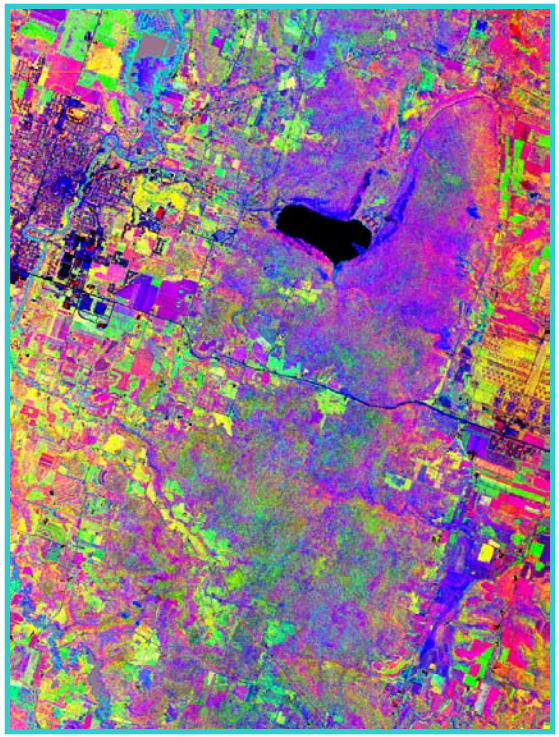
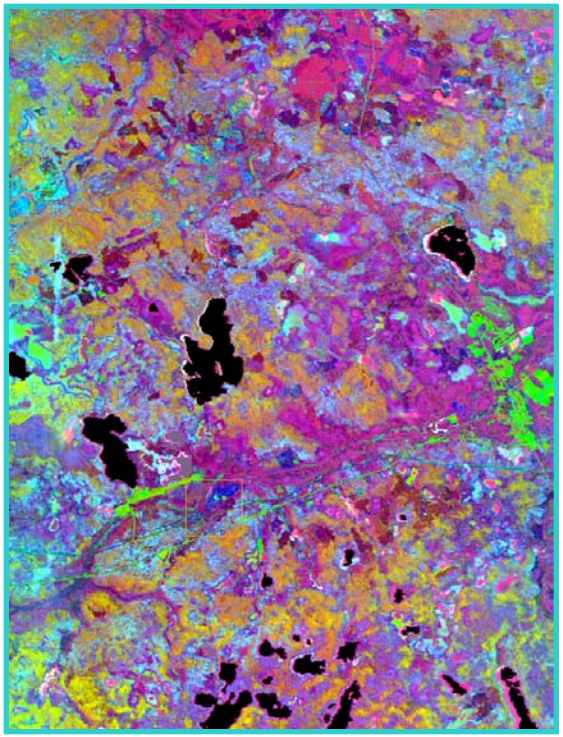
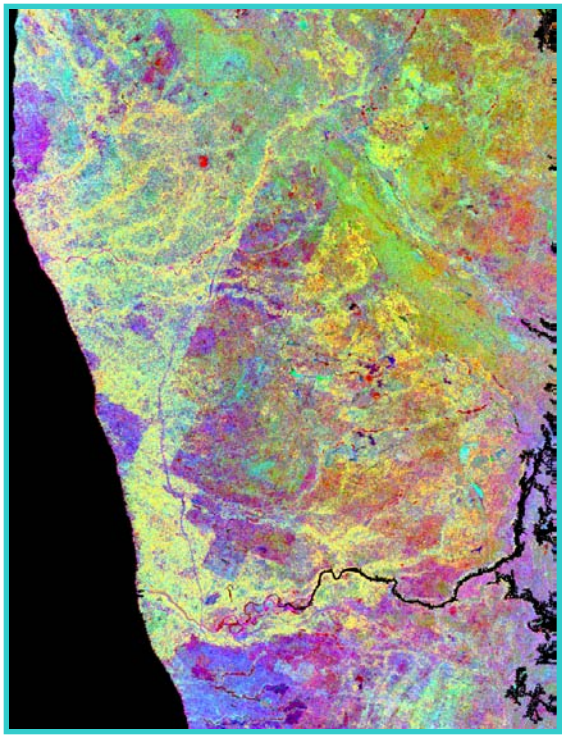
HyspIRI: Imaging Spectroscopy of Plant Metabolic and Ecological Function

Phil Townsend, Shawn Serbin, Aditya Singh, Dylan Dillaway, Brenden McNeil and Eric Kruger







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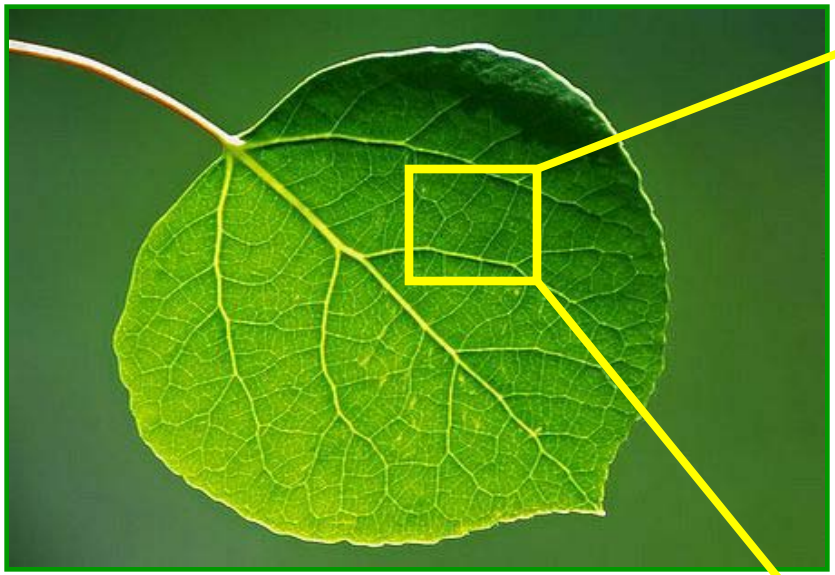
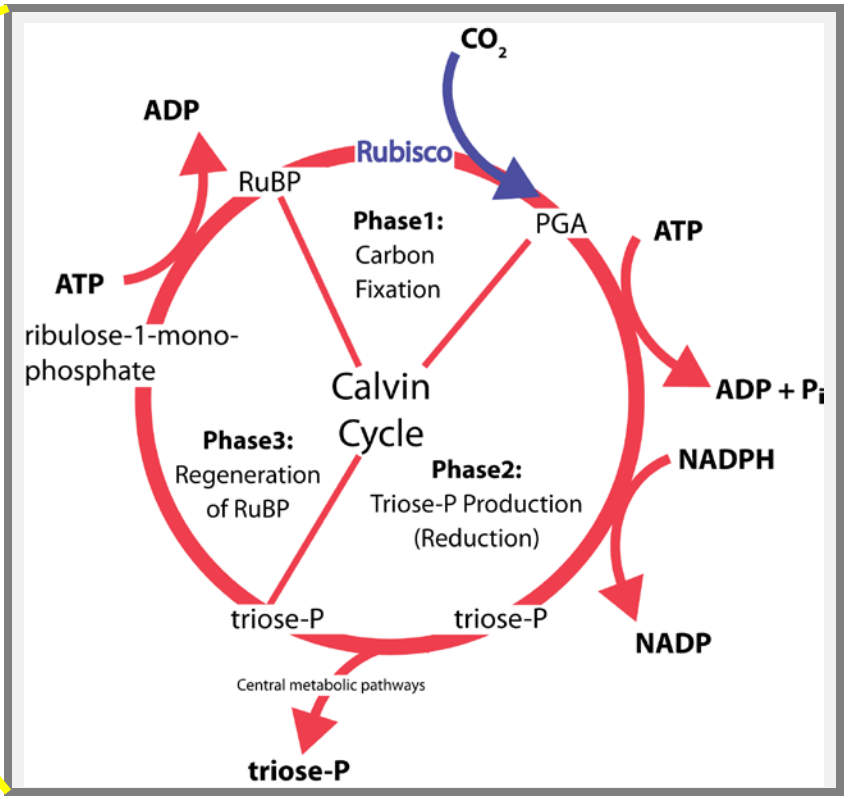
Photosynthesis:
A temperature-mediated photochemical reaction



Climate is key to photo-synthetic potential.



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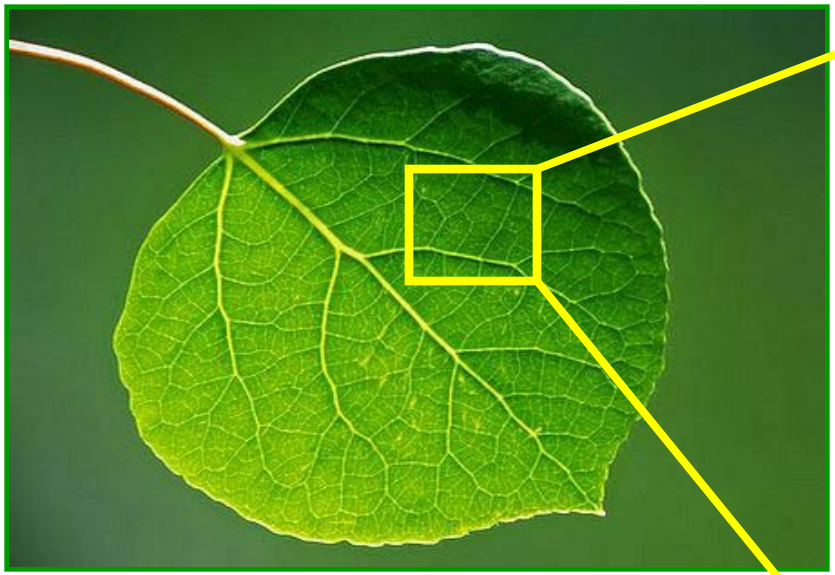
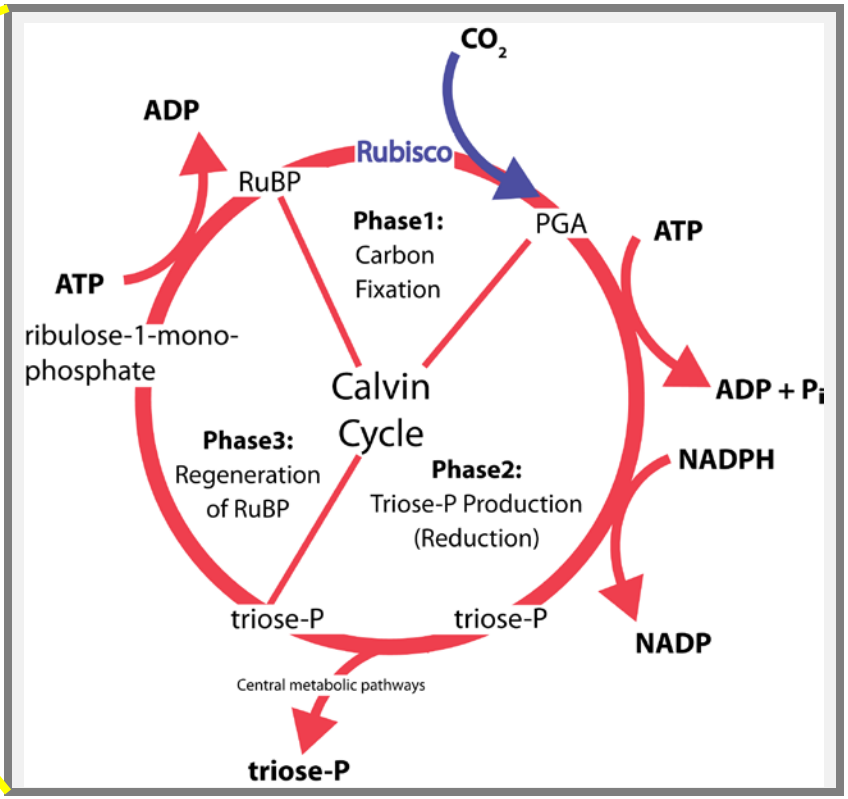
Nutrient dynamics:
Plant allocation and use of resources





Cell structure (water use),
shade tolertance (N use),
recalcitrance (decomposition)

