Remote sensing of photosynthesis: Challenges and opportunities

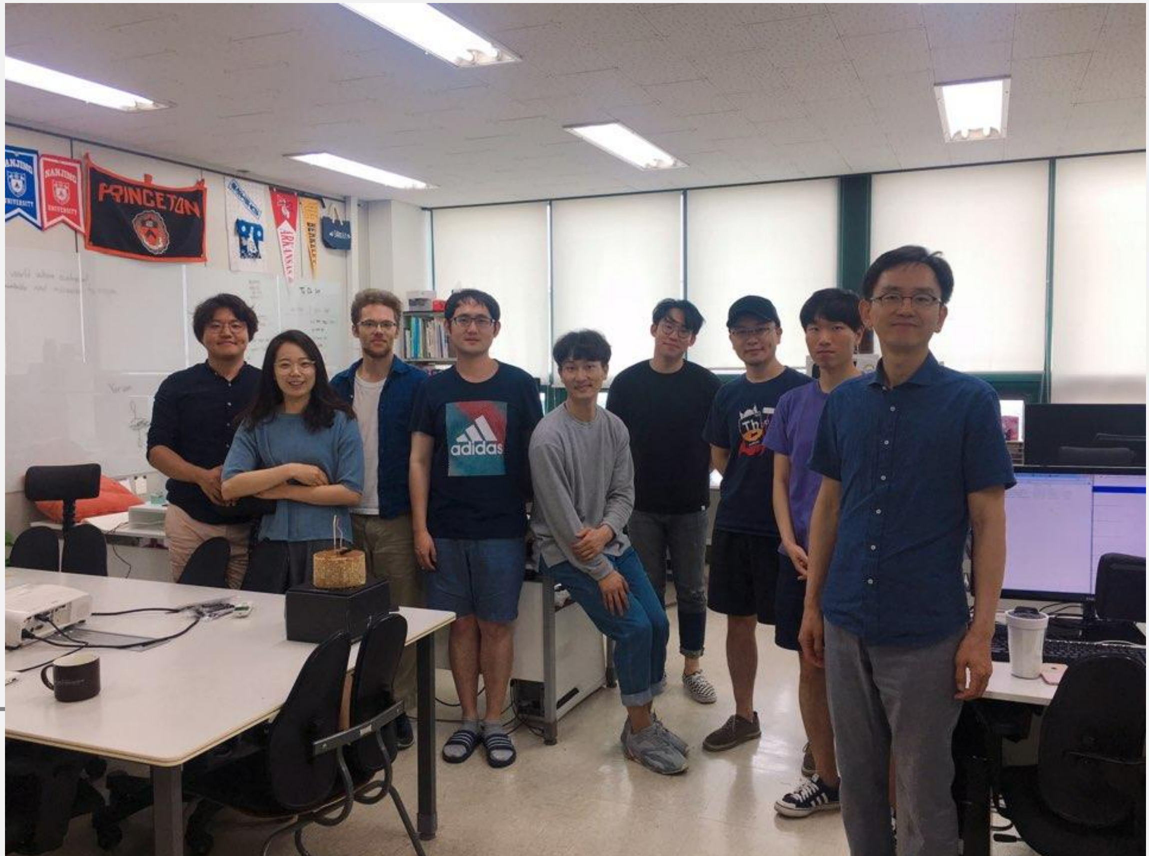
Youngryel Ryu, Ph.D.

ECOPROPHET
13 Sep 2019

서울대학교
SEOUL NATIONAL UNIVERSITY

Acknowledgements

- Rasmus Houborg at Planet Labs
- Dennis Baldocchi at UC Berkeley
- Joe Berry/Grayson Badgley/Yelu Zeng at Carnegie
- Minseok Kang at NCAM

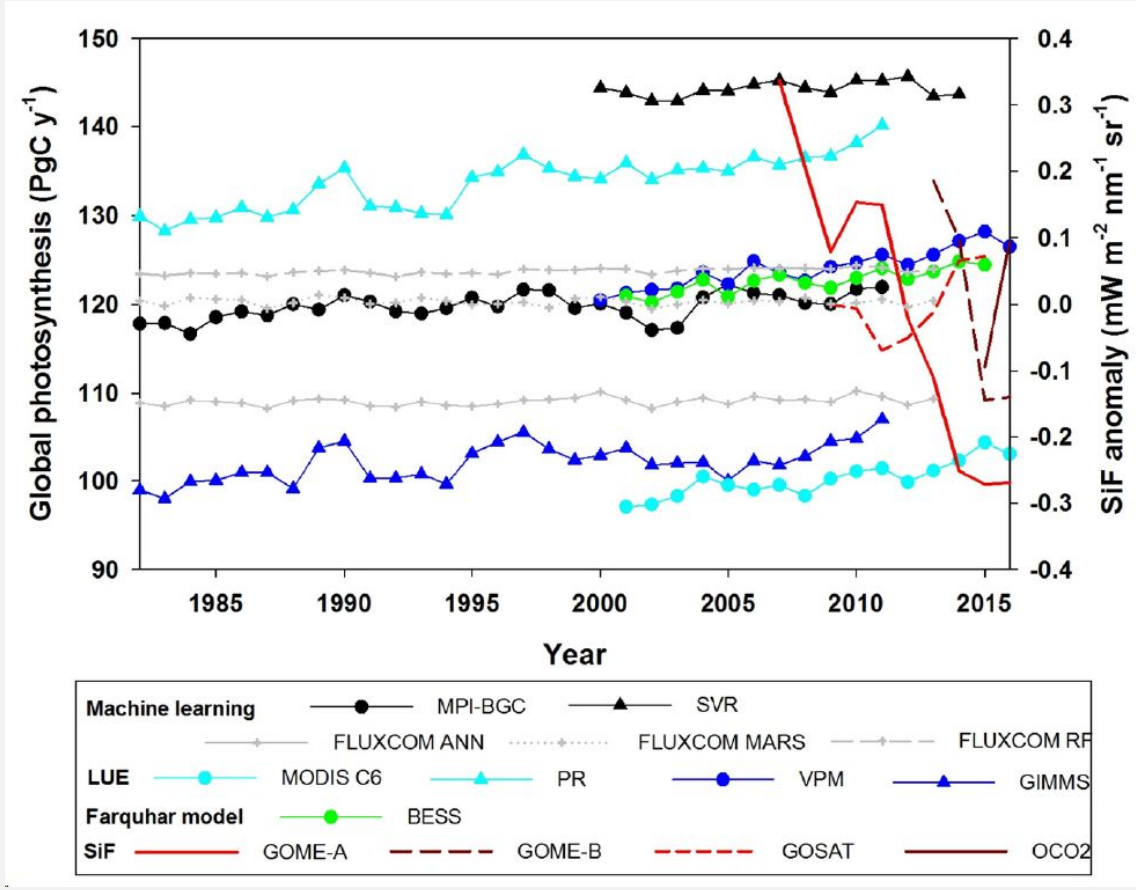


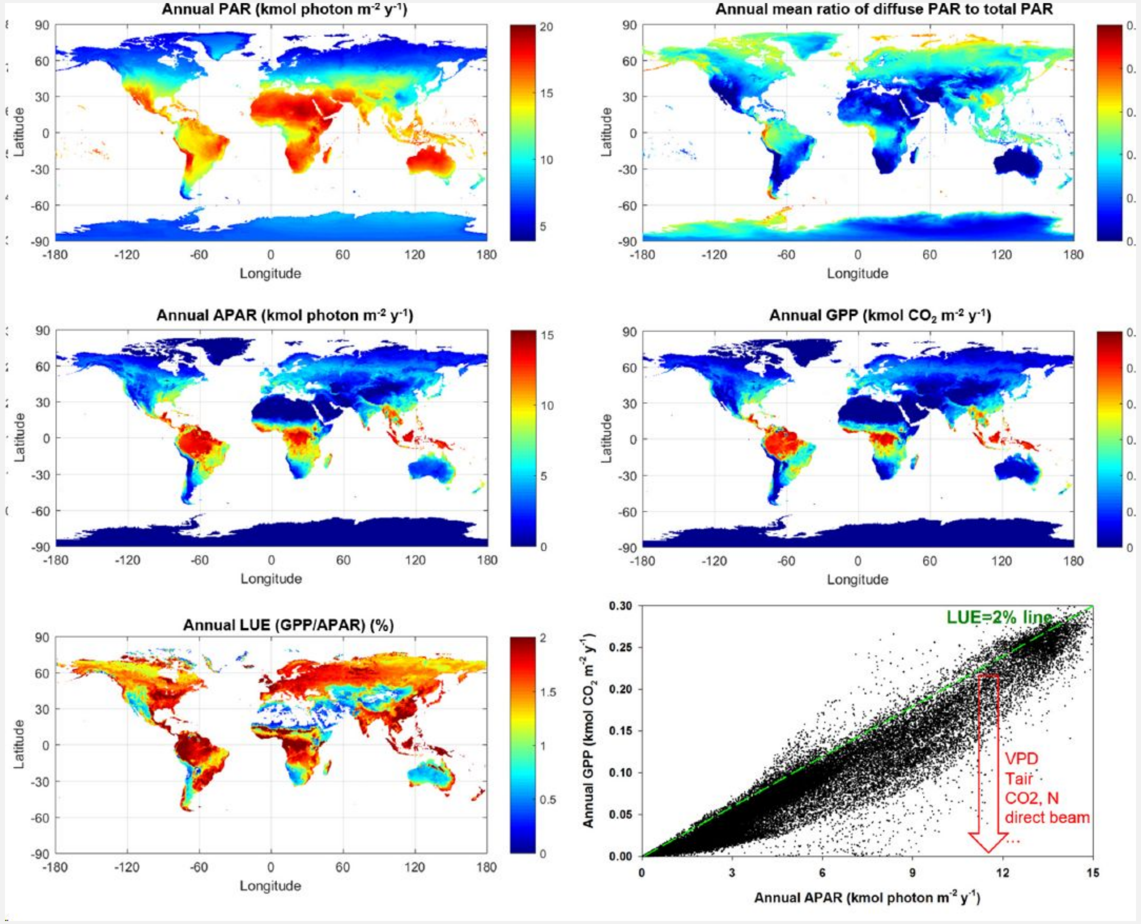
SNU Lab members

ENVIRONMENTAL ECOLOGY LAB
SEOUL NATIONAL UNIVERSITY

Towards global photosynthesis everywhere, all of the time

What will be ECOPROPHET global GPP?





Ryu, Berry, Baldocchi (2019) Remote Sensing of Environment

SiF as a proxy of GPP

New global observations of the terrestrial carbon cycle from GOSAT: Patterns of plant fluorescence with gross primary productivity

Christian Frankenberg,[1] Joshua B. Fisher,[1] John Worden,[1] Grayson Badgley,[1] Sassan S. Saatchi,[1] Jung-Eun Lee,[1] Geoffrey C. Toon,[1] André Butz,[2] Martin Jung,[3] Akihiko Kuze,[4] and Tatsu

Global Change Biology

Global Change Biology (2015) 21, 4673–4684, doi: 10.1111/gcb.13017

TECHNICAL ADVANCE

Sun-induced fluorescence – a new probe of photosynthesis: First maps from the imaging spectrometer *HyPlant*

U. RASCHER[1], L. ALONSO[2], A. BURKART[1], C. CILI
A. DAMM[4], M. DRUSCH[5], L. GUANTER[6], J. HANUS
J. JUSSILA[8], K. KATAJA[8], P. KOKKALIS[9], S. KRAFT
J. MORENO[2], O. MULLER[1], C. PANIGADA[3], M. PIK
M. ROSSINI[3], A. SCHICKLING[1], U. SCHURR[1], D. SC
F. ZEMEK[7]

OCO-2 advances photosynthesis observation from space via solar-induced chlorophyll fluorescence

Y. Sun,[1*†] C. Frankenberg,[2,1*] J. D. Wood,[3] D. S. Schimel,[1] M. Jung,[4] L. Guanter,[5] D. T. Drewry,[1,6] M. Verma,[7] A. Porcar-Castell,[8] T. J. Griffis,[9] L. Gu,[10] T. S. Magney,[1] P. Köhler,[2] B. Evans,[11] K. Yuen[1]

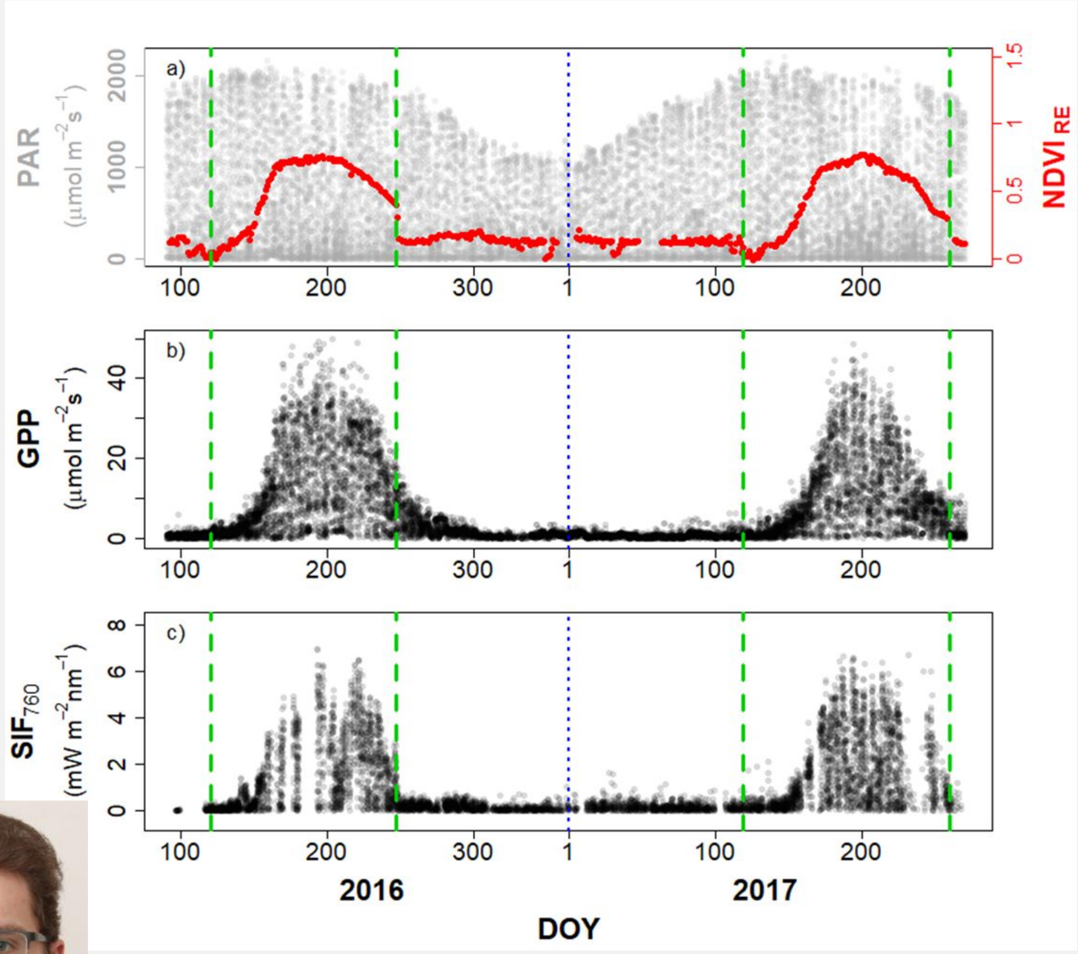
Spectral super site
-Cherwon rice paddy site in KoFlux-

Flux tower: 10 m
Spectral sensors:

- SiF (730-780 nm)
- VIS-NIR (400-900 nm)
- LEDs X micro-cameras
- ASD FieldSpec

Eddy covariance system: CO_2, H_2O, CH_4

Data is open to public!



