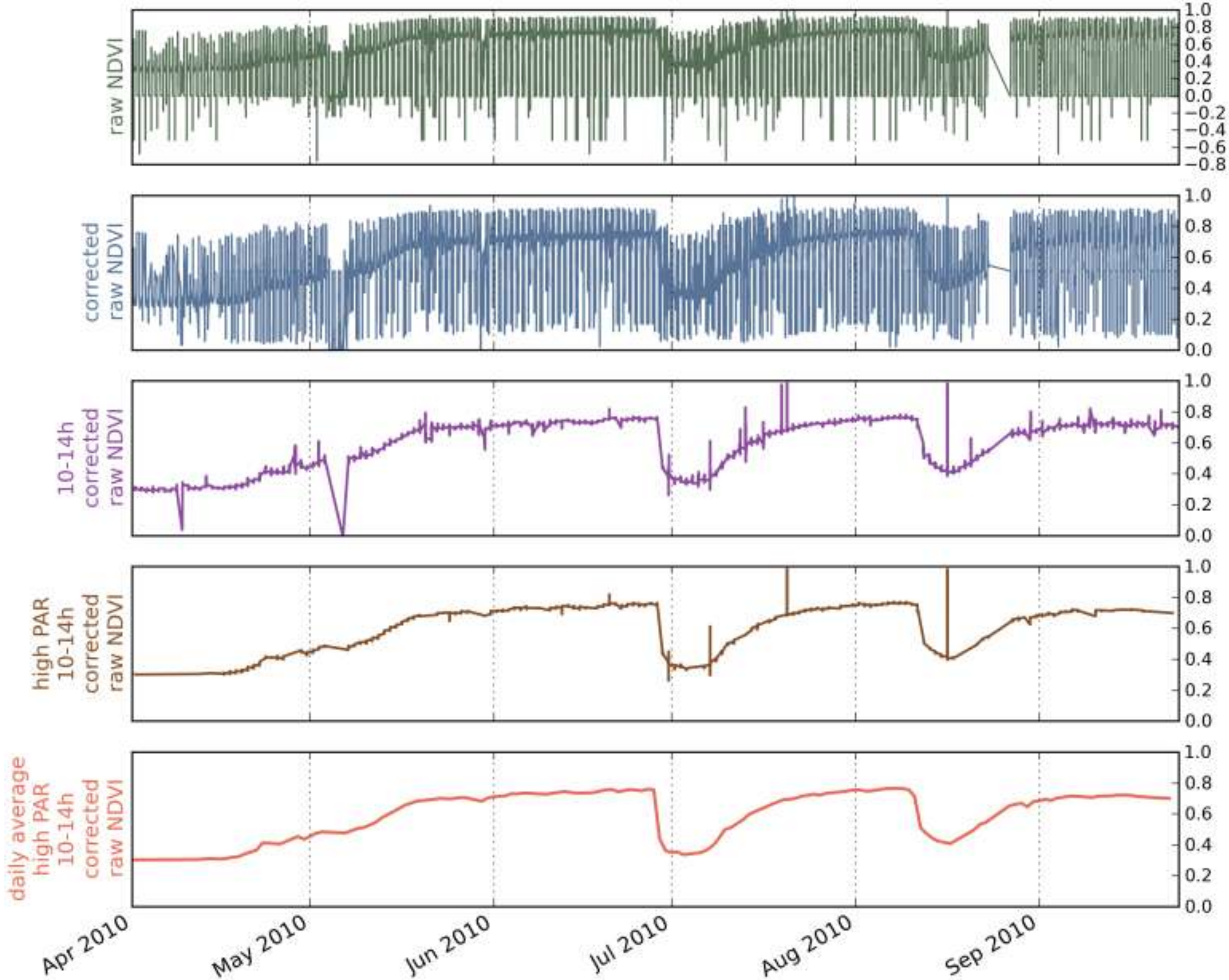
MODIS data courtesy Oak Ridge DAAC
& Donnette Thayer

Is global terrestrial productivity declining?

