Optical Sensing of Ecosystem Carbon Fluxes

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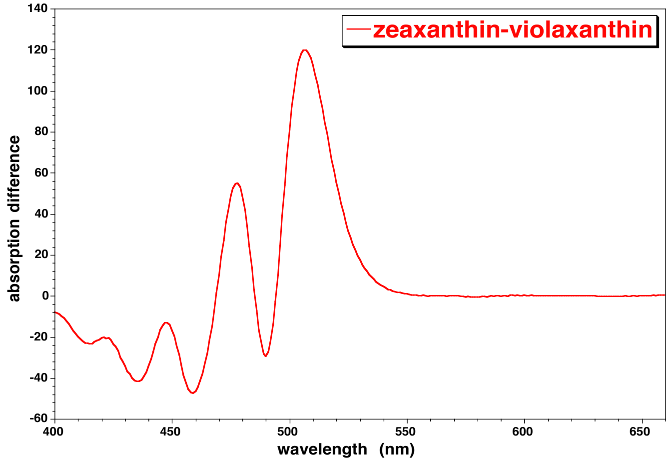
Optical Signals

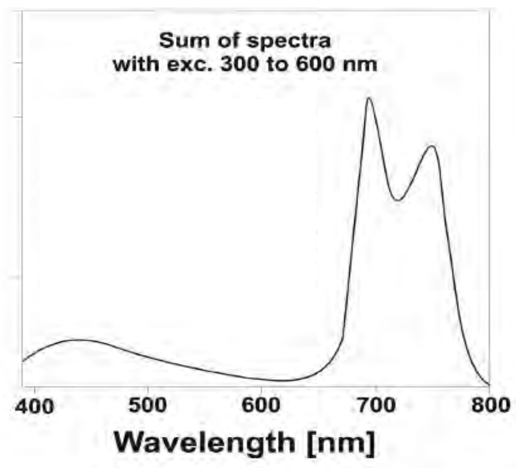
Corresponding to physiological responses there are specific effects on spectral reflectance

1. Leaf chlorophyll concentration (multiple visible wavelengths) - light absorbed by chlorophyll drives photosynthesis
2. Non-photosynthetic quenching - changes in Xanthophyll cycle pigment concentrations (531 nm)
3. Solar Induced Fluorescence (peaks at 690 and 735 nm)

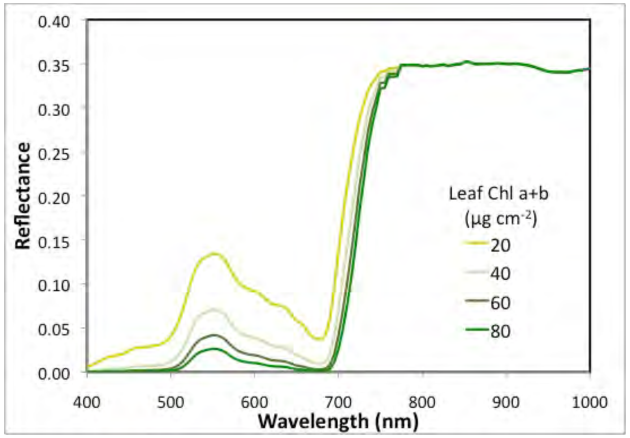
Xanthophyll



Fluorescence



Chlorophyll



Light Use Efficiency Model

$$GEP = \varepsilon \, f_{APAR} \, PAR_{in}$$

Where:

GEP is the gross ecosystem production

PARin is the incident Photosynthetically Active Radiation (PAR)

