Prototyping MuSLI Canopy Chlorophyll Content for the Assessment of Vegetation Function and Productivity

presenter: ***Petya Campbell, PI***

University of Maryland Baltimore County
GSFC Biospheric Sciences Laboratory

Team and Collaborators

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[e]University of Lincoln, NE; [f]Global Change Research Institute - CzechGlobe, Brno, Czech Republic;

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** petya@umbc.edu*

The project builds on the long term collaboration between the Co-Is and Collaborators, and on the significant progress made through prior work supported by NASA's Terrestrial Ecology (TE), Carbon Cycle Science (CCS), ACCESS and land-cover land-use (LCLUC) Programs.

Project Goal and Objectives

MOTIVATION: 'Leaf chlorophyll content is arguably the most important photosynthetic indicator of vegetation function and physiological condition, since it drives photosynthesis'

To produce consistent medium resolution (30m) Chl product prototypes and robust algorithms that can reliably be scaled to regional and continental scales. The Chl product is required to enhance and standardize LCLUC monitoring of vegetation function and productivity.

Specific objectives include:

1) provide a multisystem data fusion approach for using the moderate ground resolution of L-8 OLI optical (30 m) and S-2 MSI images (10-60 m) to generate high frequency product;
2) generate workflows and produce high density (10 days) time series of VIs and Chl, for the regionally important species, represented at the study sites;
3) produce seasonal time series of Chl, and 'function/stress maps' as the difference between optimal vs. observed vegetation Chl for selected regions.

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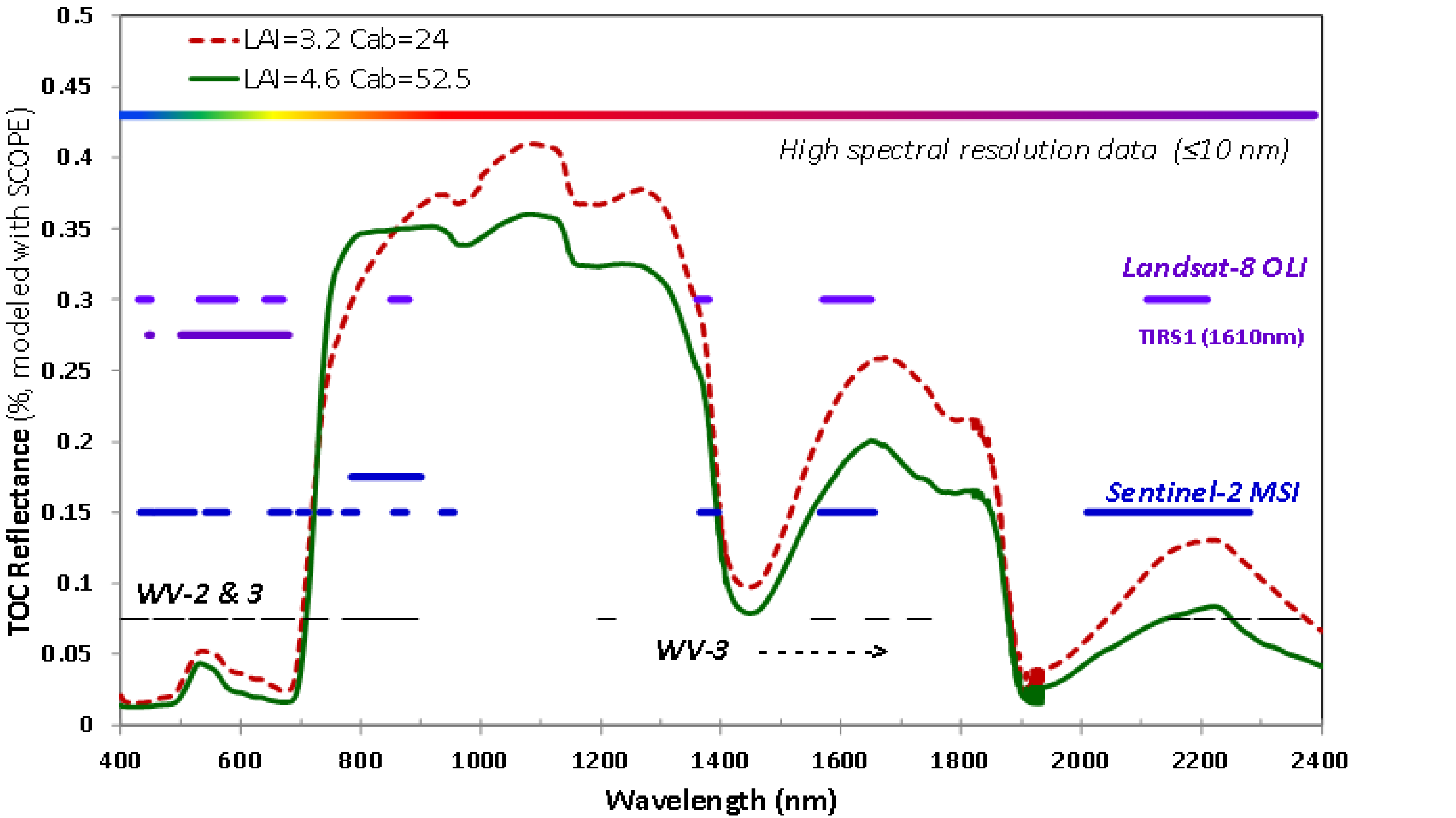
DATA - Comparison of the spectral characteristics of OLI, MSI, WV2 and WV3 spectral characteristics (band position & resolution)

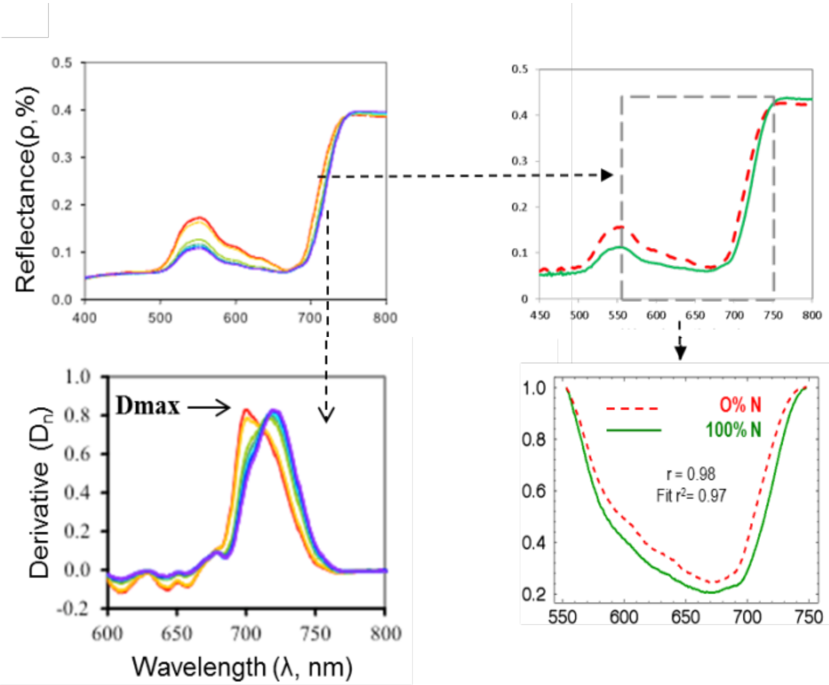


Desirable criteria of VIs to derive a metric (TOC Chl)

1) Variation in the VI should be sensitive to variation in TOC Chl. A VI will be selected based on a balance of optimal performance and consistent sensitivity across the Chl range. We will report optimum performers based on R^2 and RMSE.

2) VI variations should be insensitive to variations in other variables - in our case LAI, canopy cover, shadow, background.

3) The relationship between VI and Chl should be linear to allow for scaling.



