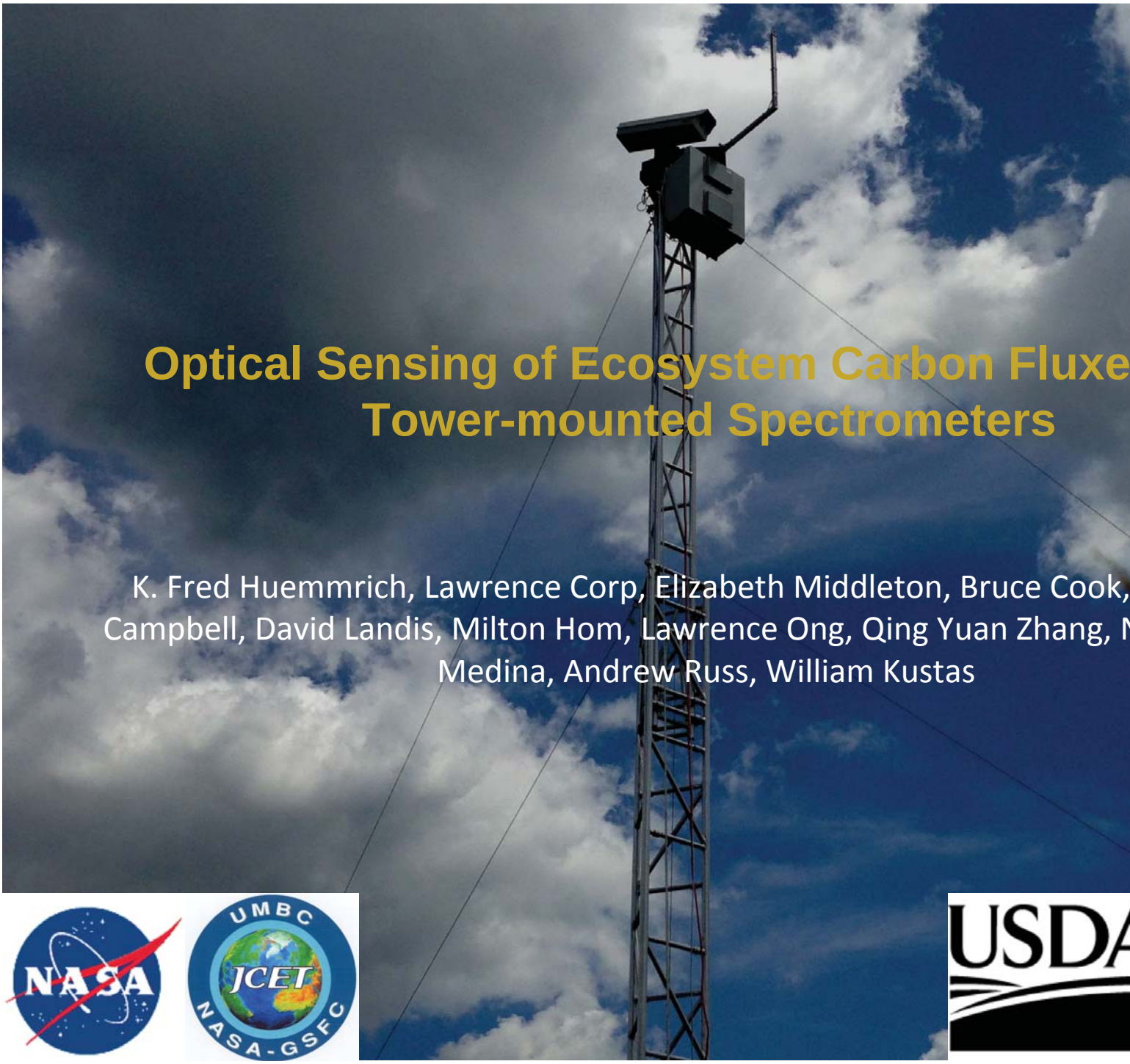


Optical Sensing of Ecosystem Carbon Fluxe
Tower-mounted Spectrometers

K. Fred Huemmrich, Lawrence Corp, Elizabeth Middleton, Bruce Cook,
Campbell, David Landis, Milton Hom, Lawrence Ong, Qing Yuan Zhang, N
Medina, Andrew Russ, William Kustas

FUSION Goals

FUSION is an automated tower-mounted in
package to provide optical measurements c
vegetation

- Sense hyperspectral reflectance and fluorescence
- Describe diurnal and seasonal dynam
- Describe bidirectional reflectance/emi
- Provide measurements that could sca satellite observations
- Make measurements with spatial and resolution that can be linked to carbor fluxes measured by flux towers

FUSION 1 Instrumentatio

An automated sensor system collecting
observations of incoming and reflected radi

- A pan-tilt unit points fiber optics of the dow
sensors
- Cosine corrected hemispheric viewing fo
viewing sensors

Instruments are housed in an insulate
thermoelectric temperature control for instru

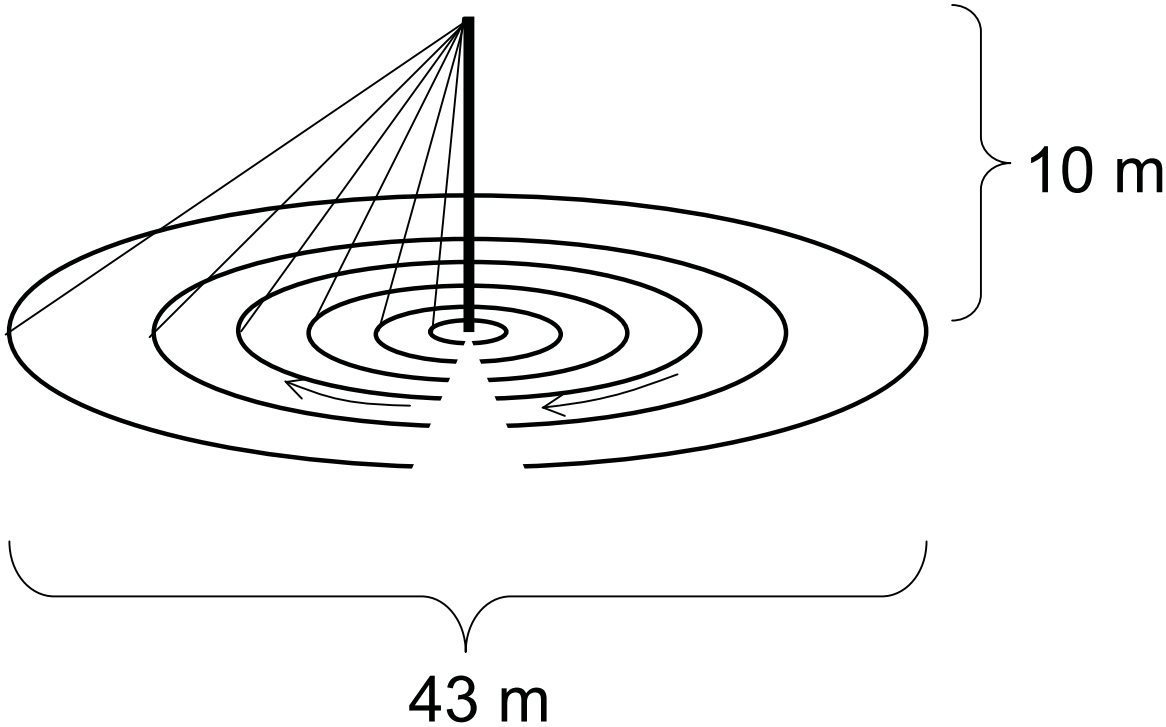
Instruments:

1) upward and downward viewing Ocean Op
Spectrometers (345-1040 nm with resolut
FWHM);
2) upward and downward viewing Ocean O
Spectrometers (650- 840 nm at a resoluti
FWHM sampled at 0.06 nm);
3) CFmicro SF15 infrared sensor (8 to 14 μm

FUSION Operations

FUSION is mounted atop a 10 m tall tower i

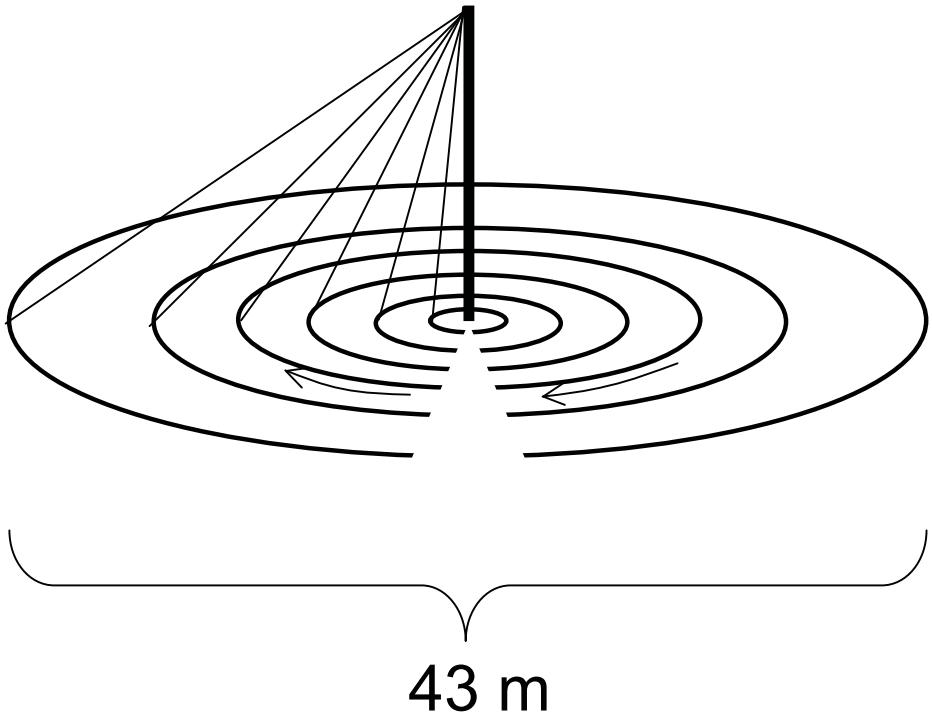
- Makes 350° azimuth angle scans
- At six zenith angles (15°,25°,35°,45°,5
- Takes about 25 minutes for a full set

