Process Studies in Photosynthesis to Improve Representation of Vegetation in Models

Next-Generation Ecosystem Experiments (NGEE Arctic) Project

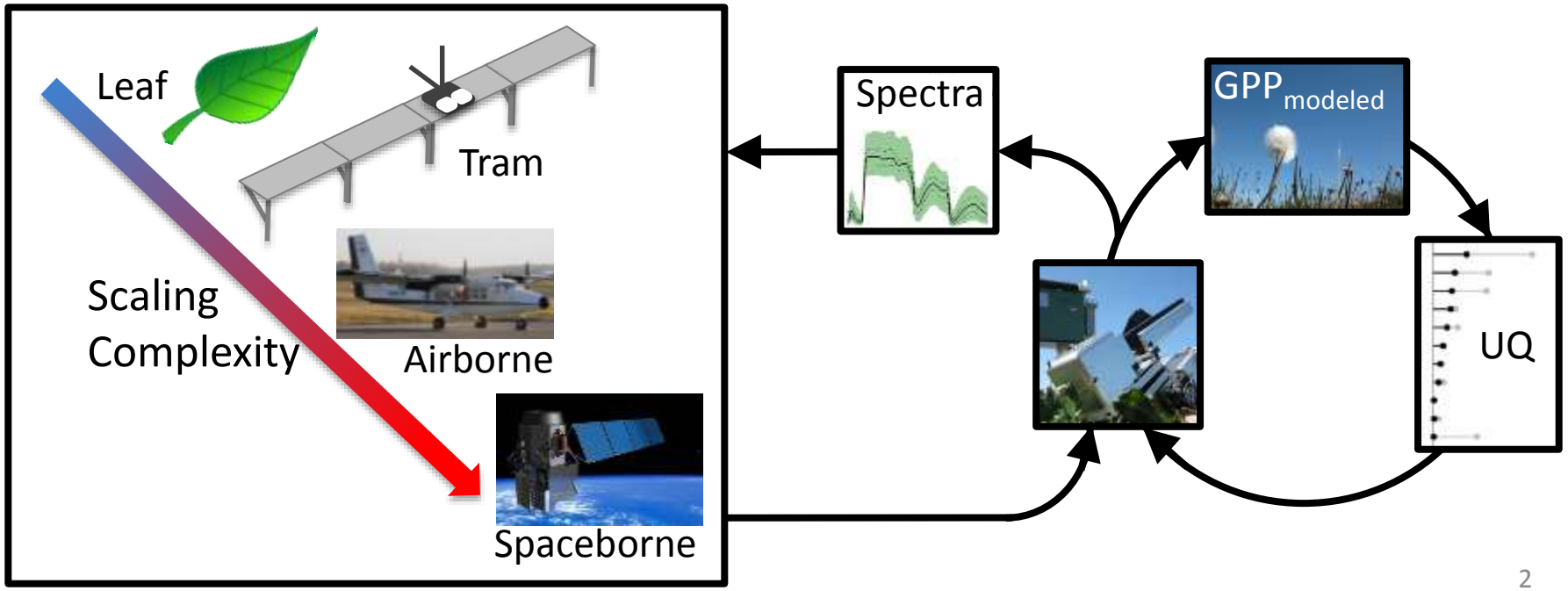
Alistair Rogers (arogers@bnl.gov)
Environmental & Climate Sciences Department
Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY | OAK RIDGE National Laboratory | Los Alamos NATIONAL LABORATORY | BERKELEY LAB | BROOKHAVEN NATIONAL LABORATORY | UAF UNIVERSITY OF ALASKA FAIRBANKS

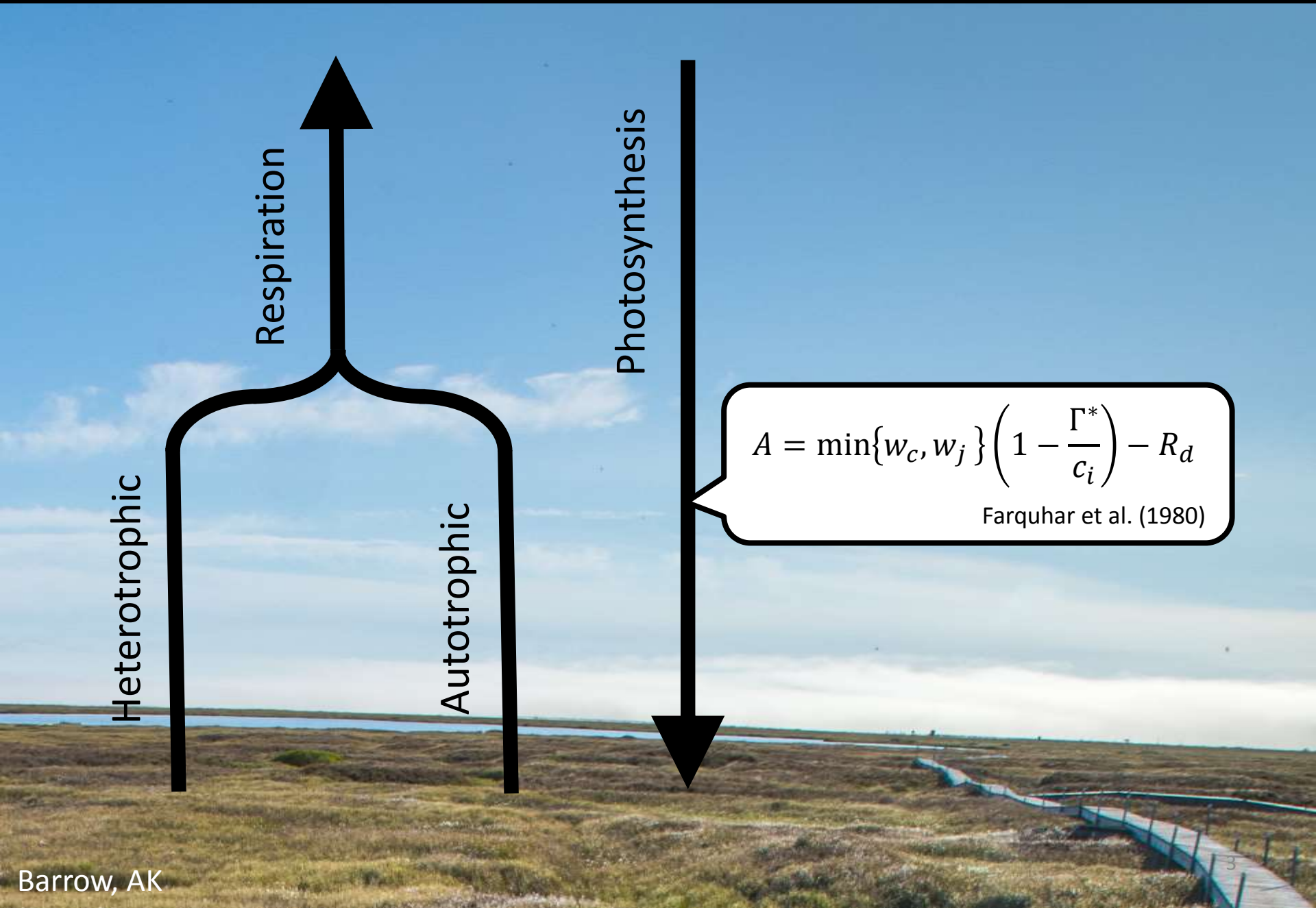
Model Representation of Arctic Photosynthesis

