Trends in Remote Sensing of Ecosystem Function and Physiology

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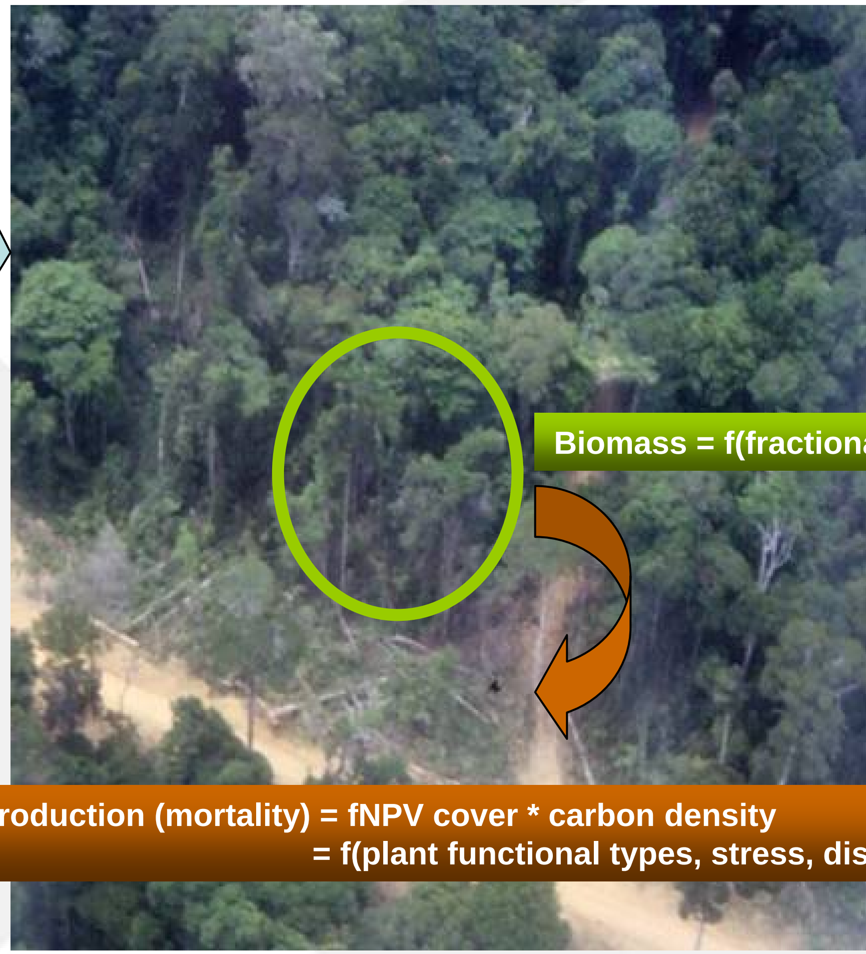
Role of optical remote sensing in many modeling studies

Mostly the NASA EOS Era

Solar NDVI; EVI; BRDF modeling

NPP = PARi * fAPAR * LUE
LUE = f(plant functional types, water/temp stress, nutrient stress)

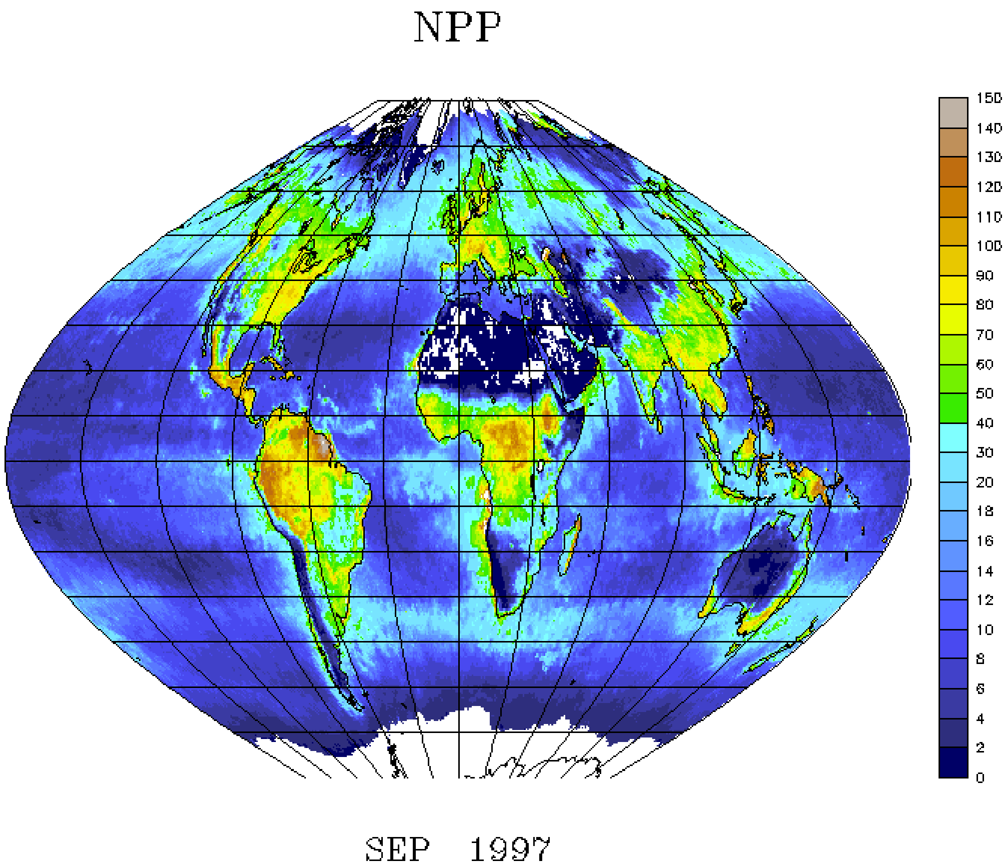


Biomass = f(fractional cover, height)

NPV Production (mortality) = fNPV cover * carbon density
= f(plant functional types, stress, disturbance)

Mapping Productivity

In the past 2 decades, global ecologists have used aircraft and satellite instruments to measure solar radiation absorption by vegetation



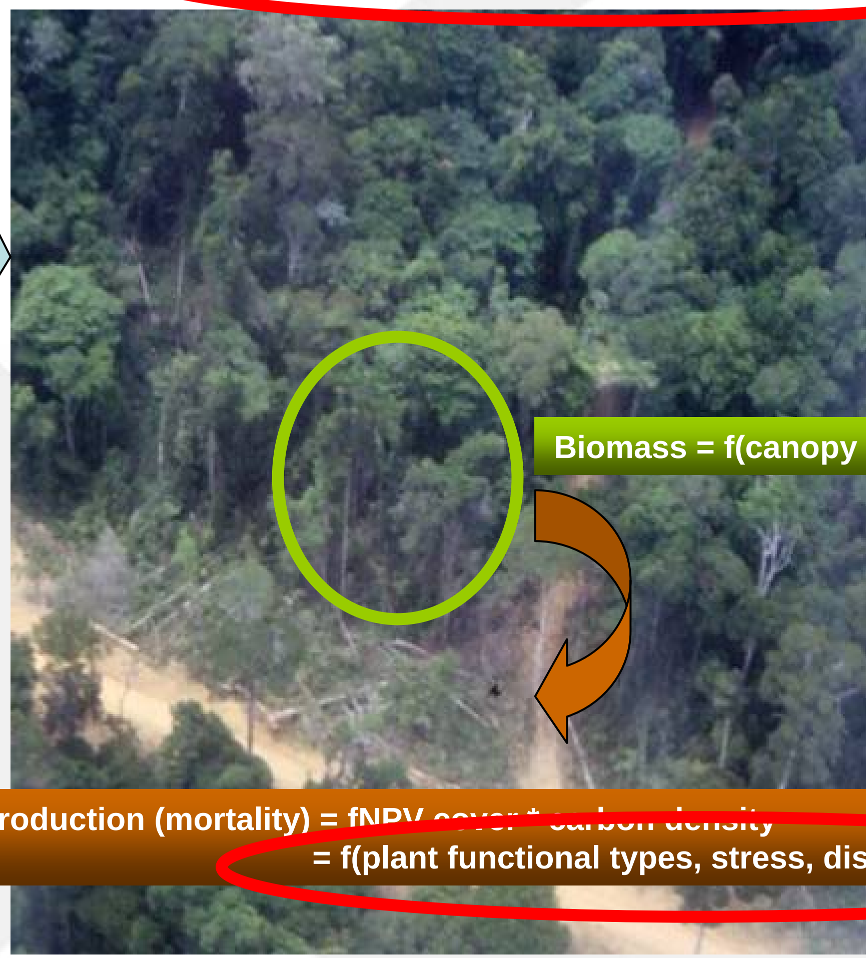
Many have now used this approach to estimate plant and plankton growth at regional and global scales. This has been instrumental in quantifying global ecological responses to climate variability.

Current role of optical remote sensing in carbon cycle studies

Mostly the NASA EOS Era

Solar NDVI

NPP = PARi * fAPAR * LUE
LUE = f(plant functional types, water/temp stress, nutrient stress)



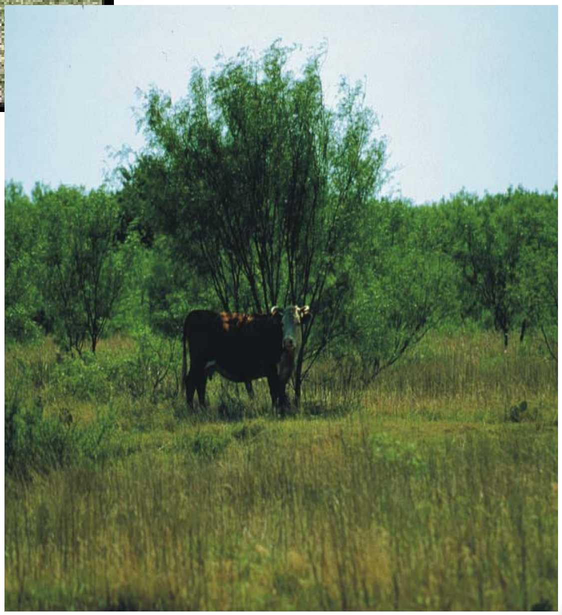
Now & Tomorrow

Biomass = f(canopy fractional cover, height)

NPV Production (mortality) = fNPV cover * carbon density
= f(plant functional types, stress, disturbance)

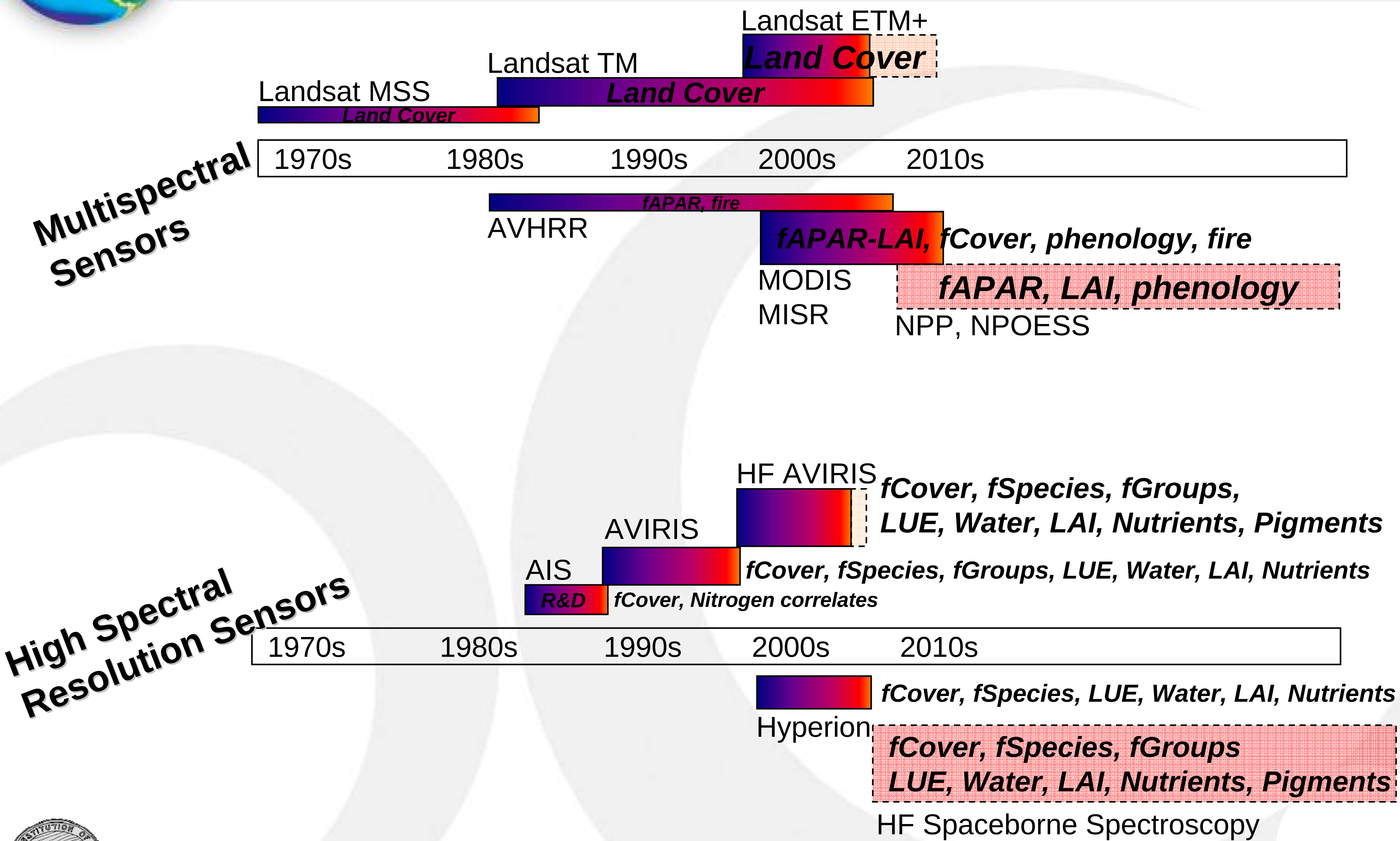
Chemical and physiological change is central to understanding ecosystems, diversity, and the carbon cycle

