NGEE (Next Generation Ecosystem Experiment) in the Tropics
What, why, where, when, who, how?

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NGEE TROPICS

NEXT GENERATION ECOSYSTEM EXPERIMENT - TROPICS

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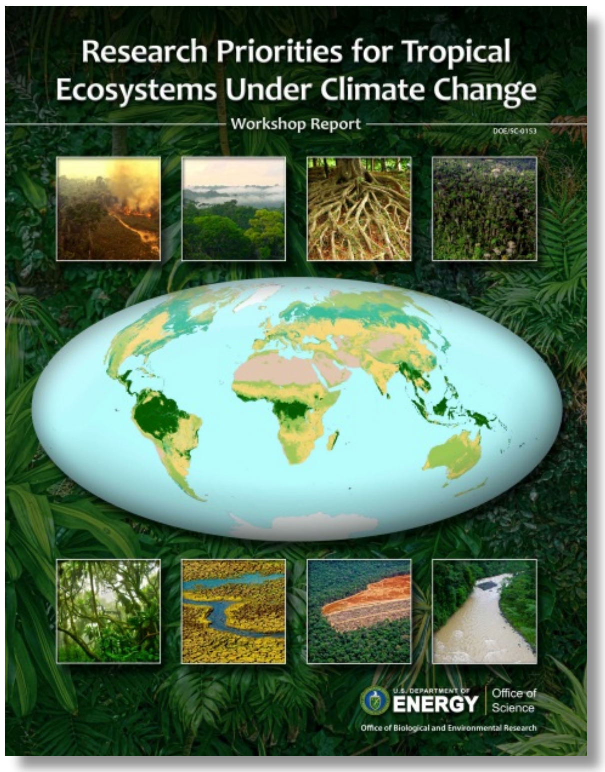
WHAT?

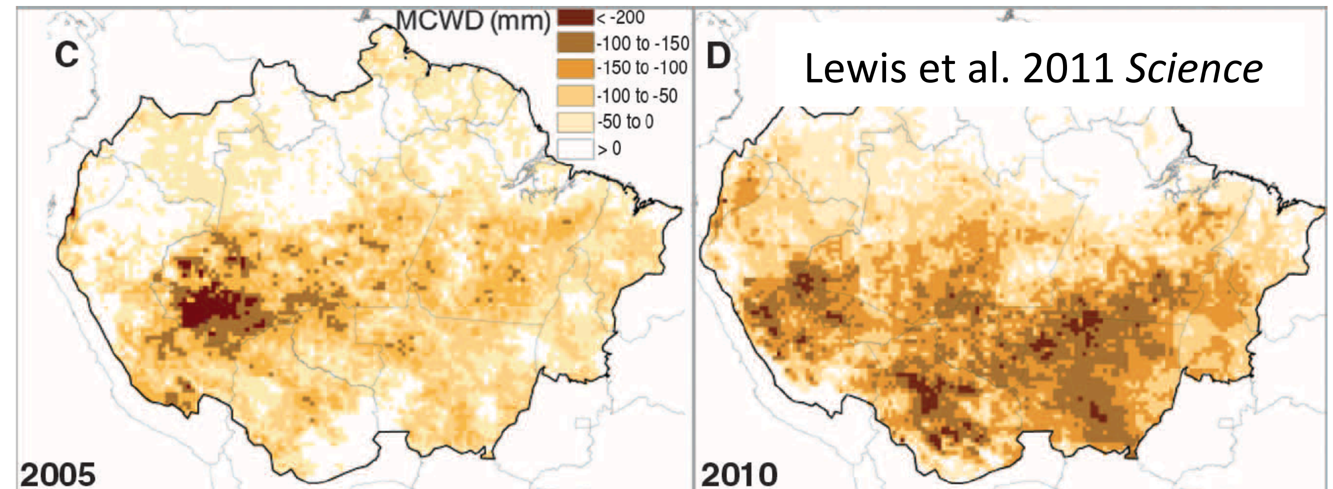
GRAND DELIVERABLE

A representative, **process-rich** tropical forest ecosystem model, extending from **bedrock** to the top of the vegetative canopy-**atmosphere** interface, in which the evolution and feedbacks of tropical ecosystems in a changing climate can be modeled at the scale/resolution of a next generation Earth System Model grid cell (~10 x 10 km^2 resolution)

WHY?

Threat to carbon sink



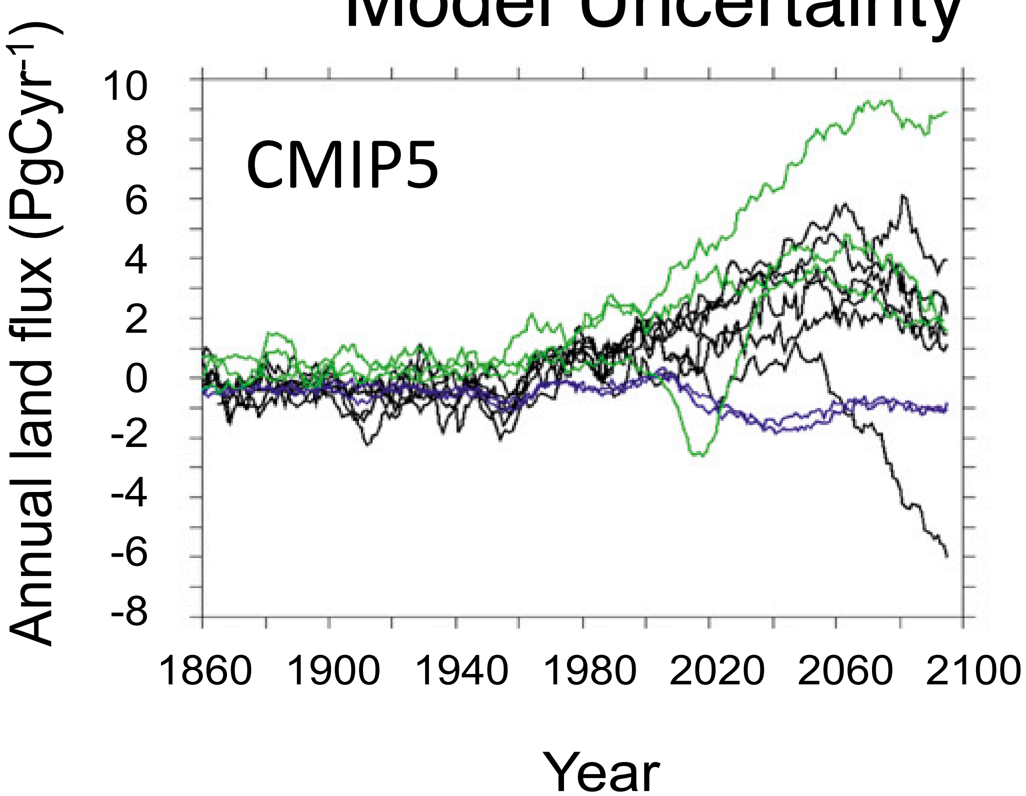


LETTER 86 | NATURE | VOL 509 | 1 MAY 2014
doi:10.1038/nature13265

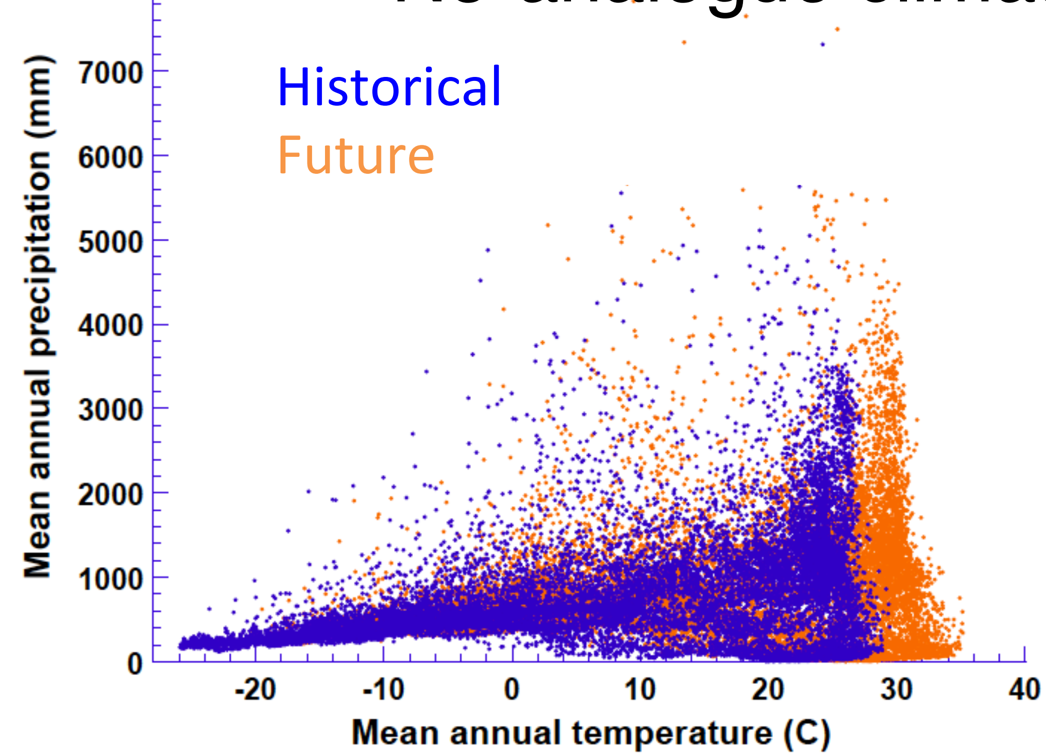
Widespread decline of Congo rainforest greenness in the past decade

Liming Zhou[1], Yuhong Tian[2], Ranga B. Myneni[3], Philippe Ciais[4], Sassan Saatchi[5], Yi Y. Liu[6], Shilong Piao[7], Haishan Chen[8], Eric F. Vermote[9], Conghe Song[10,11] & Taehee Hwang[12]

Model Uncertainty



No-analogue climate



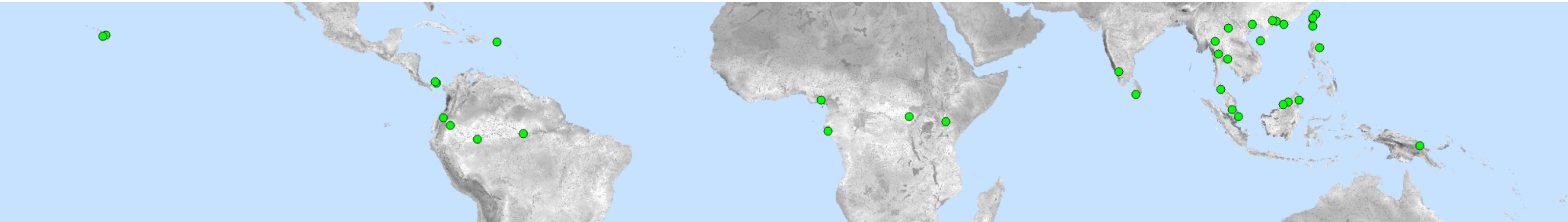
WHERE?

NGEE-T will be **PAN-TROPICAL**

We will use data from existing known Forest Observation Networks (FORESTGEO, RAINFOR, TRY, GLOPNET ETC.)

Early **pilot studies** in Manaus, Puerto Rico, and Panama

Future sites determined by uncertainty analysis



WHEN?

- NGEE is a solicited a **10 year** activity.
- The Phase I (3y) proposal is at the final review stage.
    - (Comments due by the end of this week)

WHO?