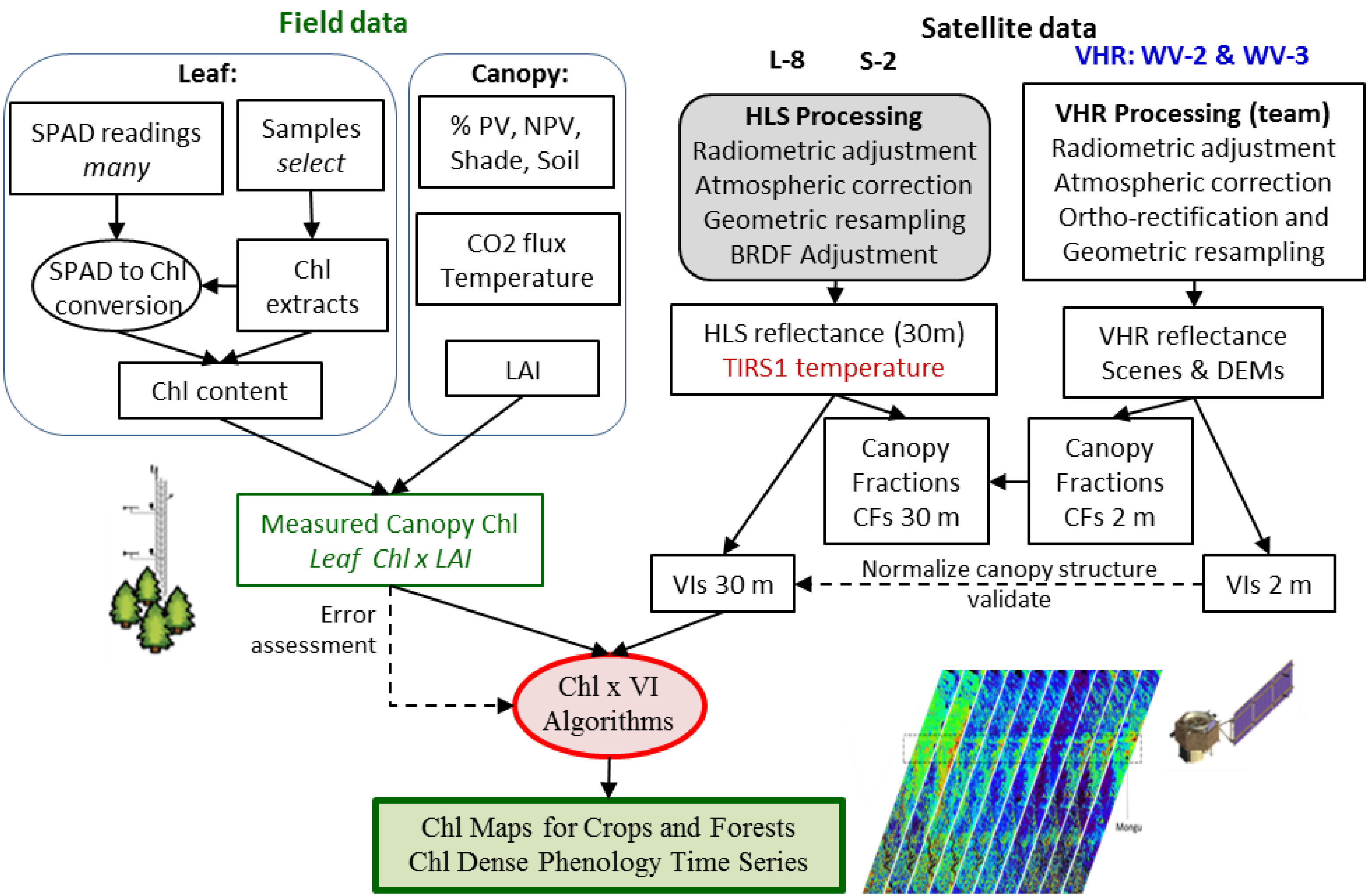
Research Hypotheses

Hypothesis 1: The HLS, L-8 and S-2 data provide spectral VIs predominantly sensitive to the changes in canopy Chl, which can be transferred across canopy structure and species composition.

Hypothesis 2: The use of homogenized HLS, L-8 and S-2 canopy Chl time series will provide higher temporal frequency, yielding improved response to physiological changes and higher Chl accuracy, than it can be produced with either L-8 or S-2 alone.

Hypothesis 3: Seasonal and shorter-term variations in the combined Chl time series will enable detection of phenology differences and stress events throughout the growing season at flux tower validation sites, thus addressing vegetation productivity.

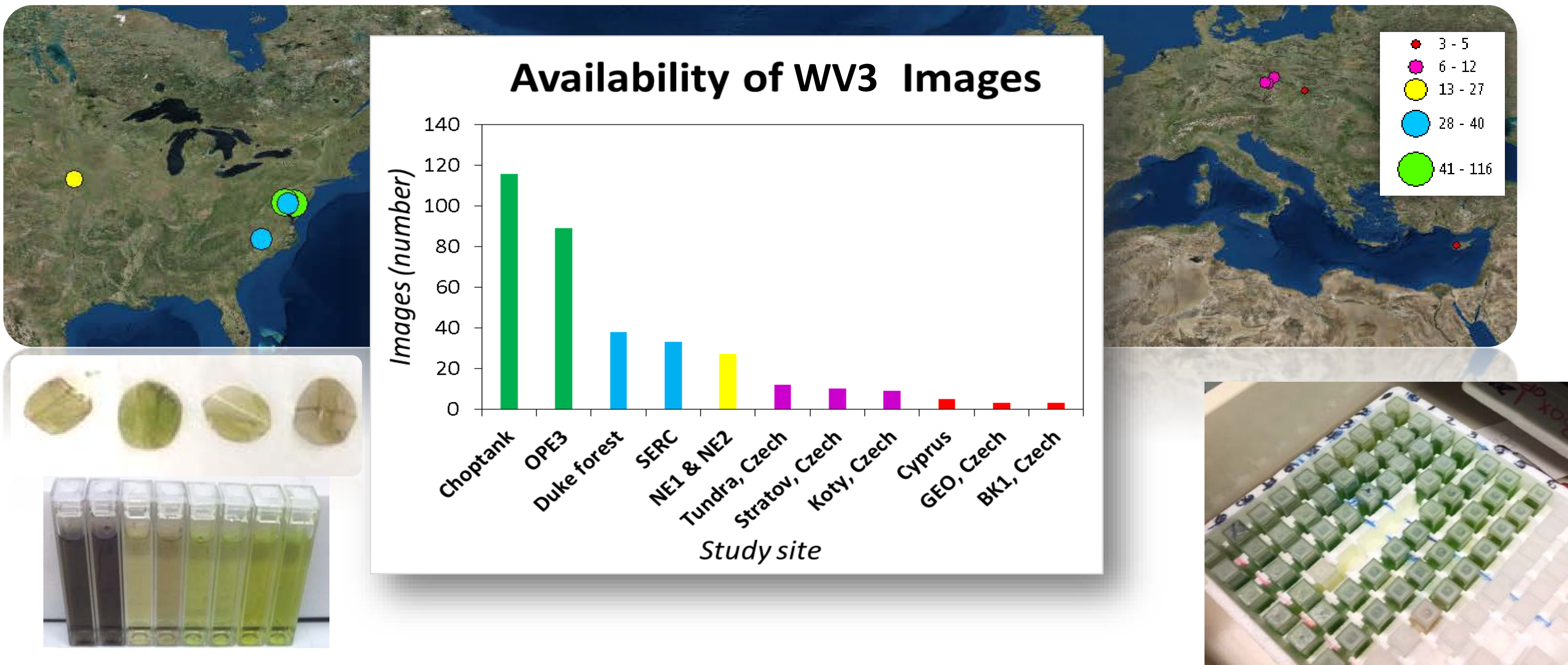
Technical Approach



Study Sites and VHR WV Data (up to 2018)

