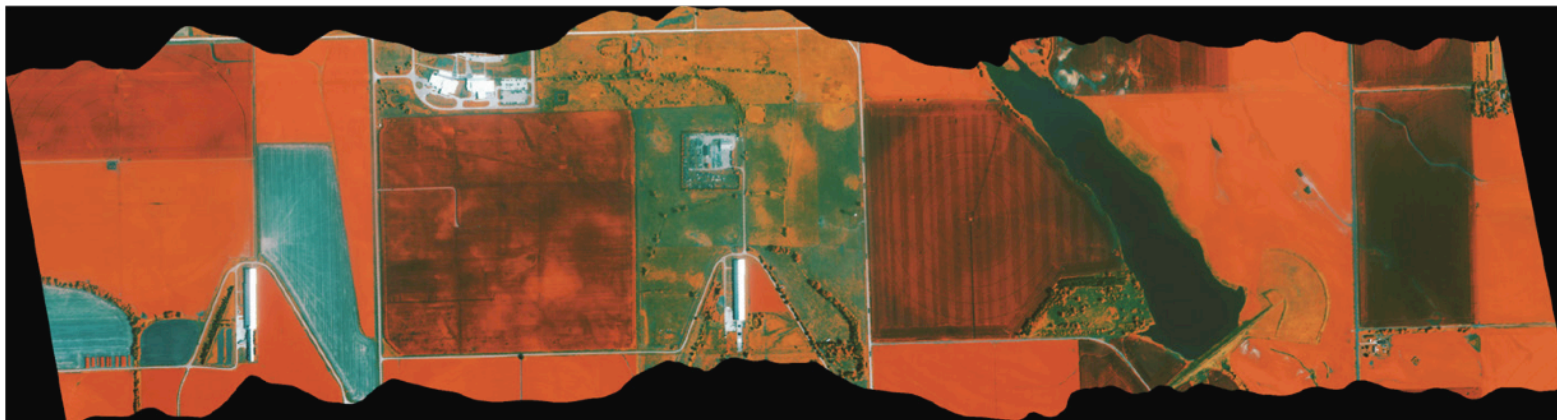


Aisa IBIS Image CSP-3 and Calibration Targets 4 August 2017

Image courtesy of Rick Perk, School of Natural Resources



Science and Application of Chlorophyll Fluorescence: Open Meeting and Airborne Fluorescence Workshop

Sept 26 -- Open Meeting

Sept 27-28 -- Airborne Workshop

Sept 29 -- Field trip

REGISTER HERE: go.unl.edu/openmeeting

Sponsored by the Agricultural Research Division (ARD), Center for Advanced Land Management Information Technologies (CALMIT), Daugherty Water for Food Global Institute, Department of Agronomy and Horticulture, NASA Earth Science Division, Office of Research & Economic Development (ORED), School of Natural Resources and University of Nebraska–Lincoln

By detecting the invisible glow of chlorophyll, solar-induced fluorescence (SIF) offers to revolutionize remote assessment of plant photosynthesis, productivity, and stress. SIF is being applied with instruments at the ground level and with satellites at the global scale, but airborne studies of individual management units, including agricultural plots and individual ecosystems, are needed to provide further understanding of the underlying mechanisms tying SIF to photosynthesis.

This meeting will evaluate the state of knowledge in this rapidly emerging field and consider related science and technical applications, with a particular focus on airborne SIF methods and their validation.

The open meeting will be of broad interest and is open to the campus community, while the airborne workshop (by invitation) will focus on technical issues for SIF practitioners. The optional field trip will enable participants to learn more about SIF research at the University of Nebraska–Lincoln.

Day 1: East Campus Union

**Days 2-3: Hardin Hall
East Campus**

Contact: JOHN GAMON, 402-472-7529, jgamon@unl.edu

Registration and information: JACKI LOOMIS, 402-472-7550, jloomis3@unl.edu

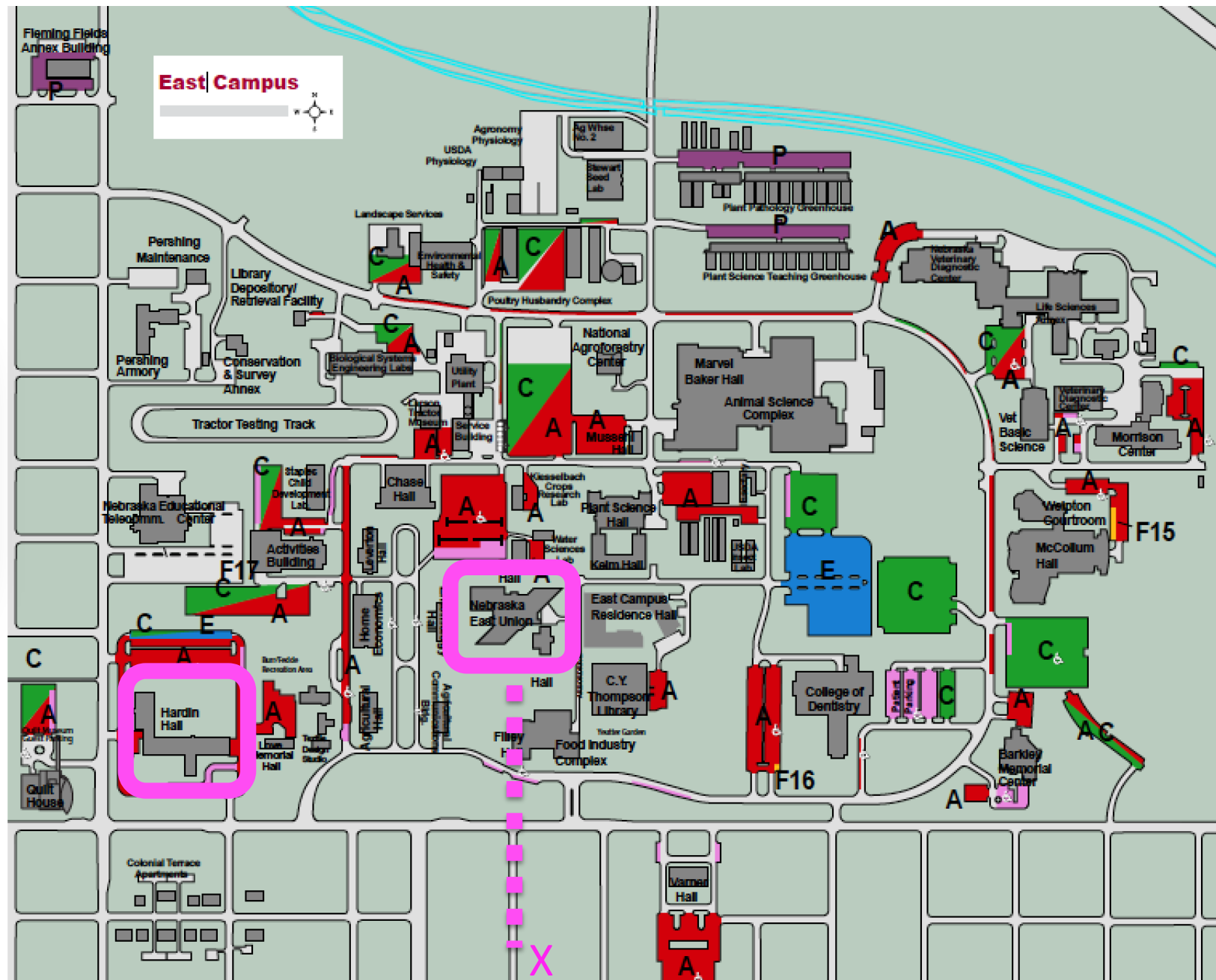


The University of Nebraska does not discriminate based upon any protected status. Please see go.unl.edu/nondiscrimination.

