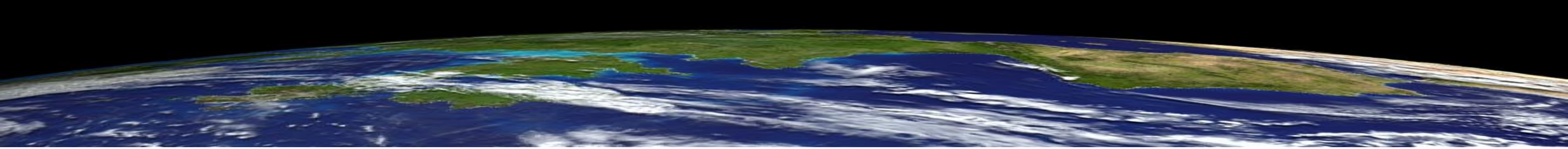


Monitoring and modeling the US crop production under climate change

Kaiyu Guan, **Guofang Miao**, Bin Peng, Hyungsuk Kim and Yunan Luo

(kaiyug@Illinois.edu; gmiao@illinois.edu)

Collaborators: Xi Yang, Joe Berry, Christian Frankenberg, Jian Peng, John Gamon

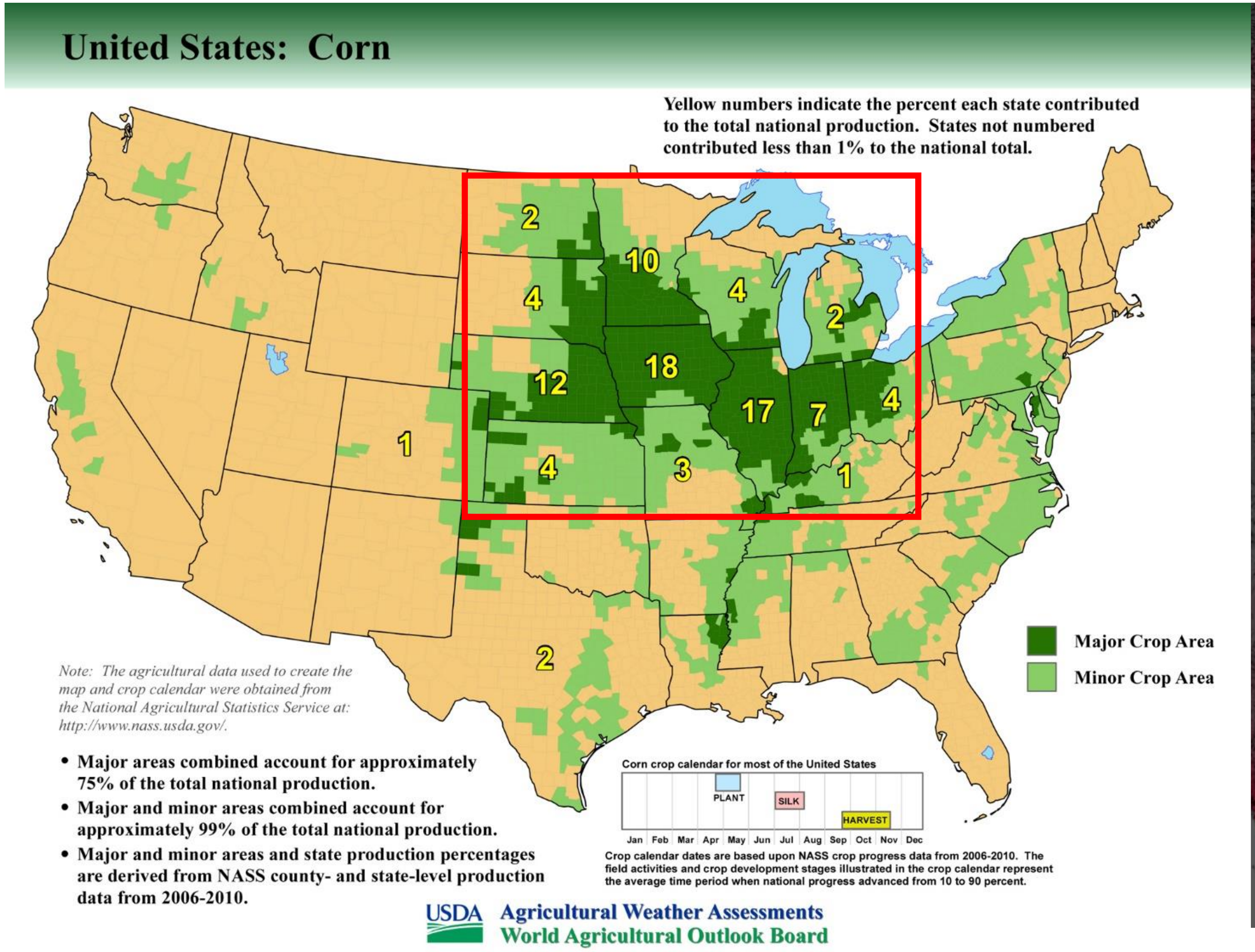
Nature Resources and Environmental Sciences

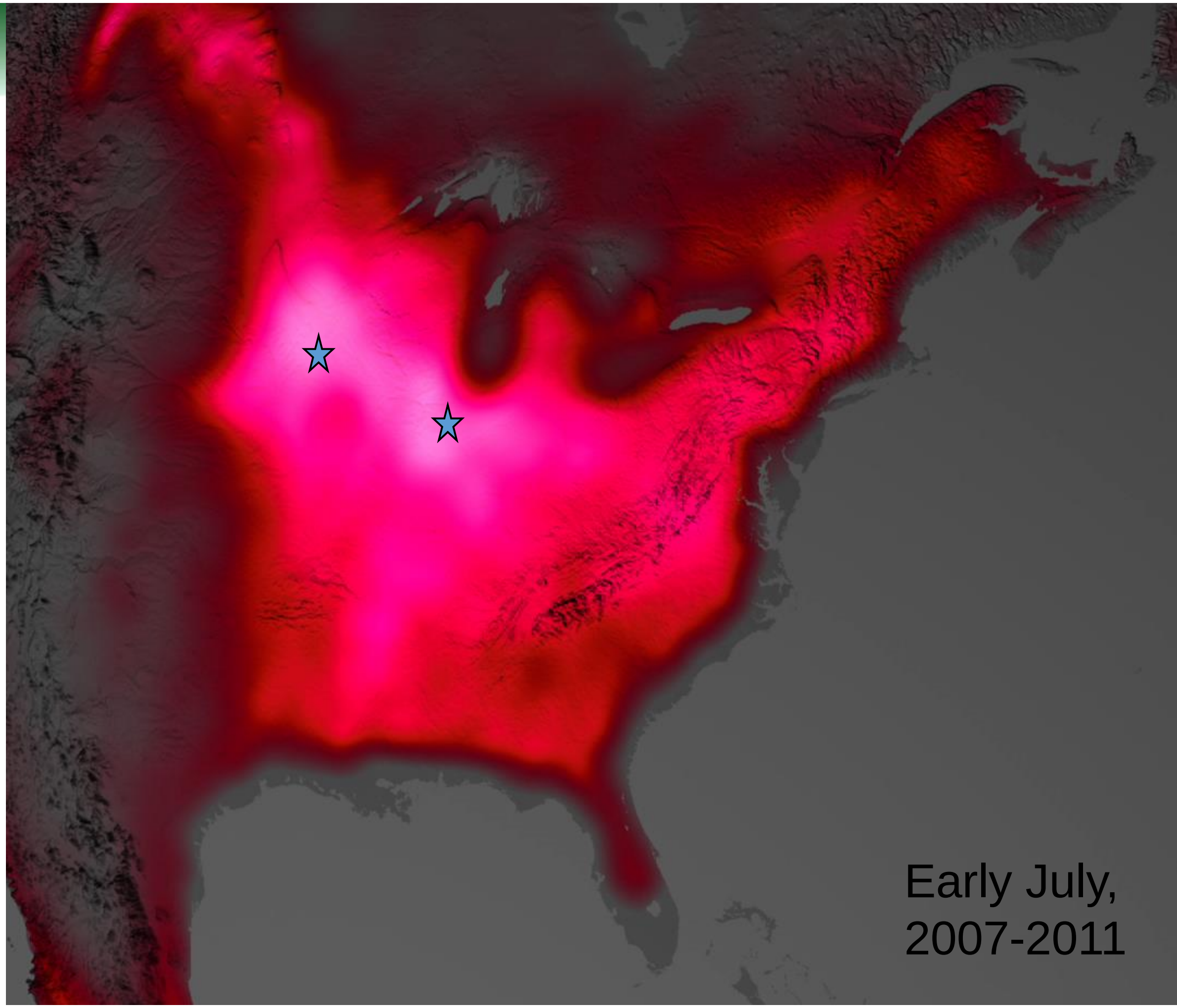
National Center for Supercomputing Applications

University of Illinois at Urbana Champaign

Website: http://faculty.nres.illinois.edu/~kaiyuguan/

UNL SIF Workshop, Sep 26, 2017





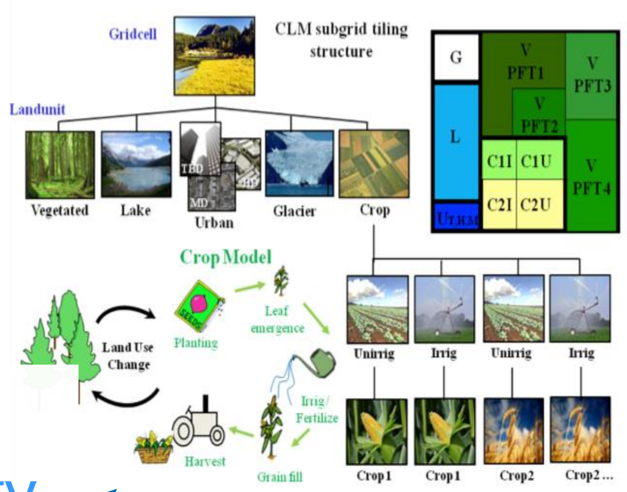
Credit: NASA

Study domain in red box. The background shows the averaged corn production from 2006-2010, and the numbers indicate the percentage (%) of the state production to the national total corn production.

Sun-induced chlorophyll fluorescence (SIF) as a proxy of photosynthesis.

Remote Sensing

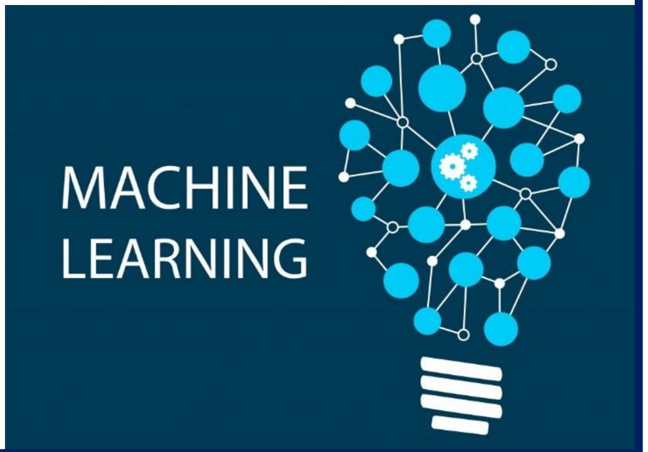
Numerical Modeling
& Parallel Computing

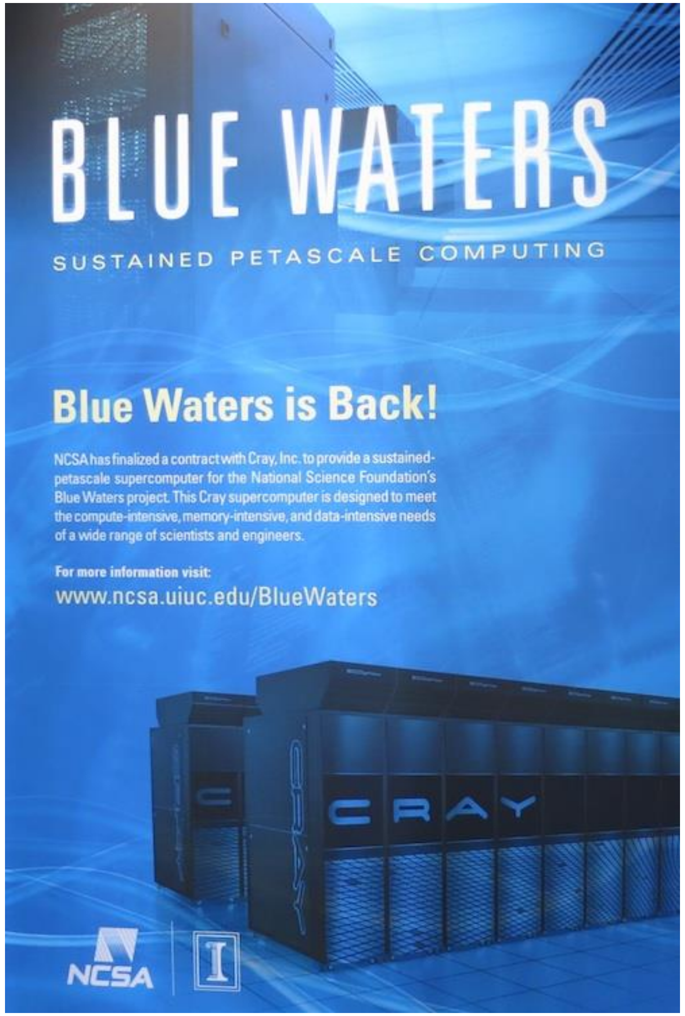


Monitoring Food
Production and Security

Field Studies

Integrating field work, satellite, and supercomputing for monitoring and modeling crop production at continental scales





Blue Waters is a petascale supercomputer at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign. On August 8, 2007, the National Science Board approved a resolution which authorized the National Science Foundation to fund "the acquisition and deployment of the world's most powerful leadership-class supercomputer." The NSF awarded $208 million for the Blue Waters project.