- Canopy stress, recovery
- Diffuse ecosystem change
- Invasive species
- Insect damage

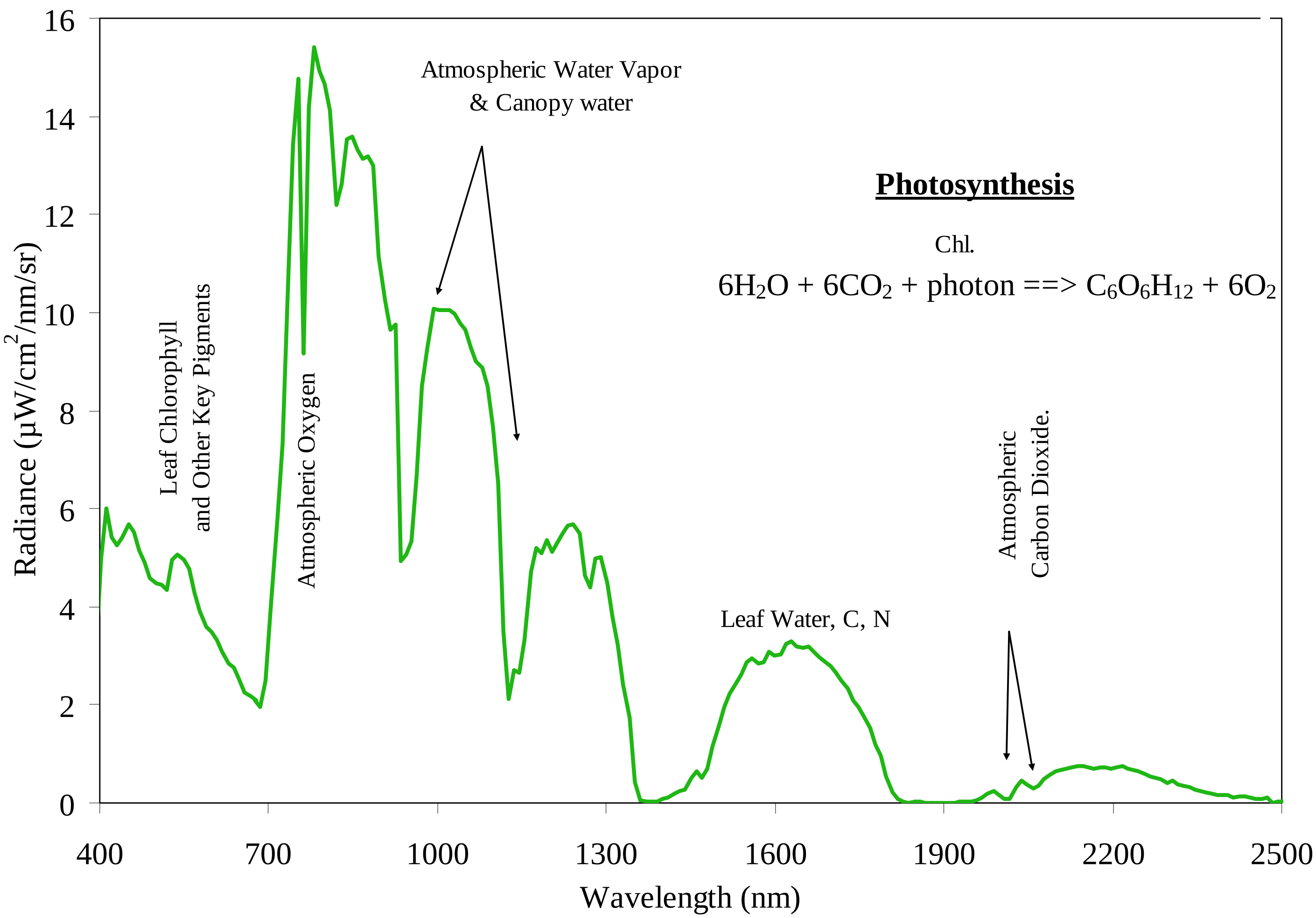


Optical systems for regional and global ecological research

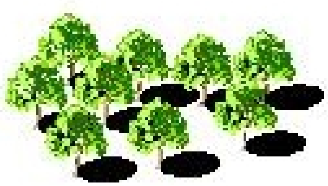
Bar thickness denotes relative differences in instrument performance (e.g., fidelity, signal-to-noise)

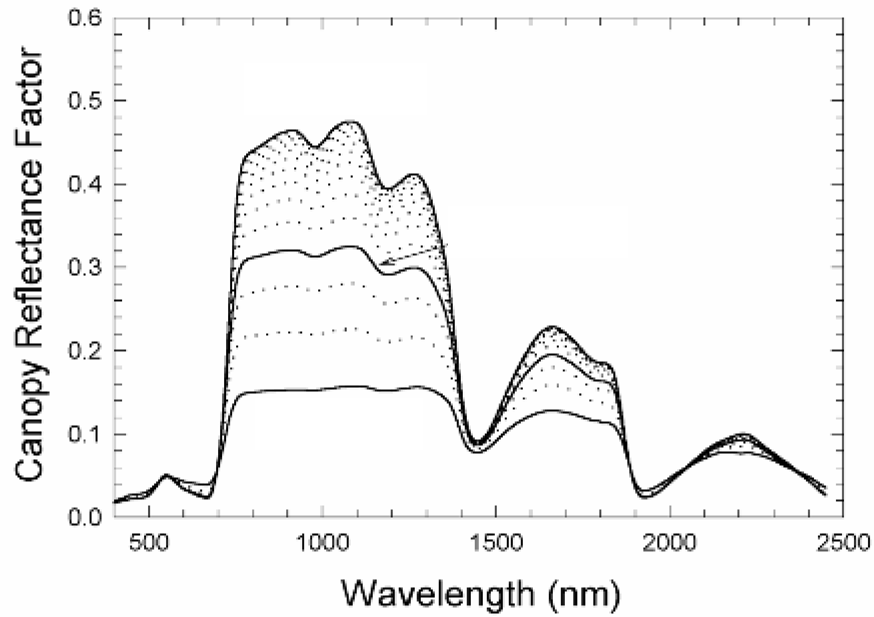


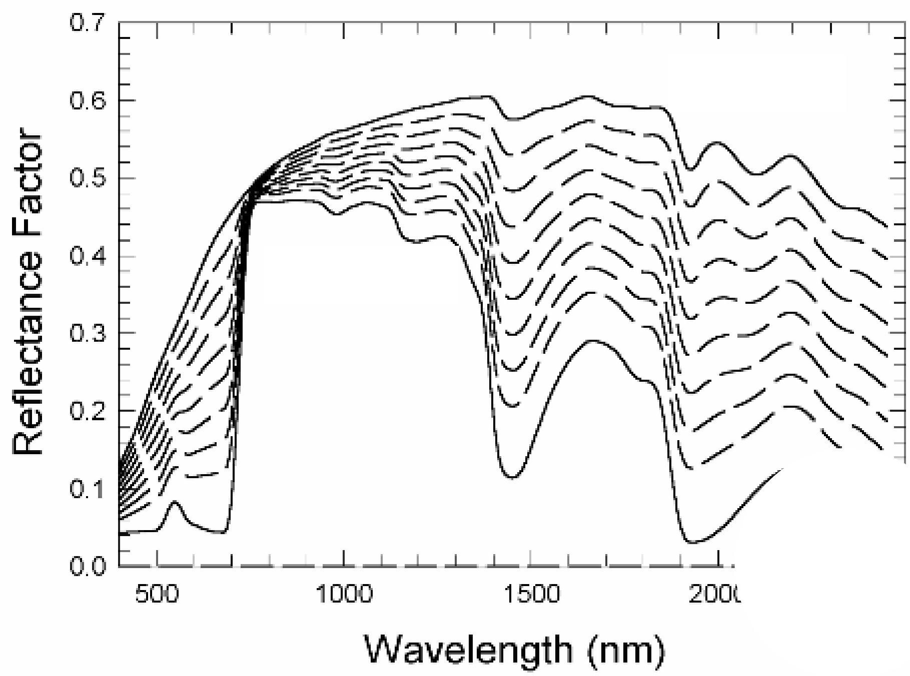
Fractional cover, physiology, and functional groups from imaging spectroscopy (a.k.a. hyperspectral imaging)



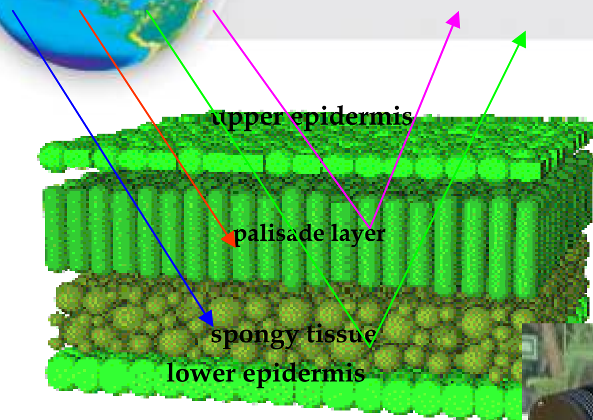
Leaves ≠ Canopies

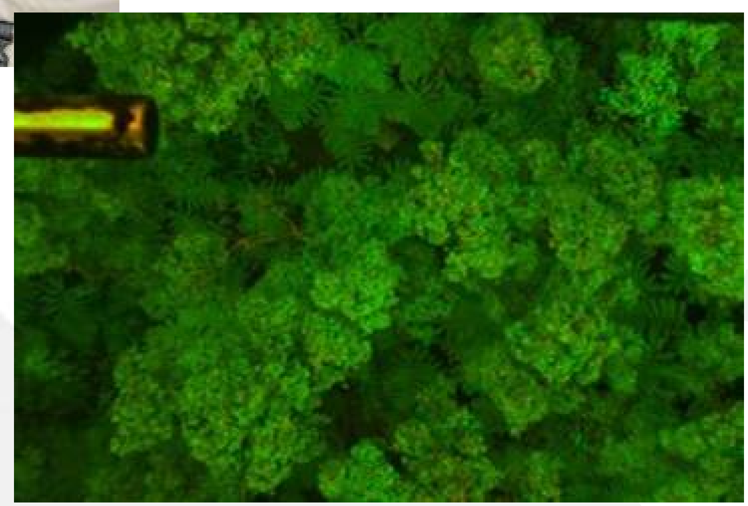






Leaf, Canopy, and Landscape Studies





Spectral Modeling Studies (putting it all together)

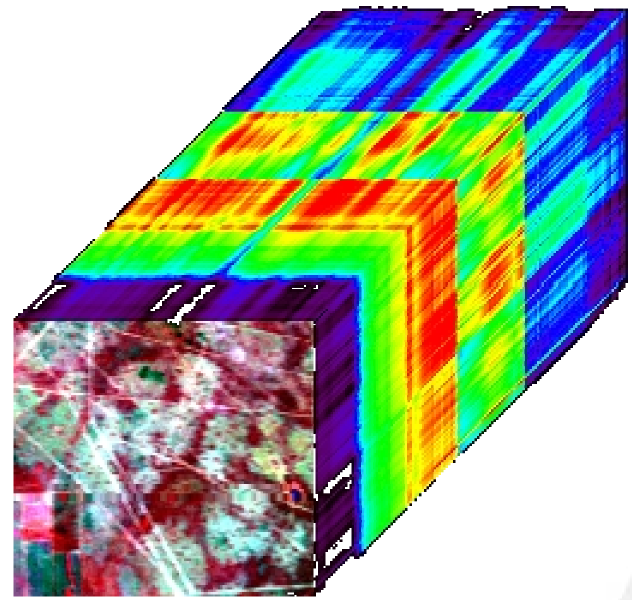
Model Inputs

- Tissue Chemistry & Optics
- Tissue Volume
- Canopy Architecture
- Soil Constituents
- Observing & Atmospheric Constituents