Schedule (in Brief)

- Open Meeting (Tuesday Sept 26)
 - Open session, East Union
 - Reception 5-7, 1250 N. 37th Street, Lincoln
- Workshop* (Wed-Thurs, Sept 27-28)
 - 901 Hardin Hall (and 2nd floor meeting rooms)
 - Dinner (TBA)
- Field Trip* (Friday, Sept 29)
 - CHAMP, Lincoln Airport
 - Field Research Station (ENREC), Mead
 - Lakehouse Farm & Prairie Plate Restaurant (Waverly)
- Posters will be on display in Hardin Hall (2nd floor lobby) Mon-Thurs (lunch and coffee room)

**Workshop and Field Trip Participation Based on Early Registration*



Reception: 1250 N 37th Street, Lincoln NE (5-7 pm)

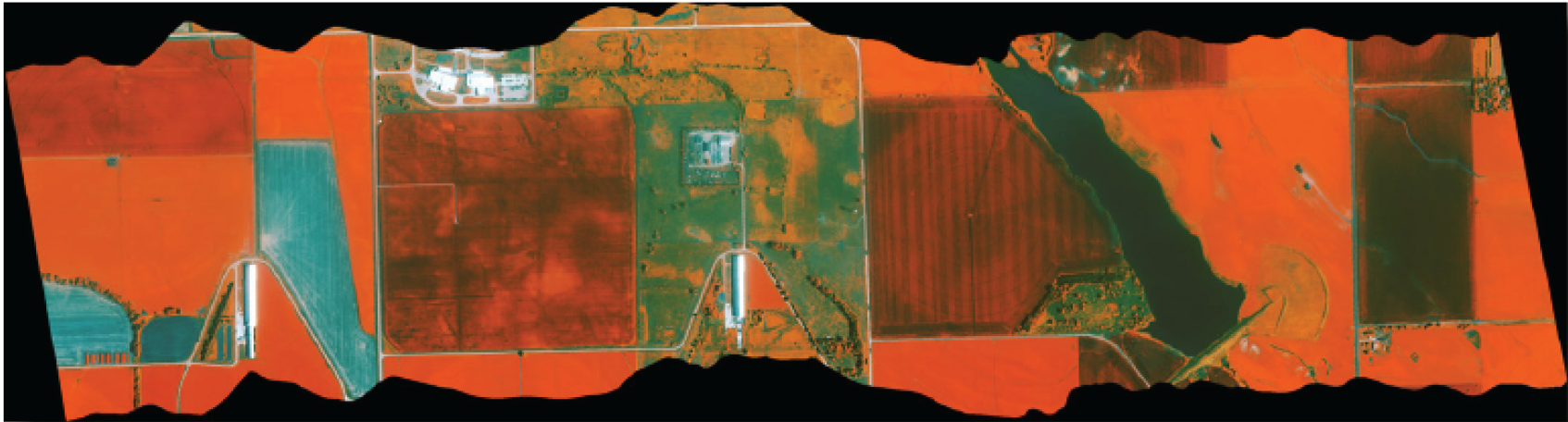


Science and Application of Chlorophyll Fluorescence



Aisa IBIS Image CSP-3 and Calibration Targets 4 August 2017

Image courtesy of Rick Perle, School of Natural Resources

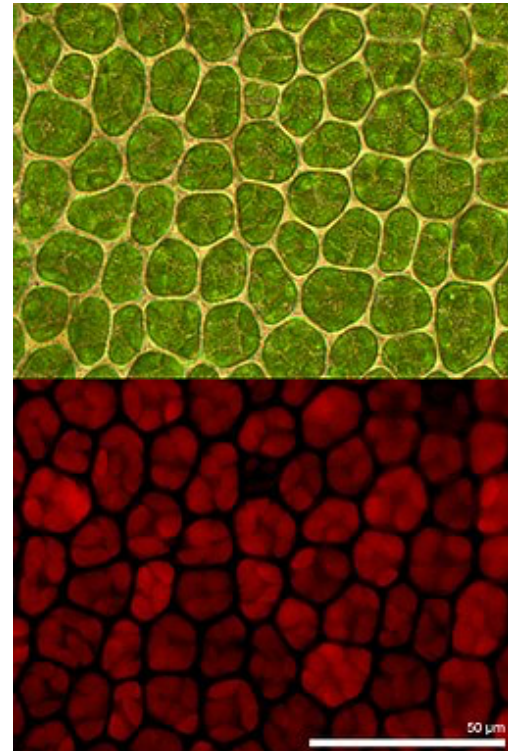


- A brief history of chlorophyll fluorescence
- Key questions & hypotheses
- Potential applications
- Workshop goals

Brief History of Chl Fluorescence...



[https://en.wikipedia.org/wiki/
Chlorophyll_fluorescence#/](https://en.wikipedia.org/wiki/Chlorophyll_fluorescence#/)



Plagiomnium undulatum

[https://commons.wikimedia.org/wiki/
File%3AZz_Plagiomnium_undulatum_fluorescence.jpg](https://commons.wikimedia.org/wiki/File%3AZz_Plagiomnium_undulatum_fluorescence.jpg)

Kautsky Effect

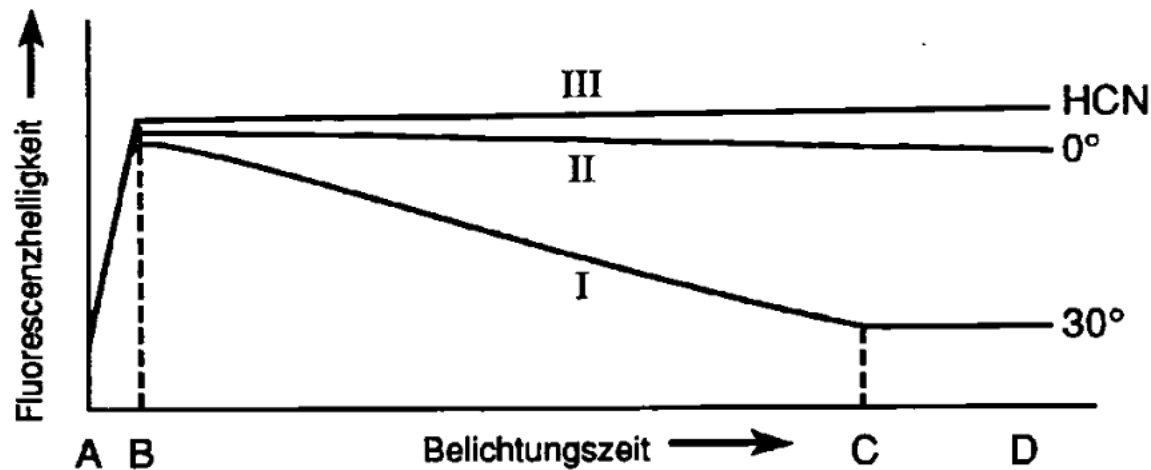
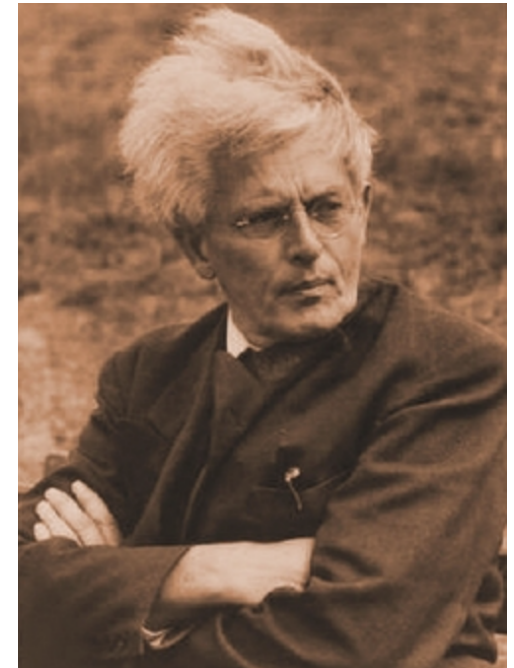


Fig. 1. Schematic representation of Chl *a* fluorescence intensity changes in leaves as observed after turning on the excitation light. I, at 30°C; II, at 0°C; III, poisoned with HCN. Data from Kautsky and Hirsch (1931).



Dr. Hans Kautsky
(1891-1966)

http://www.fluoromatics.com/kautsky_effect.php

Kautsky, H., and Hirsch, A. (1931).

Neue Versuche zur Kohlensäureassimilation, *Naturwissenschaften*, **19**:964-964.