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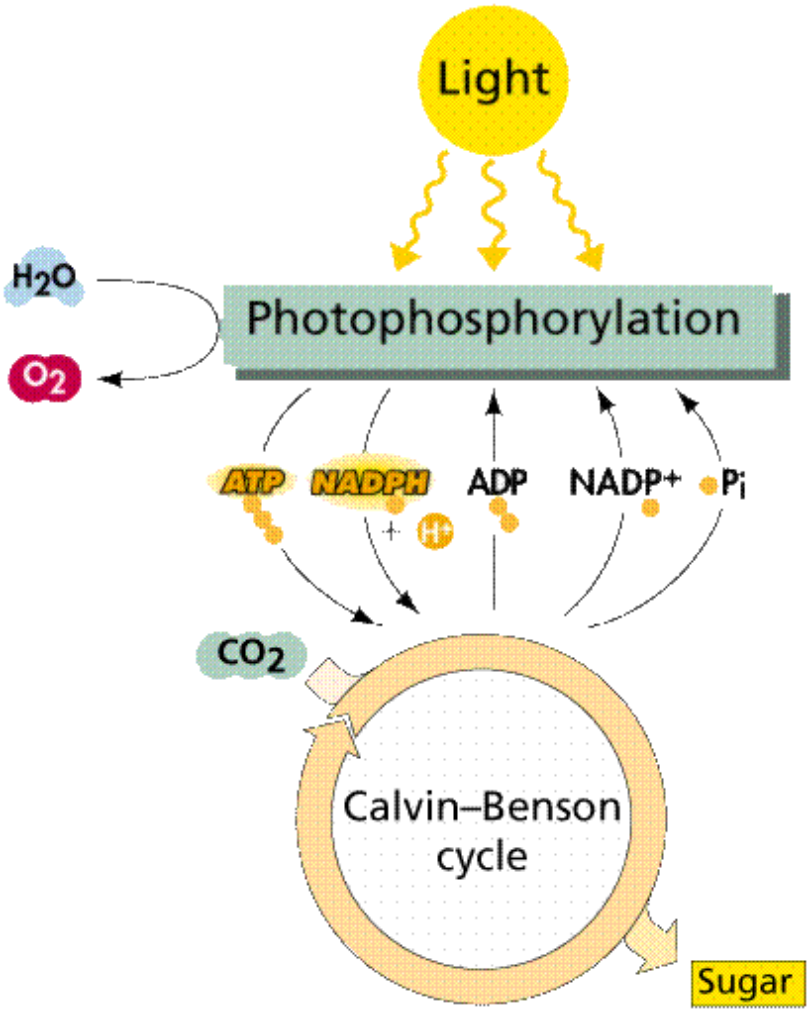
Key concepts for climate change research:

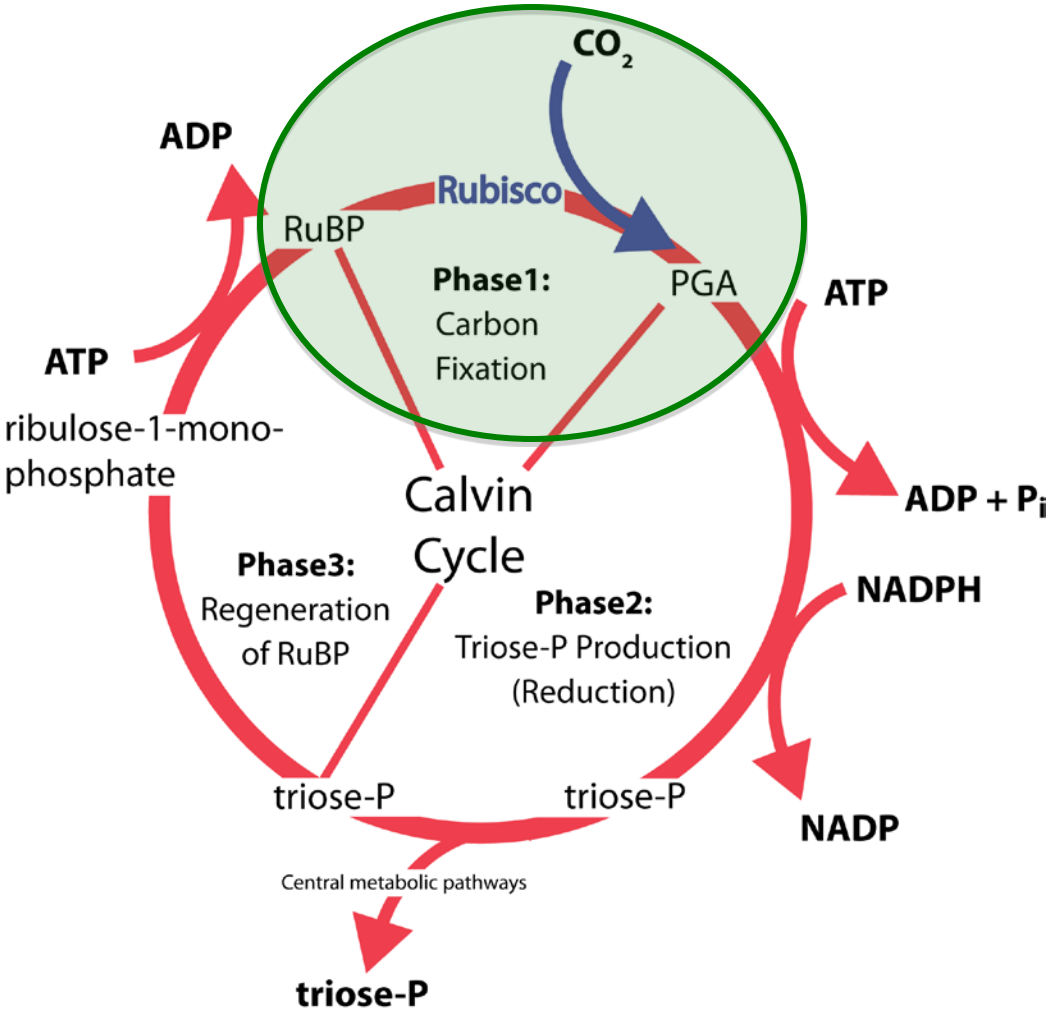
Photosynthesis is driven by light, temperature, water availability, nutrients, etc.

If we can measure specific processes of photosynthesis using imaging spectroscopy and thermal (temperature) measurements, then:

- We can measure changes in photosynthetic rates, and:
- Assess changes in carbon assimilation by vegetation and changes in vegetation function associated with ΔT.
- *Global mission necessary to evaluate changes in photosynthesis that occur over large areas.*

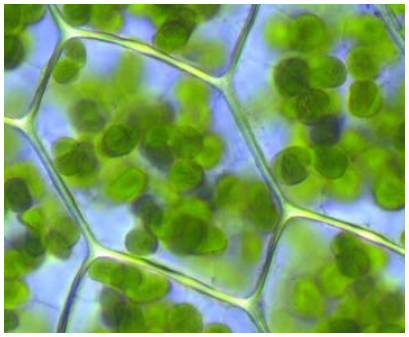
Definition: V(c)max – maximum rate of carboxylation

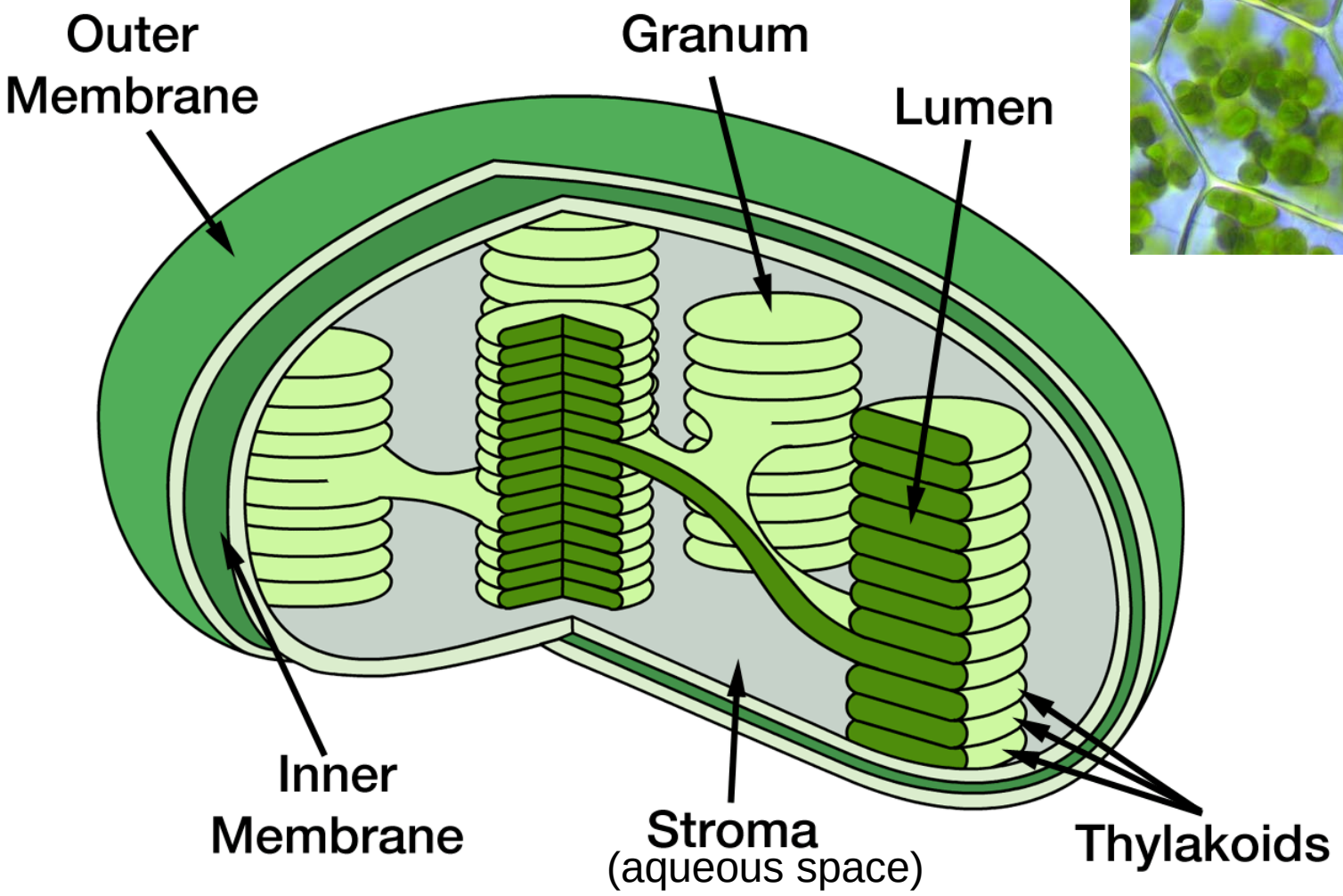




Carboxylation – initial addition of CO_2 to RuBP (catalyzed by RuBisCO). Addition of ATP and NADPH → triose phosphate