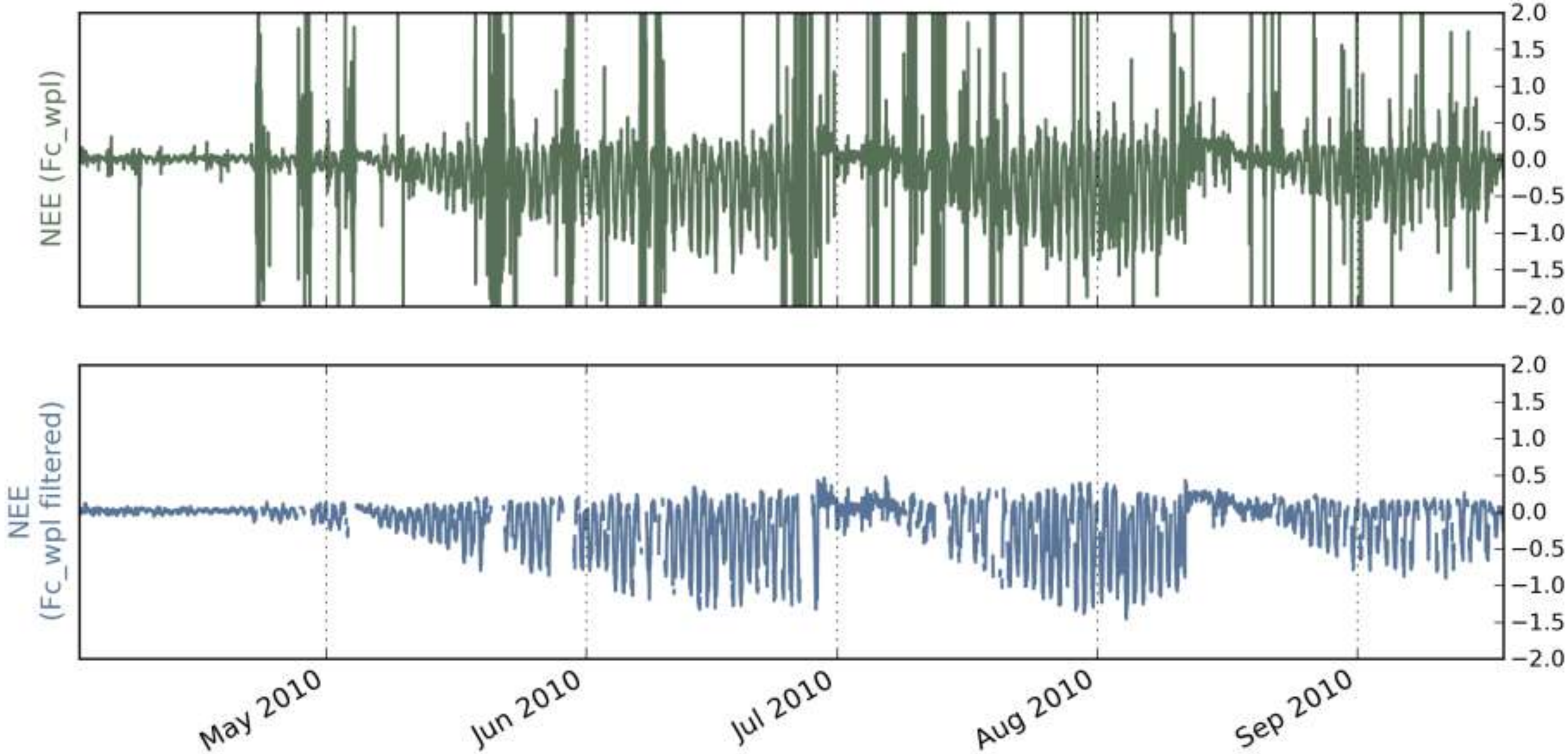
Informatics & Cyberinfrastructure



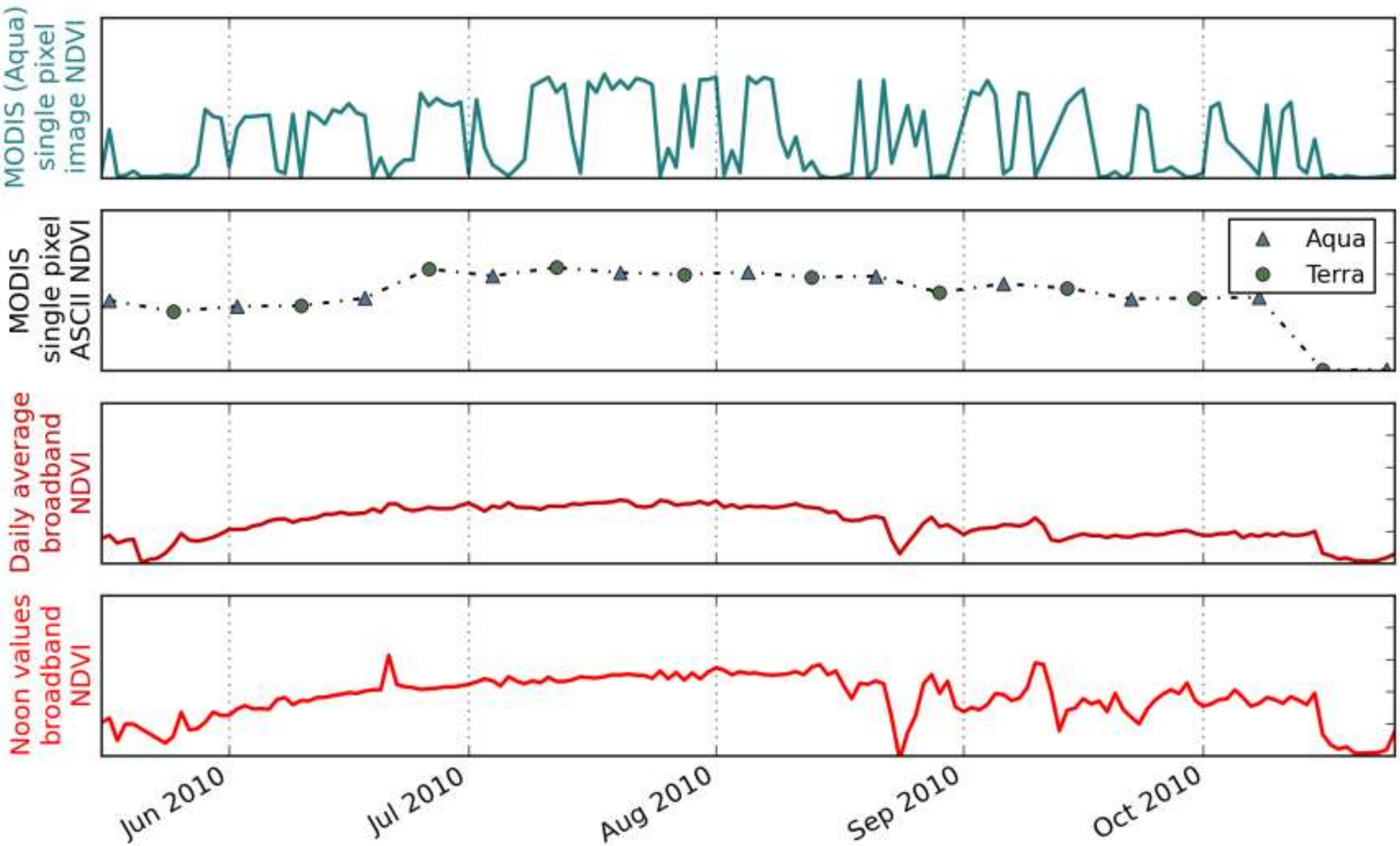
NEE (Fc_wpl)
0.5
0.0
−0.5
−1.0
−1.5
APAR aproximation
2000
1500
1000
500
0
−500
NEE (Fc_wpl) daily aggregate
4000000
2000000
0
−2000000
−4000000
−6000000
−8000000
R^2 =0.600295
1e9
APAR aproximation daily aggregate
8
7
6
5
4
3
2
1
0
−1
May 2010
Jun 2010
Jul 2010
Aug 2010
Sep 2010



