

Photosynthetic Efficiency and Carbon/Nitrogen Cycling in Vegetation Using Active and Passive Optical Techniques*

Dr. Elizabeth M. Middleton¹

Dr. Petya Entcheva-Campbell¹, James E. McMurtrey III²,
Lawrence A. Corp^{1,2}, L.M. Butcher^{1,2}, Emmett W. Chappelle^{1,2}

¹Laboratory for Terrestrial Physics, Biospheric Sciences Branch Code 923
National Aeronautics and Space Administration GSFC, Greenbelt, MD 20771

²Hydrology and Remote Sensing Laboratory, Agriculture Research Service
United States Department of Agriculture, Beltsville, MD 20705

*Code YS Program Review 3/17/2004



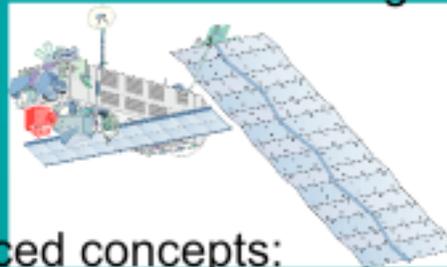
Goddard Space Flight Center

To understand and protect our home planet, to explore the Universe and search for life,
to inspire the next generation of explorers...as only NASA can.



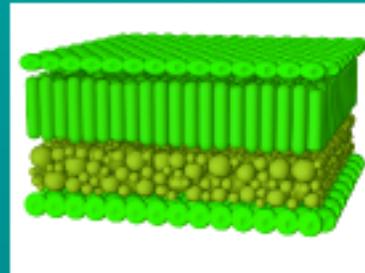
Terrestrial Ecology Science Theme

Remote Sensing

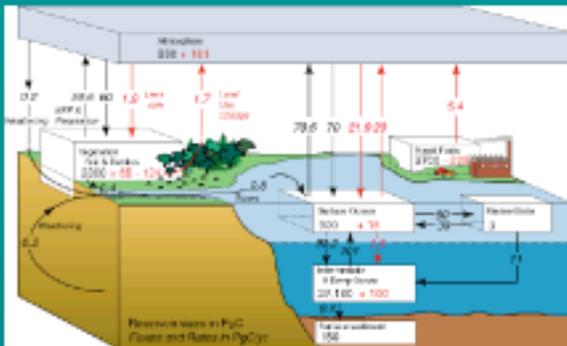


Advanced concepts:
Reflectance & Fluorescence Spectroscopy

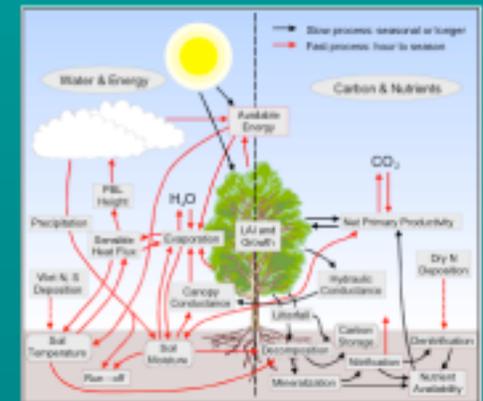
Fluorescence/Reflectance



Carbon Cycle
Biogeochemical Cycles



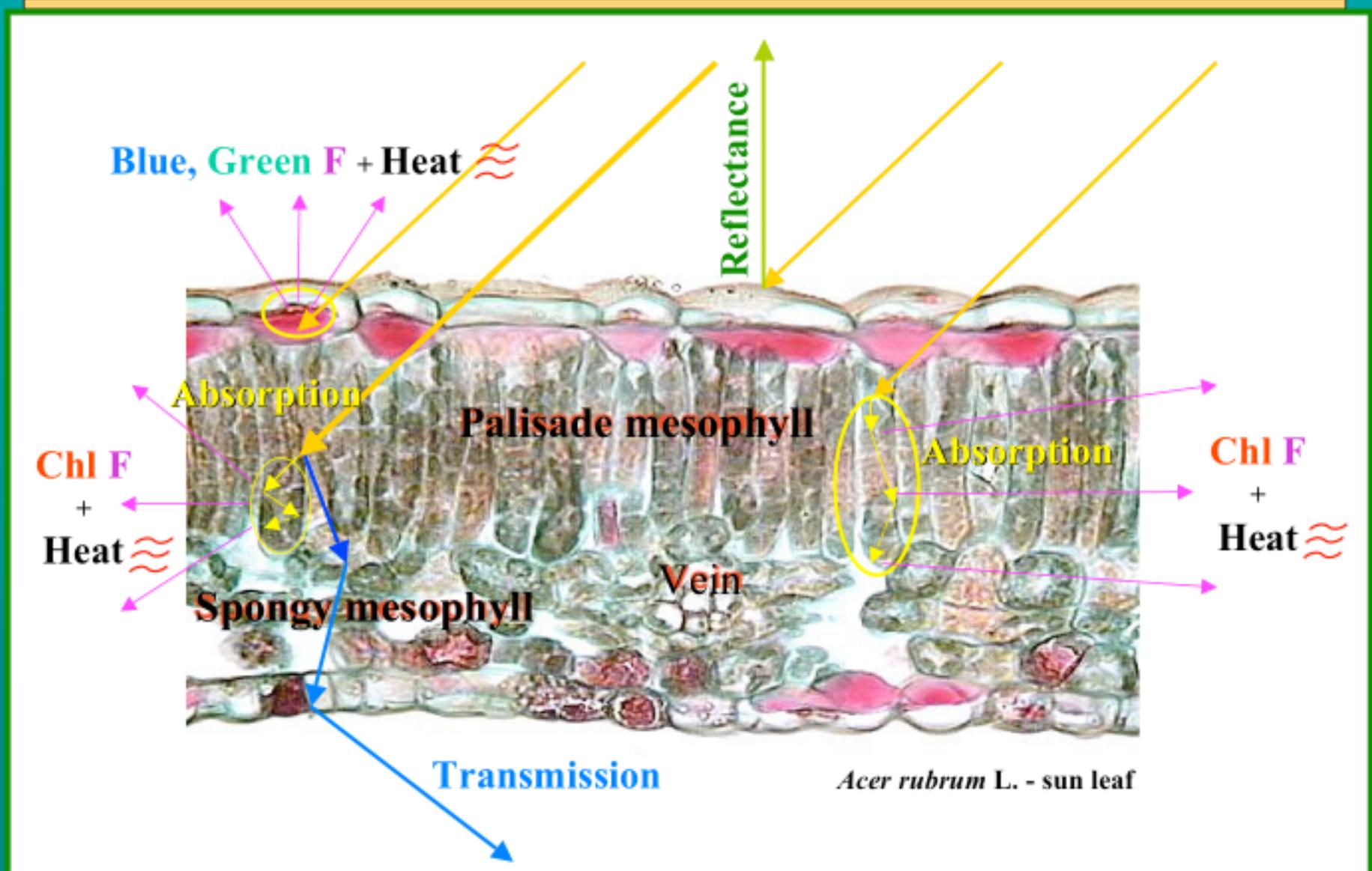
Ecosystems



Technology / Instruments
Future Hyperspectral Satellite
Future Fluorescence Sensors