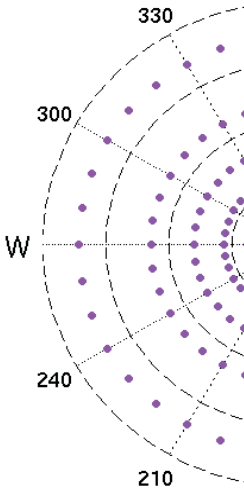


FUSION Operations

FUSION is mounted atop a 10 m tall tower i

- Makes 350° azimuth angle scans
- At six zenith angles (15°,25°,35°,45°,5
- Takes about 25 minutes for a full set





Locatio
cent

FUSION and Satellite Cal/V

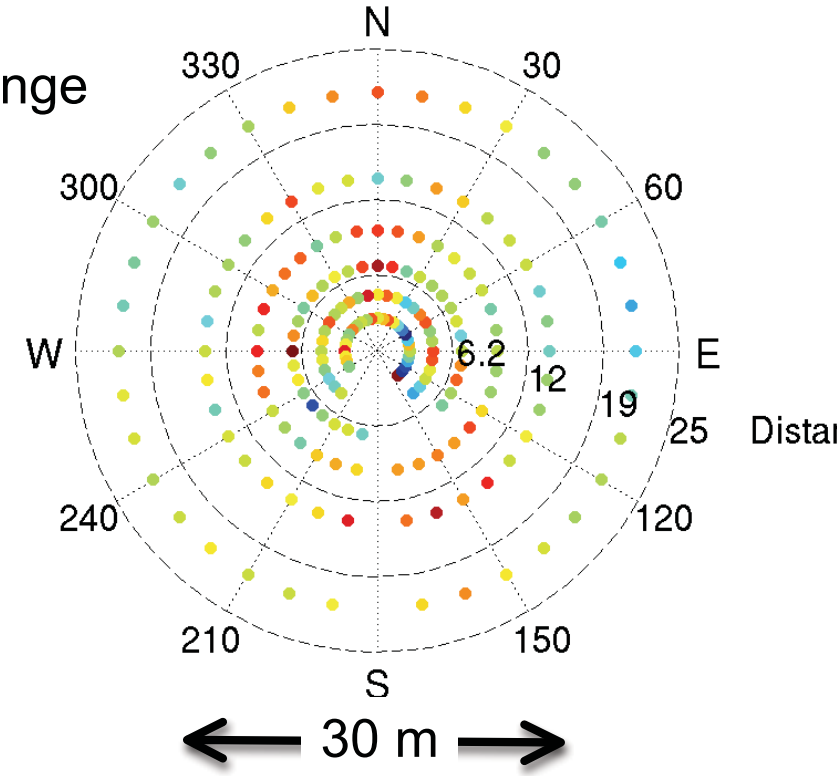
FUSION collects a large number of samples within an area
satellite pixels

Provides a description of bidirectional reflectance patterns f
to interpret view angle effects

Spectral data can be convolved to any satellite band

Continuously collect measurements to examine effects of di
overpass times

Describes seasonal change



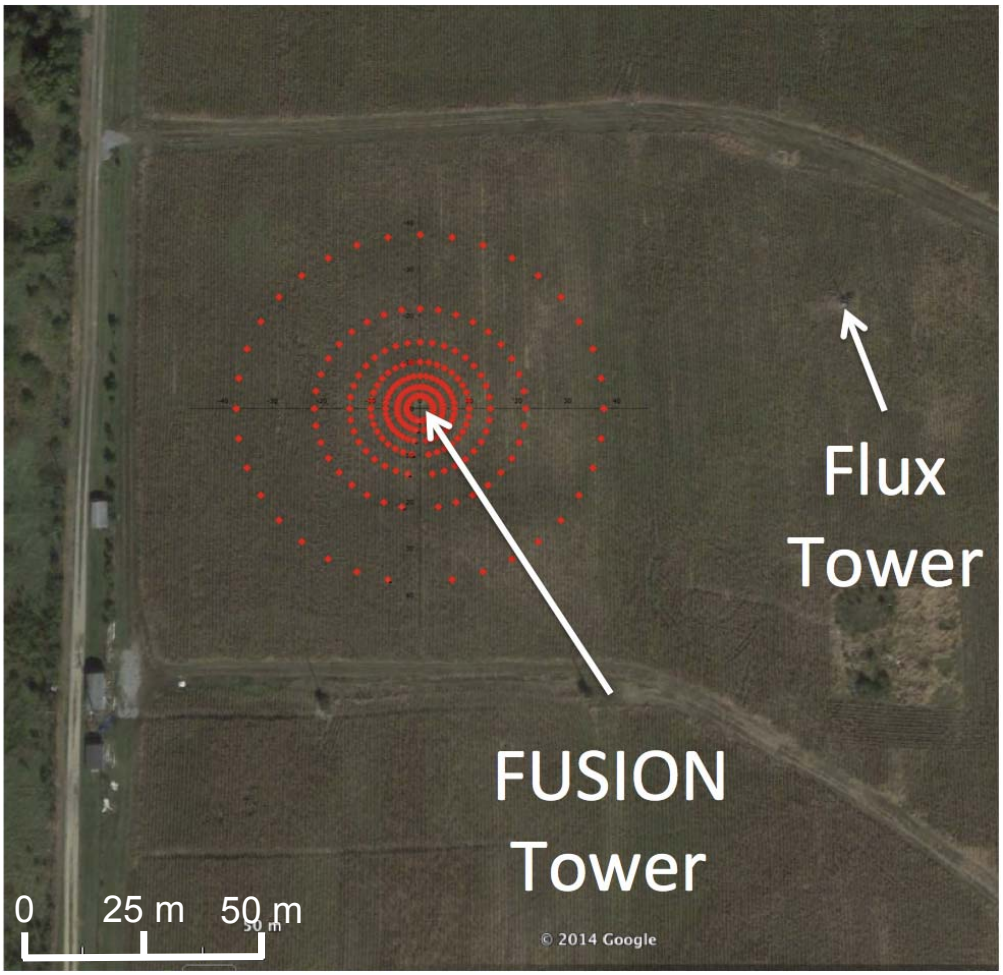
From Neu

FUSION Operations

An important challenge is deciding on the tr
the measurement strategy
Collect full set of measurements as quickly
- Avoid cloud contamination in BRDF de
- Capture short-term transients if possibl
- Match with flux tower data

Balanced against
- Number of different view angles observ
(more angles are better)
- Observation integration time
(longer times provide better signa