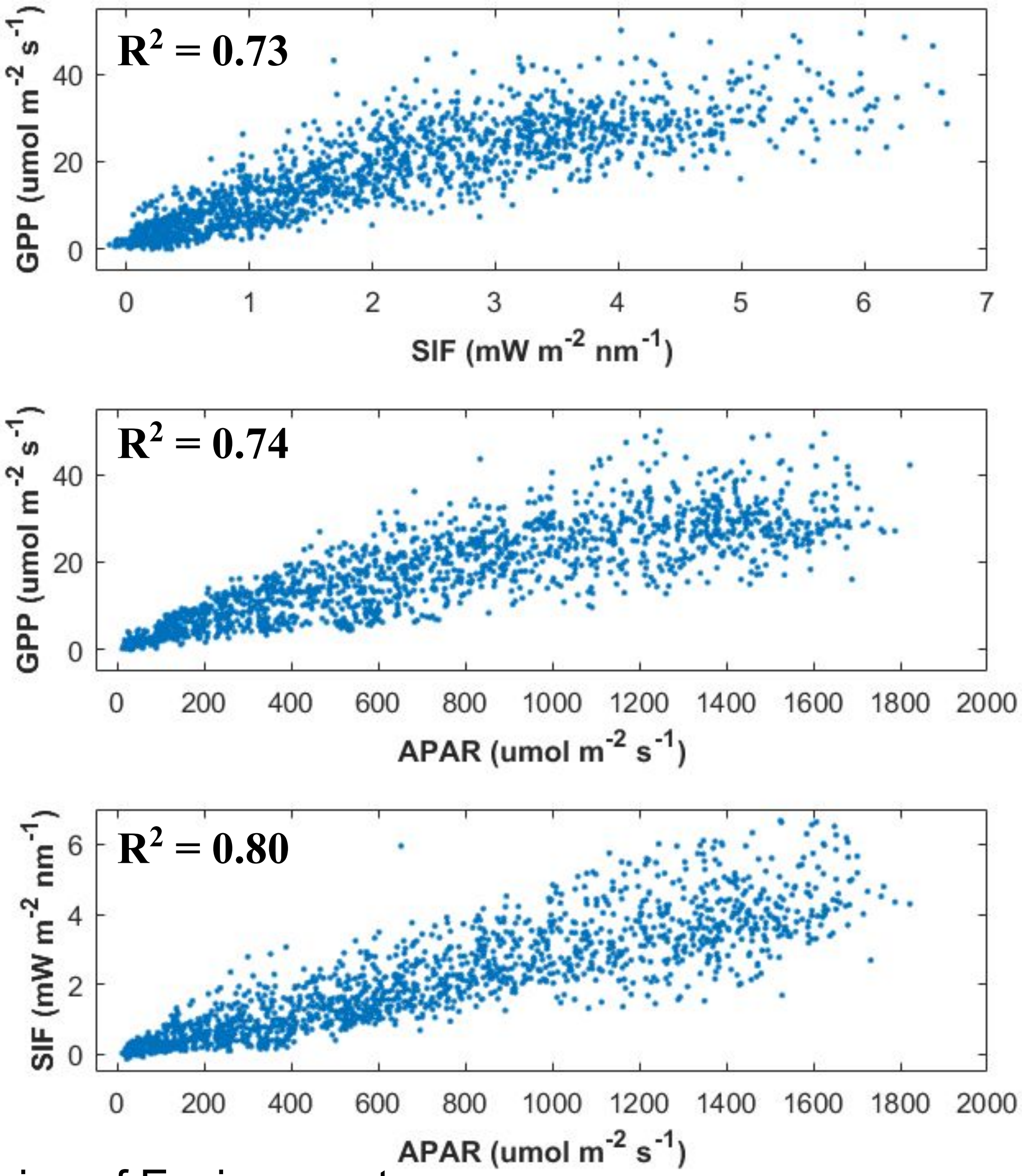
- Goldmine to explore relationships between GPP, SiF, APAR
- VNIR hyperspectral data available too
- Continuous until now

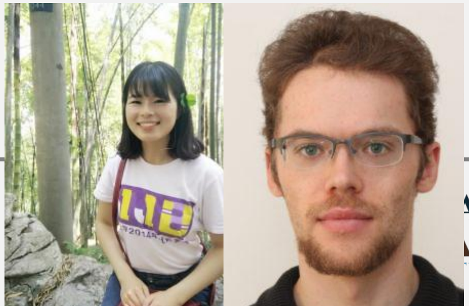
IRONMENTAL
OLOGY LAB
NATIONAL UNIVERSITY

Dechant et al (revised) Remote Sensing of Environment

SiF~APAR, not GPP

- SiF is a better proxy for APAR than GPP
- To convert SiF to GPP, one has to know light use efficiency (=GPP/APAR)
- Back to John Monteith's light use efficiency approach

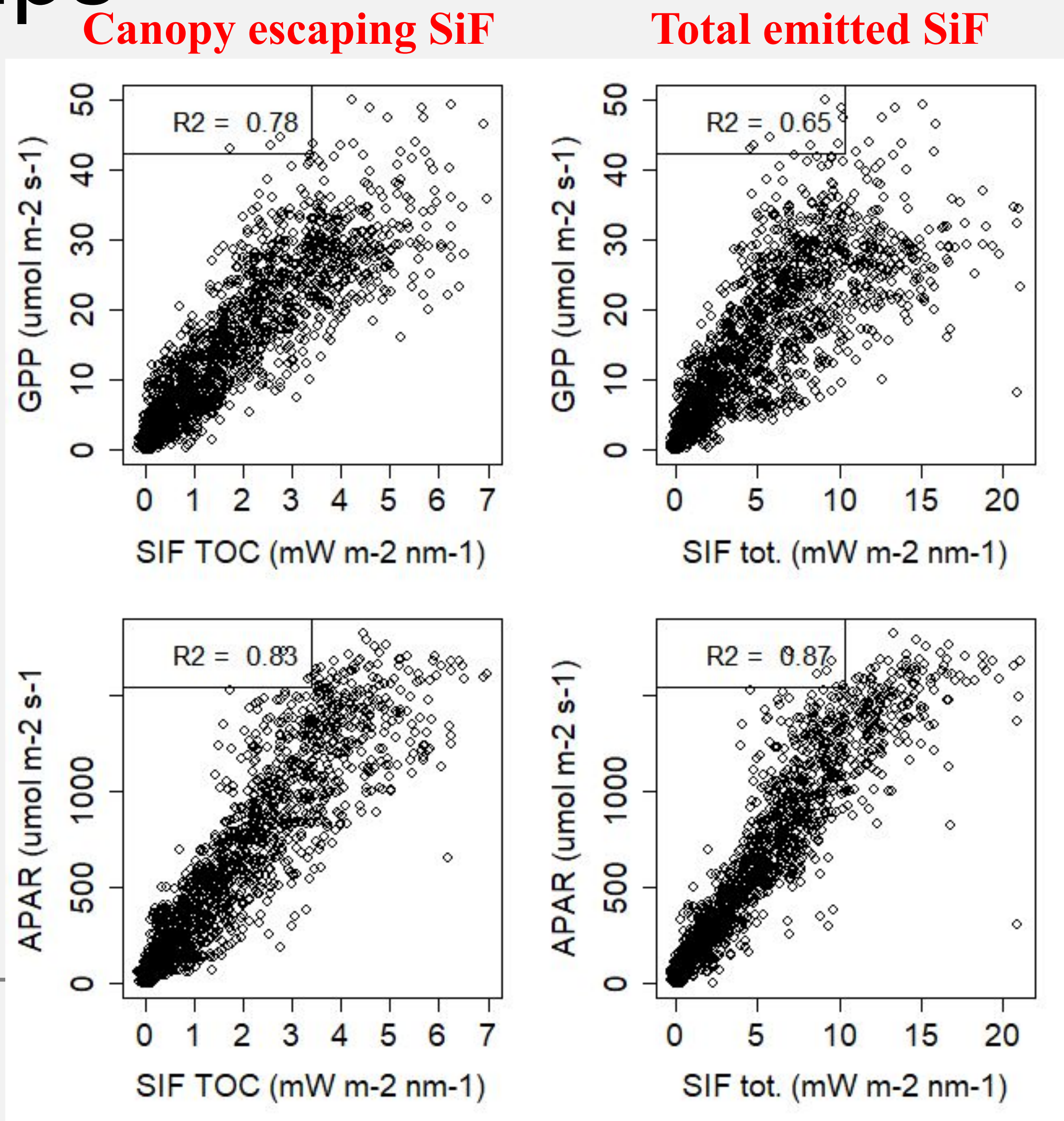




Yang et al., (2018) Remote Sensing of Environment

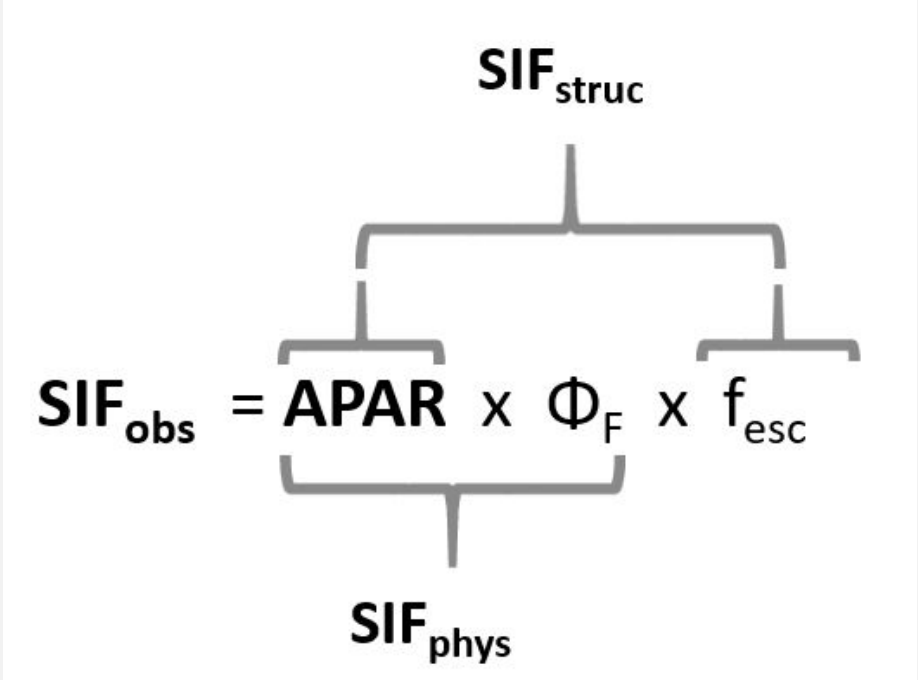
Escape ratio do not help in improving SIF:GPP relationships

- Escape ratio (~NIRv/fPAR) helped improving APAR:SiF relationship
- But, SiF:GPP relationship became poorer!
- Further supports SiF~APAR, not SiF~GPP



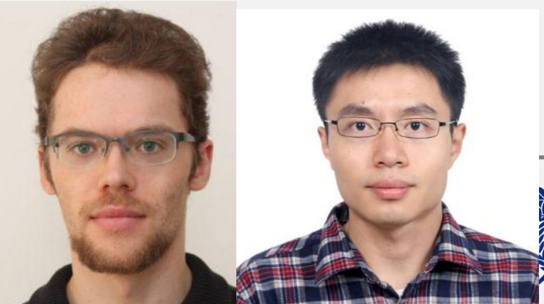
Dechant et al (revised) Remote Sensing of Environment

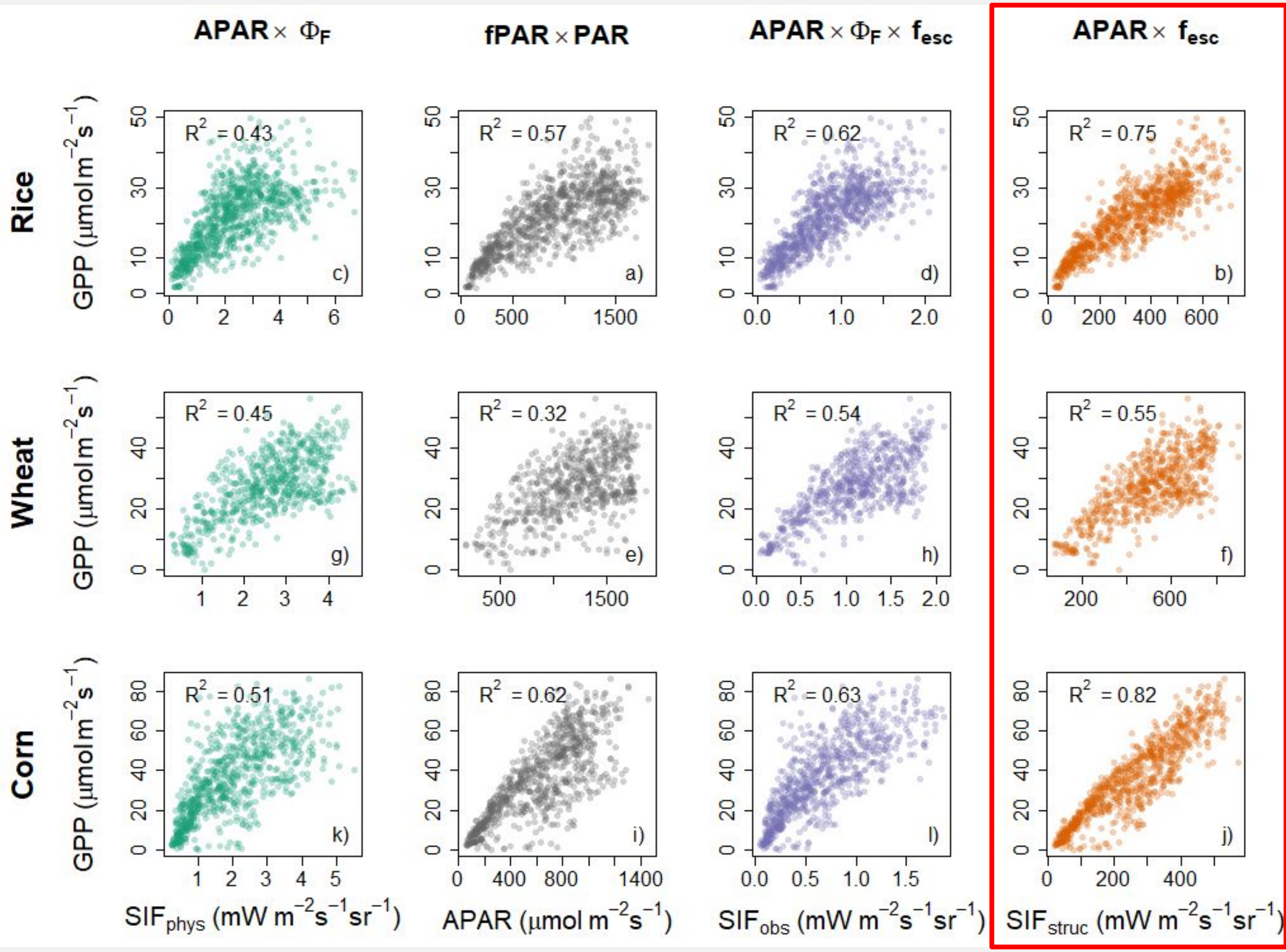
We extended to three major crops field datasets -same answer: APAR*fesc predicts GPP best-