Processing

Coupled Atmosphere and Vegetation-soil Photon Transport Model

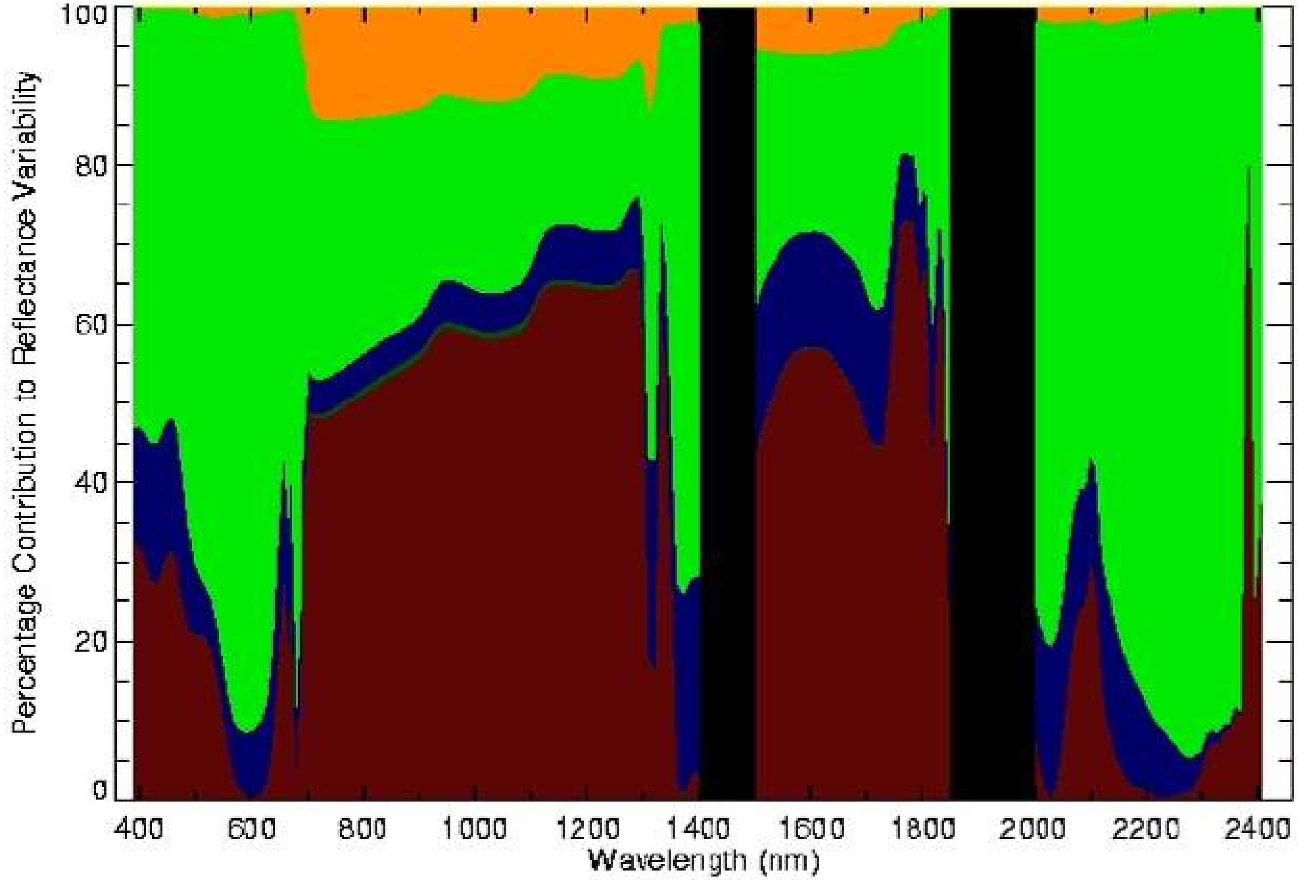
Output: Simulated Radiance



Carefully constrained by extensive spatial field measurements

Spectral Modeling Studies – Signature Prediction

Closed-canopy Tropical Forest Example



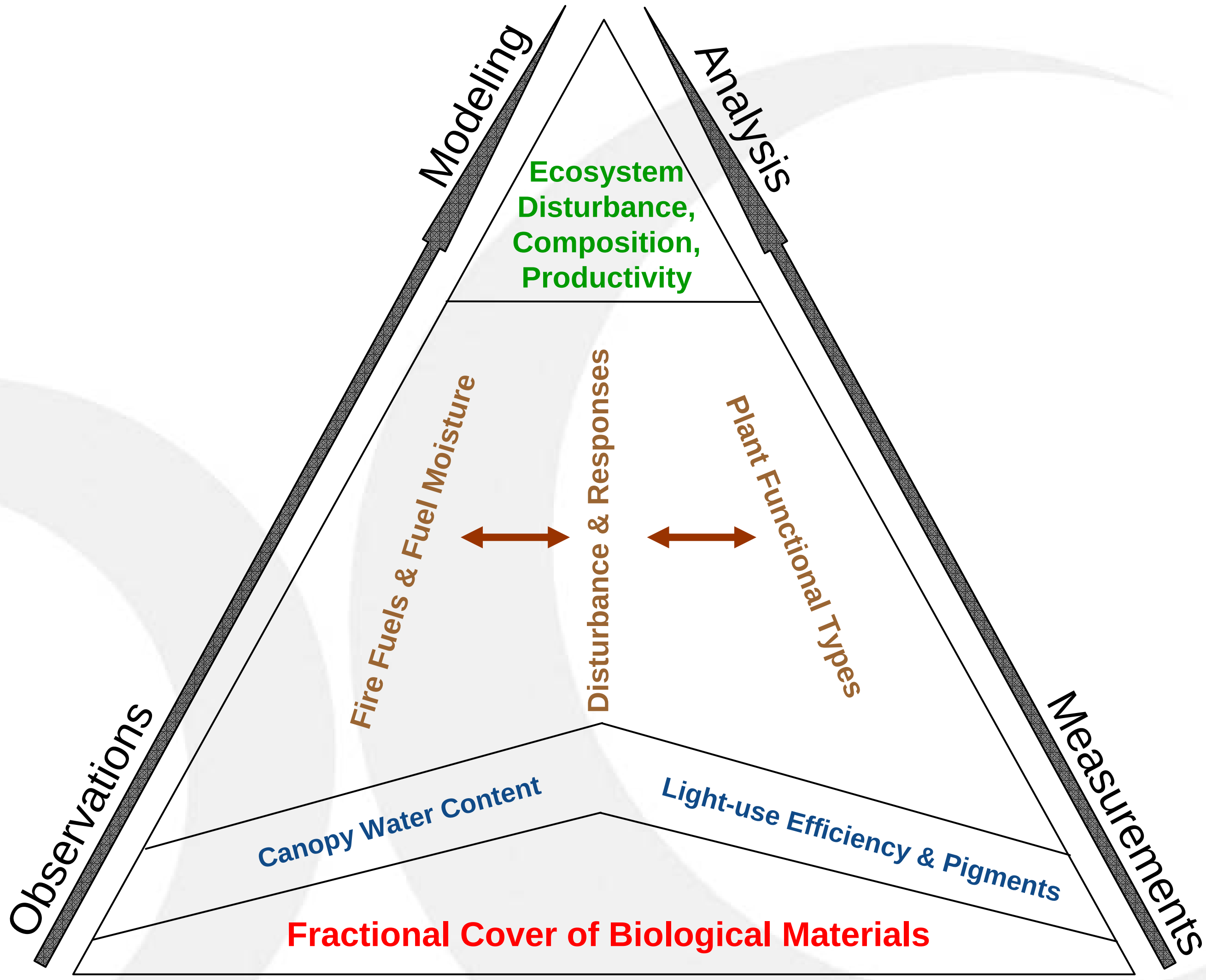
Canopy gaps and shade

Leaf Angle Orientation

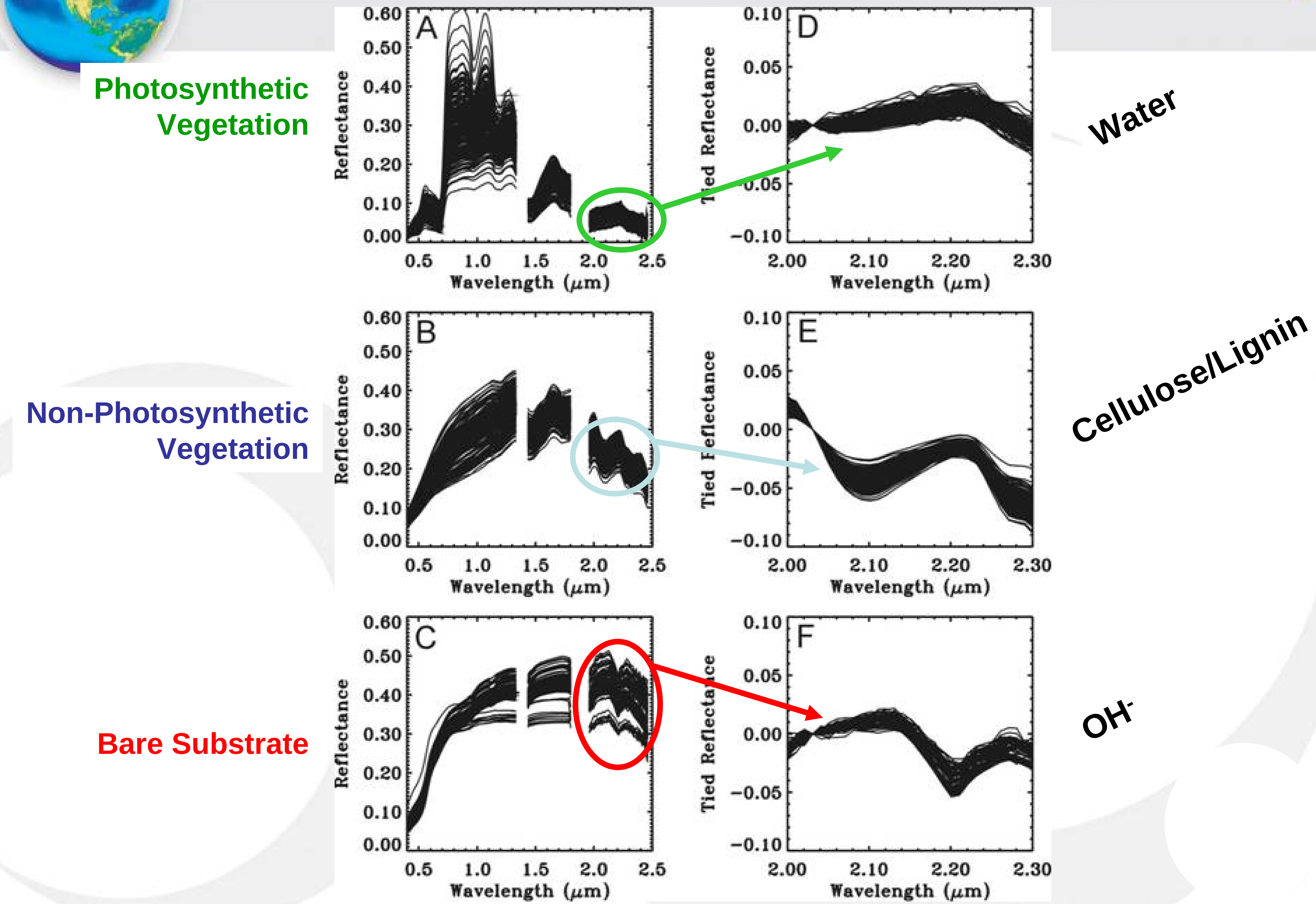
Leaf Reflectance / Chemistry

Leaf Transmittance / Chemistry

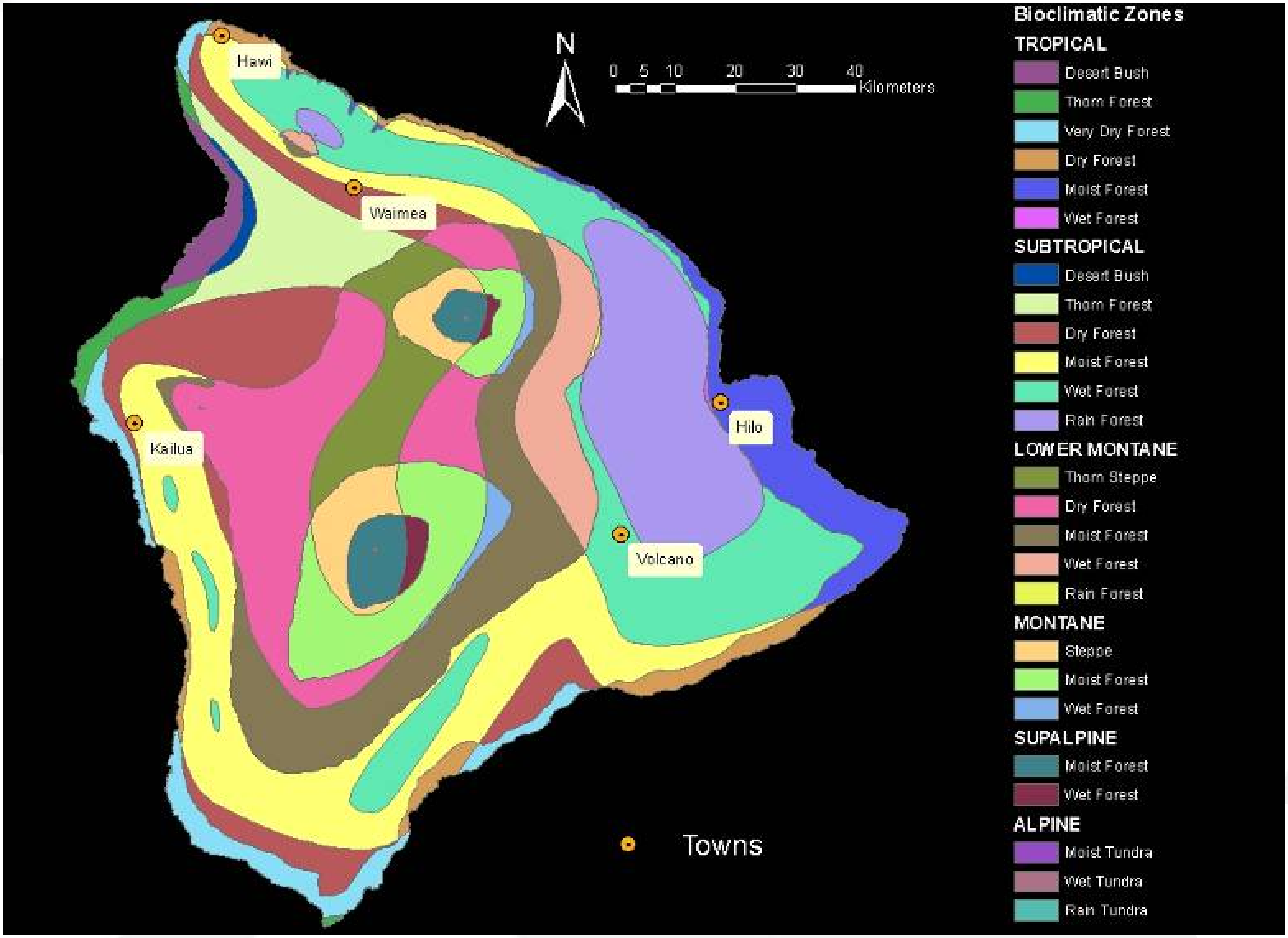