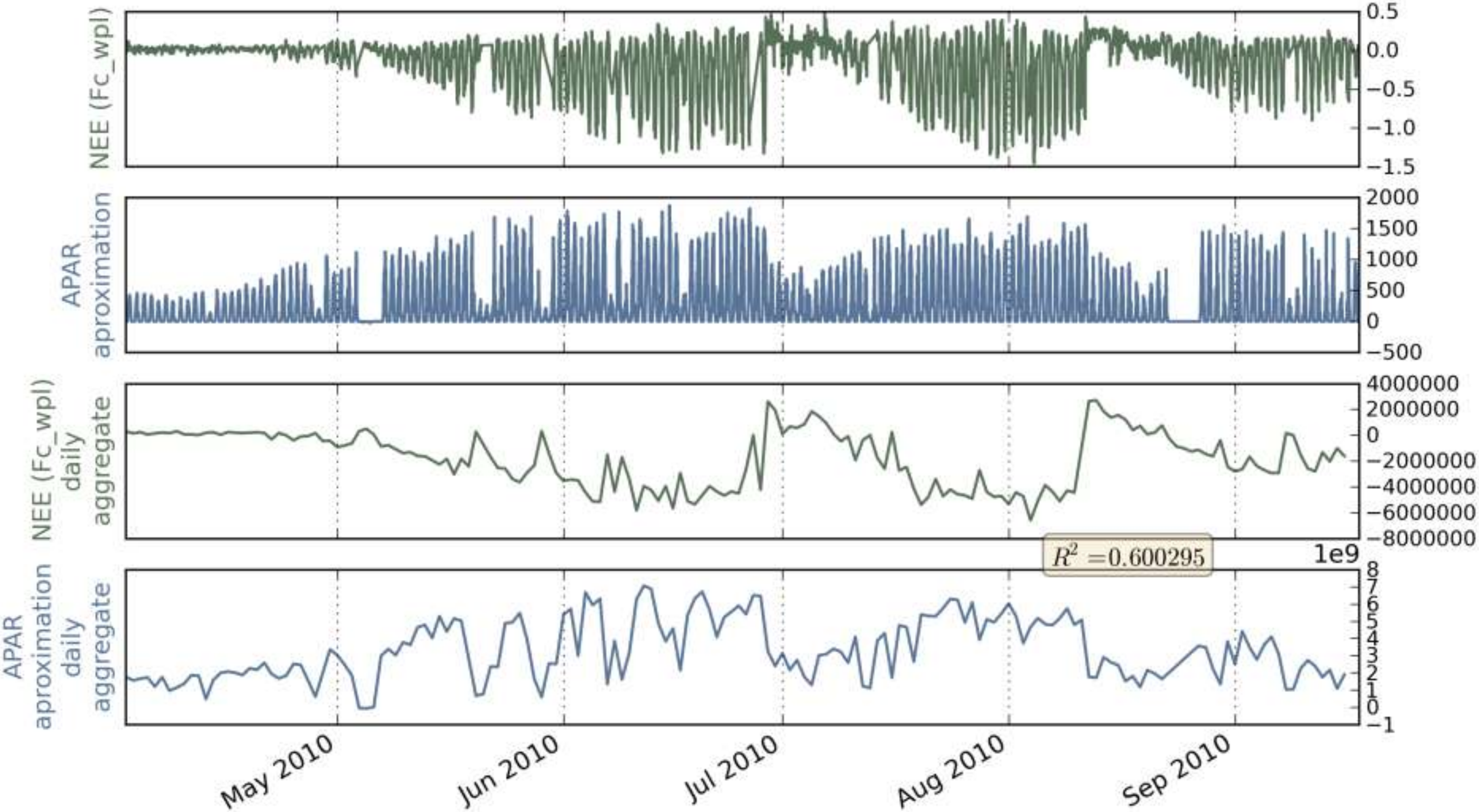
raw NDVI
corrected raw NDVI
10-14h corrected raw NDVI
high PAR 10-14h corrected raw NDVI
daily average high PAR 10-14h corrected raw NDVI
Apr 2010
May 2010
Jun 2010
Jul 2010
Aug 2010
Sep 2010



NEE (Fc_wpl)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
NEE (Fc_wpl filtered)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
May 2010
Jun 2010
Jul 2010
Aug 2010
Sep 2010



MODIS (Aqua) single pixel image NDVI
MODIS single pixel ASCII NDVI
Aqua
Terra
Daily average broadband NDVI
Noon values broadband NDVI
1.0
0.8
0.6
0.4
0.2
0.0
Jun 2010
Jul 2010
Aug 2010
Sep 2010
Oct 2010



NEE (Fc_wpl)
0.5
0.0
−0.5
−1.0
−1.5
APAR aproximation
2000
1500
1000
500
0
−500
NEE (Fc_wpl) daily aggregate
4000000
2000000
0
−2000000
−4000000
−6000000
−8000000
R^2 =0.600295
APAR aproximation daily aggregate
1e9
8
7
6
5
4
3
2
1
0
−1
May 2010
Jun 2010
Jul 2010
Aug 2010
Sep 2010

GCI

the global carbon index

- Home
- Our Mission
- Our Data
- Field Sites
- Our Economics
- Contact Us
- Wiki
- Your Land's Value