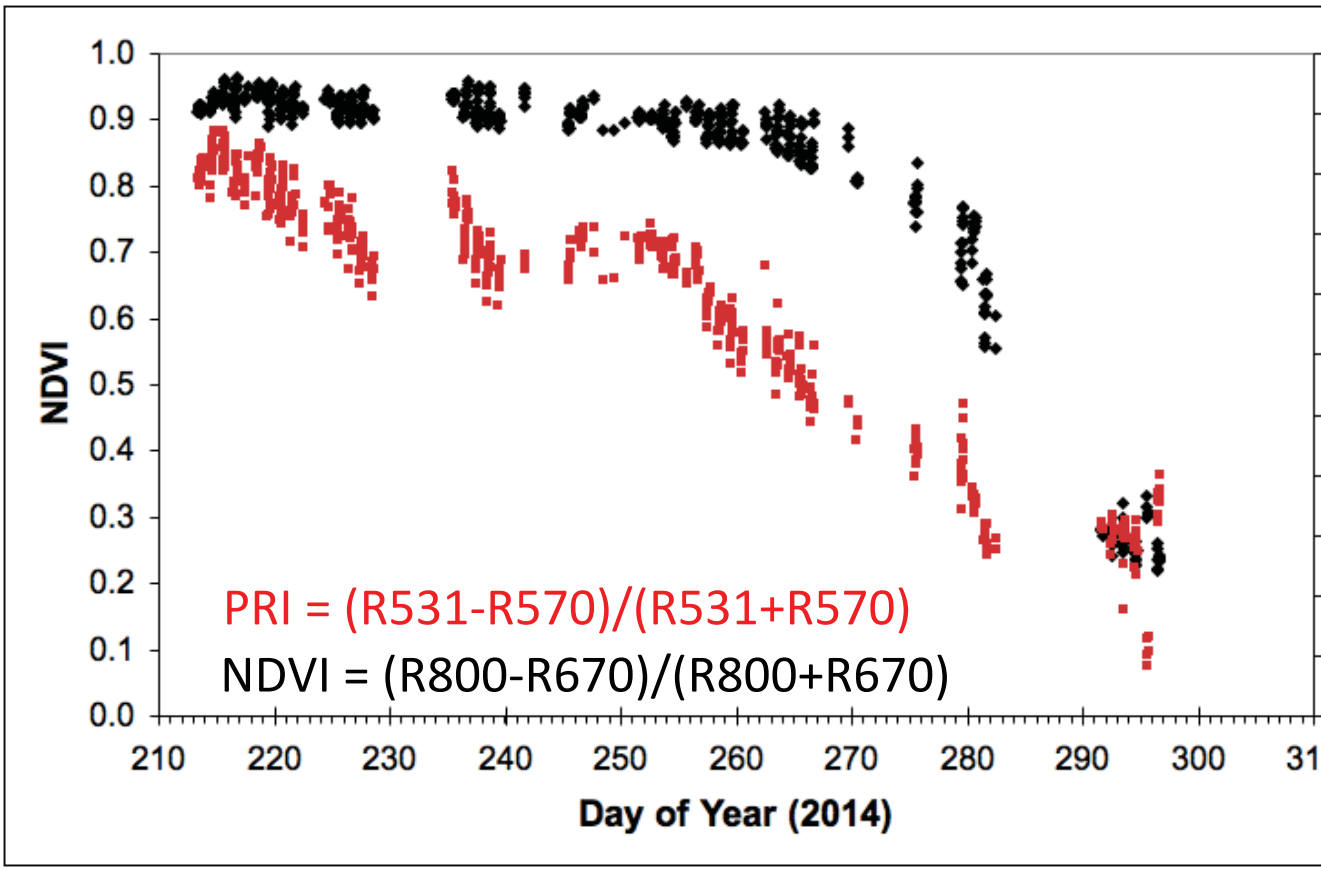
Combining Optical and Flux Data



Flux tower ~105 m from FUSION tower

Seasonal/Diurnal Observati

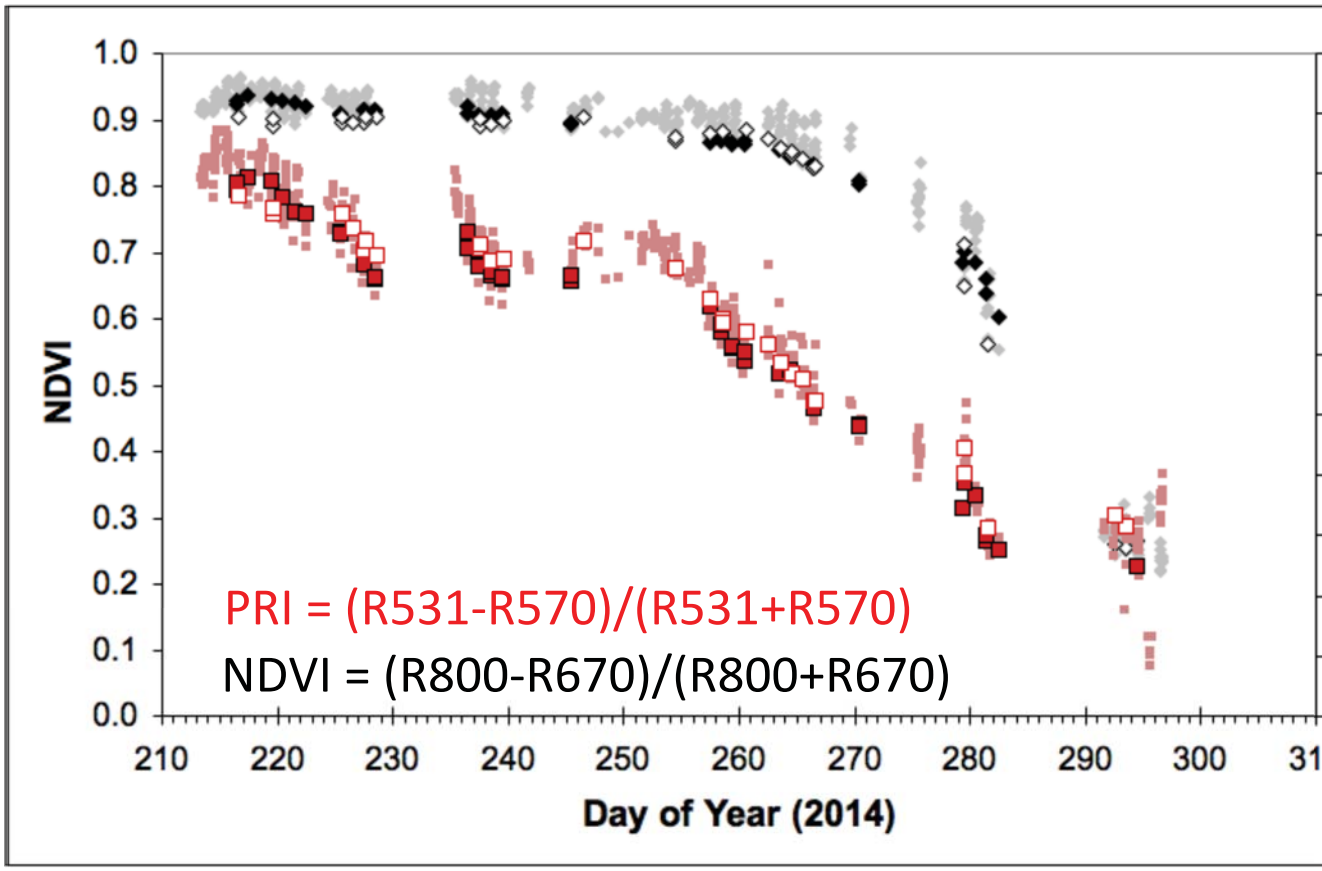
Simultaneous measurements of incident and refl
radiance allow data collections under cloudy con



Single view angle: 25° VZA, 330° VAZ

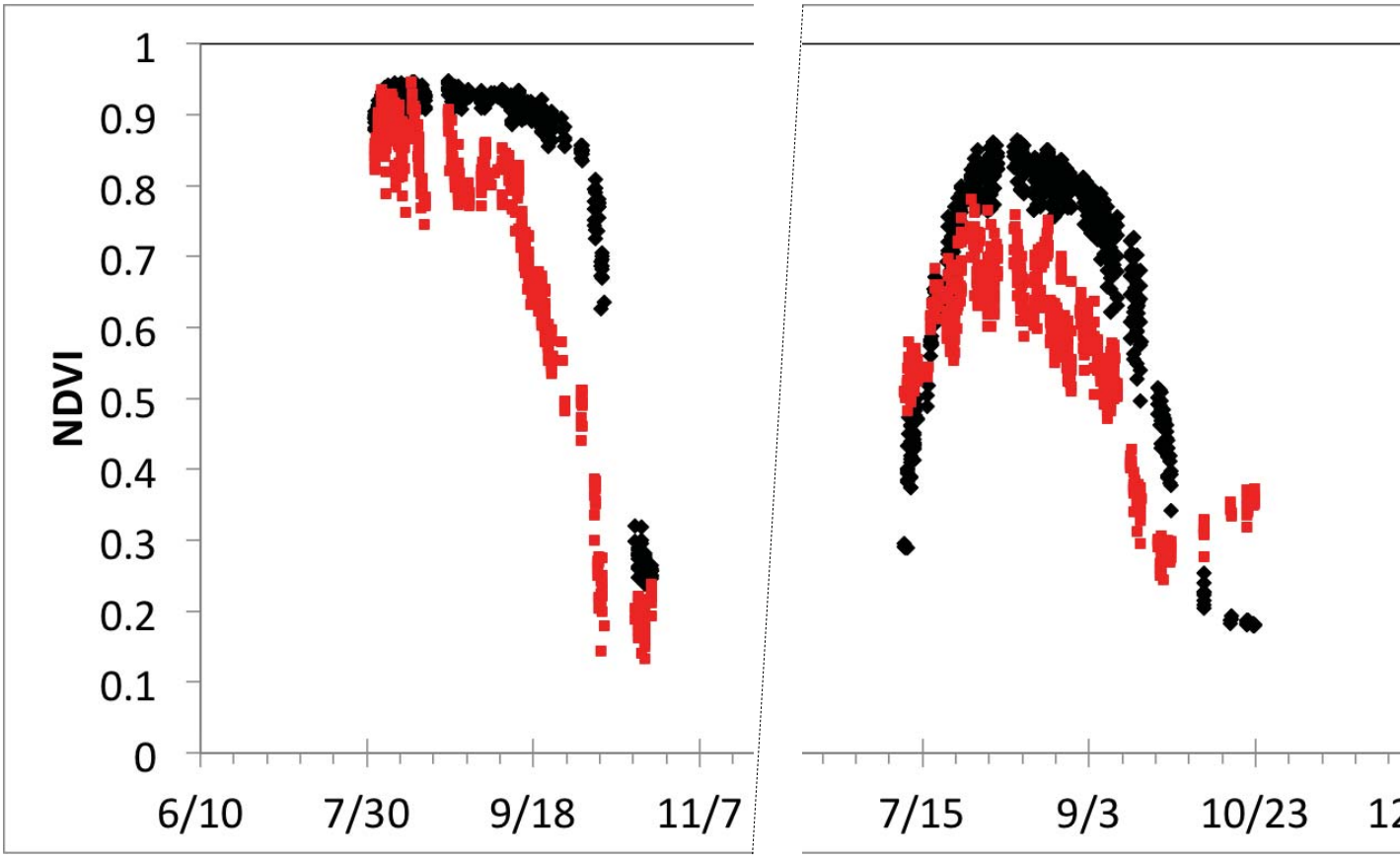
Seasonal/Diurnal Observati

Solid points - clear sky observations near AM overpass
Open points - clear sky observations near PM overpass



Single view angle: 25° VZA, 330° VAZ

Seasonal/Diurnal Observati



2014 2015

PRI = (R531-R570)/(R531+R570)