	Study area	Vegetation cover type(s)	Network
1	USDA, MD, USA - OPE3 & Choptank, GB	Maize and Soybean	2 flux towers, LTAR[2]
2	SERC, MD, USA	Mixed hardwood forest	Smithsonian, NEON[3]
3	Mead, NE, USA: Ne2 and Ne3	Maize-soybean rotation	Fluxnet[1], SpecNet[4]
4	Duke Forest NC, USA	Mixed hardwood forest	Fluxnet, SpecNet
5	Spruce forest (10 sites, Tab. 3), including acid rain decline	Norway spruce forest (evergreen conifers)	Forest study sites – survey BK - Fluxnet, CzechCOS/ICOS[5]

[1] Fluxnet, http://fluxnet.ornl.gov/site_list ; [2]Long Term Agricultural Research (LTAR); [3]National Ecological Observatory Network (NEON), [4]SpecNet, http://specnet.info; [5]CzechGlobe, http://www.czechglobe.cz/en/home



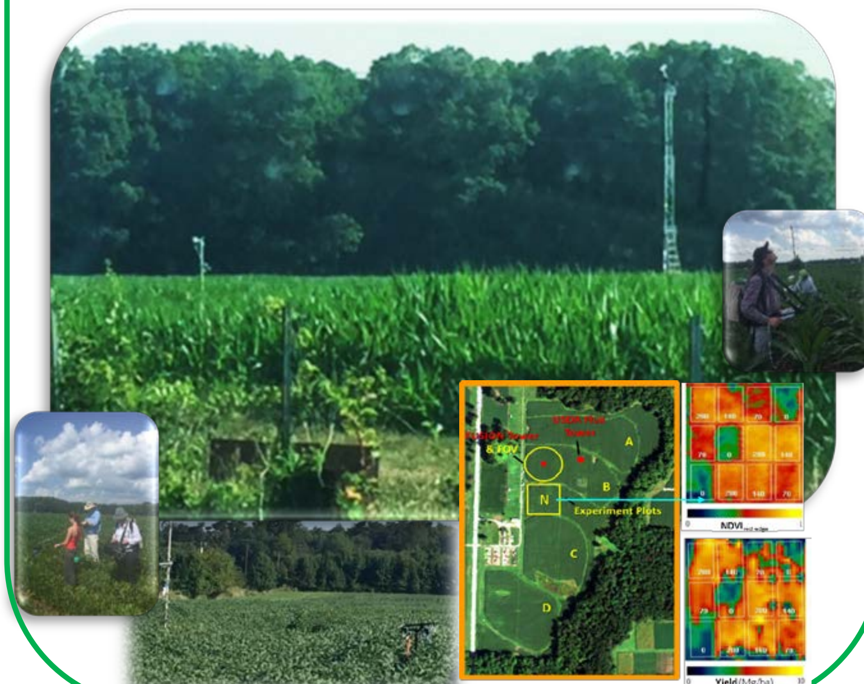
US Sites – OPE3, SERC, NE2 and NE3

Smithsonian Environmental Research Center (SERC), Edgewater, MD

- Mature mixed deciduous forest
- Diurnal FLoX measurements, focused on tulip poplar (*Liroendron tulipifera* L.)
- One week support of NASA/FLARE, PI B. Cook & ESA/FLEX
- Data collection: cal/val for NASA/FLARE; for major species leaf and canopy gas exchange and fluorescence, leaf pigments, LA, SLM, optical properties

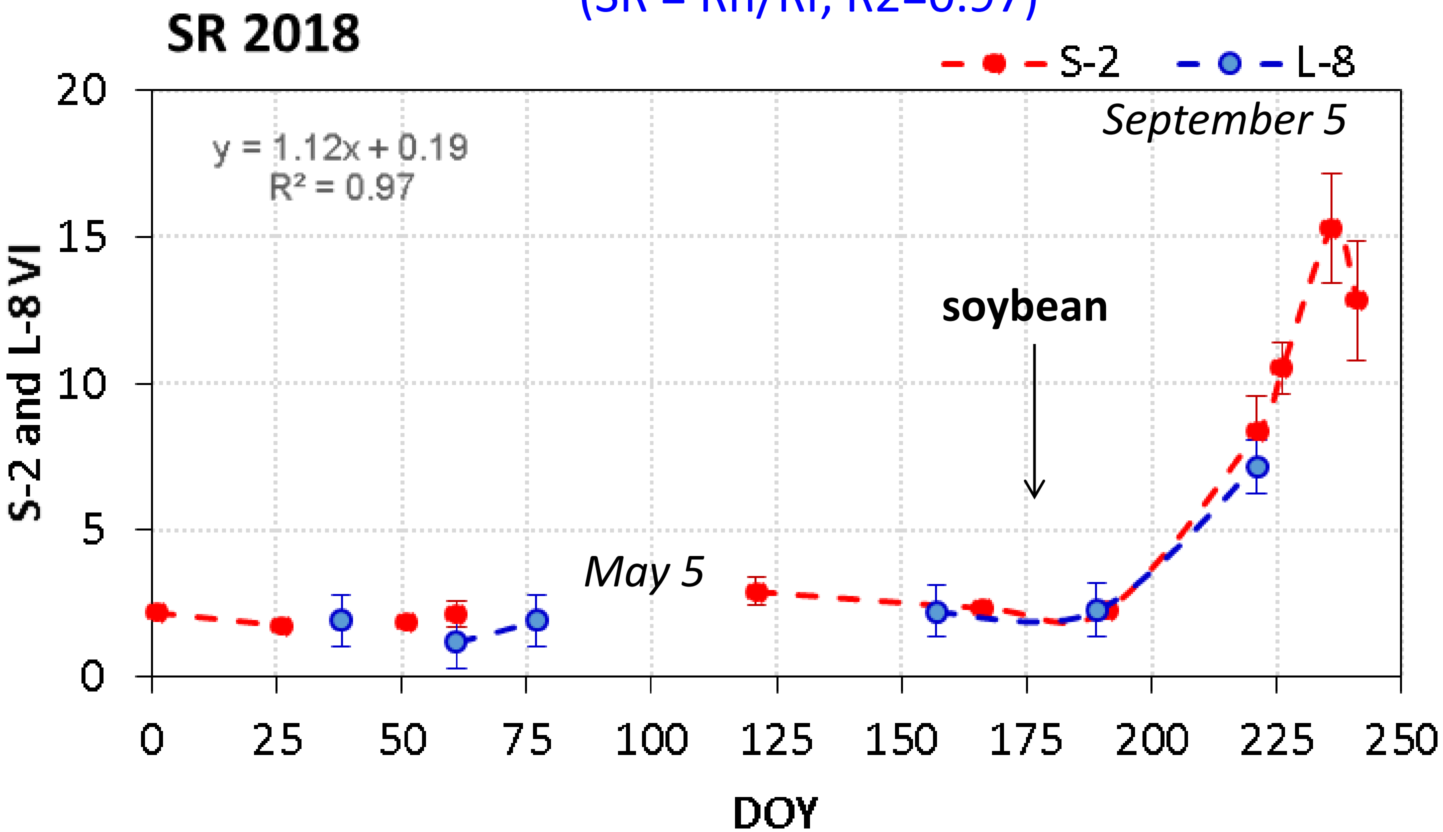
OPE3, USDA/ARC, Greenbelt, MD

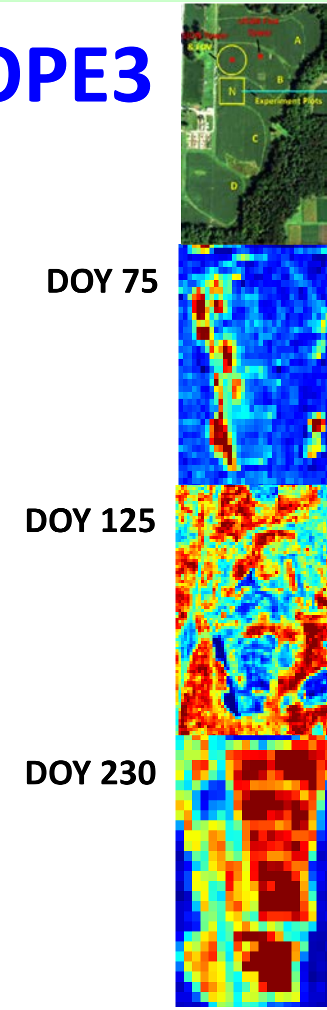
- Corn under optimal nitrogen treatment
- Diurnal and seasonal FLoX measurements capturing phenology changes
- FLoX measured canopy instrumented with FLUX tower and MONIPAM sensors
- Data collection: leaf and canopy gas exchange and fluorescence, leaf pigments, LA, SLM, optical properties; FUSION tower measurements