Conceptual model for ecosystem analysis via spectral remote sensing



Spectroscopic techniques isolate fractional cover of materials

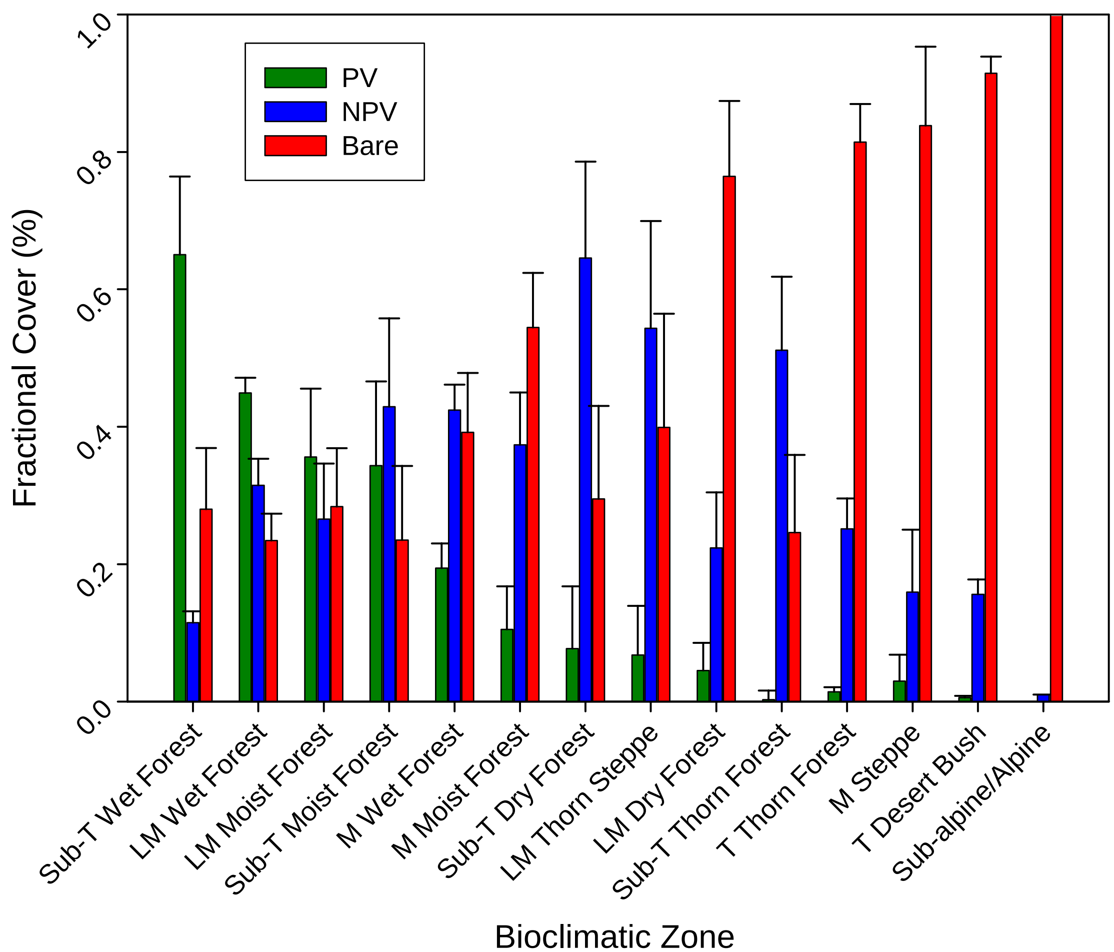


Cross-ecosystem Studies of Fractional Material Cover

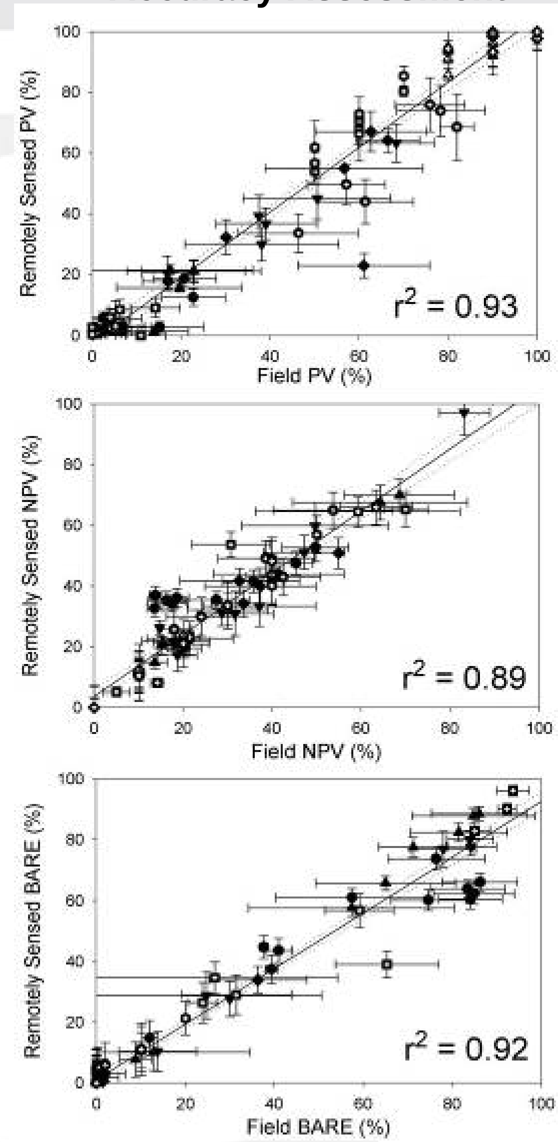


Asner et al. 2005

Automated Tied-SWIR2 unmixing across ecosystems

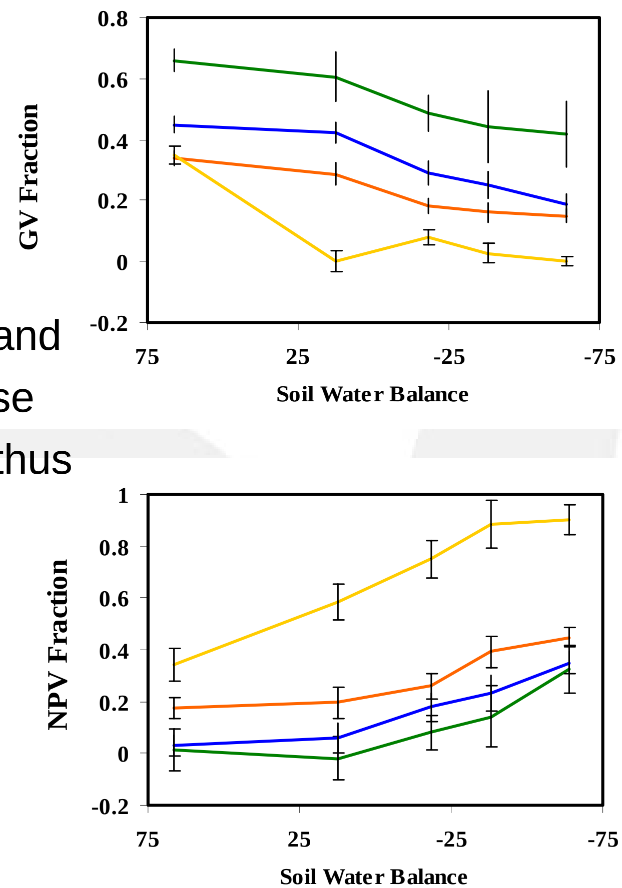


Accuracy Assessment



Asner et al. 2005

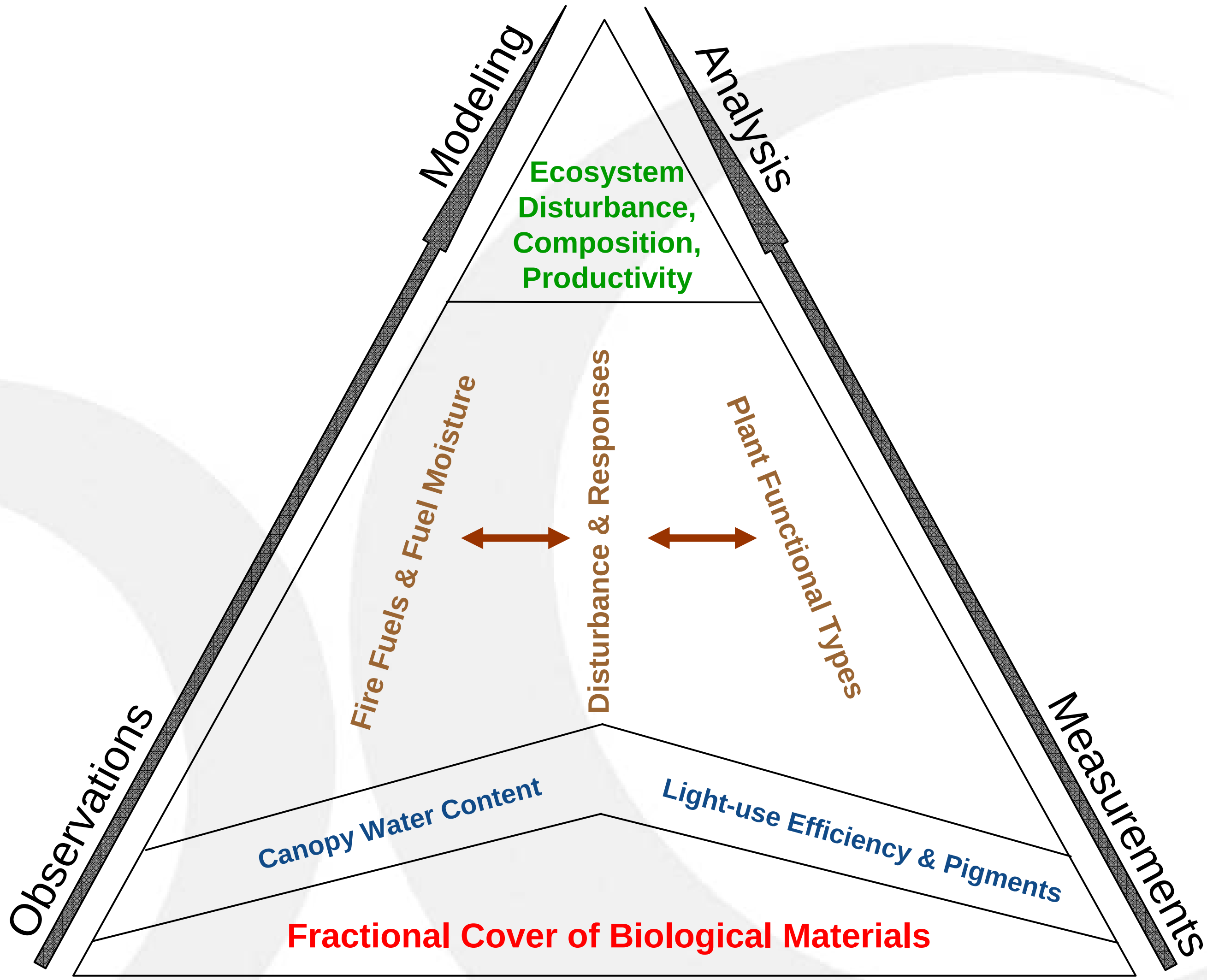
More detailed analysis of fraction cover + functional type