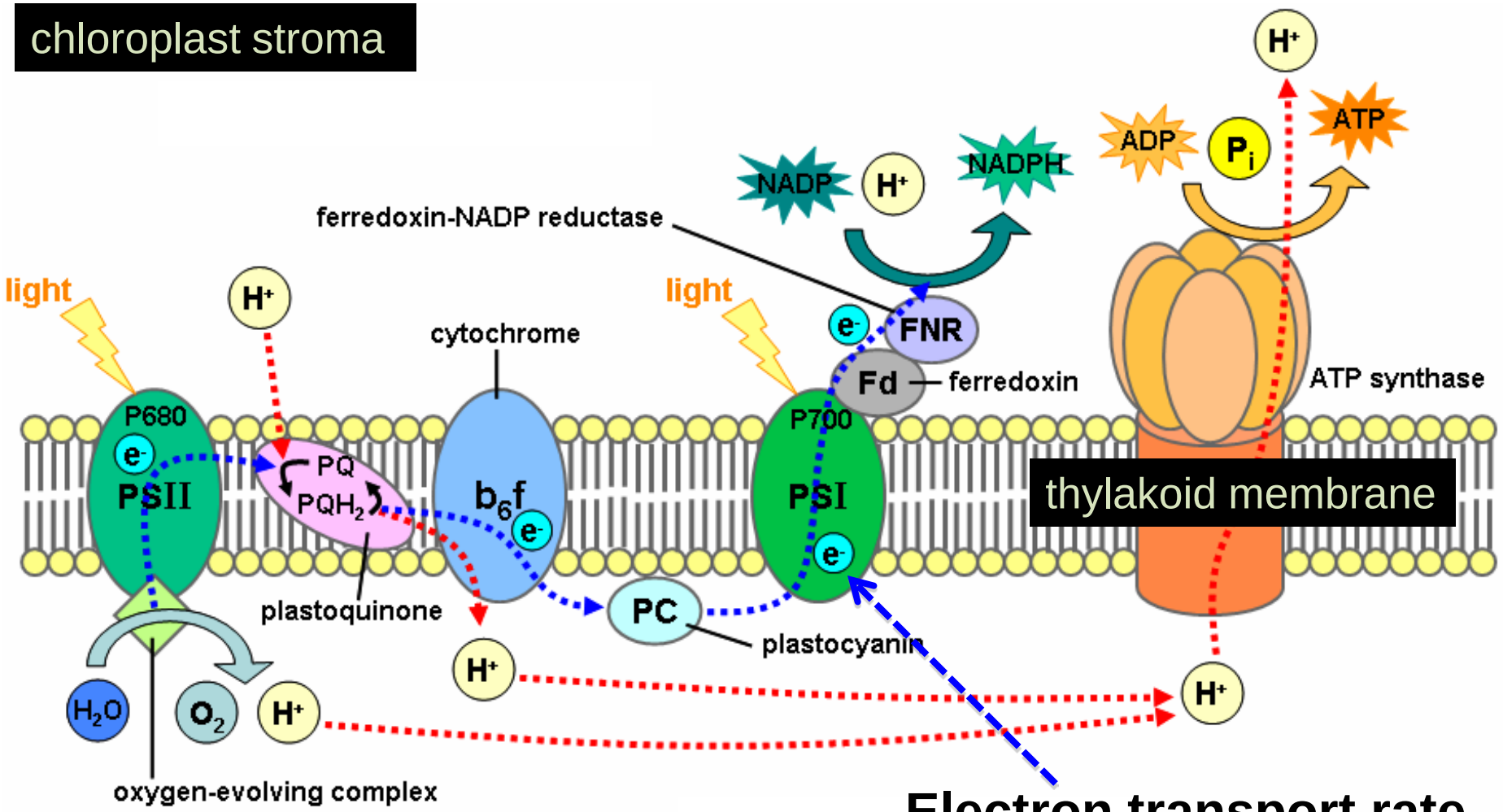
Photosynthesis – The Chloroplast





http://photoprotection.clinuvel.com/custom/uploads/LUV_fig4_chloroplast_v(1).gif

Definition: Jmax – electron transport rate



Electron transport rate
Jmax

Diagram from wikipedia commons

Background:

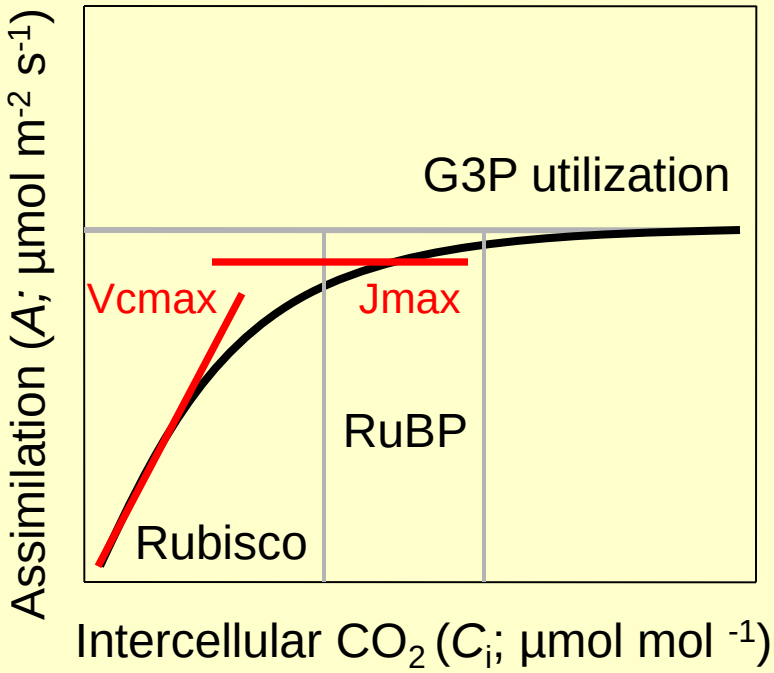
$V_{(c)max}$: Measurement of process by which Rubisco catalyzes RuBP with CO_2 to produce the carbon compounds that eventually become triose phosphates (G3P, PGAL)

Triose phosphates are the building block for sugars and starches.

J_{max}: Transport of electrons through the thylakoid membrane is critical to producing NADPH and ATP, which provide the metabolic energy necessary to produce triose phosphates.

Biochemical modeling of photosynthesis

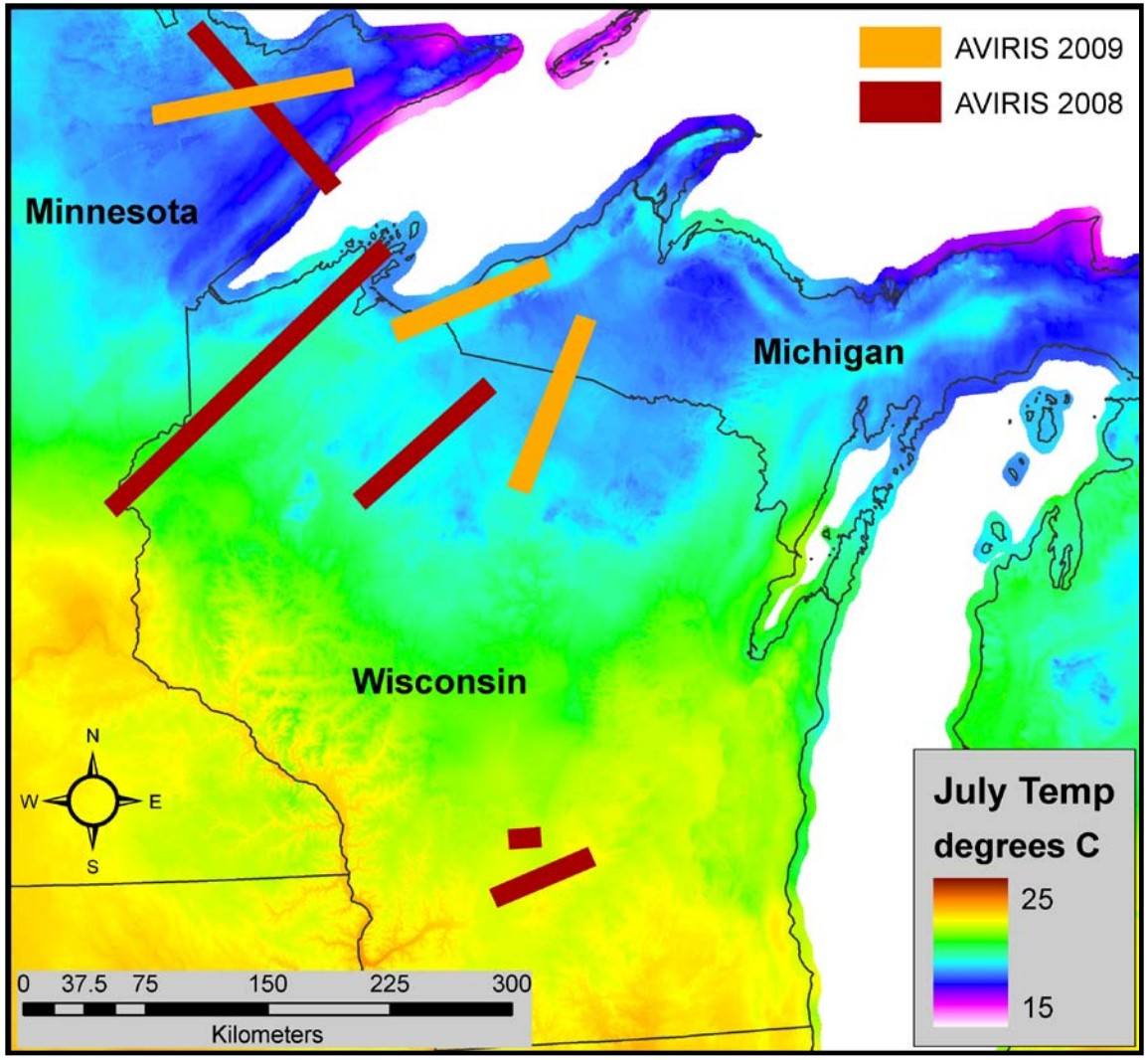
$$A_n = \min(A_c, A_j, A_p) - R_d$$



- Limited by
  - Rubisco
  - RuBP regeneration
  - triose phosphate utilization
- Determine key metabolic variables
  - **Vcmax**: Rubisco activity
  - **Jmax**: Electron transport

How will climate change affect composition and metabolism?

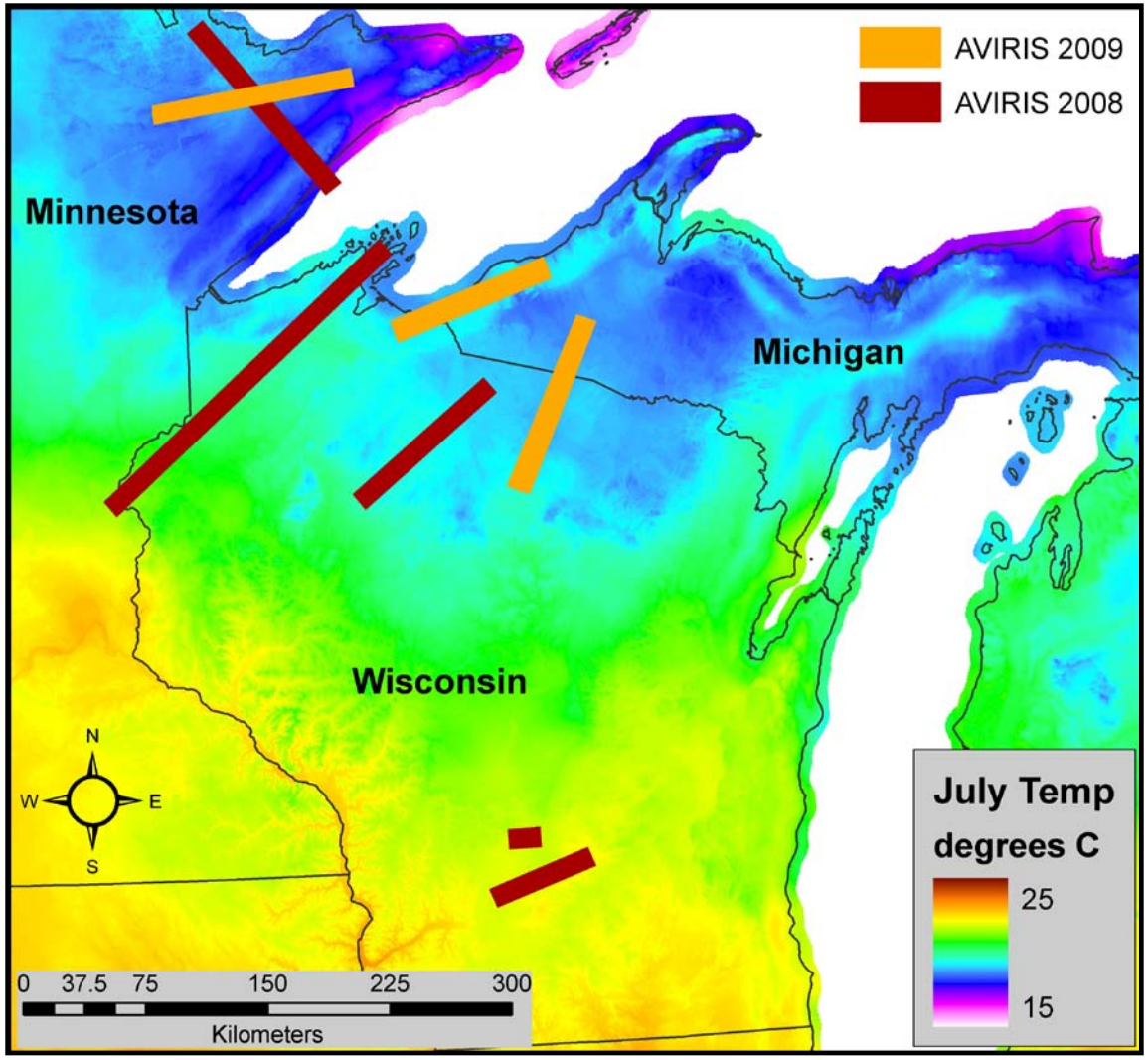
- Across the range of a species**
- Photosynthetic capacity varies according to climate
- Changes in climate should be expressed in changes in rates (Vcmax, Jmax)



PRISM Data: http://www.prism.oregonstate.edu/

How will climate change affect composition and metabolism?