Current Research Directions in our lab

(1) Multi-sensor integration for crop yield monitoring

- Various satellite data

(2) Long-term sensing network for agricultural ecosystems

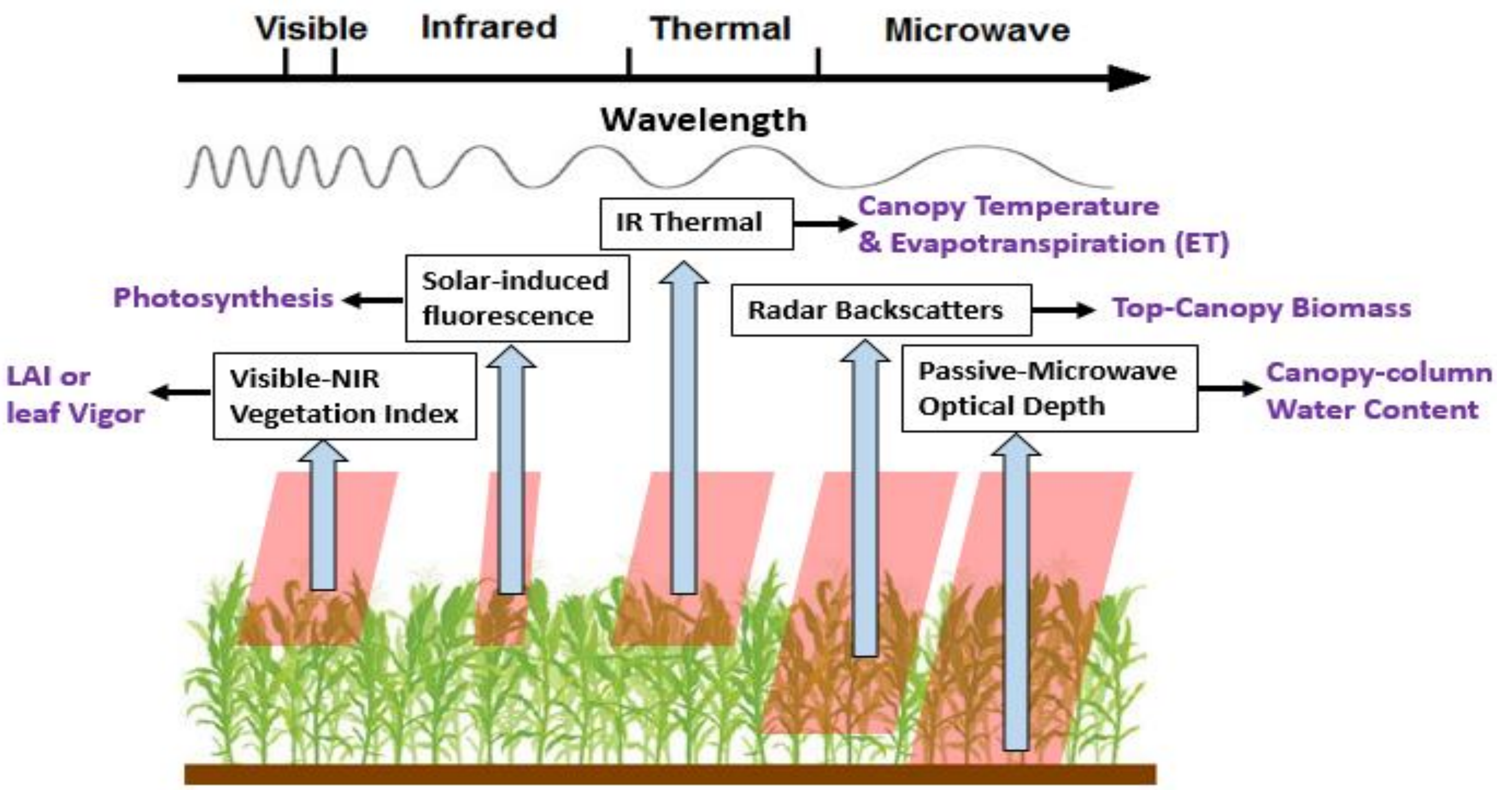
- Ground-based SIF, camera network

(3) High-resolution satellite fusion and field-level mapping

(4) Modeling crop responses to drought and heat stress

Multi-sensor integration for crop yield monitoring

A New Era of Earth Observation from Satellite:
Vegetation Properties



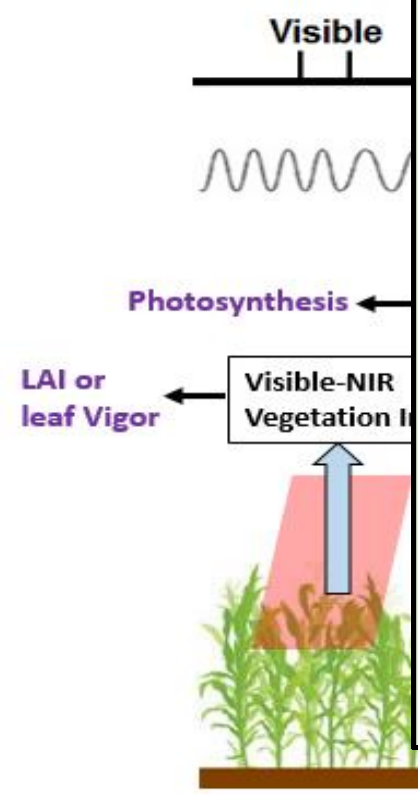
(Guan et al., RSE, 2012; Guan et al., Ecosphere, 2013; Guan et al., IEEE, 2014; Guan et al., JGR, 2014; Guan et al., GCB, 2016; He et al., RSE, 2016; Guan et al., RSE, 2017)

what people and satellite see

what people really care about

Multi-sensor integration for crop yield monitoring

A New Era of Earth Observation from Satellite:
Vegetation Properties



what people and satellite see

Take home message:

All the satellite data share some common information.

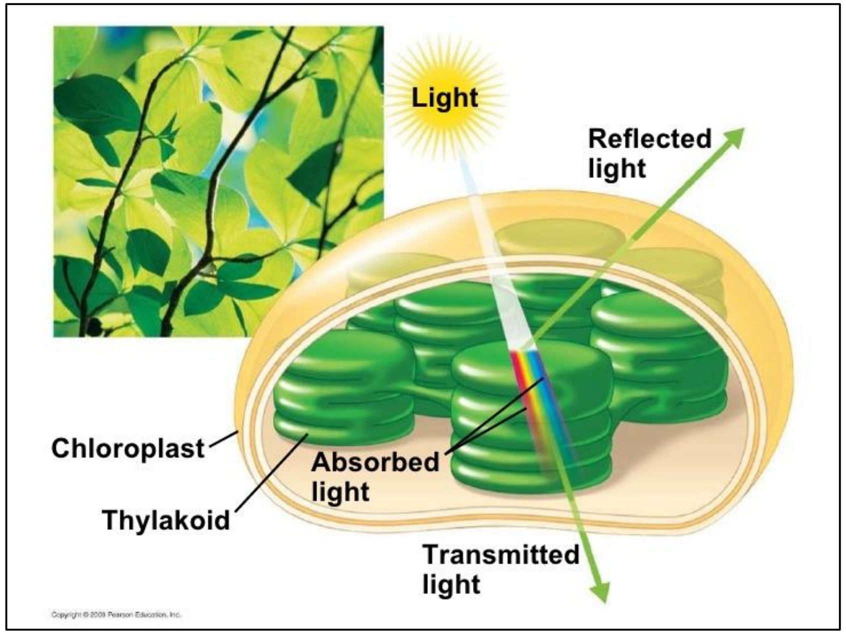
However, when excluding this common information, many data contain their unique information that tremendously improve our understanding of vegetation growth.

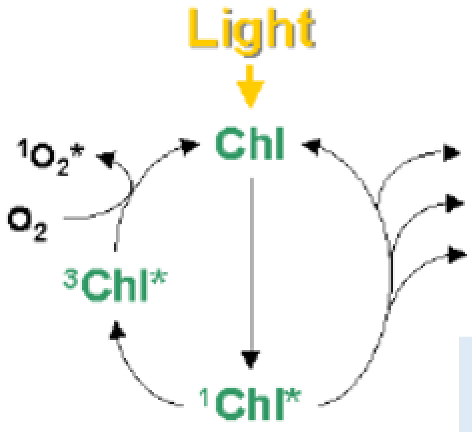
really care about

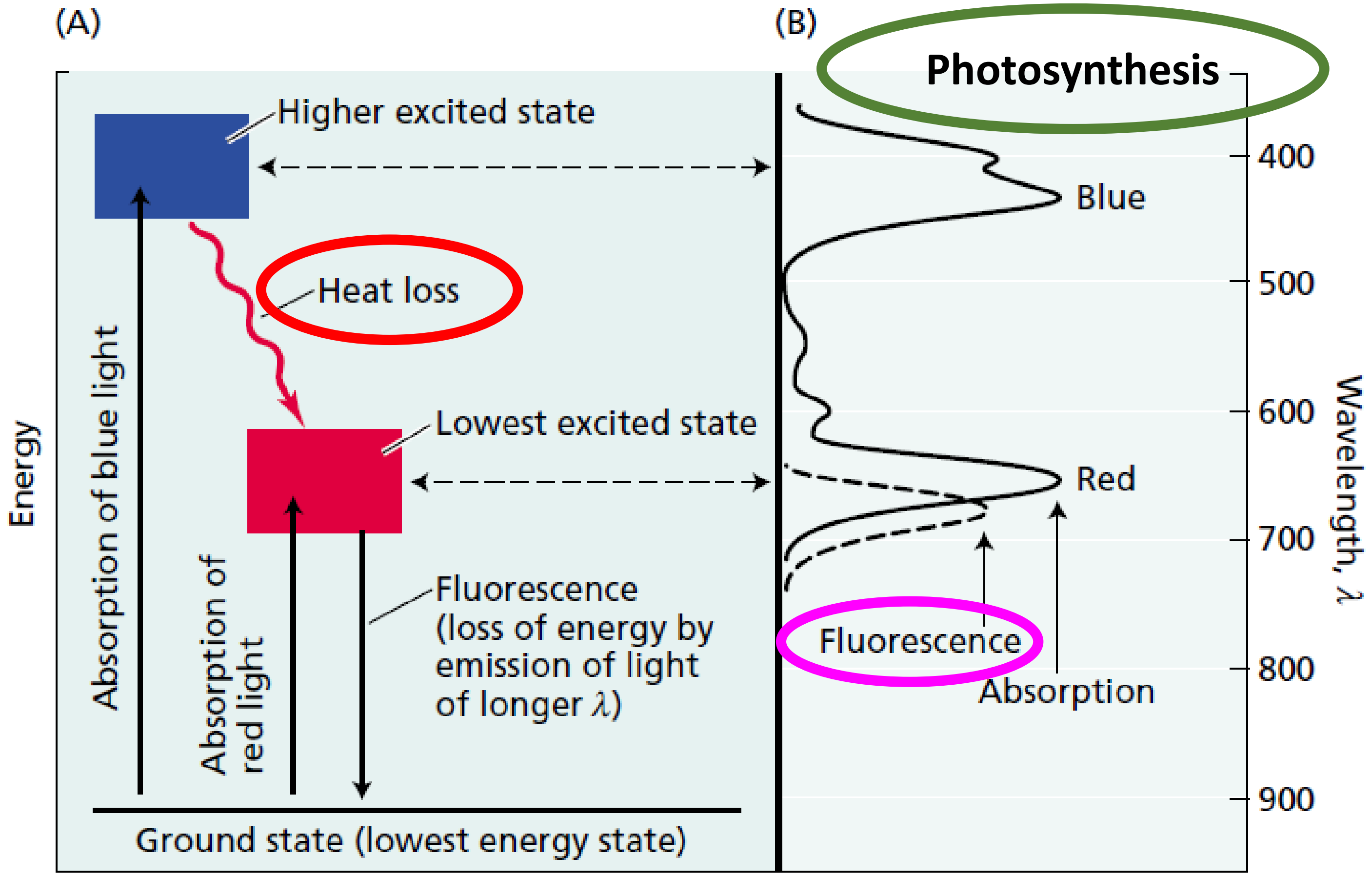
(Guan et al., RSE, 2012; Guan et al., Ecosphere, 2013; Guan et al., IEEE, 2014; Guan et al., JGR, 2014; Guan et al., GCB, 2016; He et al., RSE, 2016; Guan et al., RSE, 2017)

Innovative use of fluorescence information

What is Solar-induced chlorophyll fluorescence (SIF)?