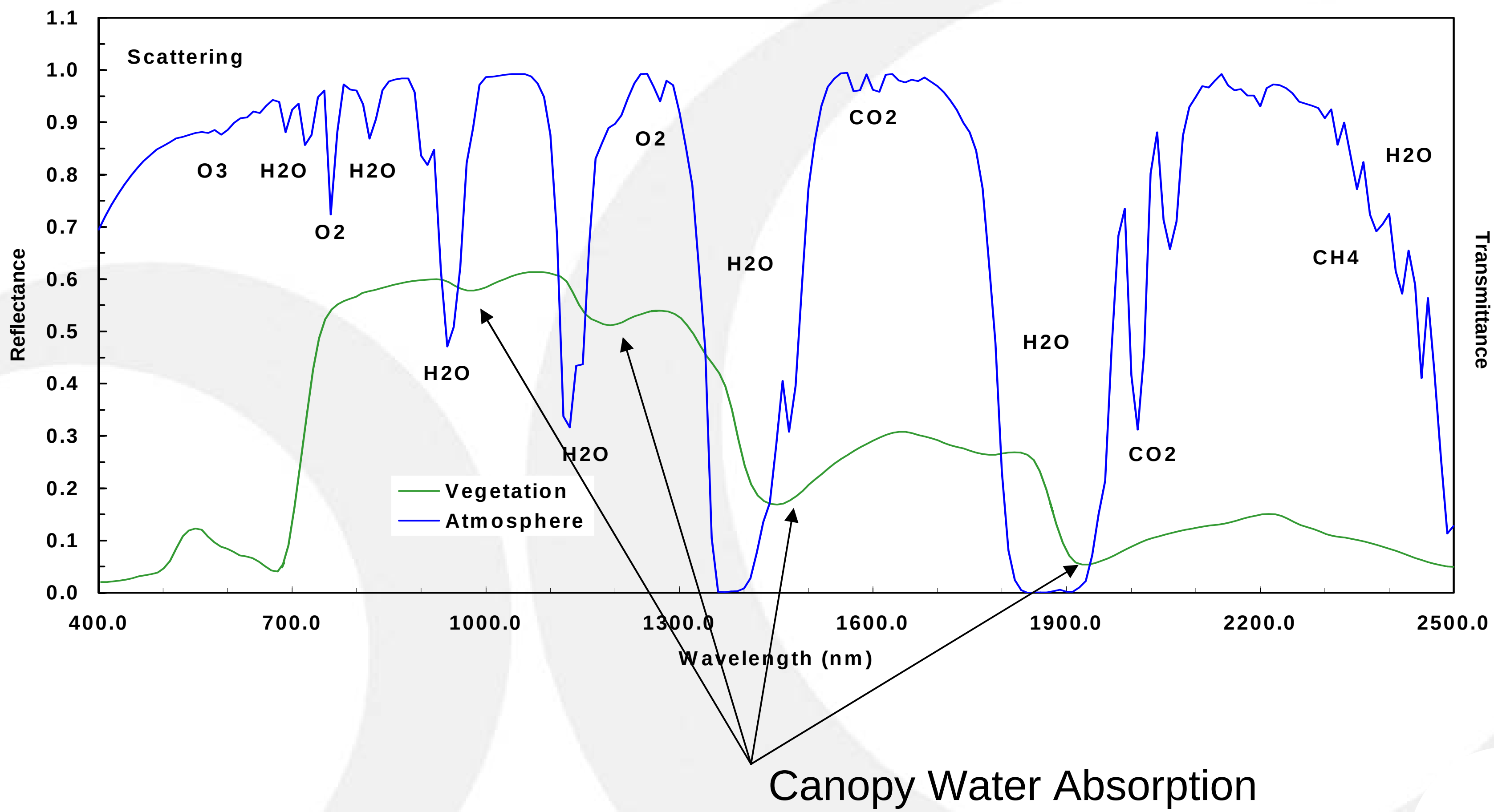
Grassland
Chamise
Ceanothus
Live Oak

Dar Roberts et al.

Conceptual model for ecosystem analysis via spectral remote sensing

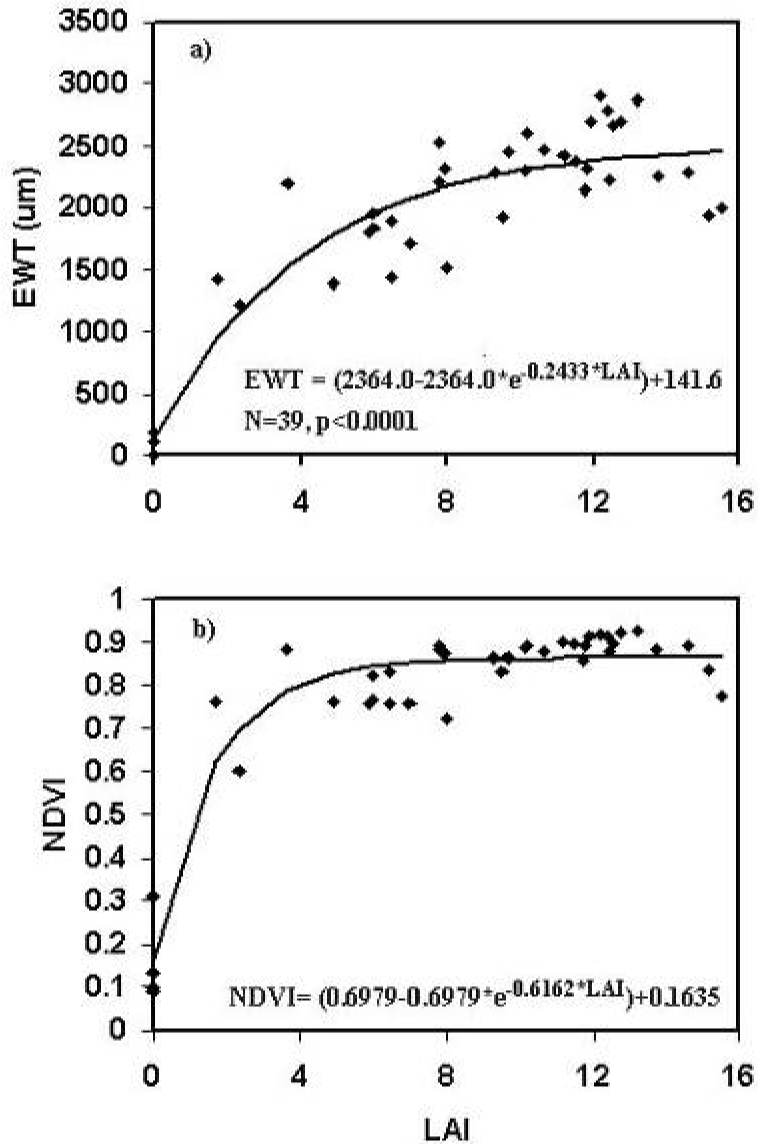


Spectroscopy Provides Routine Analysis of Atmospheric Water Vapor and Canopy Water Content



Rob Green et al., JPL

Canopy water as a gateway into high-LAI environments (forests)



Dar Roberts et al.

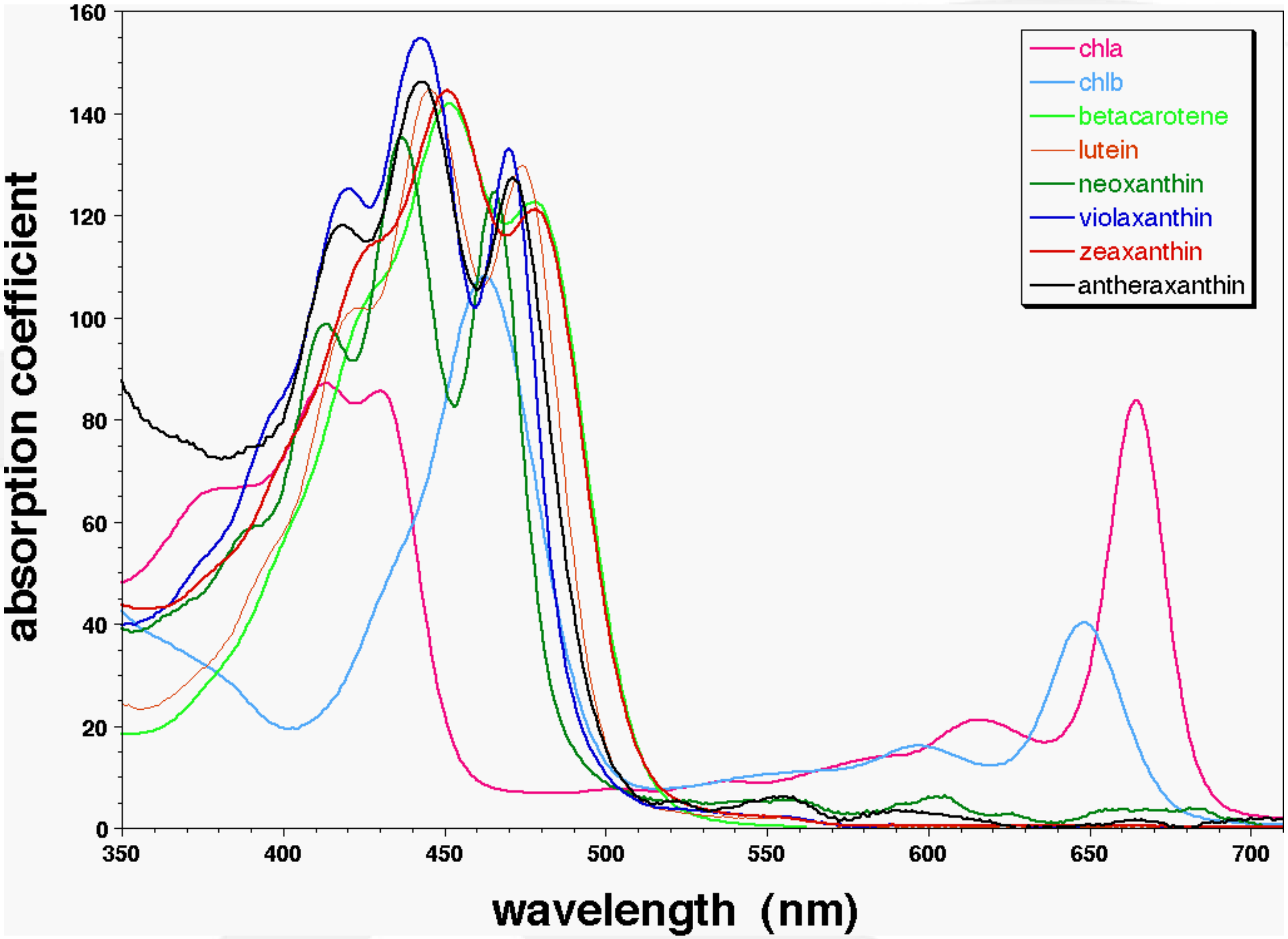
Both NDVI and EWT appear non-linear

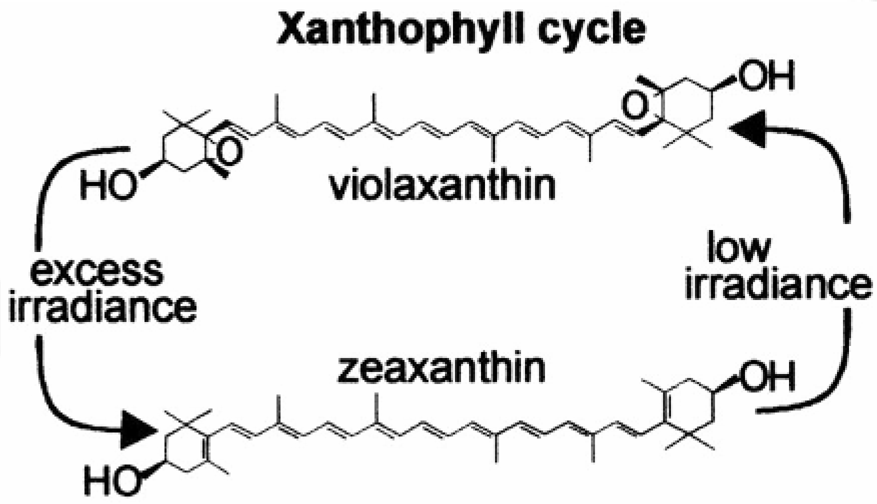
EWT reaches an asymptote at much higher LAI