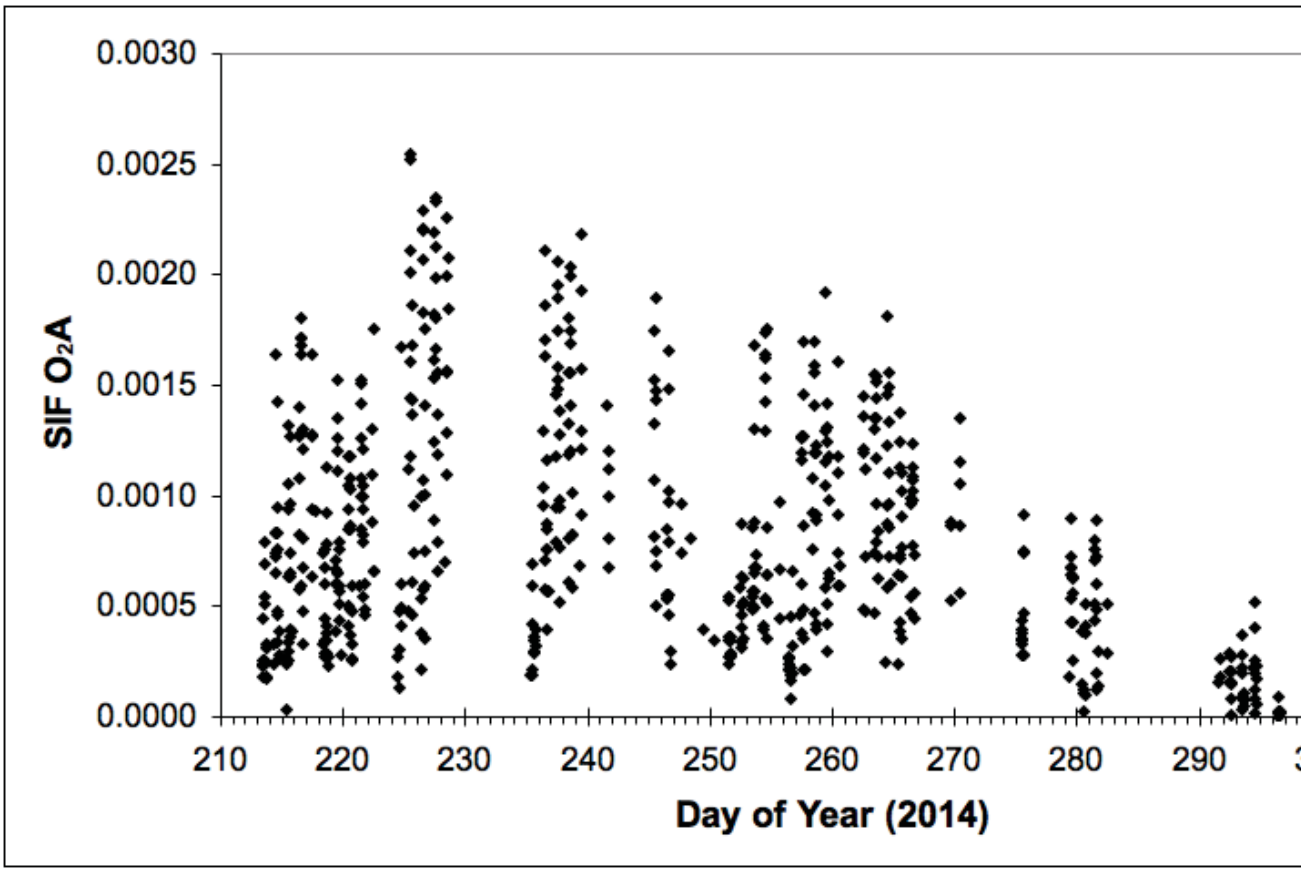
NDVI = (R800-R670)/(R800+R670)

Single view angle: 25° VZA, 330° VAZ

Seasonal/Diurnal Observati

Solar Induced Fluorescence at O_2A (760 nm) from 3FLD al

All observations

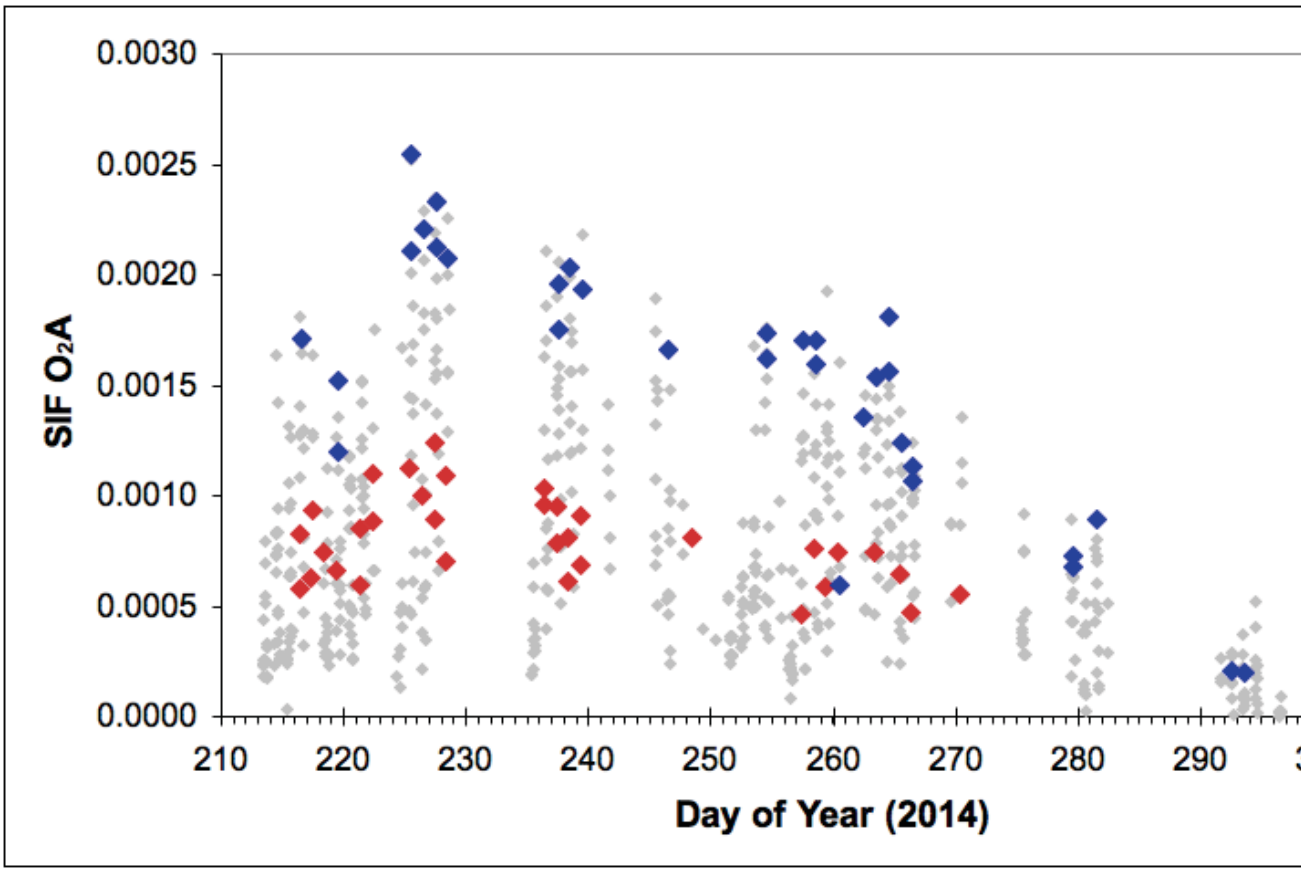


Single view angle: 25° VZA, 330° VAZ

Seasonal/Diurnal Observati

Solar Induced Fluorescence at O_2A (760 nm) from 3FLD al

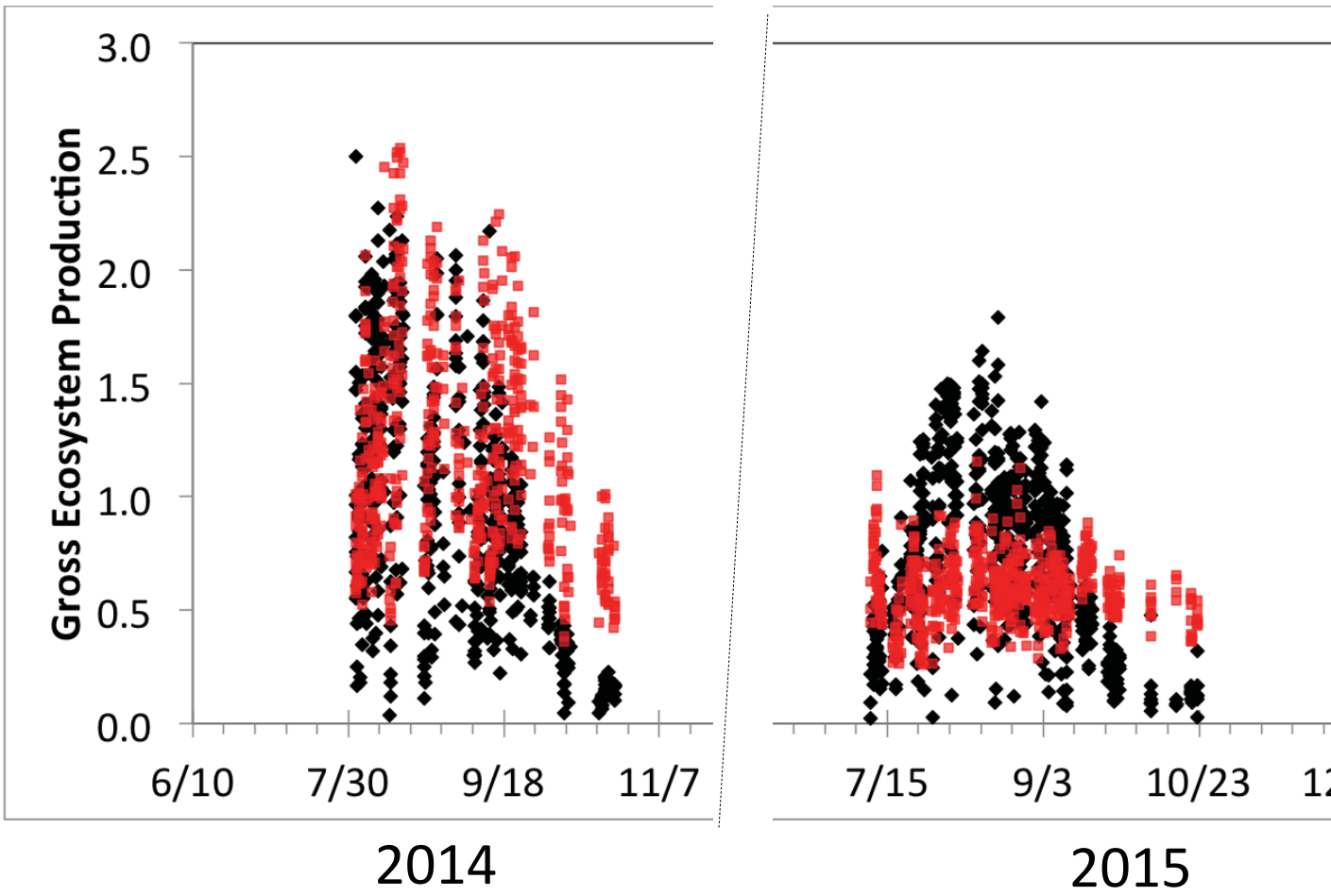
Red points - clear sky observations near GOME-2 overpass
Blue points - clear sky observations near OCO-2 overpass