Scientific Advisory Board
David Schimel (Chair)
Paulo Artaxo
Greg Asner
Gordon Bonan
Yadvinder Malhi
Susan Trumbore
Stan Wullschleger

BER
Dan Stover, POC

Leadership Team
Jeff Chambers, Director (LBNL)
Lara Kueppers, Deputy Director (LBNL)
Stuart Davies, Chief Scientist (STRI)
Keith Lewin, Deputy of Field Operations (BNL)
Sandy Chin, Project Manager (LBNL)

Modeling
Charlie Koven, Lead (LBNL)
Rosie Fisher, Co-Lead (NCAR)

Data Synthesis
Deb Agarwal (LBNL)

Research Objectives

RO1 Drought
Nate McDowell (LANL)

RO2 Temperature & CO_2 Change
Alistair Rogers (BNL)

RO3 Disturbance & Recovery
Lara Kueppers (LBNL)

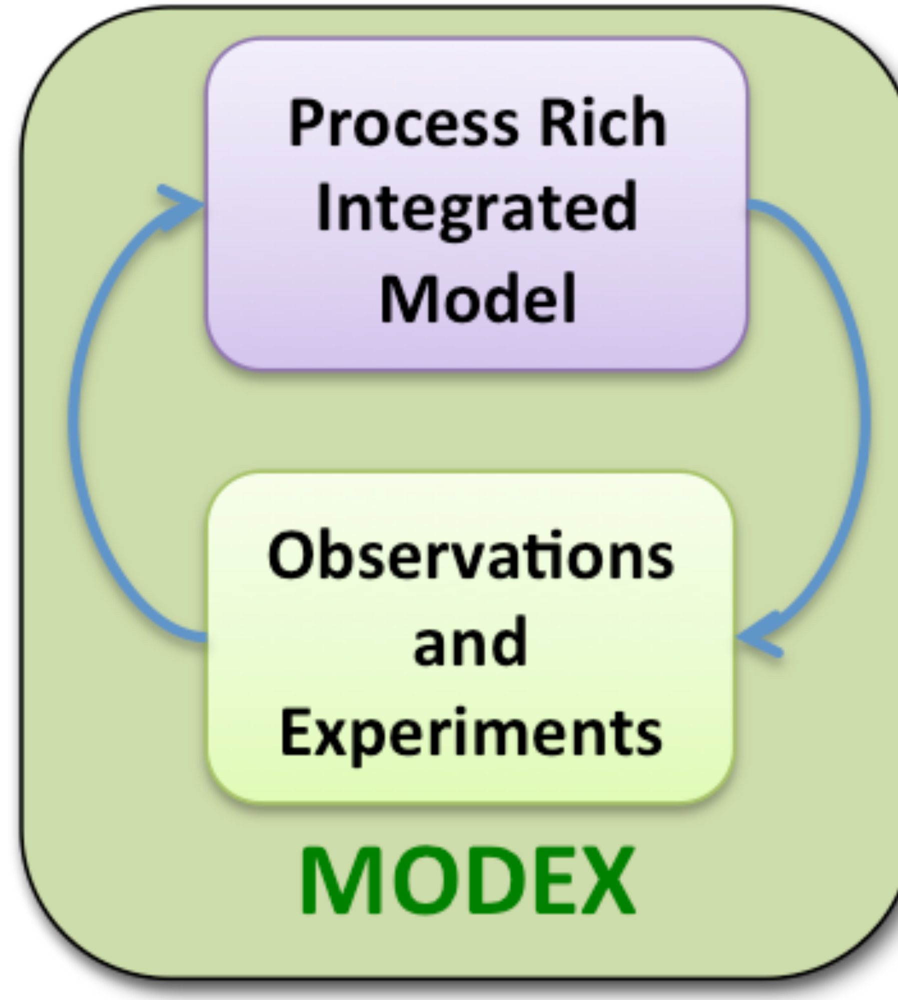
RO4 Anthropogenic Land Use
Michael Keller (USFS)

RO5 Hydrologic Heterogeneity
Ruby Leung (PNNL)

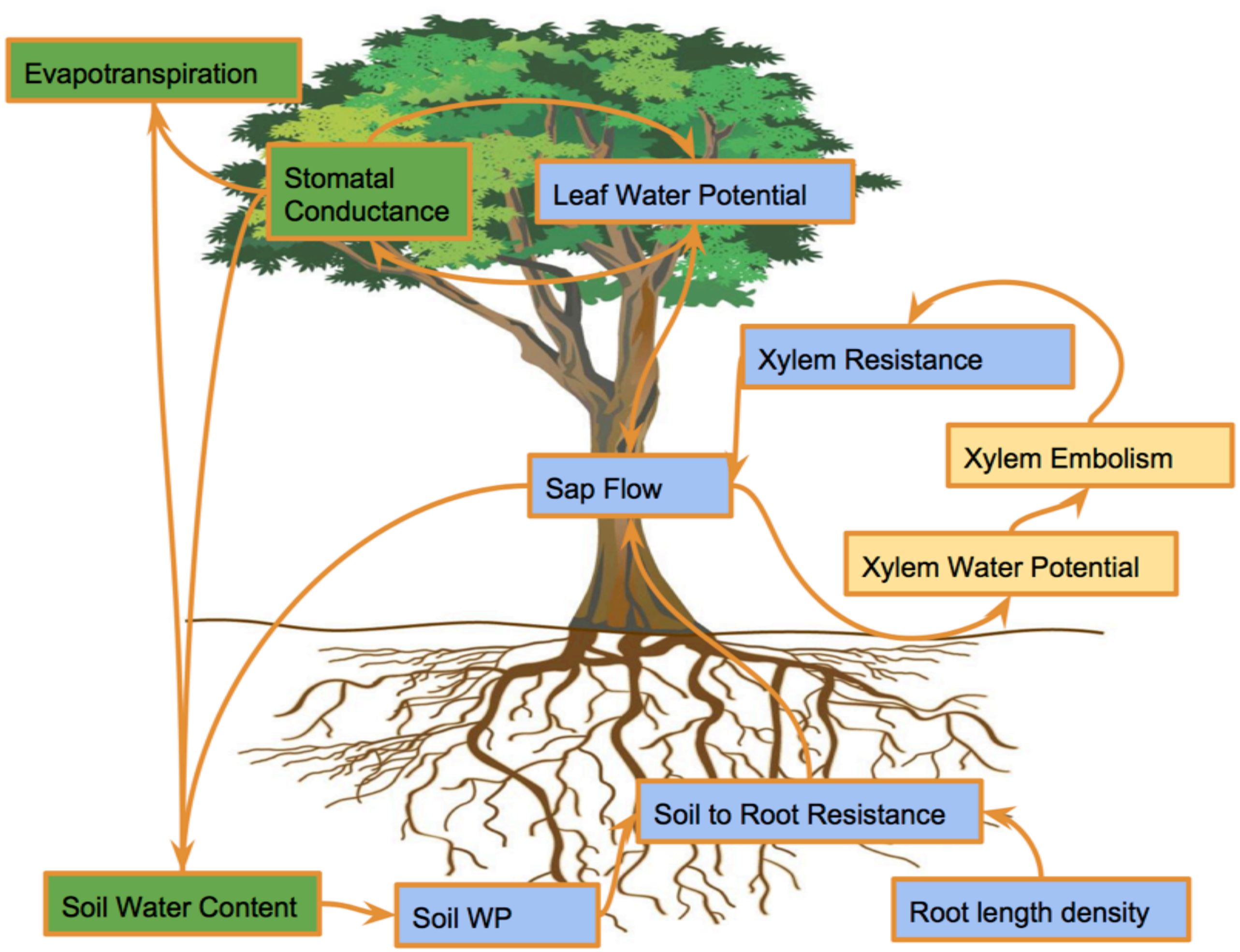
RO6 Nutrient Biogeochemistry
Rich Norby (ORNL)

ESD14-031

How?



Modular "Multi-Physics" Approach

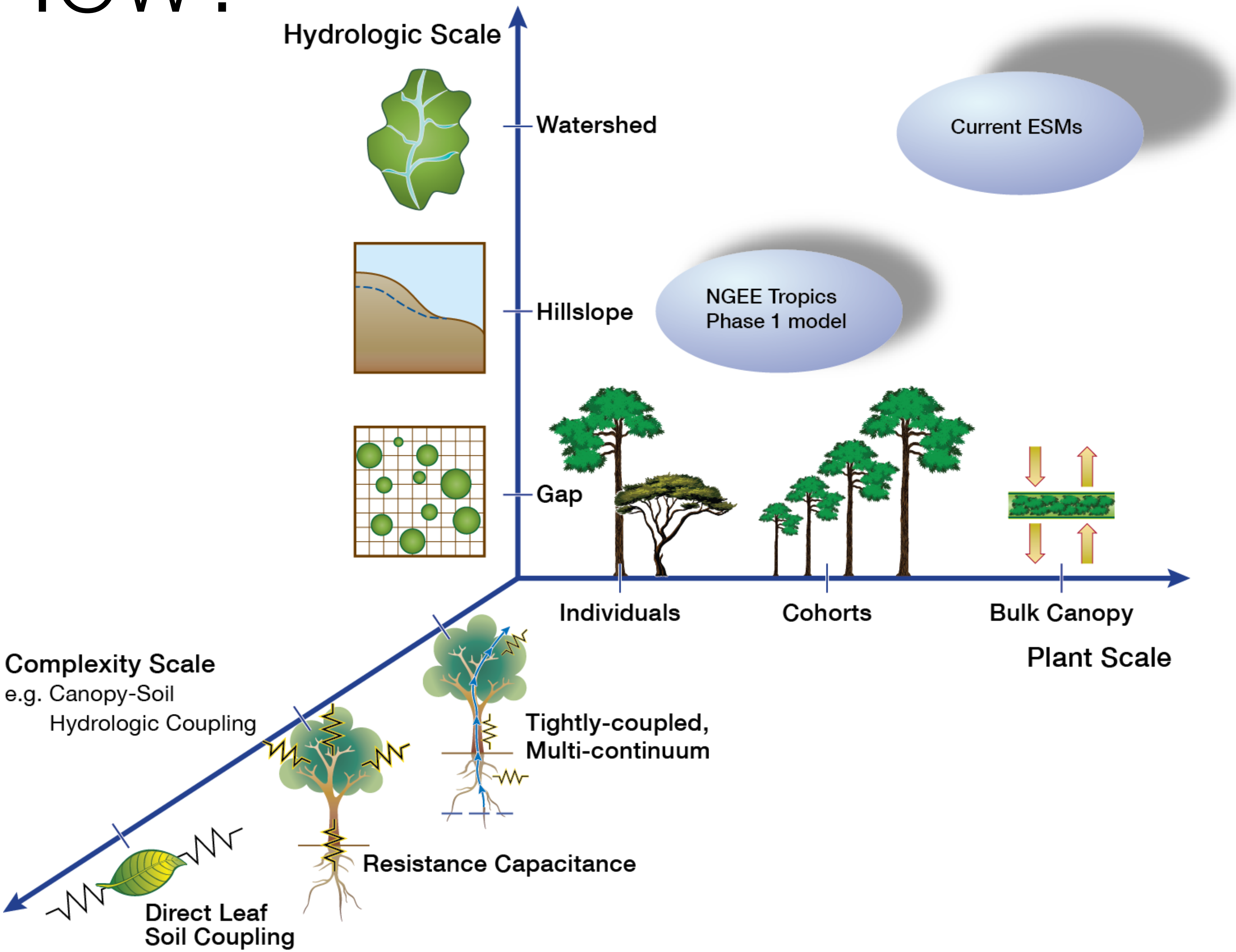


Lowest Complexity

Intermediate Complexity

Highest Complexity

How?