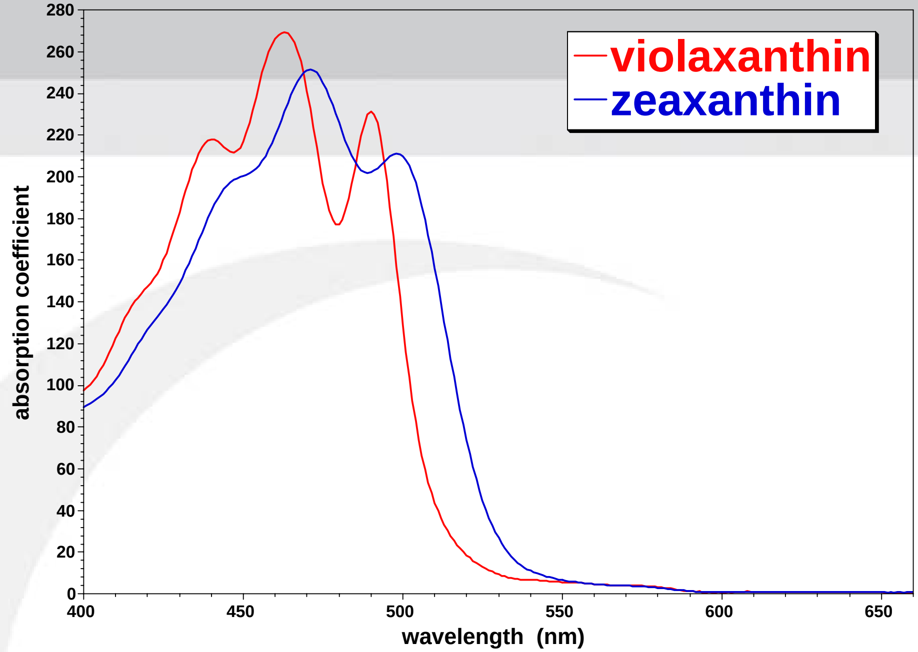
NDVI, ~ 4

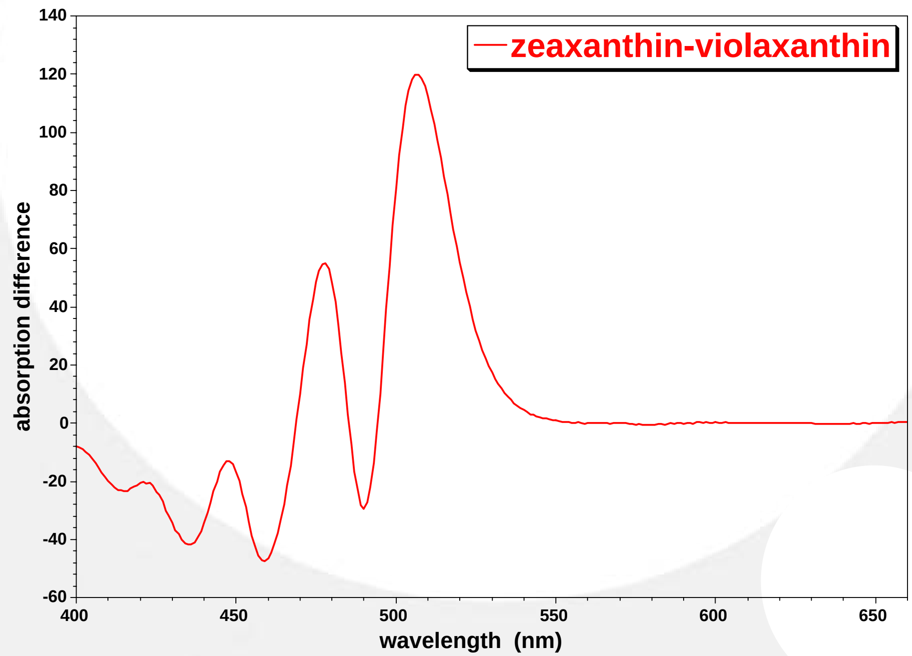
EWT, ~ 9

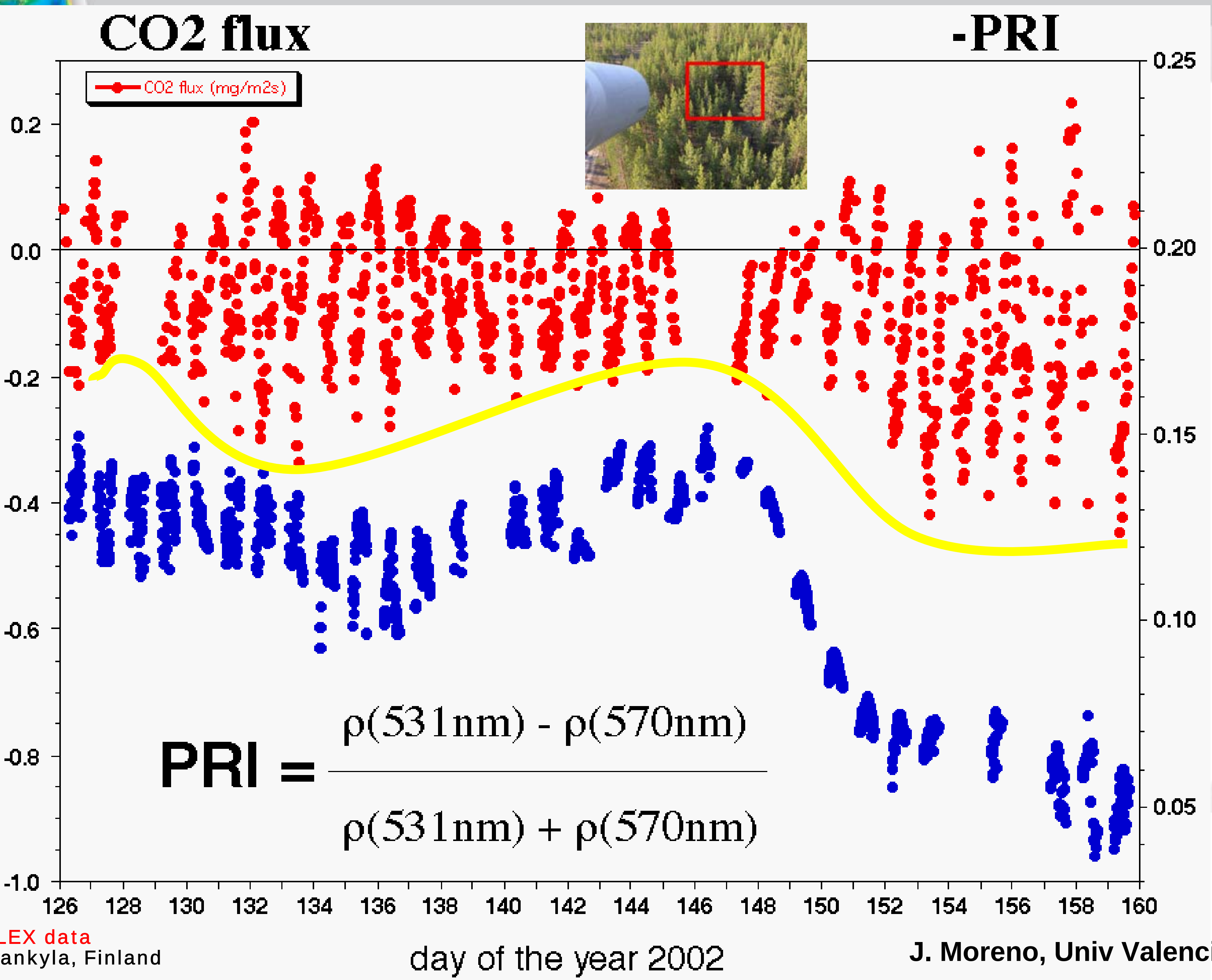
Leaf Pigments, Light-use Efficiency, and Photosynthetic Capacity




Xanthophyll cycle
OH
O
O
HO
violaxanthin
low
irradiance
excess
irradiance
zeaxanthin
OH
HO


violaxanthin
zeaxanthin
absorption coefficient
wavelength (nm)
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
400
450
500
550
600
650


zeaxanthin-violaxanthin
absorption difference
wavelength (nm)
140
120
100
80
60
40
20
0
-20
-40
-60
400
450
500
550
600
650

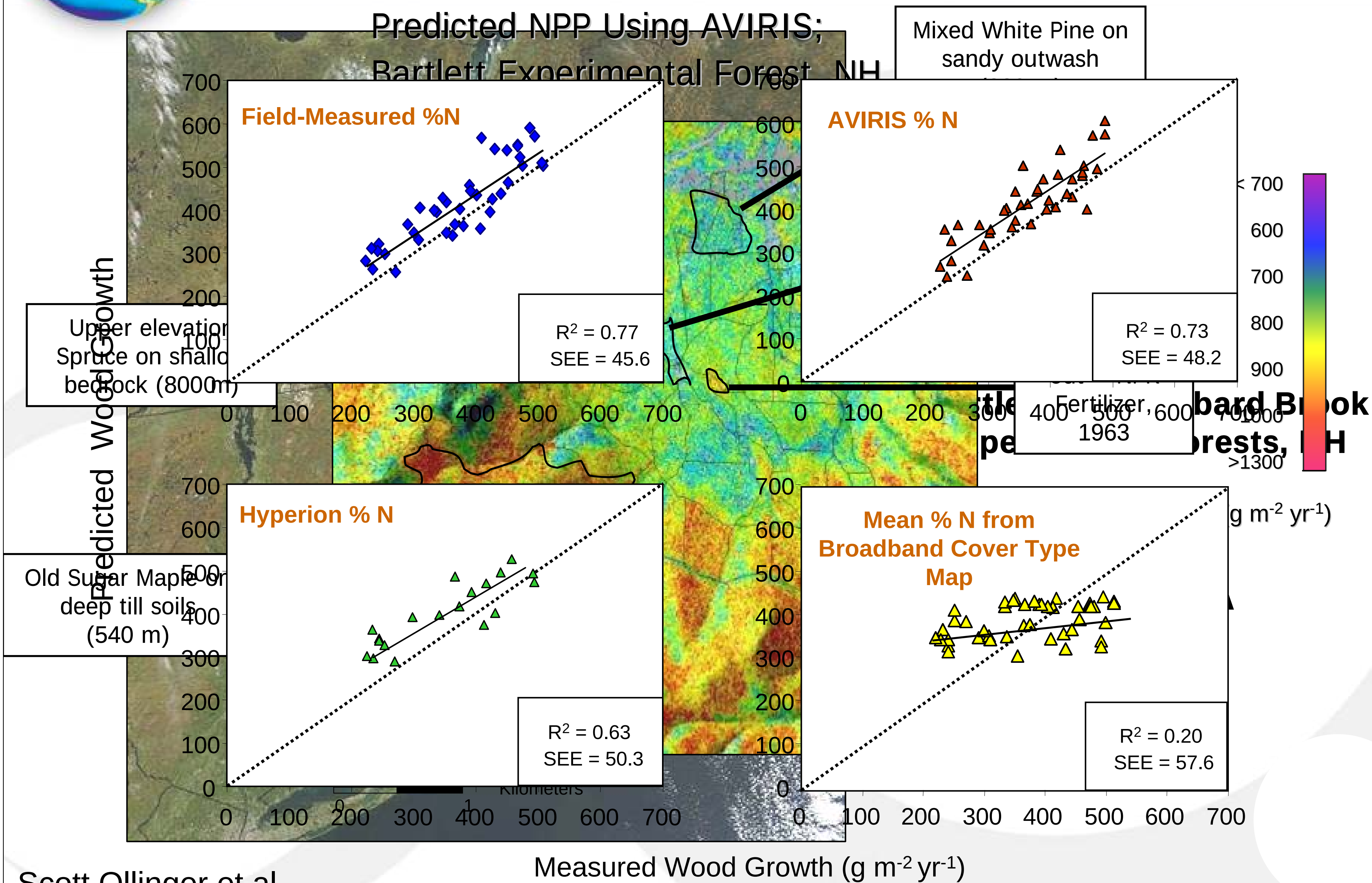


$$\text{PRI} = \frac{\rho(531\text{nm}) - \rho(570\text{nm})}{\rho(531\text{nm}) + \rho(570\text{nm})}$$