Fesc=NIRv/fPAR (Zeng et al 2019 RSE)

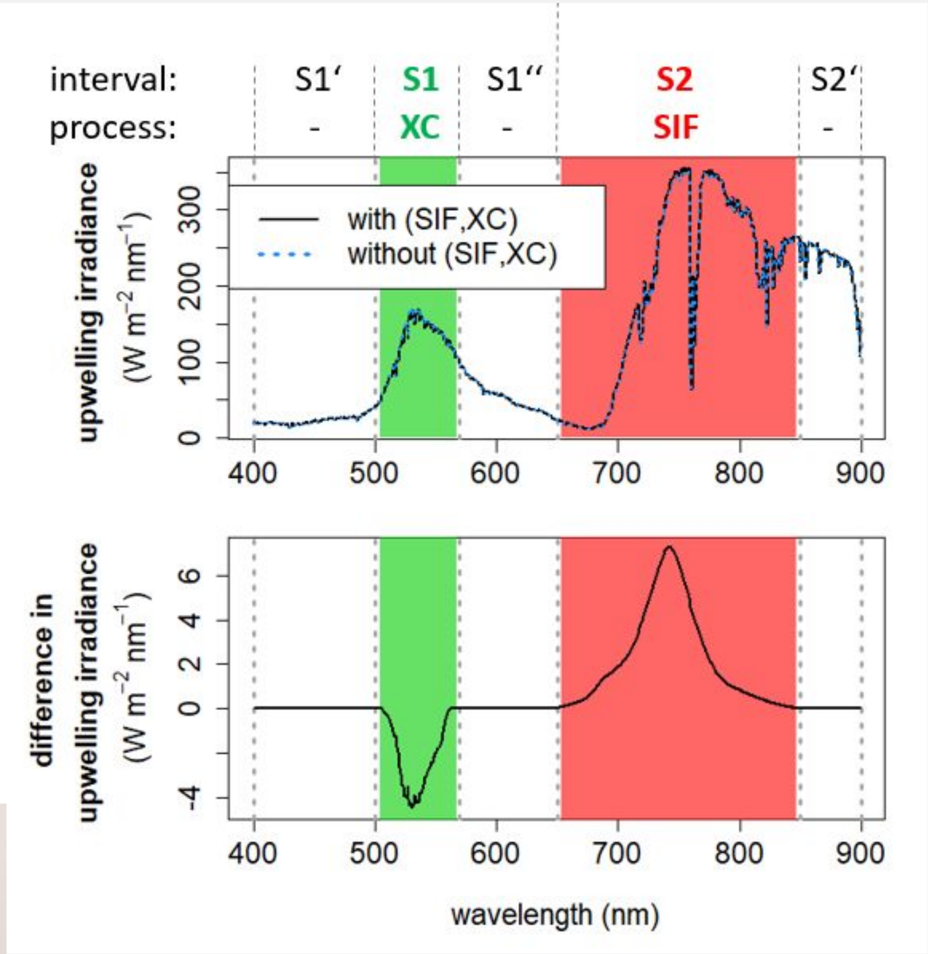
APAR*fesc=NIRv*PAR

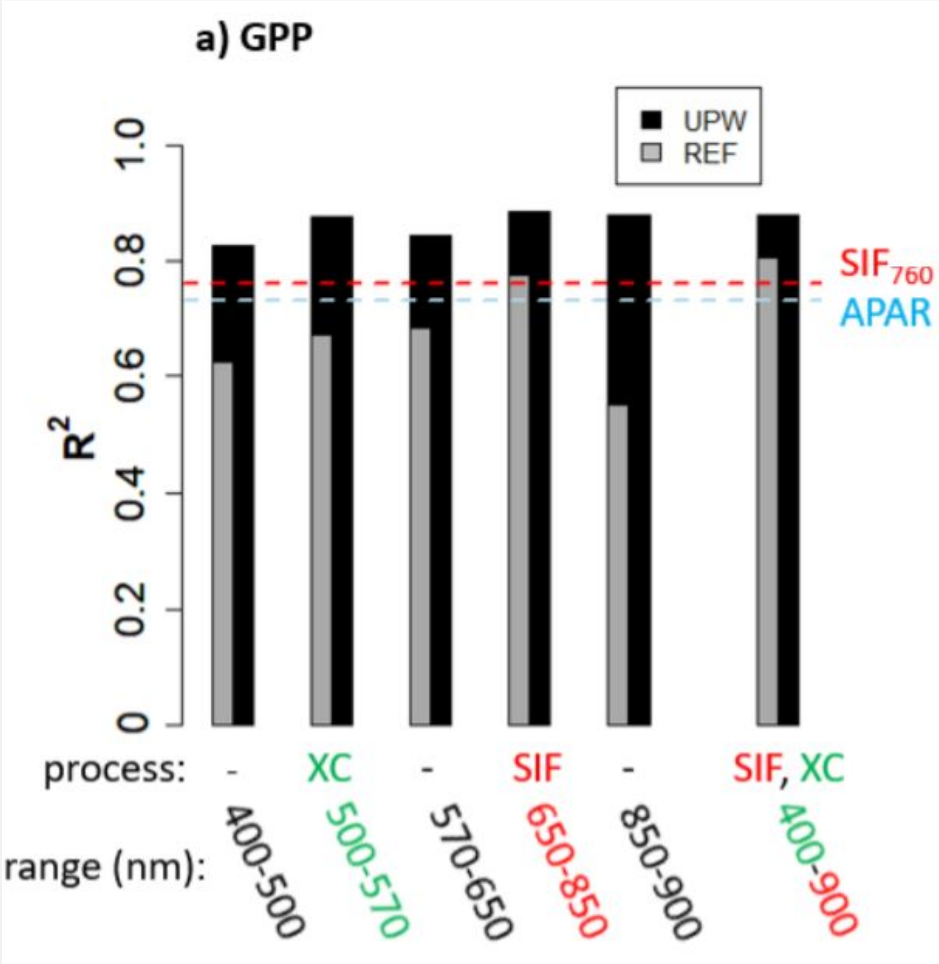


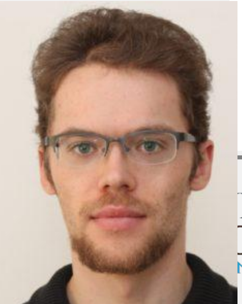


Dechant et al (in review) Remote Sensing of Environment

In the rice paddy, applying PLS to in-situ hyperspectral data showed reflected NIR is so powerful in predicting GPP



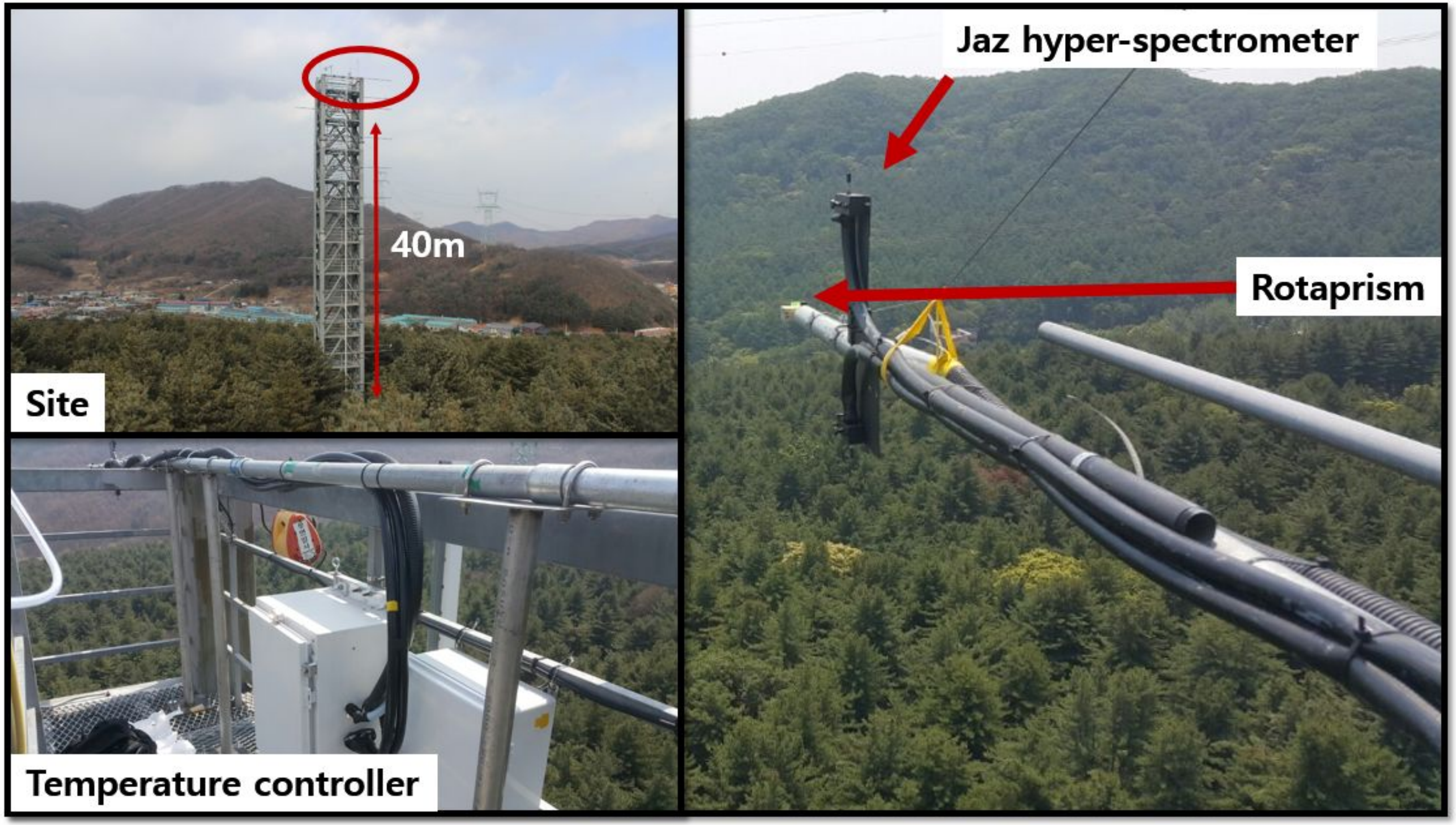




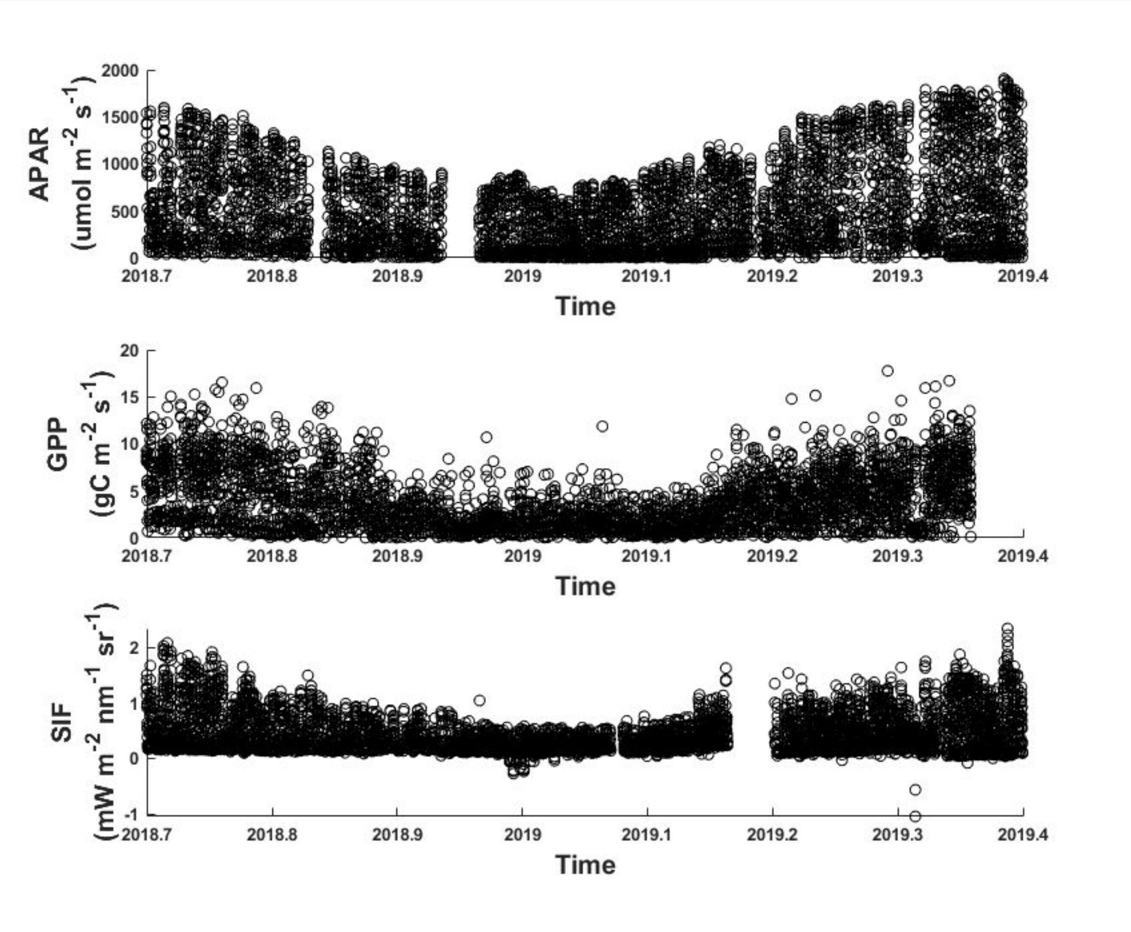
IRONMENTAL
OLOGY LAB
NATIONAL UNIVERSITY

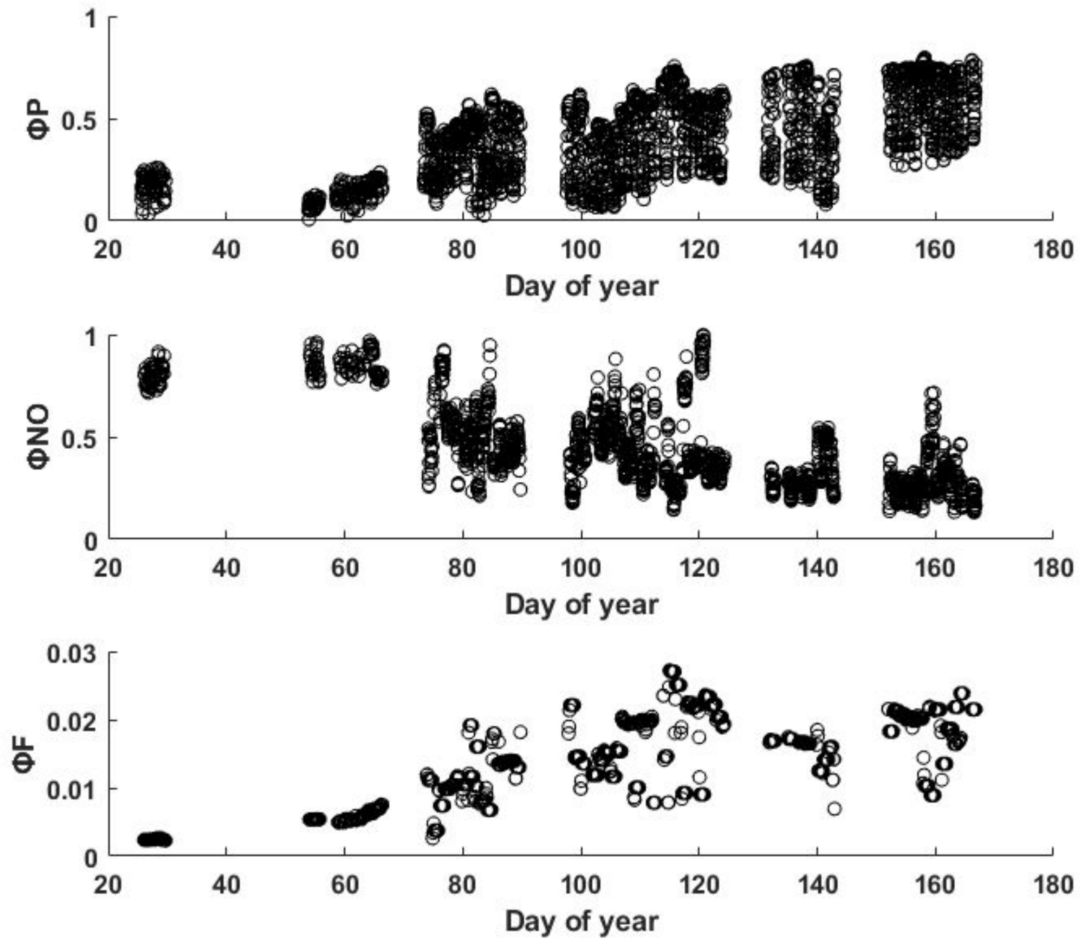
Dechant, Ryu et al (in press) Remote Sensing of Environment