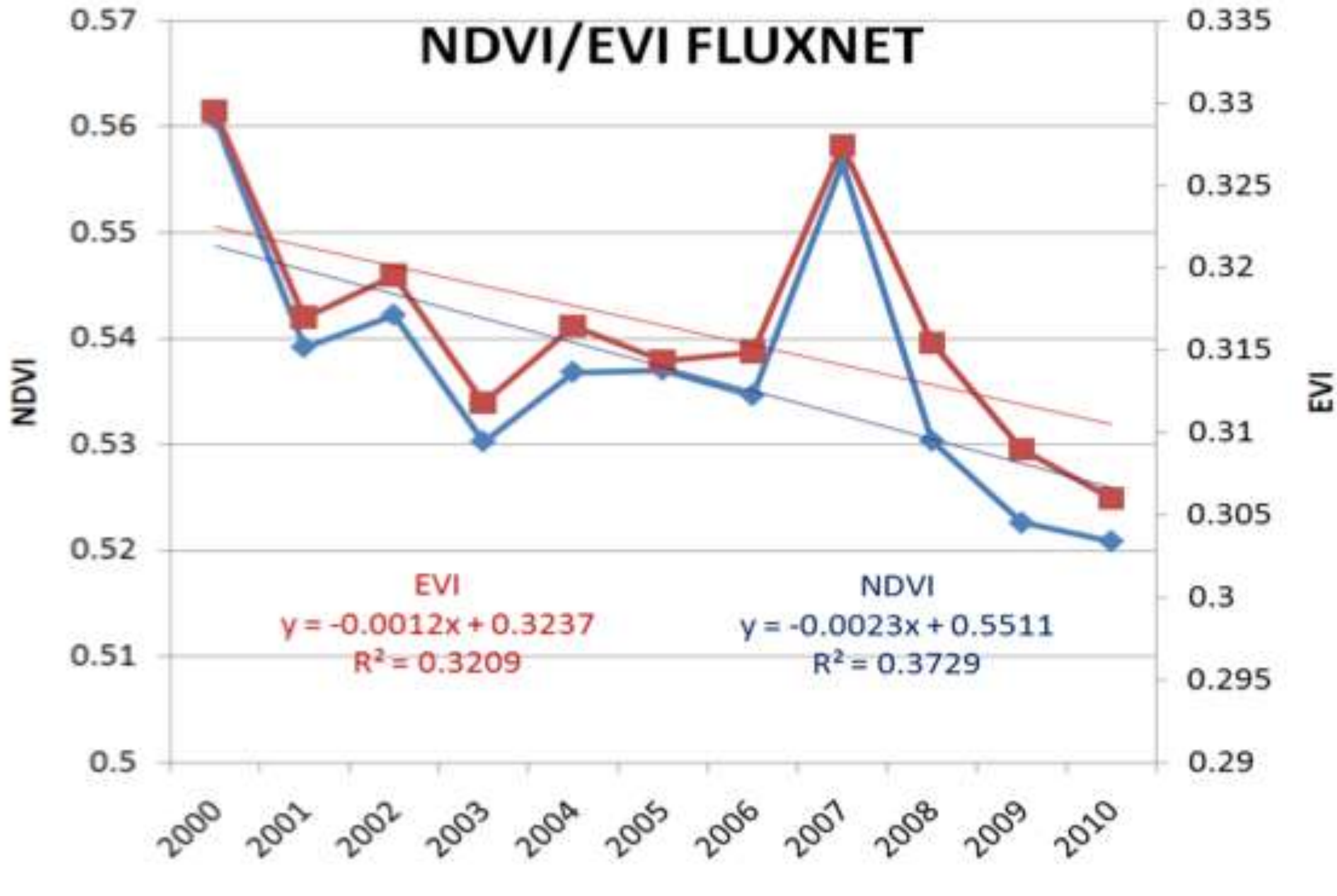
Data-Derived Global Vegetation Values

Placing a dollar value on biospheric carbon sequestration.