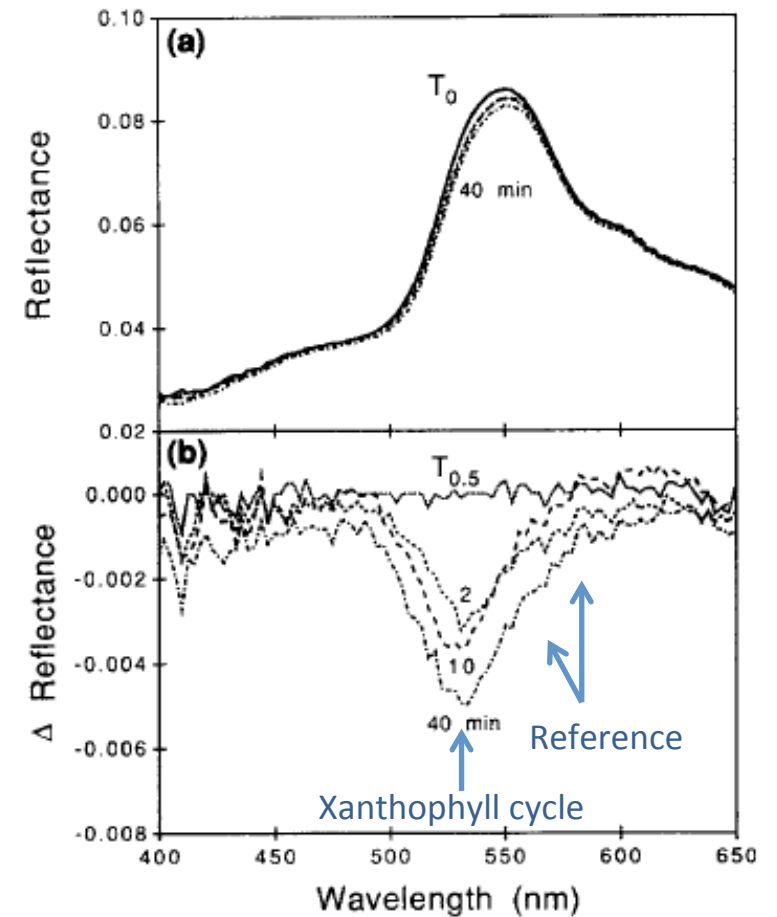
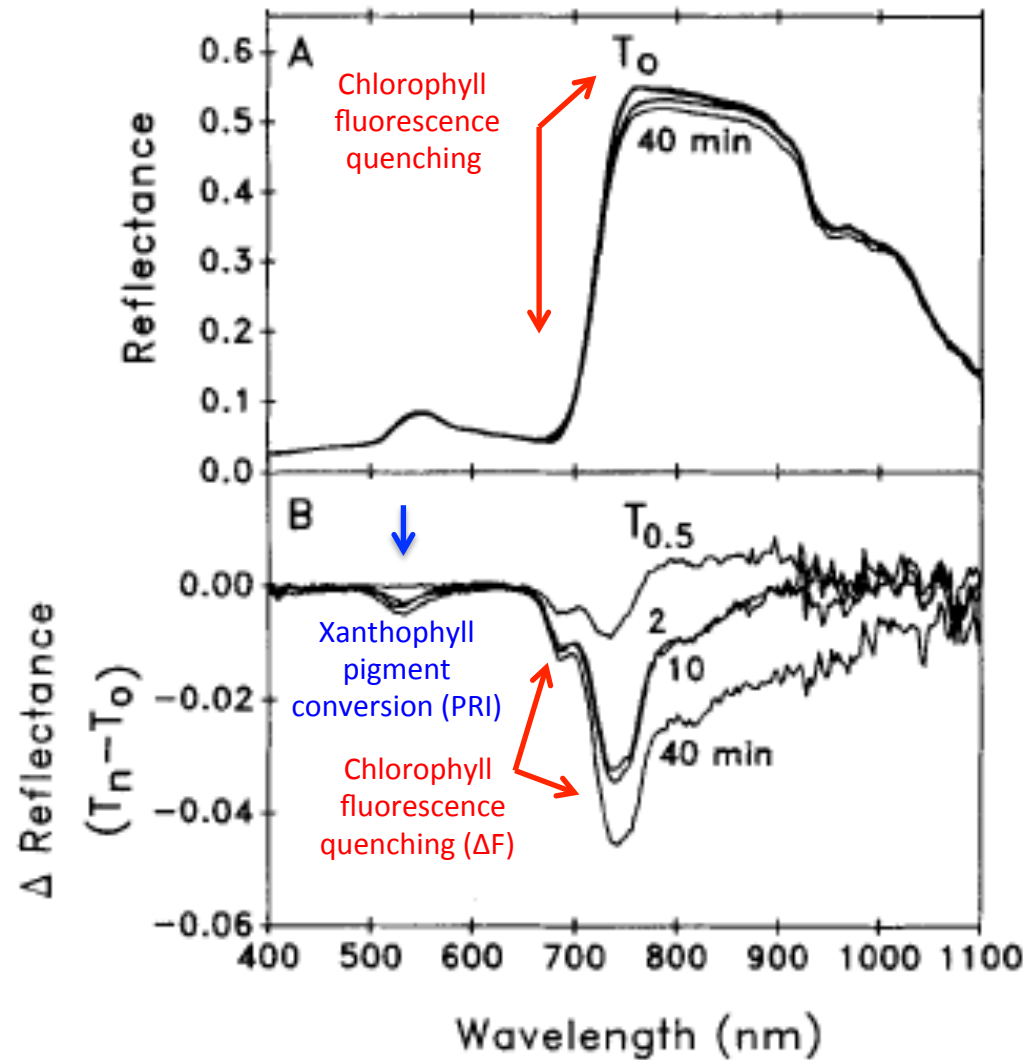
(cited in Govindjee (1995) Sixty-three years since Kautsky chlorophyll *a* fluorescence
Aust. J. of Plant Physiol., 22, 131-160

Optical studies of photosynthetic dynamics



Gamon et al. (1990) *Oecologia* 85:1-7.

Spectral Plots of Photosynthetic Dynamics upon Illumination



Photochemical Reflectance Index

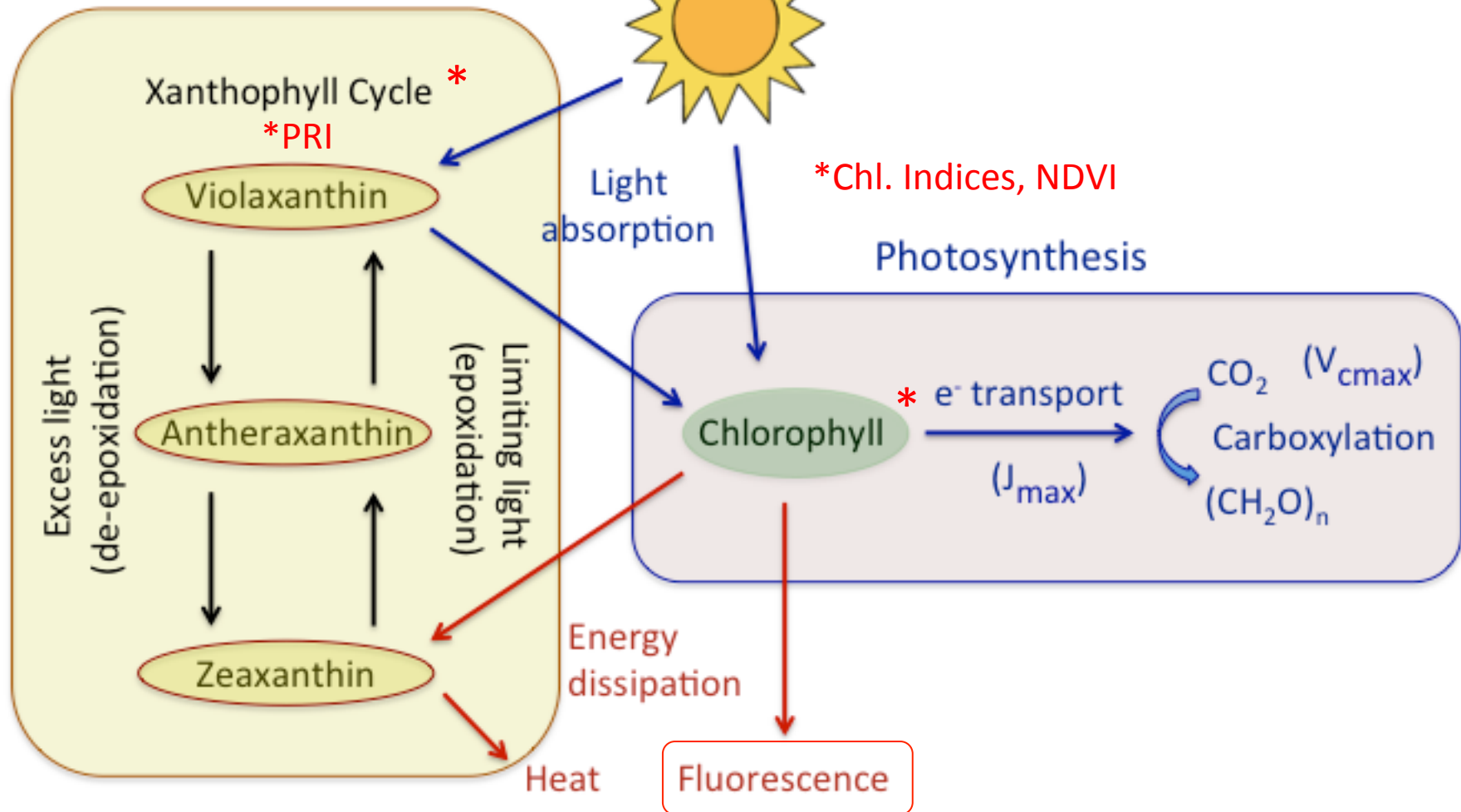
$$PRI = (R_{531} - R_{Ref}) / (R_{531} + R_{Ref})$$