Goal

- Quantify model sensitivity and target critical areas where new data will reduce model uncertainty.
- Link measurement of key parameters to spectral signatures that enable scaling.
- Test and inform models iteratively.



Early NGEE-Arctic example - Photosynthetic capacity



Two key variables for modeling CO_2 uptake are the maximum carboxylation rate -photosynthetic capacity- ($V_{c,max}$) and the electron transport rate (J)

Rubisco
(dark reactions)

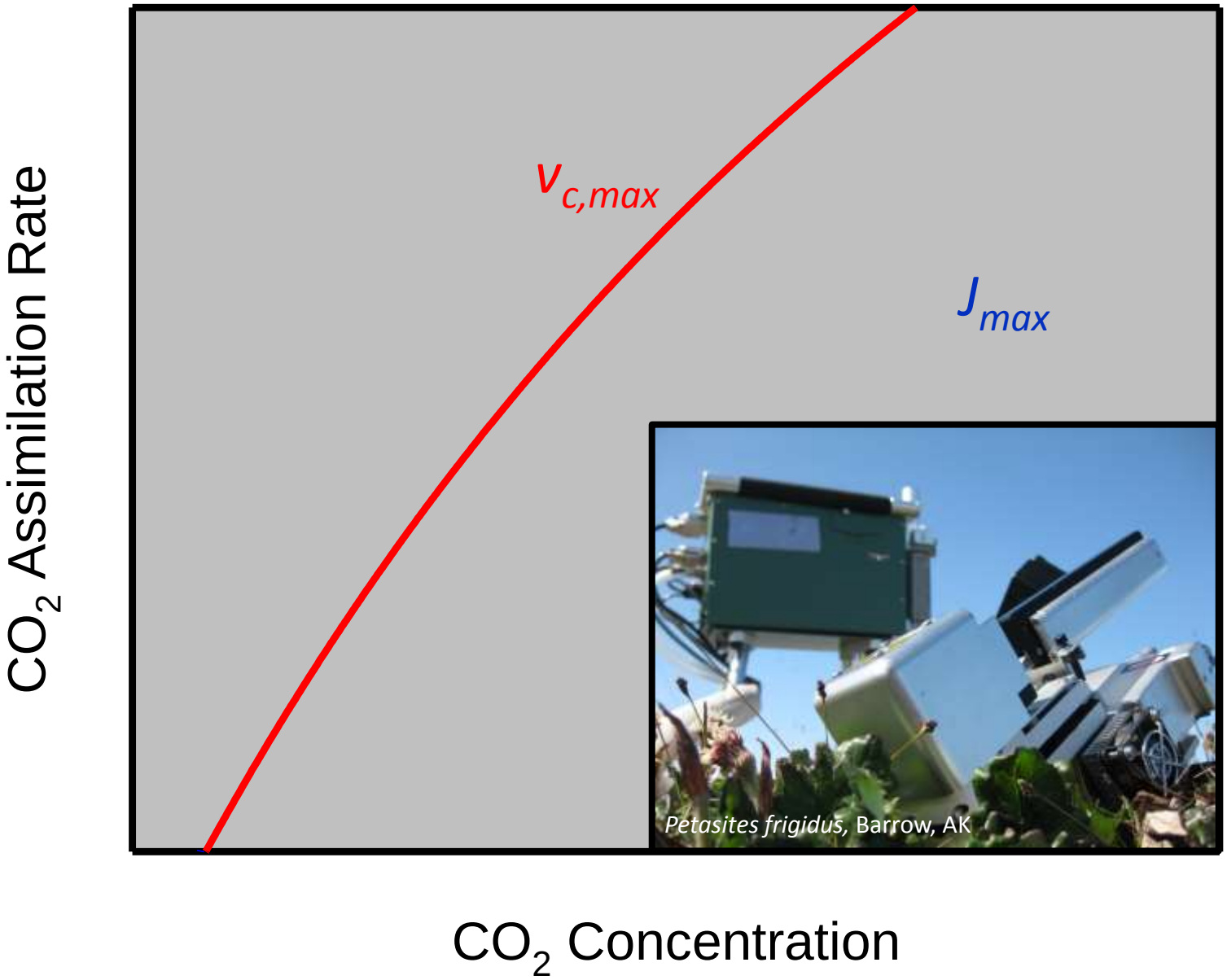
$$w_c = \frac{V_{c,max} c_i}{c_i + k_c\left(1 + \frac{O}{k_o}\right)}$$

RuBP regeneration
(light reactions)