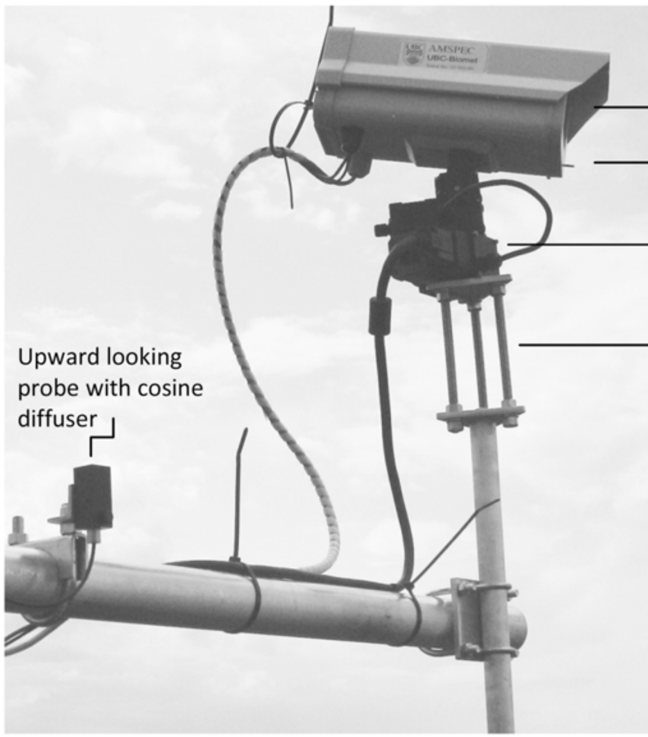
f_{APAR} is the fraction of PAR absorbed by vegetation

e is the light use efficiency, the conversion factor between energy and absorbed carbon

- In existing models ε is assigned a maximum value based on cover type and downregulated based on responses to meteorological variables such as temperature and humidity