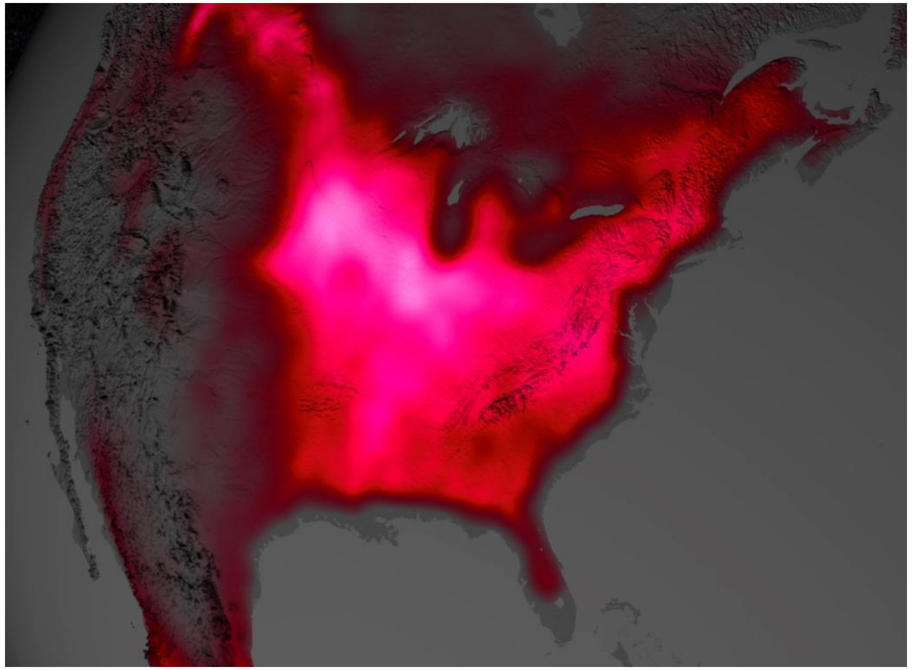


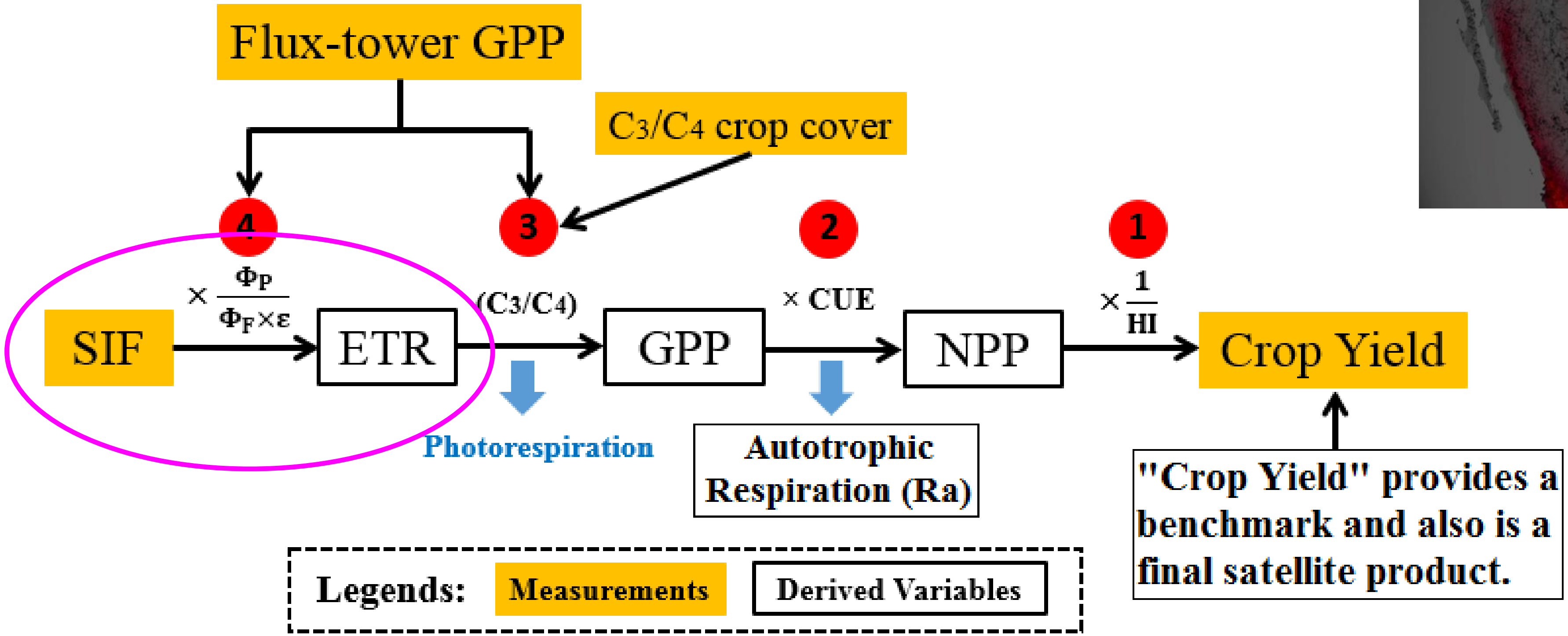


Plant Physiology (Taiz & Zeiger)

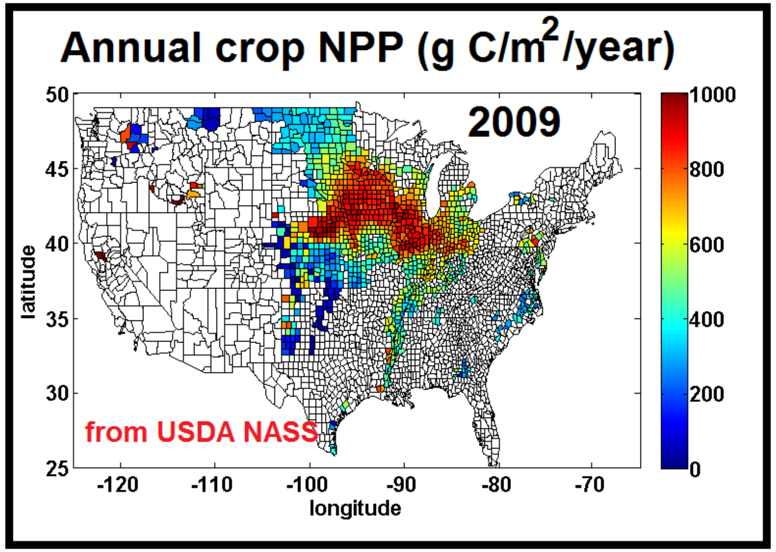
SIF is only possible to retrieve from space in recent years.

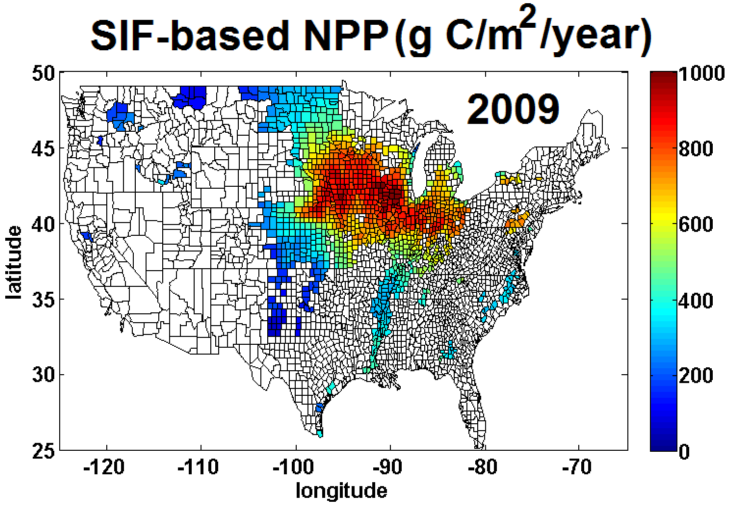
A new framework of using remote sensing SIF for crop monitoring

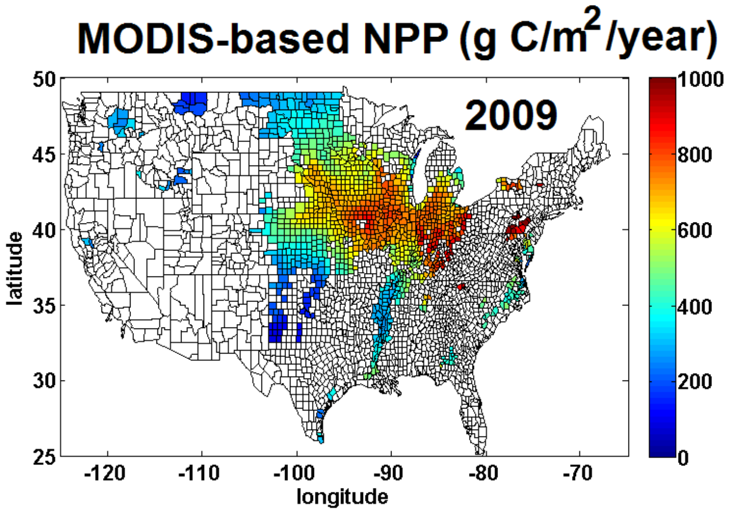


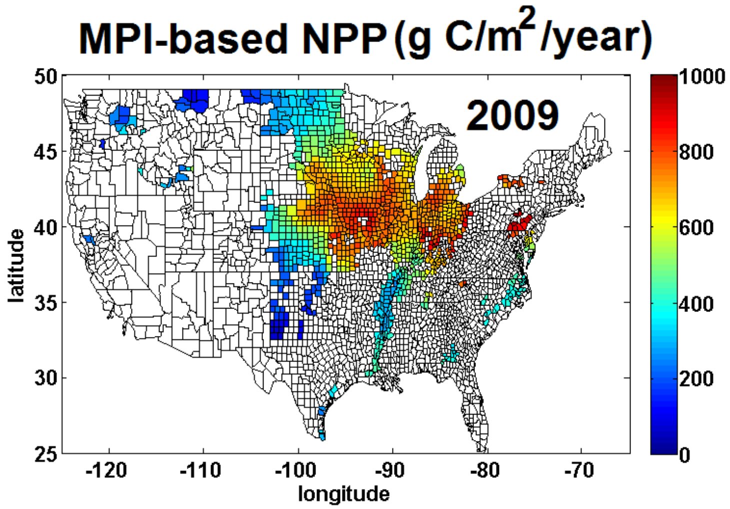


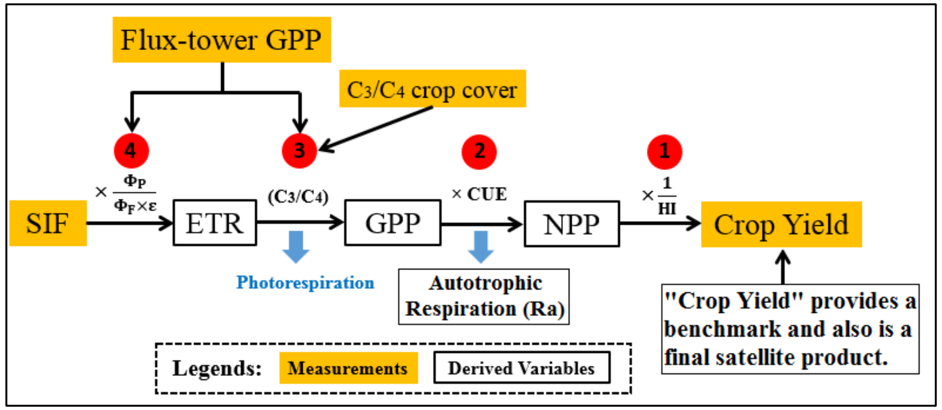
(Guan et al., "Improving the monitoring of crop productivity using spaceborne solar-induced fluorescence", Global Change Biology, 2016)