Comparison of L-8 and S-2 Chlorophyll VIs, OPE3

(SR = Rn/Rr, R2=0.97)

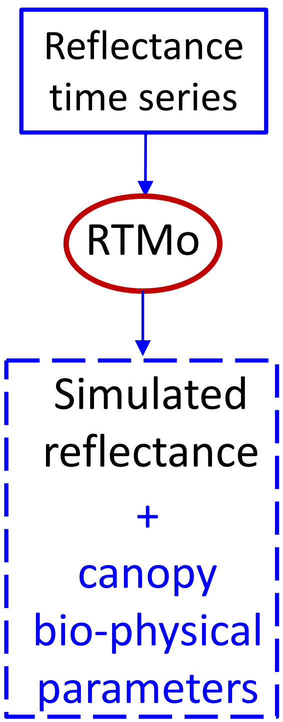


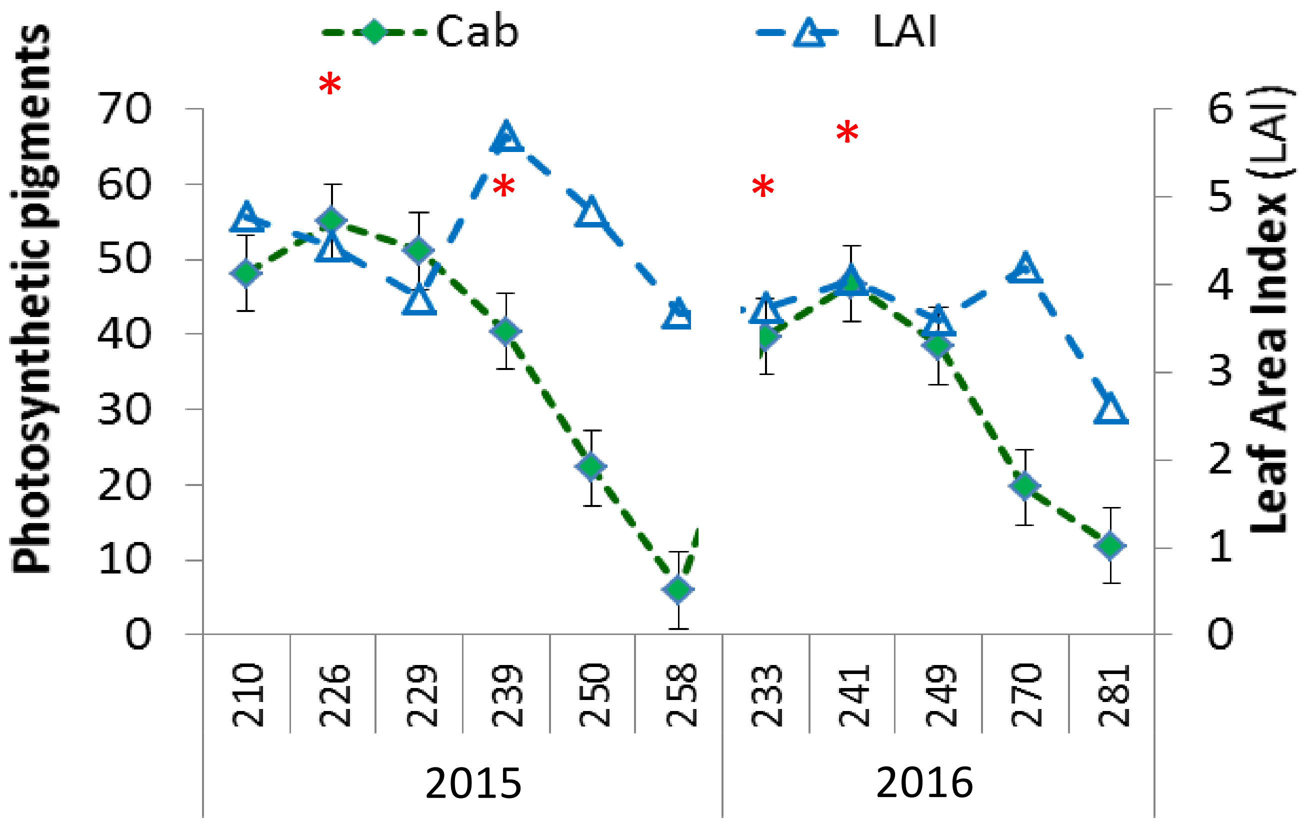


- Completed processing of leaf spectra and pigments from 2018 completed
- Large list of VIs were tested and SR performed optimal at OPE3, for soybean 2018
- Currently algorithms for calibration to chlorophyll are being developed
- Prior collections are being added to the 2018, the 2019 collection is starting!

EO-1 Hyperion Reflectance Time Series at OPE3

Campbell et al. 2017, 2019 in preparation





RTMo LUT inversion applied to reflectance to yield canopy chlorophyll content and LAI, which are currently being validated

SERC: VHR WV 3, TOC reflectance, Chlorophyll VIs

1. **Atmospheric correction > Ortho-rectification > 2 m resampling > Reflectance > VIs**
2. **DSMs > Canopy Fractions - -** canopy structure normalization/ comparison to HLS VIs

NDVI (May-June)

Metadata 2015-05-04

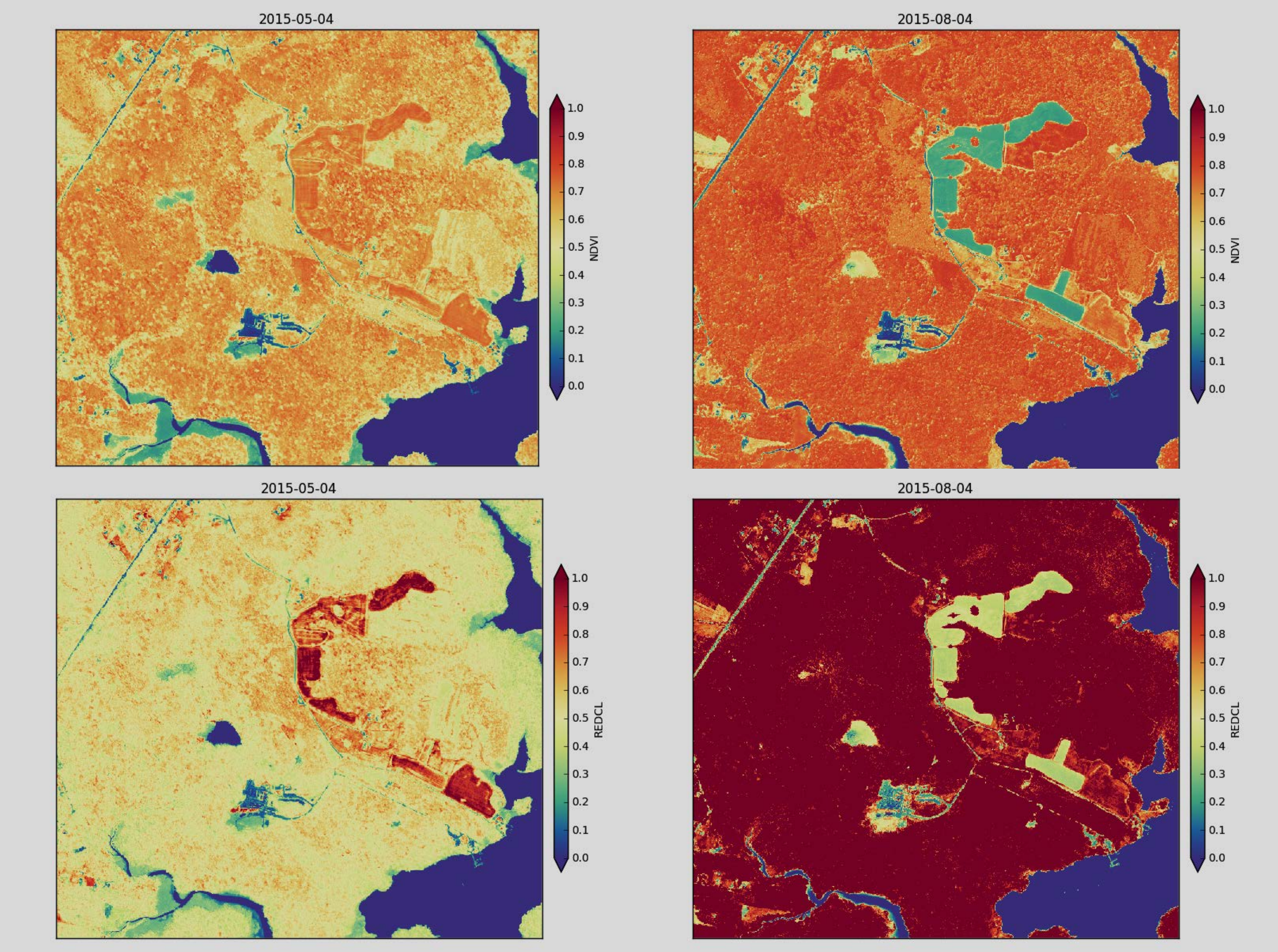
Off_nadir: 28.168802
Sun_Elev: 62.590866
Trgt_azmuth: 320.286407