Single view angle: 25° VZA, 330° VAZ

Seasonal/Diurnal Observati

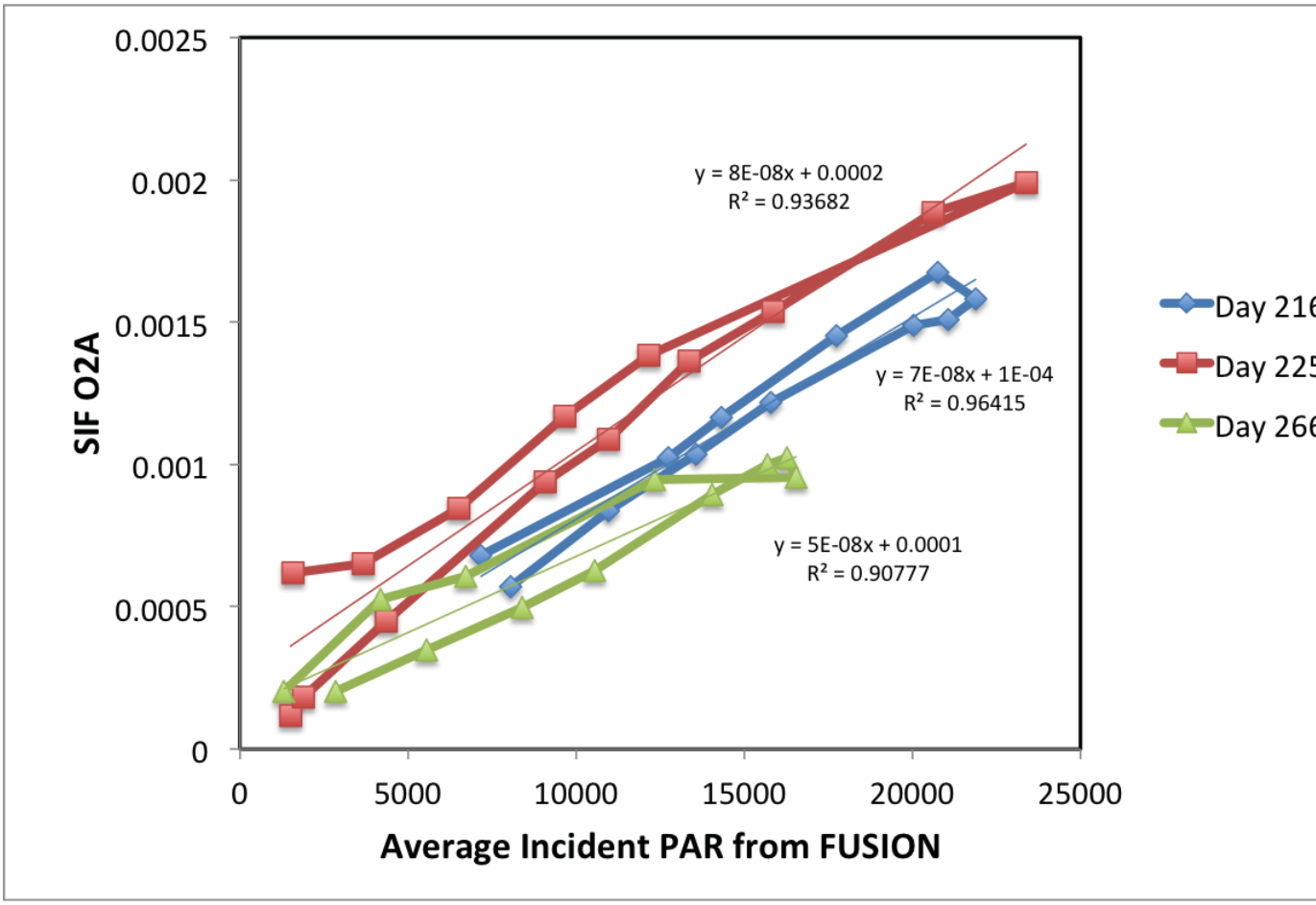
Solar Induced Fluorescence at O_2A (760 nm) from 3FLD al



Single view angle: 25° VZA, 330° VAZ

Seasonal/Diurnal Observati

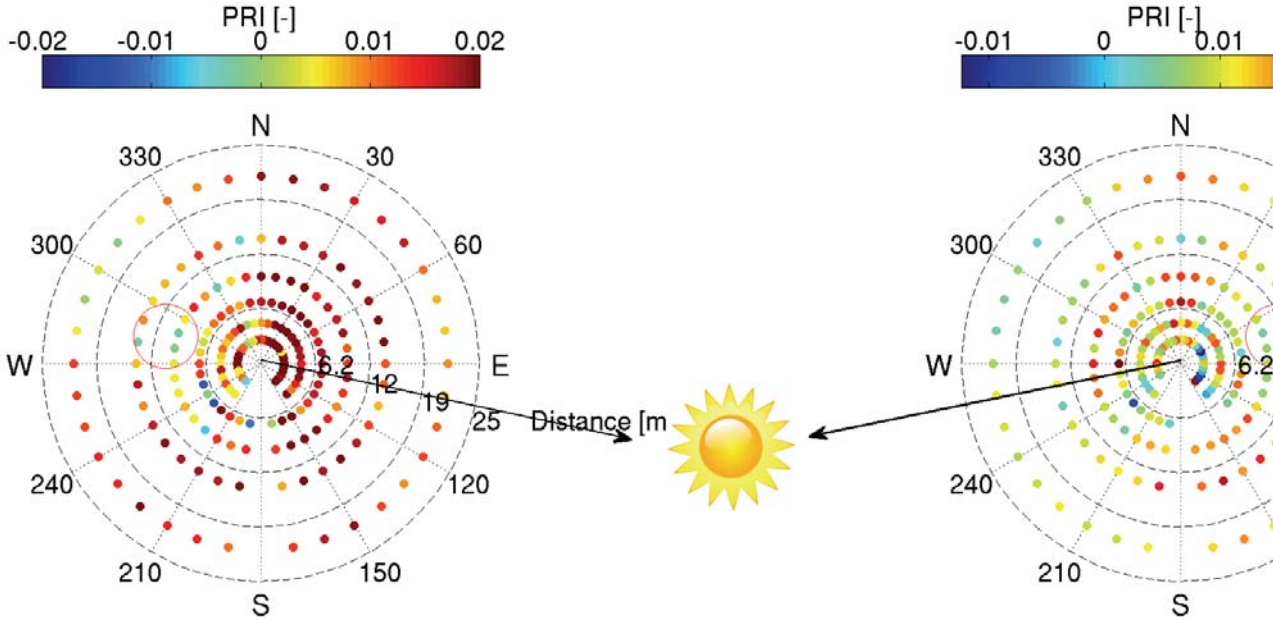
Variations in Fyield at different times in the growing se



3FLD O2A Average over all View Azimuths, VZA=35°

Bidirectional Observations -

Morning and afternoon bidirectional patterns of Photochemi
Reflectance Index (PRI = (R531-R570)/(R531+R570))
August 14, 2014, SZA ~ 50° at both times



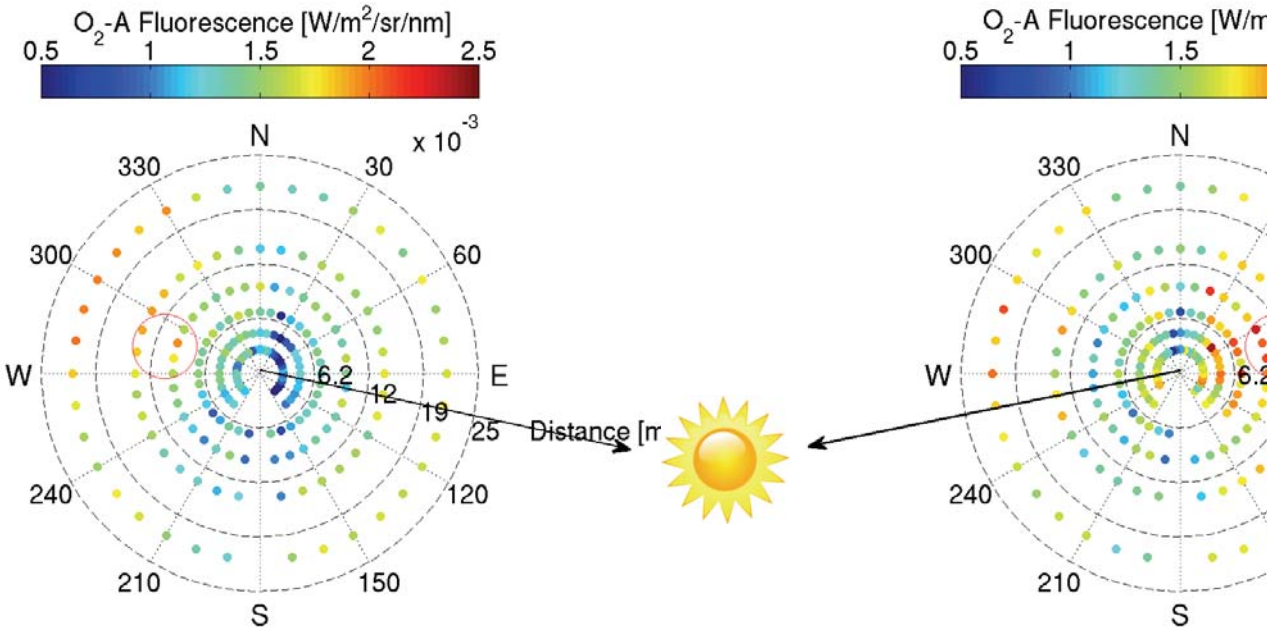
Morning
10:00 AM

Afternoon
4:30 PM

From Neu

Bidirectional Observations -

Morning and afternoon bidirectional patterns of Far-red Sola
Fluorescence (SIF) in the O_2A absorption band (760 nm)
August 14, 2014, SZA ~ 50° at both times