- **Hyperspectral imagery**
- Field collection
  - Gas exchange
  - Spectra
  - **Canopy temperature**
- Examine regional trends
  - Lat/Long variation



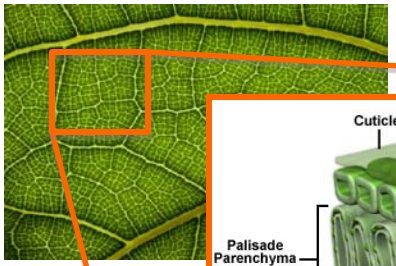
PRISM Data: http://www.prism.oregonstate.edu/

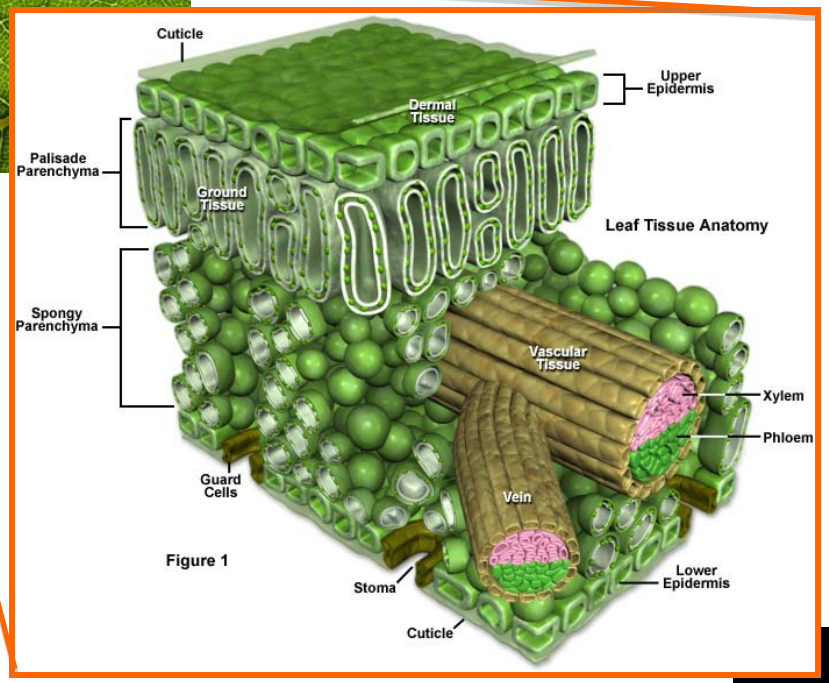
Where does HyspIRI fit in?

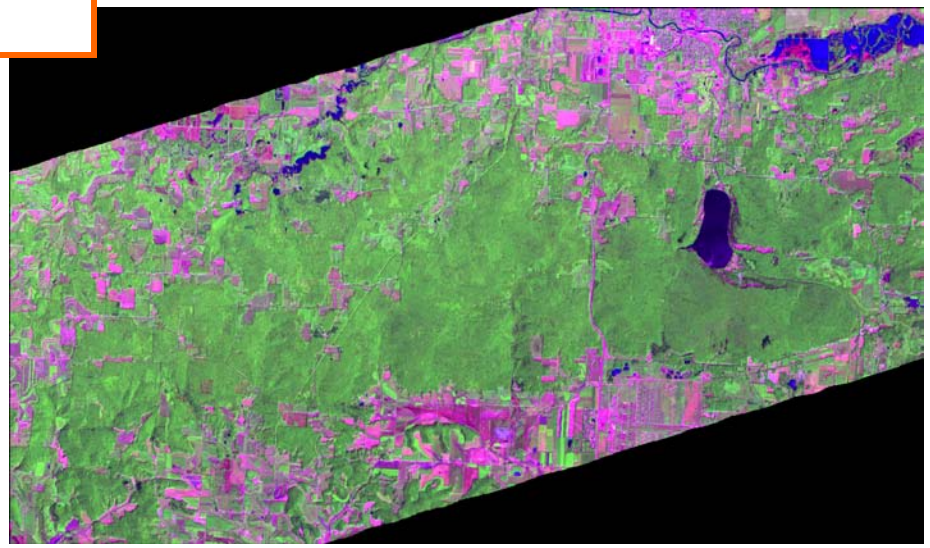
HyspIRI spectral and thermal measurements provide the opportunity to directly measure the photochemical processes associated with carbon assimilation (e.g., A_{max}) and respiration ***by plants across the ranges of species***.

These HyspIRI products provide the potential to identify changes in photosynthetic processes associated with climate change (e.g., temperature) across species.

Detection of leaf metabolic rates using spectroscopy



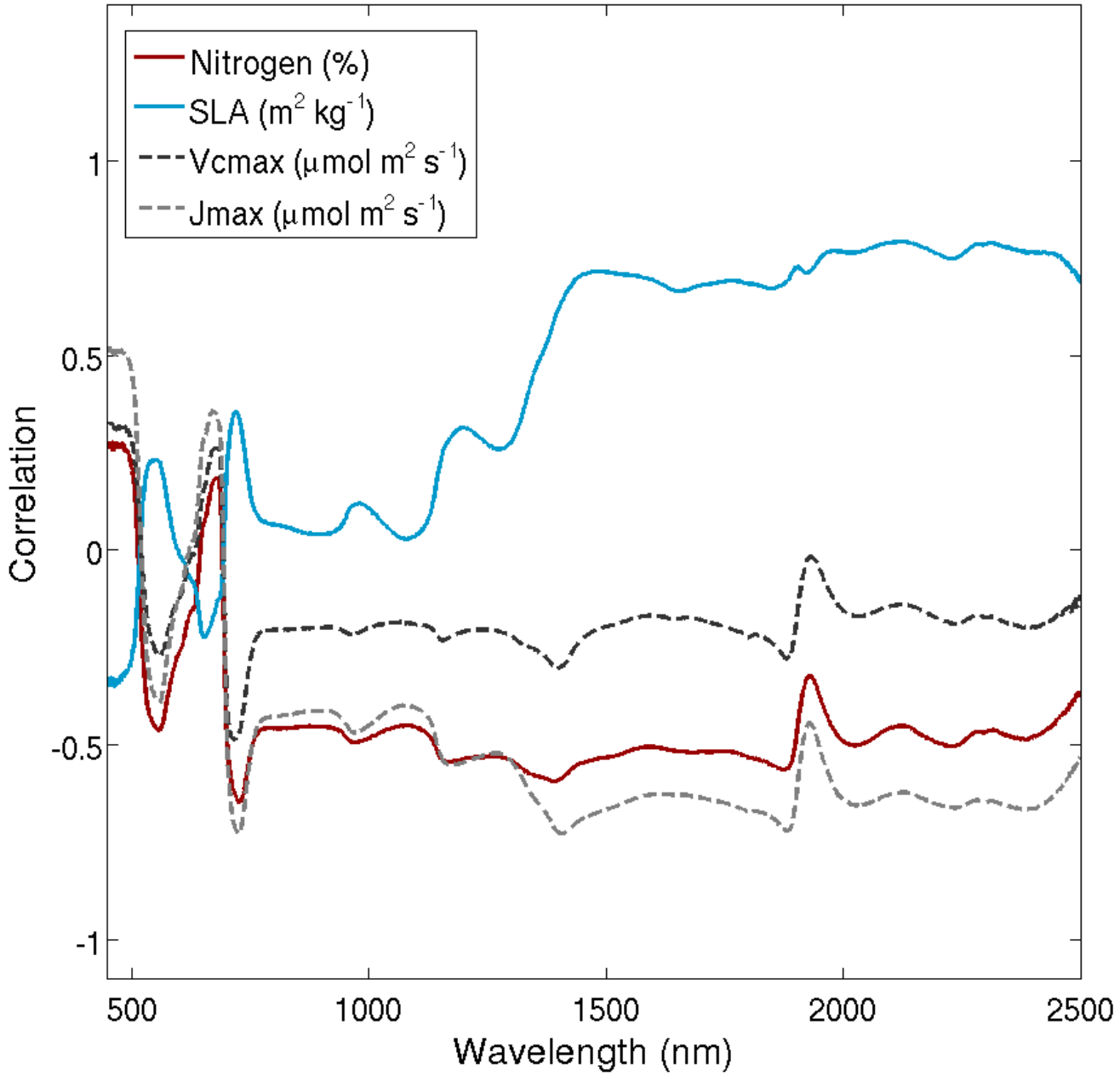




Physiological data in glasshouse study

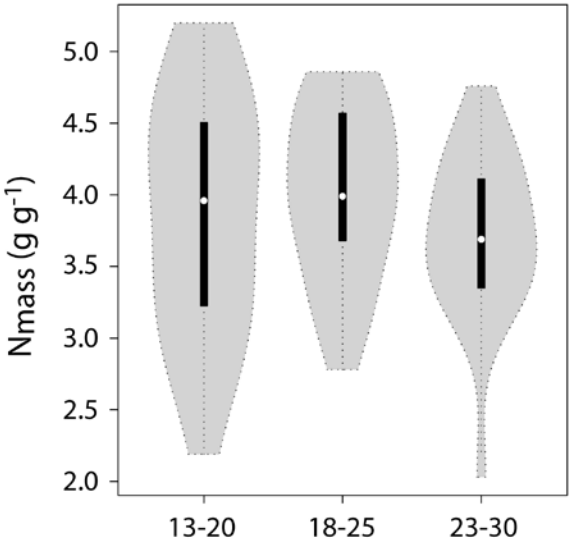
- Three temperature regimes
  - 13/20 ° C, 18/25 ° C, 23/30 ° C
- Leaf gas exchange
  - Vcmax, Jmax, A_{mass}, A_{area}
- Morphology and nutrition
  - SLA, Leaf N
- Leaf optical properties (350-2500 nm)

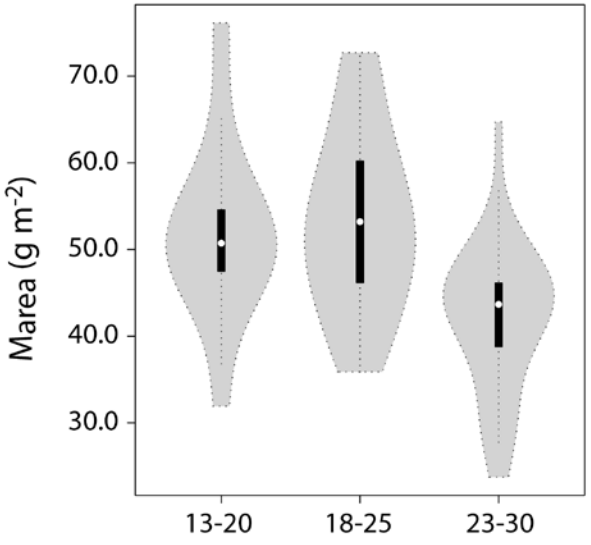
Empirical evidence: Cottonwood and Aspen



Physiological measurements across temperature regimes

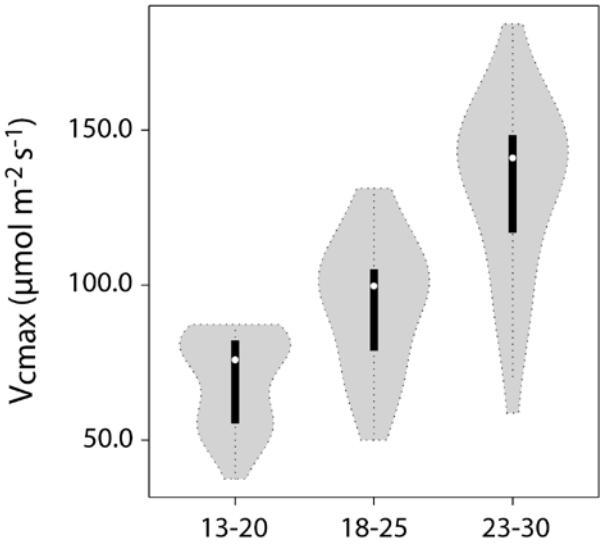
N (mass)