CLred (May-June)

Metadata 2015-08-04

Off_nadir: 4.807142
Sun_elev: 63.988712
Trgt_azmuth: 325.213776

Clred = Rnir/Rre - 1

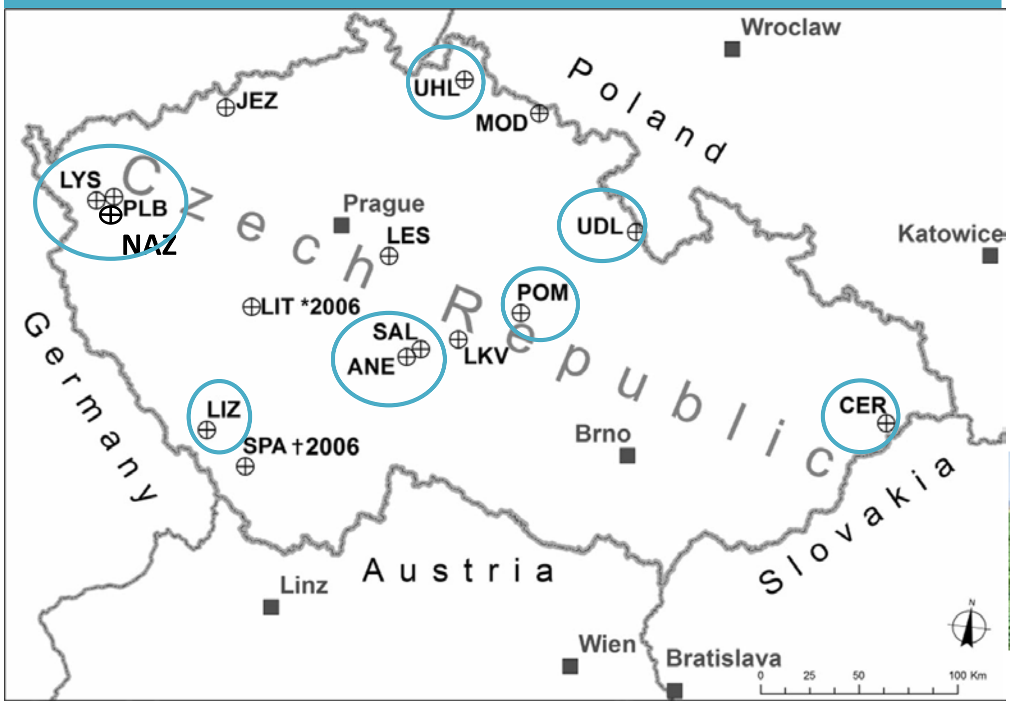


W. Wagner & C. Neigh

Czech Sites - Norway spruce, European beech and Agricultural plots

Site	Mean stream pH	Elevation m a.s.l.	Annual S deposition (meq.m^{-2})	Annual N deposition (meq.m^{-2})
LYS	4,09	829-949	76	67
PLB	7,23	690-804	59	56
LIZ	6,53	828-1024	46	50
ANE	6,85	480-540	70	66
SAL	6,87	557-744	84	45
POM	6,43	512-640	128	54
UDL	5,21	880-950	289	164
UHL	4,94	780-870	182	92
CER	6,78	640-961	104	63

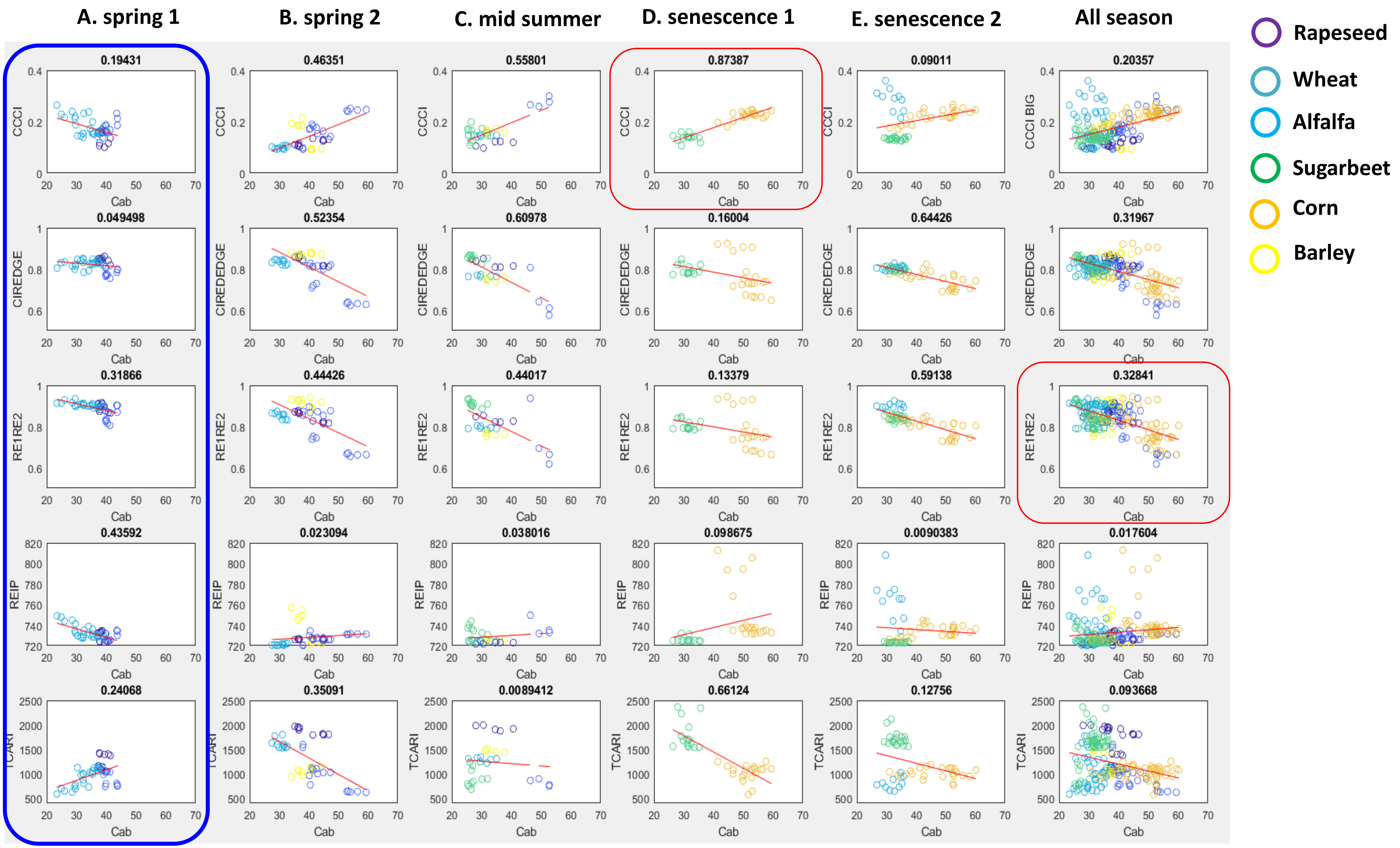
Czech sites location
10 small forested watersheds, Norway spruce