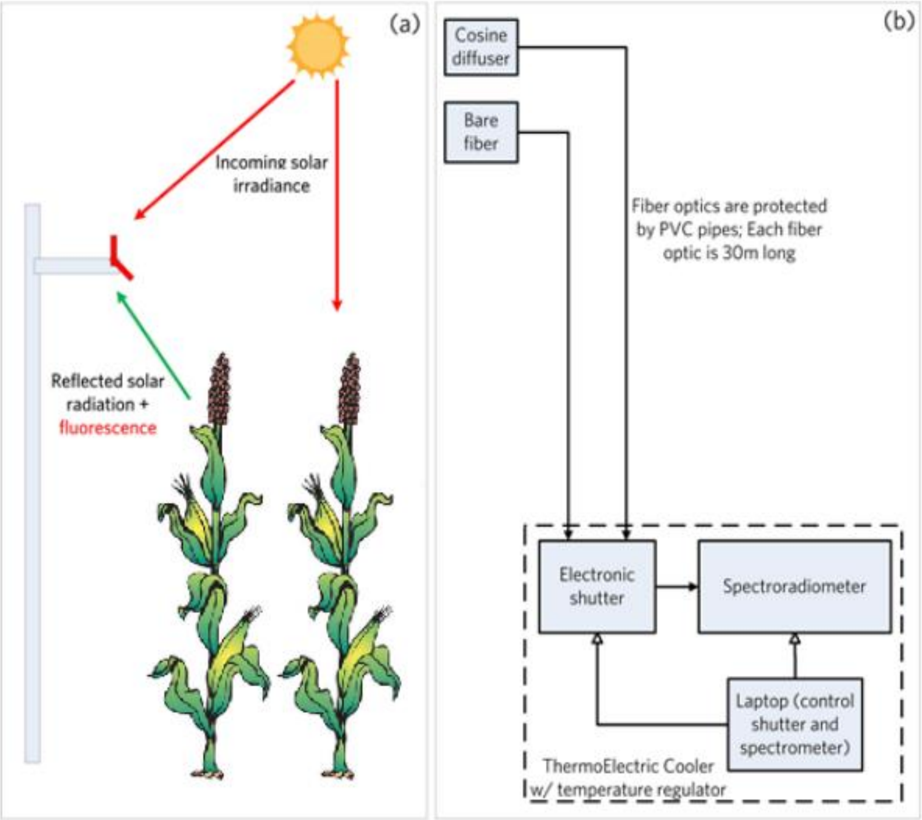




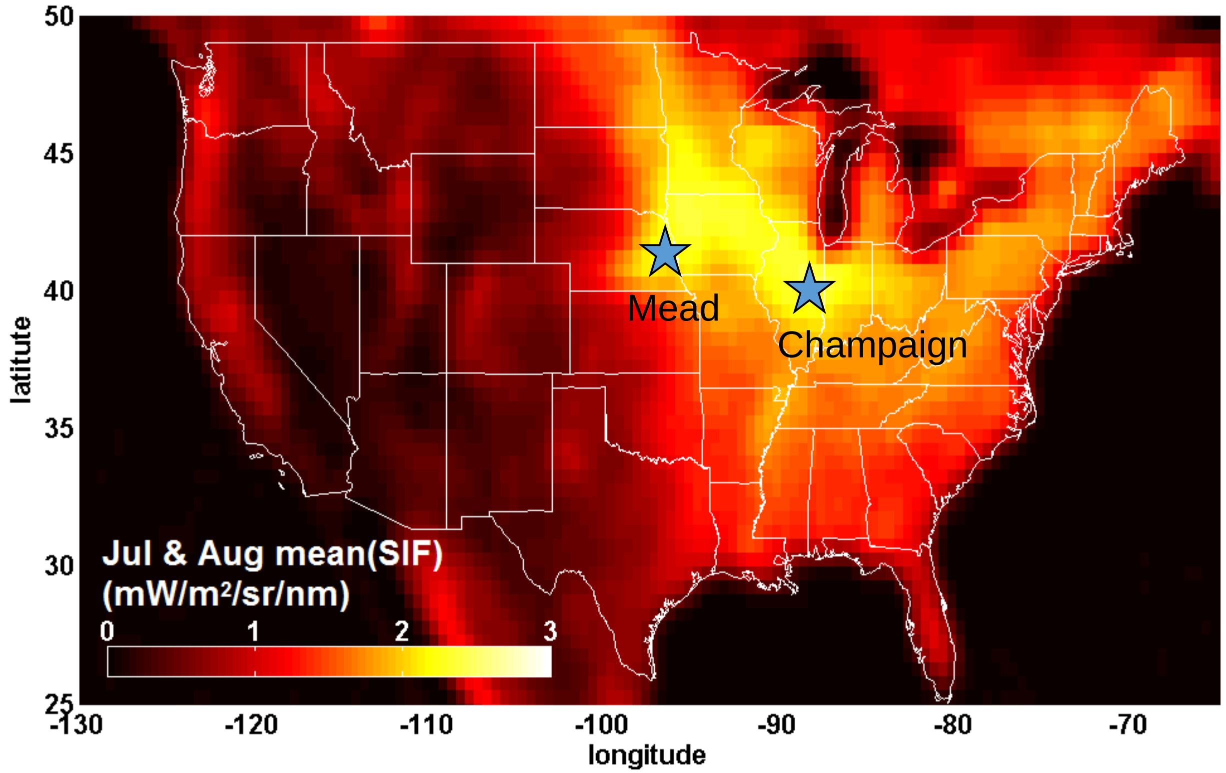


(Guan et al., "Improving the monitoring of crop productivity using spaceborne solar-induced fluorescence", Global Change Biology, 2016)

Long-term measurements of solar-induced fluorescence (SIF) – Guofang Miao



FluoSpec2 designed by Dr. Xi Yang

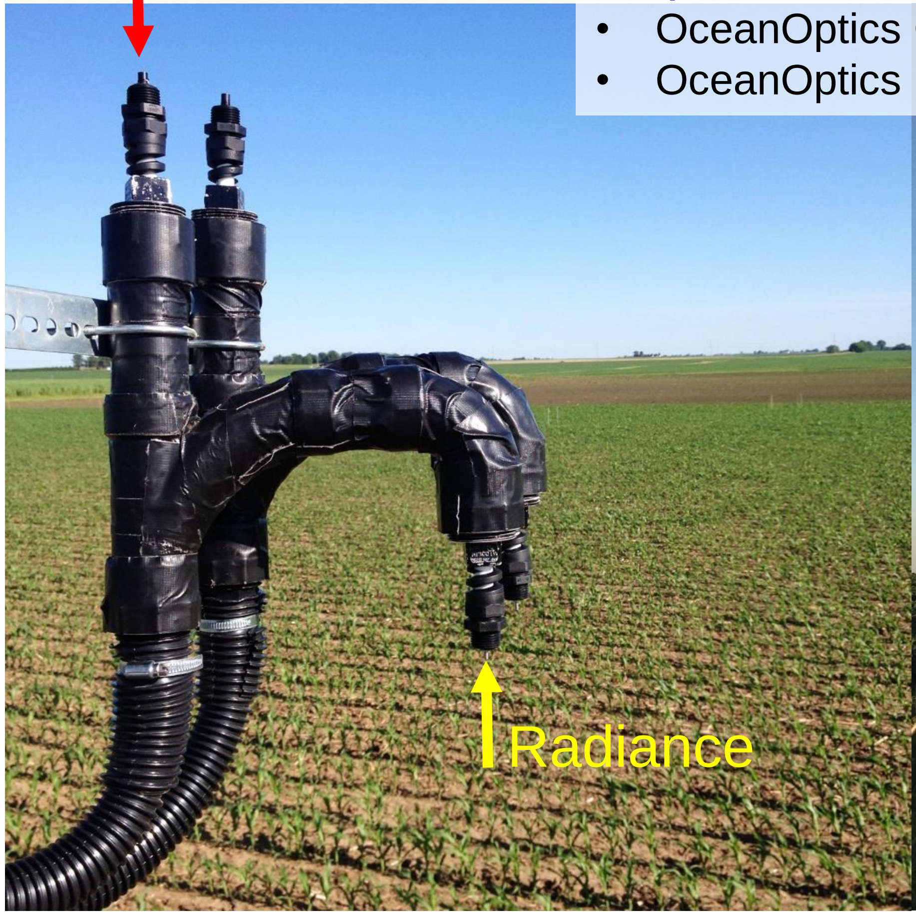


(Guan et al., NASA New Investigator, 2016)
(Frankenberg, Guan et al., NASA Carbon Sciences, 2016)

Site	Management	Growing season (May-Oct)		Expected crop calendar			
		total rainfall (mm/y)	daily mean temperature (℃)	2016	2017	2018	2019
Champaign1	Rain-fed	834	25.6	Corn		TBD	TBD
Champaign2	Rain-fed			Soybean	Corn	Soybean	Corn
Mead Ne3	Rain-fed	598	19.1		Corn	Soybean	Corn
Mead Ne2	Irrigated				Corn	Soybean	Corn

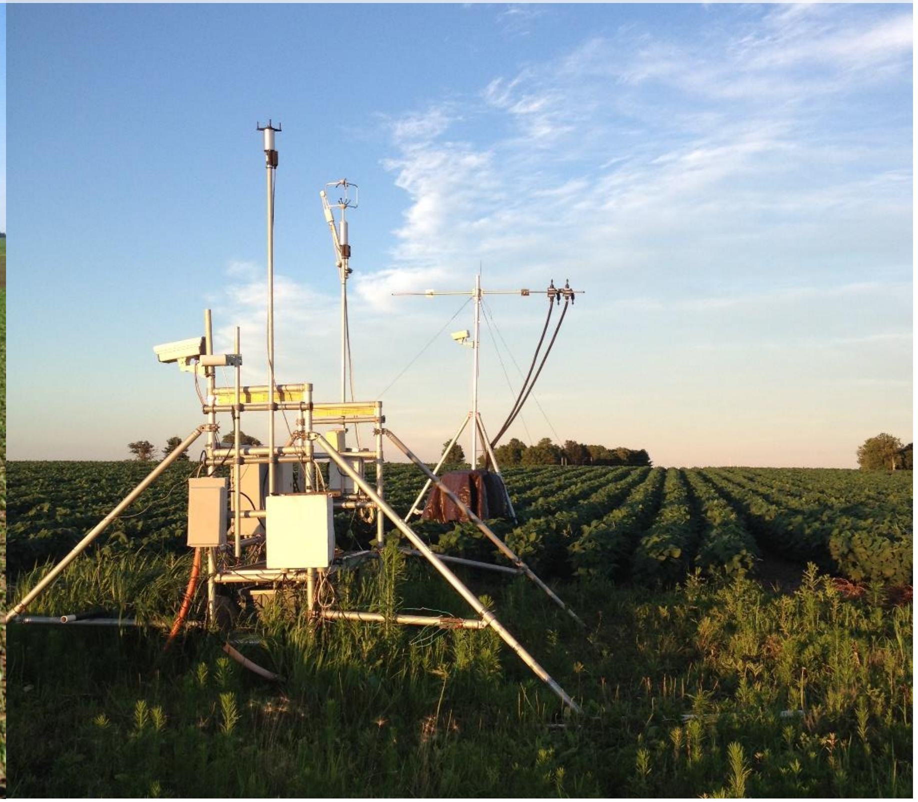
2016 field deployment

	Fiber height (h)	Footprint (diameter d = (h-hc)*tan(12.5)*2)
Soybean	3.6 m	1.1 m (if h-hc = 2.5 m)
Maize	4.8 m	0.9 m (if h-hc = 2.0 m)



2 spectrometers per site:

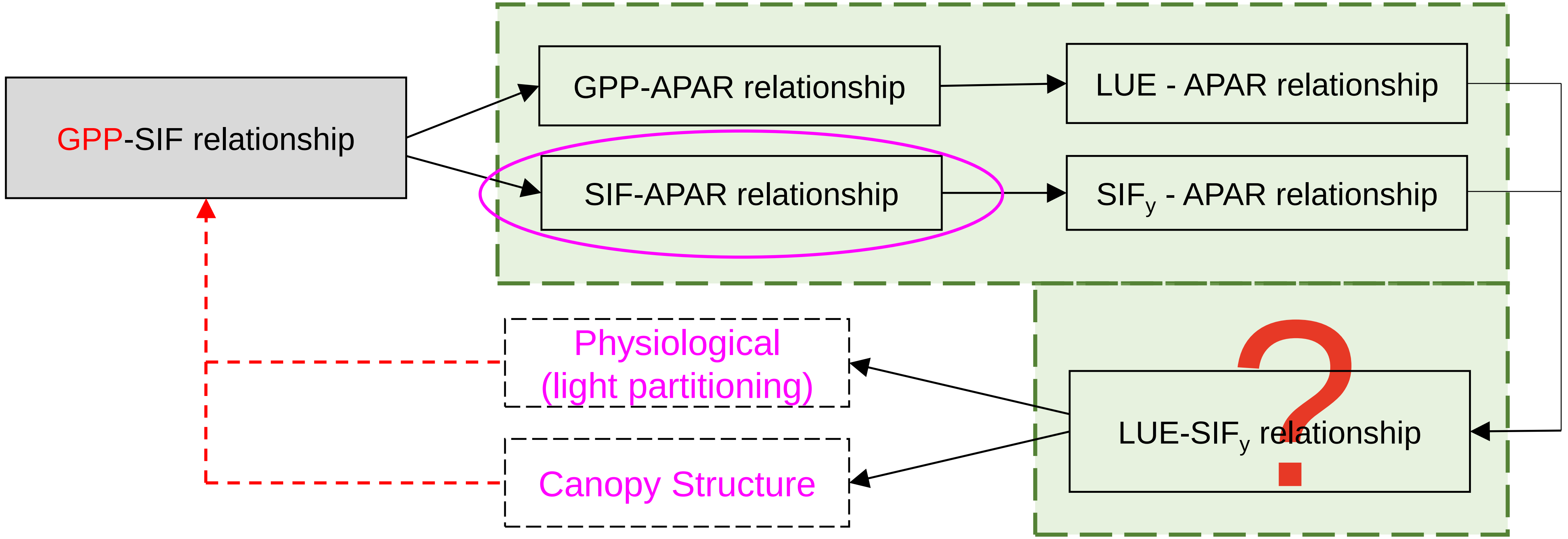
- OceanOptics QEPRO: 730-780 nm (0.04-0.07 nm)
- OceanOptics HR2000+: 400-900 nm (0.42-0.47 nm)