Tower-based Spectrometers

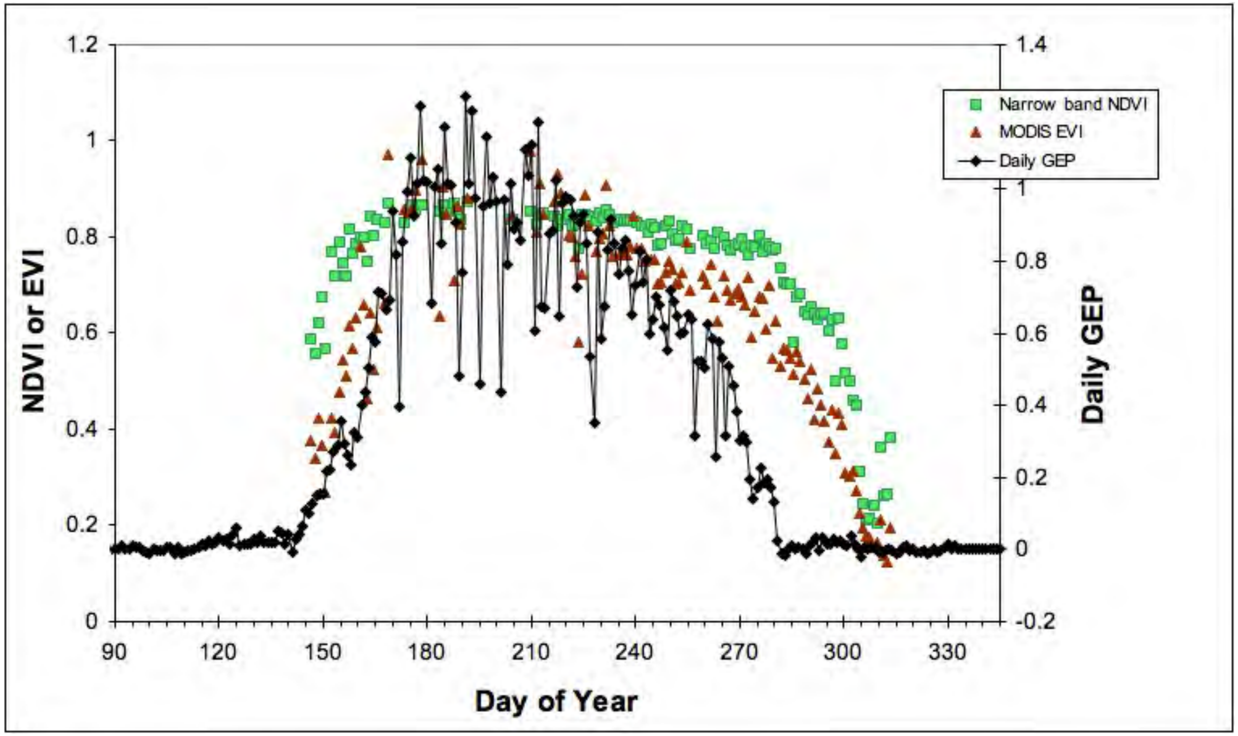
AMSPEC



FUSION

From T. Hilker

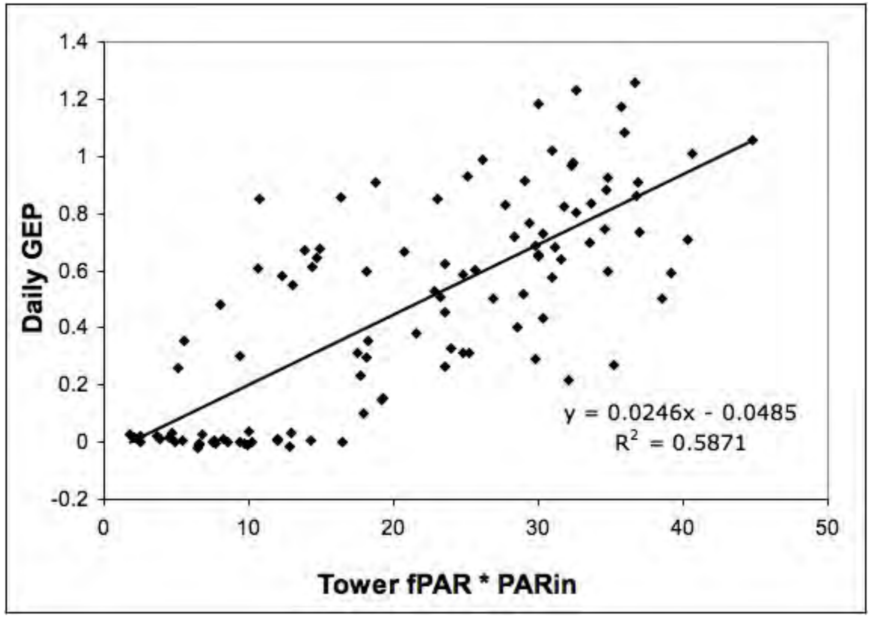