J. Albrechtova, P. Lukes et al.

- **A range of S-2 VIs tested to predict TOC chlorophyll of range of crops and growth stages**
  - **Best-performing VIs were based on red-edge spectral bands (r^2 up to 0.9),**
    - **All combined – optimal VI RE1/RE2 (r^2 = 0.34)**
      - **The results were phenology-specific**

P. Lukes et al.



- RTMo LUT inversion applied to yield crop-specific maps of leaf chlorophyll content, leaf area index and leaf water content

- The evaluation of the maps is currently being performed

Example of the retrievals of leaf chlorophyll content (left), water content (middle) and leaf area index (right)

P. Lukes et al

NASA 17-LCLUC17-0013

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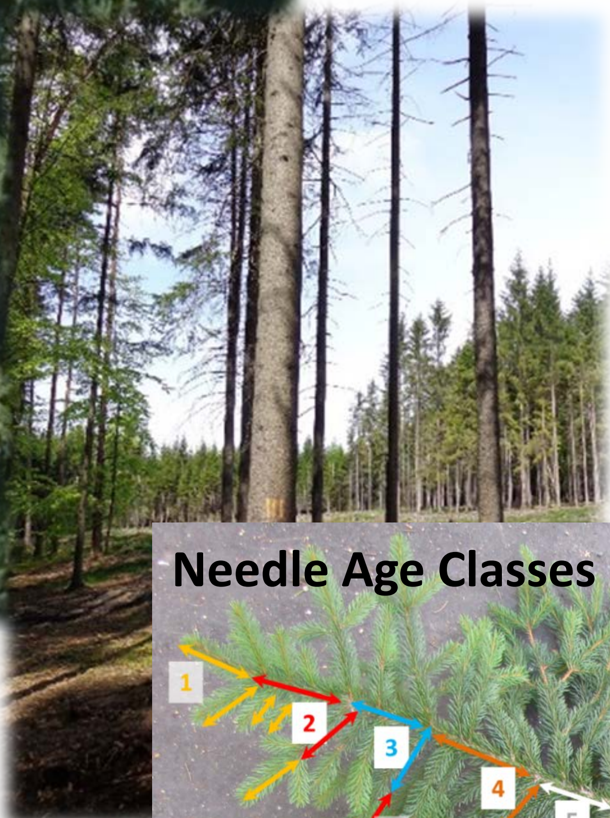
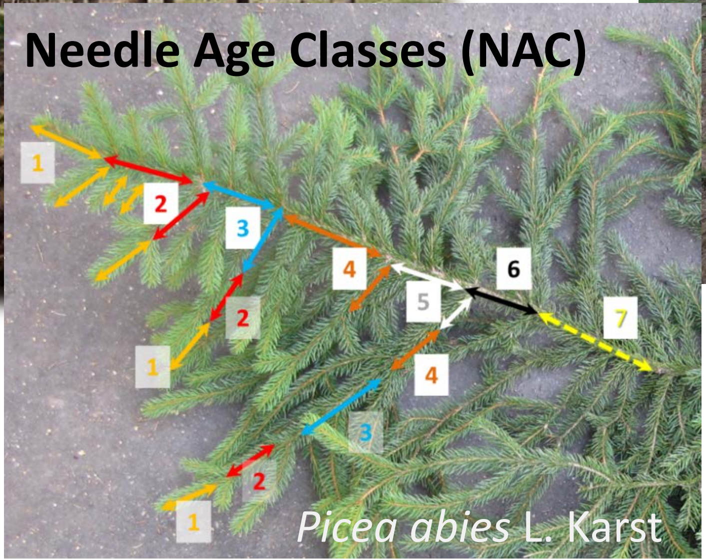
Are the relationships of foliar spectra and biochemistry needle-age-dependent?





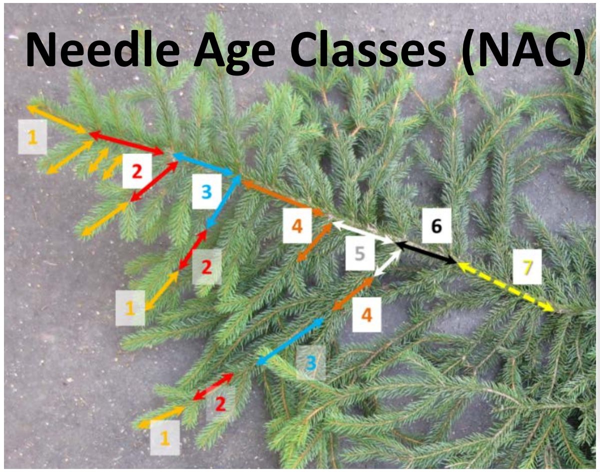
August 2017 (2nd-25th) a field campaign
Collection of 123 Norway spruce trees
Branch from sun-exposed upper crown part

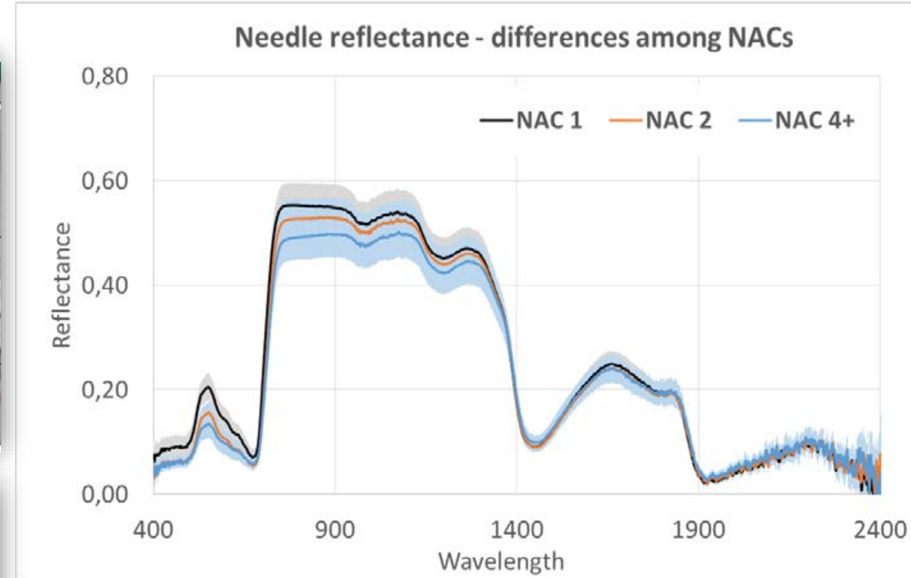
- current needles (NAC 1)
- previous-year needles (NAC 2)
- 4-years and older needles (NAC 4+)