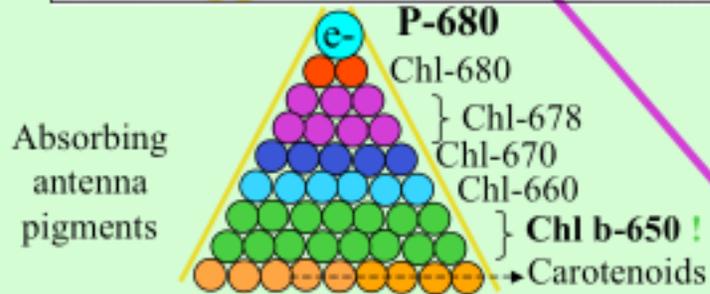
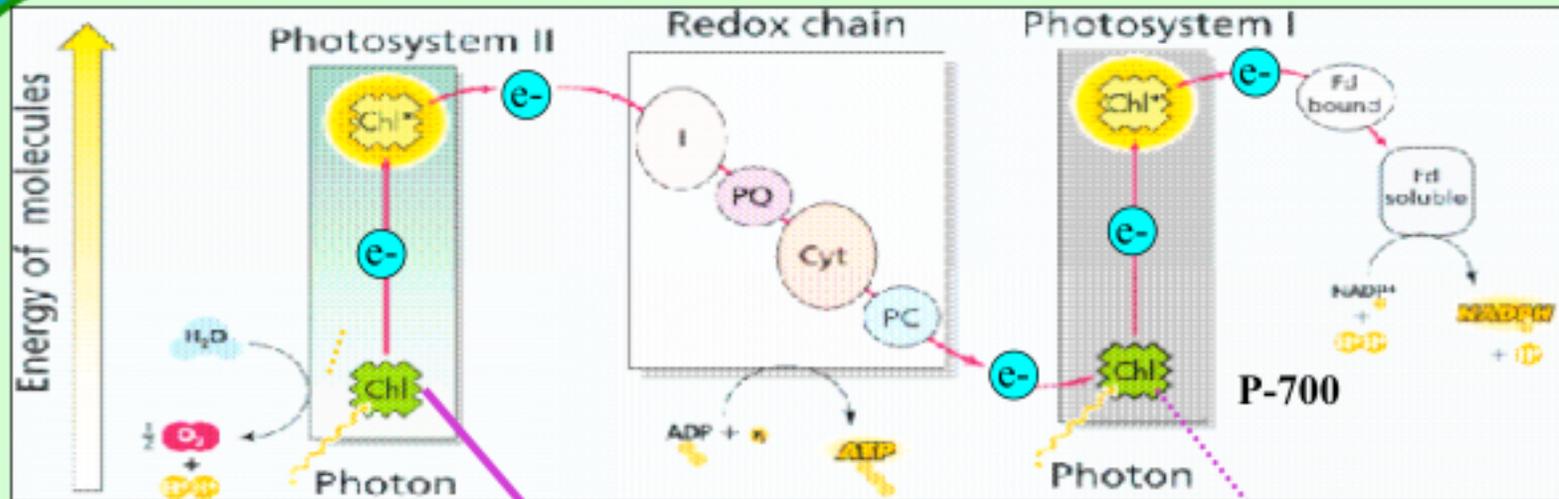