Tall ENF site
-in situ SiF, VNIR system with Moni-PAM-



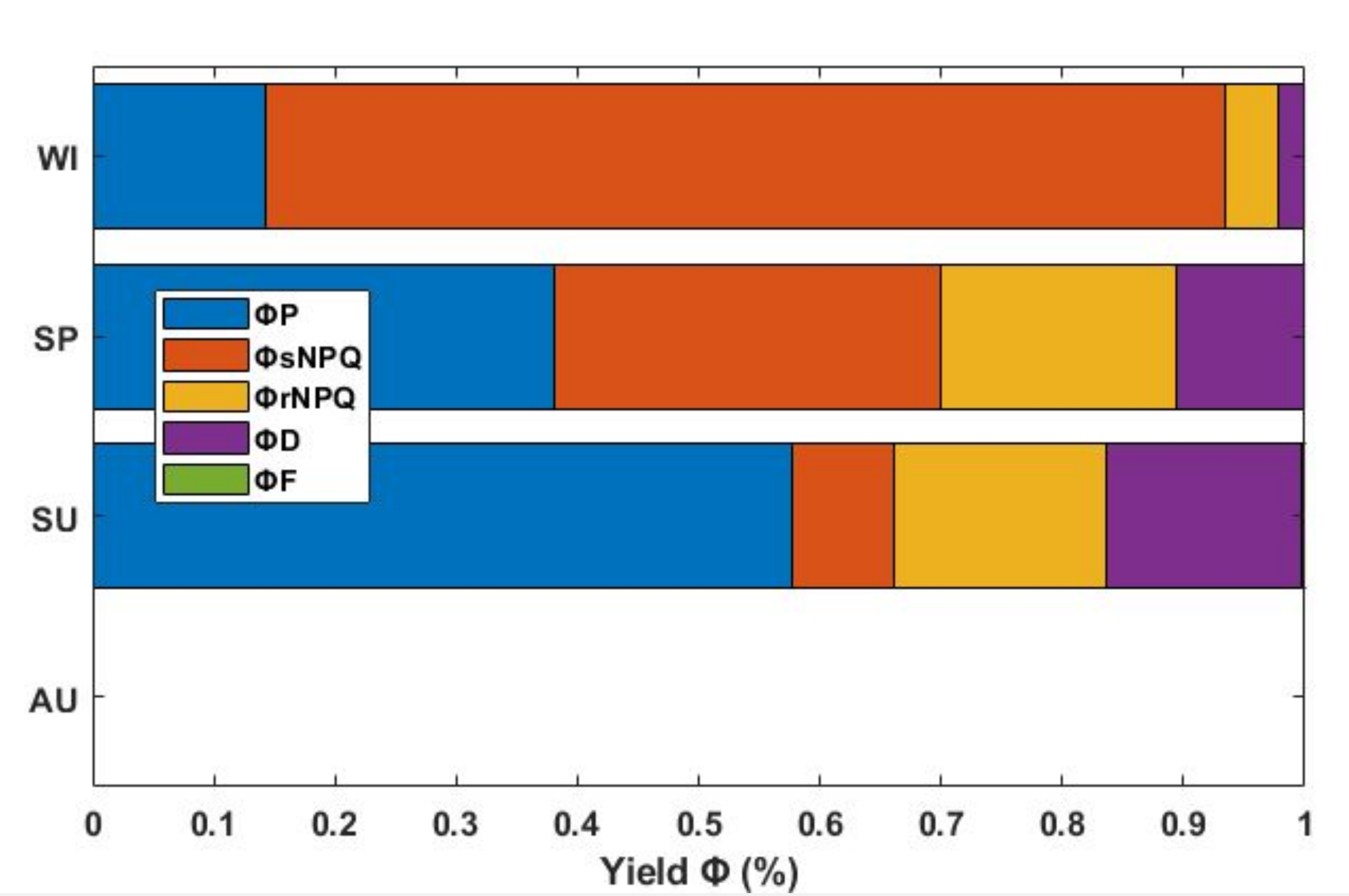
Continuous observations at canopy and leaf

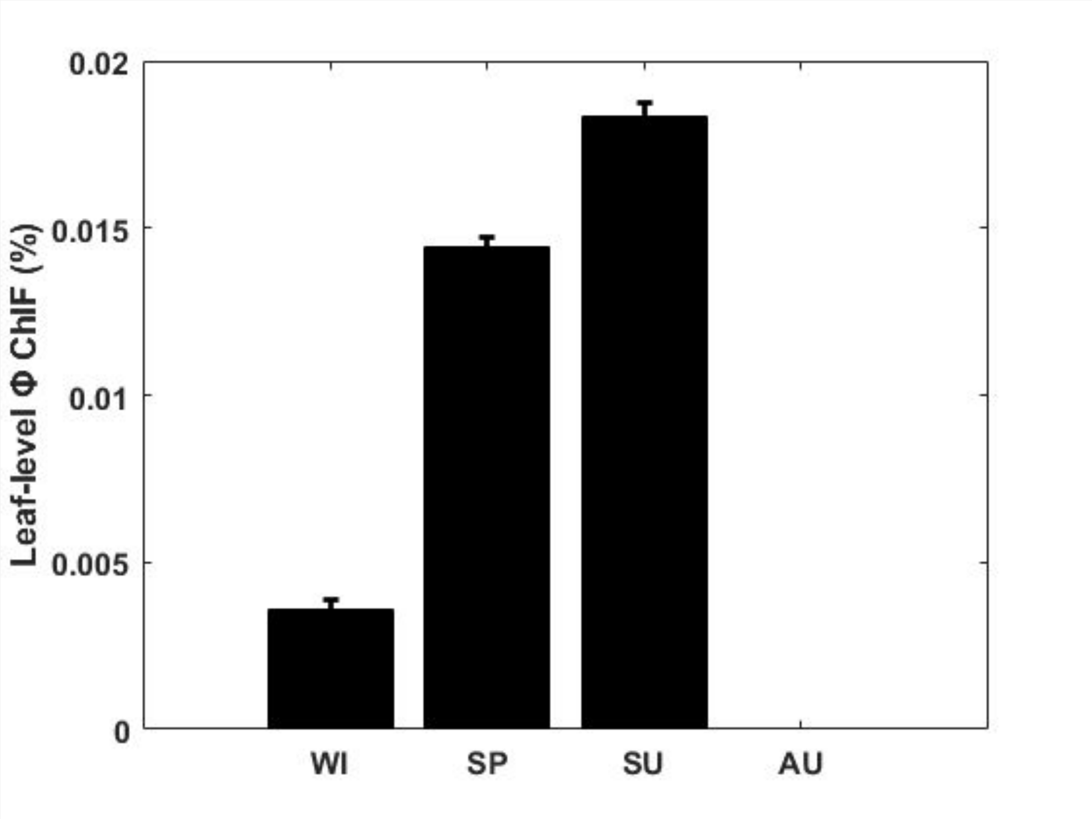




Kim et al (to be submitted)

PhiF shows large seasonal variations
Sustained NPQ too

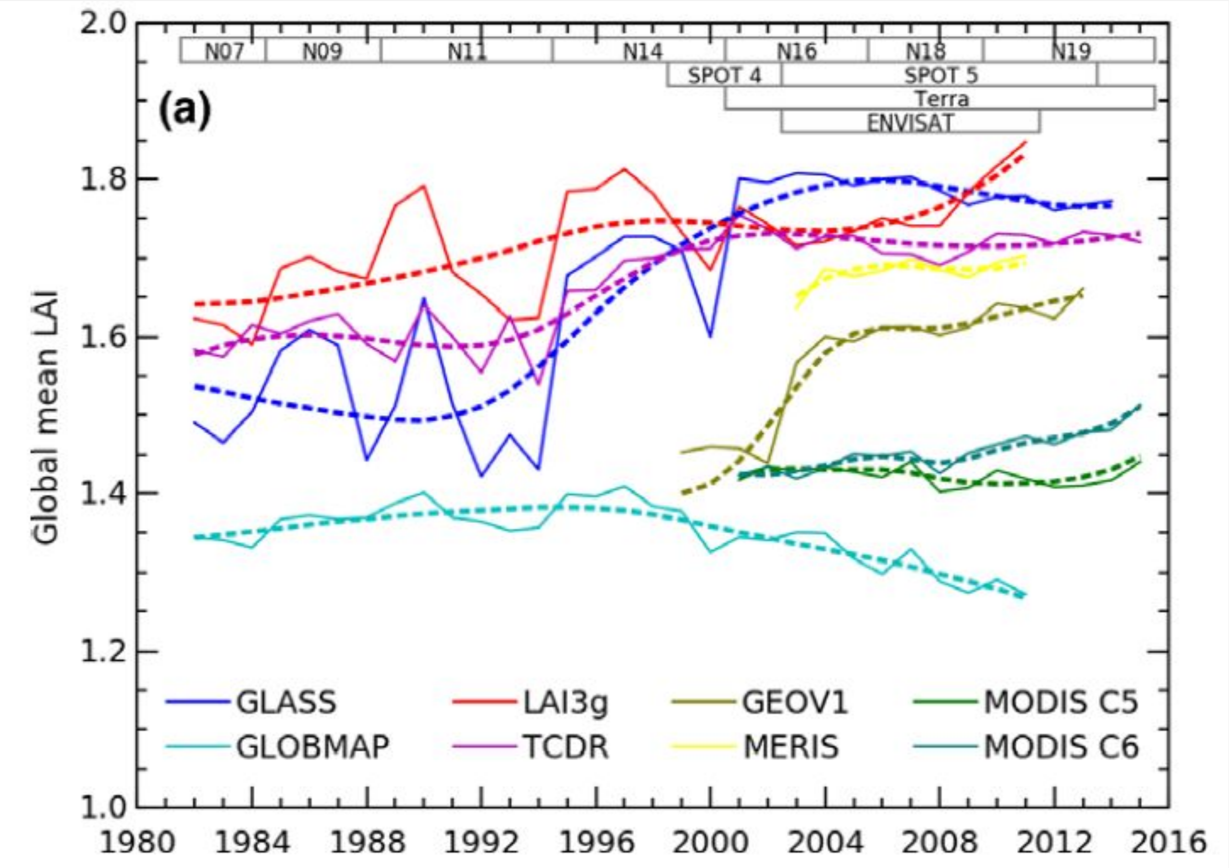




ENVIRONMENTAL ECOLOGY LAB
SEOUL NATIONAL UNIVERSITY

Kim et al (to be submitted)

Inconsistent global long-term LAI products



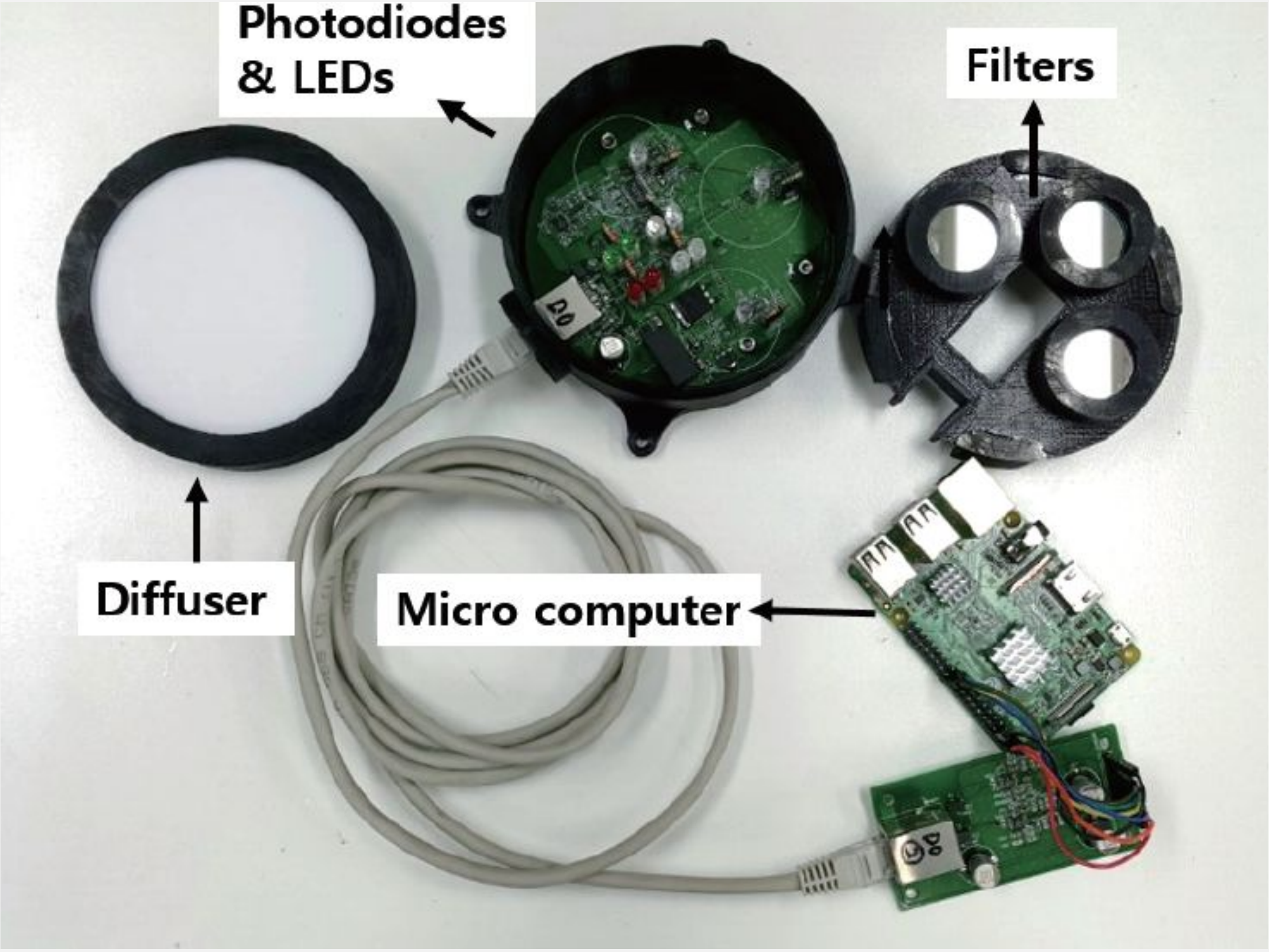
- Magnitudes
- Interannual variability
- Trends