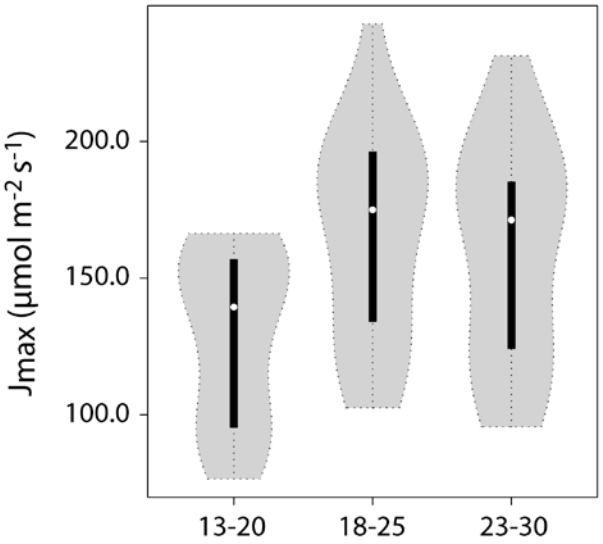




LMA

V(c)max

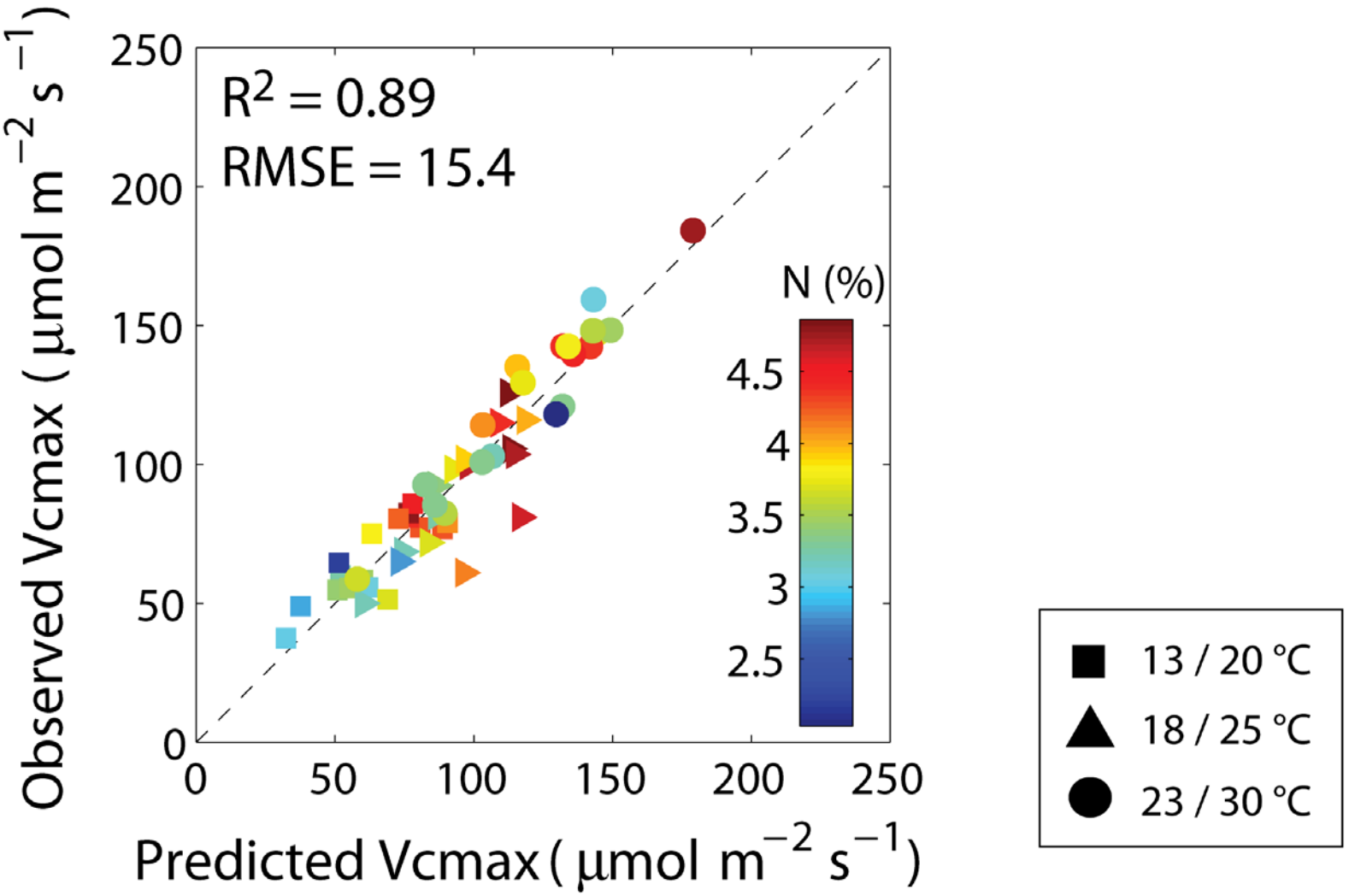




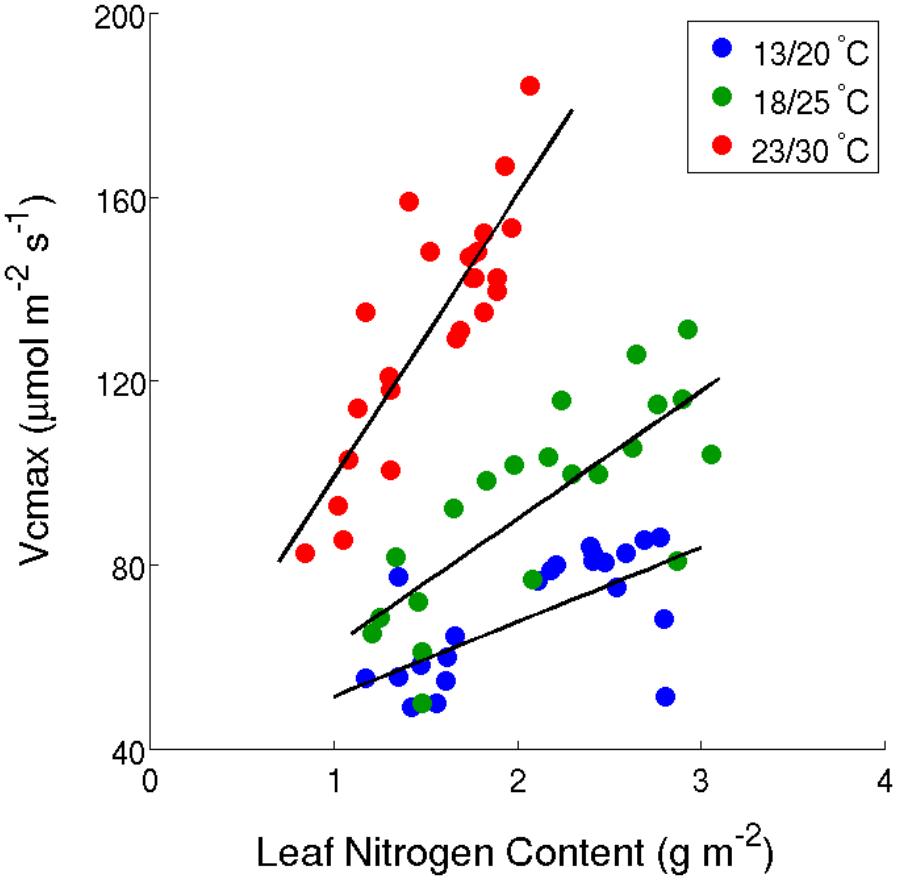
Jmax

Night – Day Temperature

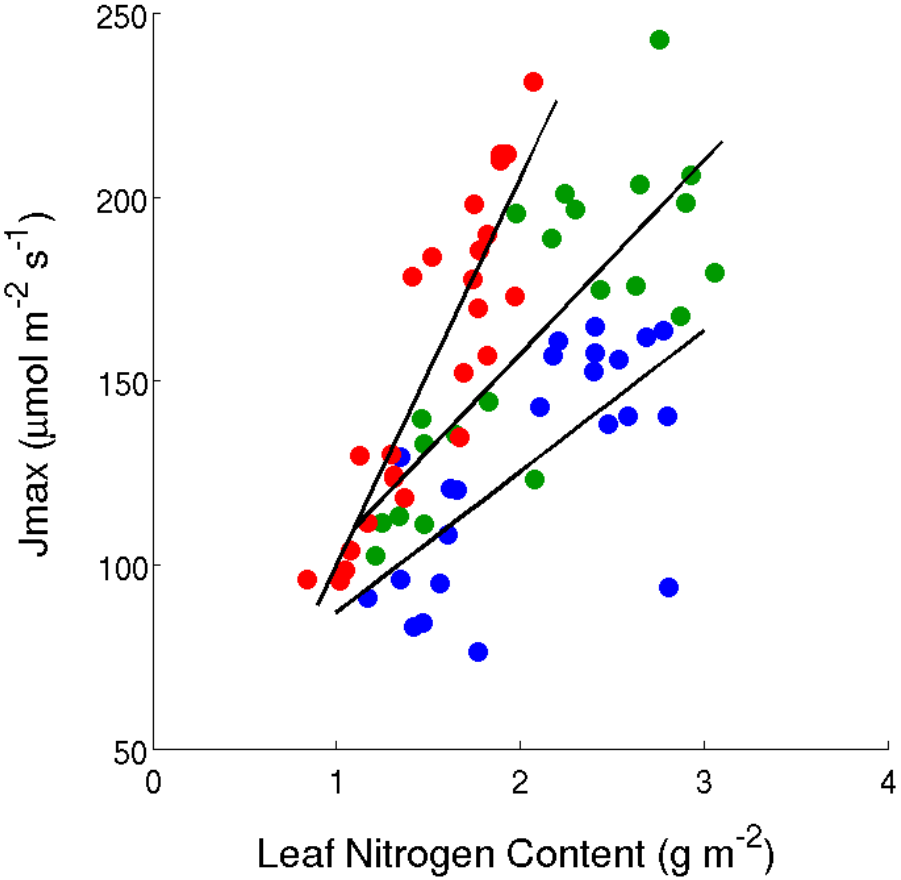
Predictions using leaf spectra and PLSR (%N example)