SK-Old Aspen Seasonality: NDVI, EVI, GEP



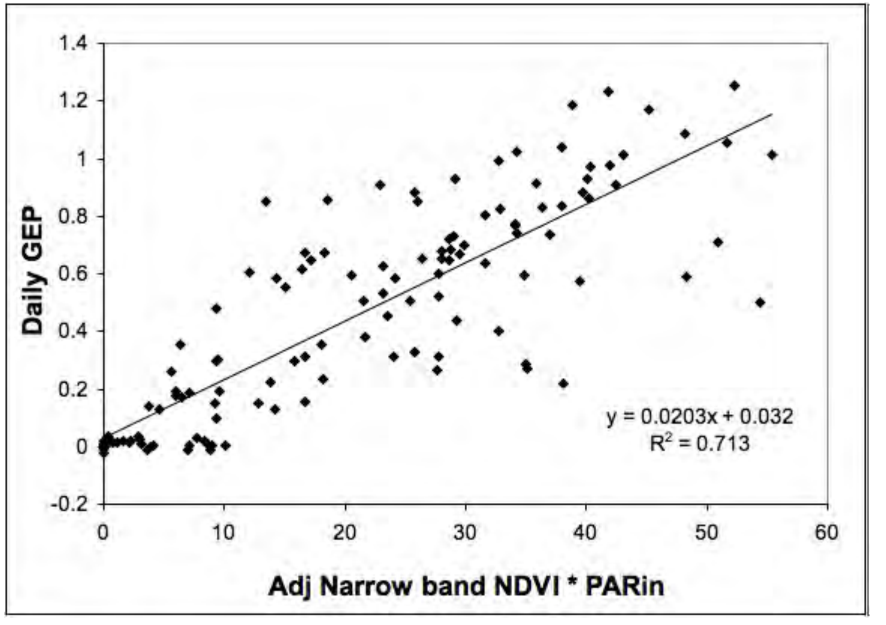
Data from T. Hilker, T.A. Black and A. Barr