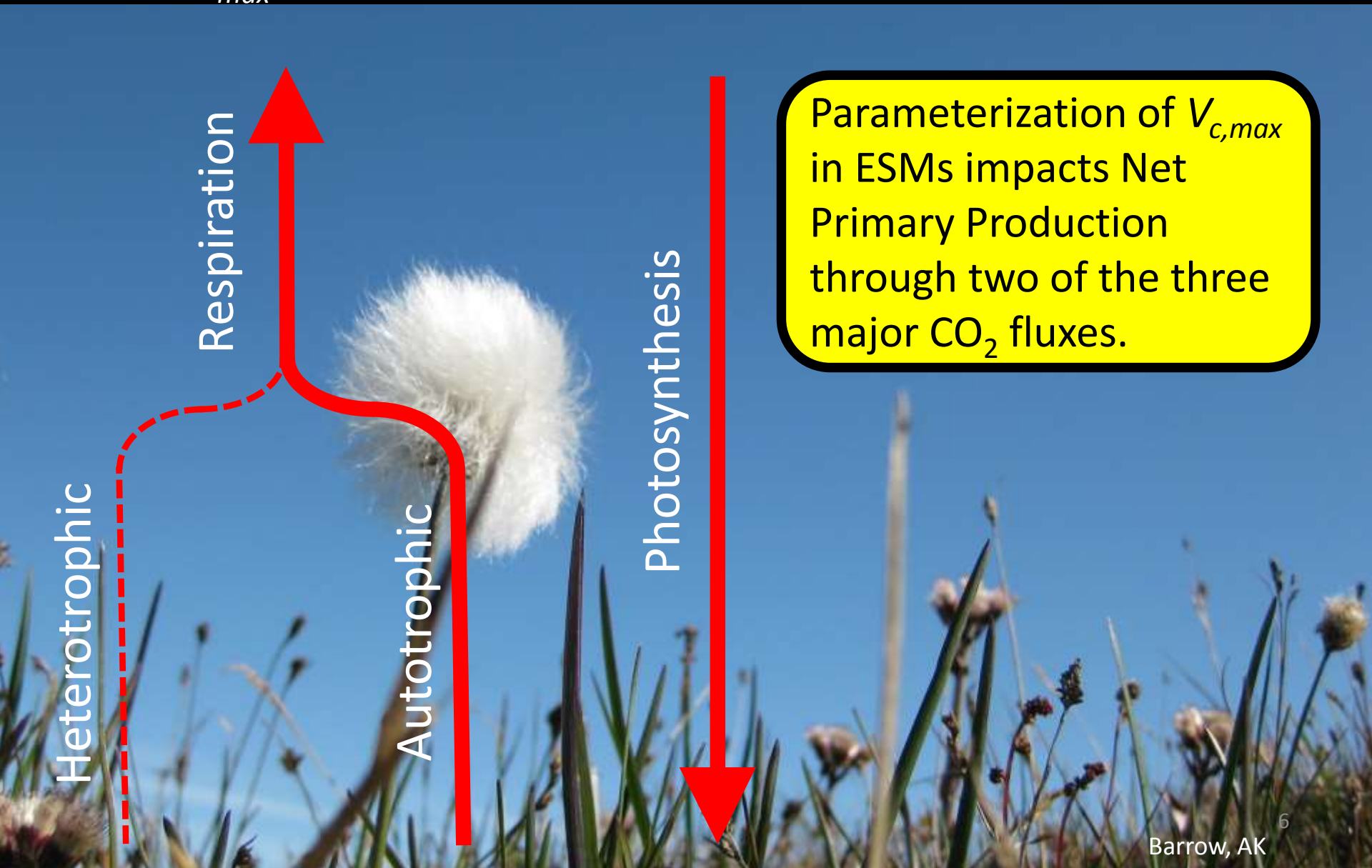
$$w_j = \frac{J c_i}{4.5 c_i + 10.5\Gamma^*}$$

Farquhar et al. (1980)

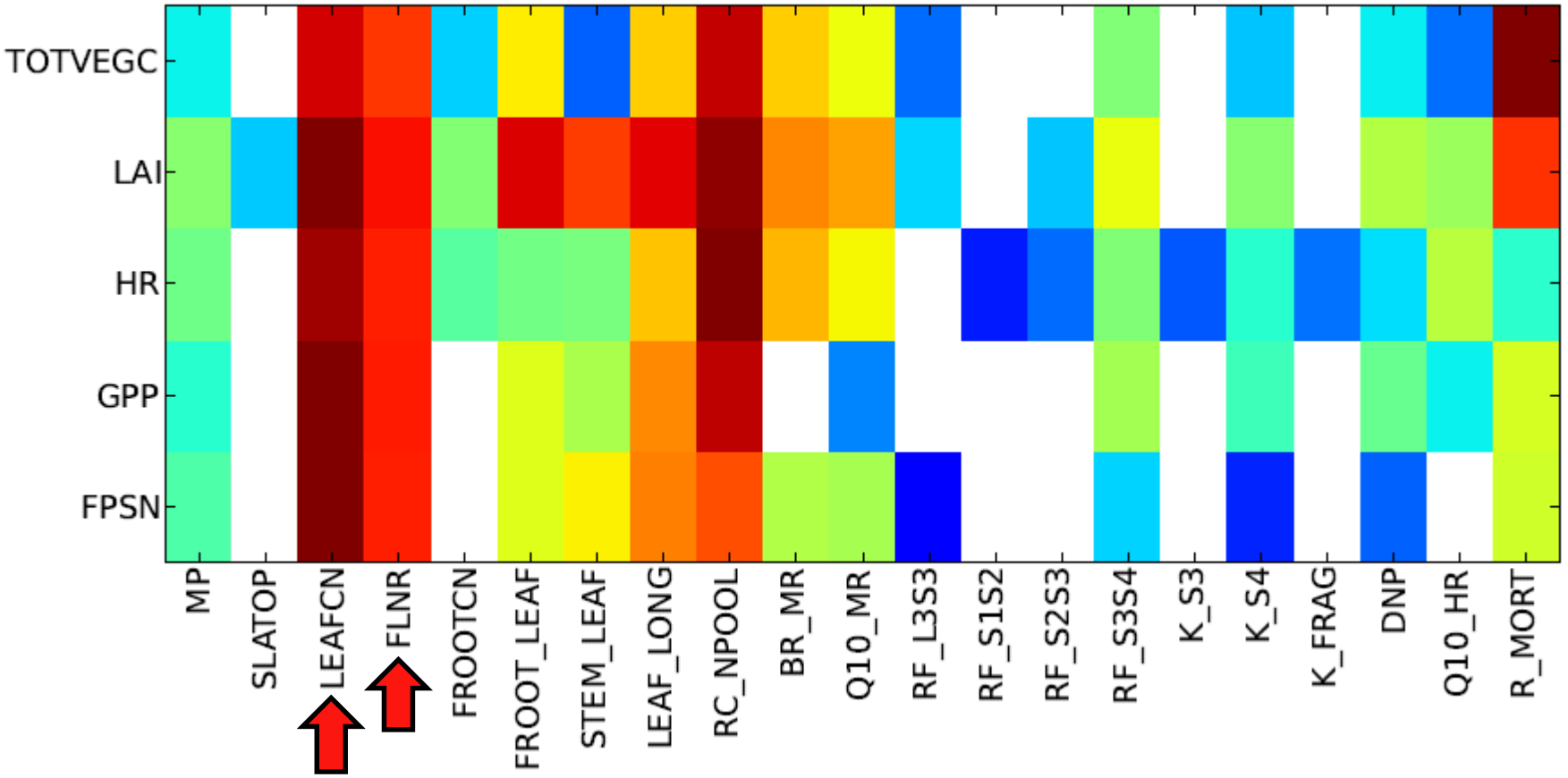
These key parameters can be estimated from an "A-c_i curve"



$V_{c,max}$ drives estimation of photosynthesis in Earth System Models (ESMs). Through multipliers it is also used to estimate other parameters, including J_{max} and autotrophic respiration.