SIFLEX data
Sodankyla, Finland

J. Moreno, Univ Valencia

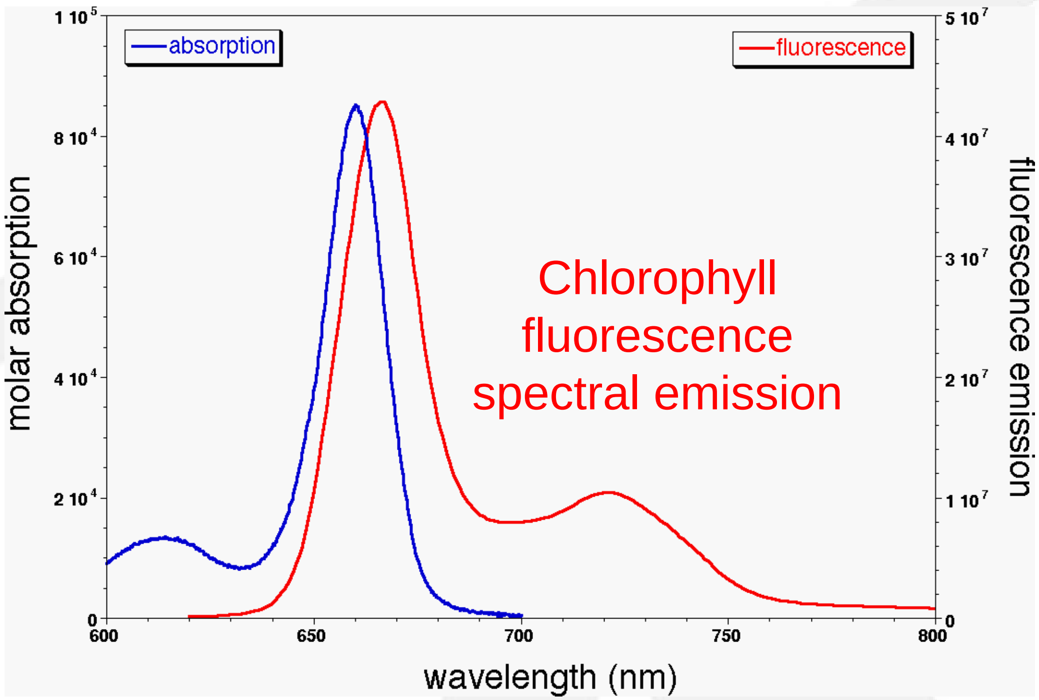
Observing leaf nitrogen to constrain photosynthetic capacity, and thus NPP

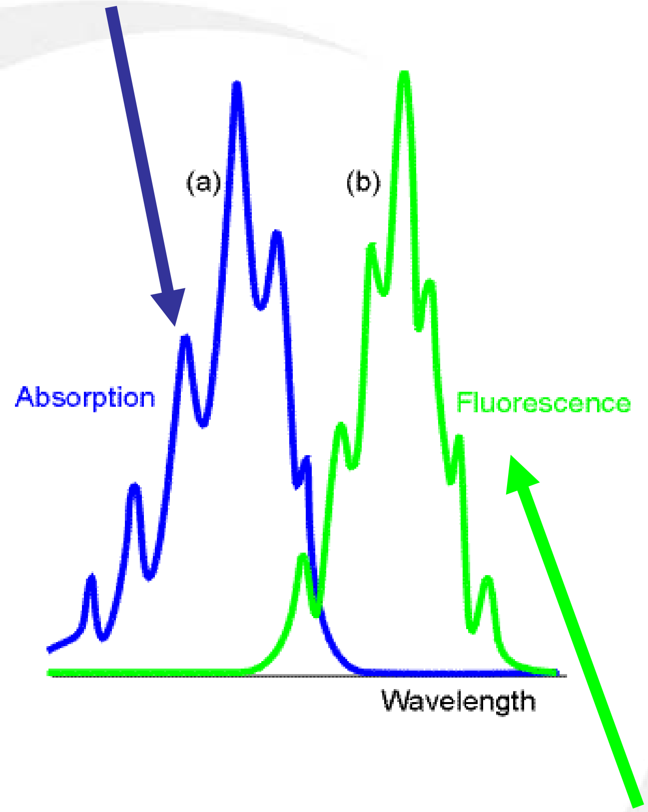


Scott Ollinger et al.

Yet another approach: Fluorescence Explorer (FLEX) Mission

An absorption spectrum (a) shows a vibrational structure characteristic of the upper state

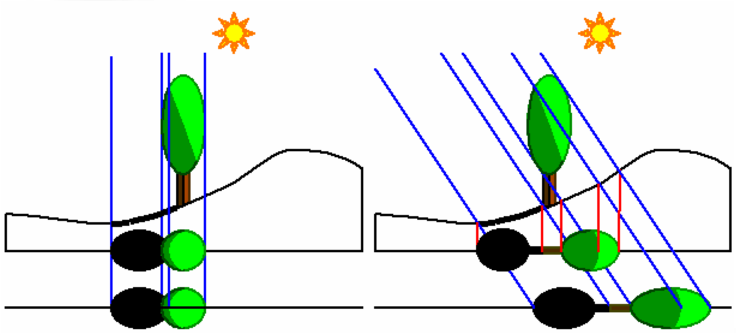




A fluorescence spectrum (b) shows a structure characteristic of the lower state, displaced to lower energies (mirror image of the absorption)

J. Moreno, Univ Valencia

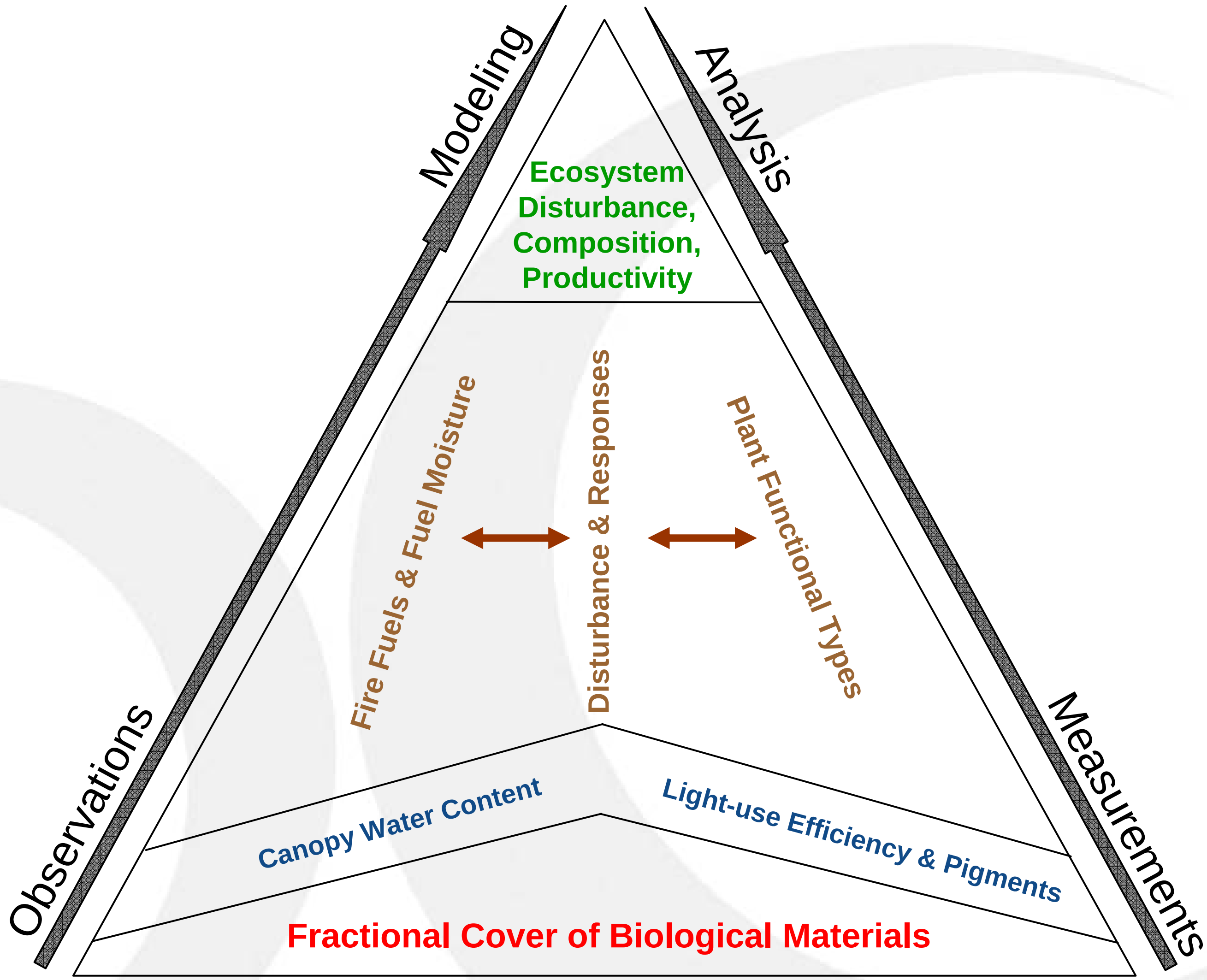
Problems with gaps and shaded leaves



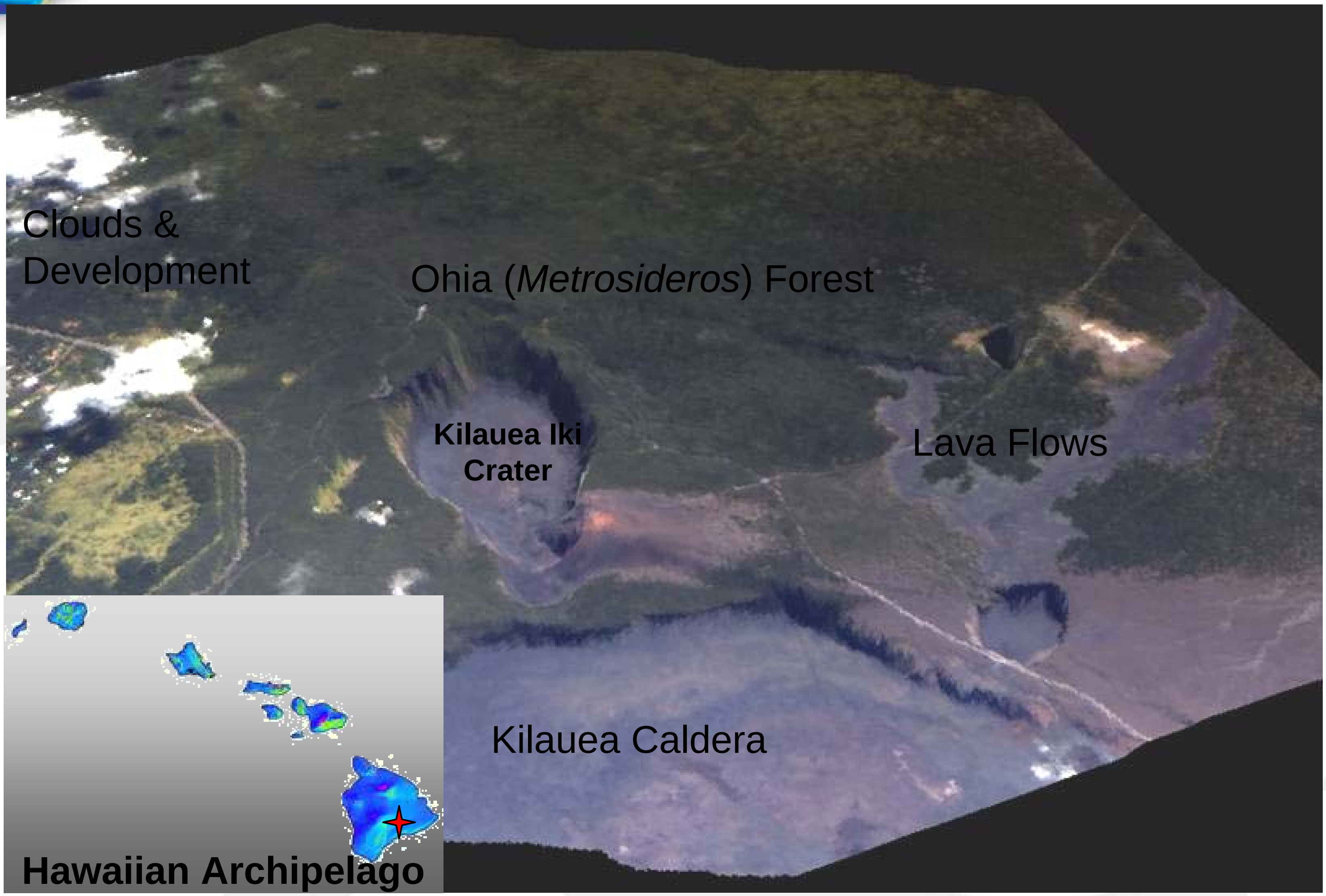
Canopy structural data are essential to separate the multiple components temperatures