Biotron measurements show thermal effects on leaf metabolism



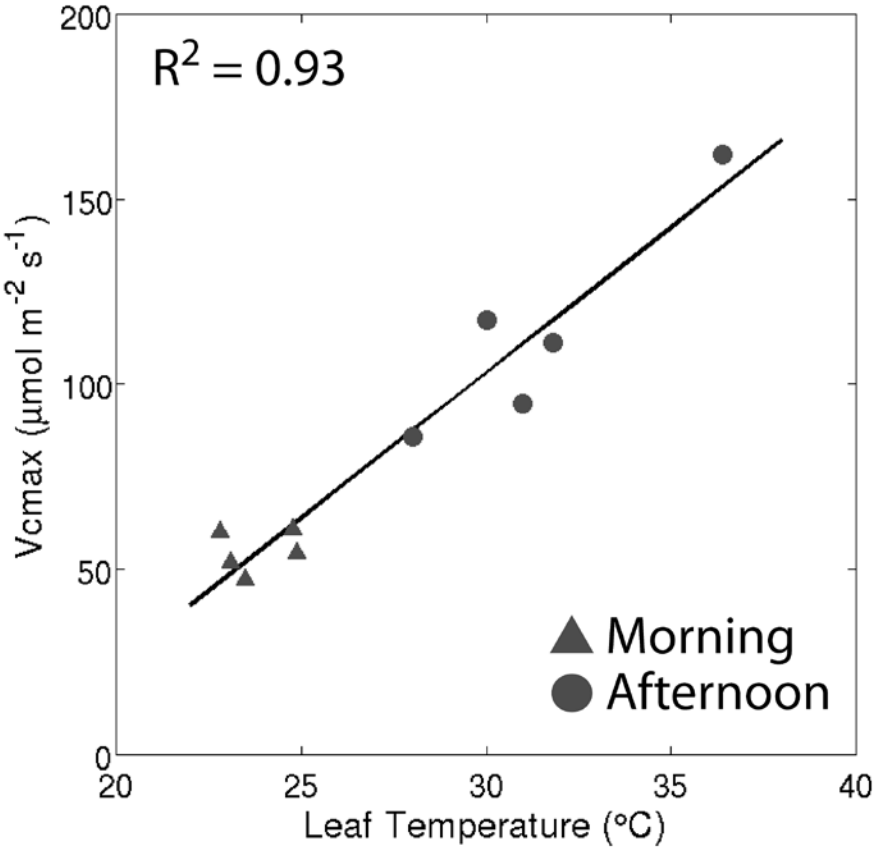
$R^2 = 0.003$

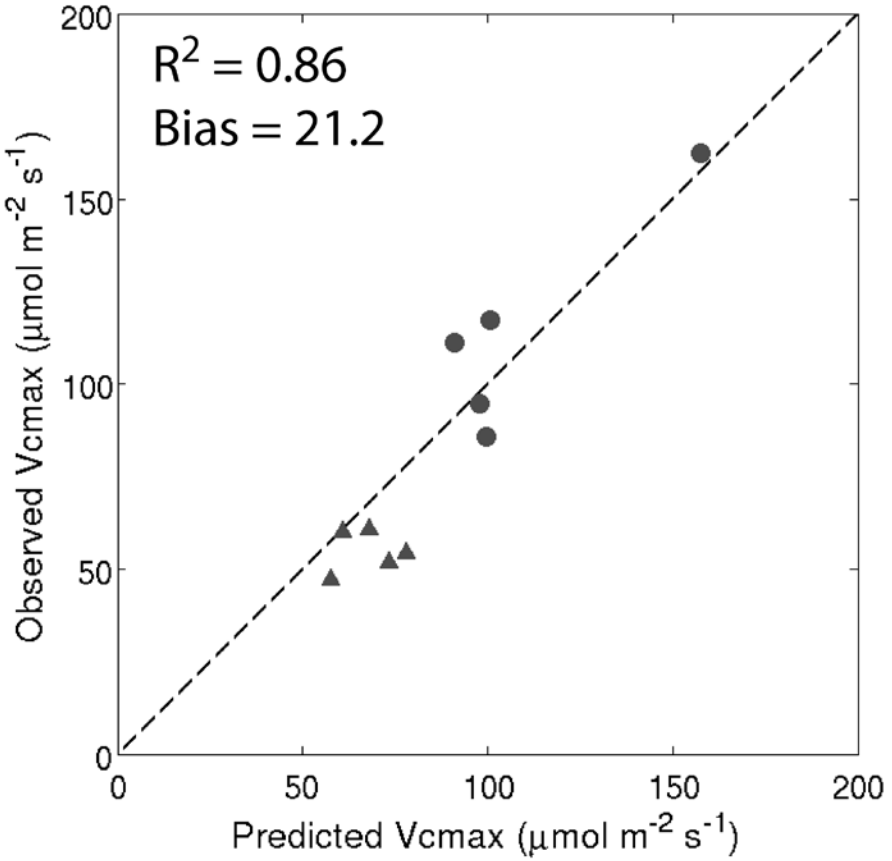


$R^2 = 0.33$

Pooled R^2 between spectra-predicted V(c)max/Jmax and leaf N

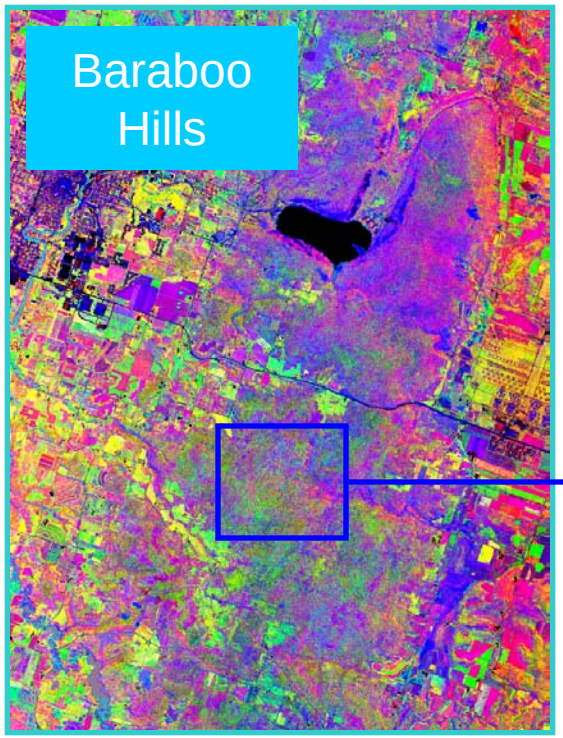
Spectra are responsive to temp.-driven variations in metabolism

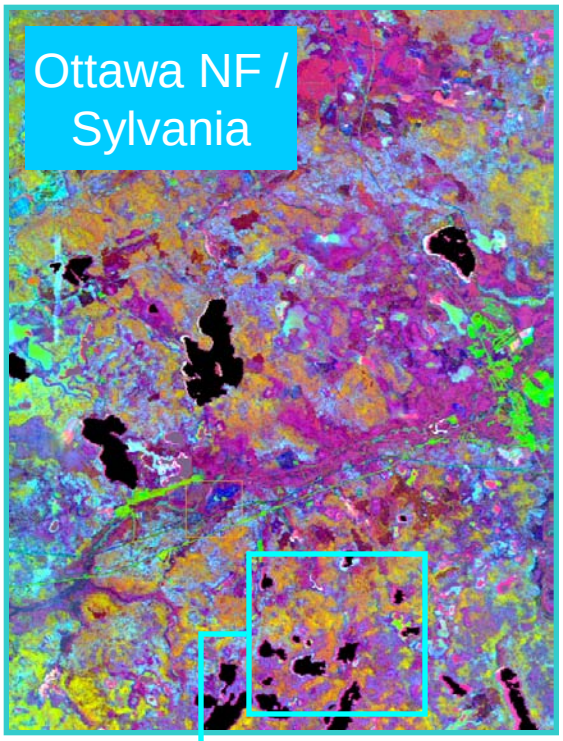


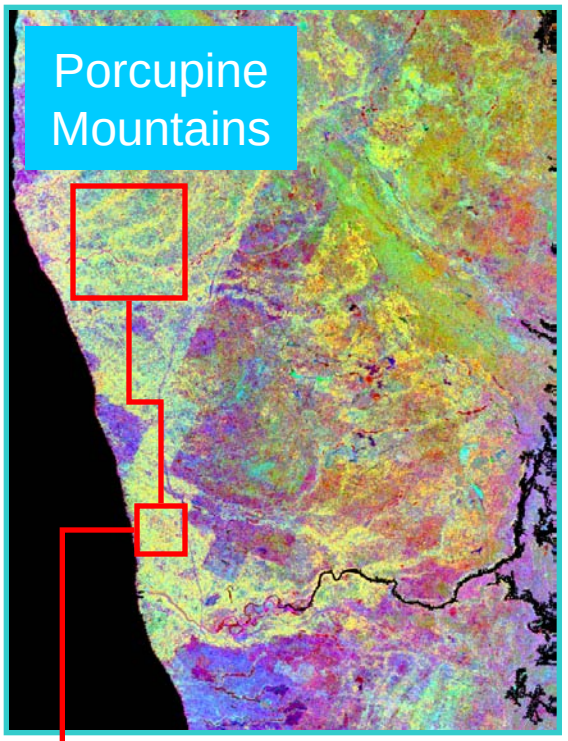


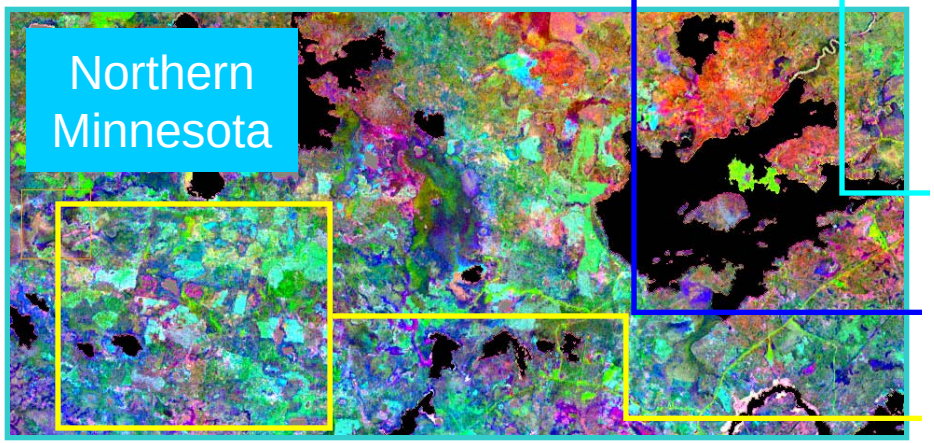
Time	Tleaf (° C)	Vcmax
Morning	23.8	54.8
Afternoon	31.4	114.3