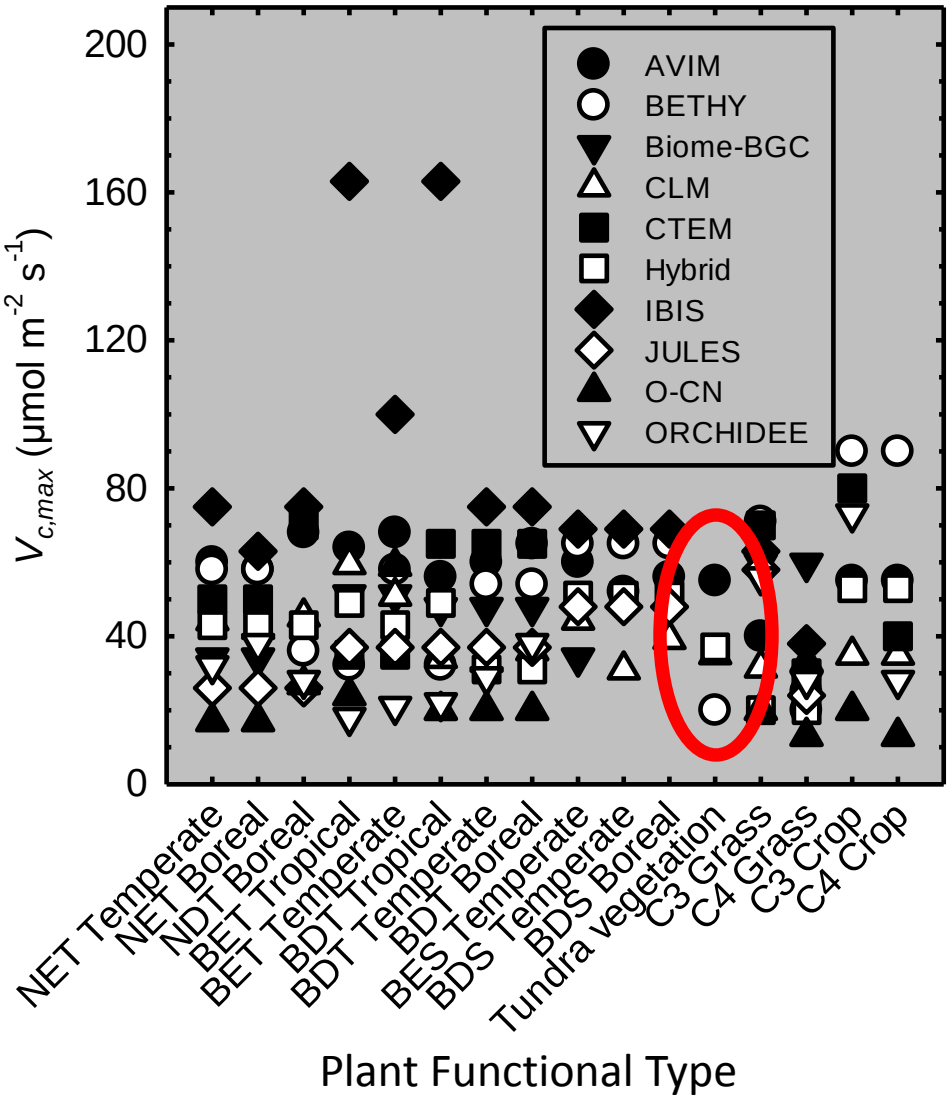
Models are extremely sensitive to parameterization of $V_{c,max}$, e.g. in CLM two of the parameters used to determine $V_{c,max}$ (red arrows) have a large impact on model outputs



Sensitivity analysis of the impact of 80 CLM inputs (x-axis) on five key outputs (y-axis). Model inputs with darker colors have a greater impact on model outputs.

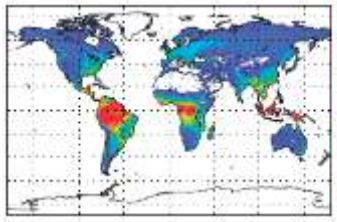
Sargysan et al. (2013)

Photosynthetic capacity is poorly represented in models – especially in the Arctic (highlighted)



Rogers (2014)

Current model representation of photosynthetic capacity in Arctic Plant Functional Types is based limited data and unsupported assumptions



AVIM (Beijing Climate Center Model) uses $V_{c,max}$ to tune their model to match remotely sensed GPP and site specific Eddy Covariance data

$$V_{c,max} = i_v + s_v . N_a$$

BETHY (JSBACH) uses a data from a single from an undefined source

$$V_{c,max} = N_a . n_2 . n_f . \frac{1000}{M_N}$$

Hybrid uses an arbitrary multiplier (n_f tundra = 0.75n_f deciduous forest + 0.25n_f tropical forest)