Gamon JA, Field CB, Bilger W, Björkman O, Fredeen A, Peñuelas J (1990) Remote Sensing of the Xanthophyll Cycle and Chlorophyll Fluorescence in Sunflower Leaves and Canopies. *Oecologia*. 85:1-7.

Photosynthetic Regulation

*Carotenoid Indices (e.g. CCI)

Carotenoid Pigment Pool *



Light-Use Efficiency Model

Solar-Induced
Fluorescence

Greenness
(Chl, NDVI)

PRI, $\Delta F/F_m'$
(NPQ)

The diagram shows the equation $\text{Photosynthesis} = (F_{\text{PAR}} \times \text{PAR}) \times \text{Efficiency}$. Three red arrows point from the top labels to the equation: from 'Solar-Induced Fluorescence' to F_{PAR} , from 'Greenness (Chl, NDVI)' to F_{PAR} , and from 'PRI, $\Delta F/F_m'$ (NPQ)' to 'Efficiency'. A blue bracket under the term $(F_{\text{PAR}} \times \text{PAR})$ is labeled A_{PAR} below it. A blue arrow points from the text 'absorbed light' to A_{PAR} . Another blue arrow points from the text 'Carbon gain, Primary Production' to 'Photosynthesis'.

$$\text{Photosynthesis} = (F_{\text{PAR}} \times \text{PAR}) \times \text{Efficiency}$$