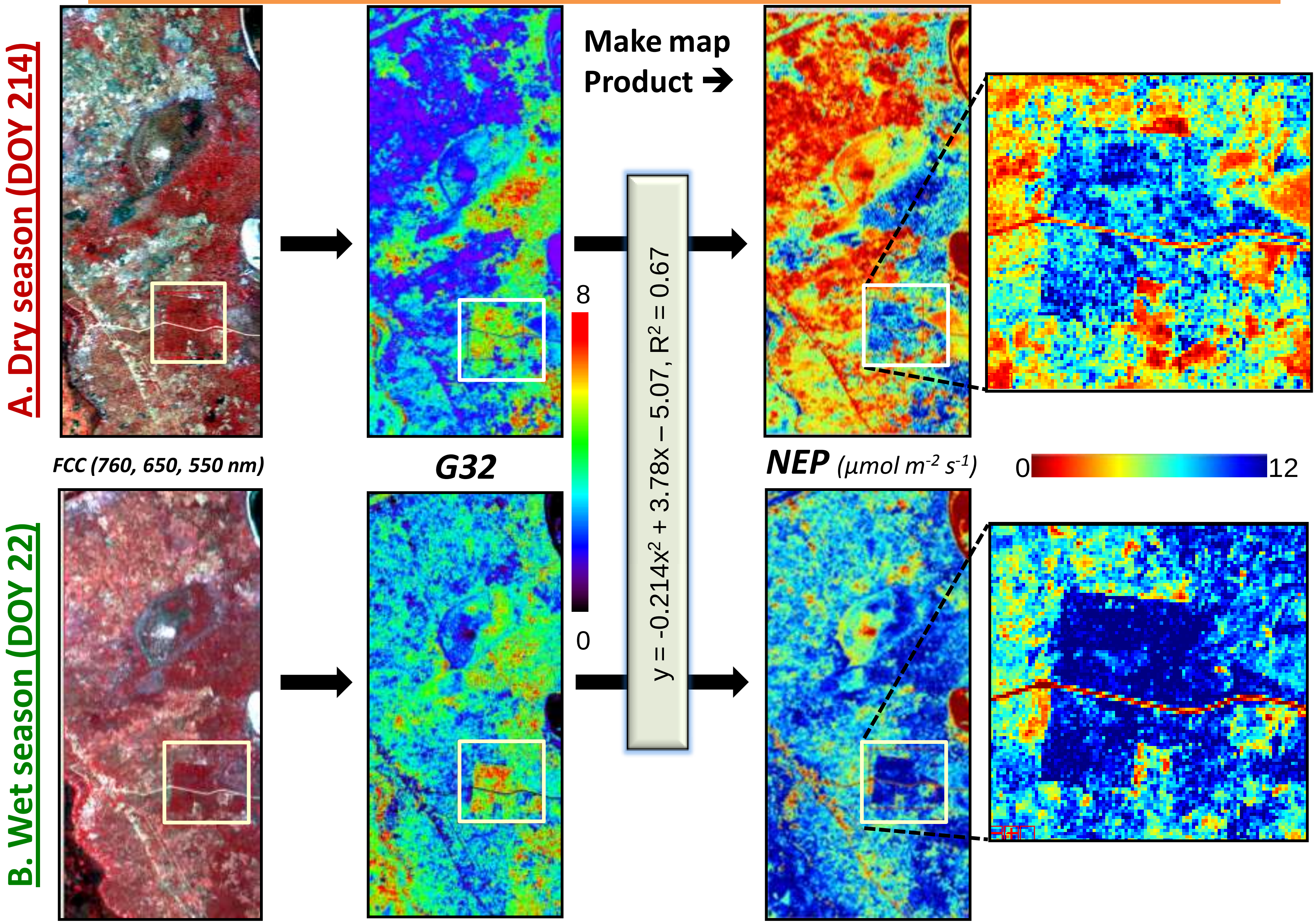
Go to first site

View field sites in tabular format

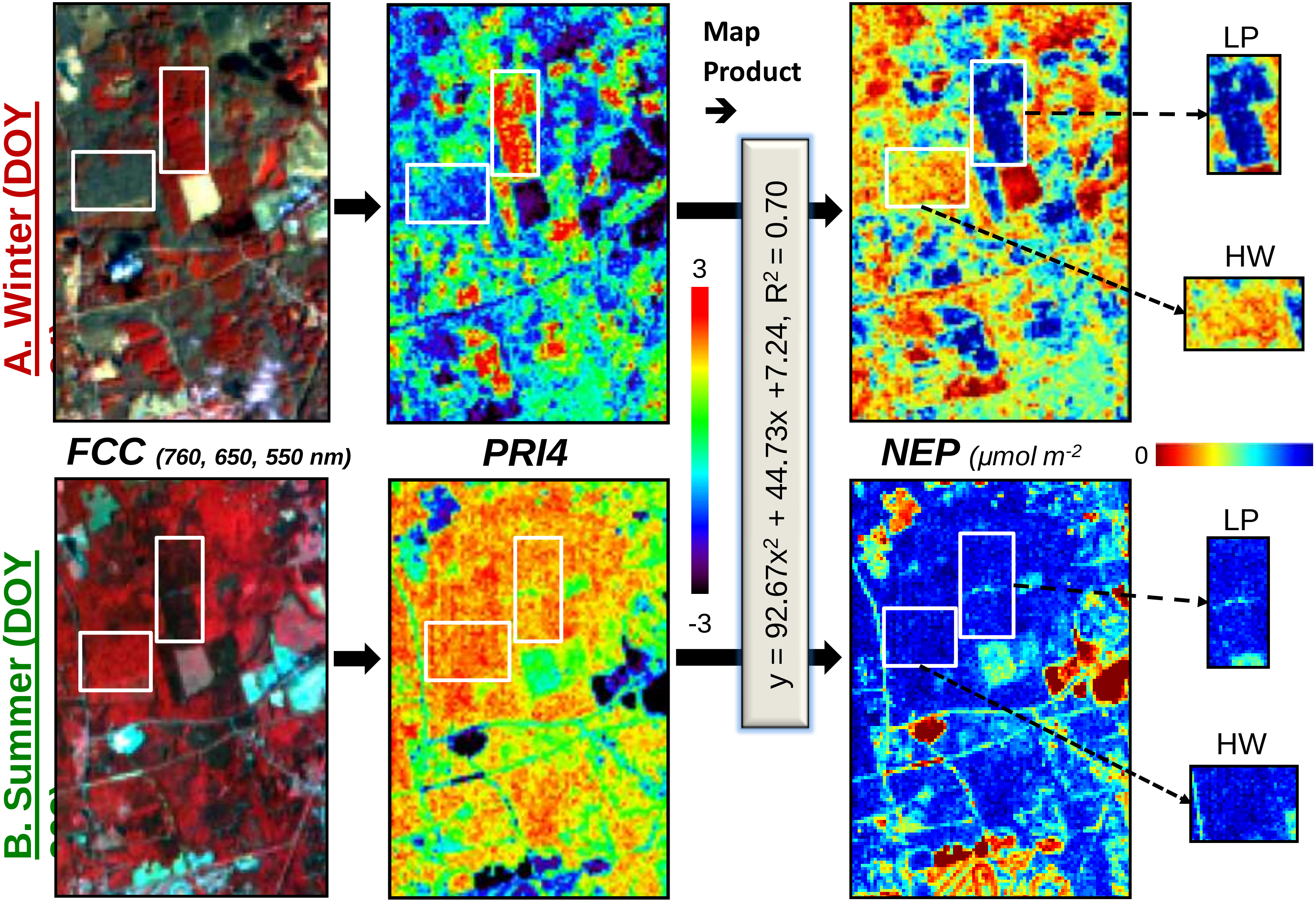
Zoom: 1d 5d 1m 3m 6m 1y Max
ValueA $ 201.70
ValueB $ 21.07
NDVI 0.61
| January 01, 2010
250
200
150
100
50
0
2002
2004
2006
2008
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009


NDVI/EVI FLUXNET
NDVI
EVI
0.57
0.56
0.55
0.54
0.53
0.52
0.51
0.5
0.335
0.33
0.325
0.32
0.315
0.31
0.305
0.3
0.295
0.29
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
EVI
y = -0.0012x + 0.3237
R² = 0.3209
NDVI
y = -0.0023x + 0.5511
R² = 0.3729