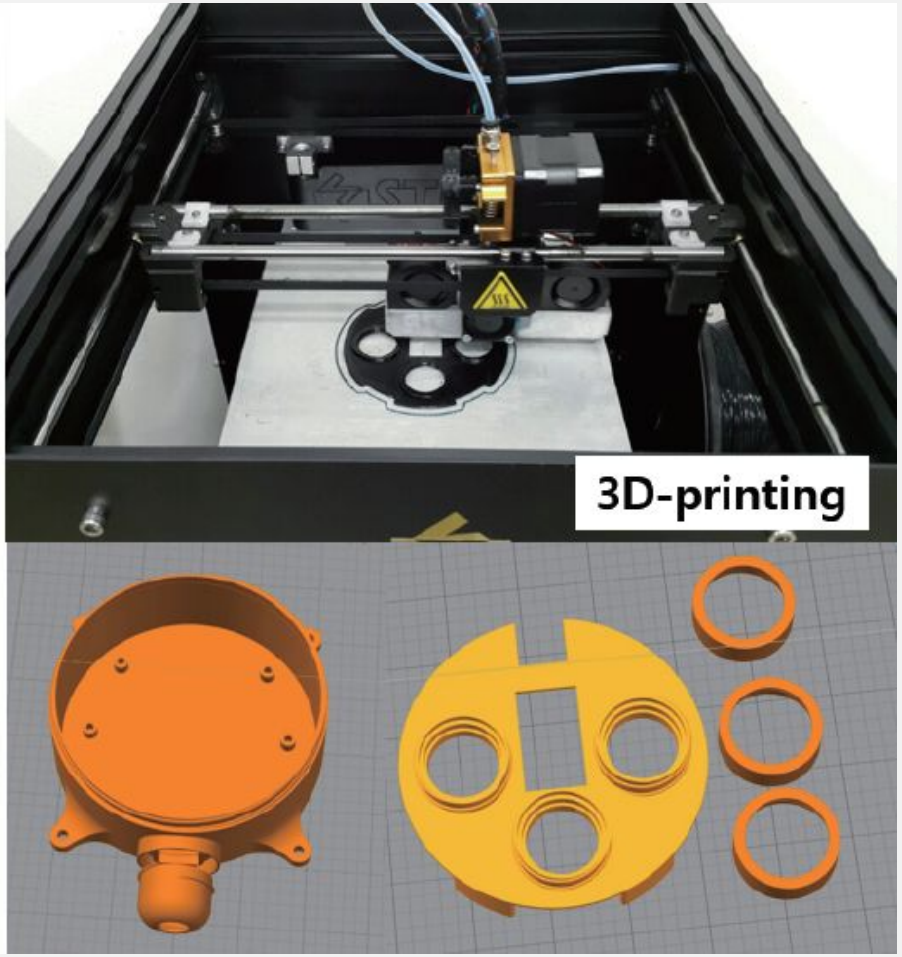
- Global greening??
- Big challenge in making land surface flux maps back to 1982

Jiang et al (2017) Global Change Biology

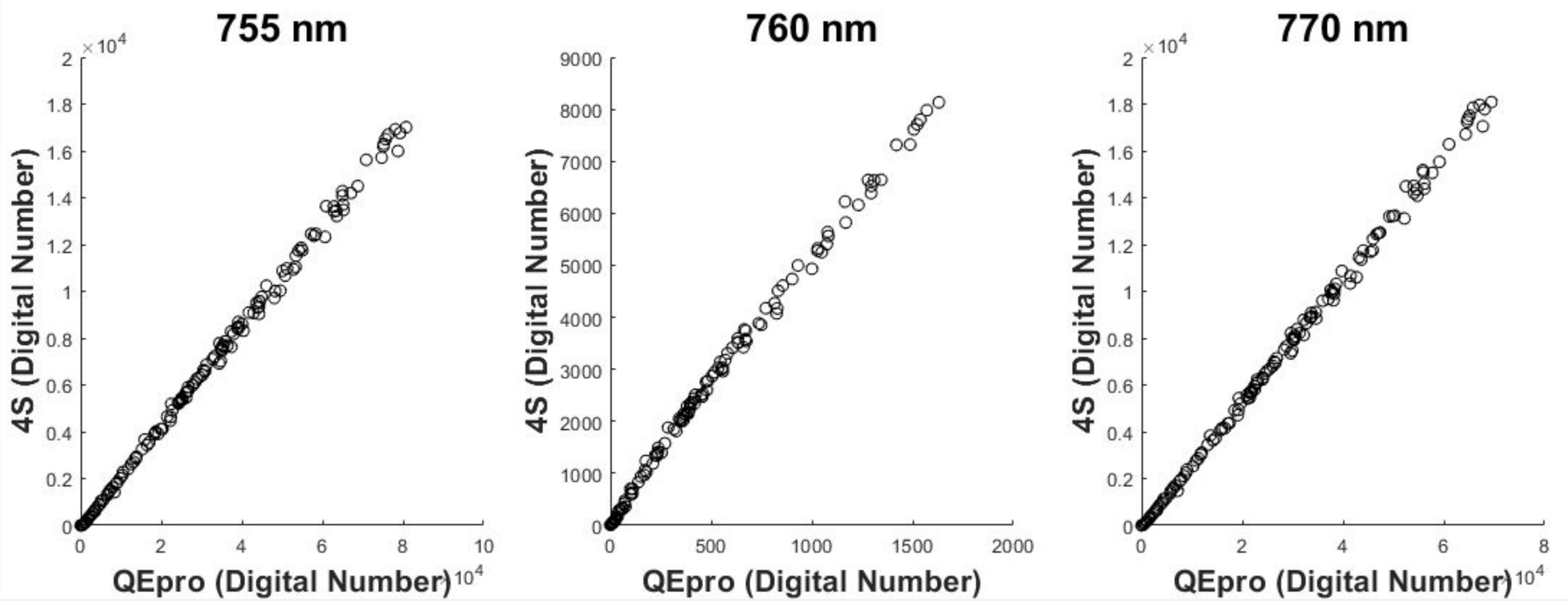
OPPORTUNITIES

Filter based 4S-SiF sensor



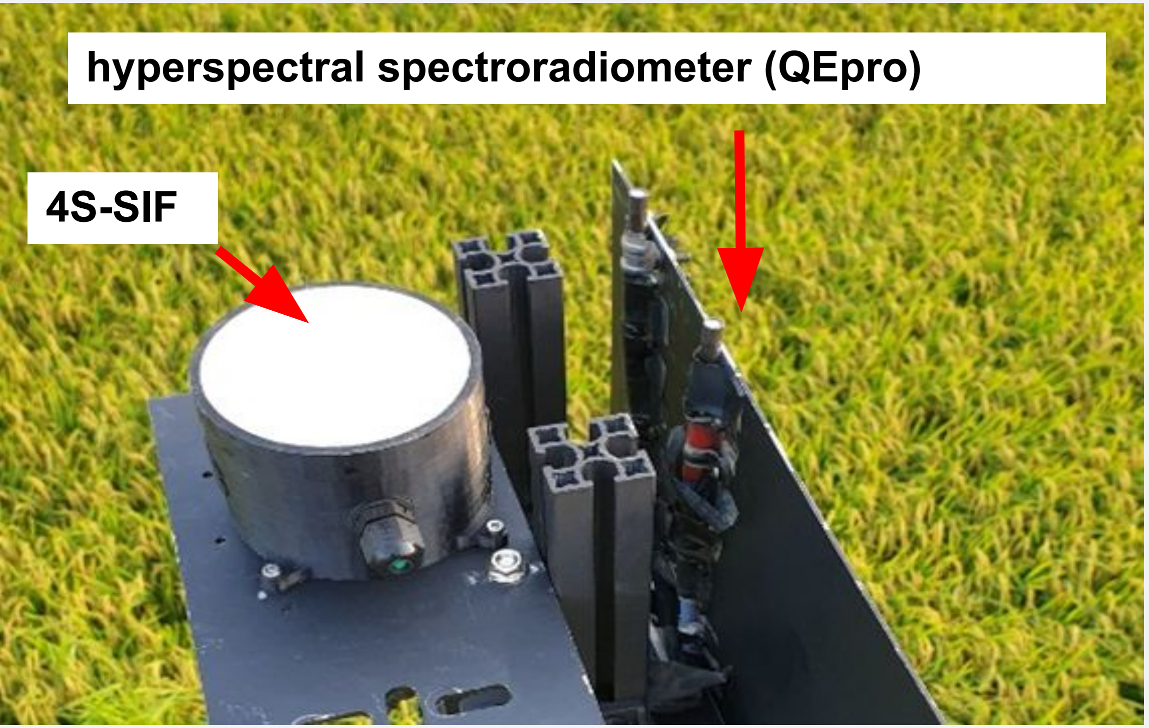


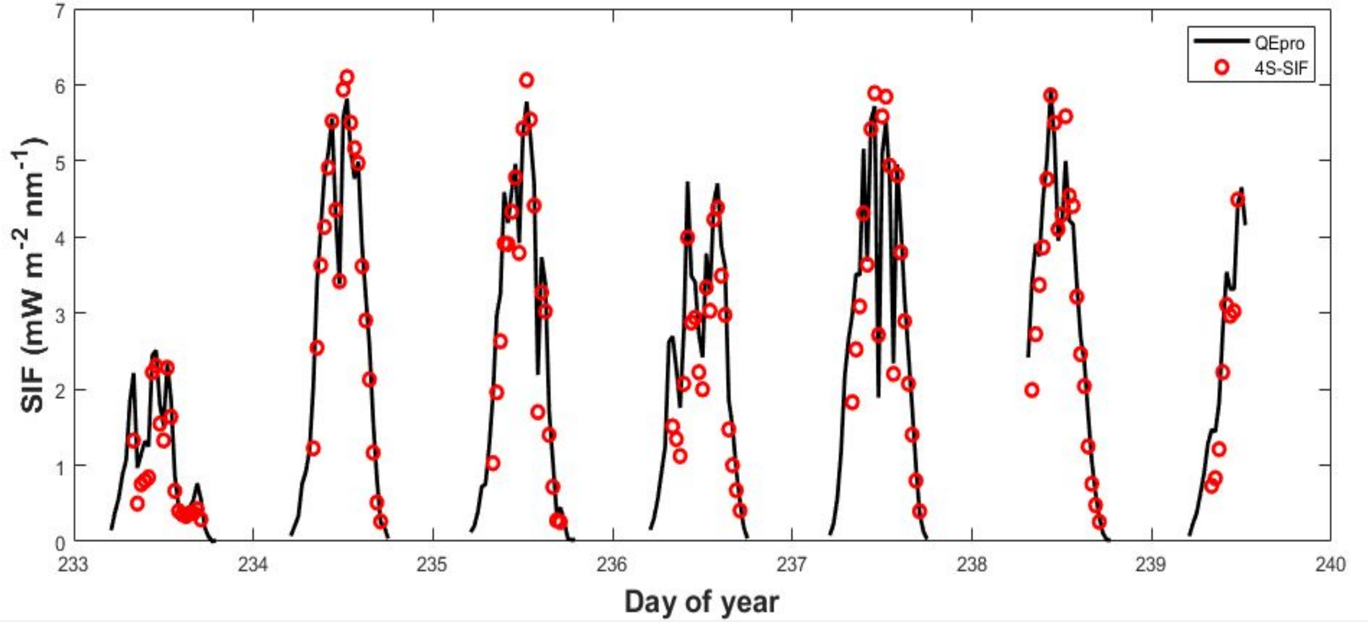
Linearity test against QEPro

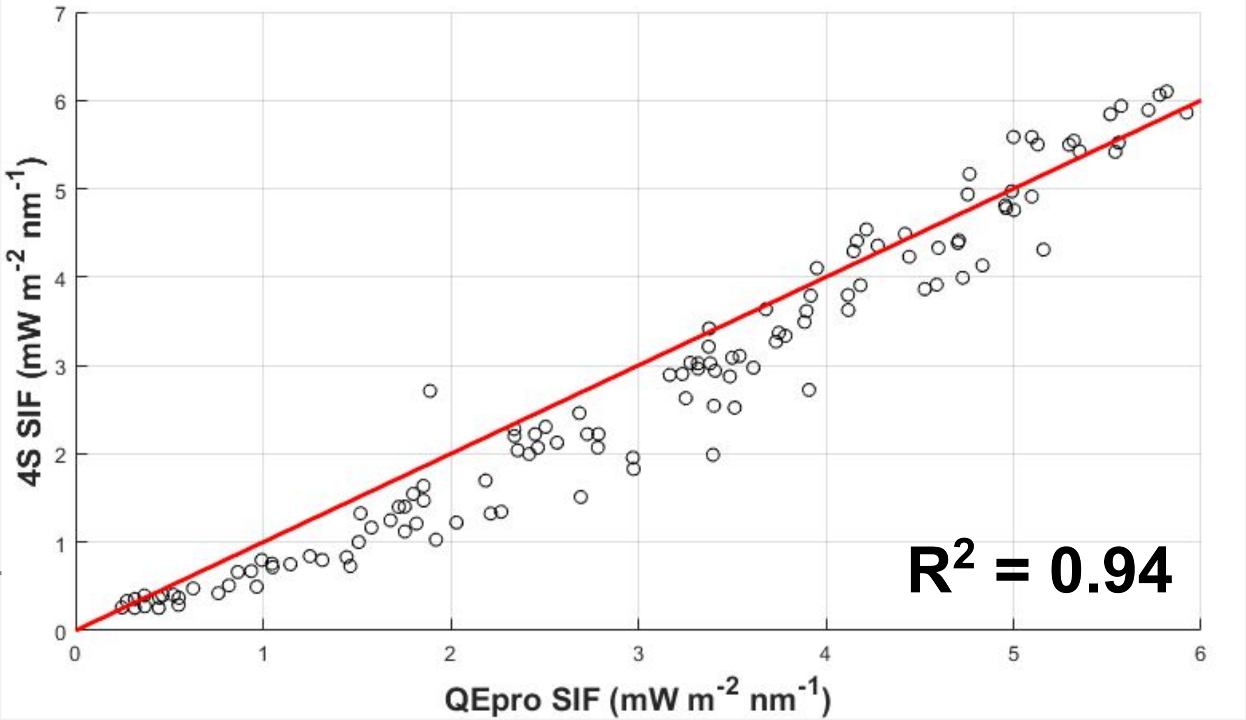


ENVIRONMENTAL
ECOLOGY LAB
SEOUL NATIONAL UNIVERSITY

Test in the field







New (actually old) approach
: near-infrared reflectance of vegetation

spectral observations of the canopy reflectance would exhibit the following characteristics:

i. the near-infrared reflectance would be a near-linear indicator of APAR and a near-linear indicator of P_c and $1/r_c$ under stress-free conditions,

ii. the SR would be functional on the near-infrared reflectance only,

iii. surface reflectance in the visible region would be invariant with leaf area index.