Daily GEP from Optical Signals

Using total *f*PAR measured at the tower using PAR sensors

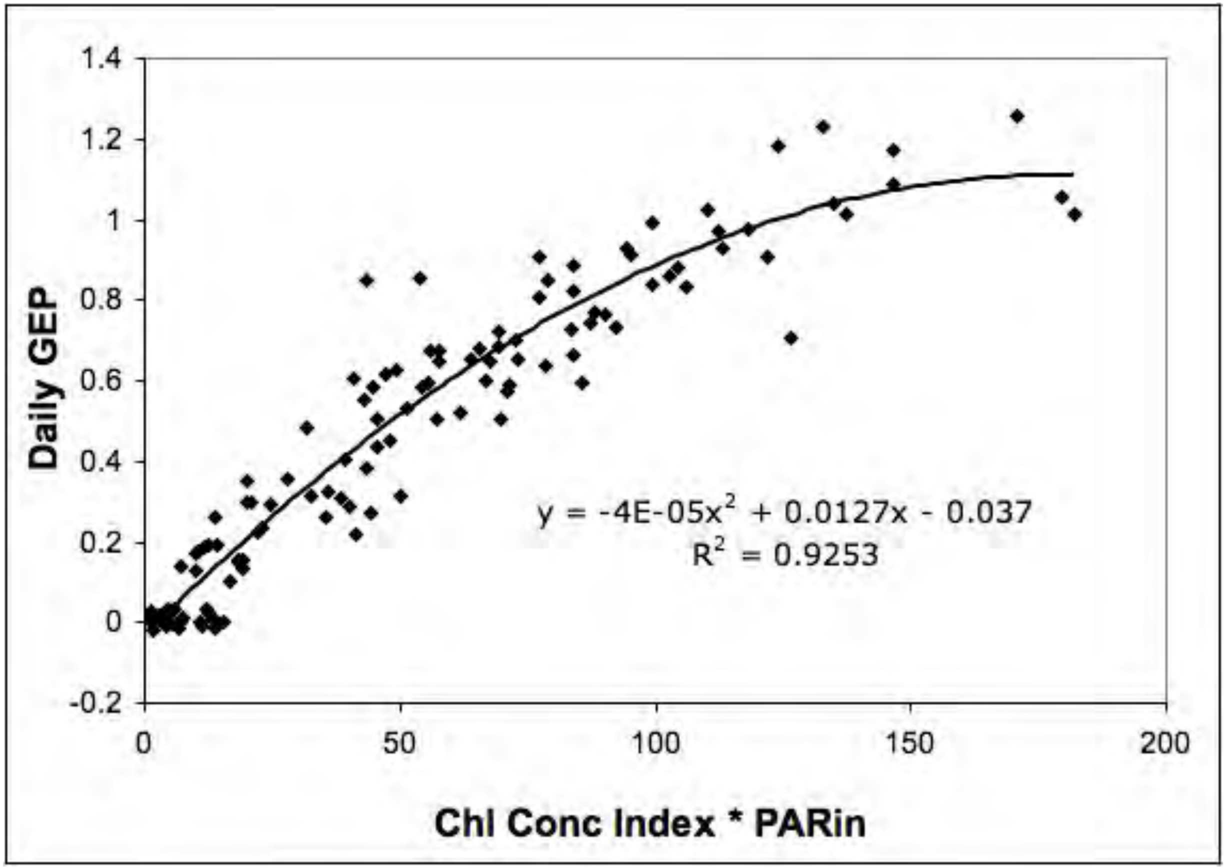


Using narrow-band NDVI to estimate green *f*PAR



Data from T. Hilker, T.A. Black and A. Barr

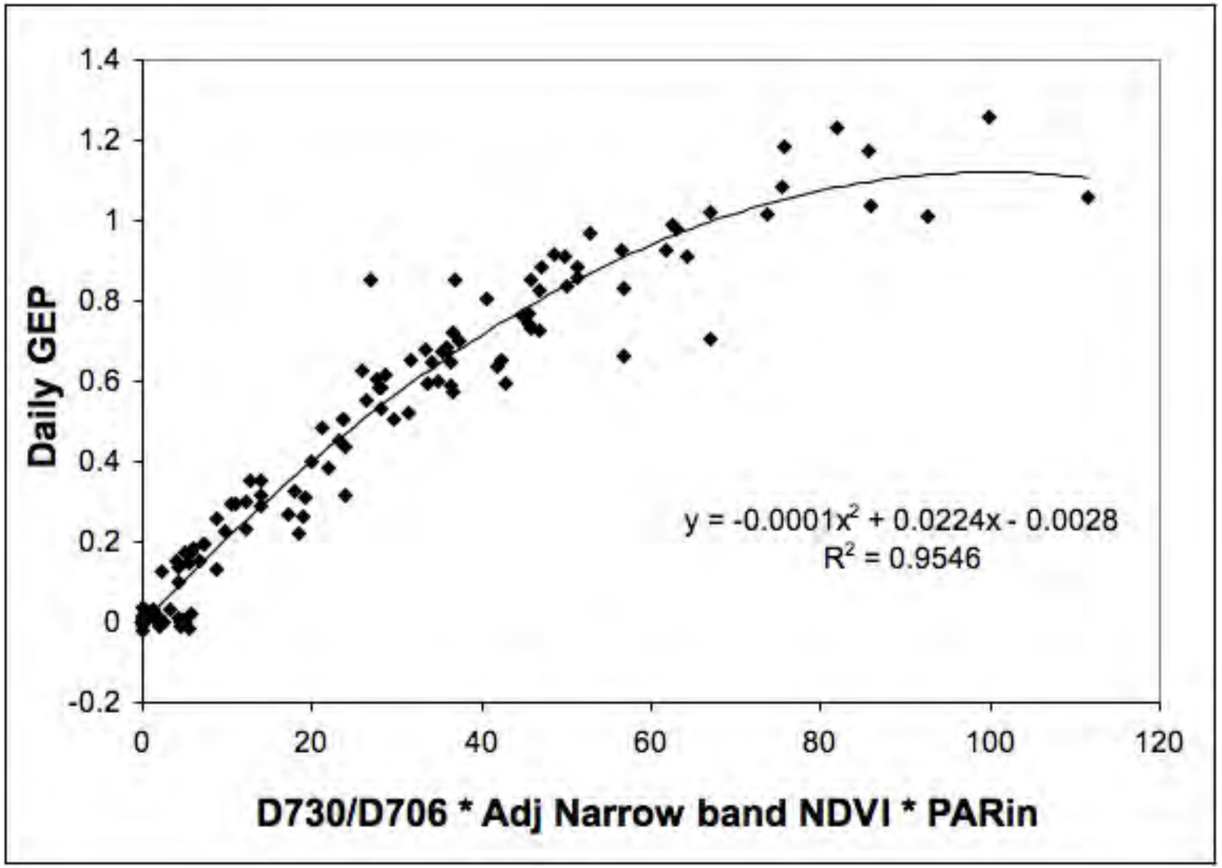
Chlorophyll Index and Daily GEP



- Spectral index describes canopy chlorophyll content