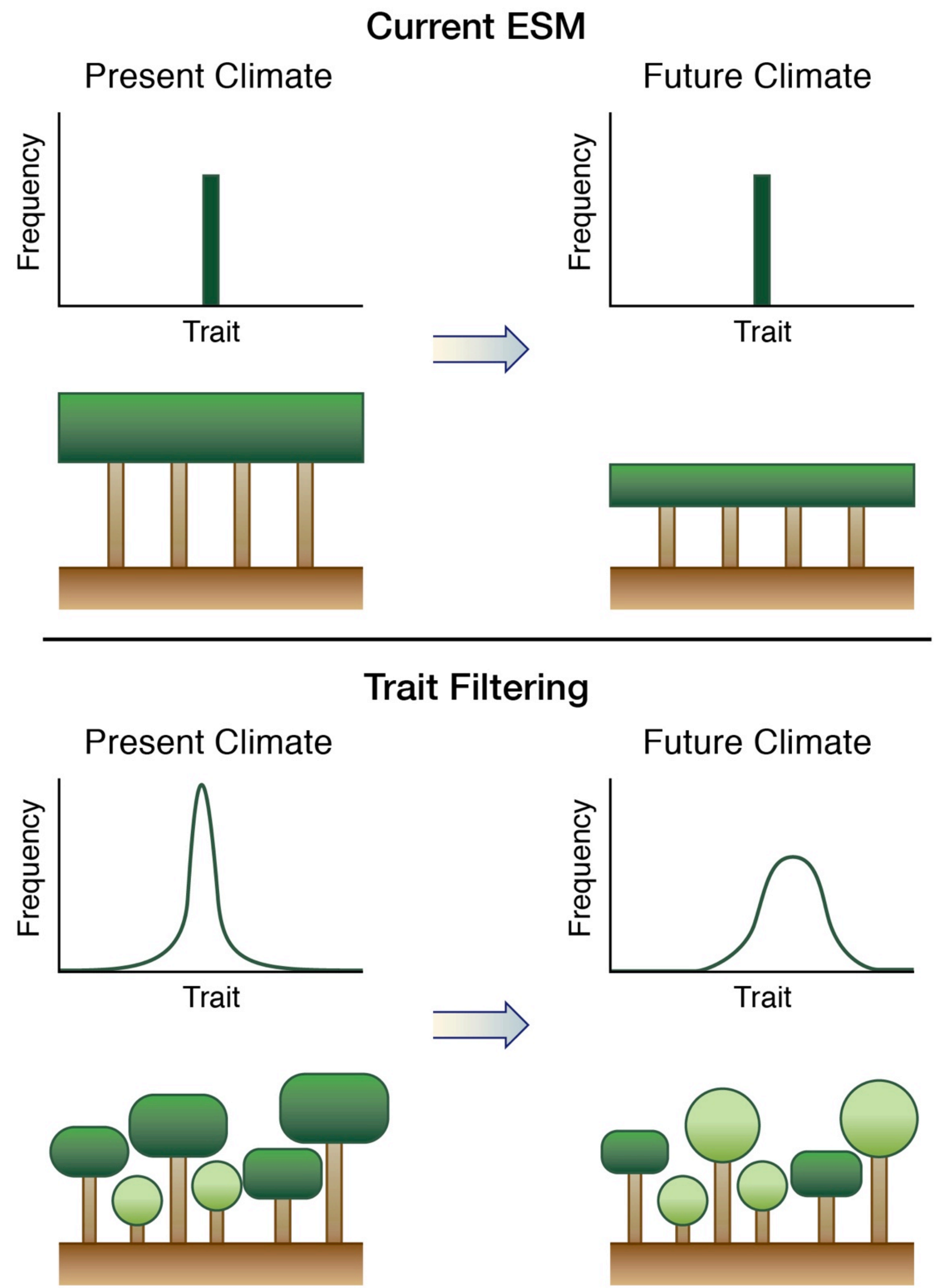
Hydrologic Scale
Watershed
Hillslope
Gap
Current ESMs
NGEE Tropics
Phase 1 model
Individuals
Cohorts
Bulk Canopy
Plant Scale
Complexity Scale
e.g. Canopy-Soil
Hydrologic Coupling
Tightly-coupled,
Multi-continuum
Resistance Capacitance
Direct Leaf
Soil Coupling

How?

CLM(ED)

↓

NGEE-Tropics
"Trait-Enabled Model"



TAKING OFF THE TRAINING WHEELS

PROPERTIES OF VEGETATION MODELS WITHOUT CLIMATE ENVELOPES

Rosie Fisher NCAR &

Stefan Muszala, Mariana Vertenstein, Chonggang Xu,
Nate McDowell, Charlie Koven, Ryan Knox, Jennifer Holm,
Peter Lawrence, David Lawrence, Gordon Bonan

NCAR

…WHAT TRAINING WHEELS?

Paradigm:

Vegetation climate limits are a function of simple climate variables, defined from current distributions

Climate envelope parameterization
from Lund-Potsdam-Jena (LPJ) DGVM
(vegetation cannot survive outside limits)

Used in:
ORCHIDEE (IPSL), CTEM (CanESM)
SEIB (MIROC-ESM), CLM-DV (CESM)

Plant Functional Type	Temp coldest month (°C)	Temp hottest month (°C)	Growing Degree Days (°C)
Tropical broad-leaved evergreen	15.5	–	–
Tropical broad-leaved raingreen	15.5	–	–
Temperate needle-leaved evergreen	−2.0	22.0	900
Temperate broad-leaved evergreen	3.0	18.8	1200
Temperate broad-leaved summergreen	−17.0	15.5	1200
Boreal needle-leaved evergreen	−32.5	−2.0	600
Boreal needle-leaved summergreen	–	−2.0	350
Boreal broad-leaved summergreen	–	−2.0	350
Temperate herbaceous (TeH)	–	15.5	–
Tropical herbaceous (TrH)	15.5	–	–

Climate envelope models have circular logic

Vegetation climate limits might change as CO_2 increases

Is it probably not reasonable to assume that all plants of one class have the same climate tolerances

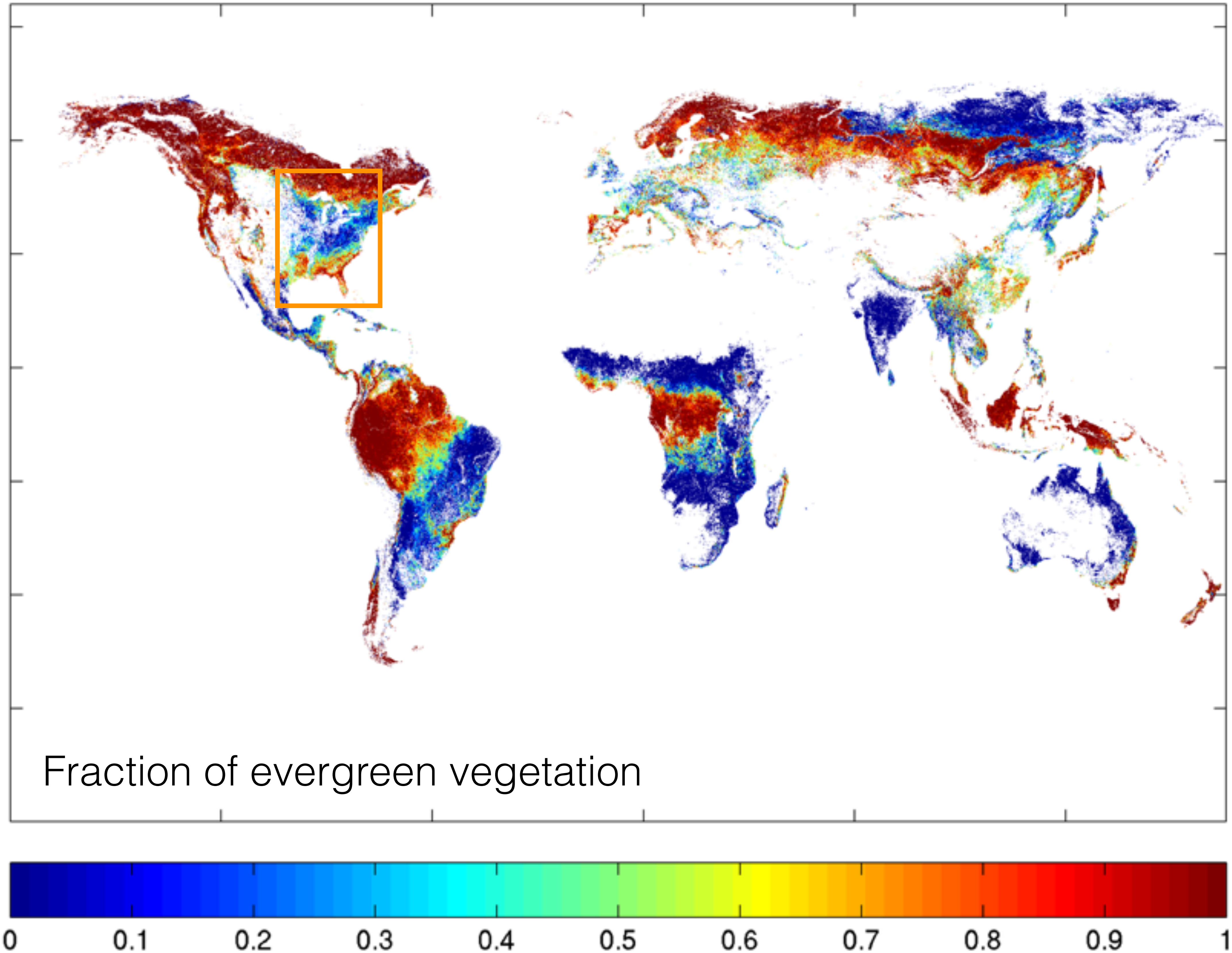
How to proceed?

The Ecosystem Demography model* we have integrated into the CLM:

- Has no climatic envelopes
- Can be parameterized directly from plant trait data
- Predicts plant distribution as an outcome of performance
- We can in theory use CLM(ED) for testing hypotheses of vegetation distribution.

*Moorcroft et al. 2001; Fisher et al. 2010; Fisher et al. in prep

What **can** we observe about vegetation distribution?



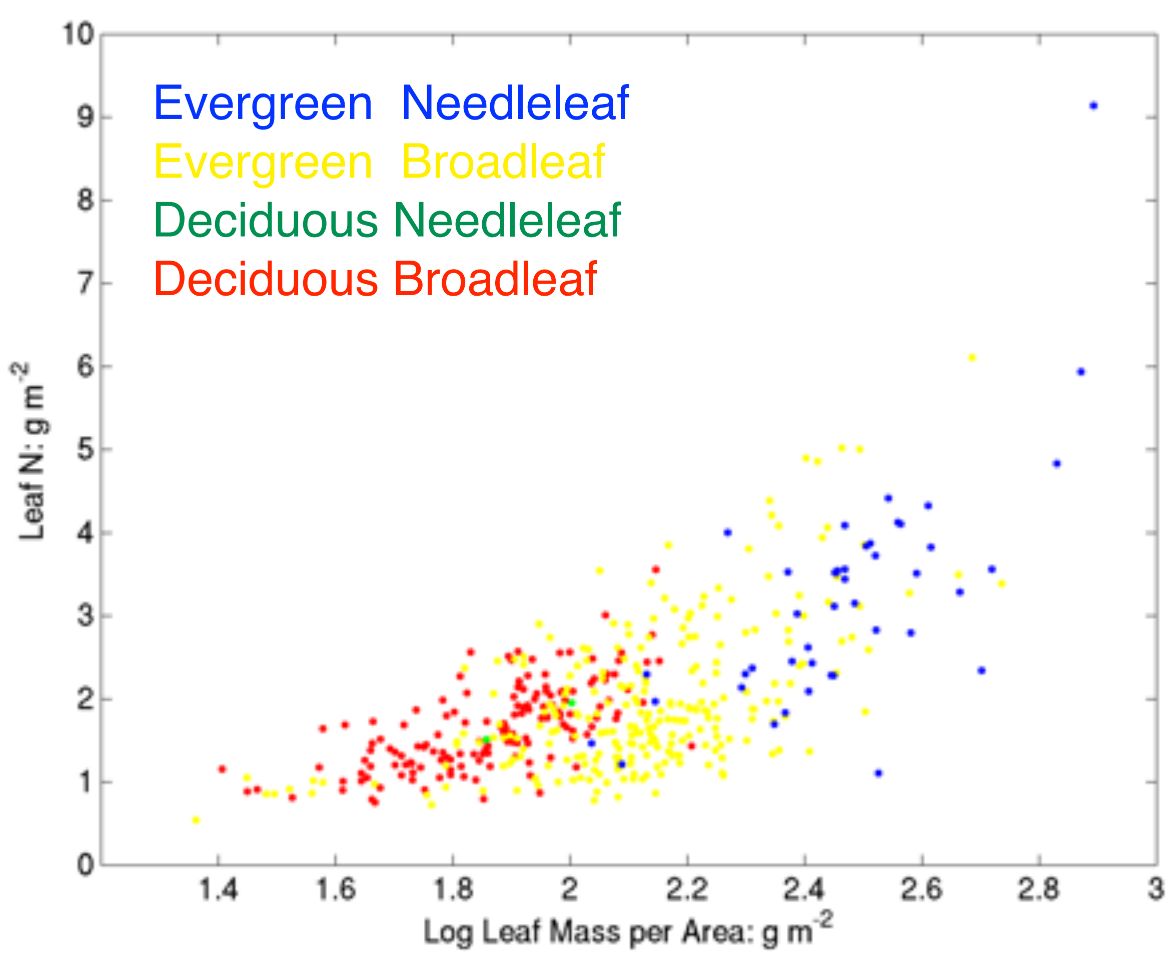
AVHRR Vegetation Continuous Fields. De Fries et al. 2000