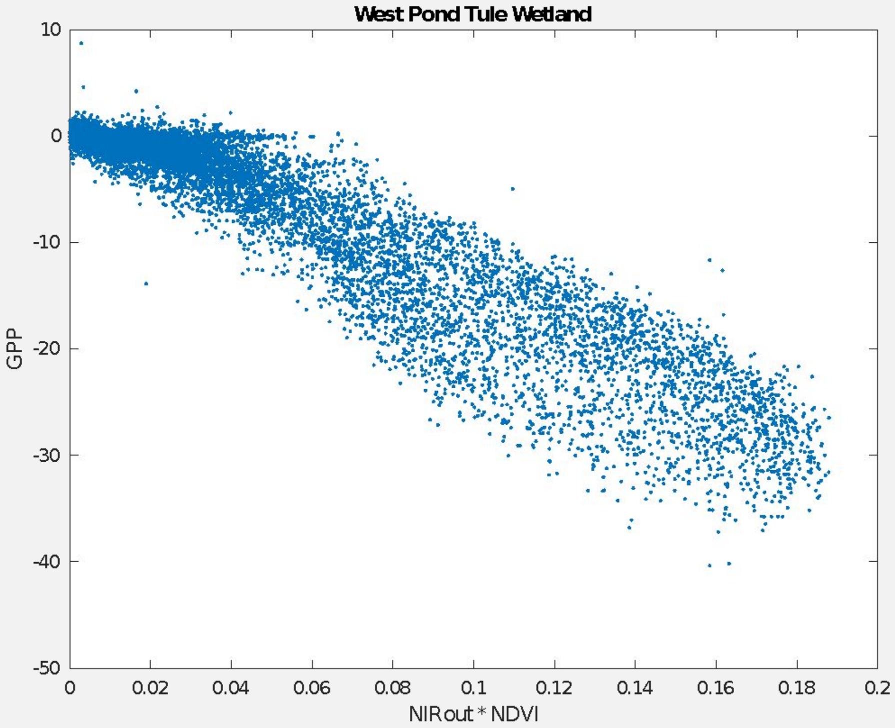
All of the above may be expressed more prosaically. If an experimenter were somehow to launch an equal number of visible/PAR and near-infrared photons at a vegetated surface, he could estimate the number of visible/PAR photons absorbed by the vegetation (as opposed to the soil) by counting the reflected near-infrared photons rather than the reflected visible/PAR photons. The relationship between the two would be most linear under the ideal conditions we have specified above in (31).

The next section discusses the fea
ity of applying reflectance data to
estimation of APAR, P_c, and $1/r$
particular, the limitations imposed by

ENVIRONMENTAL ECOLOGY LAB
SEOUL NATIONAL UNIVERSITY

Sellers 1987 Remote Sensing of Environment

NIRvP across flux towers in California -half hourly, whole year-

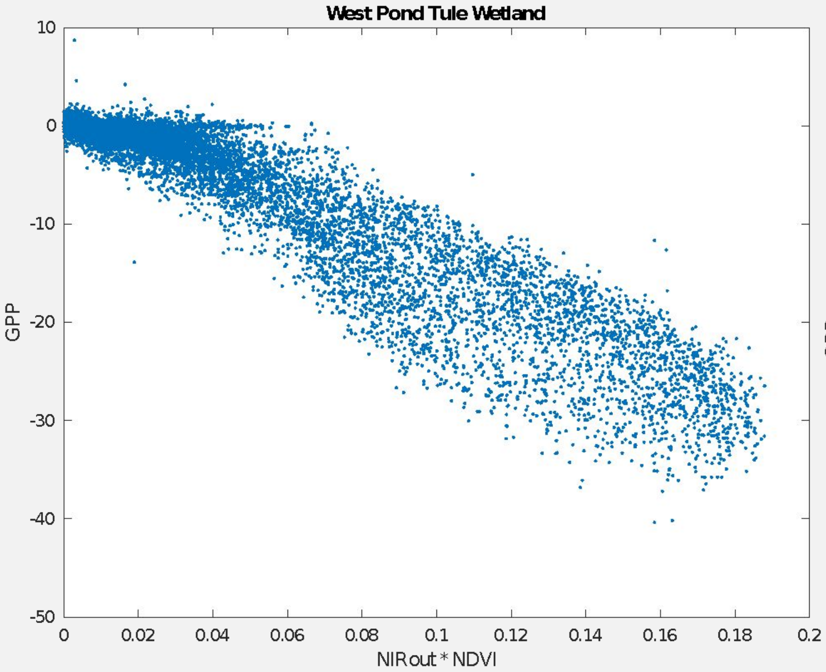


X: NIRout X NDVI (a sort of NIRvP)
Y: Photosynthesis

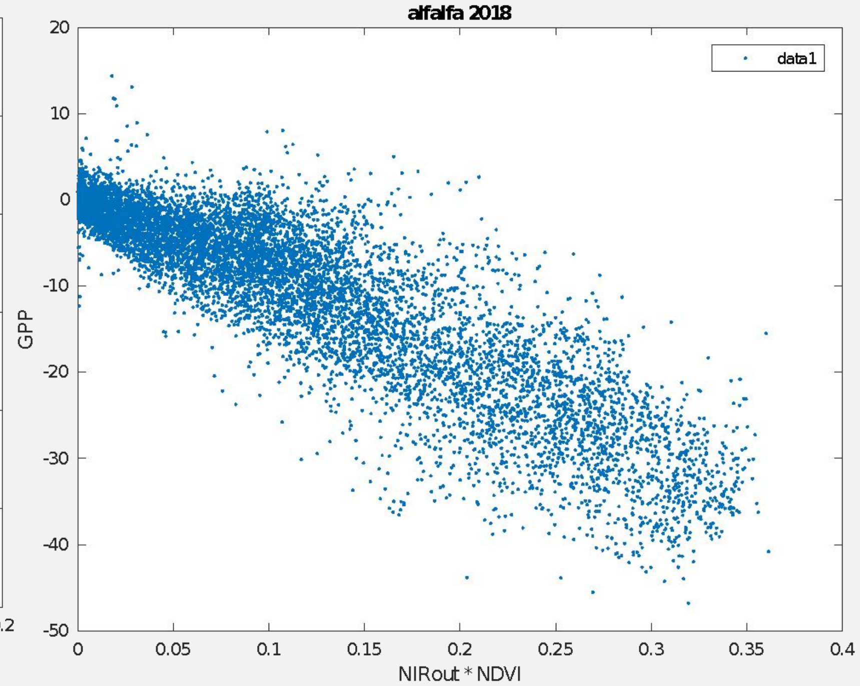
Baldocchi, Ryu, Dechant et al (to be submitted)

NIRvP across flux towers in California -half hourly, whole year-

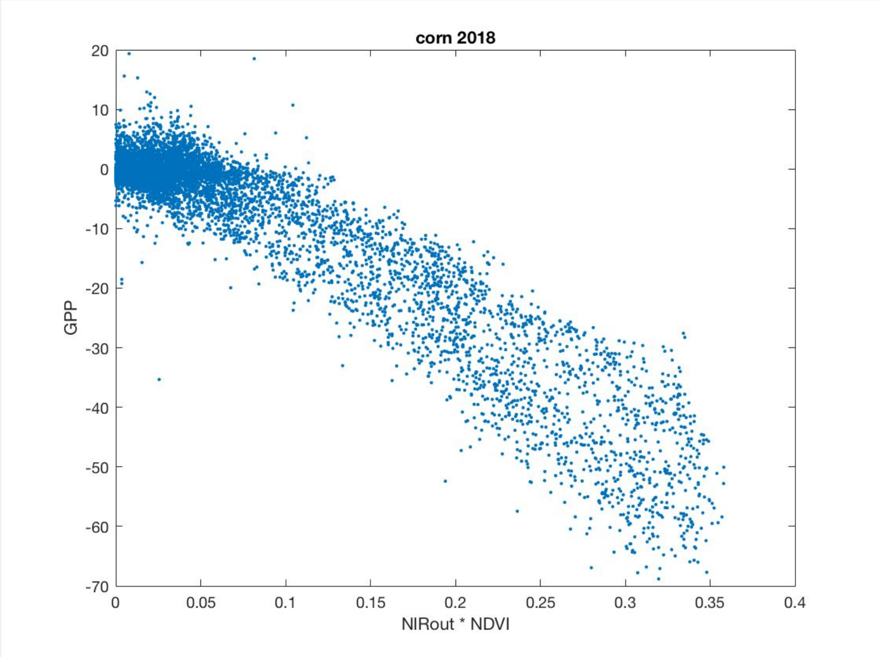
Wetland



Alfalfa



Corn



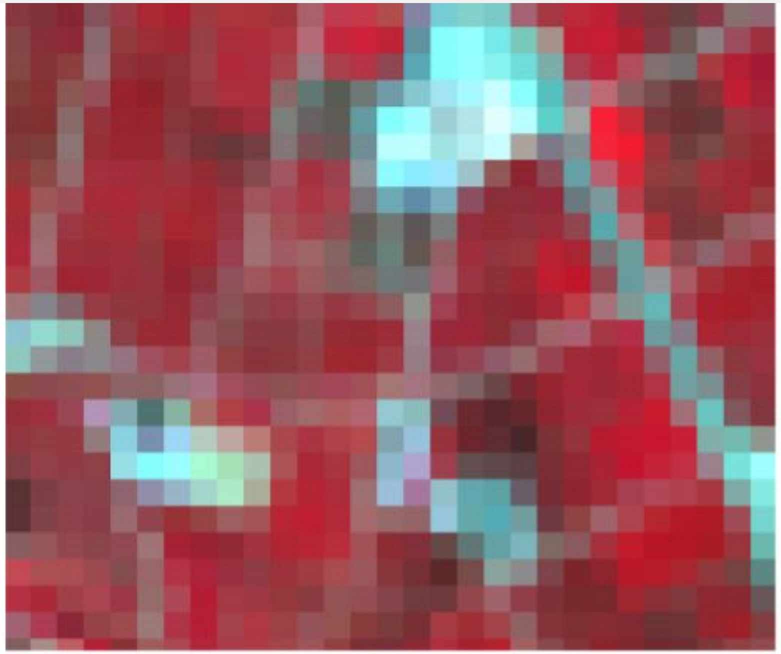
ENVIRONMENTAL ECOLOGY LAB
SEOUL NATIONAL UNIVERSITY

X: NIRout X NDVI (a sort of NIRvP)
Y: Photosynthesis

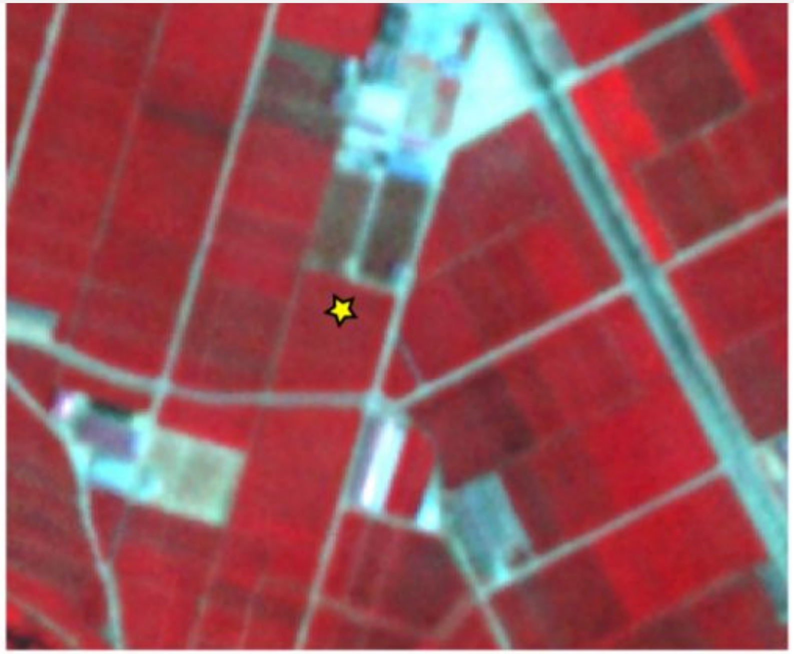
Baldocchi, Ryu, Dechant et al (to be submitted)

CubeSats: very high resolution, with poor spectral quality

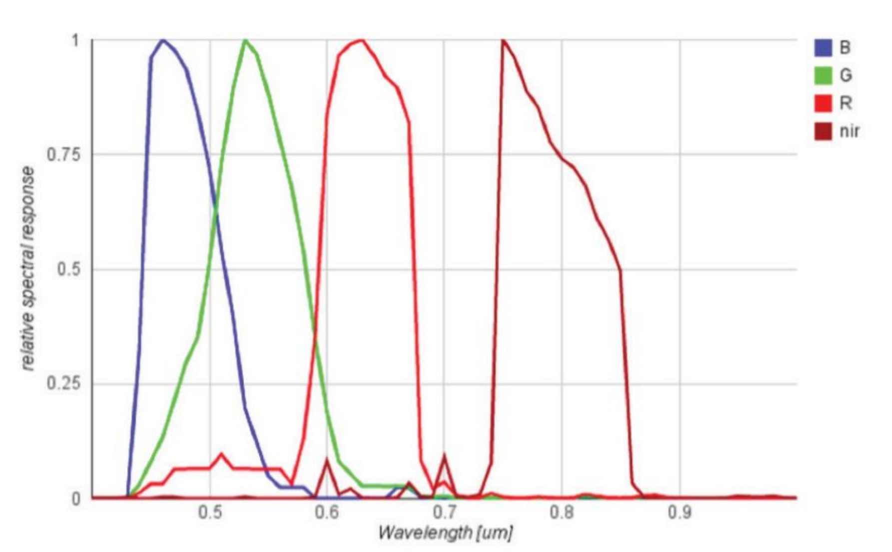
Landsat 8 (23 June 2017)



CubeSat (23 June 2017)



Spectral response of R/G/B/NIR



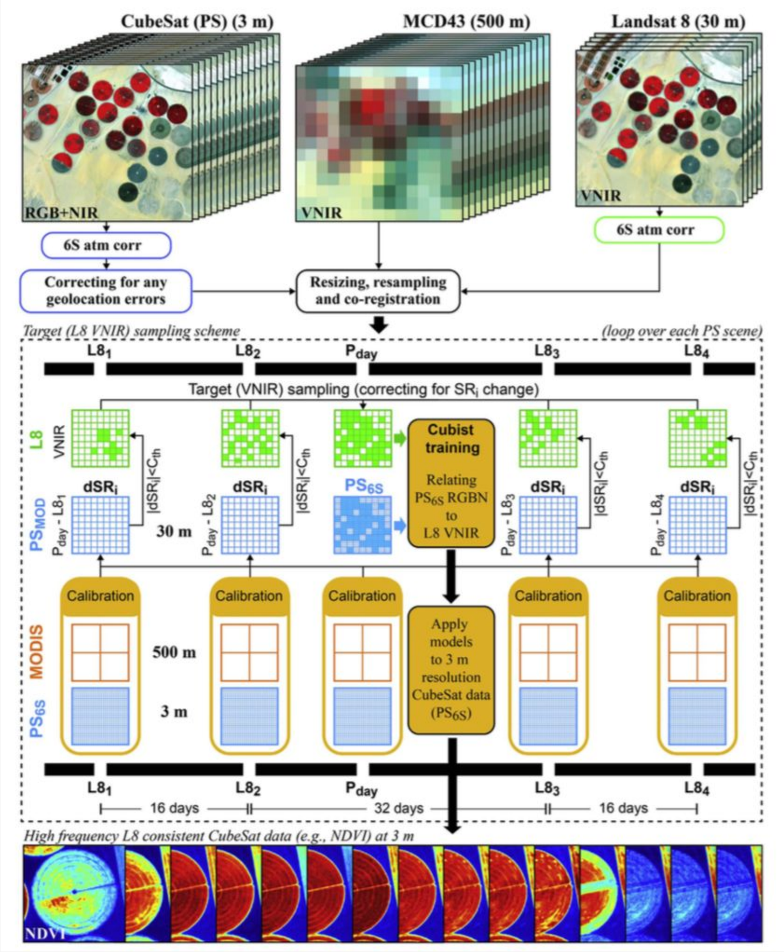
Rice paddy landscape (star: flux tower)