Morning
10:00 AM

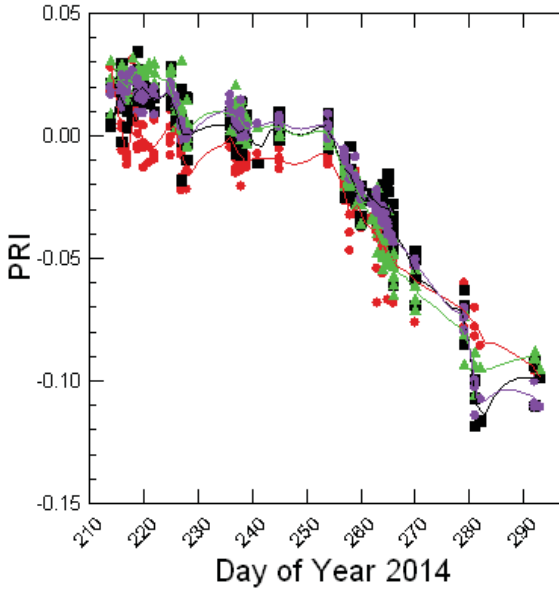
Afternoon
4:30 PM

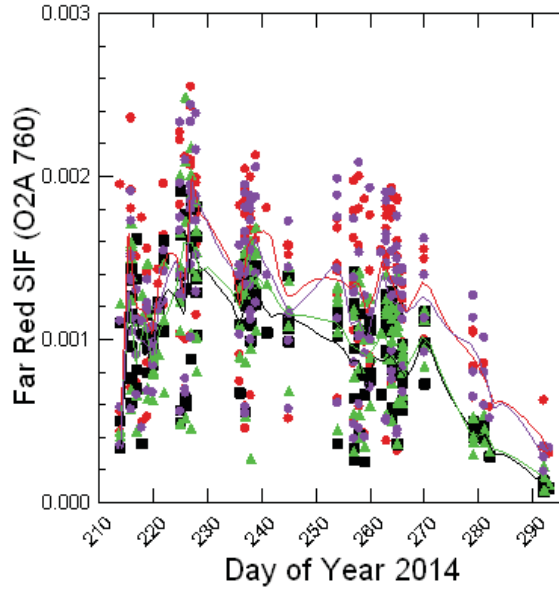
From Neu

Bidirectional/Seasonal Observat

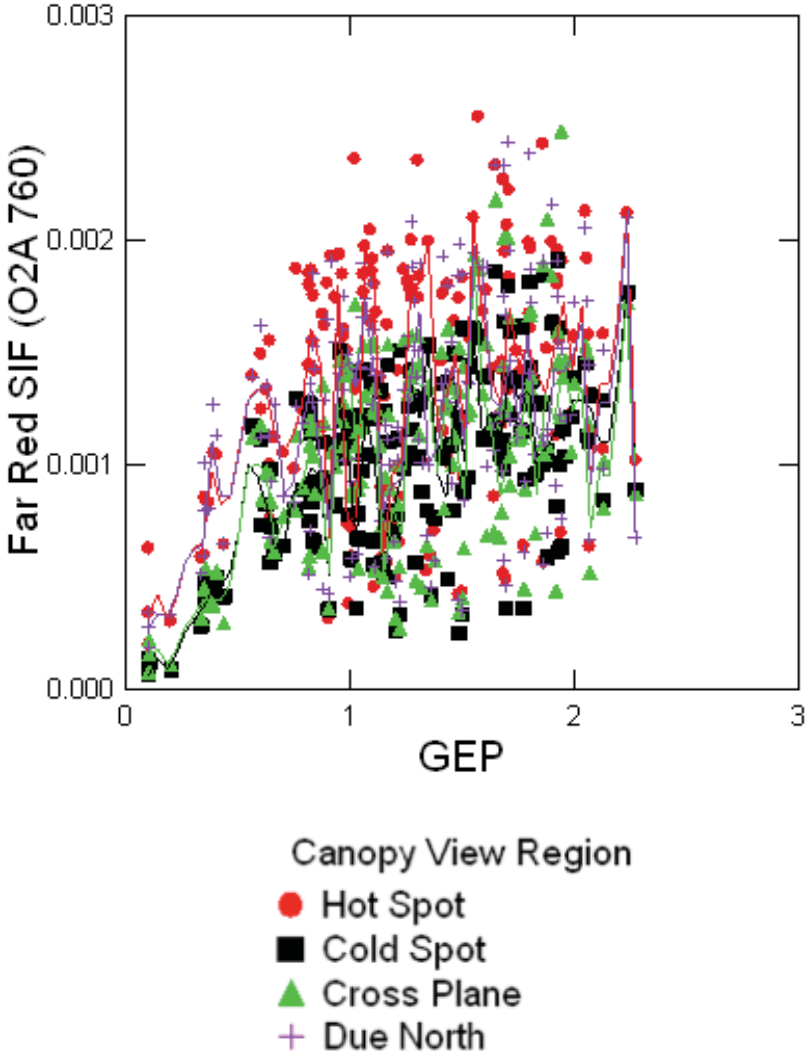
Diurnal/seasonal patterns of PRI and Far-Red SIF from four distinct viewing geometries:

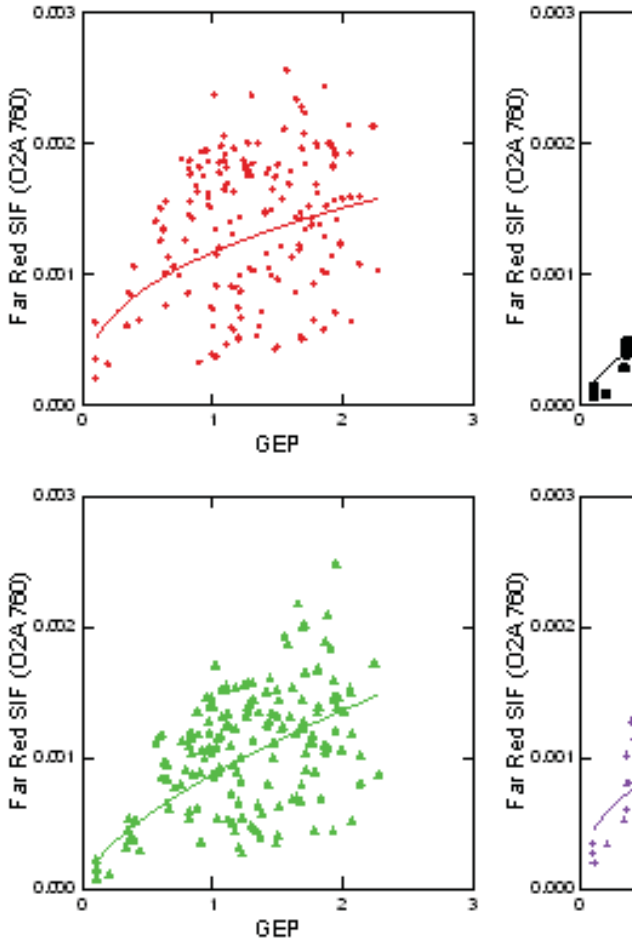
- in the direction of the hot spot (backscattering)
- in the direction of the cold spot (forward scattering)
- perpendicular to the solar principle plane (cross plane)
- in a fixed direction (due north)
- all with 45° view zenith angles
- all observations under clear conditions