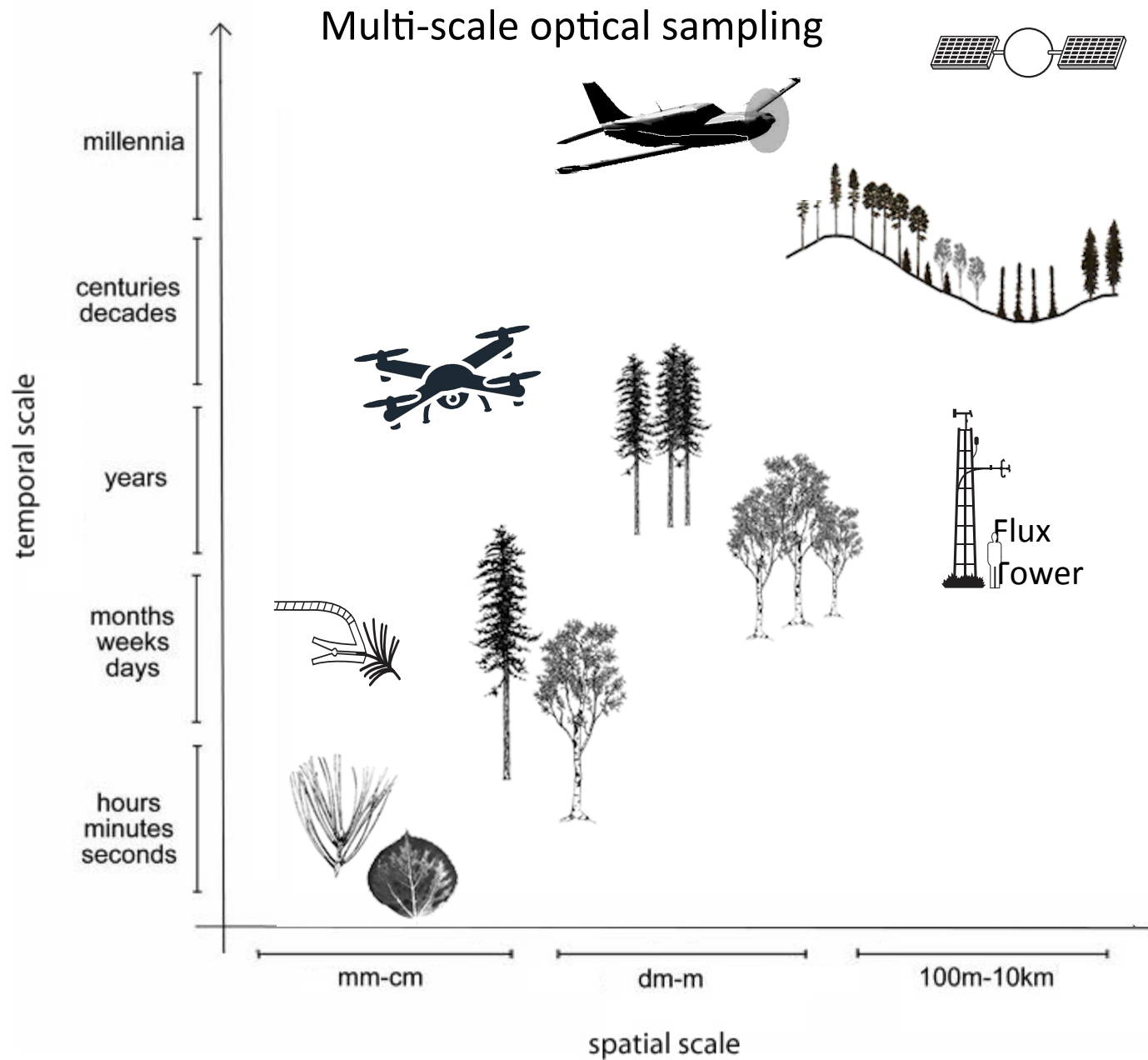
Carbon gain,
Primary Production

A_{PAR}

← absorbed light

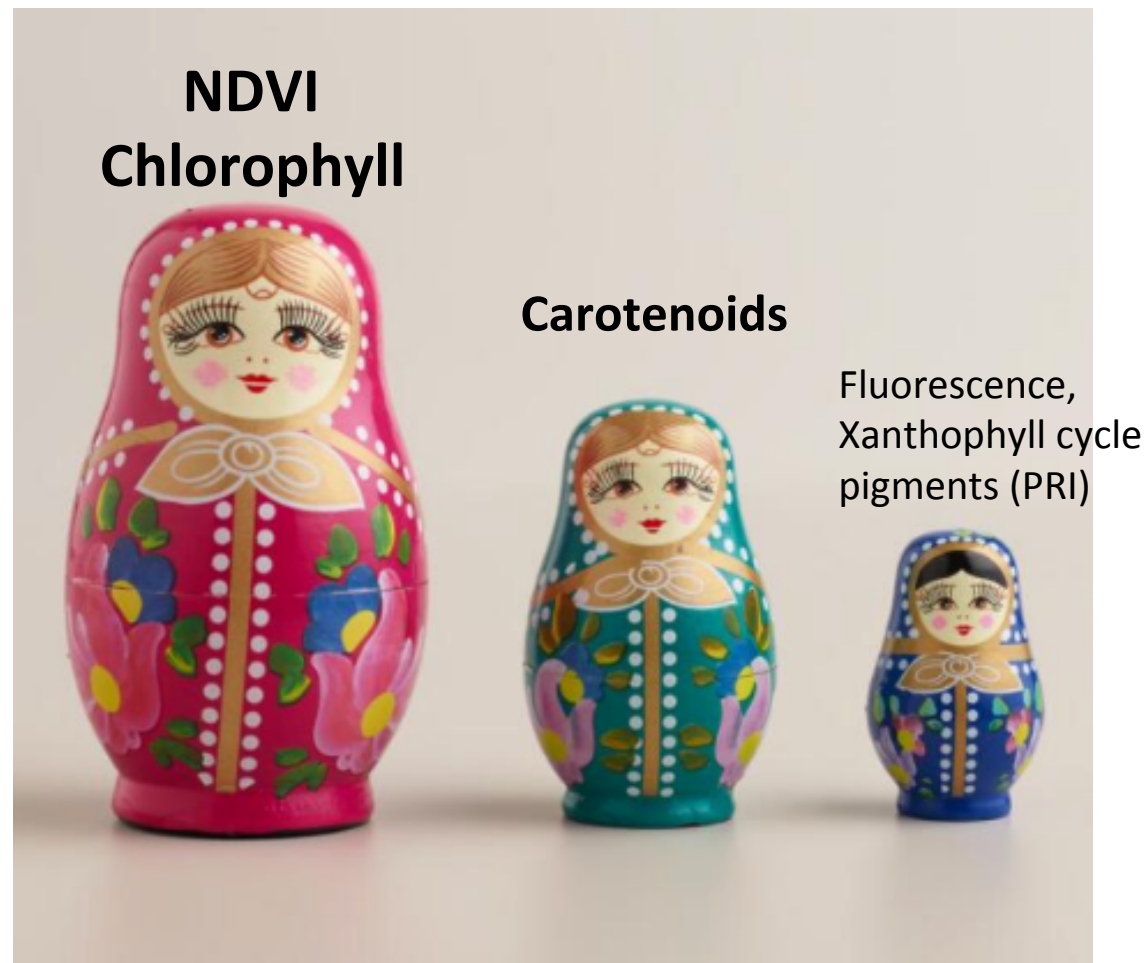
PAR = Photosynthetically Active Radiation

How “scaleable” is SIF?



Sampling Challenges

(detecting tiny things inside bigger things)

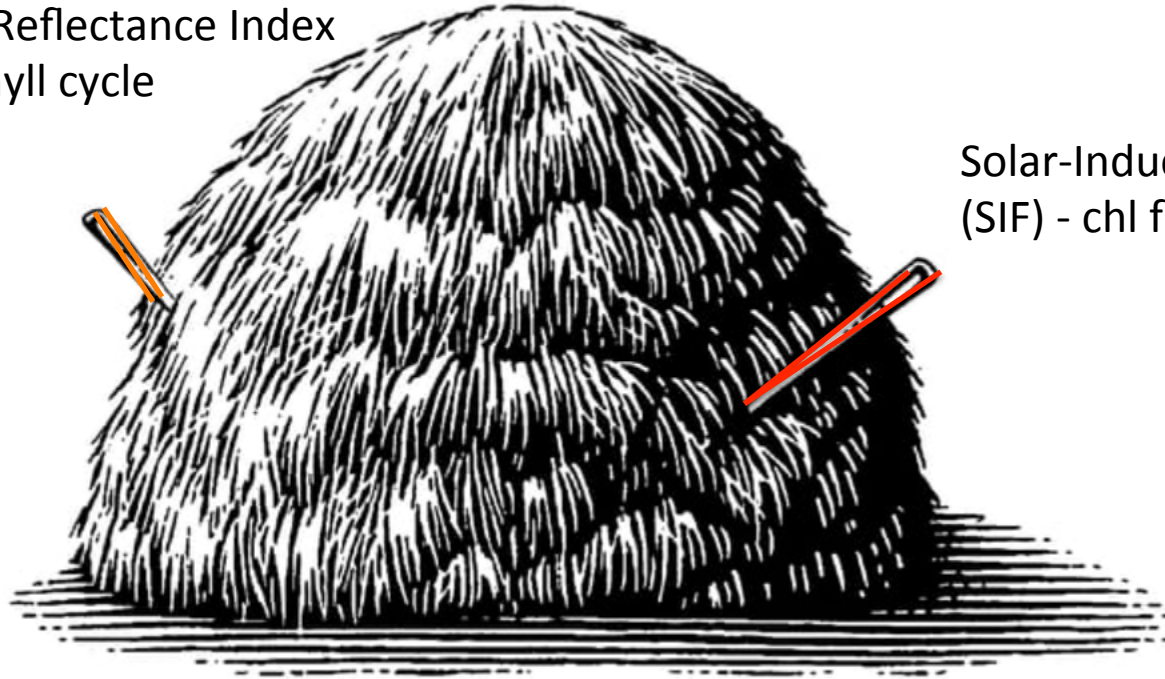


<https://www.worldmarket.com/>



Needles in the Haystack

Photochemical Reflectance Index
(PRI) - xanthophyll cycle

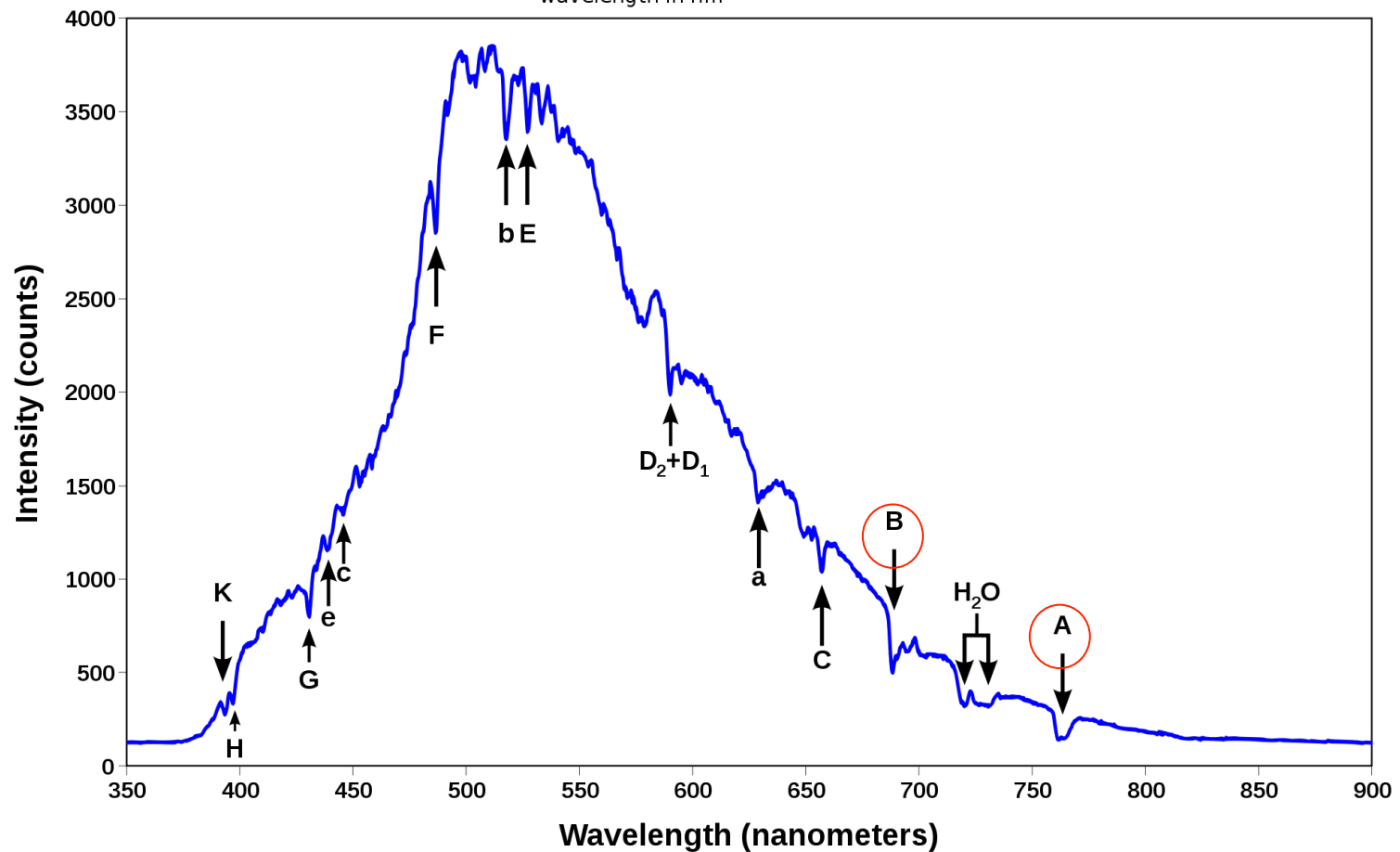
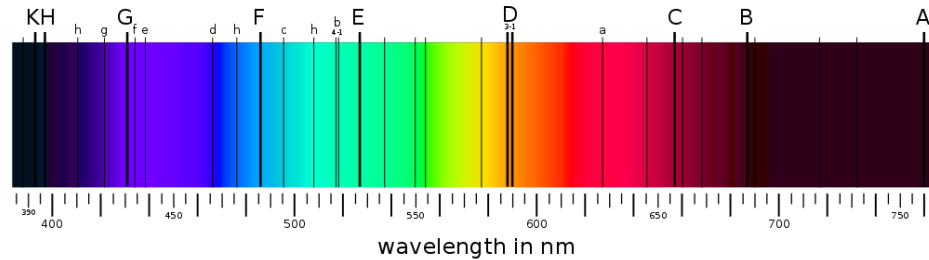