Mongu: Seasonal change in G32 & *NEP*



Duke Forest : PRI4 *& NEP*



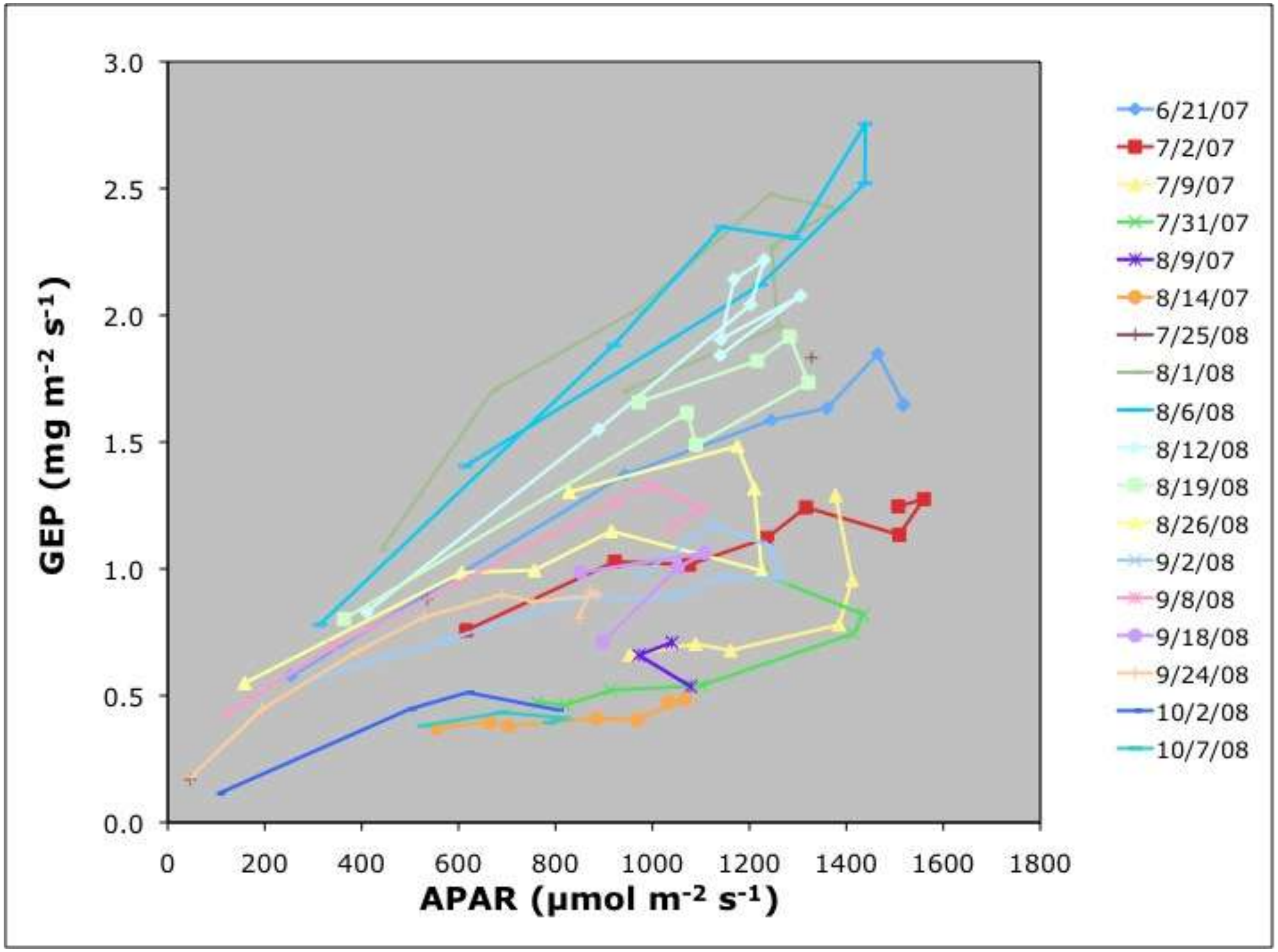


Figure 2. GEP from cornfield flux tower vs. APAR based on NDVI using values collected throughout daylight periods of multiple days in the 2007 and 2008 growing season. Lines connect points from the same observation day. It does not account for varying LUE.

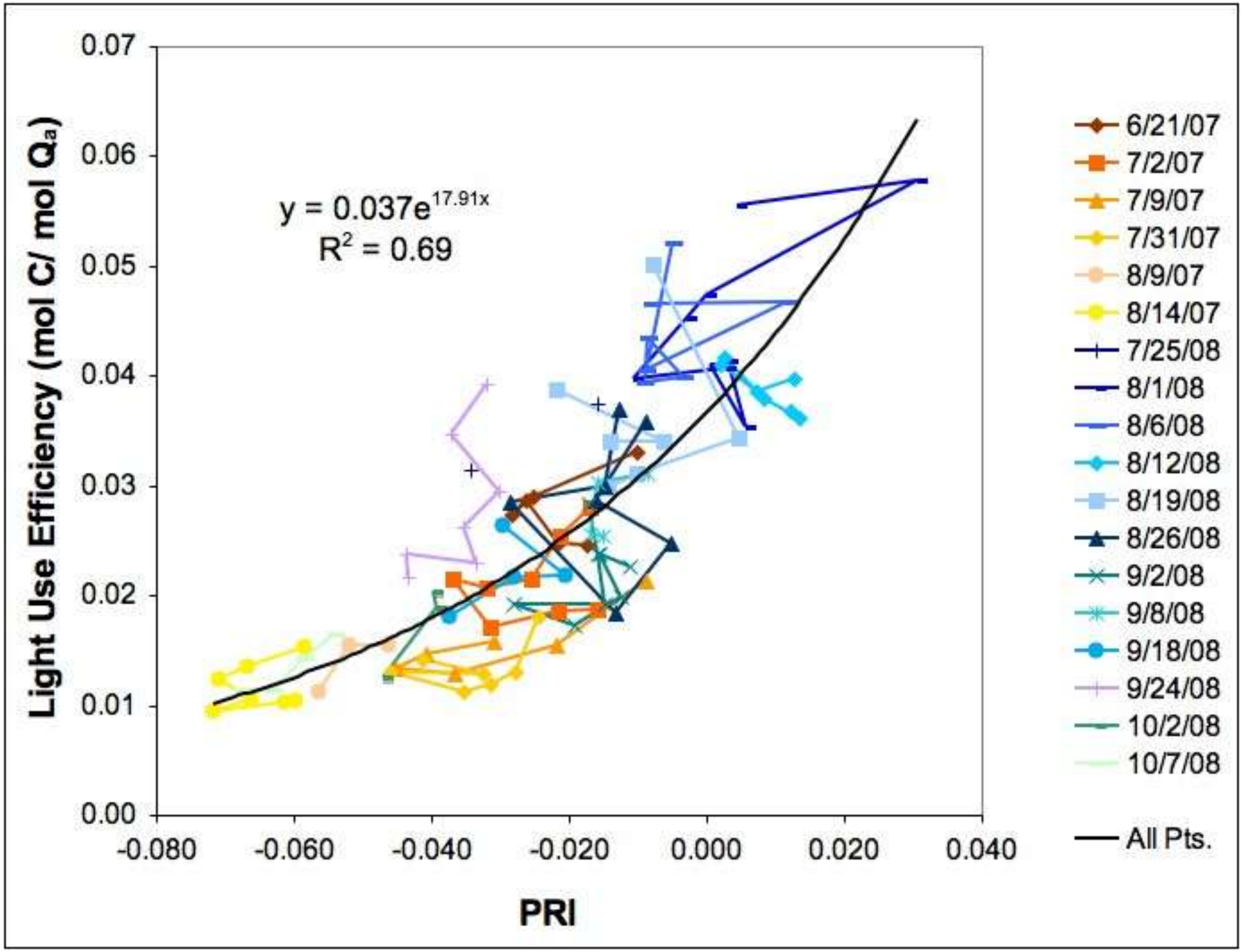


Figure 1. LUE from cornfield flux tower versus PRI from field spectrometer data collected along a 100 m transect, using values collected throughout daylight periods of multiple days in the 2007 and 2008 growing seasons. Lines connect points from the same observation day.