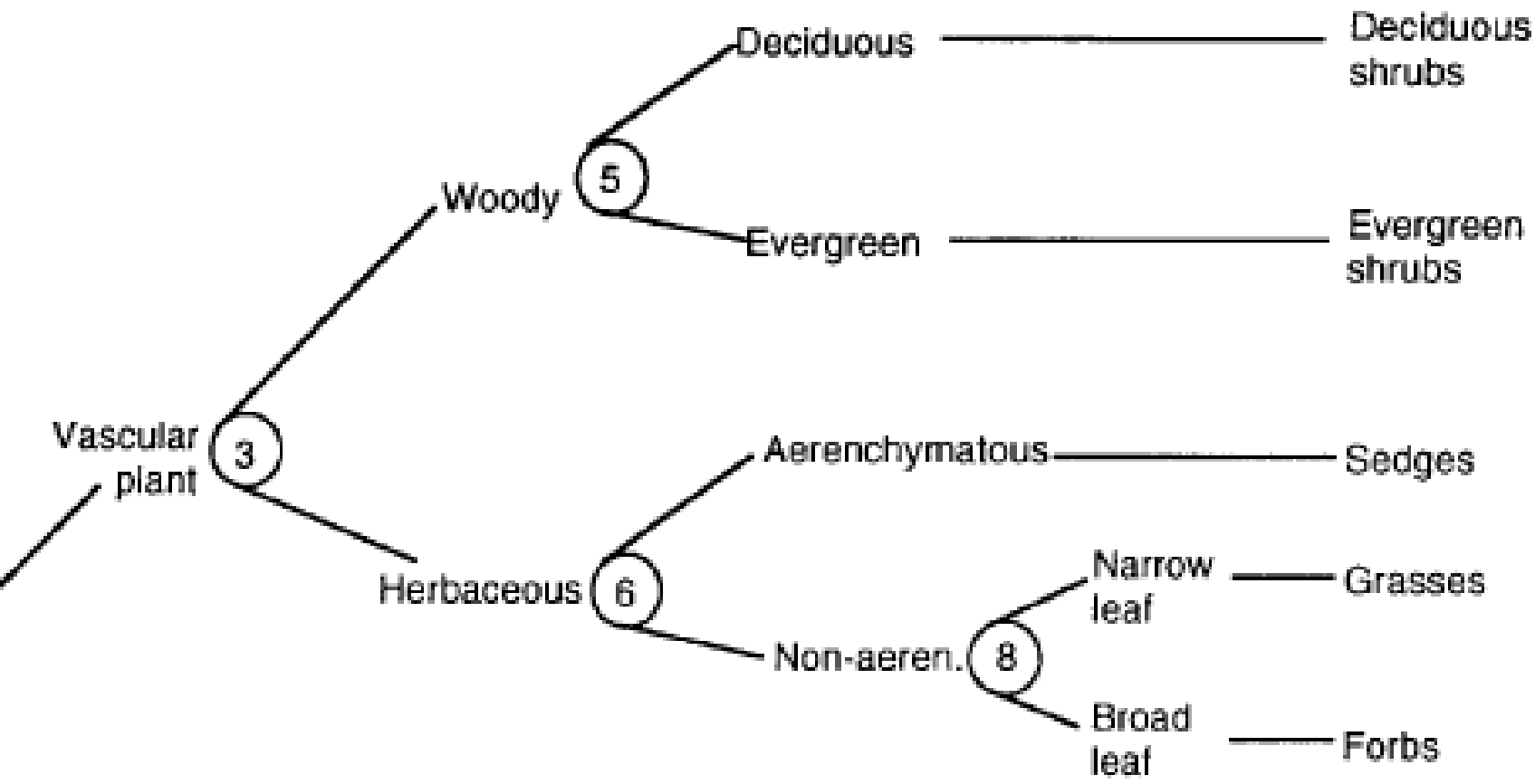
$$V_{c,max} = \frac{1}{CN_L . SLA} . F_{LNR} . F_{NR} . \alpha_{R25}$$

CLM4.0 uses parameters derived from datasets lacking representation of Arctic species

Rogers (2014)

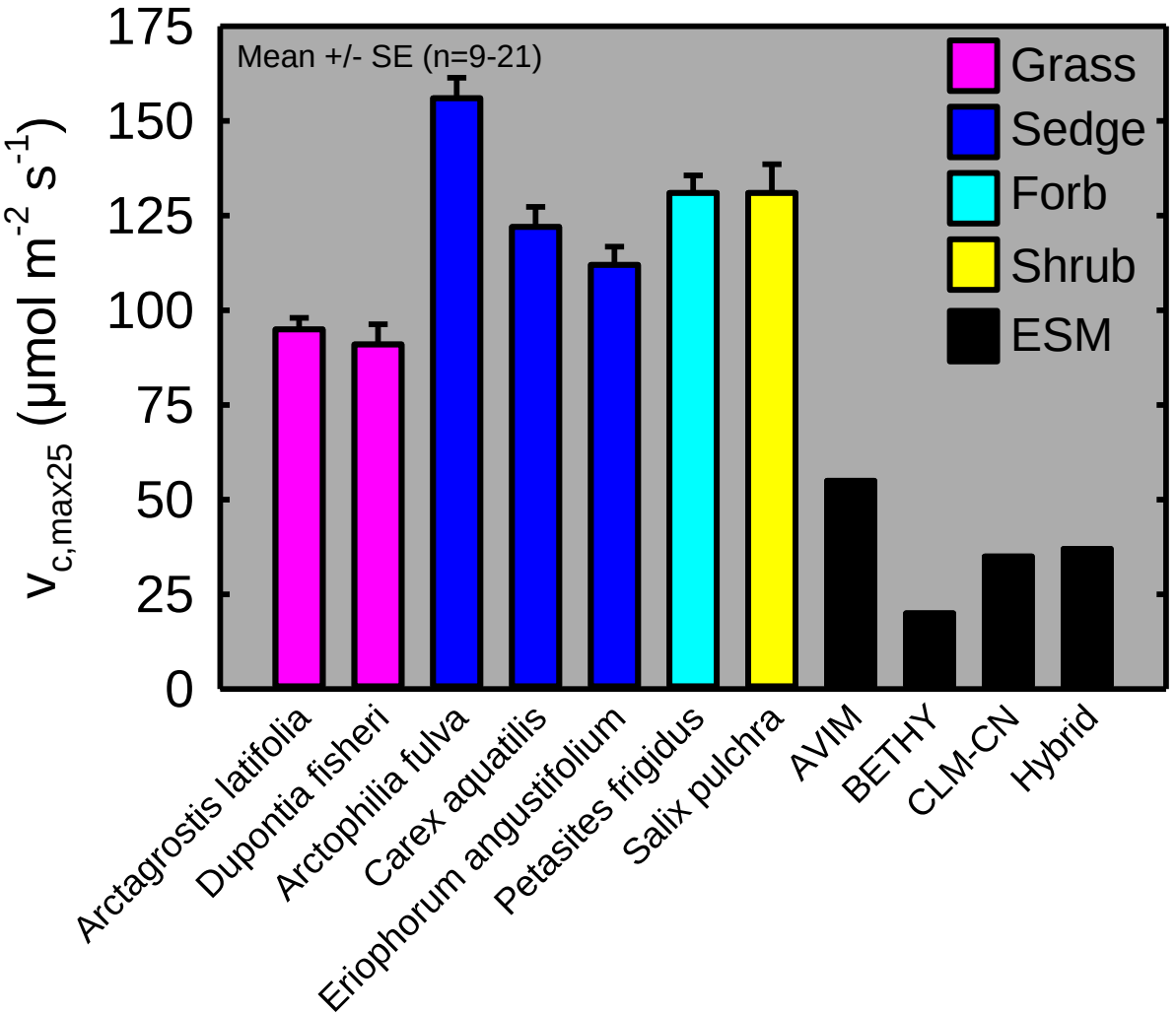
Measuring Photosynthetic capacity in Barrow