J. Moreno, Univ Valencia

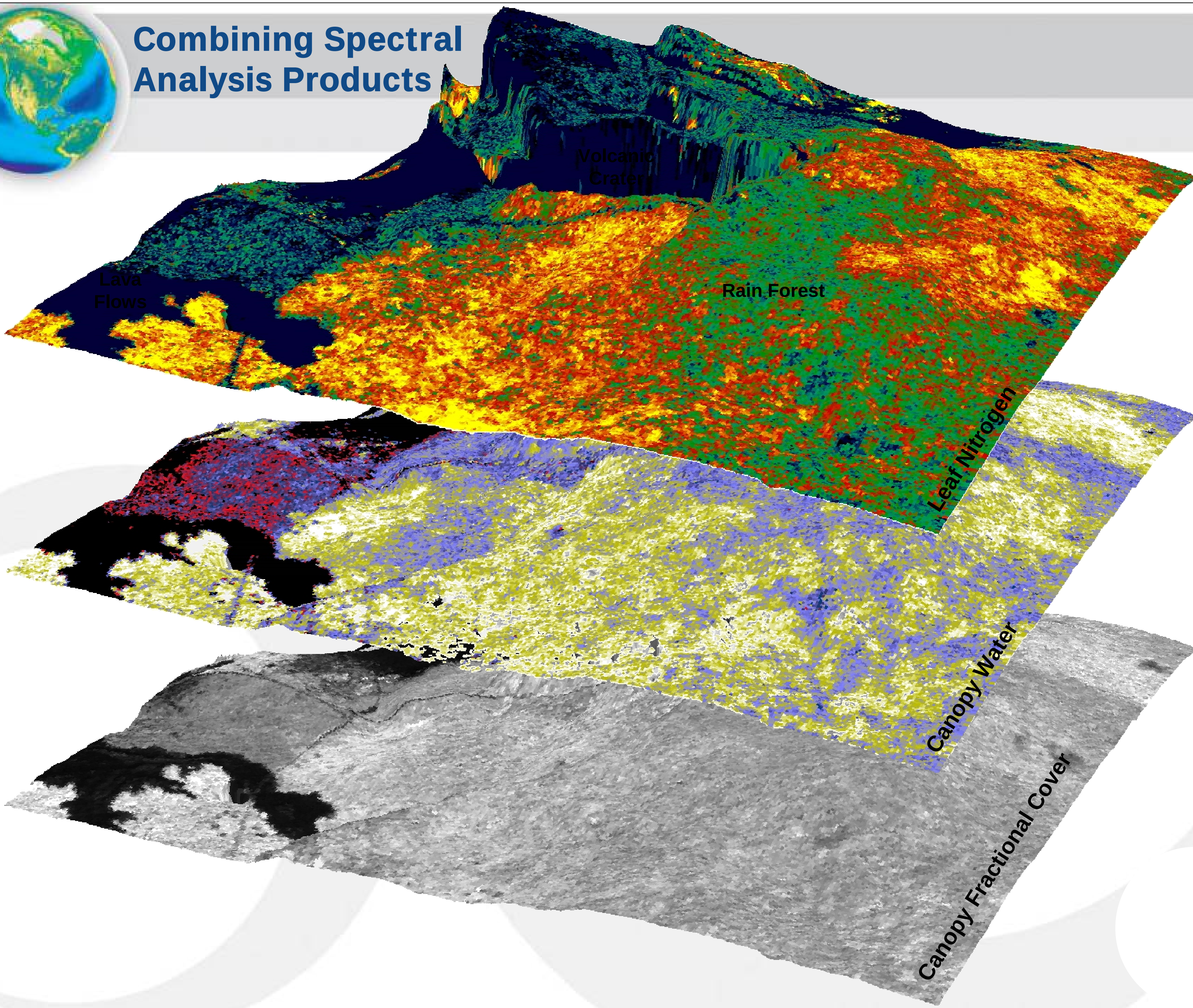
Conceptual model for ecosystem analysis via spectral remote sensing



Canopy chemistry → functional types → invasive species



Combining Spectral Analysis Products



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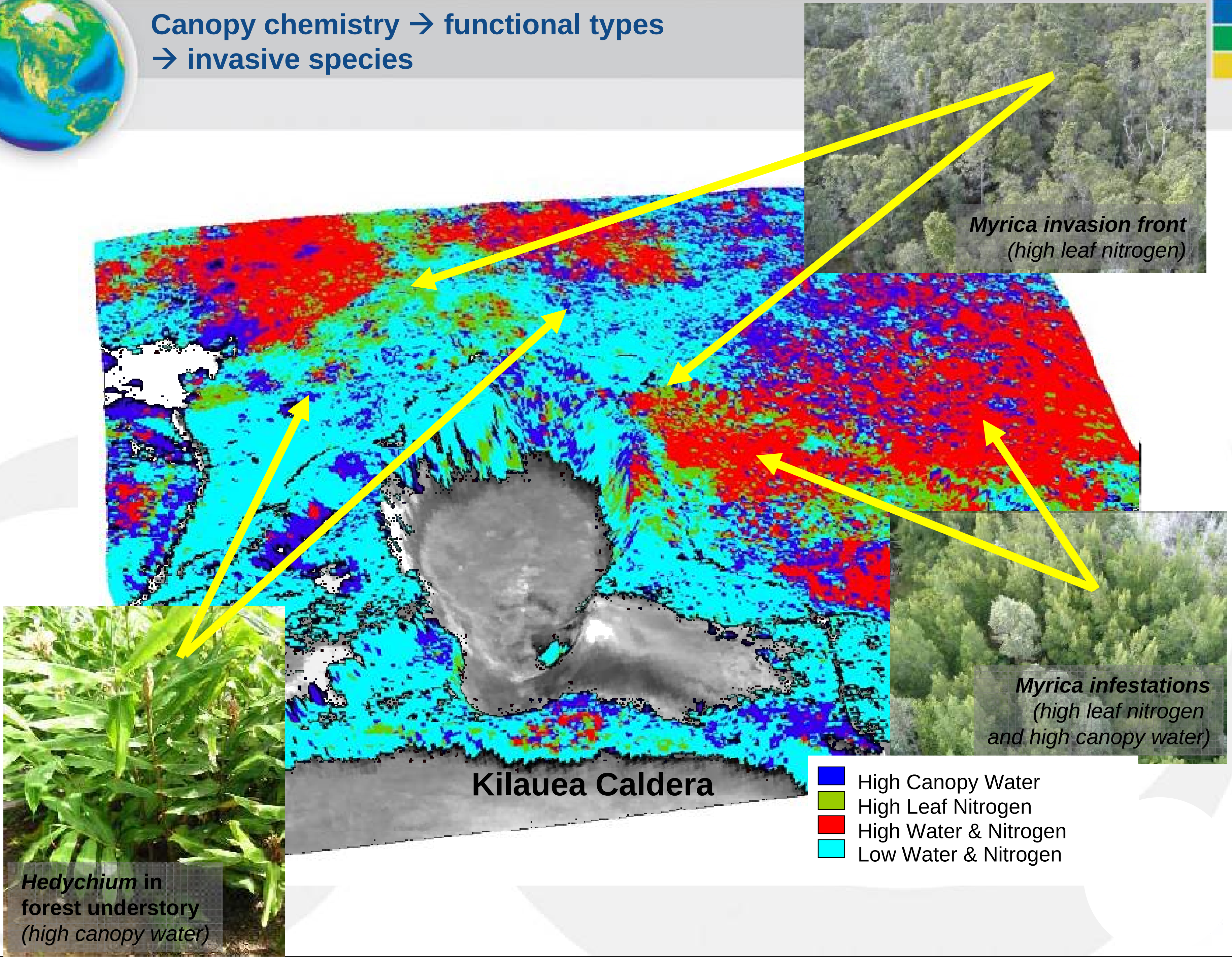
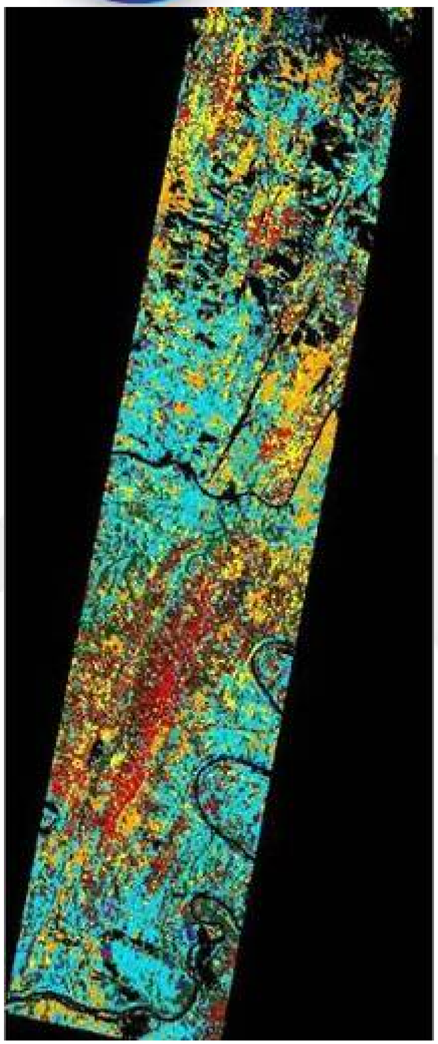


Species & Functional Type Mapping with Imaging Spectroscopy



- Forest
  - Conifers 88.3%
    - Hard Pine
    - White Pine
    - Hemlock
  - Broadleaf Deciduous Hardwoods 100%
    - Red Oaks 86.5%
      - Red Oak 37.5%
      - Chestnut Oak 62.5%
      - Black Oak 47.6%
      - Scarlet Oak 53.3%
    - White Oak 71.0%
    - Mixed Conifer / Oaks 76.9%
    - Successional 84.6%

Overall 96.5% 79.8% 59.3%

Townsend and Foster, UMD

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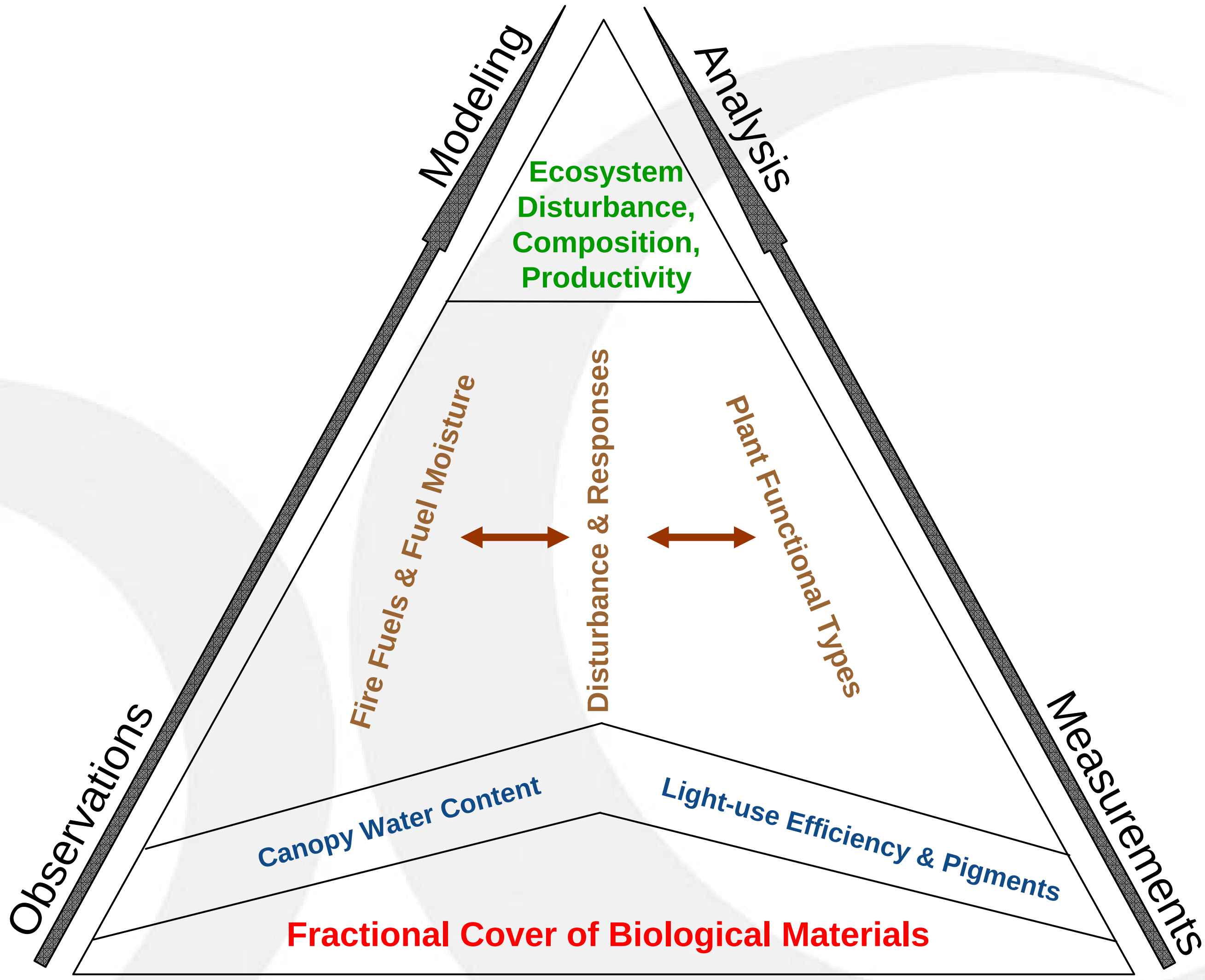

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