Source: https://www.planet.com/

ENVIRONMENTAL ECOLOGY LAB
SEOUL NATIONAL UNIVERSITY

From Rasmus Houborg (Planet Labs)

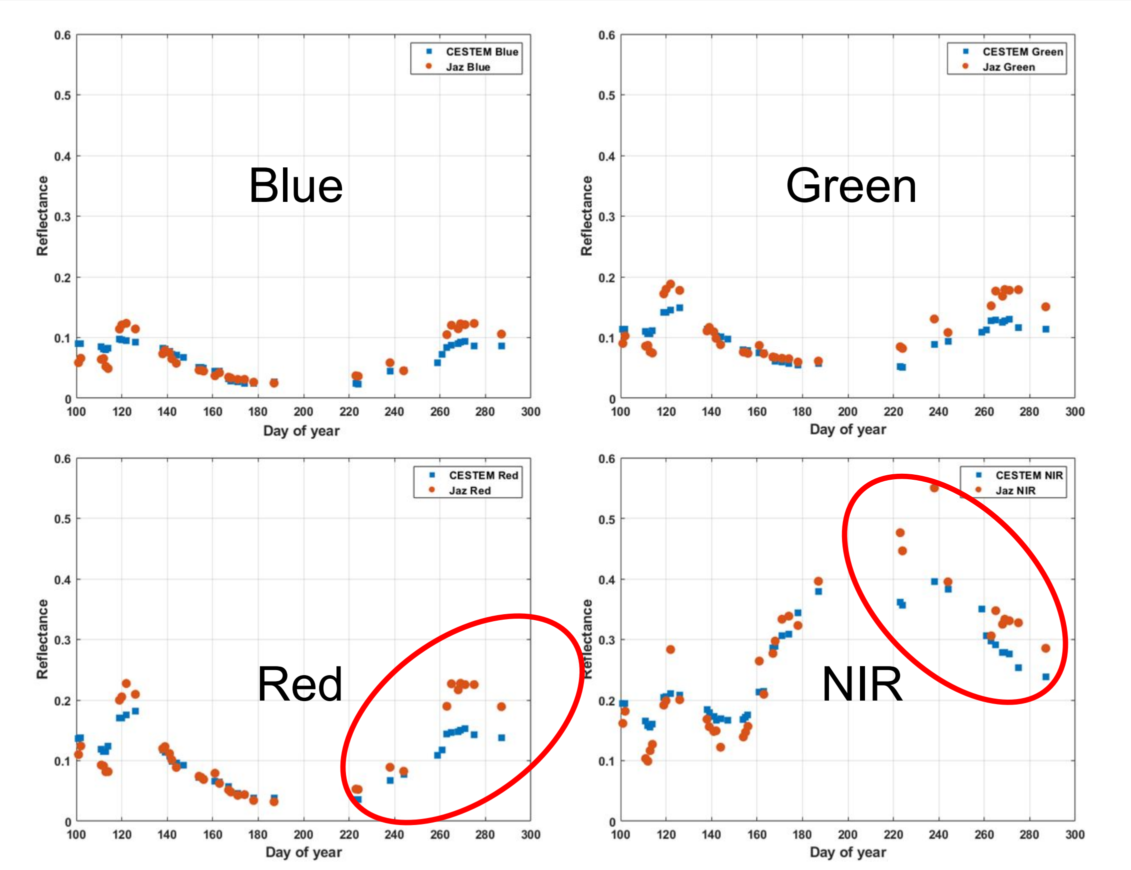
CESTEM



- Surface reflectance at the quality of Landsat and MODIS
- Consistent radiometric calibration across CubeSats constellation
- Why not using NIRv?

Houborg and McCabe 2018 Remote Sensing of Environment

Testing CESTEM time series in the rice paddy landscape

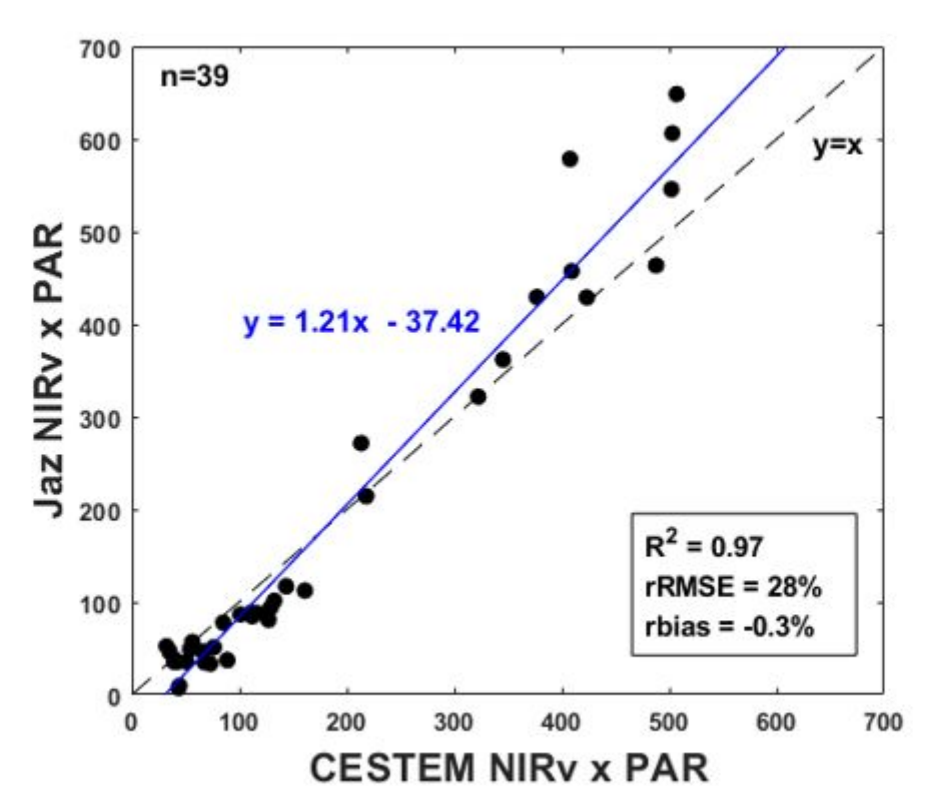


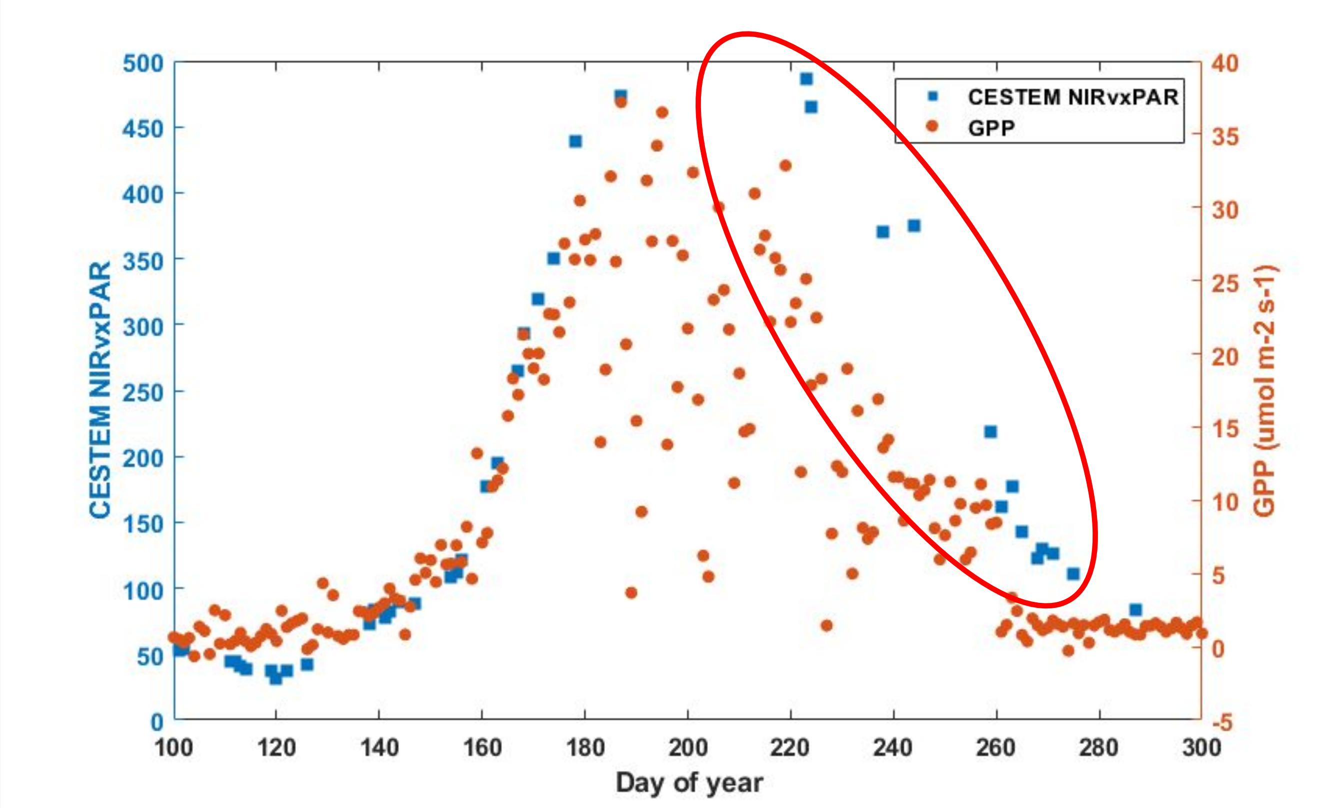
- Blue: CESTEM
- Red: In-situ spectral sensor

- CESTEM well tracked four band spectral reflectance over the seasons

Processed by Juwon

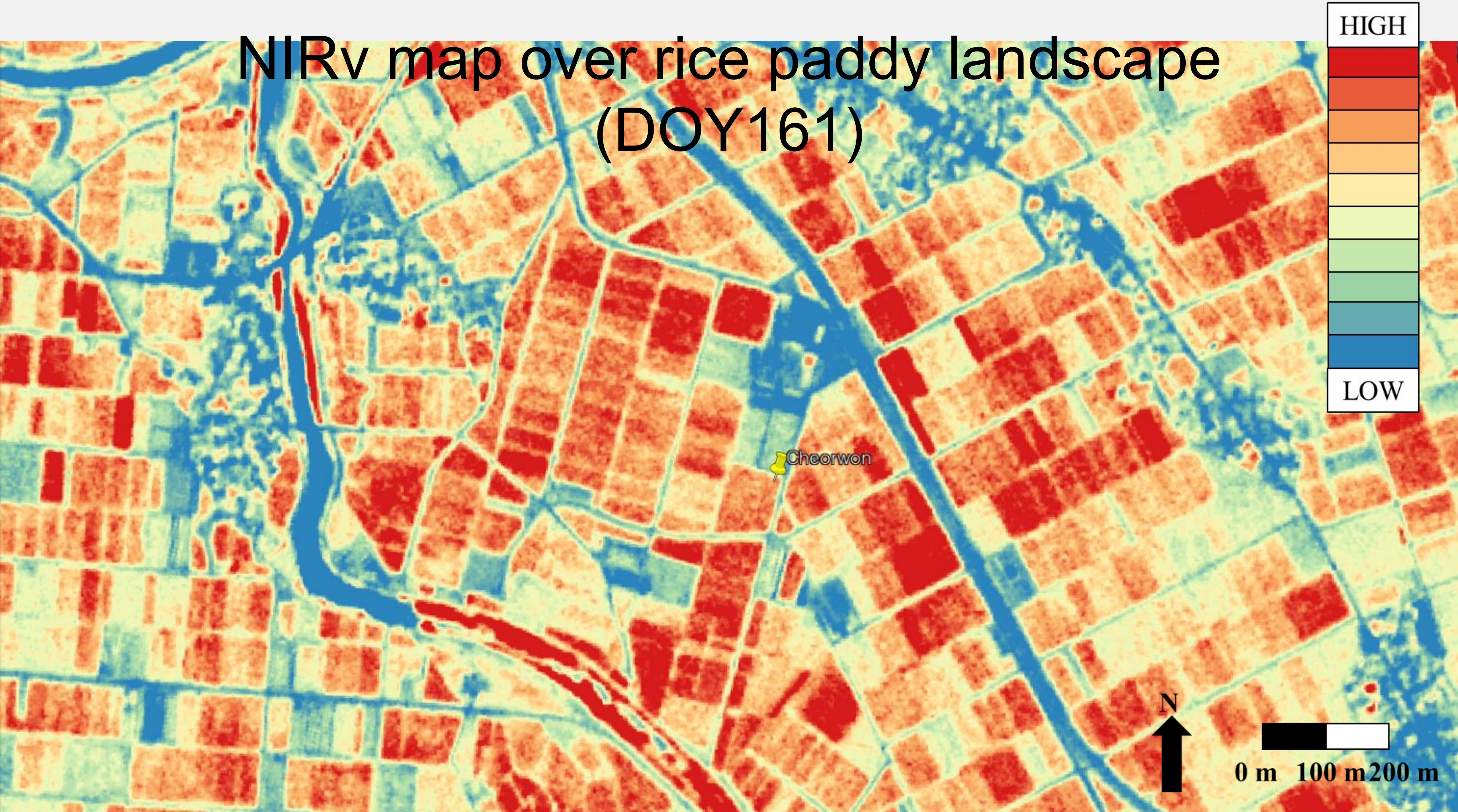
Testing CESTEM time series



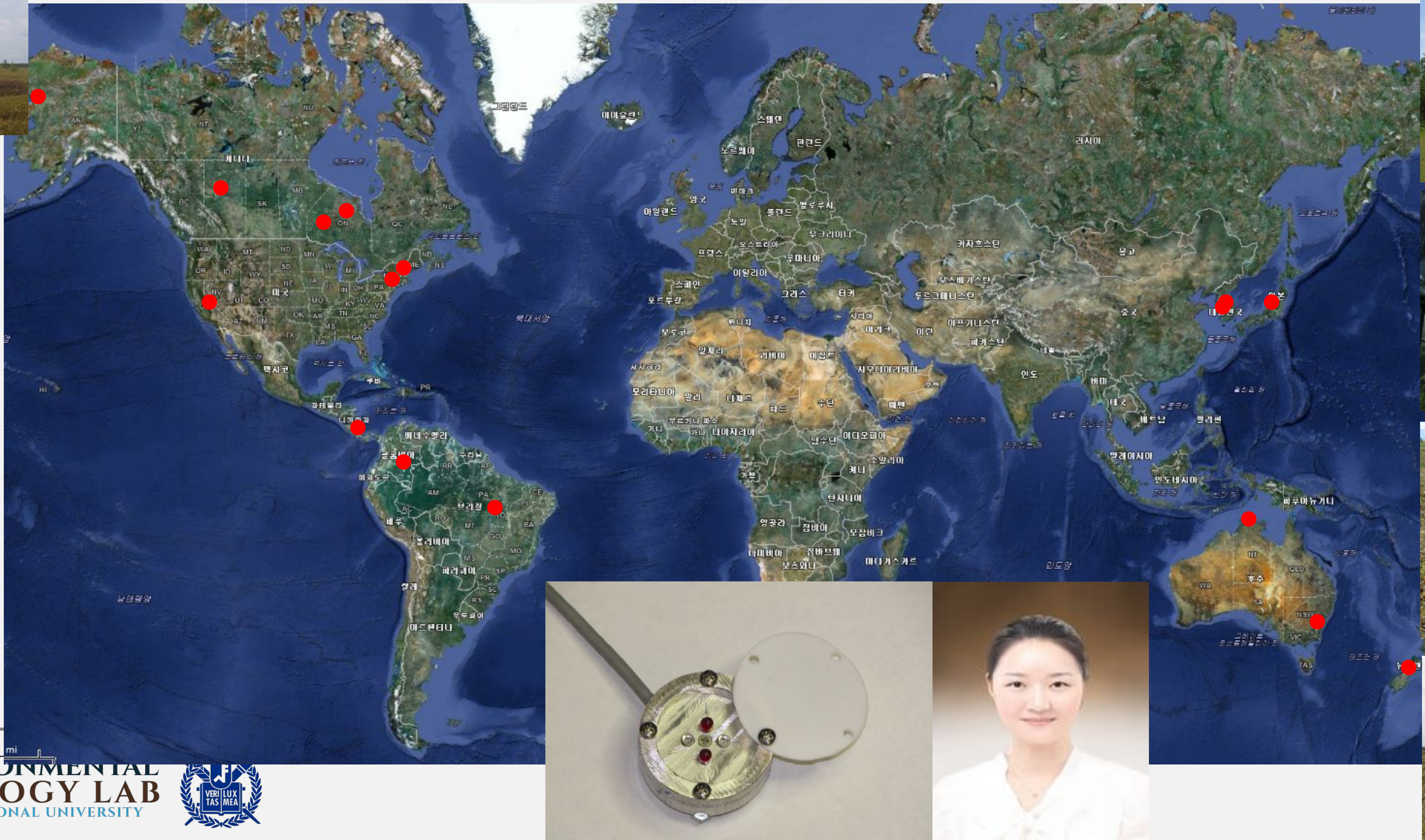



Cheorwon

NIRv map over rice paddy landscape (DOY161)