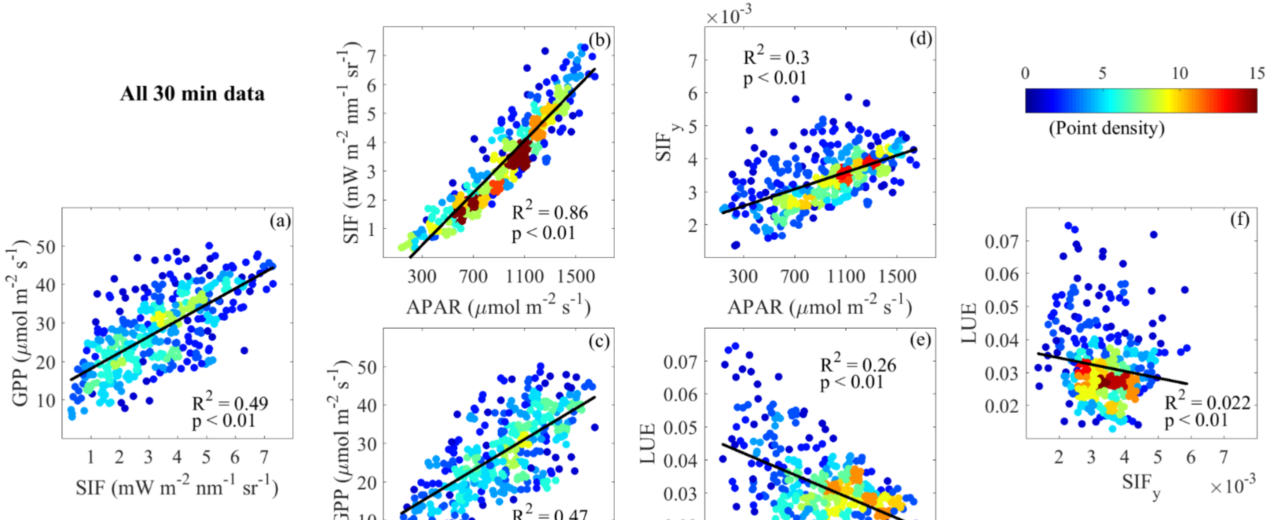
Ground-based SIF

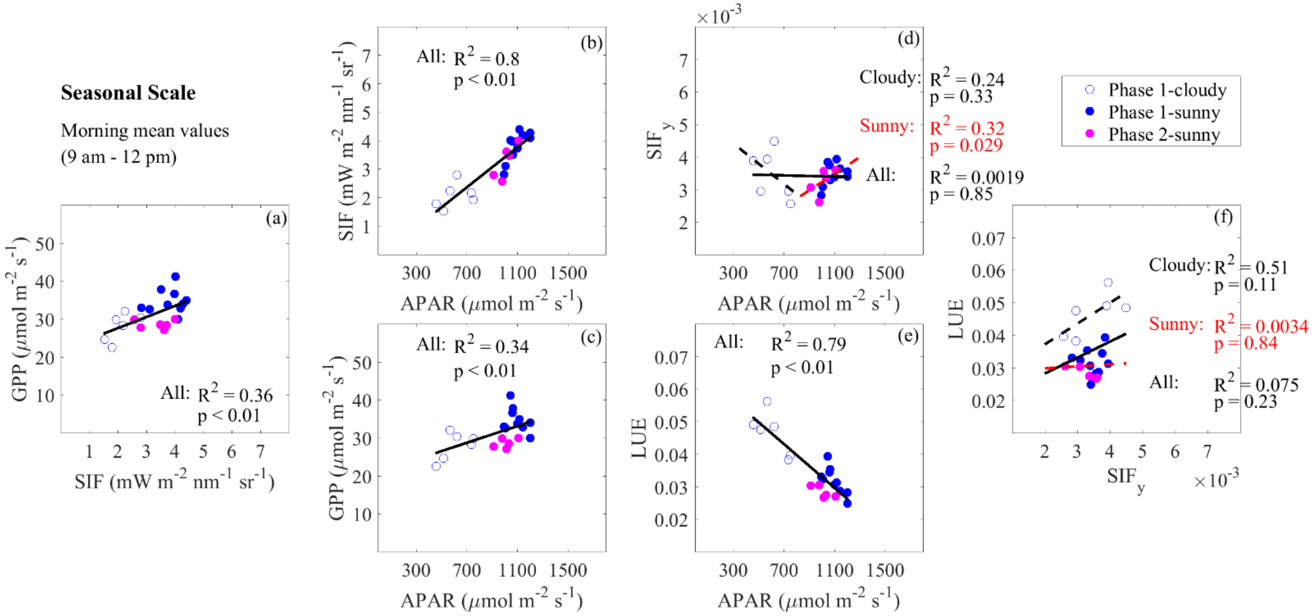
$$GPP = APAR \times LUE$$

$$SIF = APAR \times SIF_y$$



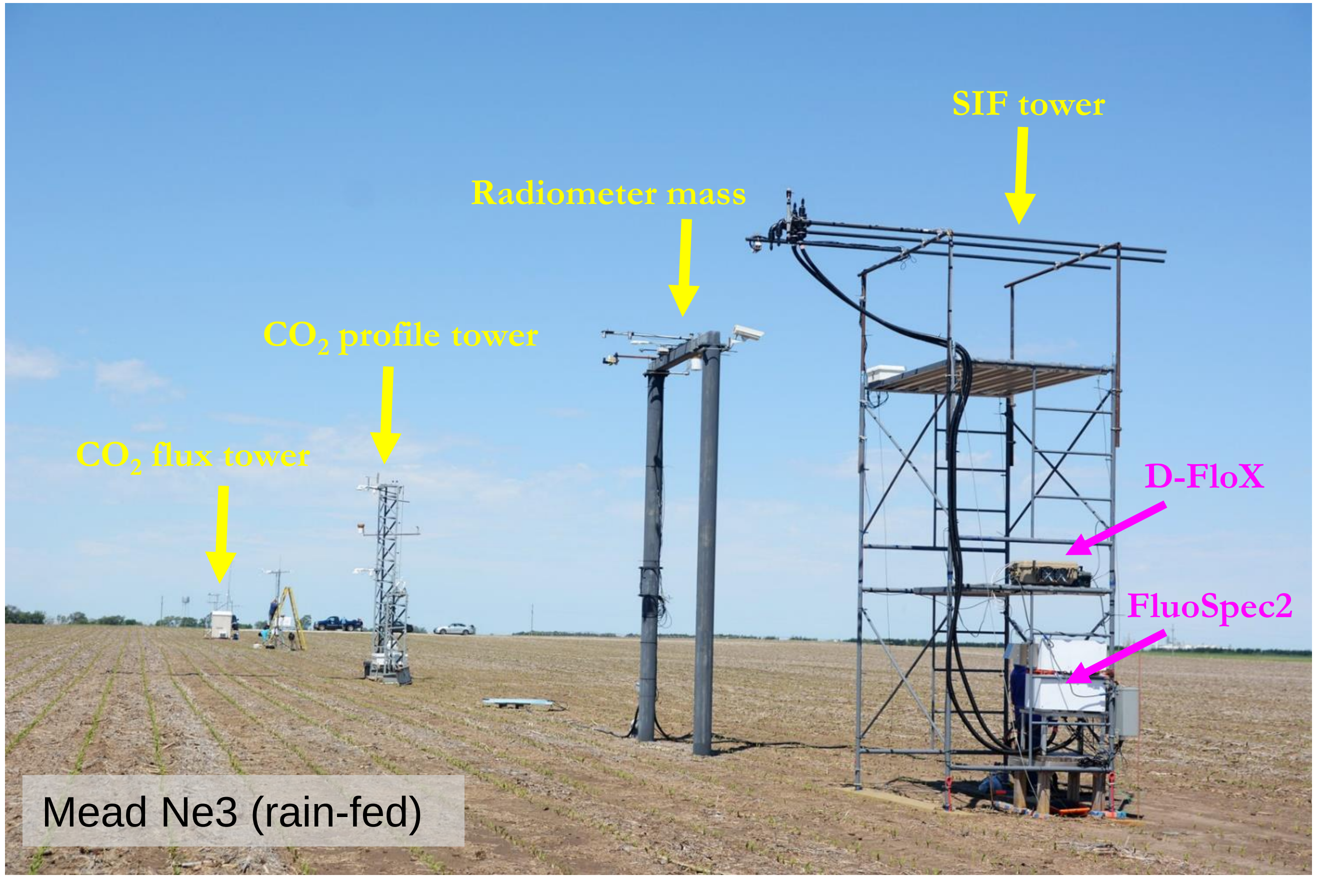
Miao, Guan et al. (In review) Sun-induced fluorescence, photosynthesis, and light-use efficiency of a soybean field.

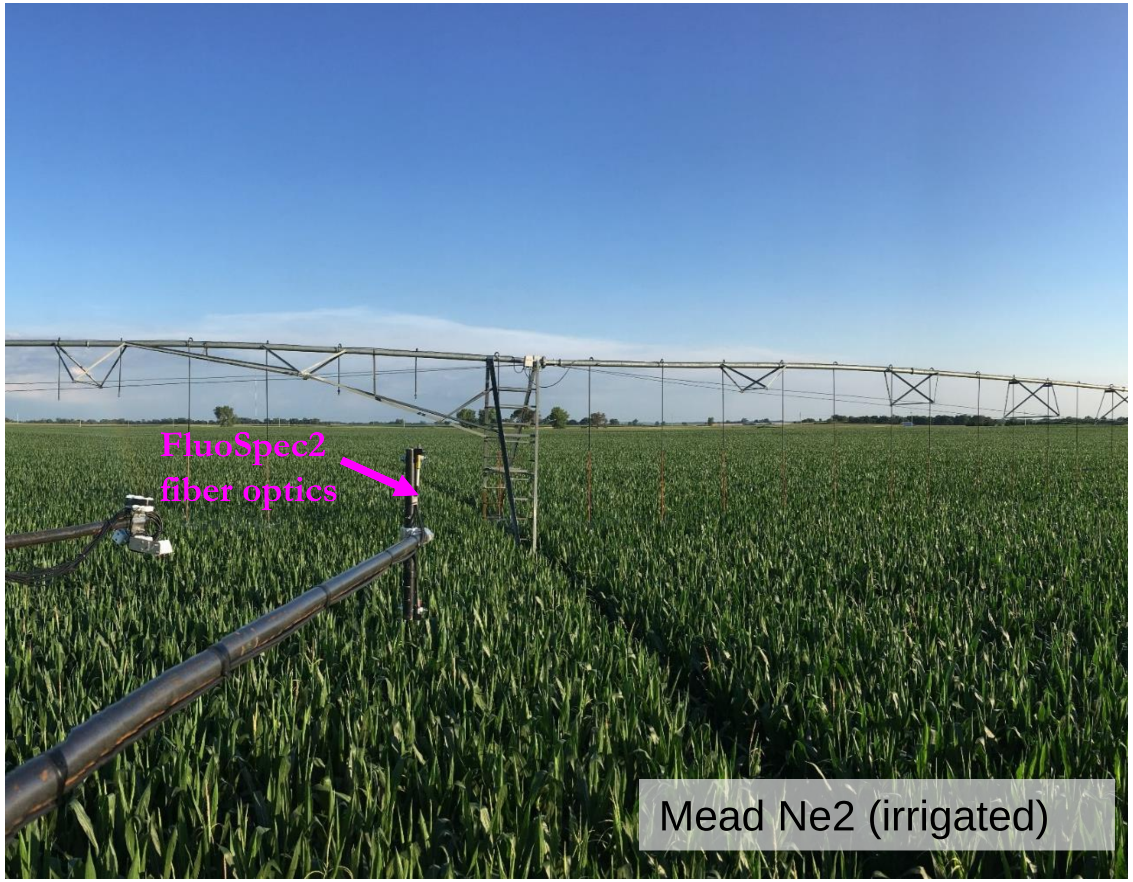




	LUE:APAR	SIF_y:APAR	LUE:SIF_y	Data sources	References
Diurnal scale					
Soybean (sunny)	Negative	Positive	Negative	Ground	This study
Corn			Negative	Ground	Damm et al., 2010
Seasonal scale					
Soybean (cloudy)	Negative	Negative	Weak positive	Ground	This study
Soybean (sunny)	Negative	Positive	Negative	Ground	This study
Temperate forest	Negative	Negative	Positive	Ground	Yang et al., 2015
C_4 Grassland	Positive	Positive	Positive	Satellite	Verma et al., 2017
Diurnal & Extrapolated Seasonal scales					
Soybean & Deciduous broadleaf forest (low light)	Negative	Positive	Negative	SCOPE model	Zhang et al., 2016
Soybean & Deciduous broadleaf forest (high light)*	Negative	Negative	Positive	SCOPE model	Zhang et al., 2016