Measurements aimed to capture dominant vegetation, but also species representing major plant functional types



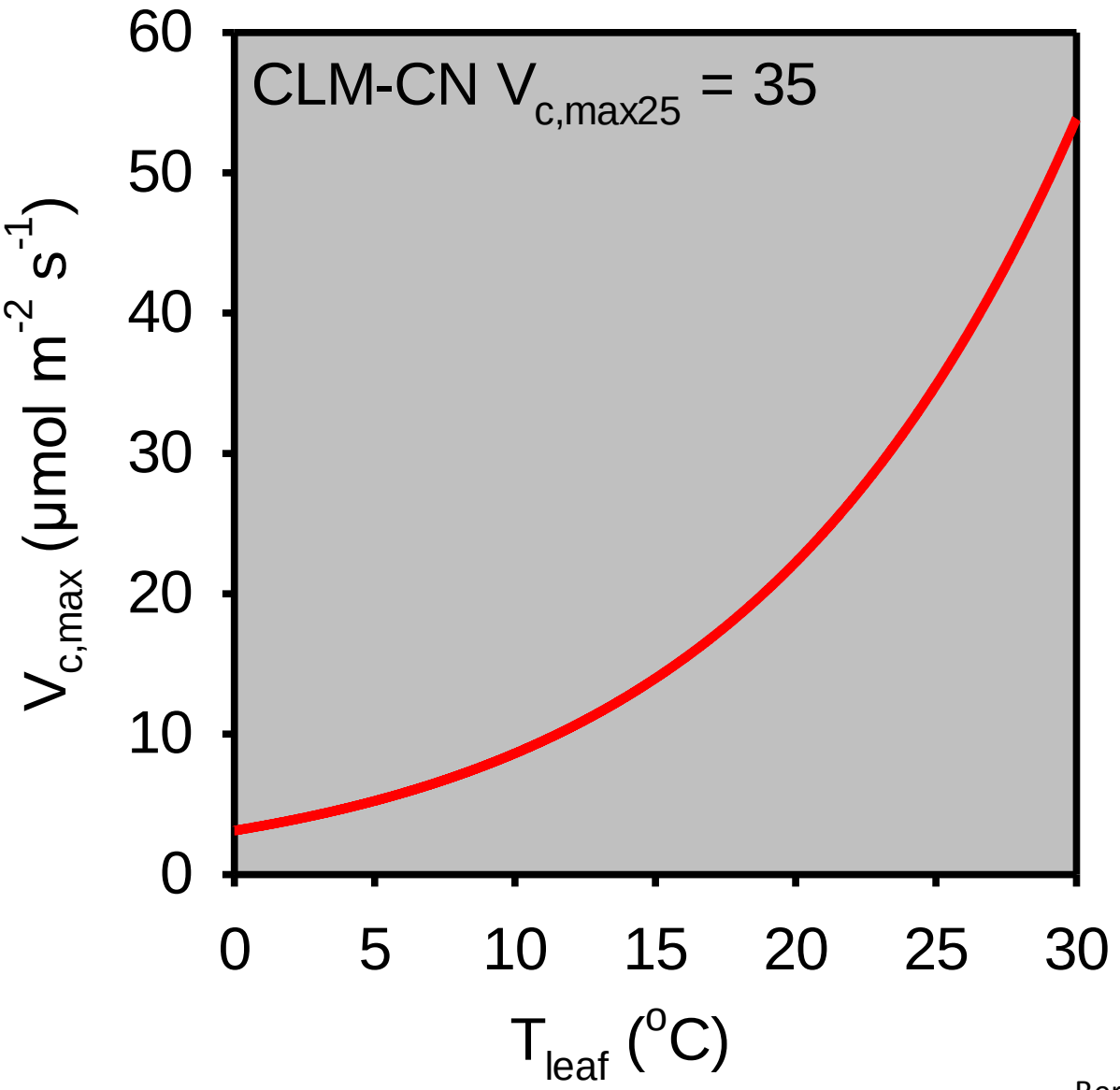
Chapin et al. (1996)