Leaf Level Processes





General Concept of Photosynthesis



Chl F

+

Heat

Chl F

+

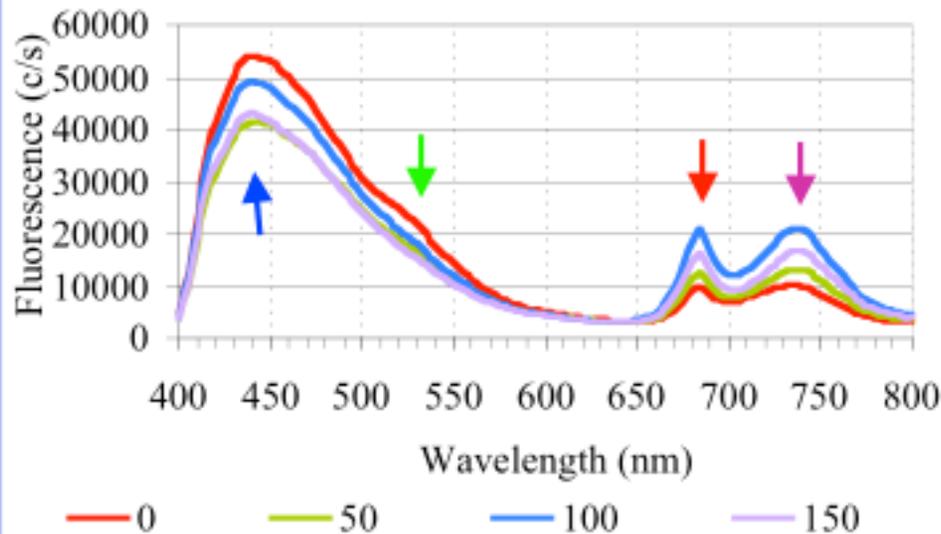
Heat

Electron Transport in the Chloroplast

E.M. Middleton, NASA/GSFC Code 923 HQ Review 3/17/04



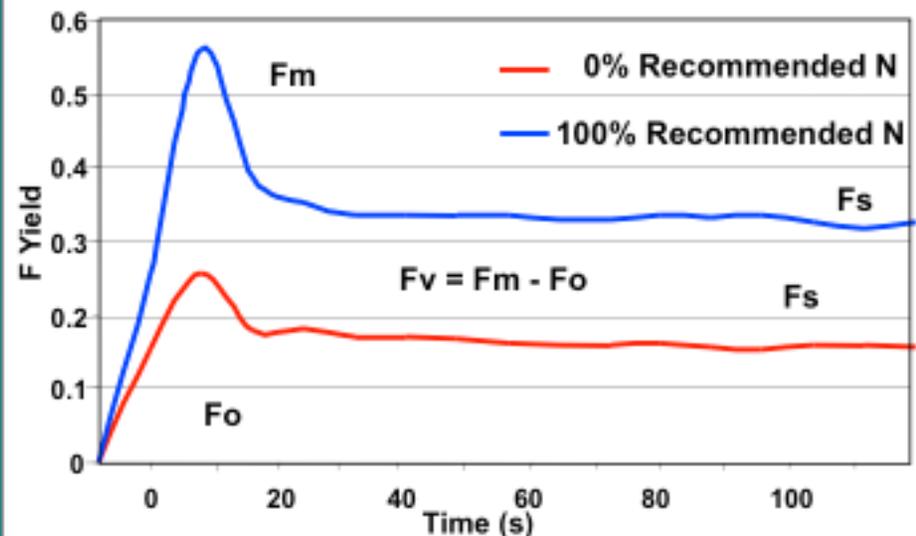
Chlorophyll Fluorescence Kinetics



Corn under N treatment
Steady State Fluorescence
Emission Spectra (excitation at 360nm)

Chl F Induction Kinetics of Soybean under N treatment

F_o = Ground fluorescence
F_v = Variable fluorescence
F_m = Maximum fluorescence
F_s = Steady state fluorescence



Our Previous Research Program

Research Theme/Activity

In-House F Instrumentation	Lab LIF 337EX	Van LIF 337EX		FIS	LIFIS
Laboratory Spectra (F)			Fluorilog-2		Hitachi
Glasshouse Exps. (F)					
* Corn	Nutrients	5N	N	N	
* Other species		9 ag (5N)			
* Soybean		N		N	
Chamber Exps.(F)					CO ₂ , ozone
*Soybean, cucumber				UV-B	UV-B
Field Exps. (F)					
* Corn	5N ('89)	7N ('91) 8N ('93)	8 N	7 N ('97)	8 N ('98, '00)
Reflectance Indices: Chl [IRIS, SE590, ASD]		Corn MCARI	Soybean CARI		Corn MCARlab
Crop Residue (F vs. R)		X	X	X	X
Timeframe	▲ 1980 1985	▲ 1985 1990	▲ 1990 1994	▲ 1995 1997	▲ 1998 2000



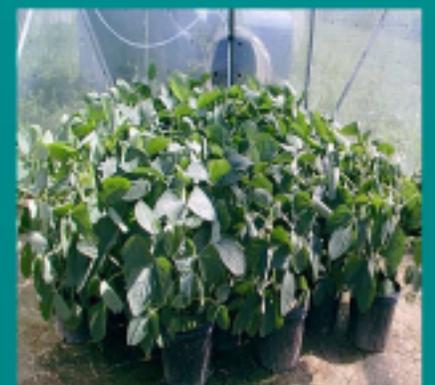
Our Early Important Findings



- 1] The existence of Blue & Green Fluorescence(B/G F) was identified
- 2] Species differences in Fluorescence (esp. R/FR_{UVEX}) were determined.
- 3] N application rates could be detected with Fluorescence.
- 4] Leaf litter can be distinguished from soil background with B/G F.
- 5] Fluorescence images show 2&3-dimensional responses to stress.
- 6] Chl content could be determined with reflectance indices.