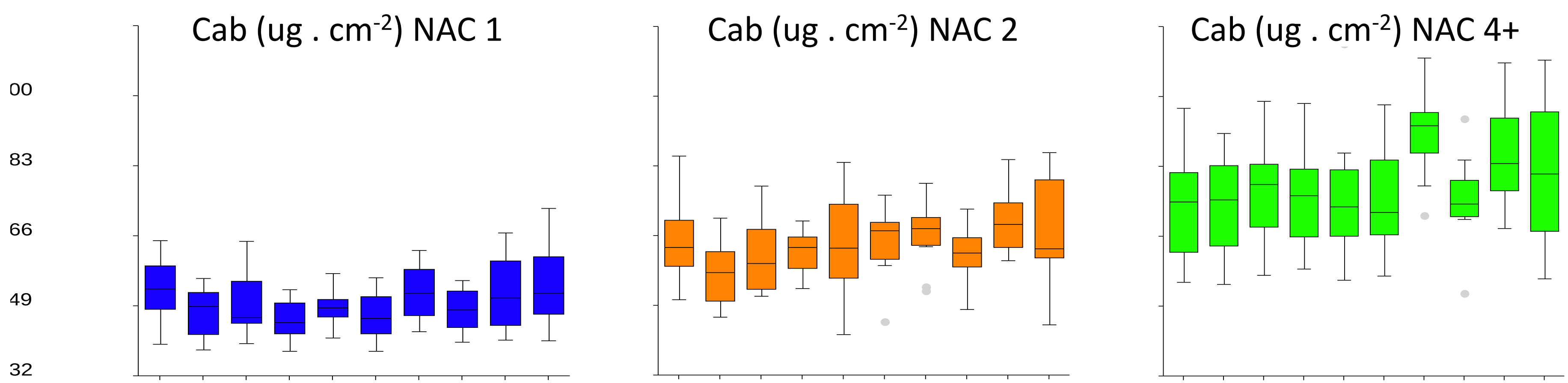
J. Albrechtova et al.

NASA 17-LCLUC17-0013

Prototyping MuSLI Canopy Chlorophyll Content for Assessment of Vegetation Function and Productivity”





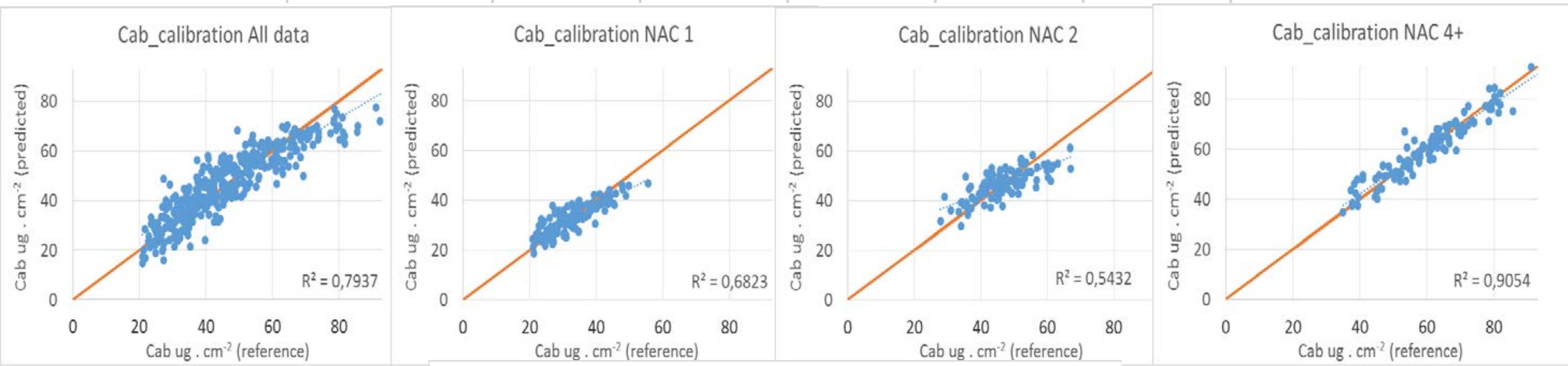


Site order: LYS, PLB, NAZ, LIZ, ANE, SAL, POM, UDL, UHL, CER

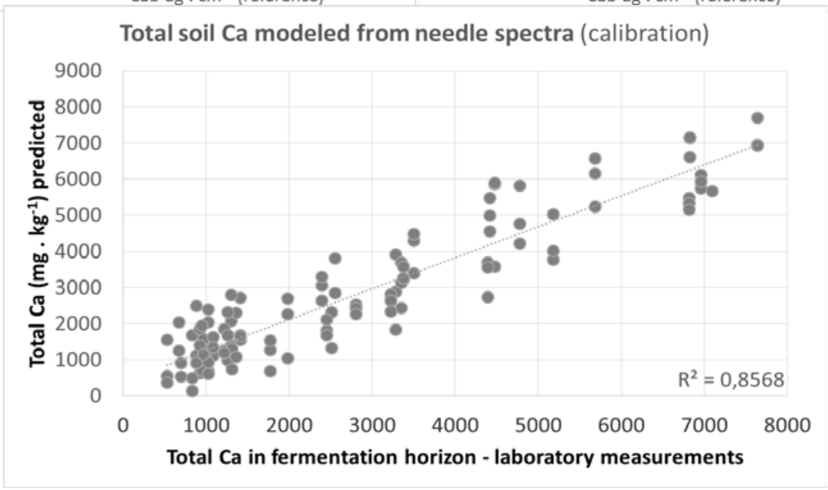
J. Albrechtova

PLSR prediction models comparison
Modeled needle traits from spectra: Cab, Car, SLA, Water

	Dataset	RMSEP	R^2(P)	R^2(V)	n
Cab	All Data	7,00	0,7937	0,6993	369
	NAC 1	4,03	0,6823	0,4634	121
	NAC 2	5,37	0,5432	0,2752	108
	NAC 4+	4,15	0,9054	0,5397	119



All data (NACs):
Needle spectra
Soil Ca, Mg, N



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Ministry of Education, Youth and Sports of the Czech Republic:
Programme INTER-EXCELLENCE, Sub-Programme INTER_ACTION LTUSA18

INTER-ACTION: Ecosystem function based on EO of vegetation quantitative parameters

Czech PI: **Prof. RNDr. JANA ALBRECHTOVÁ, Ph.D.**
Czech Co-I: **Ing. Petr Lukeš, Ph.D.,** CzechGlobe- Global Change Research Institute, Czech Academy of Sciences, Department of Remote Sensing, Brno, Czech Republic
Project Duration: 1.1. 2019 – 31.12. 2022

U.S. Partners :
Dr. Petya Campbell: University of Maryland Baltimore County (UMBC)
Joint Center for Earth Systems Technology (JCET), NASA/Goddard Space Flight Center
Greenbelt, MD 20771 USA
Prof. Howard E. Epstein
University of Virginia, Department of Environmental Sciences, Charlottesville, VA 22904-4123
Goals: A evaluation of a seasonal dynamics of physiological status, function and productivity of vegetation in different ecosystems using phenological course of quantitative parameters of vegetation derived from various sources of EO data with different spatial and spectral resolution (novel HLS dataset, satellite data WorldView-2/RapidEye and very high spatial resolution airborne / drone-based hyperspectral images) and trained and validated based on field and laboratory in-situ (biochemical and biophysical parameters - Cab, water content, LAI).

Future Steps and Anticipated Outcomes

1) Expand the dataset to include 2015-2019
2) Evaluate transferability of workflows and high density time series of canopy Chlorophyll
3) Detection of vegetation stress based on canopy Chl, and assessment of the dynamics in vegetation function
4) Quantify the impact on algorithms and canopy Chl estimates caused by acid rain damage and dynamic environmental perturbations

- The project serves as a prototype for the synergistic use of the data from multiple satellites.
- It will contribute for developing approaches for diagnostic understanding, upscaling and comparing vegetation Chl content and function, evaluating ecosystem dynamics and mapping key biophysical variables.
- The Chl product will help to meet requirements of the Decadal Surveys (e.g. 2007 and 2017), which identify the following terrestrial ecosystem properties as key observables: *Distribution and changes in key species and functional groups; Disturbance patterns; Vegetation stress and nutrient status; Primary productivity*.