Photosynthetic capacity is underestimated in the Arctic



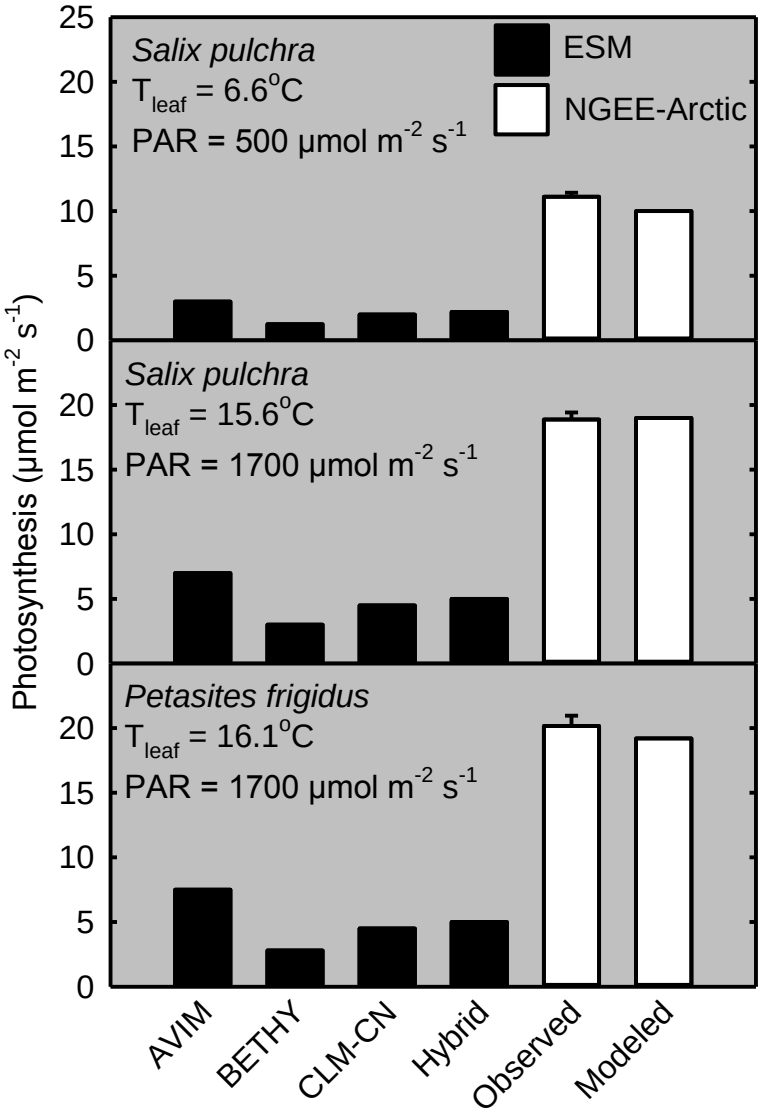
Rogers Unpublished

$V_{c,max}$ is very sensitive to temperature so low values at 25°C are *really* low at observed temperatures



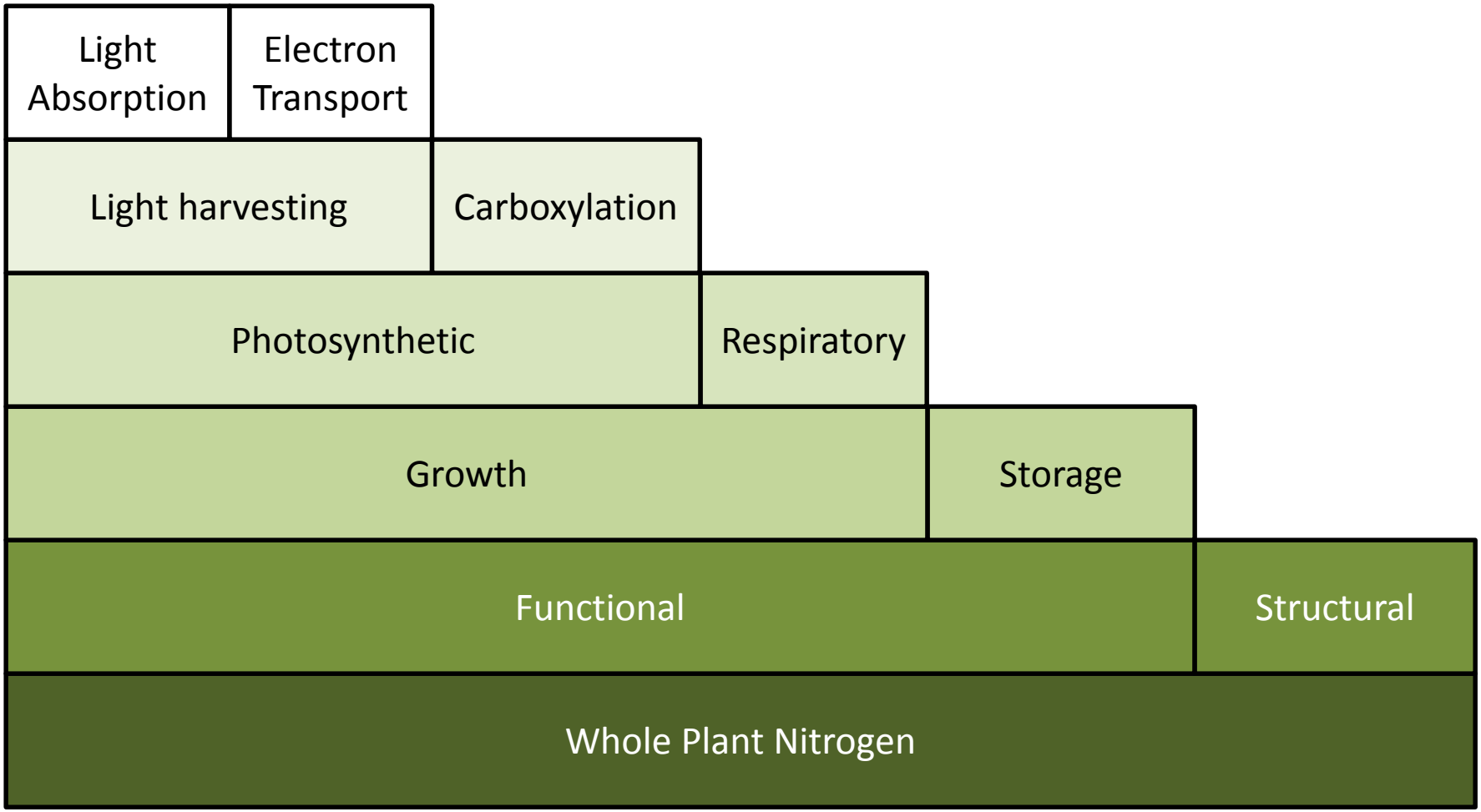
Bernacchi et al. (2001)

Modeling photosynthesis reveals flaws in ESM estimates of photosynthetic capacity



Rogers Unpublished

These data are also providing key inputs that inform the incorporation of N partitioning into new model frameworks

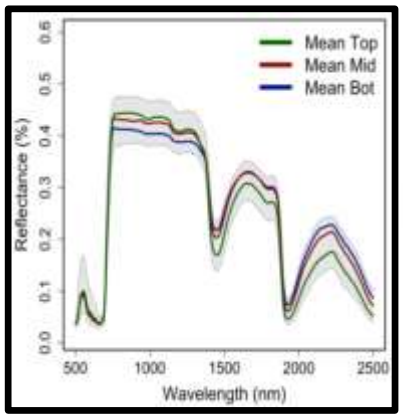


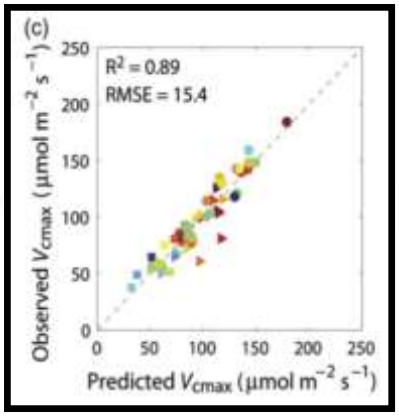
Xu et al. (2012)