Examples: AVIRIS imagery from the Upper Midwest









Old growth hemlock / Hwd

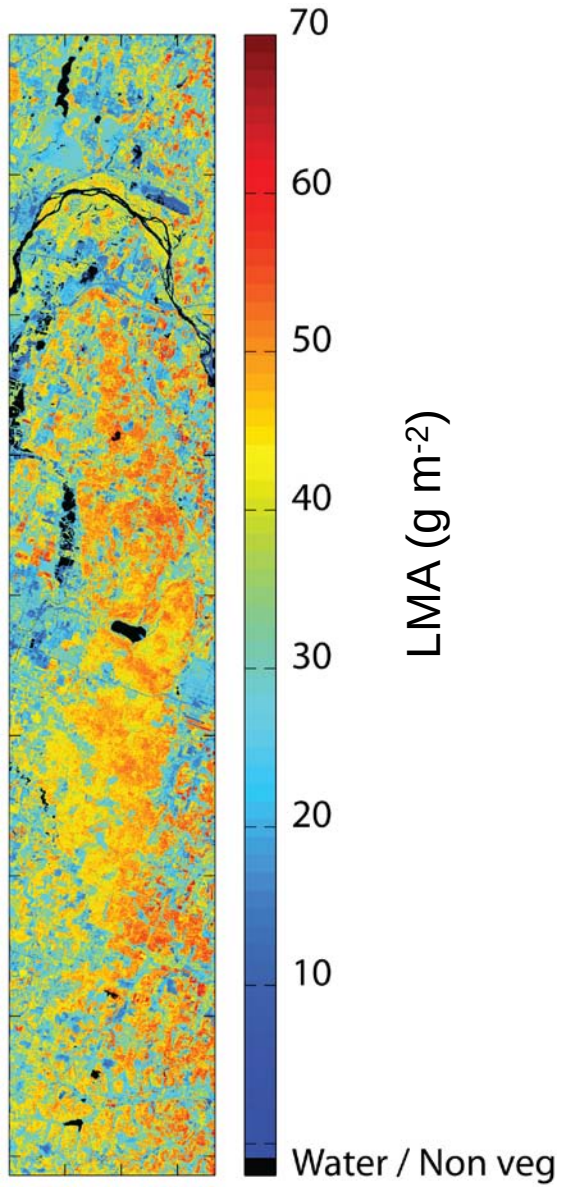
Northern hardwood

Oak / hickory

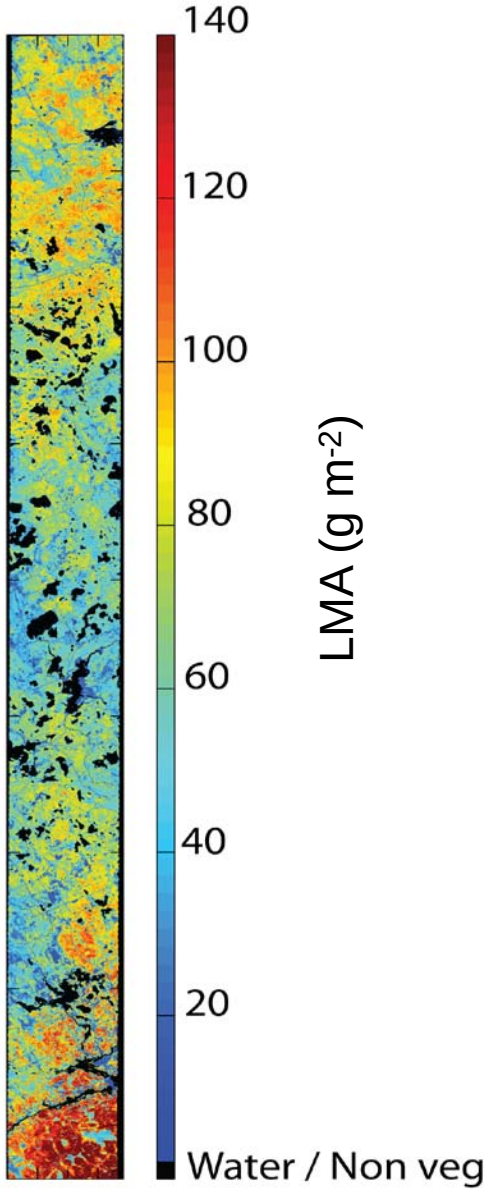
Boreal forest

Examples: LMA – based on hypothesized relationships

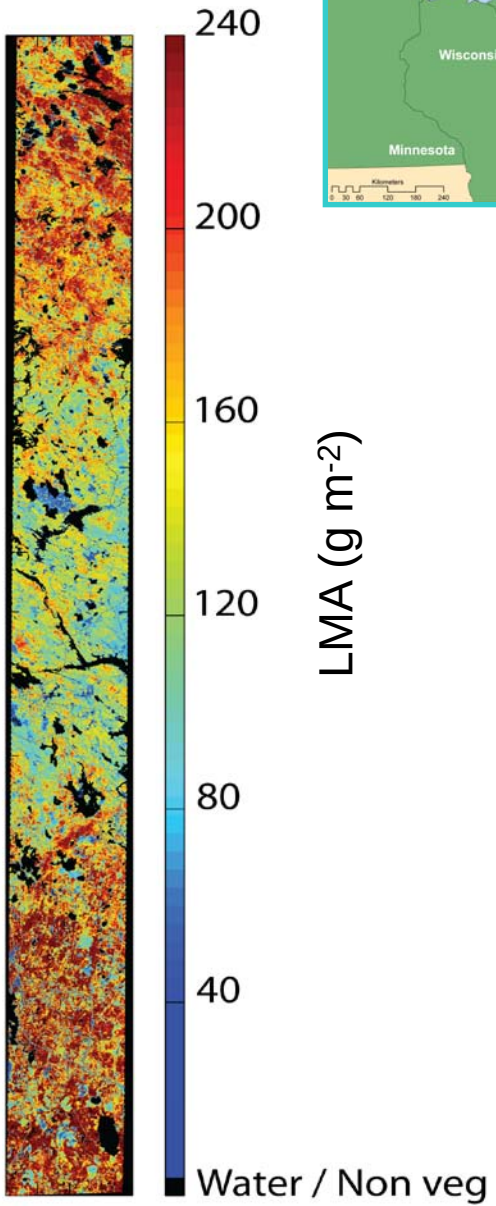
Baraboo Hills



Ottawa NF

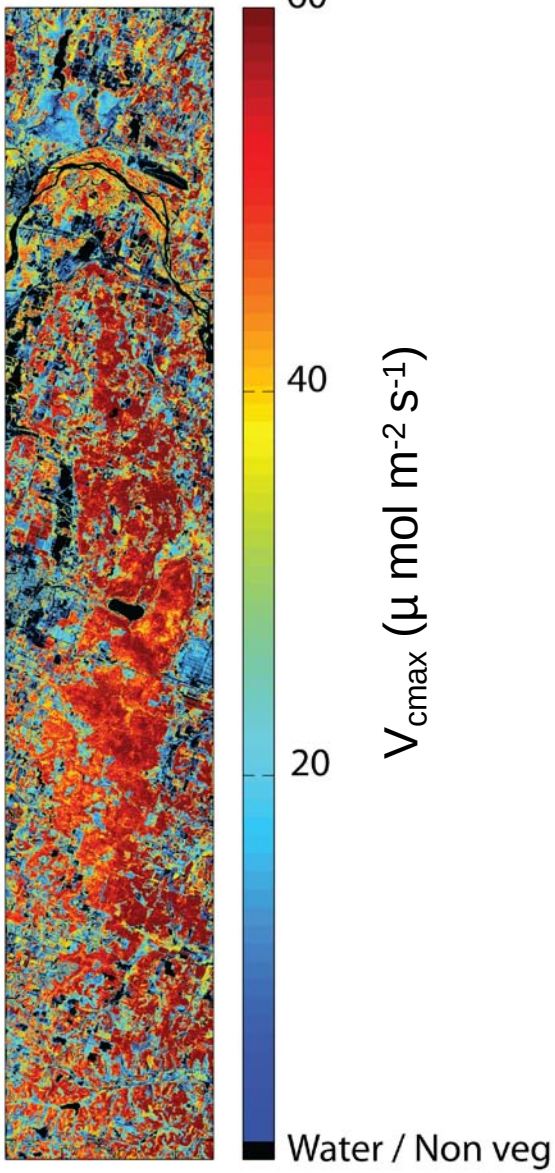


Minnesota



Examples: V(c)max – based on hypothesized relationships

Baraboo Hills



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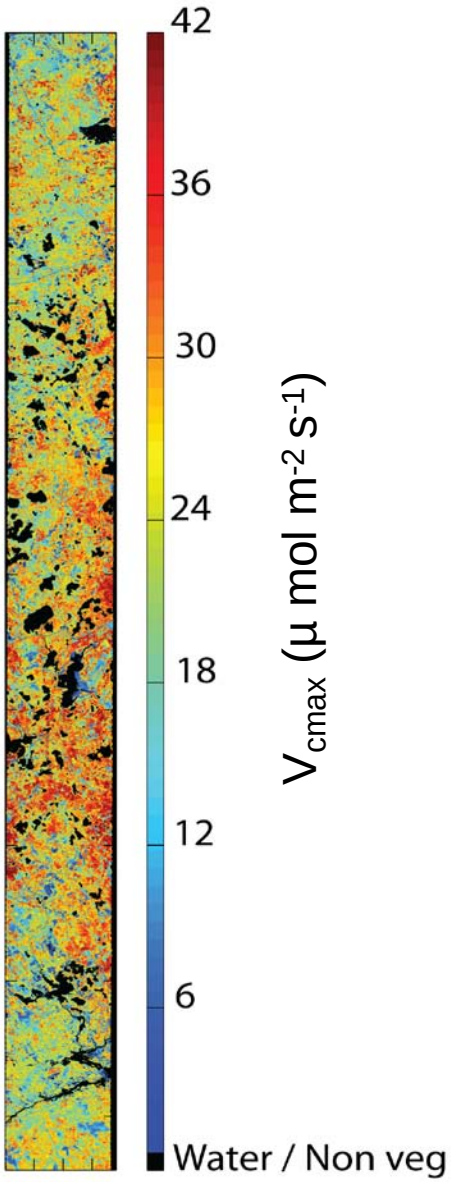

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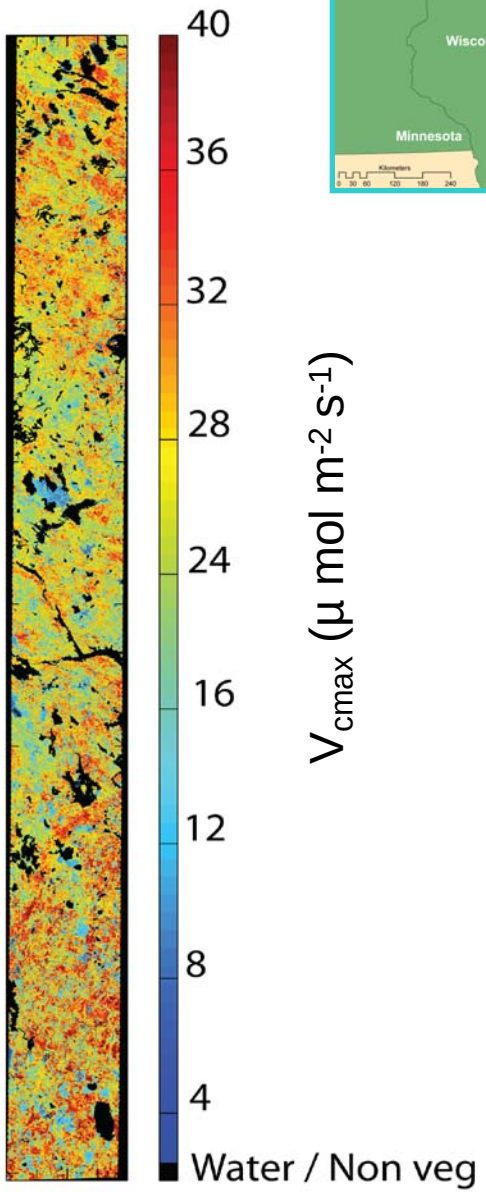
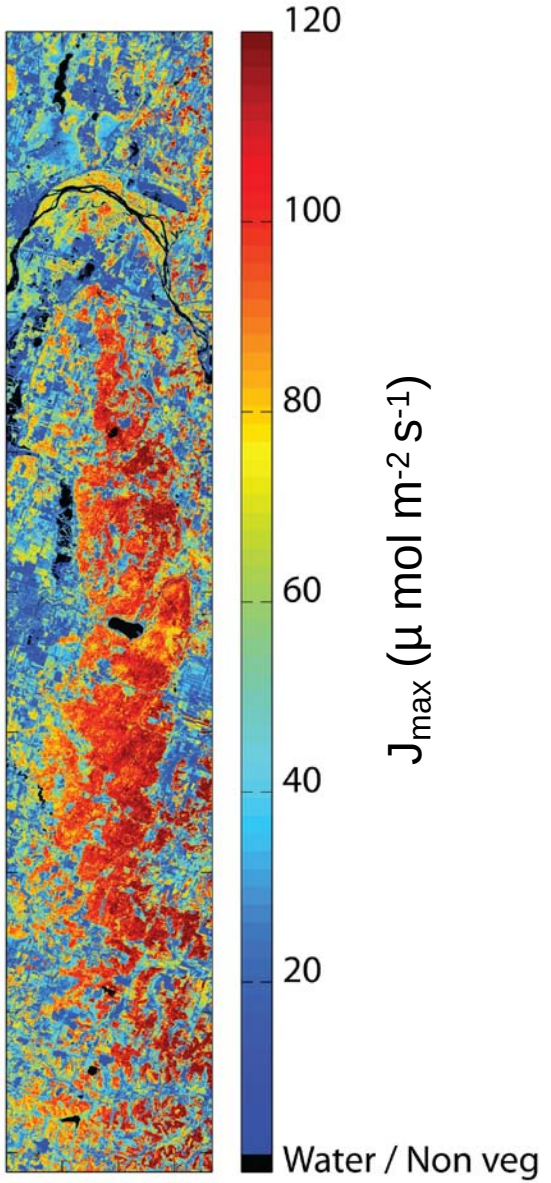


Examples: Jmax – based on hypothesized relationships

Baraboo Hills



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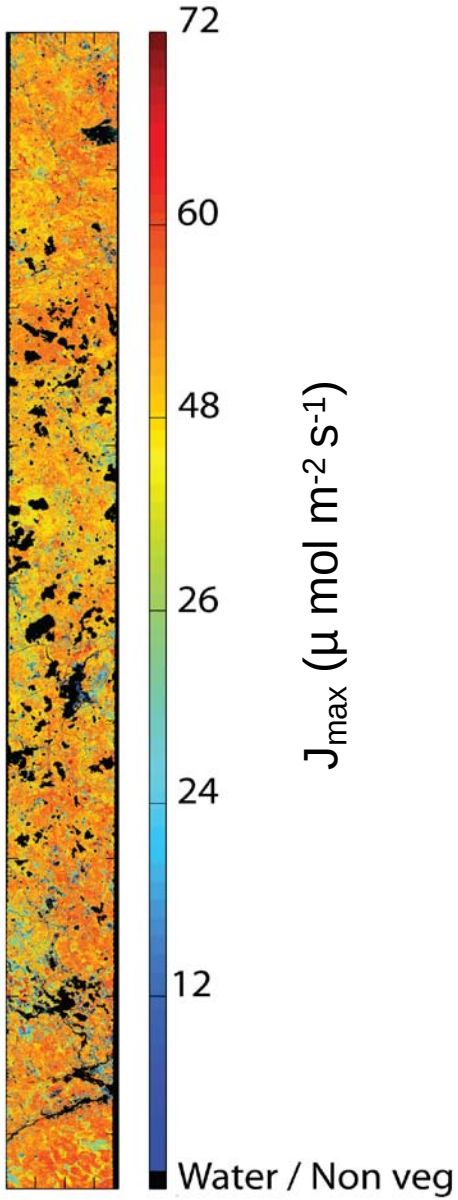