Data from T. Hilker, T.A. Black and A. Barr

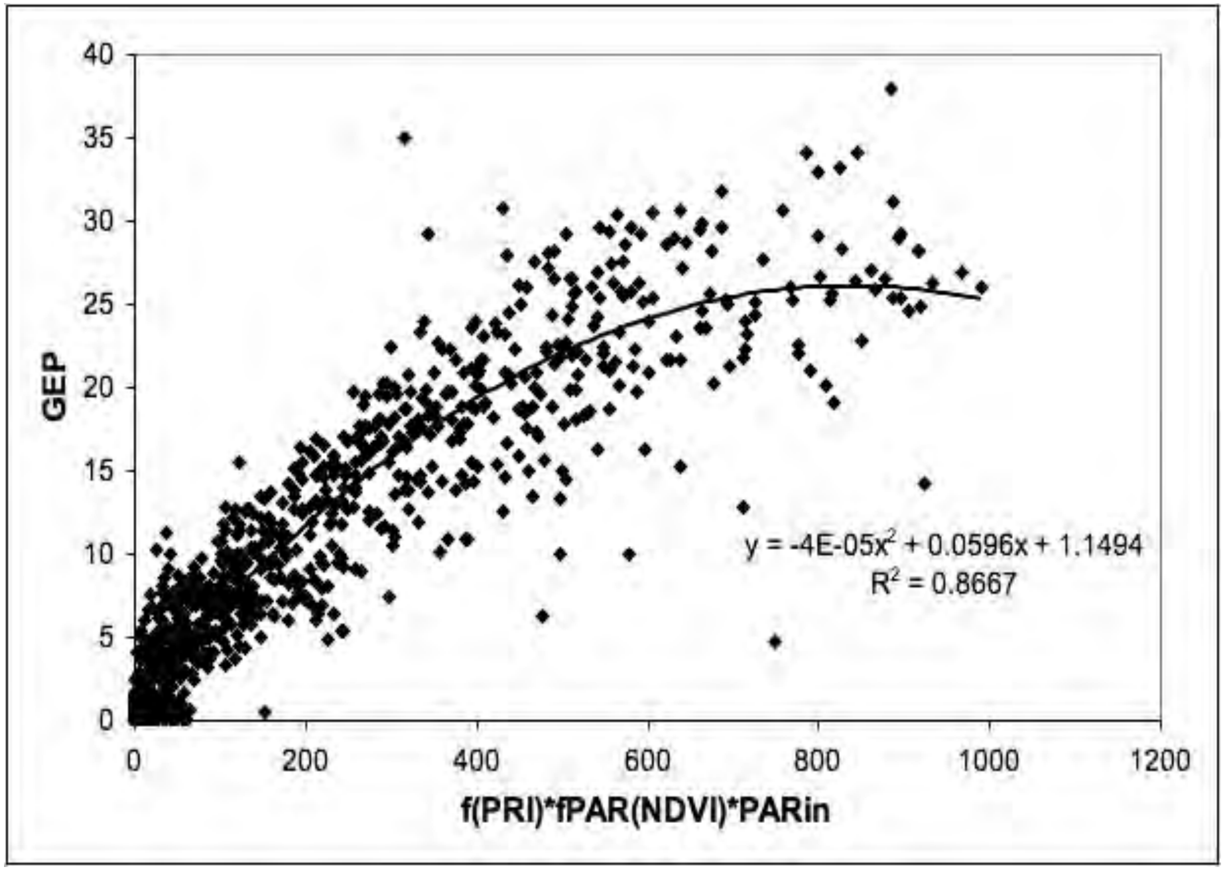
Daily GEP from Optical Signals



- This spectral index is the ratio of the first derivatives of the spectral reflectance at 706 and 730 nm
- Derivative index is related to solar induced chlorophyll fluorescence and used to describe variations in light use efficiency