Future Direction

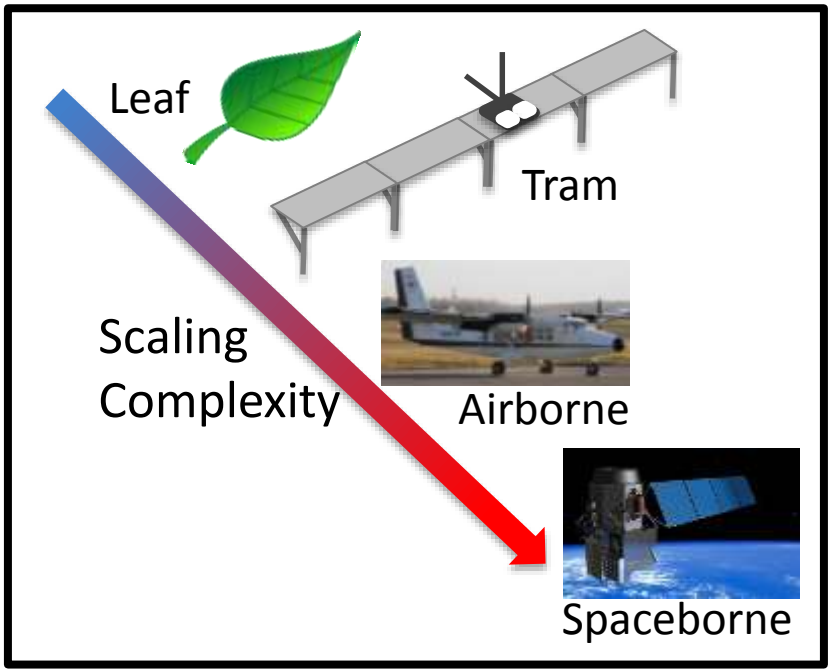
- Develop and validate spectral signatures for Arctic plant physiological traits.

- Scale leaf level process knowledge using near surface, airborne and satellite sensors.

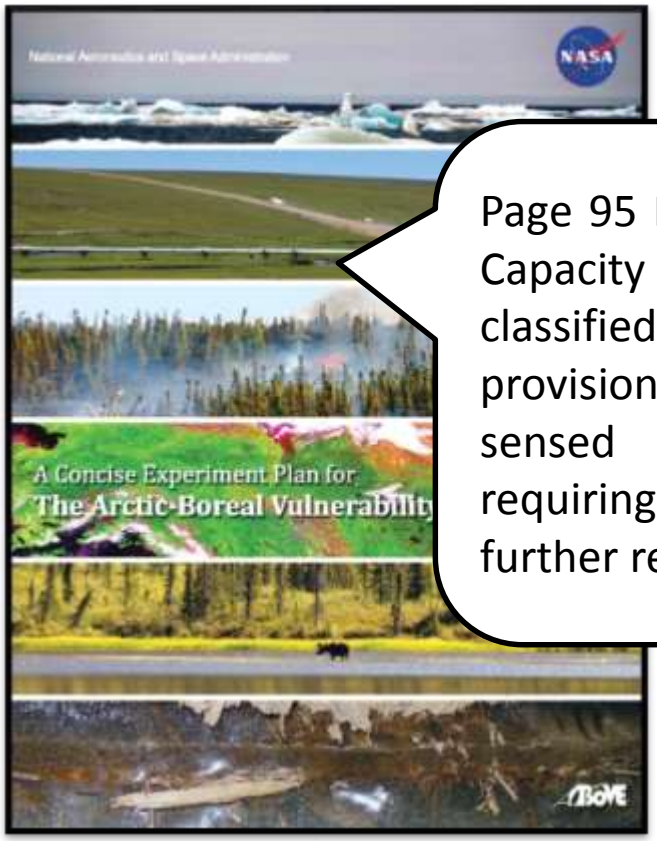




Serbin et al. (2012)

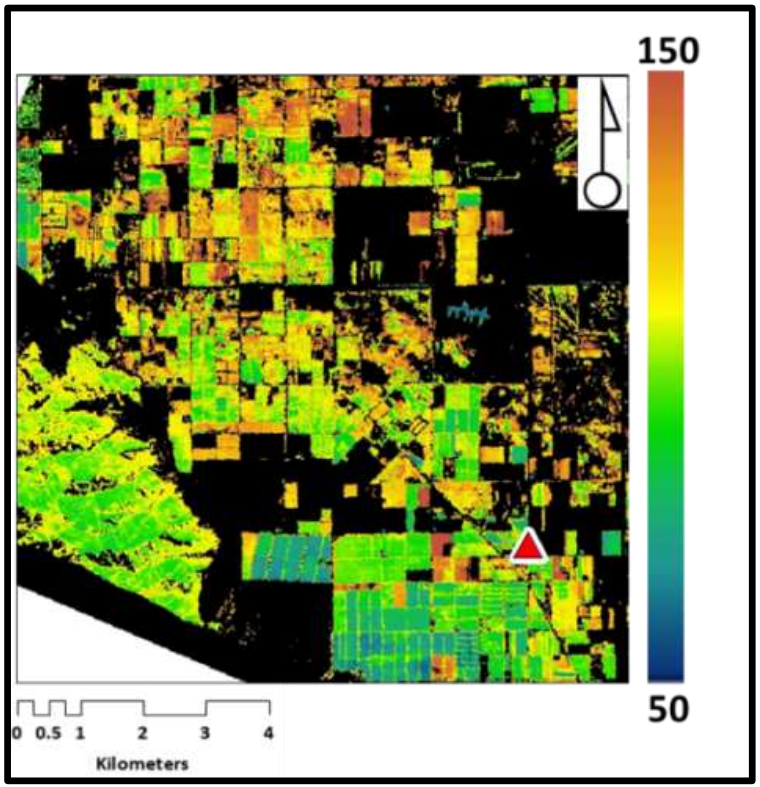


Interagency links with NASA-ABoVE



Page 95 Photosynthetic Capacity ($V_{c,max}$) is classified as a provisional remotely sensed data product requiring resources for further refinement.

Prototype $V_{c,max}$ Map (NASA HyspIRI)



Serbin et al. unpublished

We aim to provide a spatially and temporally resolved trait database for key physiological traits, and an independent method to ground truth prognostic state variables generated by new models.

The Next-Generation Ecosystem Experiments (NGEE Arctic) project is supported by the Office of Biological and Environmental Research in the DOE Office of Science.