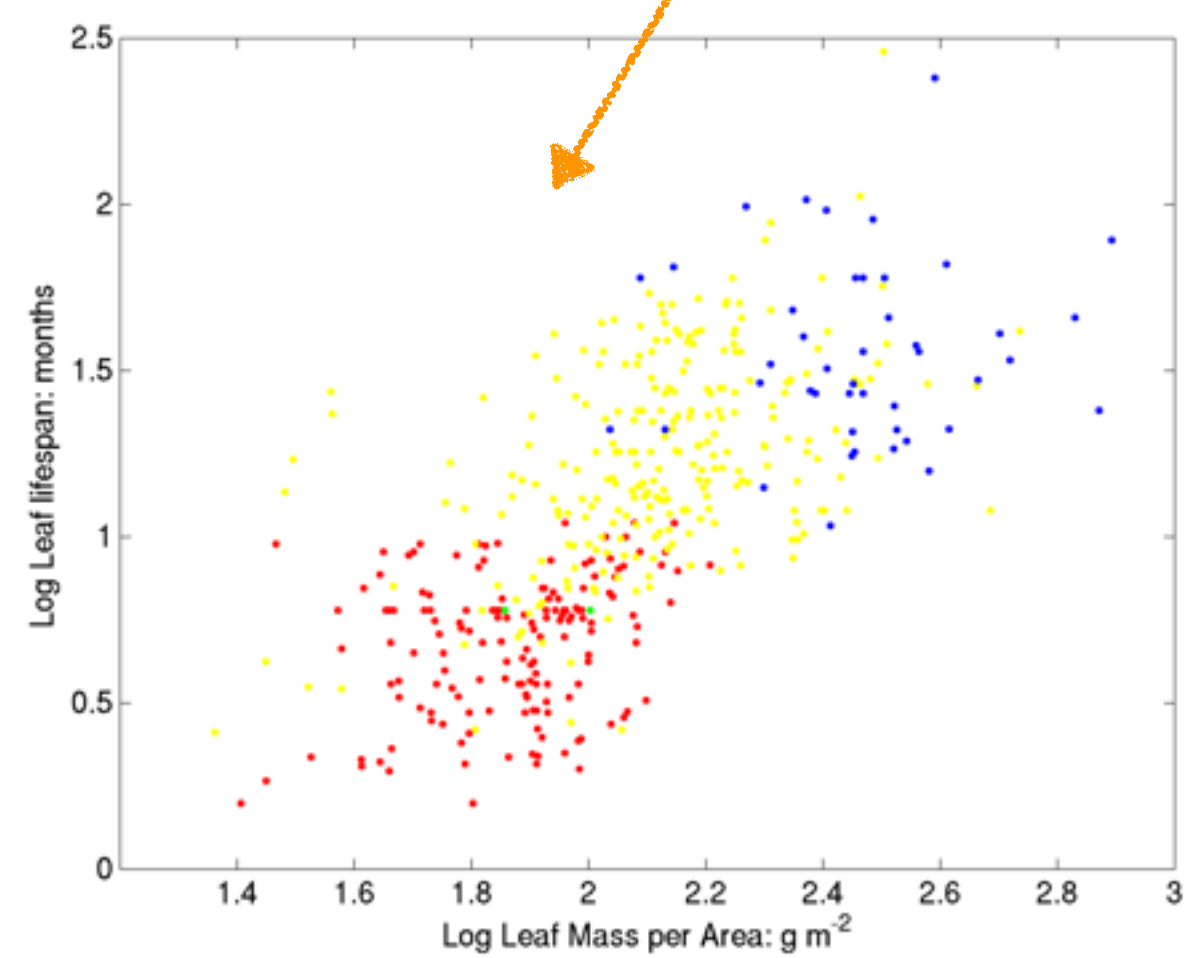
The worldwide leaf economics spectrum

Ian J. Wright[1], Peter B. Reich[2], Mark Westoby[1], David D. Ackerly[3], Zdravko Baruch[4], Frans Bongers[5], Jeannine Cavender-Bares[6], Terry Chapin[7], Johannes H. C. Cornelissen[8], Matthias Diemer[9], Jaume Flexas[10], Eric Garnier[11], Philip K. Groom[12], Javier Gulias[10], Kouki Hikosaka[13], Byron B. Lamont[12], Tali Lee[14], William Lee[15], Christopher Lusk[16], Jeremy J. Midgley[17], Marie-Laure Navas[11], Ülo Niinemets[18], Jacek Oleksyn[2,19], Noriyuki Osada[20], Hendrik Poorter[21], Pieter Poot[22], Lynda Prior[23], Vladimir I. Pyankov[24], Catherine Roumet[11], Sean C. Thomas[25], Mark G. Tjoelker[26], Erik J. Veneklaas[22] & Rafael Villar[27]

LEAF CONSTRUCTION HAS A 3-WAY TRADE OFF:

Leaf mass per area (**cost**)
vs.
Leaf Lifespan (**durability**)
vs.
Leaf Nitrogen per area (**performance**)