Solar-Induced Fluorescence
(SIF) - chl fluorescence

The SIF needle in the haystack

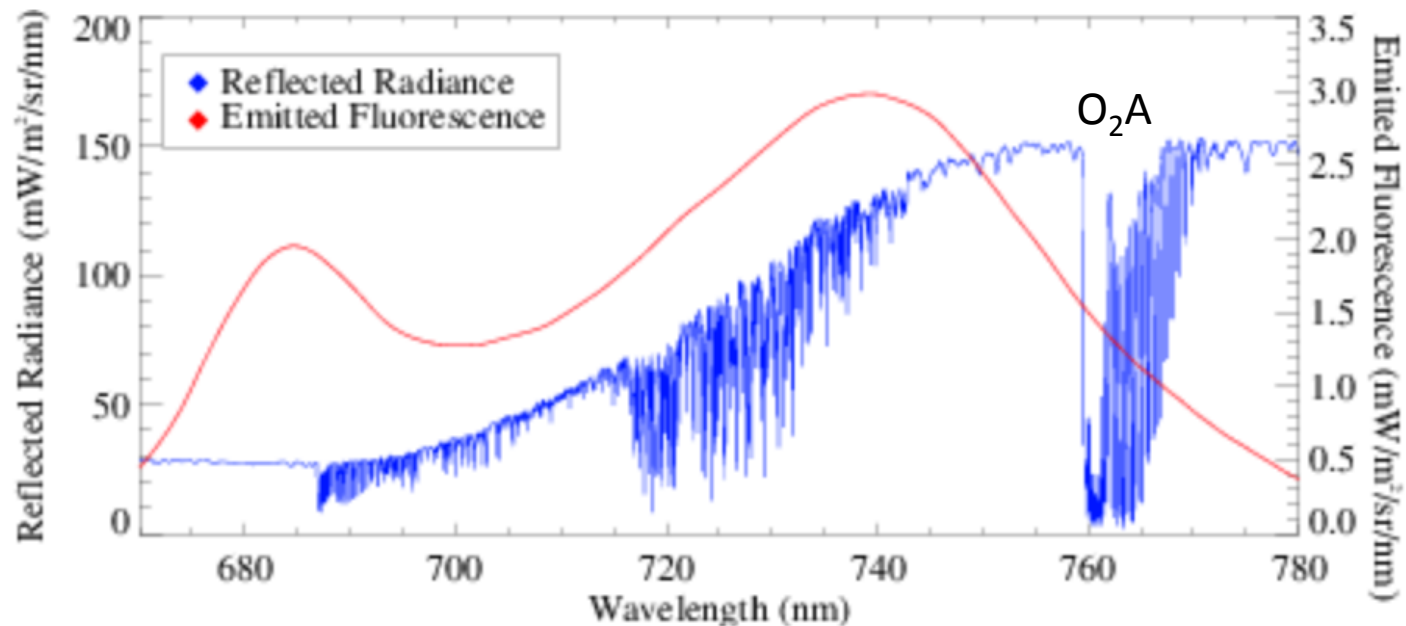
- Carter et al. (1990) used the Fraunhofer line-depth principle to quantify a fluorescence signal in the H α line at 656.3 nm.
- Frankenberg et al. (2011) and Joiner et al. (2011) reported that existing satellites could detect a tiny fluorescence signal in Fraunhofer lines.

Fraunhofer Lines



https://en.wikipedia.org/wiki/Fraunhofer_lines

Detecting Fluorescence in Reflected Radiance from Space



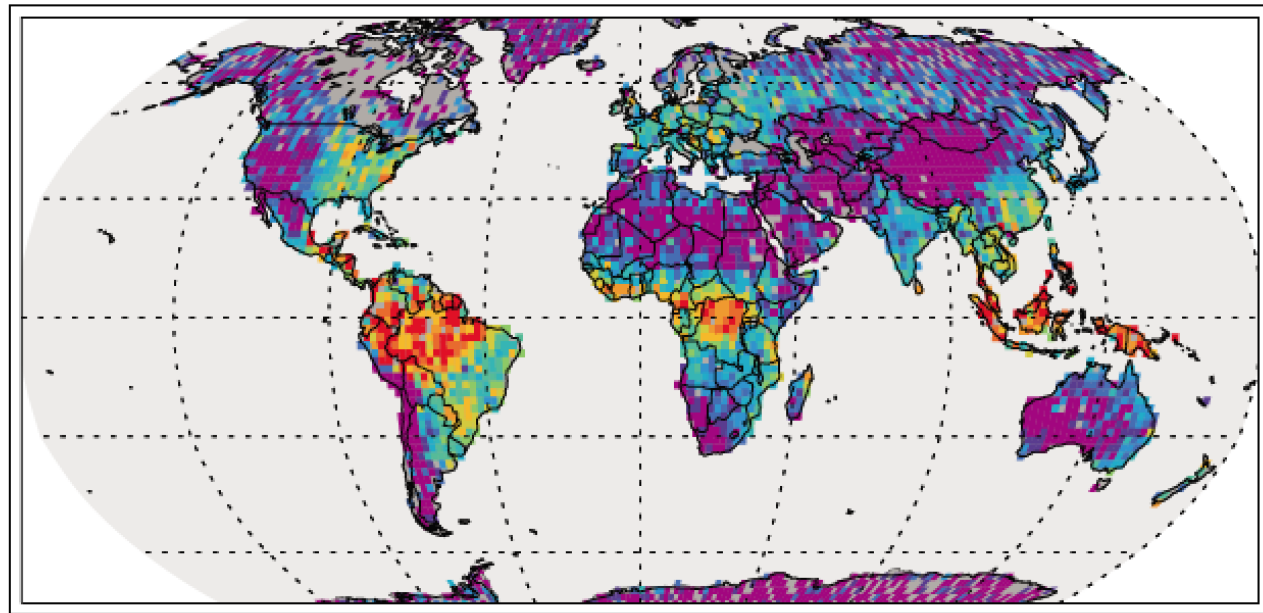
Several satellites (GOSAT, GOME-2, SCIAMACHY and OCO-2) can be used to retrieve the tiny vegetation fluorescence signal from space