Data from T. Hilker, T.A. Black and A. Barr

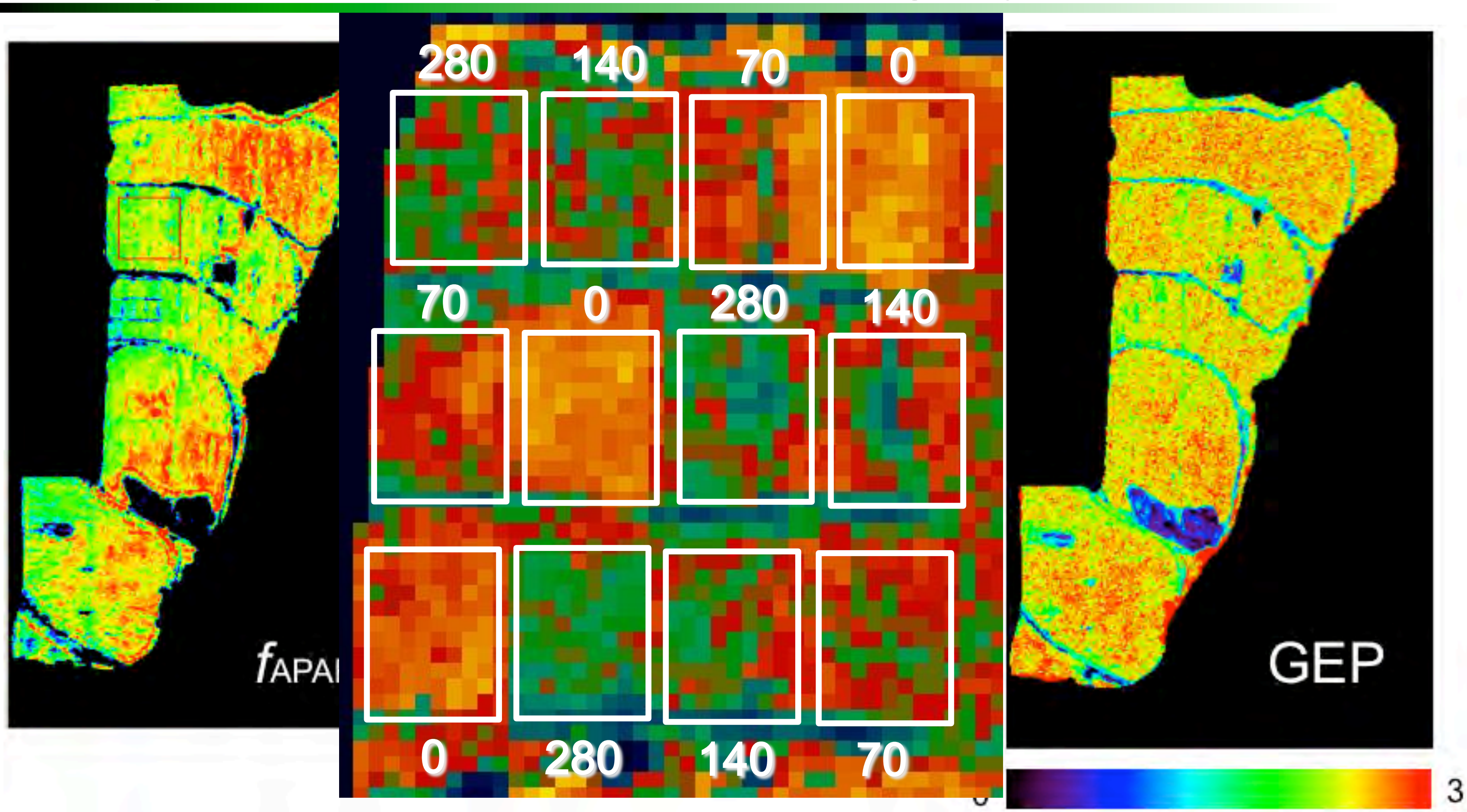
Hourly GEP from Optical Signals



- PRI is related to xanthophyll cycle pigments and chlorophyll/carotenoid pigment pools
- Used to describe variations in light use efficiency

Data from T. Hilker, T.A. Black and A. Barr

Scaling Fluxes with Aircraft Imagery



Imagery of USDA ARS cornfield in Beltsville, MD from Airborne Imaging Spectrometer for Applications (AISA) data collected on September 14, 2009. Left panel shows *f*APAR from NDVI; middle panel is PRI; and right panel is modeled GEP in mg CO_2 m^{-2} s^{-1} using the model derived from ground reflectance data.

L. Corp

Conclusions

- To even approach our goal of observing fluxes "everywhere and all the time" we need take advantage of optical sensing
- Optical approaches provide direct observations of vegetation stress responses
  - Directly measures physiological responses of plants
  - Can describe spatial distributions of fluxes
  - Is scalable from plot to satellite (local to global)
  - Flux estimation independent of meteorological data (used as inputs in most carbon models)
- We need to compare results from different sites to develop and test robust algorithms