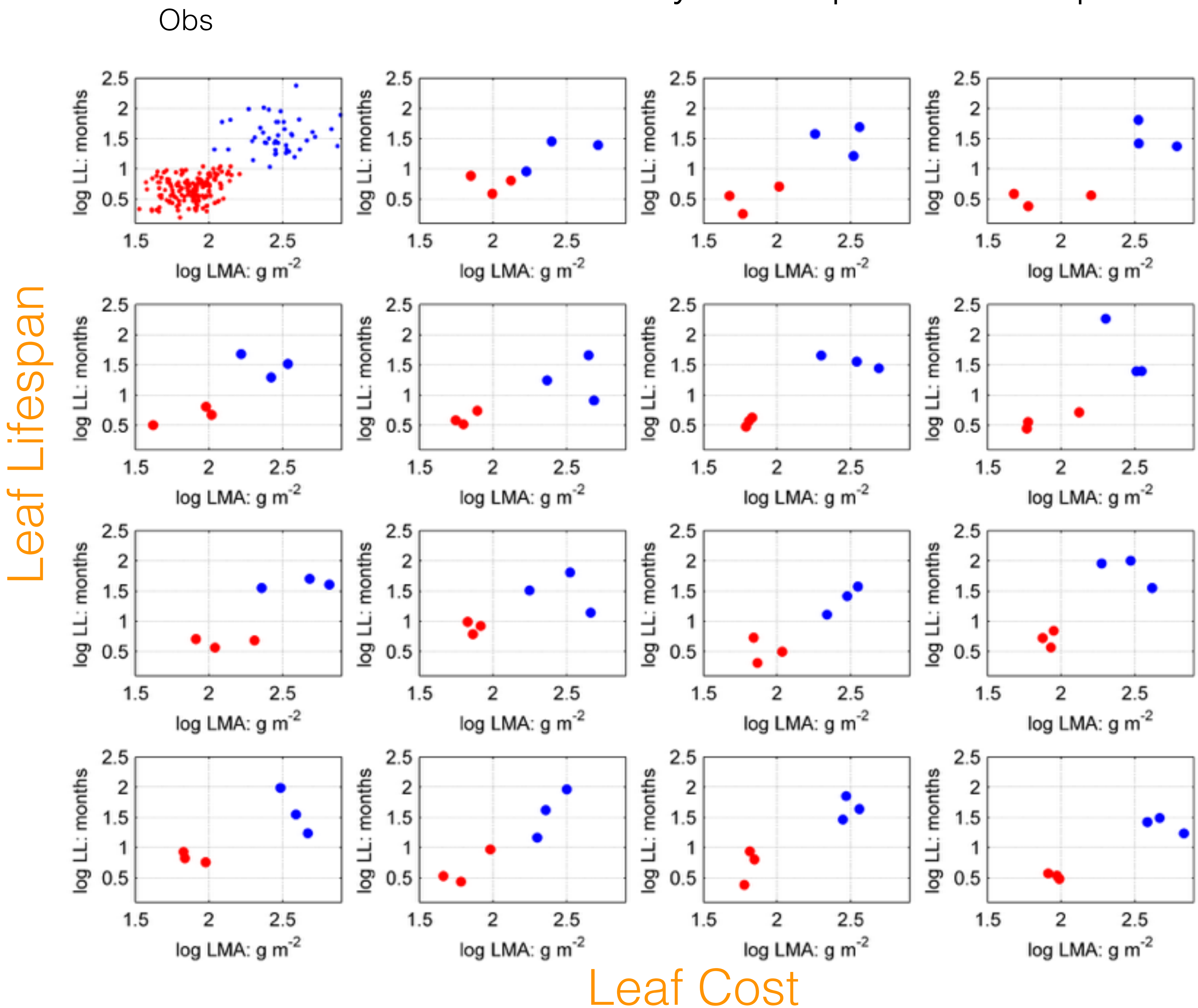


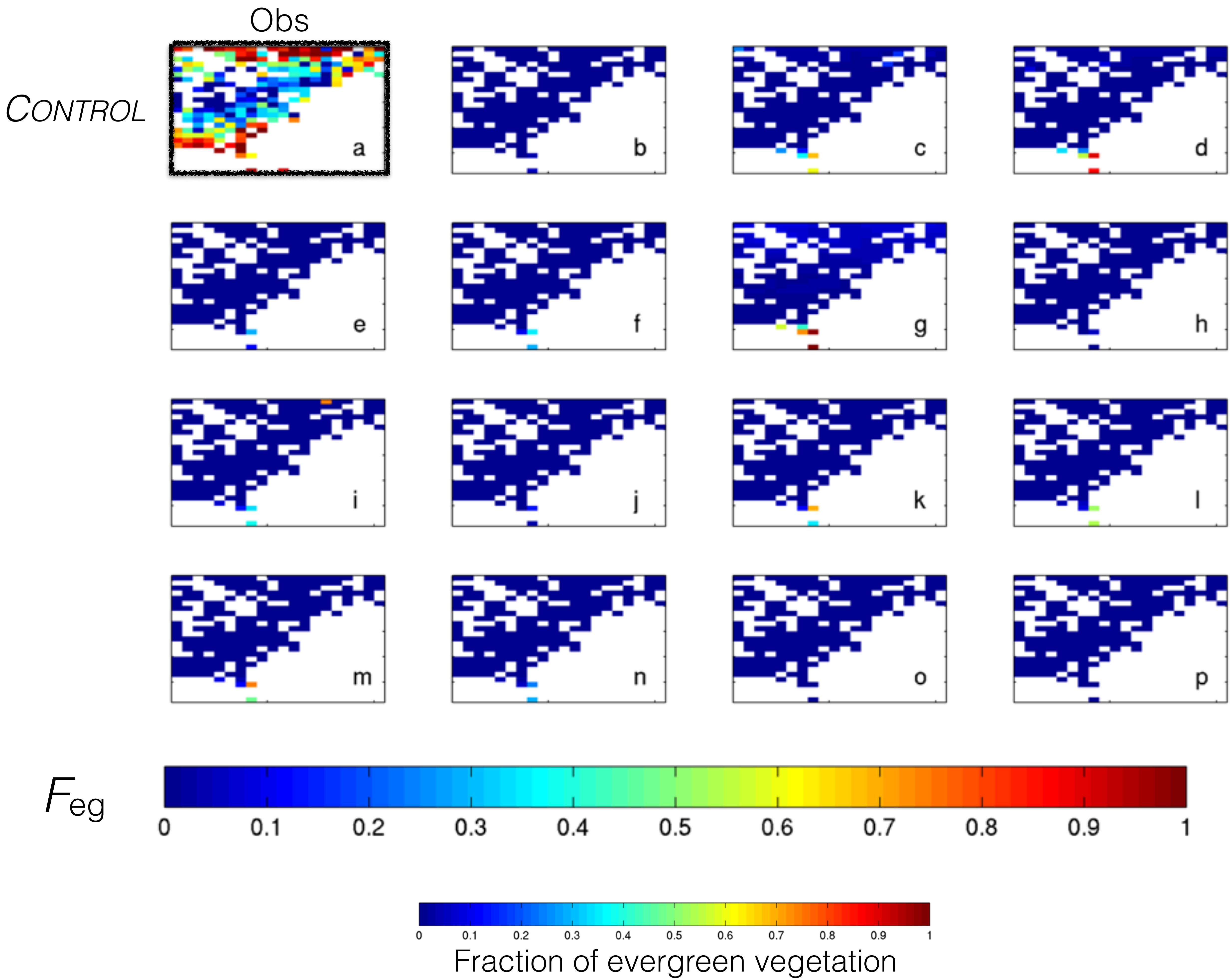


Hypothesis: The relative carbon economy of deciduous vs. evergreen habits can predict biome boundaries

Evergreen Needleleaf
Deciduous Broadleaf

Question: Does how you sample the trait space matter?

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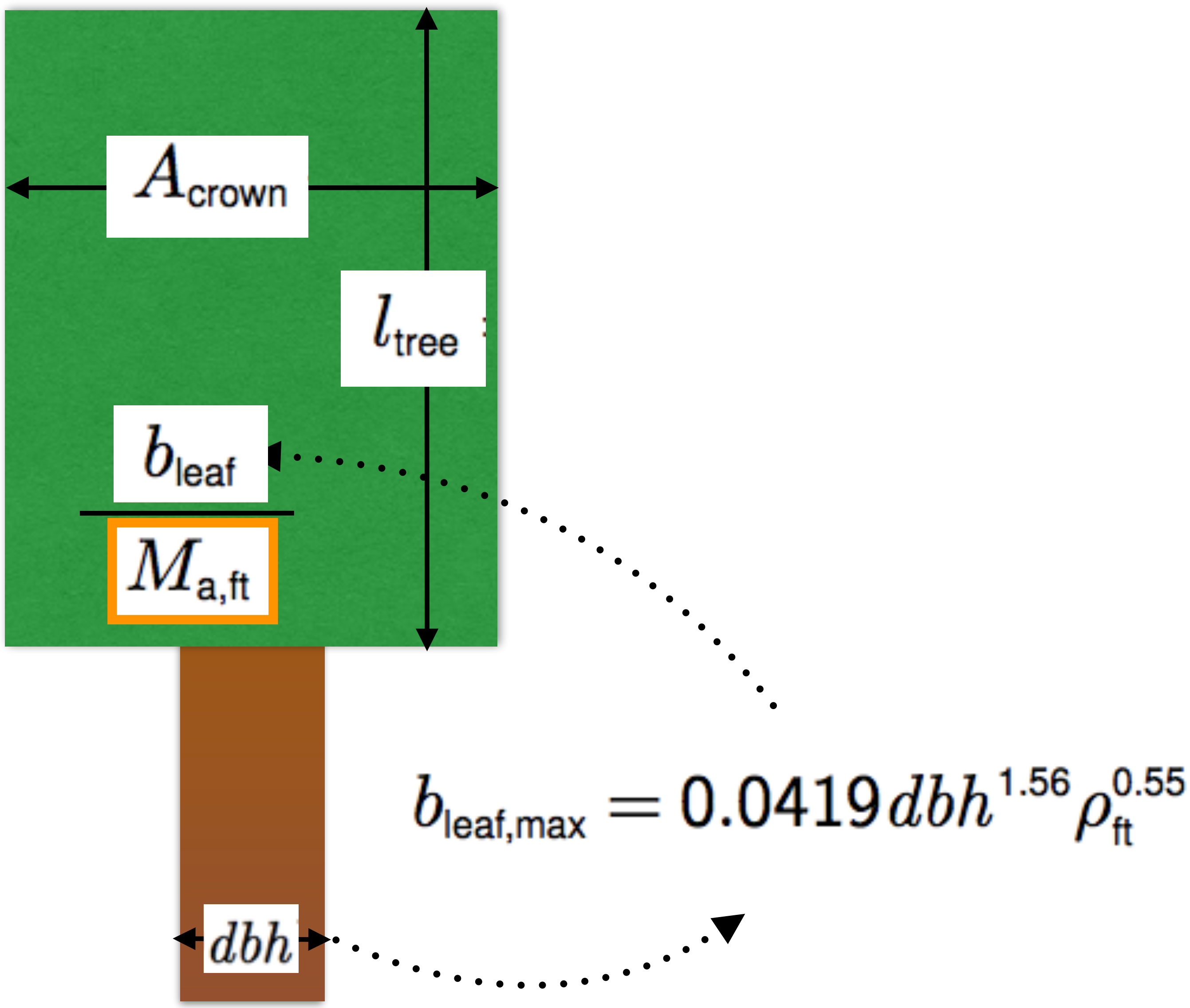
Fraction of evergreen vegetation

Initial Leaf Biomass

$$l_{\text{tree}} = \frac{b_{\text{leaf}}}{A_{\text{crown}} \cdot M_{\text{a,ft}}}$$

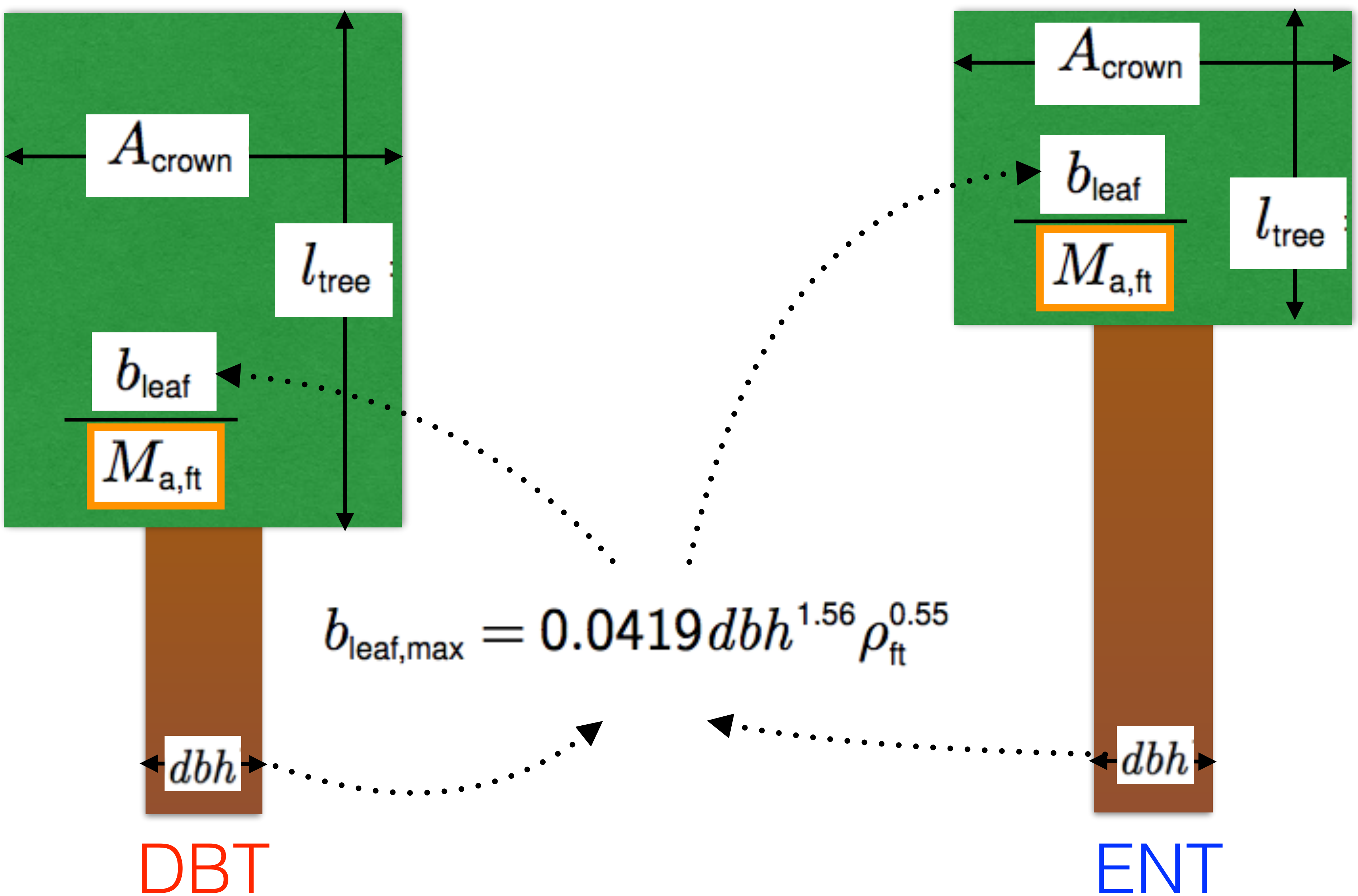
Leaf area index (l_{tree}) is a function of tree diameter, and leaf mass per area (M_a)