Figure: Luis Guanter

<https://www.gfz-potsdam.de/>

Global SIF image

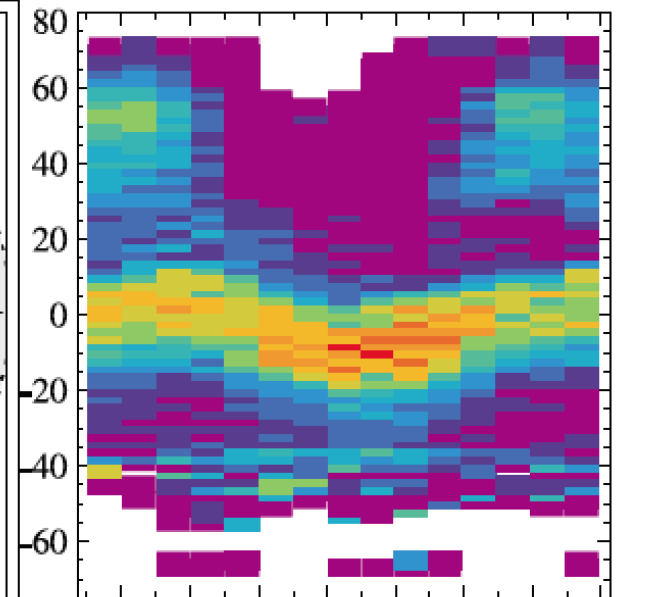
A Chlorophyll a fluorescence at 755 nm, June 2009 through May 2010 average



$F_s / (\text{W m}^{-2} \text{ micron}^{-1} \text{ sr}^{-1})$

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3

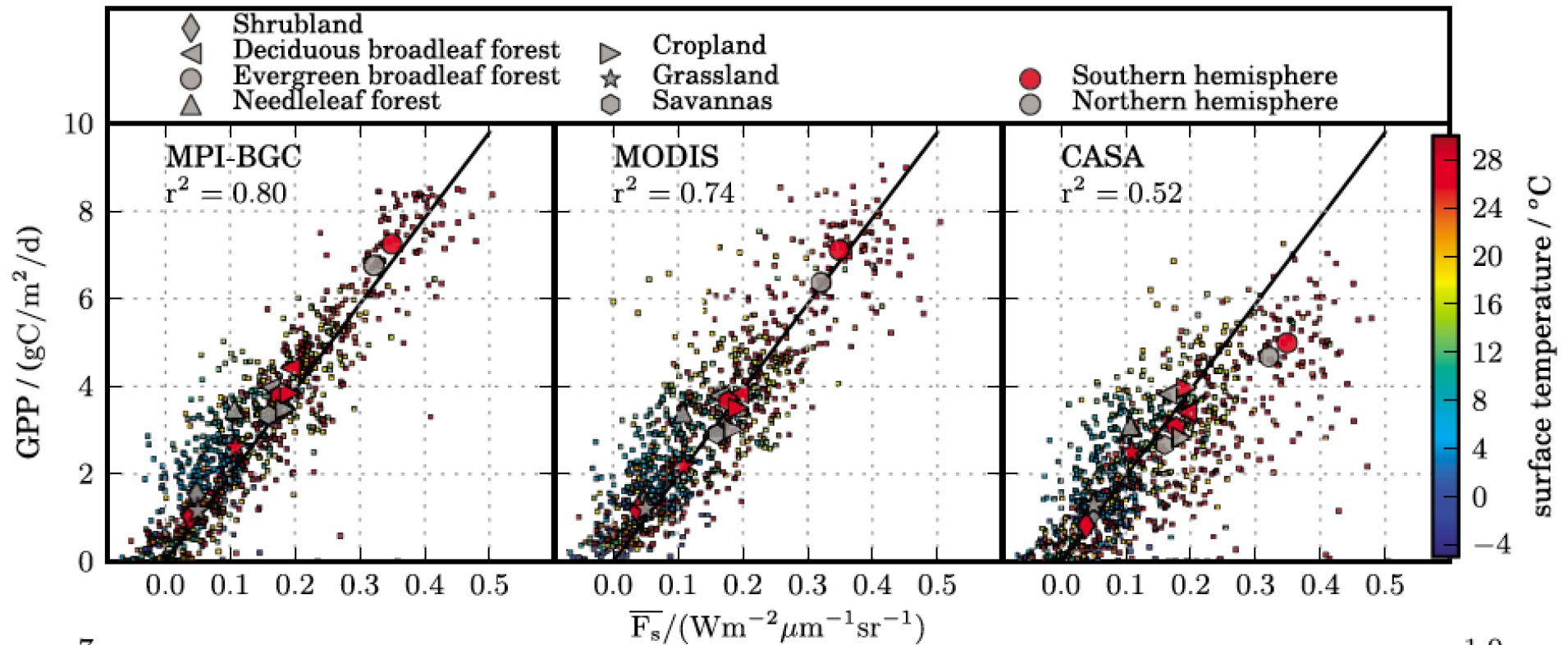
B Timeseries



Jul Sep Nov Jan Mar May Jul Sep
2010

Frankenberg et al. (2011) *GRL* New global observations of the terrestrial carbon cycle from GOSAT: Patterns of plant fluorescence with gross primary productivity, Vol. 38, L17706, doi:10.1029/2011GL048738

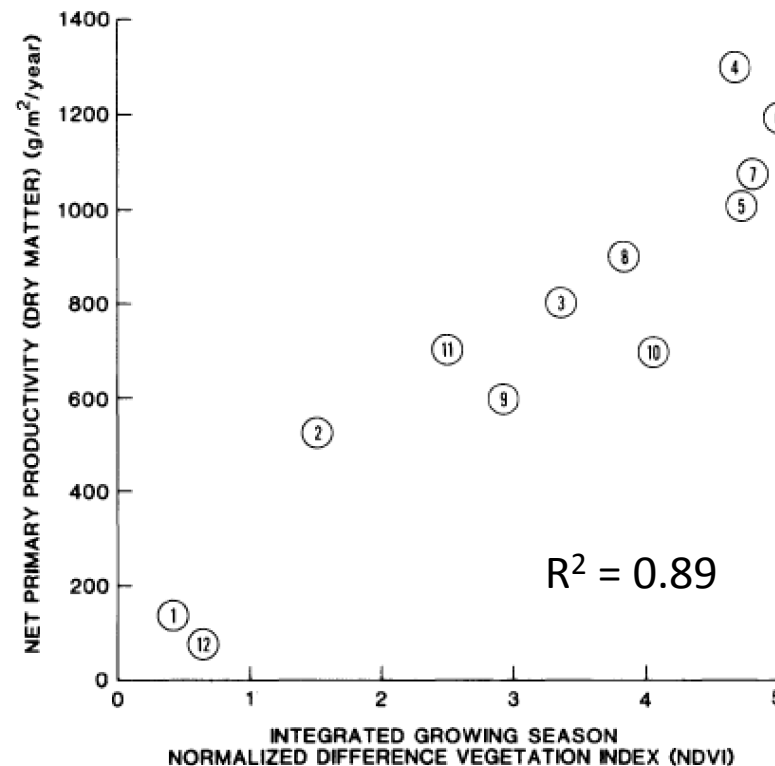
SIF (F_s) vs. primary production (GPP)



Is SIF “better” than reflectance approaches based on NDVI?

Frankenberg et al. (2011) *GRL*

NDVI vs. Net Primary Production (NPP)