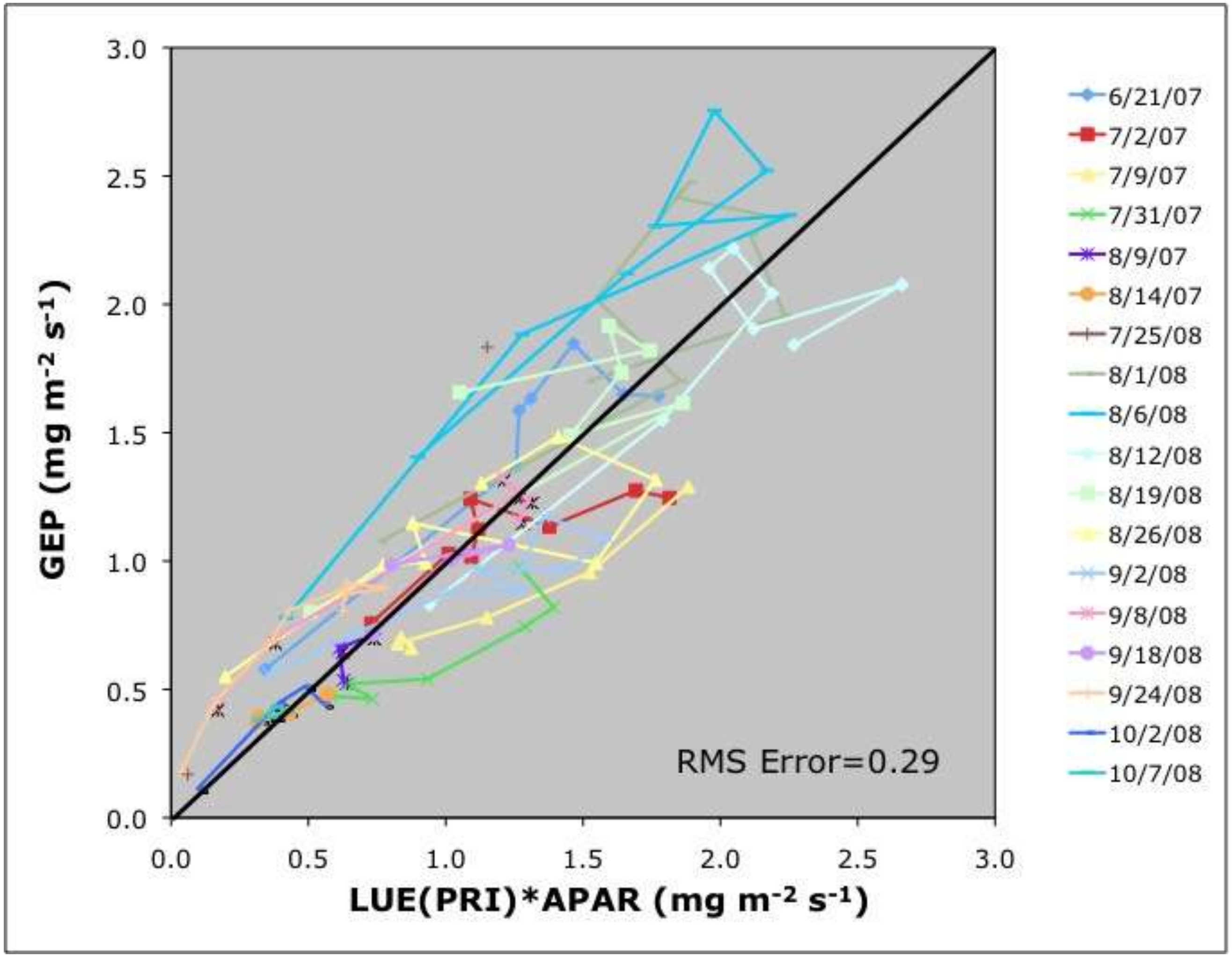
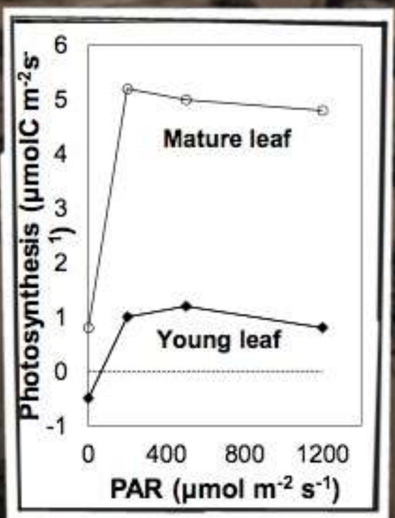


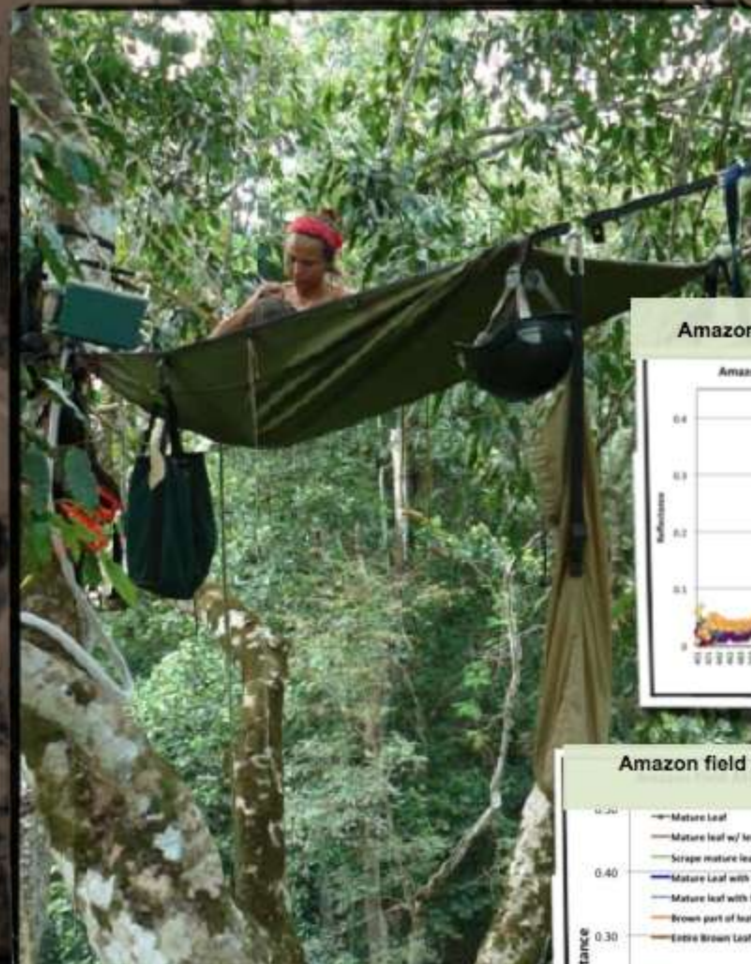
Figure 3. GEP from flux tower vs. modeled GEP from optical sensors with dynamic estimate of light use efficiency based on PRI (shown in Figure 1).