2017 field deployment

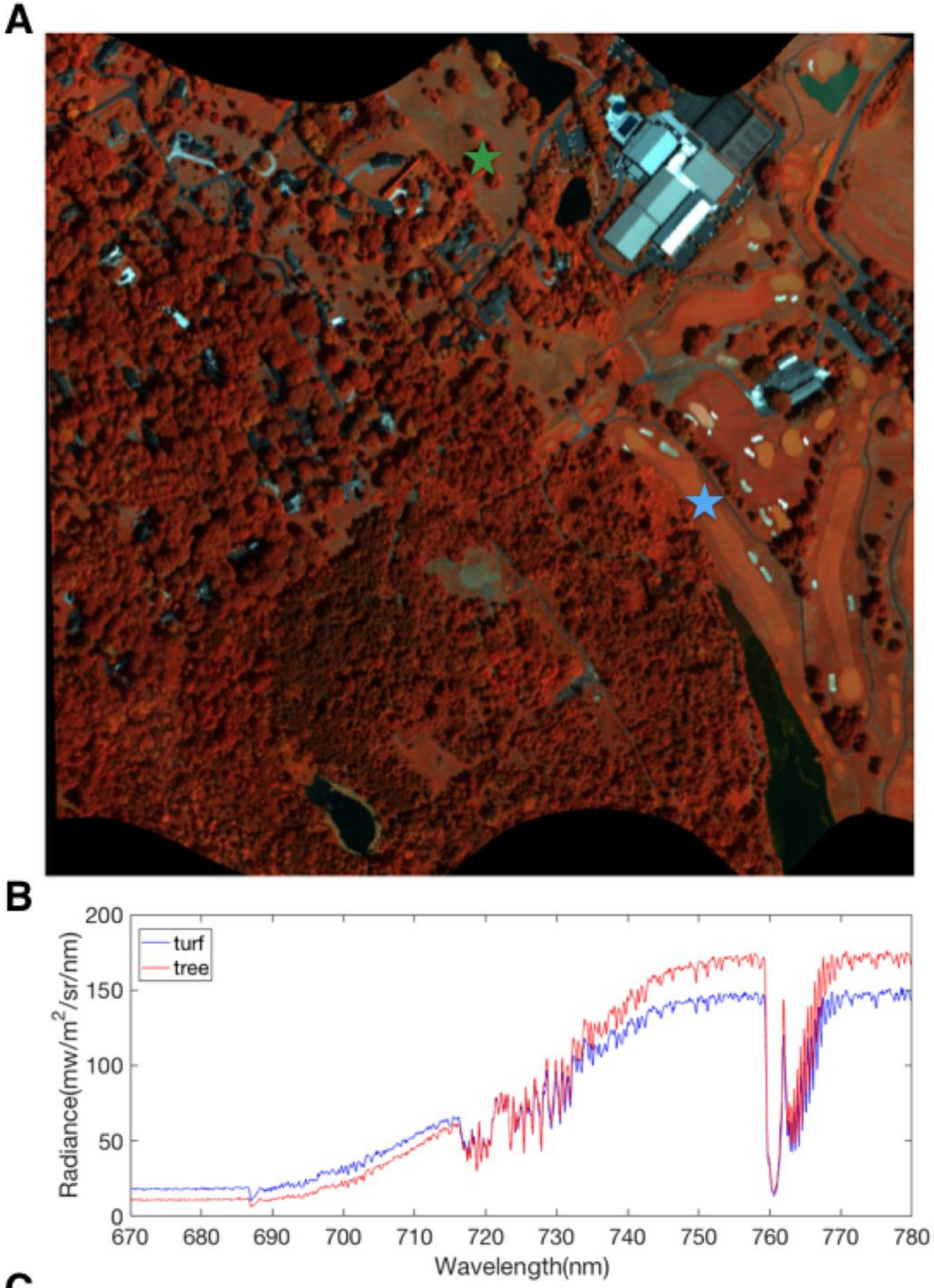




- Compare GPP and SIF, LUE and SIF_y as indications of the difference in maize growth across a water stress gradient.
- Assess the potential of SIF in identifying the growth stages that are mostly affected by water stress.

2018 Plan (Ground + Airborne)

(From Xi Yang)



Ag webcam network

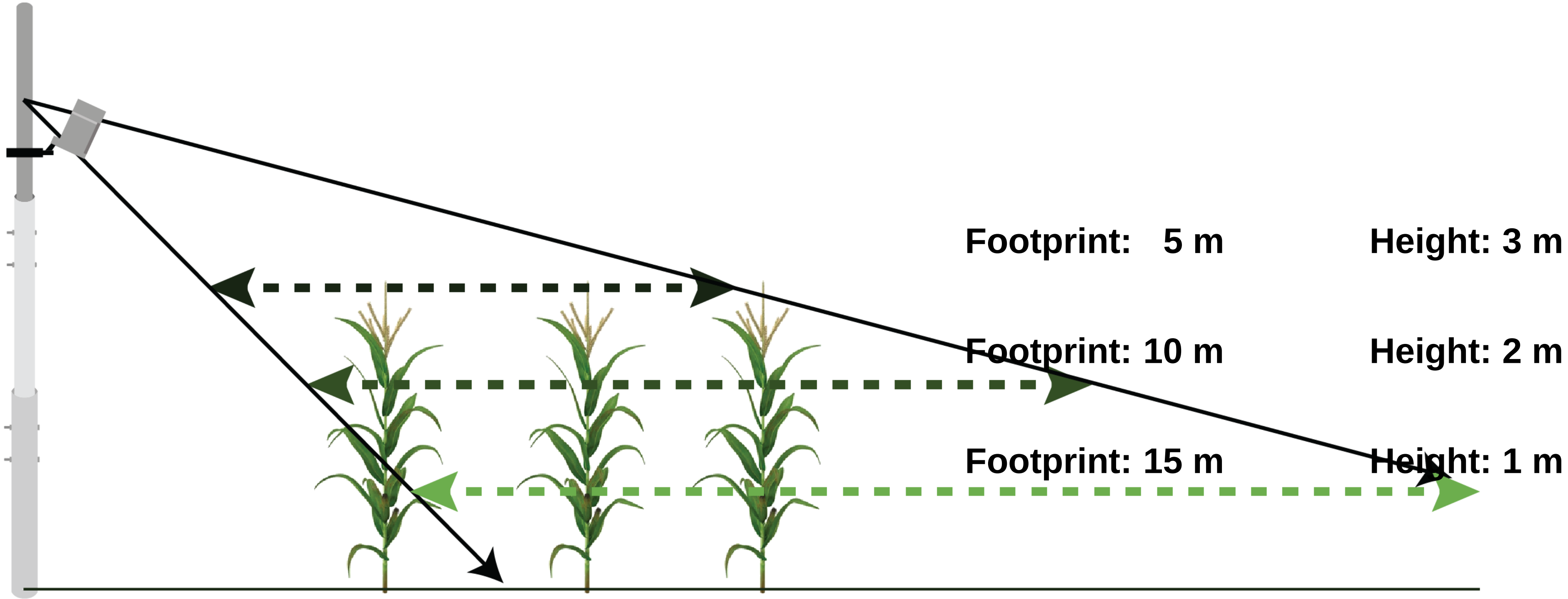
– Hyungsuk Kim (PhD student)

Network of images (for now, 20 corn and 20 soy sites in Champaign county)

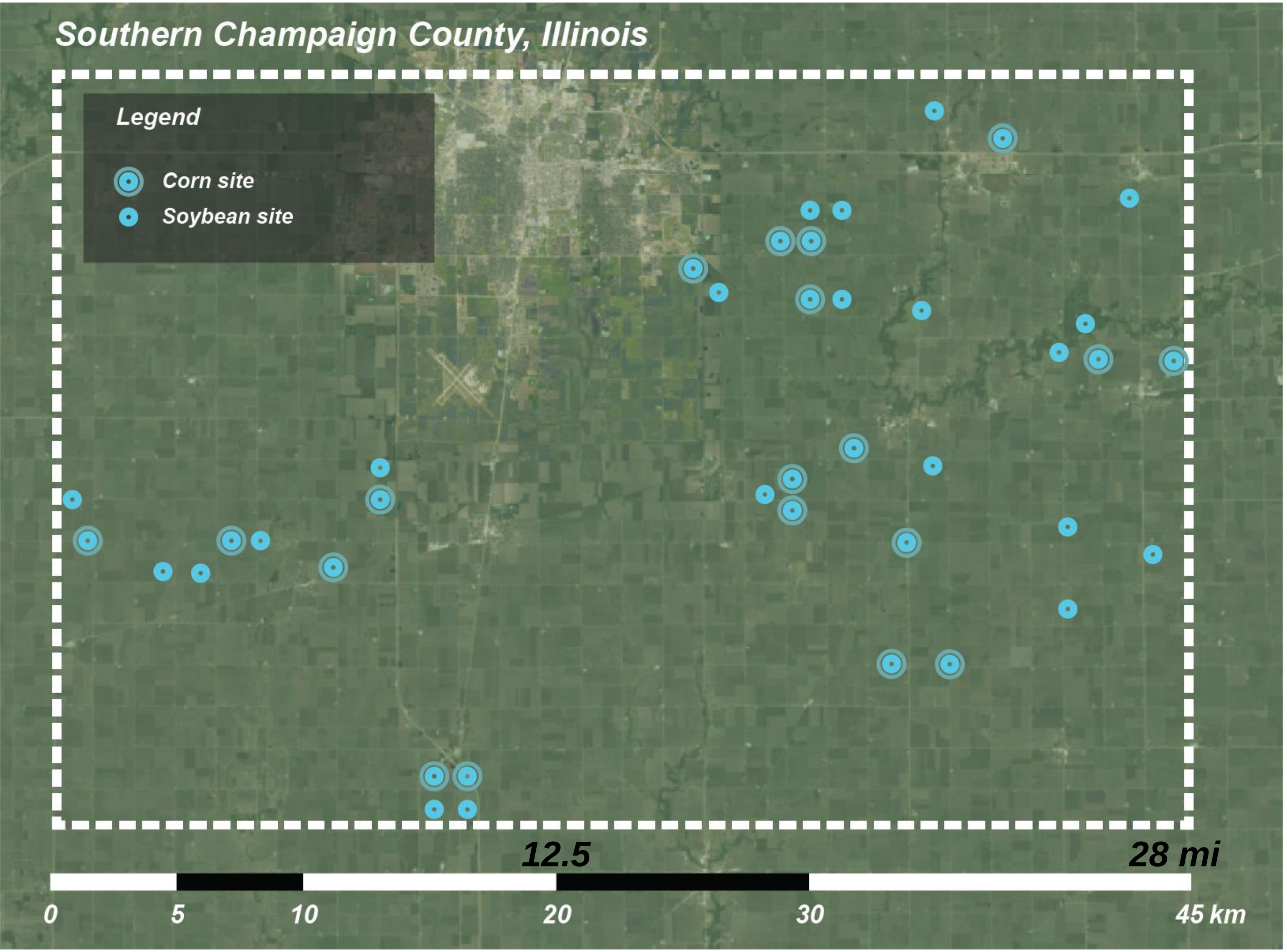
Machine learning/computer vision to identify crop phenology stage and growth condition

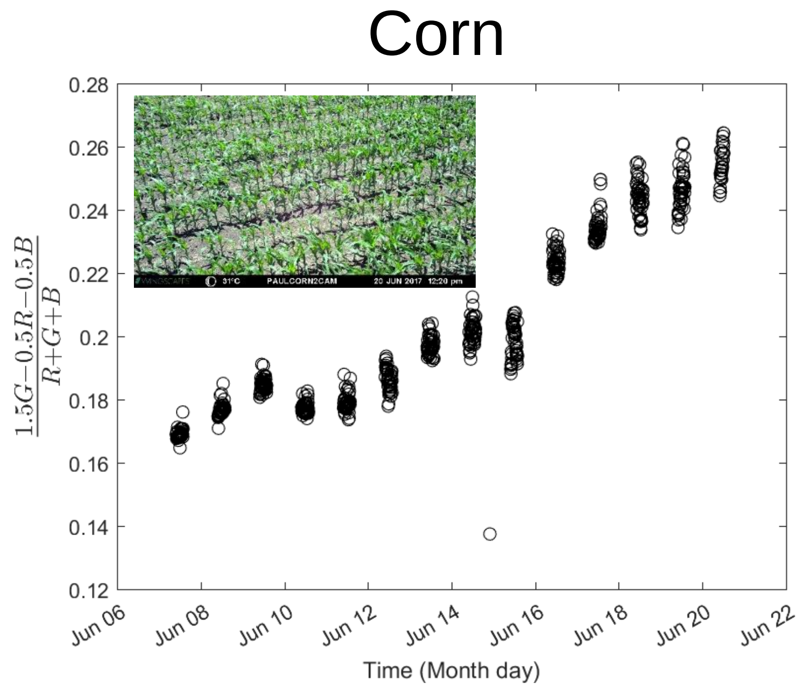
Use these signals to scale up to the whole Champaign county, State of Illinois, and whole Corn Belt