Initial Leaf Biomass

Higher M_a causes lower leaf area index

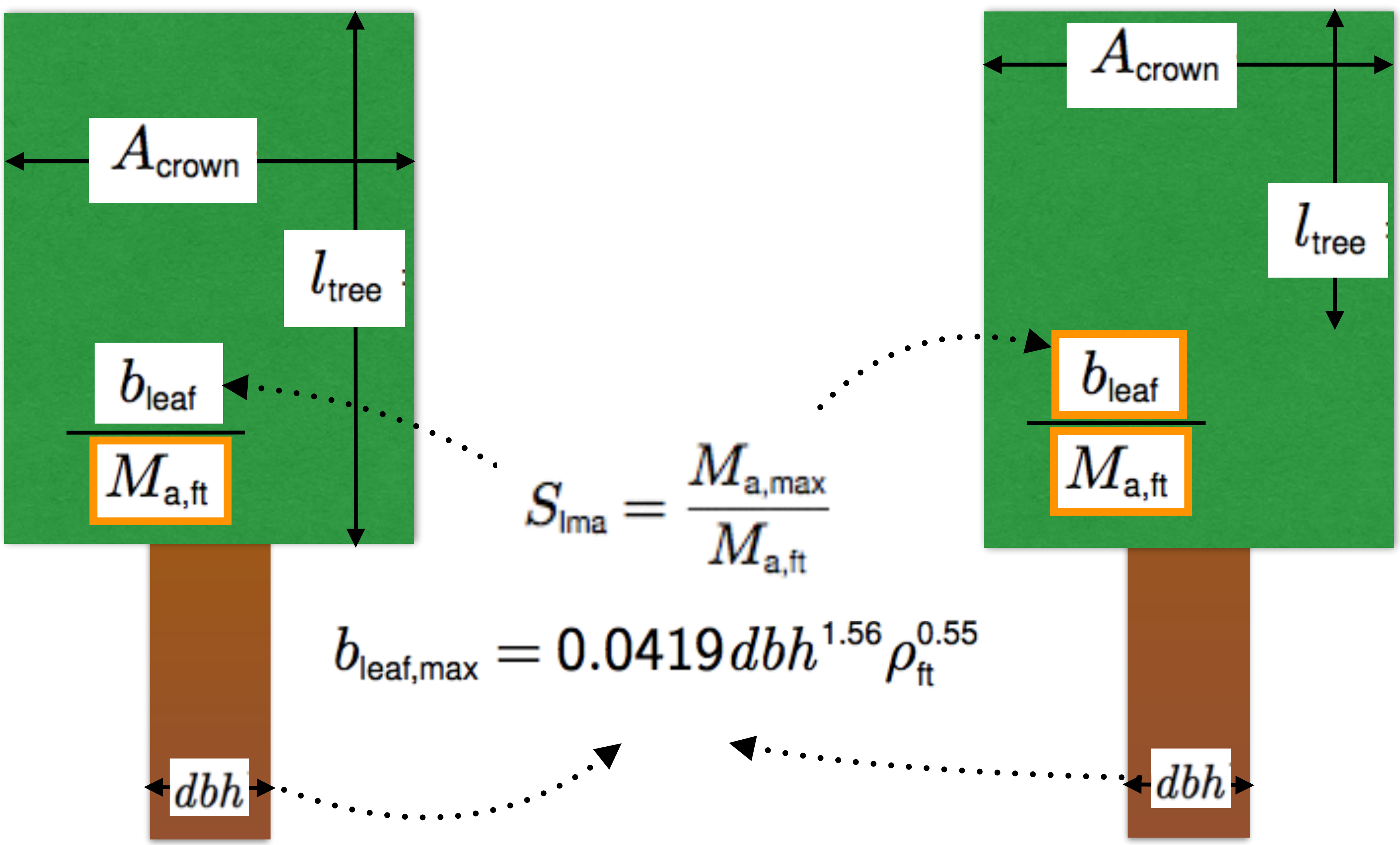
$$l_{tree} = \frac{b_{leaf}}{A_{crown} \cdot M_{a,ft}}$$

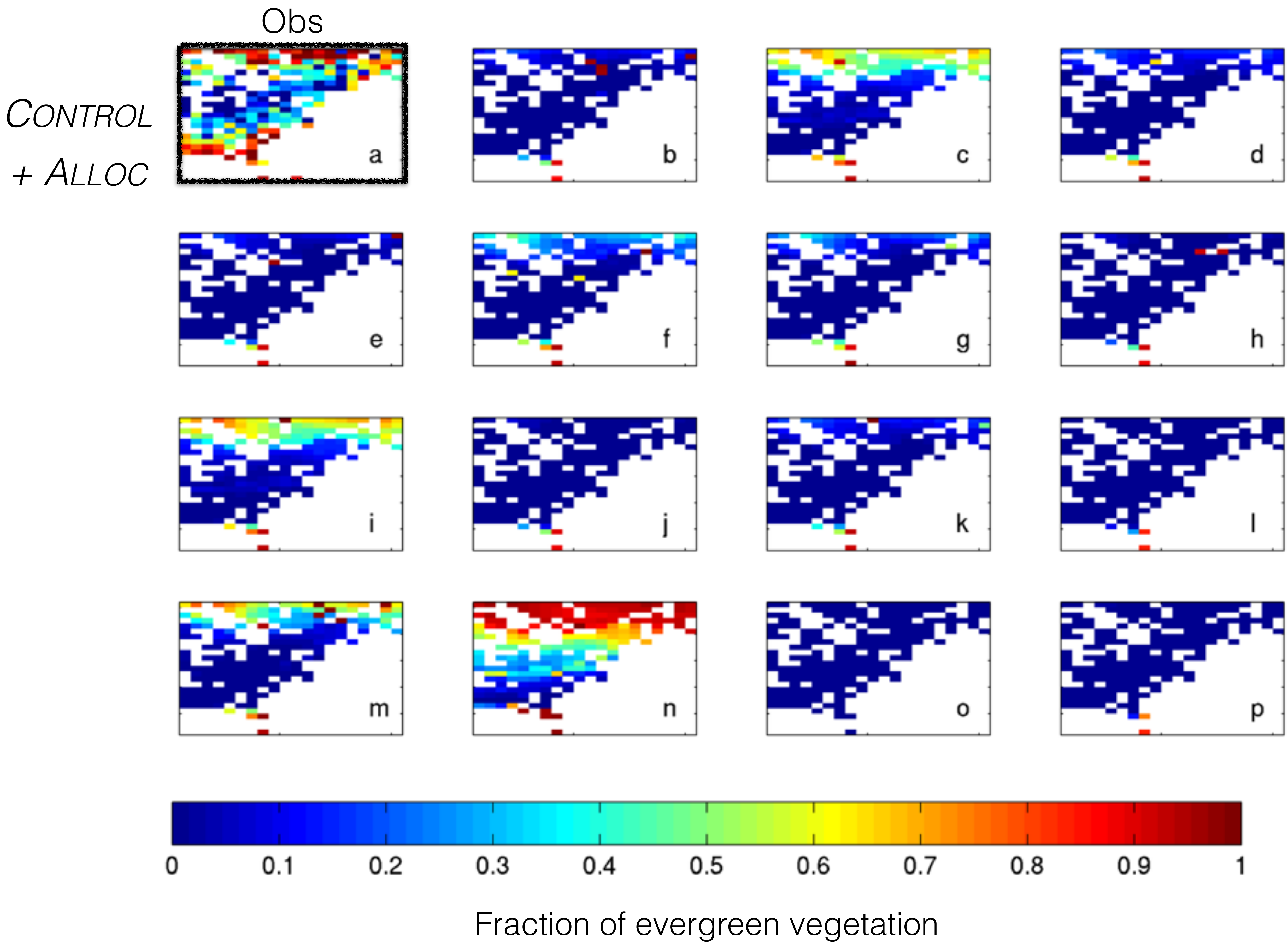


Initial Leaf Biomass

$$l_{\text{tree}} = \frac{b_{\text{leaf}}}{A_{\text{crown}} \cdot M_{\text{a,ft}}}$$

Add in leaf mass per area ($M_{\text{a,ft}}$) based correction factor.





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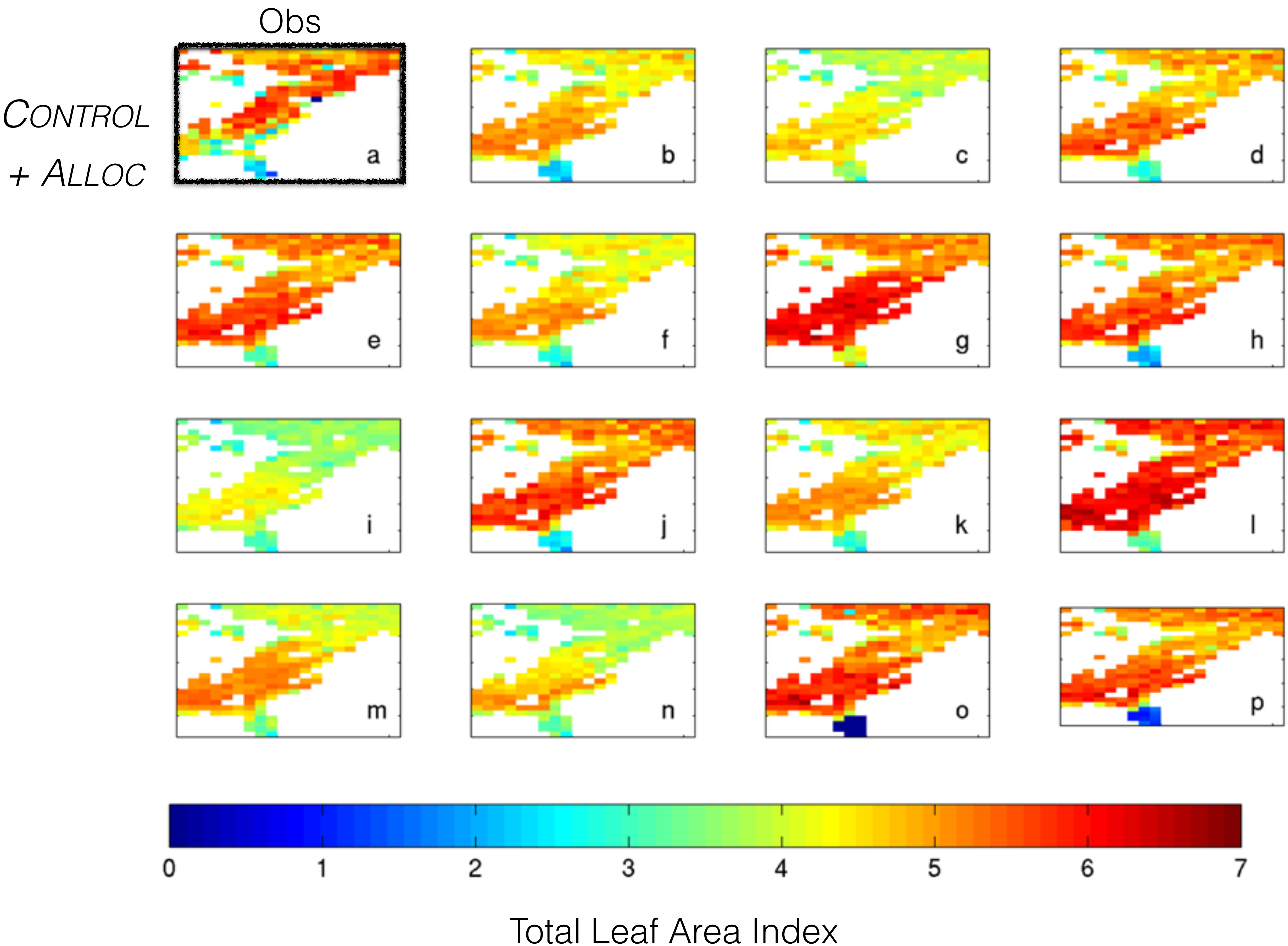
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Total Leaf Area Index

Leaf Maintenance Respiration

CLM4.5 (Ryan et al, 1991)

$$\mathrm{lmr}_{\mathrm{top},25} = N_{\mathrm{area}} \cdot b_{\mathrm{resp}}$$

$=0.257$ gC gN^{-1} s^{-1}

CLM4.5(ED) (Atkin et al. 2015)

for BDT

$$\log_{10}(\mathrm{lmr}_{\mathrm{top},25,\mathrm{BDT}}) = \log_{10}(N_{\mathrm{area}}) \cdot 1.134 - 0.300$$

~ 0.536 gC gN^{-1} s^{-1}

and for NET

$$\log_{10}(\mathrm{lmr}_{\mathrm{top},25,\mathrm{NET}}) = \log_{10}(N_{\mathrm{area}}) \cdot 1.005 - 0.346$$