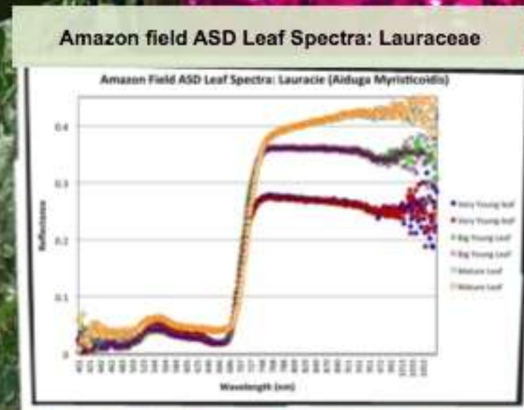
Cross-ecosystem analyses –
Environmental constraints on productivity
Structural differences
Sun angle differences with season and latitude
Functional differences

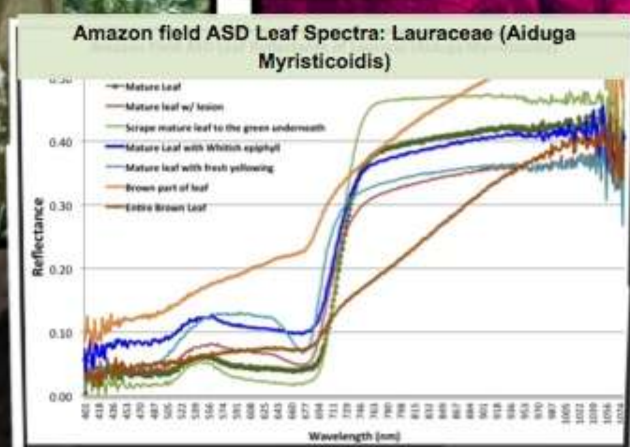
Spectral sampling in the Amazon (from within)

Leaf-, Canopy- Scale Phenology, Photosynthesis, and Optical Variations







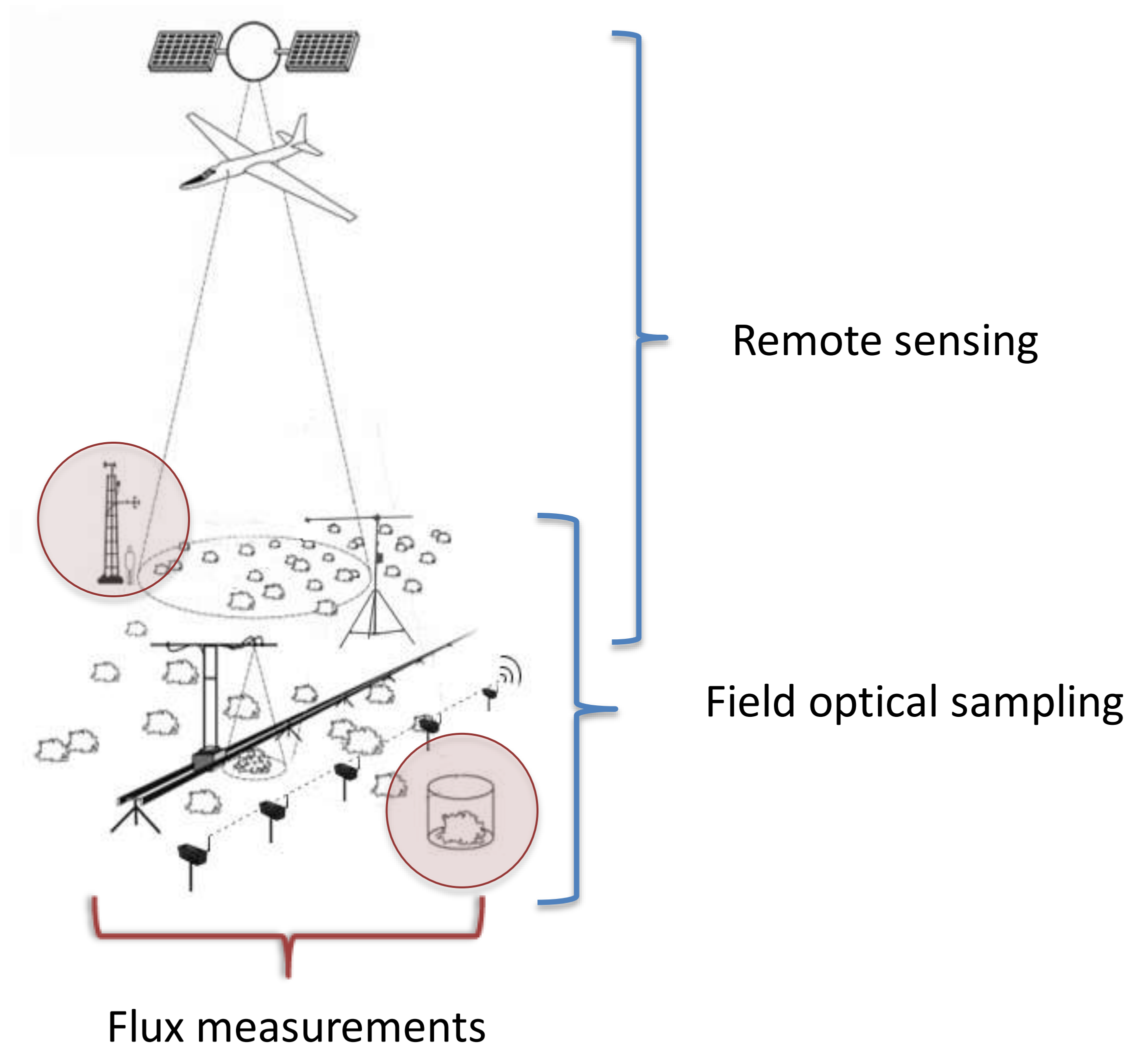


"Scaling photosynthesis in Amazonian ecosystems: from forest to savanna, from seasons to extreme events"
Huete, Dye, Saleska, et al..

Arctic sites –
Phenology
Different slopes
Cross-site analysis

Alternative indices

Scaling…


Remote sensing
Field optical sampling
Flux measurements

Outline

- SpecNet defined
- History & Current status
- Why integrate optical sampling with flux measurements?
- SpecNet Tour (sites, methods, issues, results)
- Future directions