Plant Growth Facilities at USDA Beltsville Agricultural Research Center





Our Current Project Goals & Objectives



Overall Goal: To improve our capacity to accurately infer carbon cycle dynamics in vegetation using remote sensing tools.

Determine the ability of high spectral resolution optical & fluorescence measurements to distinguish the relative level of stress induced by environmental factors (nutrient deficiency & excess, pollution, drought etc.) in physiologically active vegetation.

Specific Objectives

1) Leaf-level Studies:

- a) For **N** availability and uptake, investigate the changes in **leaf chemistry** and spectral properties that occur throughout **phenology**.
- b) Identify spectral indicators of **physiologic stress**.
- c) Identify spectral indicators of **carbon dynamics**.
- d) Understand the **relationship** between reflectance and fluorescence.
- e) Quantify the **contribution of chlorophyll fluorescence (Chl F)** to the "apparent" red reflectance.
- f) Improve understanding of underlying mechanisms.

2) Relate leaf-level responses to **canopy-level** spectral (R & F) observations.

3) Guide **new instrumentation** development & future sensors.



Experiments & Activities (2000 - 2003)



- 2000** Acquired Hitachi (for Excitation-Emission-Matrices).
LIFIS field measurements were made.
Conducted experiments:
Field Corn with 8 N levels, at several growth stages.
2 Soybean cultivars in outdoor chamber (CO₂ X ozone) studies.
Red maple UV-B field study.
- 2001** Acquired Fluorilog-3 (HQ support).
Conducted experiments:
2 glasshouse (+) Soybean studies with 6 N levels.
Field Corn with 4 N levels, at 2 growth stages (V, R3).
- 2002** Refurbished Cold-frames.
Conducted experiments:
Initiated N Experiment on 200 tree seedlings (red maple, sweet gum, tulip poplar). Measurements made in June, July, September, October.
Corn crop lost to drought. Replaced with cold-frame study on 4 spp (TNT).
- 2003** Transplanted trees in permanent plots.
Refurbished LIFIS.
Conducted experiments:
2 studies on chlorophyll genetic lines (Chl *b* deficient)
2 measurement sets on trees (June, September).
Field corn N treatments washed away by wet season.



Routine Measurements



- ***In Situ* Photosynthesis & Fluorescence Kinetics**
LI-COR 6400 Photosynthesis Unit with Fluorimeter Attachment
- **Multi-Spectral Fluorescence Imaging**
FIS – leaf level fluorescence imaging
[LIFIS – plant level laser induced fluorescence imaging]
- **Fluorescence Spectral Characterizations**
Spex Fluorolog II & III
Hitachi F4500
- **Leaf Optical Properties: Reflectance, Transmittance, Absorptance**
ASD Fieldspec-Pro Spectral radiometer; LI-COR 1800 Integrating Sphere
- **Solar Stimulated Fluorescence**
Oriol 300 W Solar Simulator
2 - ASD Fieldspec-Pro Spectral radiometers
- **Spectroscopic Pigment Determinations**
Perkin-Elmer Lambda 40 Spectrophotometer
- **C and N chemical determinations**



Project Obstacles & Setbacks



Destruction of NASA research van and USDA greenhouse facilities by the tornado which struck the Beltsville Agricultural Research Center in September 2001.



Research Themes (2000 - 2003)



- T1: Capturing Nitrogen Effects on Field Corn Productivity & Biophysical Characters with Spectral Observations**
- T2: Spectral Indicators of Stress or Environmental Factors**
- T3: Spectral Indicators Related to Carbon & Nitrogen Dynamics**
- T4: Understanding the Underlying Photochemistry / Photobiology**
- T5: Unraveling the Relationship of Fluorescence and Reflectance**
- T6: Measurements Supporting Instrumentation Development**
- T7: Relating Active Fluorescence to Passive Fluorescence Observations**



Theme # 1

Capturing Nitrogen Effects on Field Corn Productivity with Spectral Observations