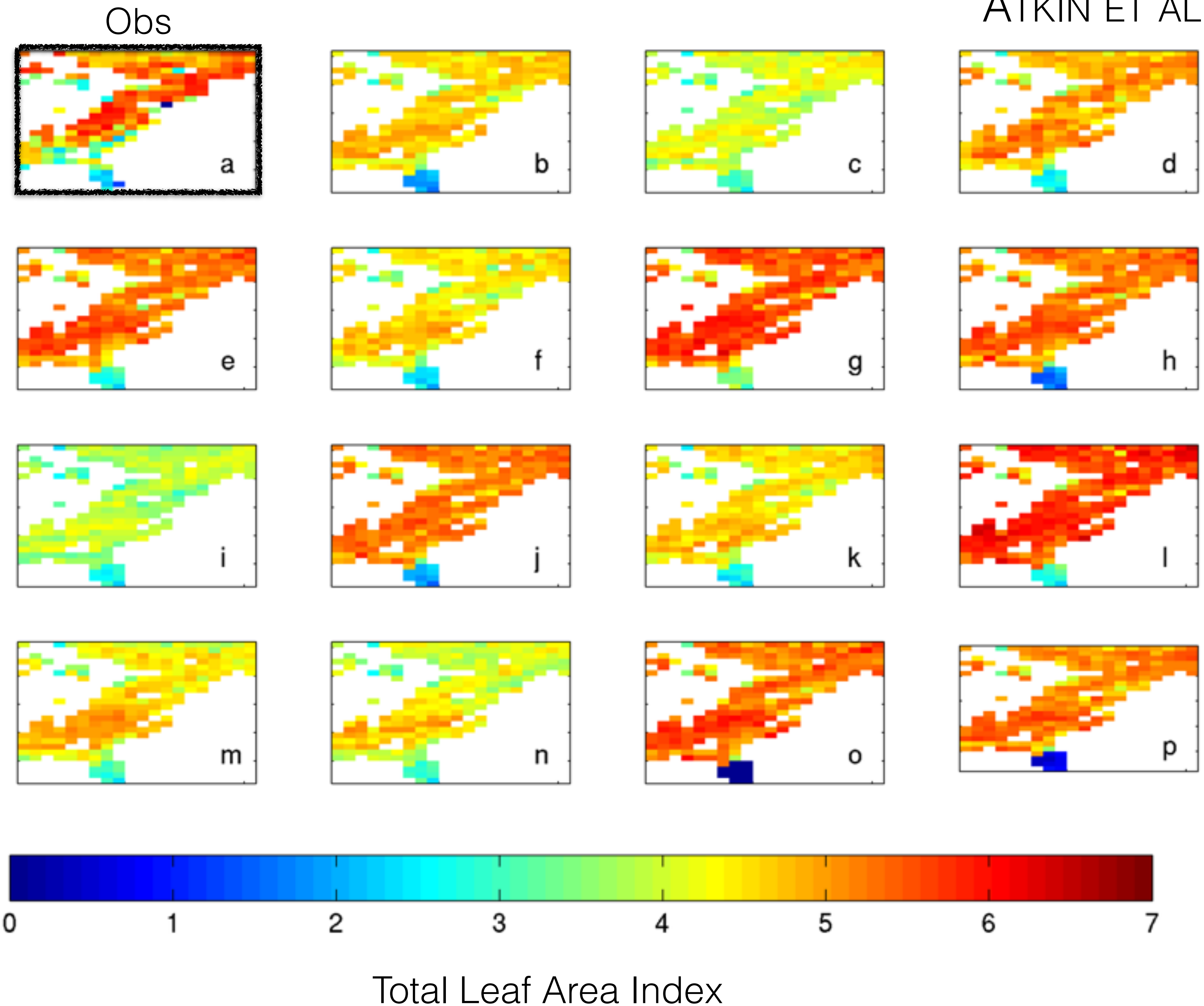
~ 0.452 gC gN^{-1} s^{-1}

ATKIN ET AL. 2015

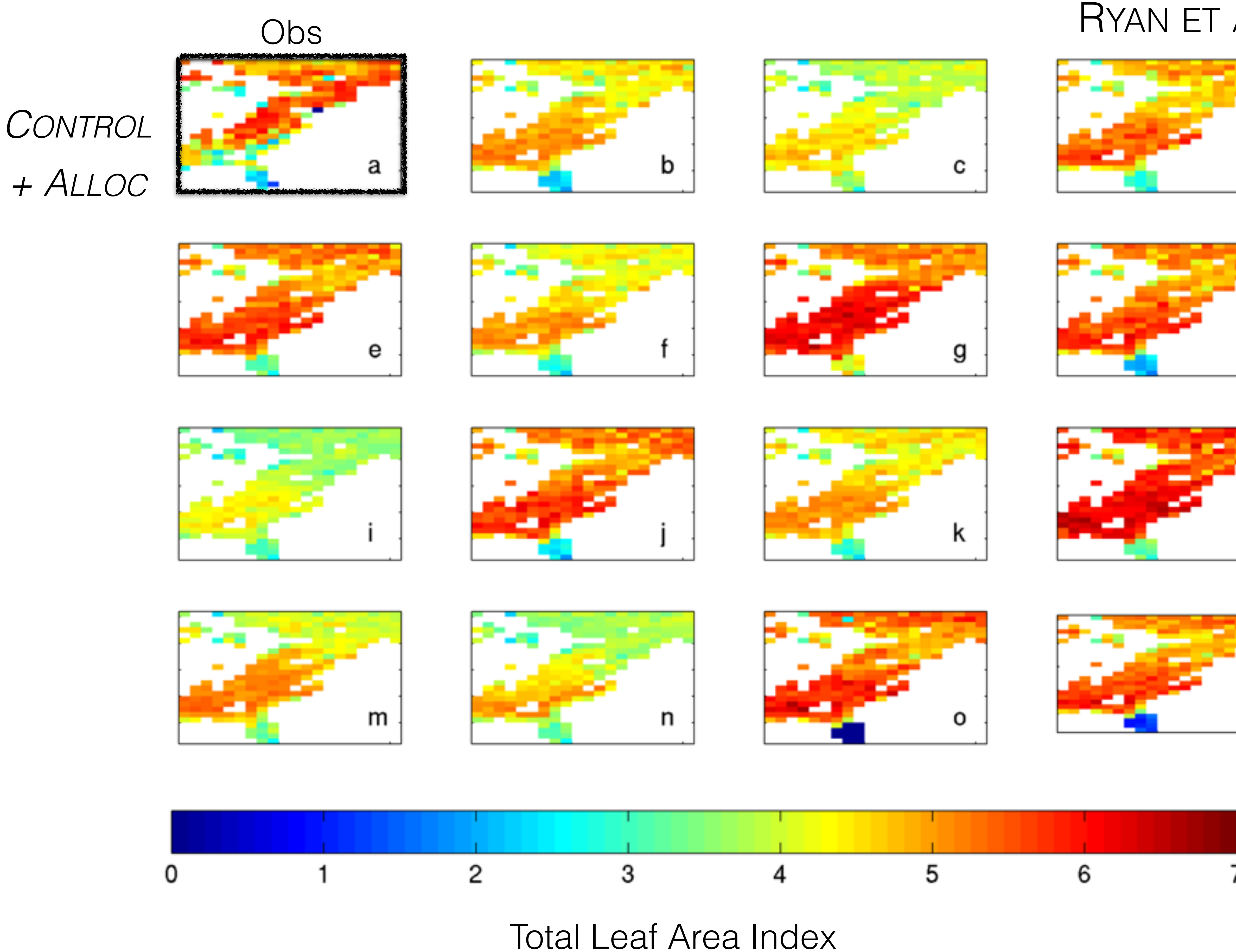
CONTROL

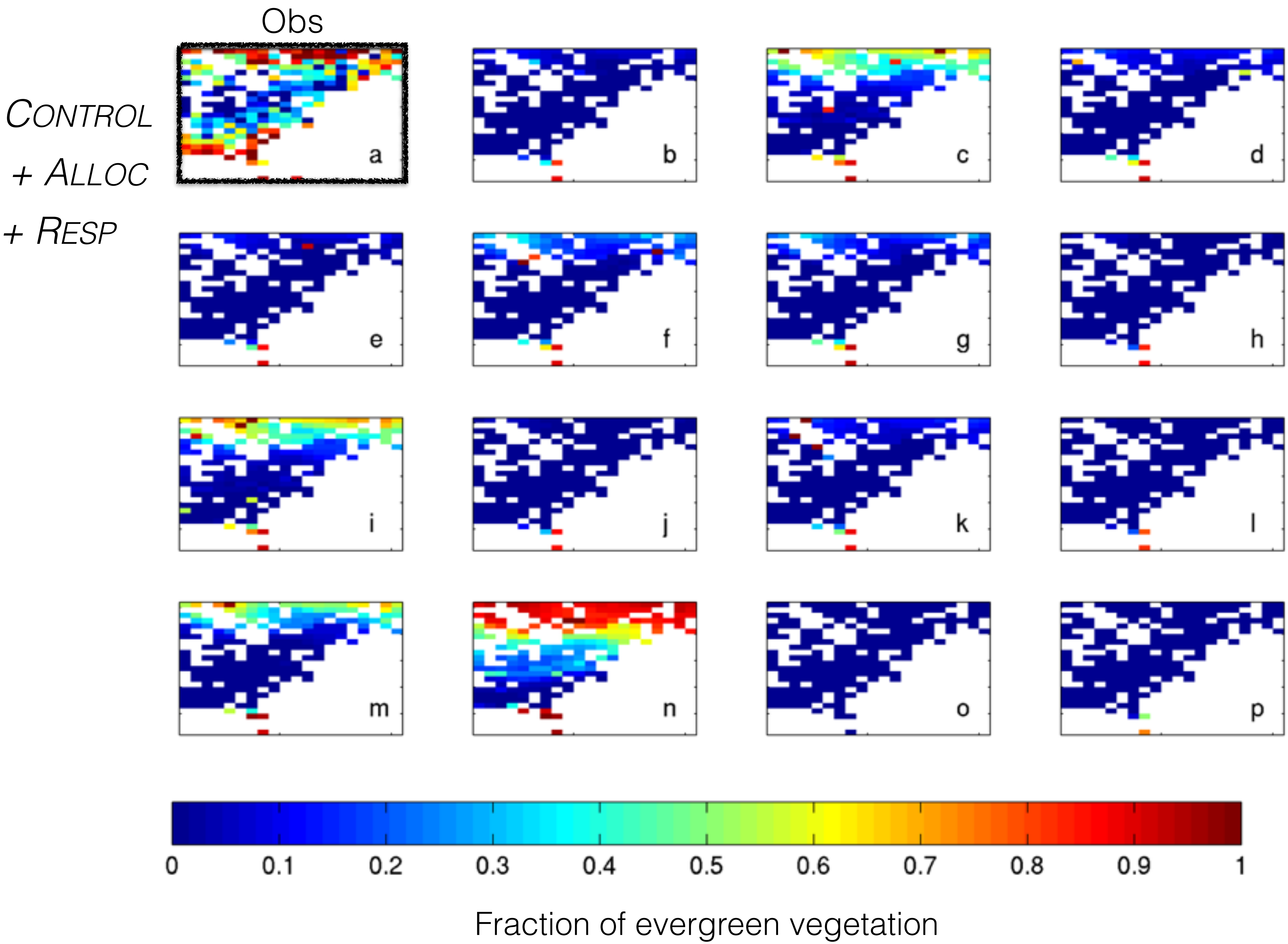
+ ALLOC

+ RESP



RYAN ET AL, 1991

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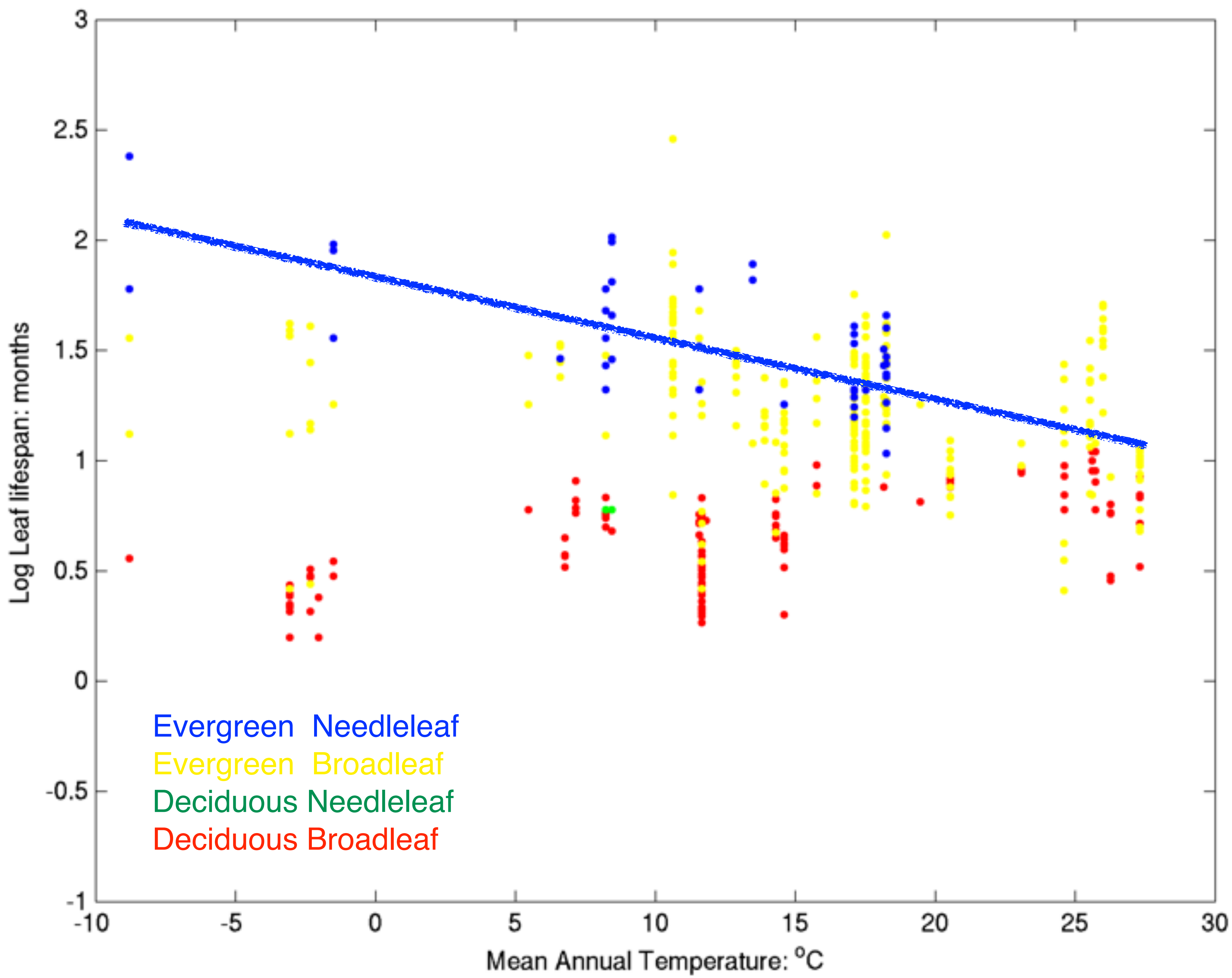
Fraction of evergreen vegetation

Leaf Turnover vs. Temperature

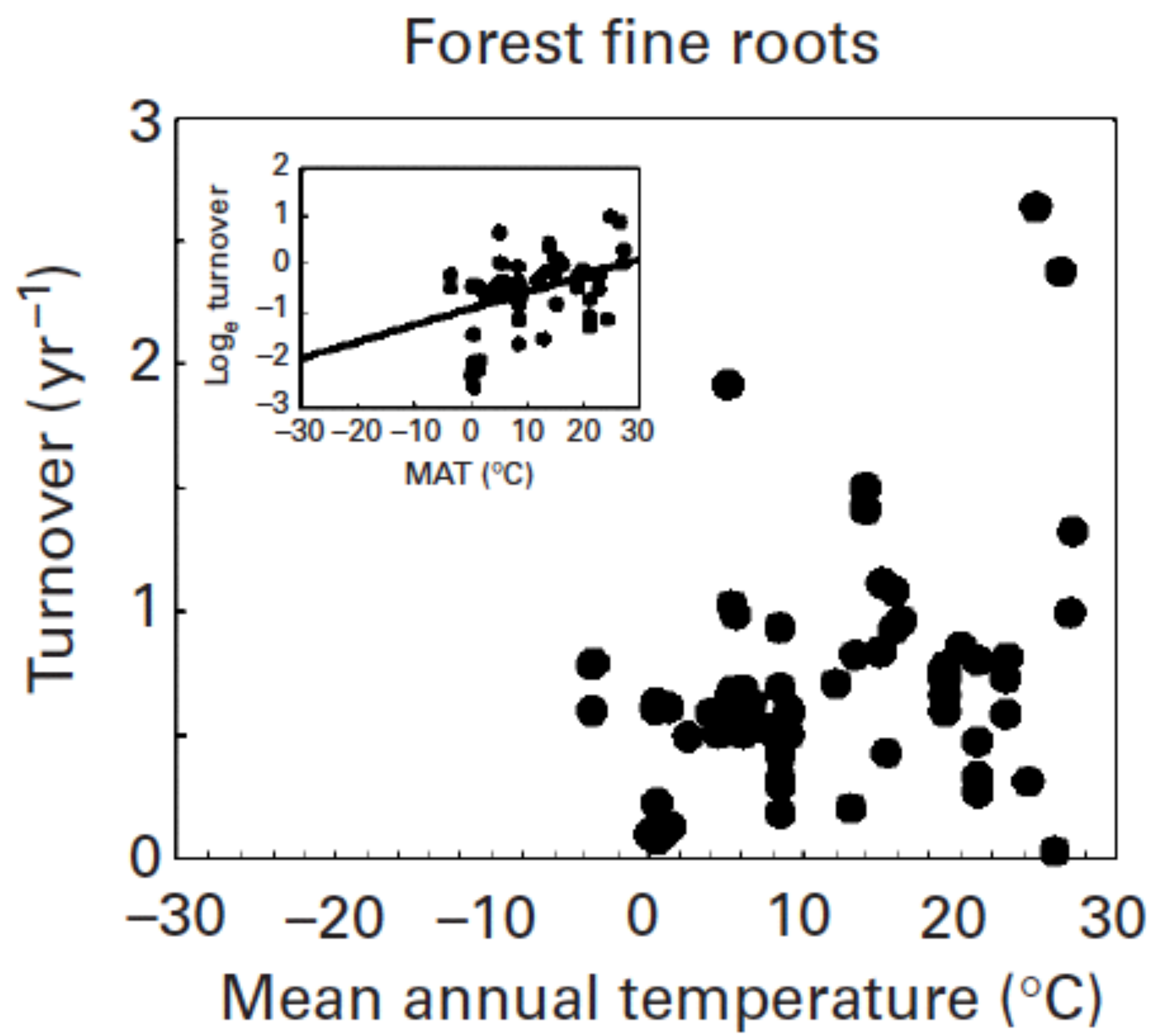