South Central and Easter European Regional Information Network (SCERIN/GOFC-GOLD)

Leads: Petya Campbell [1], Jana Albrechtova[2] and Lucie Kupkova[2]

[1] University of Maryland Baltimore County and NASA/GSFC, USA; [2] Charles University in Prague, Cz

Contributing countries: Bulgaria, Czech Republic, Greece, Hungary, Moldova, Macedonia/FYROM, Poland, Romania, Serbia, Slovakia, Slovenia, Turkey, and Ukraine

Goals: Provide a platform for collaboration and networking, to foster regional implementation of innovative LCLUC monitoring methods, consistent product development and monitoring of the dynamics of major land cover types.

Capacity building activities in progress:

- **SCERIN collaborative regional projects/publications** *(leads)*
  - Validation of global land cover products in SCERIN *(I. Manakos)*
  - Land use and land cover changes and their driving forces *(Taff and Stych)*
  - Monitoring of forest cover and function *(Zemek, Albrechtova, Kupková)*
  - 30-yrs changes for SCERIN forest types and climatic forcings *(Pilas)*
- **Collaborative information and workspace:** website, research presentations, references and validation information
- **Regional workshops:** Sofia 2012; Prague 2013*; Krakow 2014; Brasov 2015; Zvolen 2016*; Pecs 2017*; Zagreb 2018*

NEW: SCERIN Workshop: Novi Sad, Serbia; 24-27 June, 2019*

** Coordinated with Trans Atlantic Training (TAT) lead P. Stych, CU Prague*

SCERIN-7 Capacity Building Workshop – TENTATIVE Agenda at a Glance

Day	*Sun*	Mon	Tue	Wed	Thu	*Fri*
Date	*23-Jun*	24-Jun	25-Jun	26-Jun	27-Jun	*28-Jun*
Event	*SCERIN Arrival*	SCERIN-7 CBW				*SCERIN Departure*
		day 1	day 2	day 3*	day 4	

* field trip

Paper including filed, canopy and leaf measurements:

Campbell, P.K.E.; Huemmrich, K.F.; Middleton, E.M.; Ward, L.A.; Julitta, T.; Daughtry, C.; Burcart, A.; Russ, A.L.; Kustas, W.P. (2019). Diurnal and Seasonal Variations in Chlorophyll Fluorescence Associated with Photosynthesis at Leaf and Canopy Scales. Remote Sens. 2019, Special Issue Quantifying and Validating Remote Sensing Measurements of Chlorophyll Fluorescence, 11(5), 488. DOI: 10.3390/rs11050488

2. INTER-ACTION: Ecosystem function based on EO of vegetation quantitative parameters

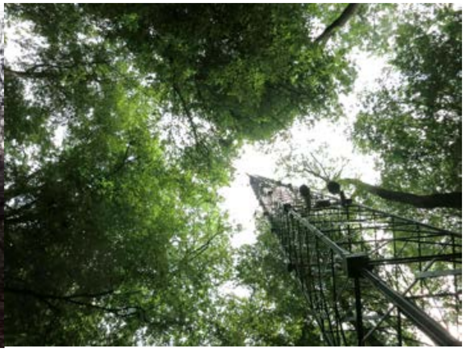
Floodplain forest ecosystem

Campaign in 2019
Floodplain forest (LANŽHOT)

-Protected remains of the floodplain forest on the borders between Czech Republic, Slovakia and Austria

Team:
Lukeš, Homolová, Janoutová - CzechGlobe
Albrechtová, Lhotáková – KEBR

Field campaigns 2019: April, June, July, October – annual phenological changes



Prototyping Multi-Source Land Imaging (MuSLI) Canopy Chlorophyll

for the Assessment of Vegetation Function and Productivity

PI: **Petya Campbell, UMBC and GSFC**

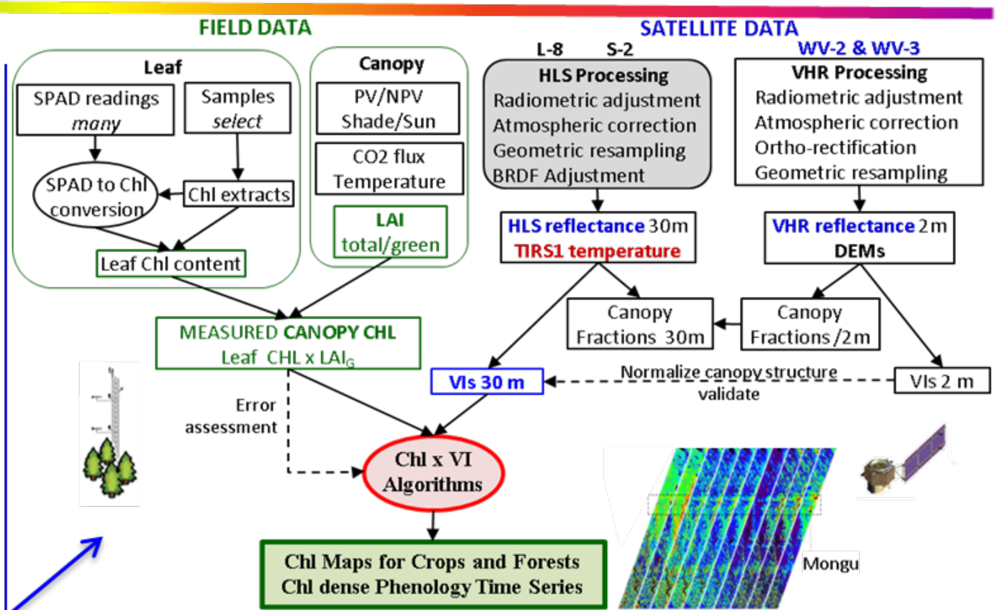
Research Goal

Produce consistent medium resolution (30m) Chl products and algorithms that can reliably be scaled to regional and continental scale.

Leaf chlorophyll content is arguably the most important driver of photosynthesis and a key characteristic of vegetation function.

Objectives

- provide a multisystem seamless approach for using L-8 OLI optical and thermal and S-2 MSI images
- produce high density time series of VIs and canopy Chl for the regionally important species
- produce dense seasonal Chl time series and 'function/stress maps' as the difference between optimal vs. observed Chl



Technical Approach

1. From satellite and field data generate spectral vegetation indices (VIs) and canopy Chl maps, and evaluate uncertainty associated with species and phenology;
2. Account for effects of shadow fraction on spectra and VIs (using VHR data) and validate the fraction of canopy photosynthetic vs. non-photosynthetic cover
3. Generate dense time-series of seasonal Chl maps.

Team

Co-Is: F. Huemmrich, C. Neigh, E. Middleton and J. Albrechtova
Collaborators: C. Daughtry, R. Hunt, A. Gitelson, J. Gamon, T. Arkebauer, E. Walter-Shea, Z. Lhotakova, L. Homolova, F. Zemek, D. Hadjimitsis, K. Themistocleous and A. Agapiou

Milestones and Deliverables

	2/1/18(start)
• **Data assembly** (existing & new)	2/18-12/20
• **Canopy VIs and reflectance inversions** (RTMo)	6/18-6/20
• **Canopy chlorophyll retrievals and validations** */sites*	9/18-9/20
• **Algorithms to scale across S-L, phenology, species**	2/19-10/20
• **Importance of S-2 RE bands**	4/19-4/20
• **Canopy Chl prototype time series** (t-s)	10/18-12/20
• **Scientific value of canopy Chl**	1/20-2/21
(stress detection; vs. t-s NEP & NDVI)	**2/1/21**(end)

Impacts This research will advance the ability to monitor vegetation function at 30 m, estimate carbon assimilation, and manage/improve biomass and yield prediction for agricultural crops, forests and grasslands.

4/18 NASA/LCLUC/MuSLI - 80NSSC18K0337