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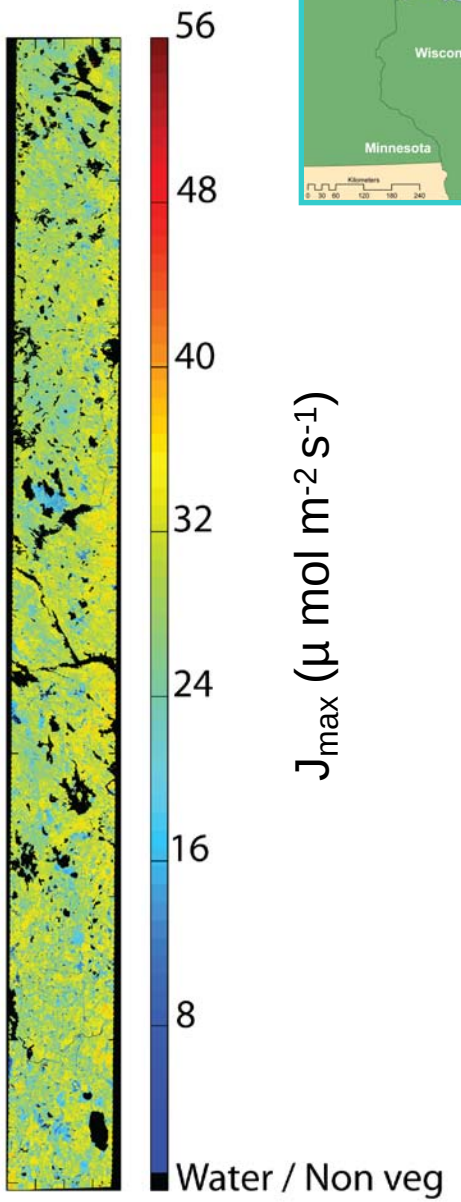
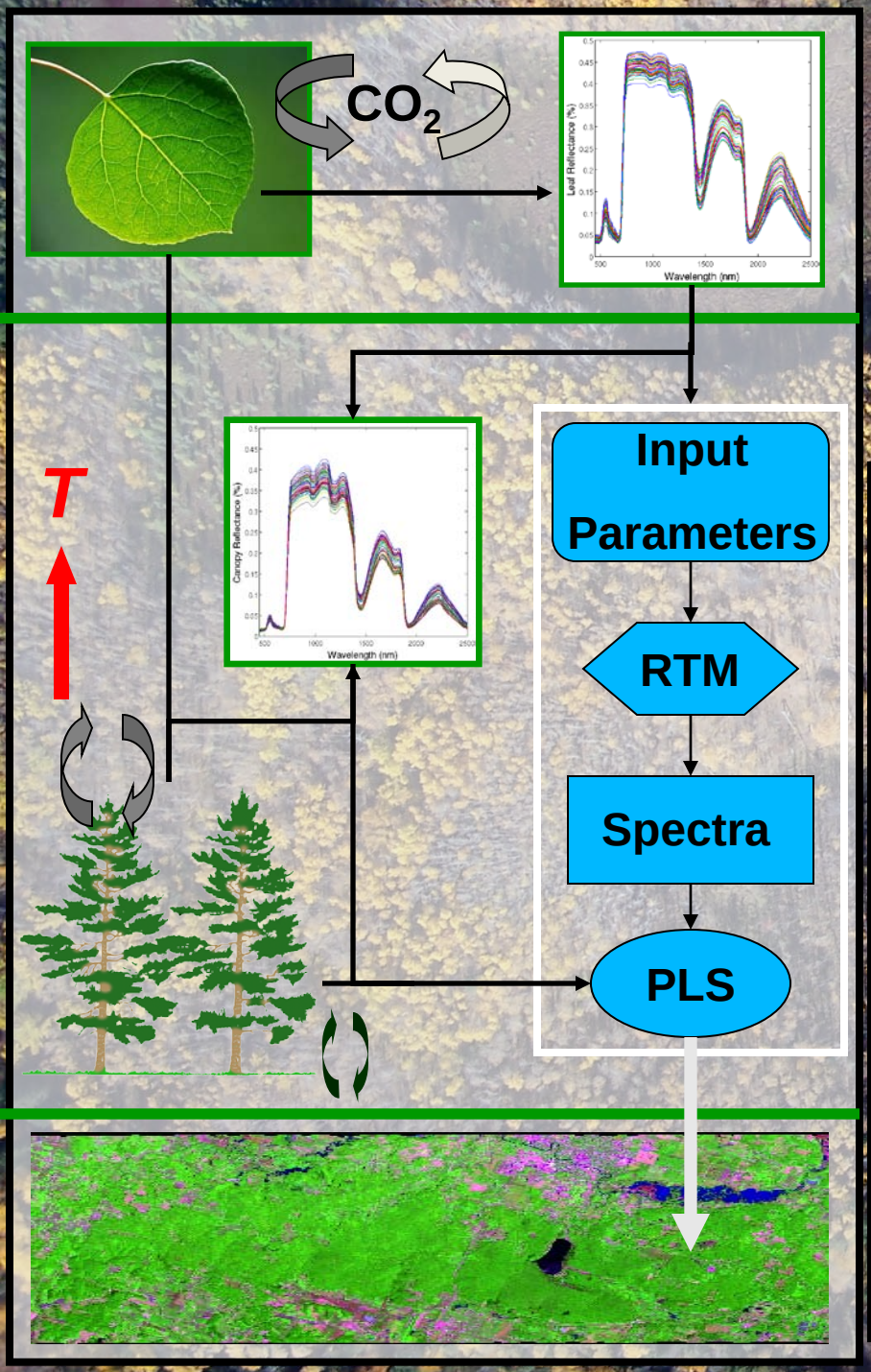
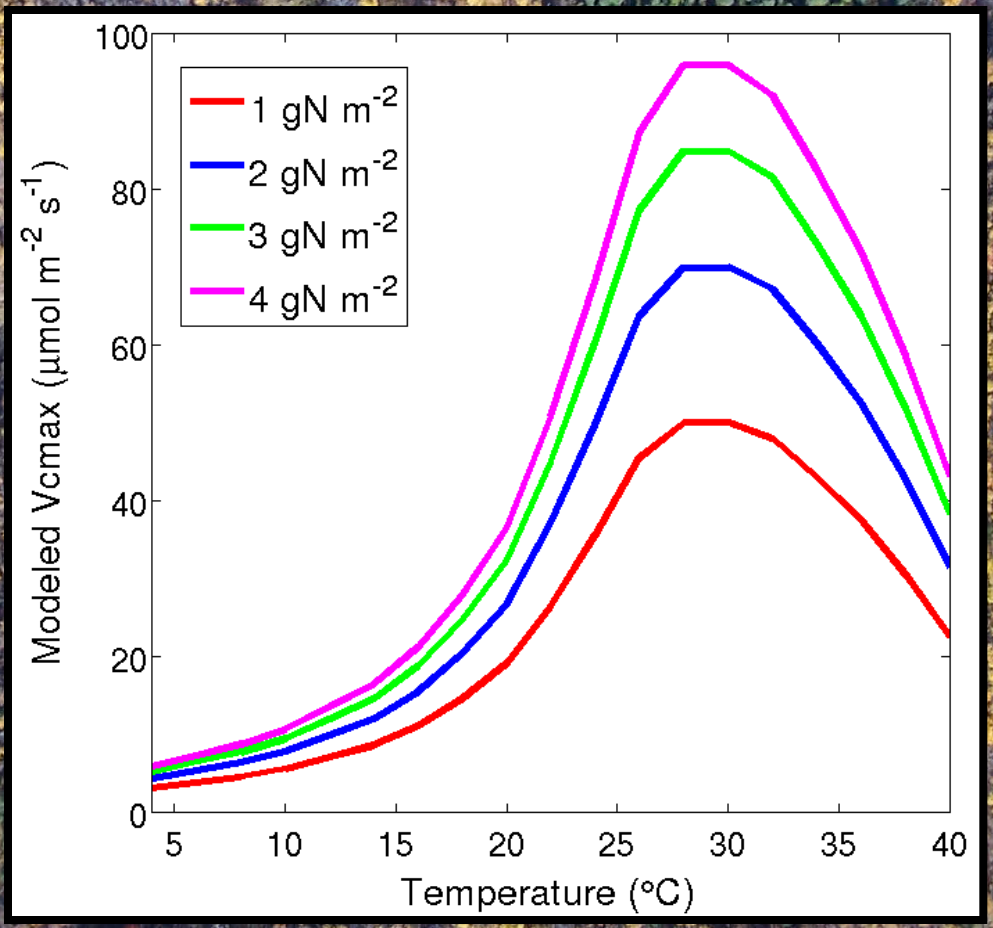


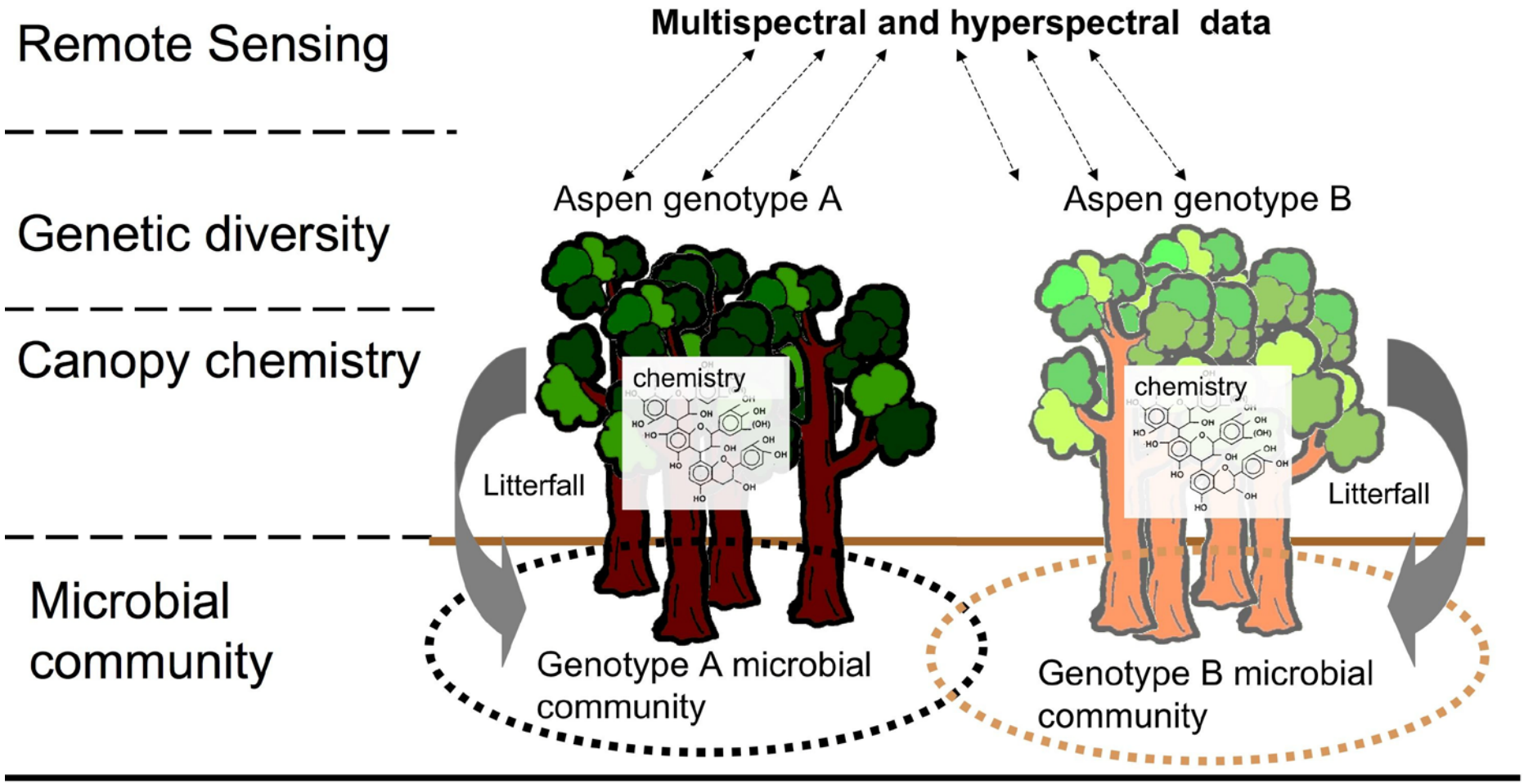


Now working on scaling leaf → canopy → sensor

Using HyspIRI-like data (AVIRIS + ASTER/MASTER), we are looking at forest acclimation to T and CO_2.

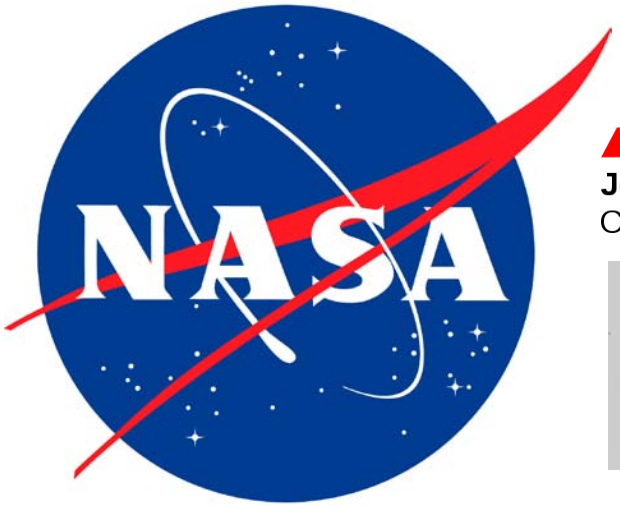


Remote sensing of genetic diversity in aspen:
Directly associated with vegetation response to climate change



Acknowledgments

- Terrestrial Ecology and Biodiversity Program
- Earth & Space Science Fellowship
- HyspIRI Preparatory Activities



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