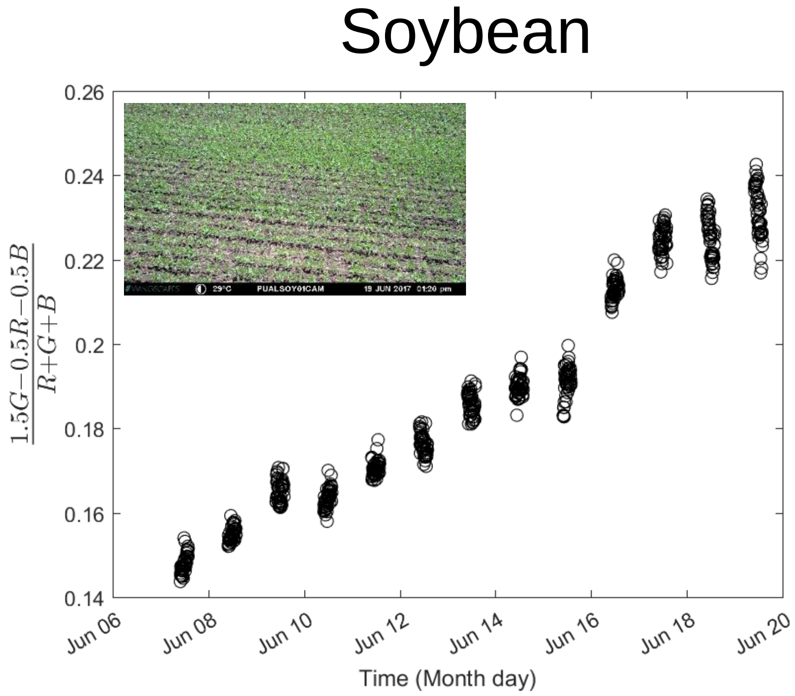
Camera installation



- Southern half of Champaign County, IL
- 21 Soybean, 19 Corn sites

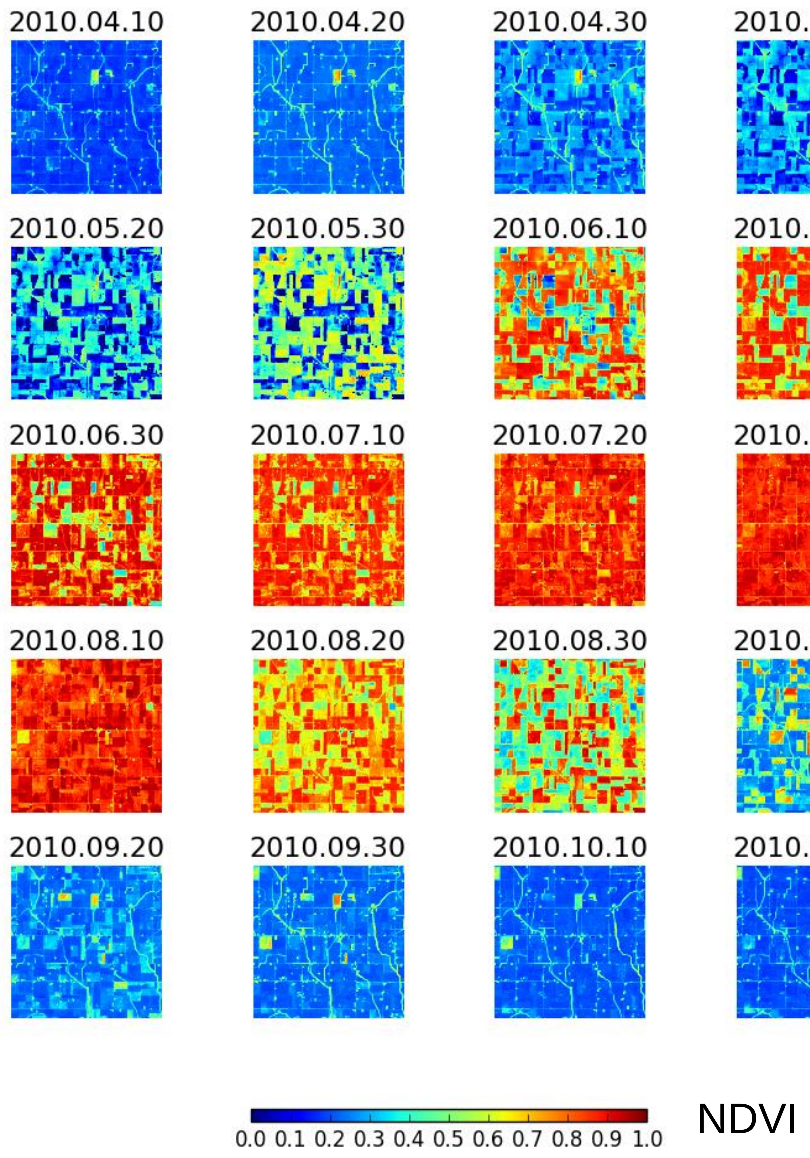




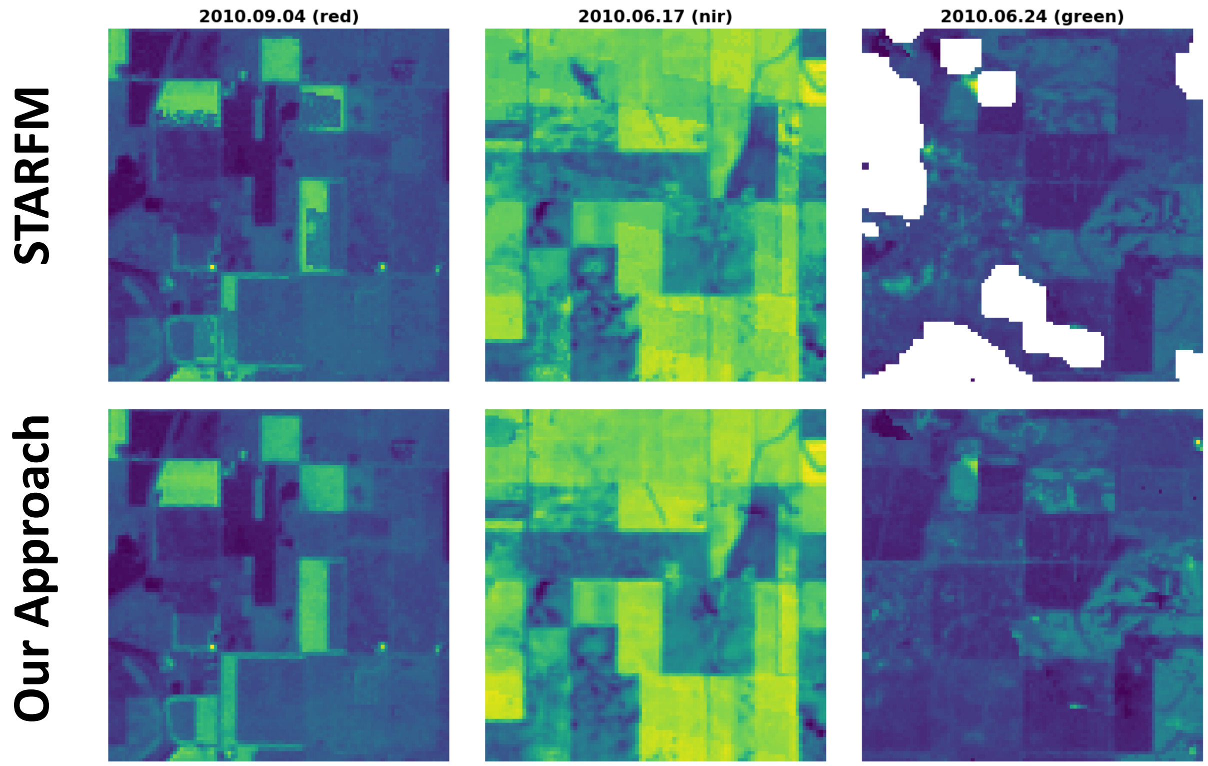


High-resolution satellite fusion and field-level mapping

- Yunan Luo (PhD student)



High frequency, high resolution, cloud- and gap-free reflectance



Luo, Guan, Peng. (In Review) “A generic method to fuse multiple sources of multi-spectral satellite data to generate high-resolution, daily and cloud-free data - the case for fusing MODIS and Landsat”

Regional crop yield mapper

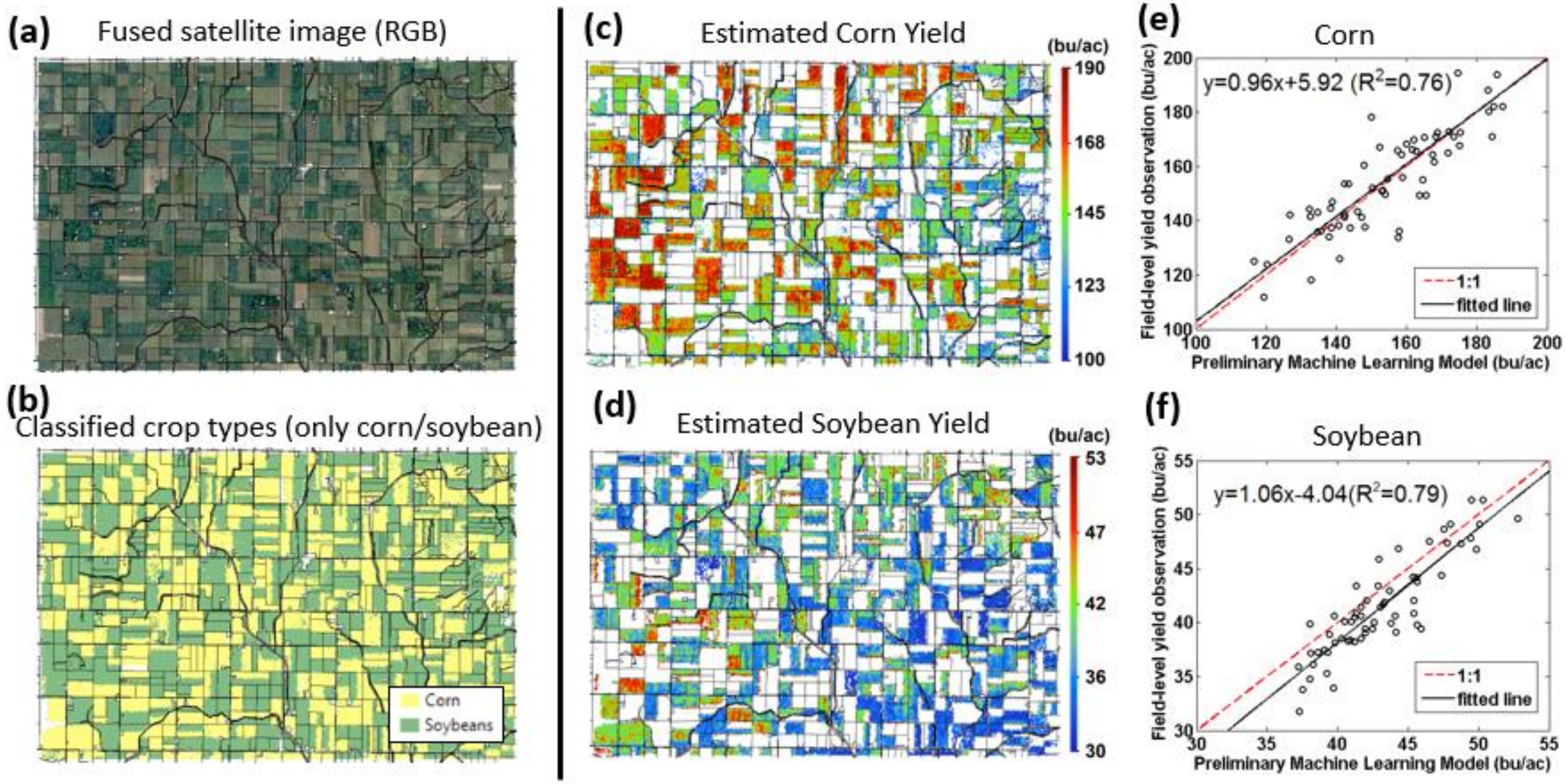
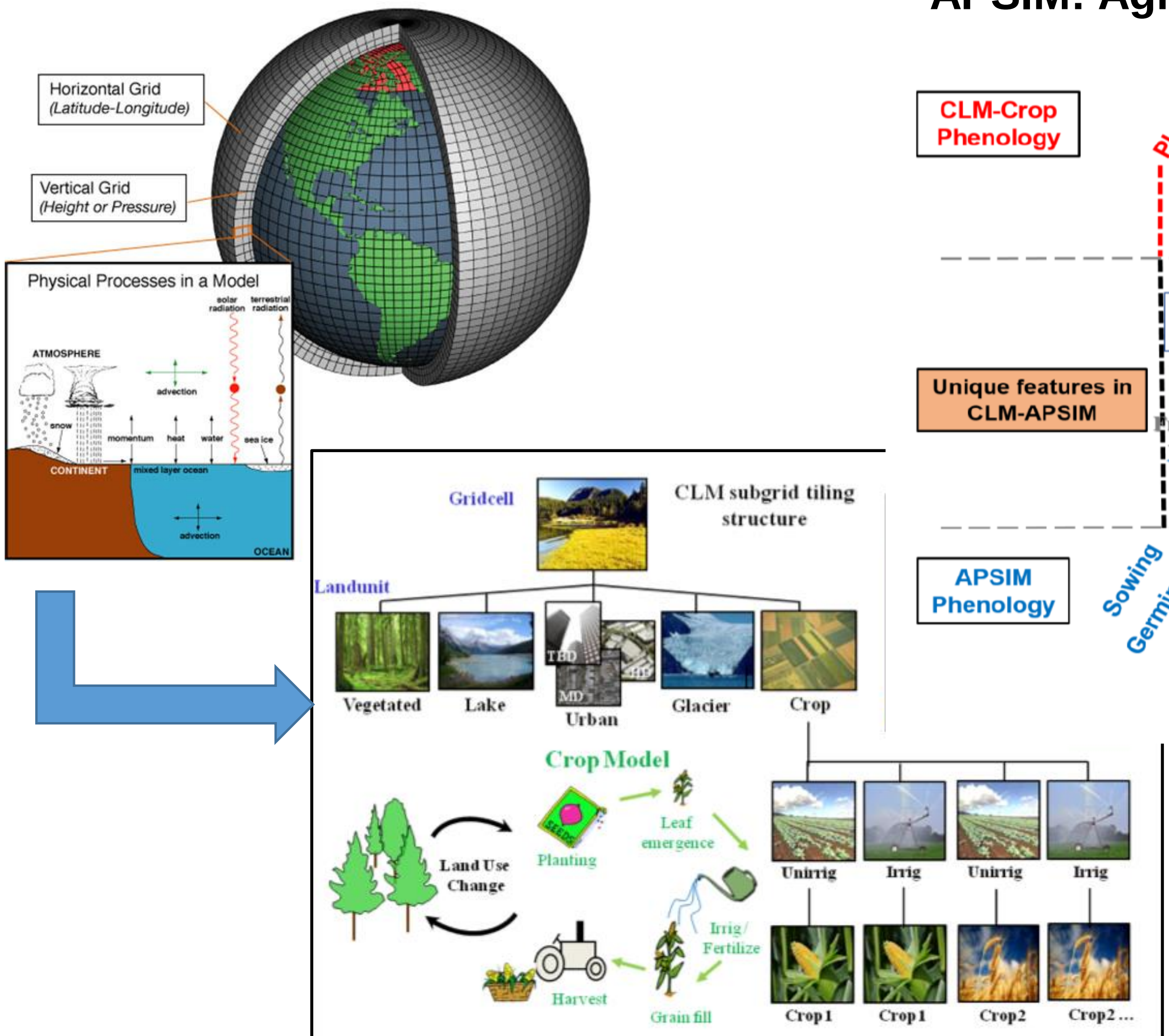