GEP and Far-Red SIF

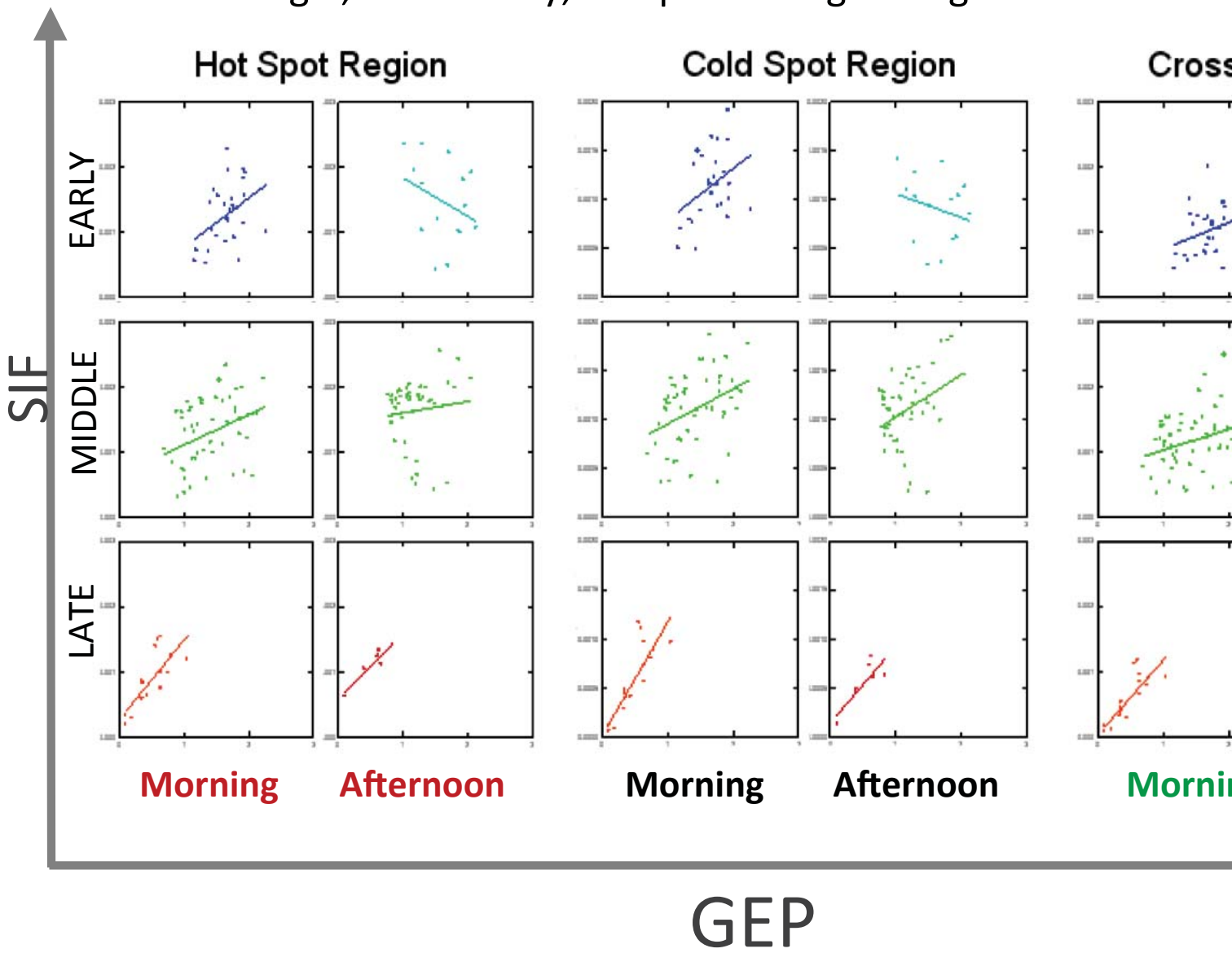




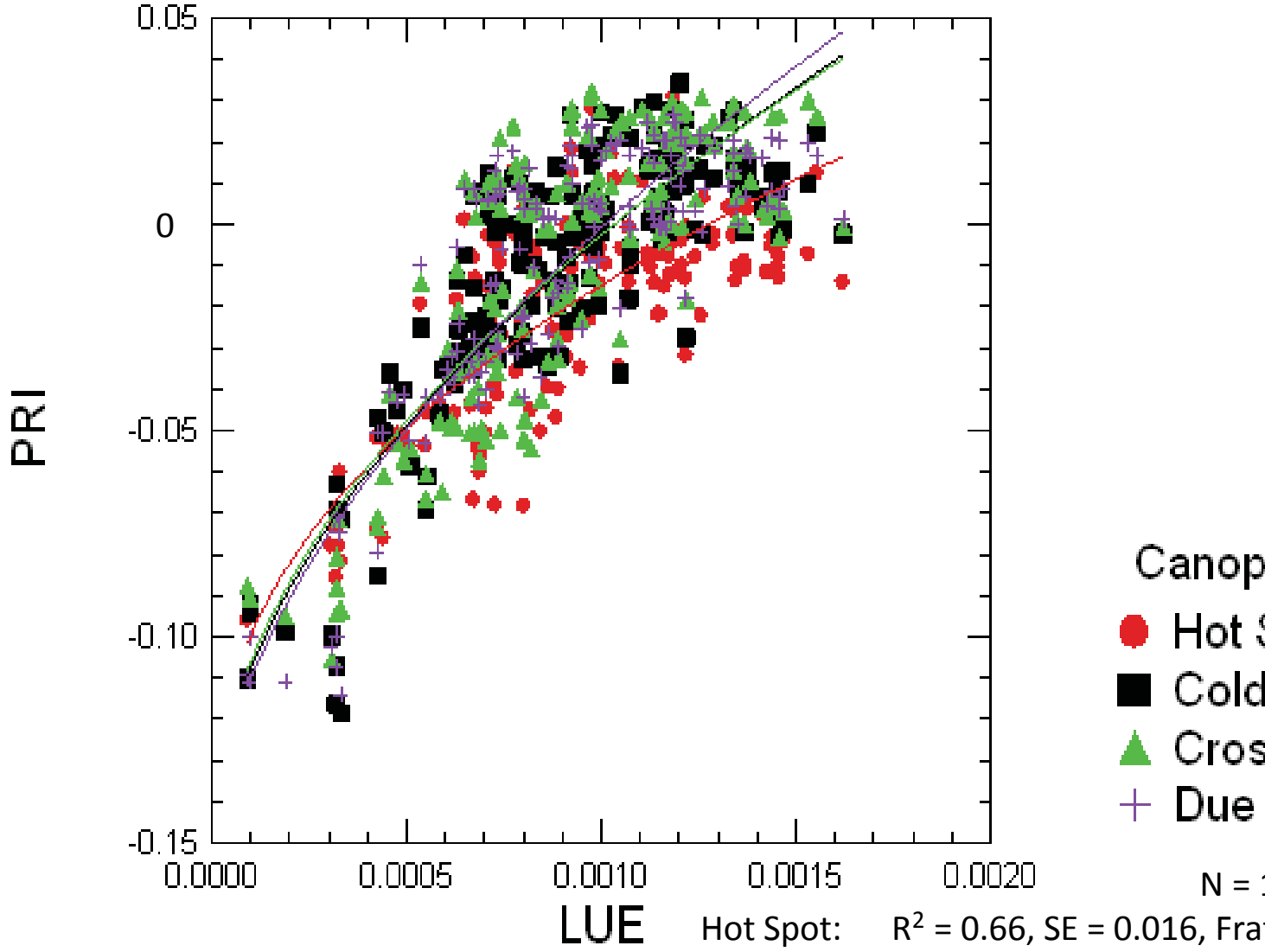
Clear observations from 2
Half-hourly GEP from flux