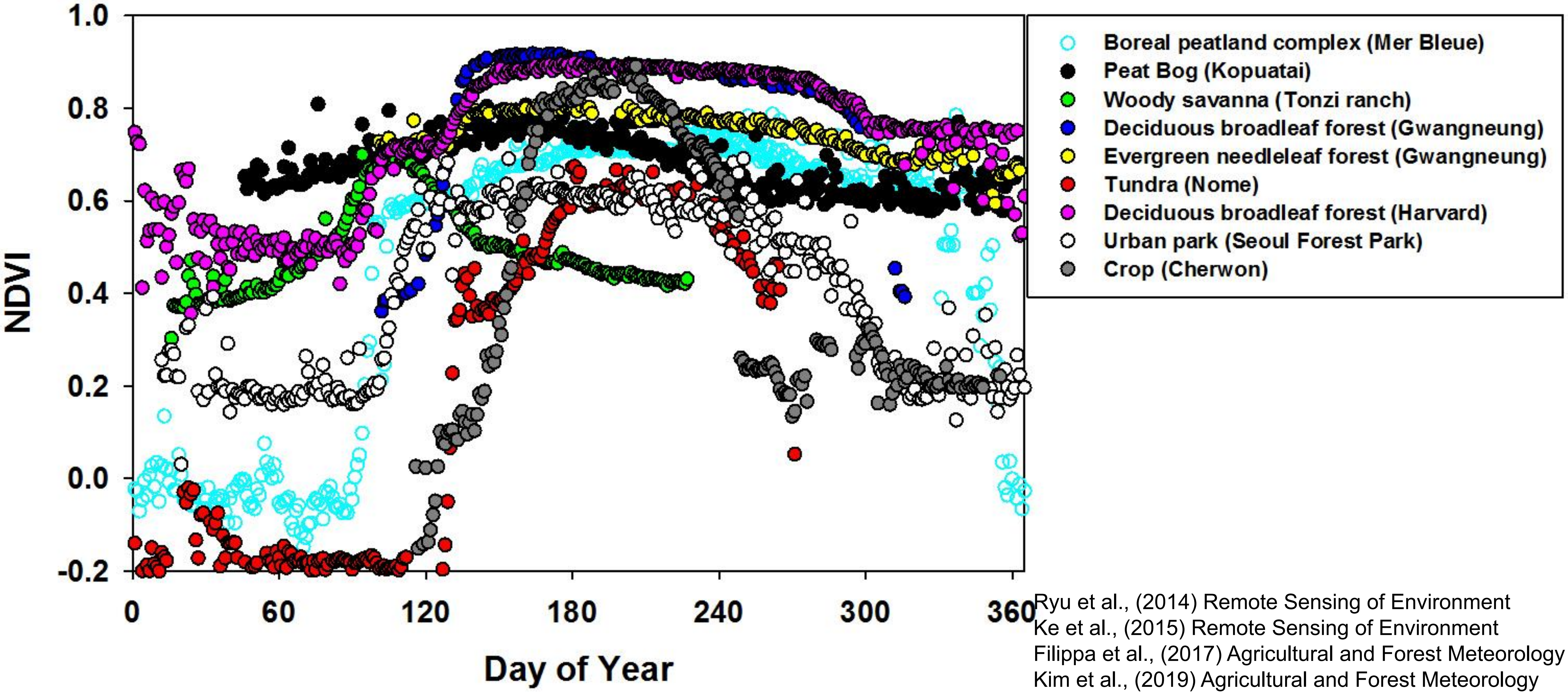


Inexpensive, LED spectral sensing network



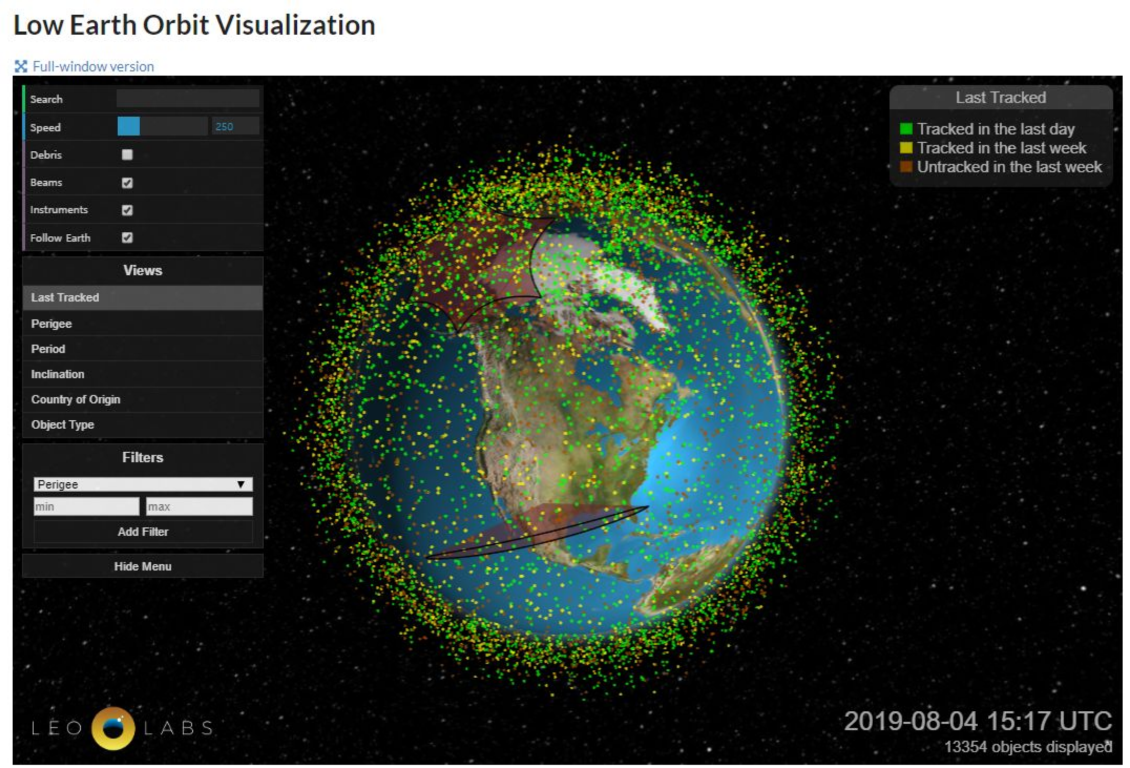
ENVIRONMENTAL ECOLOGY LAB
SEOUL NATIONAL UNIVERSITY

In-situ NDVI time series (NIRv can be done)



Ryu et al., (2014) Remote Sensing of Environment
Ke et al., (2015) Remote Sensing of Environment
Filippa et al., (2017) Agricultural and Forest Meteorology
Kim et al., (2019) Agricultural and Forest Meteorology

CubeSats X in-situ sensing network
: a new frontier in photosynthesis monitoring



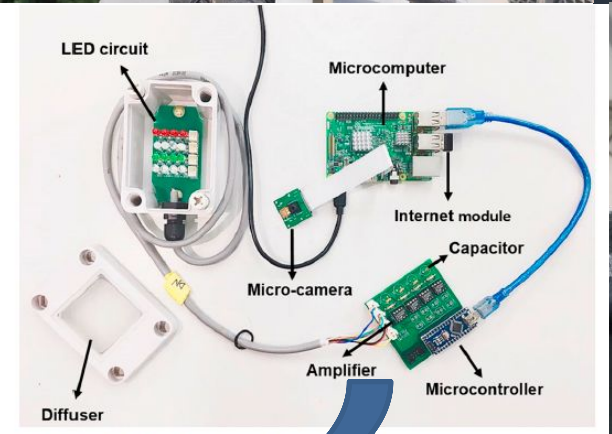


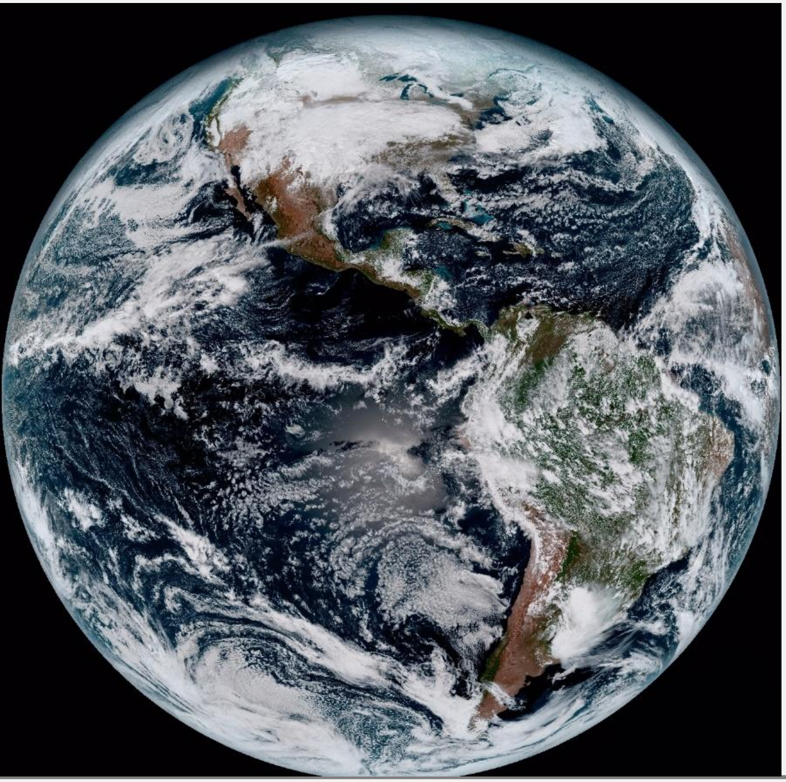
Fig. 2. The Smart Surface Sensing Syste...). All components are connected, and the microcomputer controls th... mated data workflow.

Calibration!

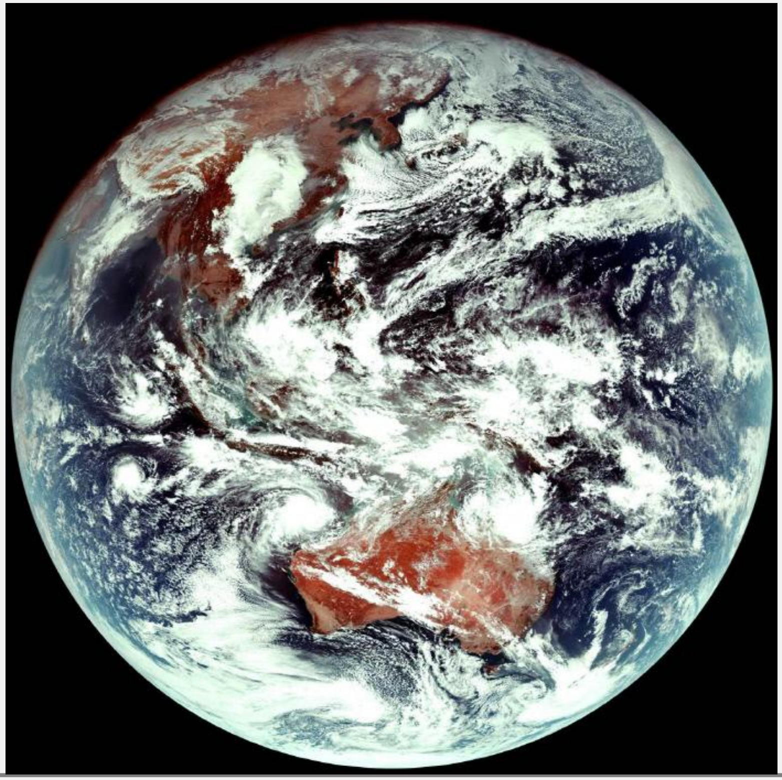
Kim, Ryu et al 2019 Agricultural and Forest Meteorolgoy

Geostationary satellites cover almost the entire world at every a few min

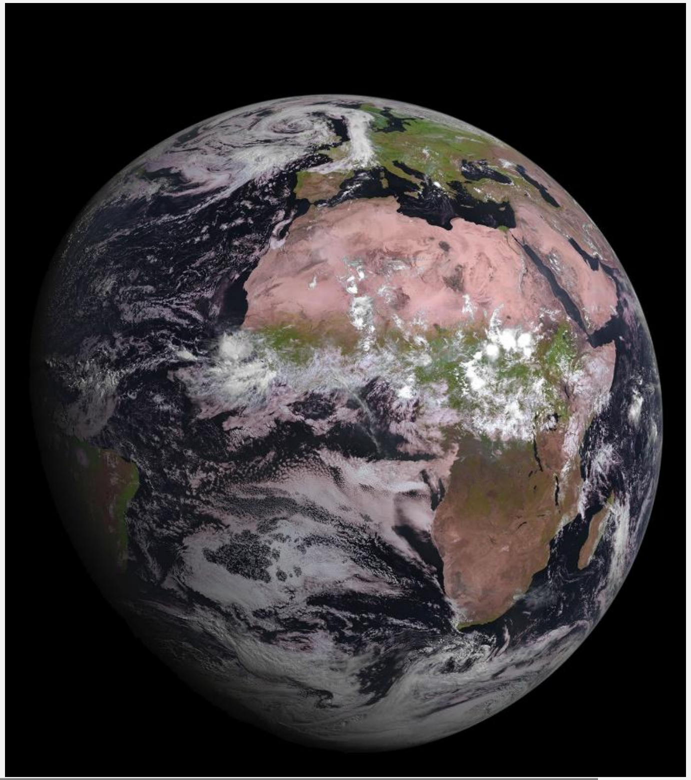
GOES



Geo-Kompsat 2A



SEVIRI



Take home message

- SiF is an exciting topic that requires understanding biochemistry and canopy structure together
- Canopy structure effects seem to be dominant in canopy SiF
- Don't trust any satellite remote sensing data too much
  - Calibration, calibration, calibration, …..
- As an end user, you have to know "uncertainty"
- CubeSat and Geostation satellite offer powerful ways to monitor photosynthesis at unprecedented scales