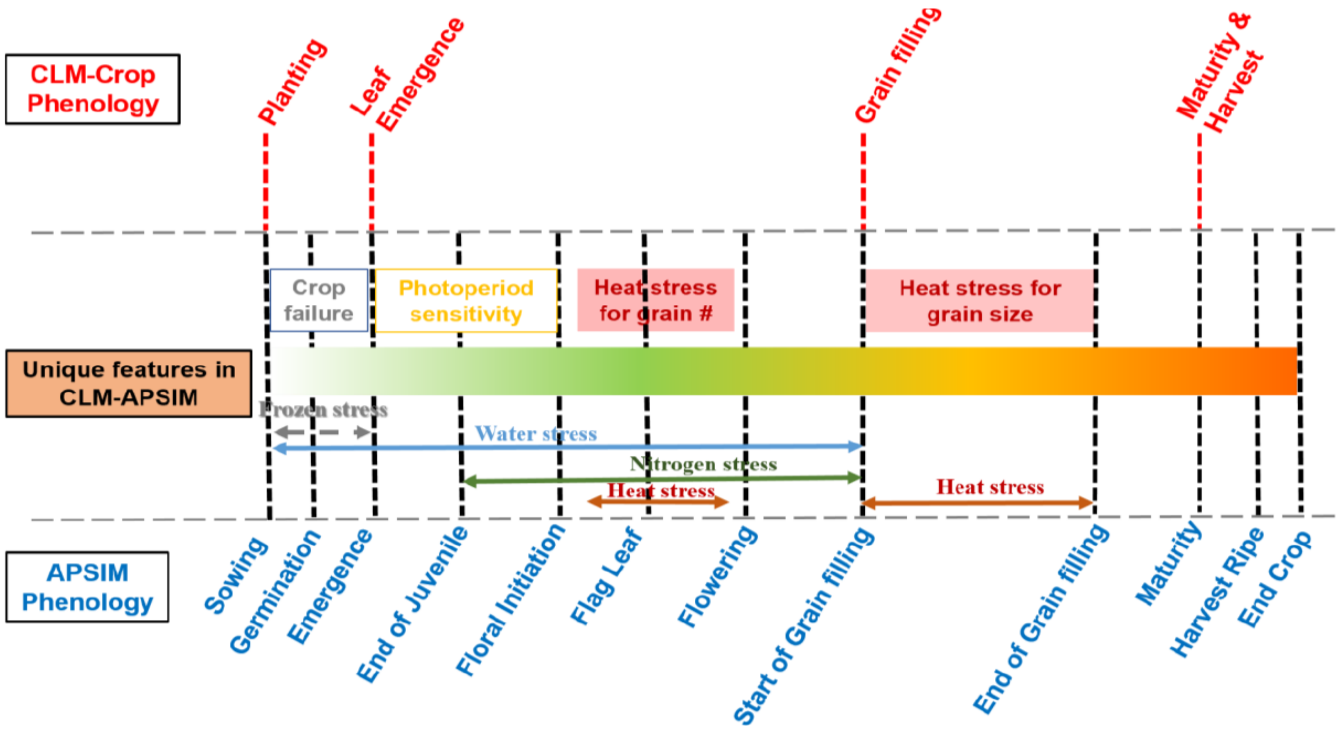
Fig. 4. A snapshot of the preliminary results for Champaign County, IL. (a) Landsat/MODIS fused satellite images for Aug 15, 2013, shown in the true color; (b) classified crop types for 2013; (c,d) estimated crop yield of 2013 for corn and soybean, respectively; (e,f) comparison between model and observation yield for corn and soybean on the test data for the whole County, respectively.

Luo, Guan, Peng. (In Review) “A generic method to fuse multiple sources of multi-spectral satellite data to generate high-resolution, daily and cloud-free data - the case for fusing MODIS and Landsat”

Coupling CLM with APSIM for large-scale crop/biofuel yield forecasting and climate change impact study - Bin Peng (Postdoc)

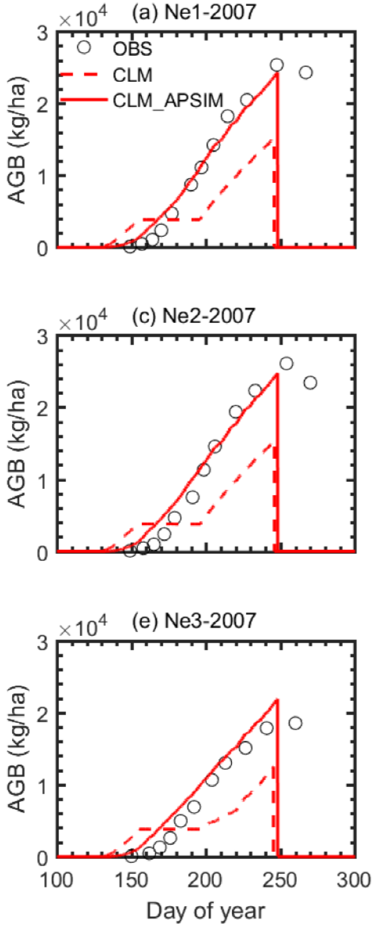


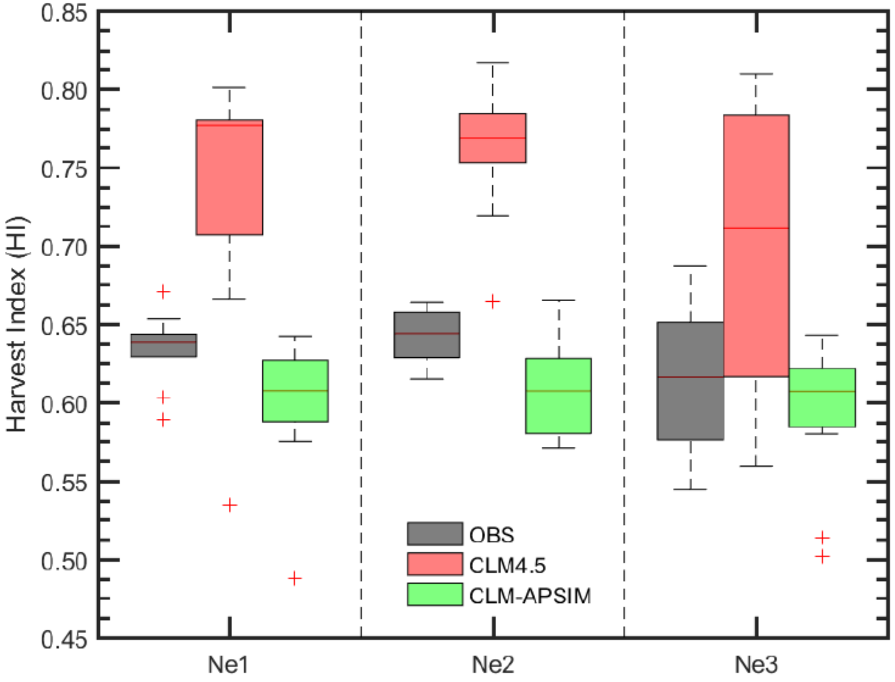
APSIM: Agricultural Production Systems sIMulator

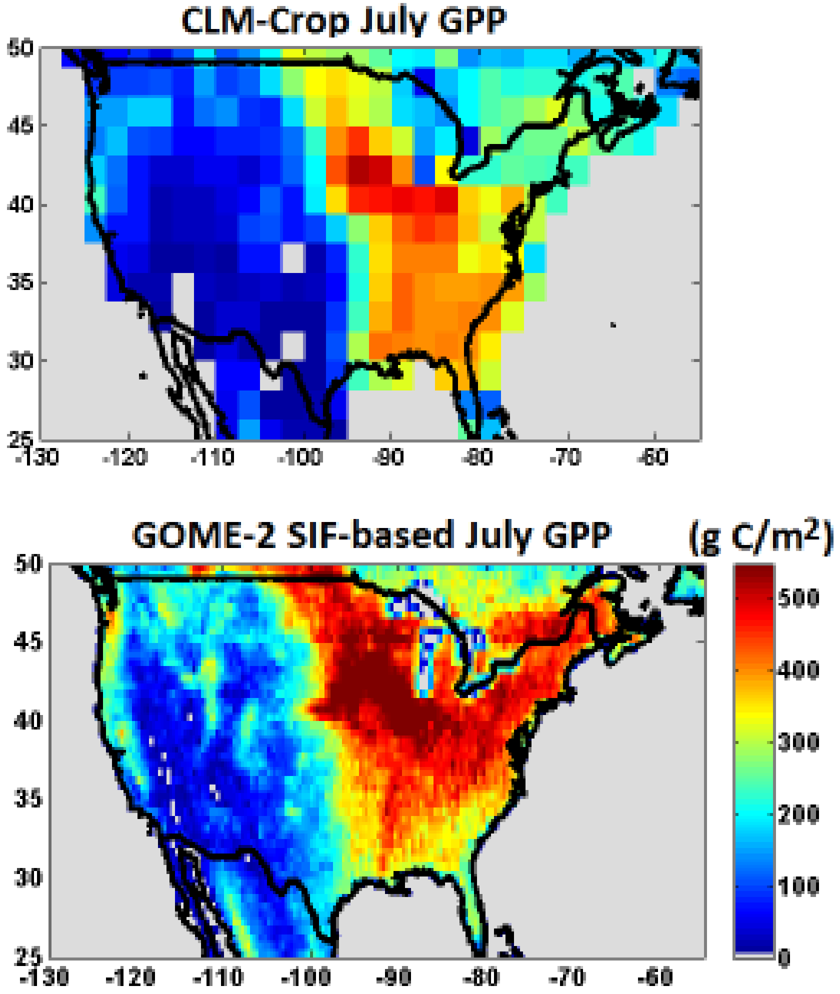


Peng, Guan et al., "Improving the maize growth processes in the Community Land Model: implementation and evaluation", accepted.

Coupling CLM with APSIM for large-scale crop/biofuel yield forecasting and climate change impact study - Bin Peng (Postdoc)







Peng, Guan et al., “Improving the maize growth processes in the Community Land Model: implementation and evaluation”, accepted.

Thanks!

Integrating field work, satellite, and supercomputing for monitoring and modeling crop production at continental scales

Dr. Kaiyu Guan
(kaiyug@Illinois.edu)
Nature Resources and Environmental Sciences & National Center for Supercomputing Applications, University of Illinois at Urbana Champaign