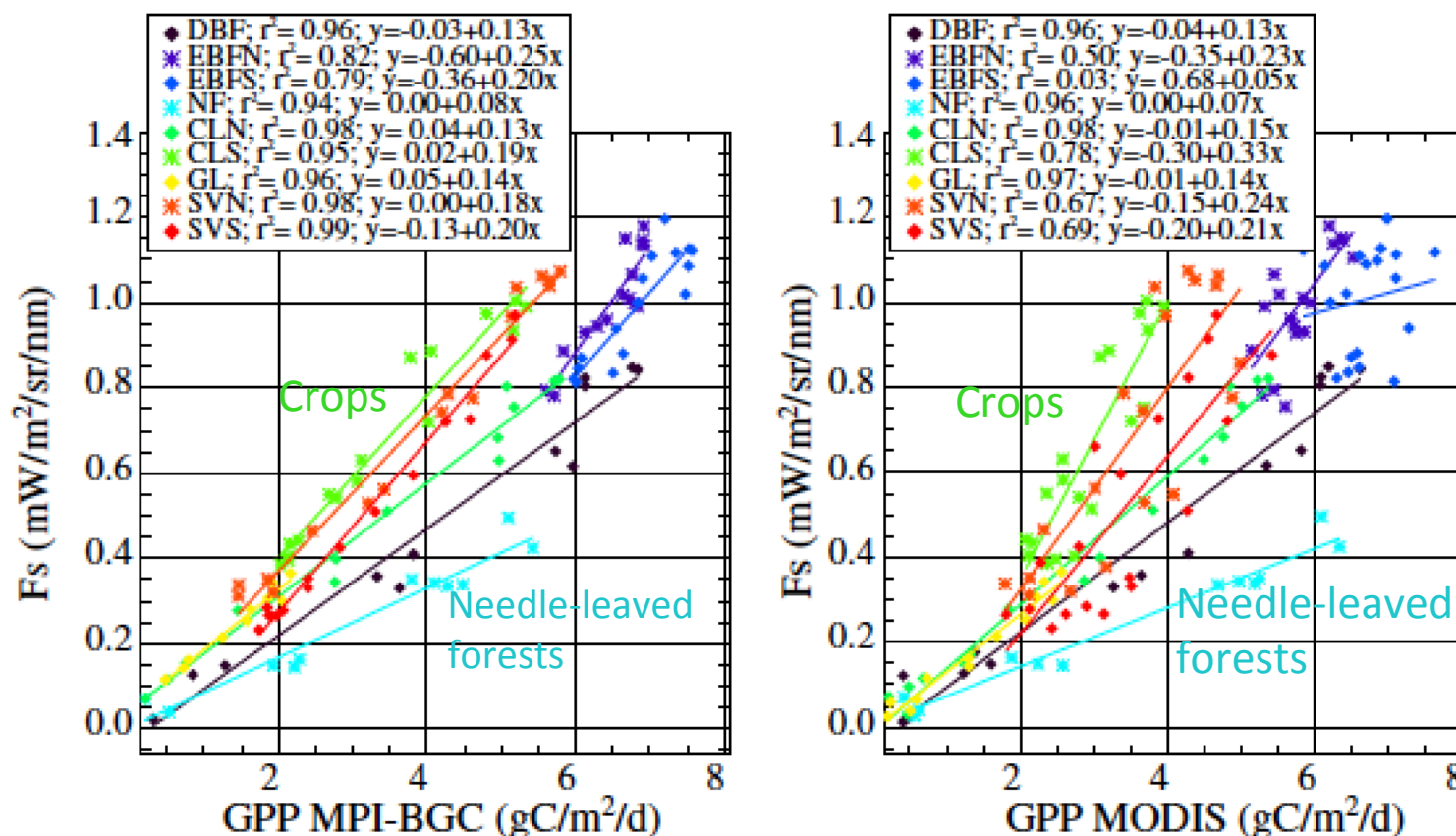
NDVI is also a good predictor of production for the world's biomes

- | | |
|--------------------------------|----------------------|
| ① TUNDRA | ⑦ OAK-PINE SUBCLIMAX |
| ② TUNDRA-CONIFEROUS ECOTONE | ⑧ PINE SUBCLIMAX |
| ③ BOREAL CONIFEROUS | ⑨ GRASSLAND |
| ④ TEMPERATE MOIST CONIFEROUS | ⑩ CULTIVATED |
| ⑤ CONIFEROUS-DECIDIOUS ECOTONE | ⑪ WOODLAND & SCRUB |
| ⑥ DECIDIOUS | ⑫ DESERT |

Goward & Dye (1985)
Vegetatio

Not all vegetation is alike!

SIF (F_s) vs. Primary Production (GPP) across biomes



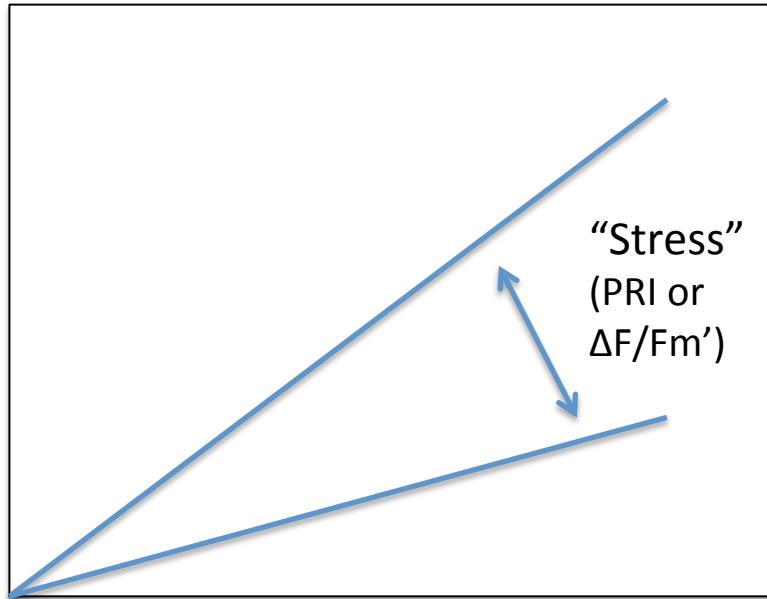
*What causes these biome-level differences in SIF-production?
Structural effects? Physiological differences?*

Hypotheses

- Fluorescence (SIF) detects both green canopy structure (APAR) and stress (NPQ or photosynthetic downregulation).
- Different vegetation types have different degrees of “physiological” vs. “structural” control over the fluorescence signal.
- Pigment information (light absorption and regulation) is essential to understanding fluorescence.

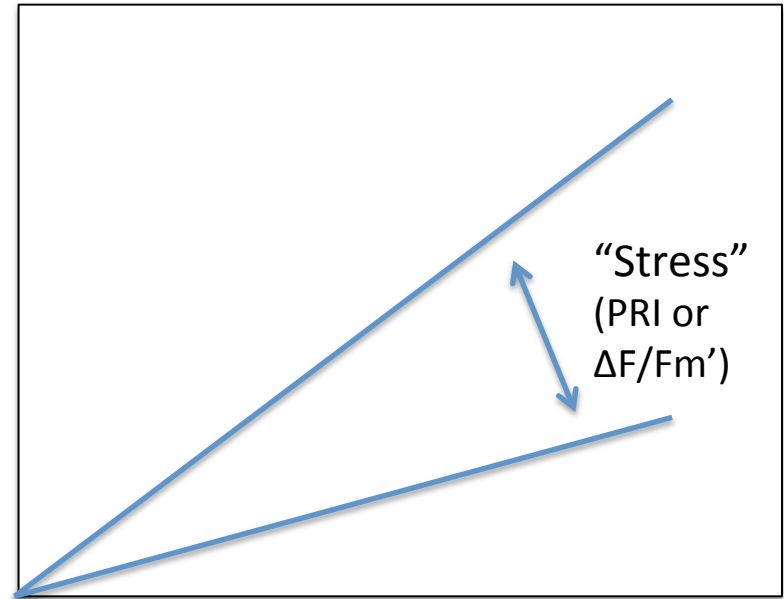
Structural & Physiological Contributions to SIF & Photosynthesis

Solar-Induced Fluorescence



"Greenness"
(APAR, NDVI, LAI, Chl...)

Photosynthetic Rate



"Greenness"
(APAR, NDVI, LAI, Chl...)

Broad Questions

- Does SIF *really* work as a combined indicator of APAR (structure) and efficiency (activity)?
- Is SIF *better* than reflectance-based approaches for measuring plant health (photosynthesis & stress)?
- Or, is SIF *complementary* to our existing toolkit of reflectance indices and other approaches?
- Are *vegetation types* different?
- How does *sampling scale* affect these signals?

Practical Applications

- Carbon cycle – getting the global budget right
- Assessing plant health
 - Productivity
 - Stress effects (e.g. drought)
- Precision agriculture – timing irrigation
- Phenotyping – detecting plant traits influencing stress responses, photosynthetic rates, yield

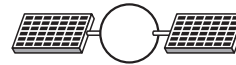
Potential Benefits:

- Plant photosynthesis, regulation & stress
- Primary production (yield), carbon cycle
- Vegetation regulation of atmosphere & climate (“feedbacks”)

Workshop Goals

- Evaluate the current state of knowledge in chlorophyll fluorescence (esp. SIF)
- Focus on airborne applications (and ground validation – FLEX Mission Concept)
- Address technical issues (calibration, validation, processing, data handling)
- Explore synergies and ongoing options for collaboration, information exchange (e.g. methods or data sharing, field campaigns)

The FLEX Mission Concept



Green canopy structure
(NDVI)



Pigment content
(Chl indices,
Chl/Carot indices)



Pigment activity
(SIF, PRI)