GEP and Far-Red SIF

View angle, time of day, and period in growing season affect r



PRI and Photosynthetic Light Use Eff



Hot Spot: R^2 = 0.66, SE = 0.016, Fra

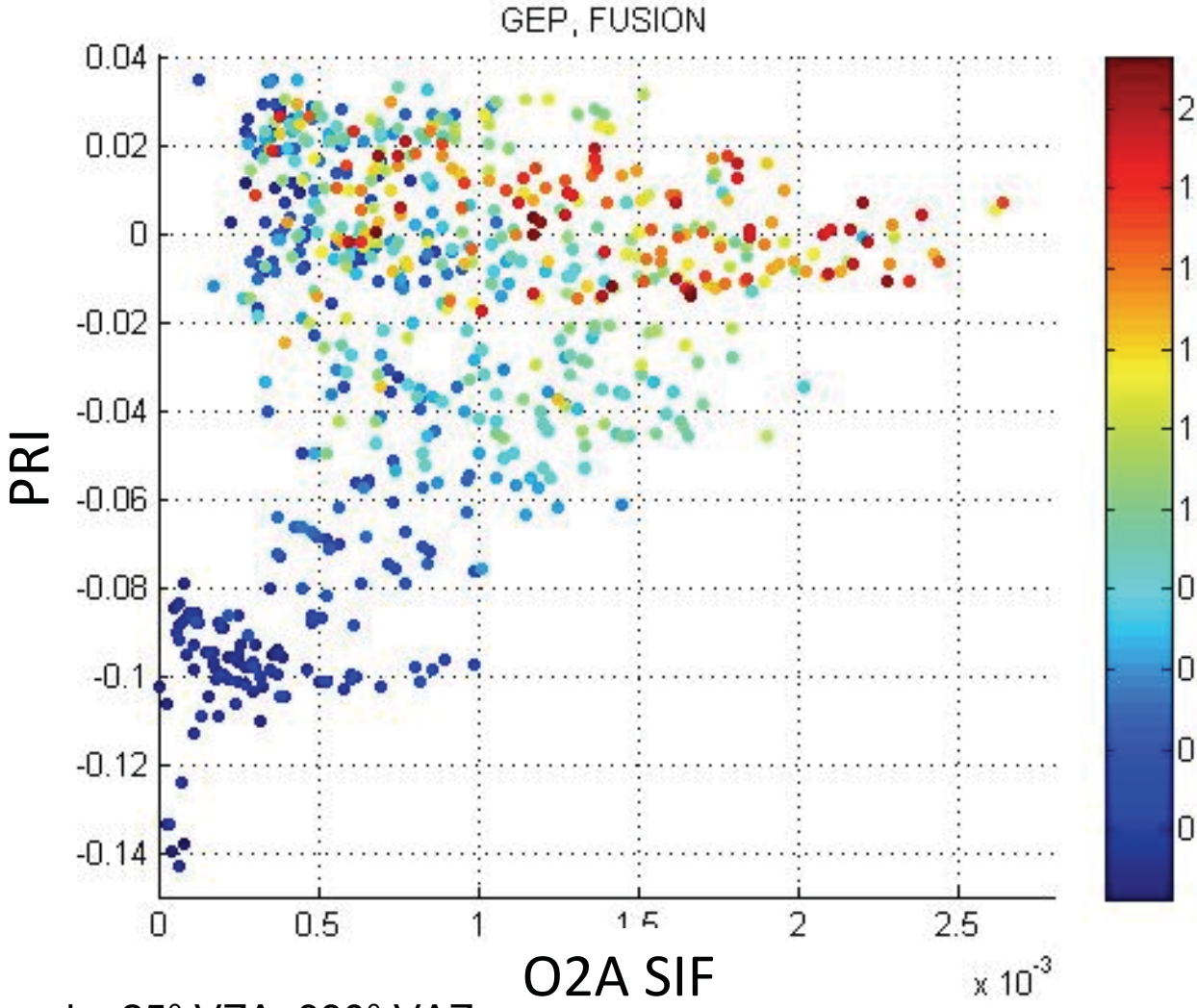
Cold Spot: R^2 = 0.76, SE = 0.015, Fra

Cross Plane: R^2 = 0.71, SE = 0.019, Fra

Due North: R^2 = 0.78, SE = 0.015, Fra

Estimating GEP from FUSION Optical

O2A SIF vs. PRI, where the colors of the points indicate GEP value

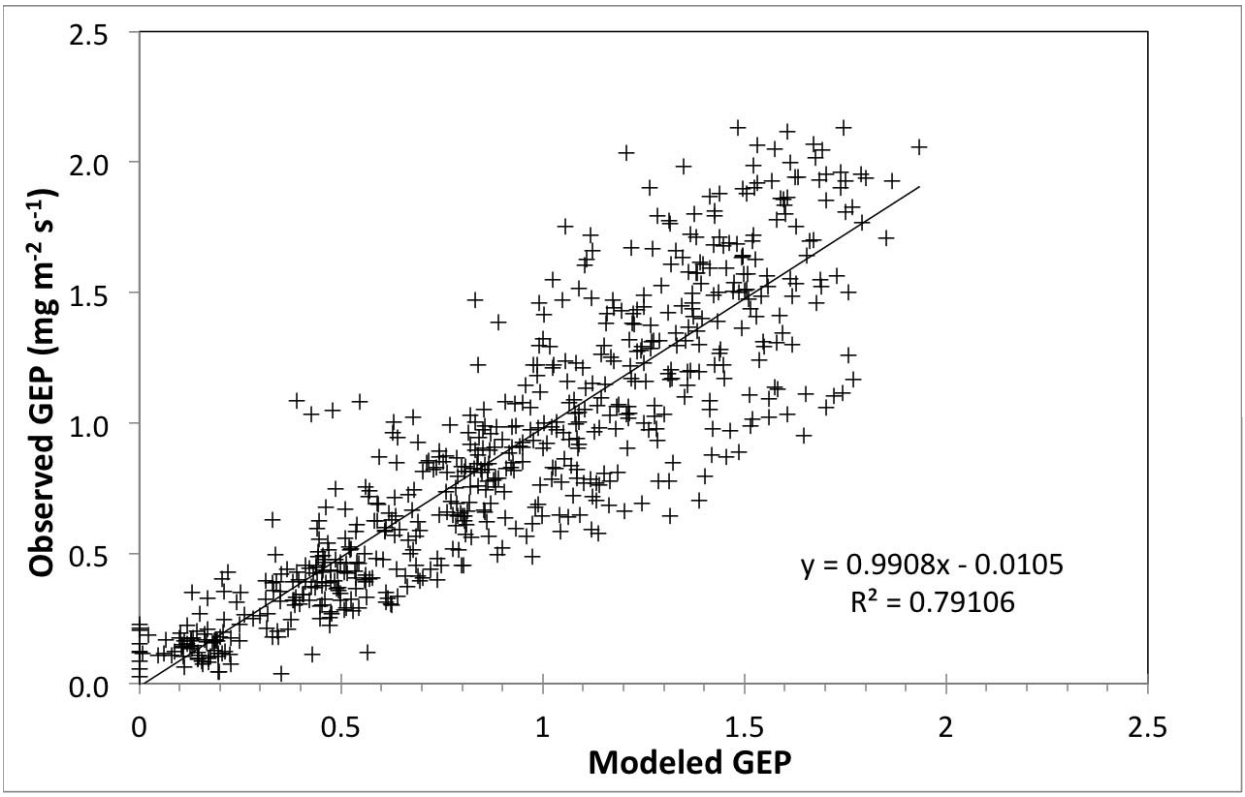


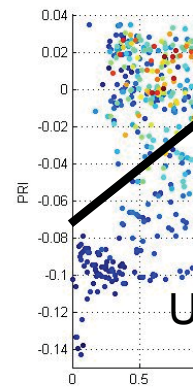
Single view angle: 25° VZA, 330° VAZ
Data covers entire 2014 season, clear and cloudy conditions

Estimating GEP from FUSION Optical

Half-hourly GEP modeled using an analytic model with NDVI, PRI
describing 79% of the variance in GEP compared to 63% using ND

Use N
and P





Single view angle: 25° VZA, 330° VAZ
Data covers entire 2014 season, clear and cloudy conditions

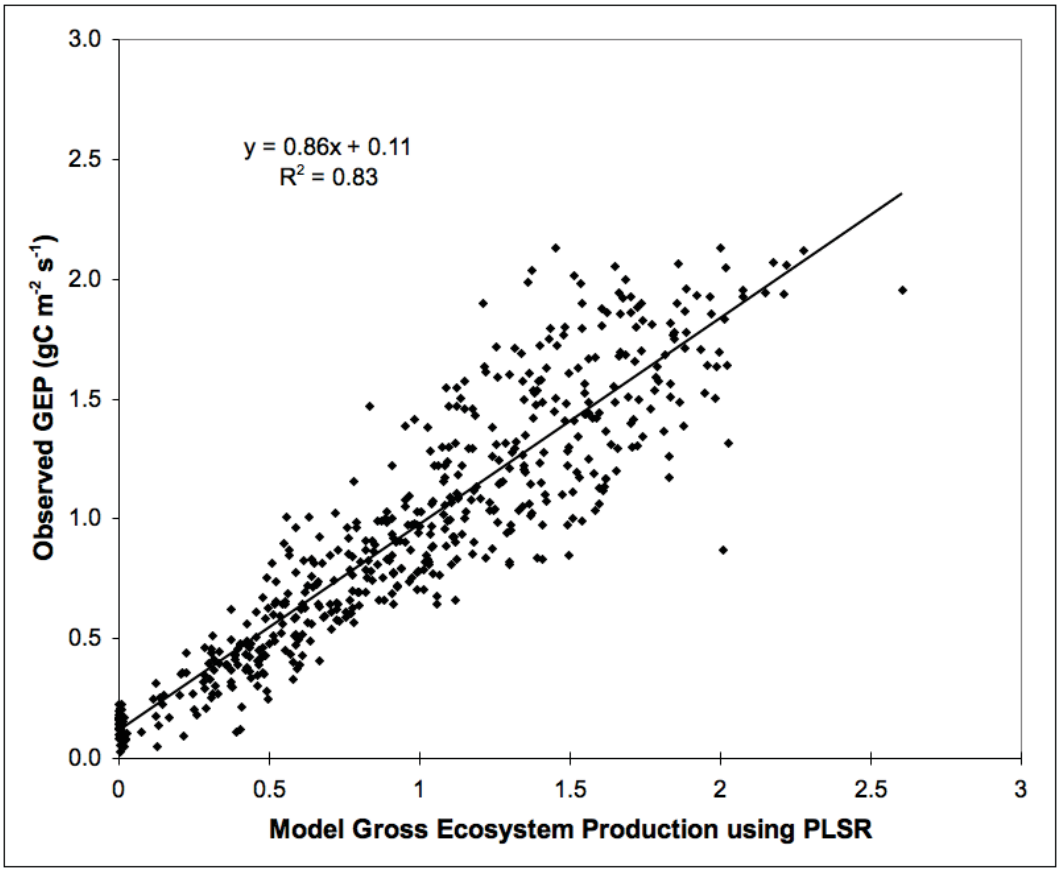
Estimating GEP from FUSION Optical

Light Use Efficiency model using NDVI and PAR with a variable LUE
regression tree model using PRI and SIF at O_2A and O_2B

Single view angle: 25° VZA, 330° VAZ
Data covers entire 2014 season, clear and cloudy conditions

Estimating GEP from FUSION Optical

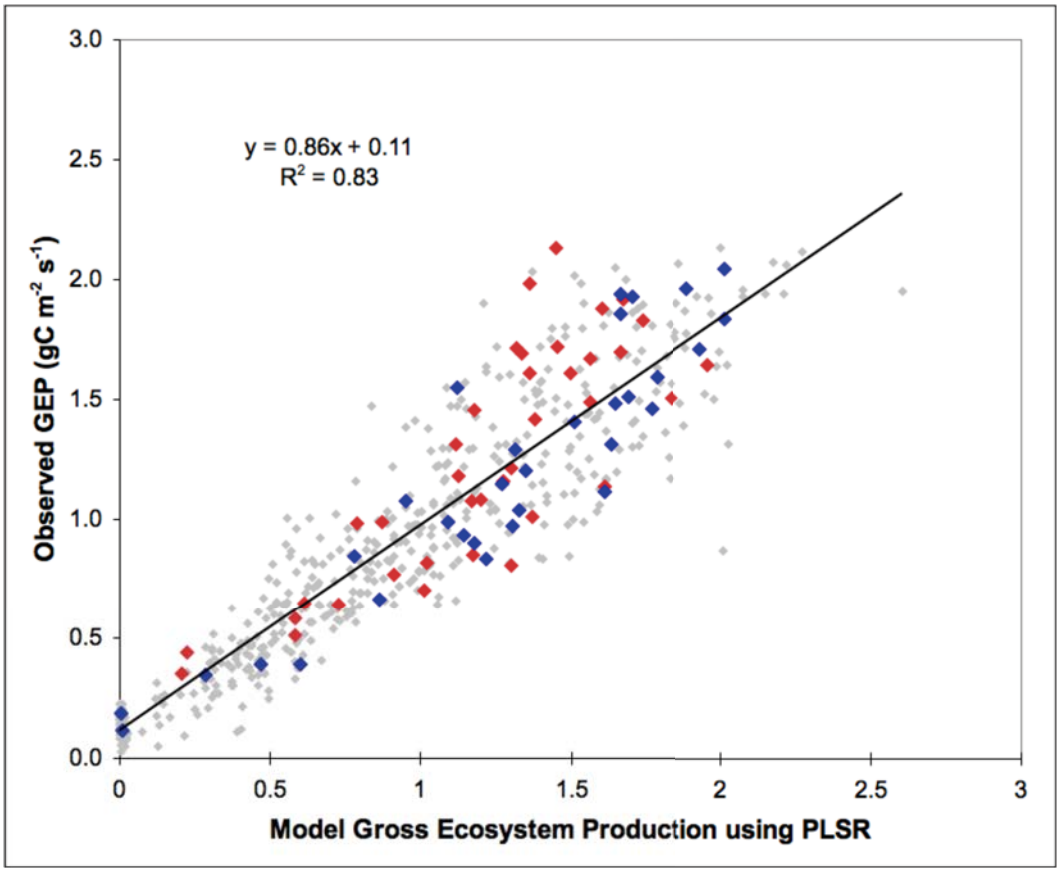
GEP determined from Partial Least Squares Regre
using spectral reflectance sampled at 5 nm train
random selection of 250 points



Single view angle: 25° VZA, 330° VAZ
Data covers entire 2014 season, clear and cloudy conditions

Estimating GEP from FUSION Optical

Red points - clear sky observations near AM overpass
Blue points - clear sky observations near PM overpass



Single view angle: 25° VZA, 330° VAZ
Data covers entire 2014 season, clear and cloudy conditions

Conclusions

- FUSION provides optical measurements supporting scientific studies, algorithm development, and satellite/aircraft produ
- In our cornfield studies with FUSION we able to:
  - Observe significant bidirectional effects in sp vegetation indices and SIF related to sun an geometry
  - Observe new aspects of seasonal phenology and optical indices
  - Develop optically-based algorithms to descri and seasonal patterns of Gross Ecosystem F

Future

OLD	NOW	NE
FUSION 1 Paired OOPs HRs viewing upward and downward Bidirectional, no Nadir View	FUSION 2 Paired OOPs QEs viewing upward and downward Bidirectional with Nadir View	FUSI Single O switching upward and vie Bidirectio Nadir