Is leaf lifespan dictated by construction cost, or the environment?



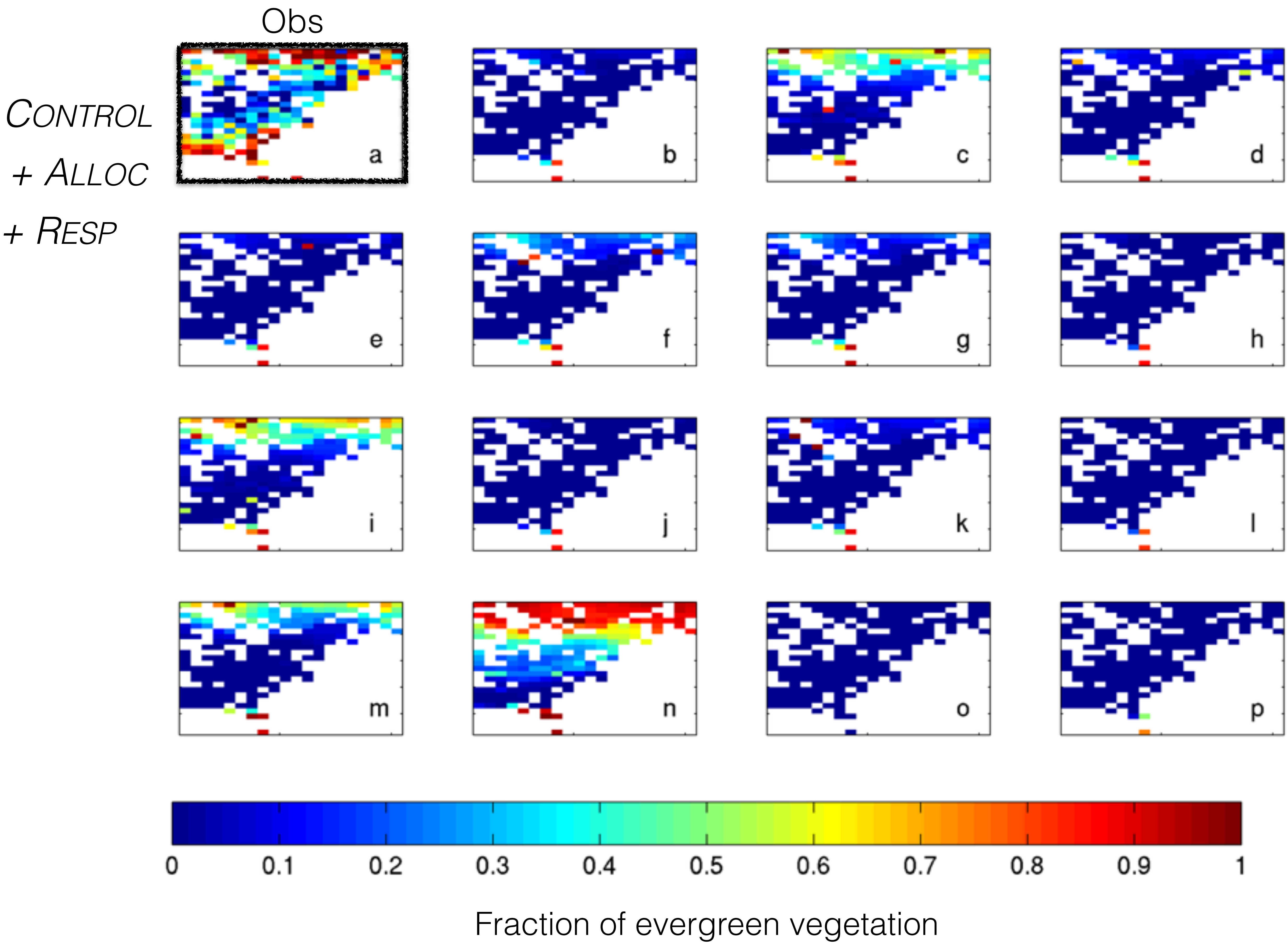
Root Turnover vs. Temperature

BDT $\log_{10}(\mathrm{lmr}_{\mathrm{top,25,BDT}}) = \log_{10}(N_{\mathrm{area}}) \cdot 1.134 - 0.300$

ENT $\log_{10}(\mathrm{lmr}_{\mathrm{top,25,NET}}) = \log_{10}(N_{\mathrm{area}}) \cdot 1.005 - 0.346$



(Data extracted from)
Gill & Jackson 2000



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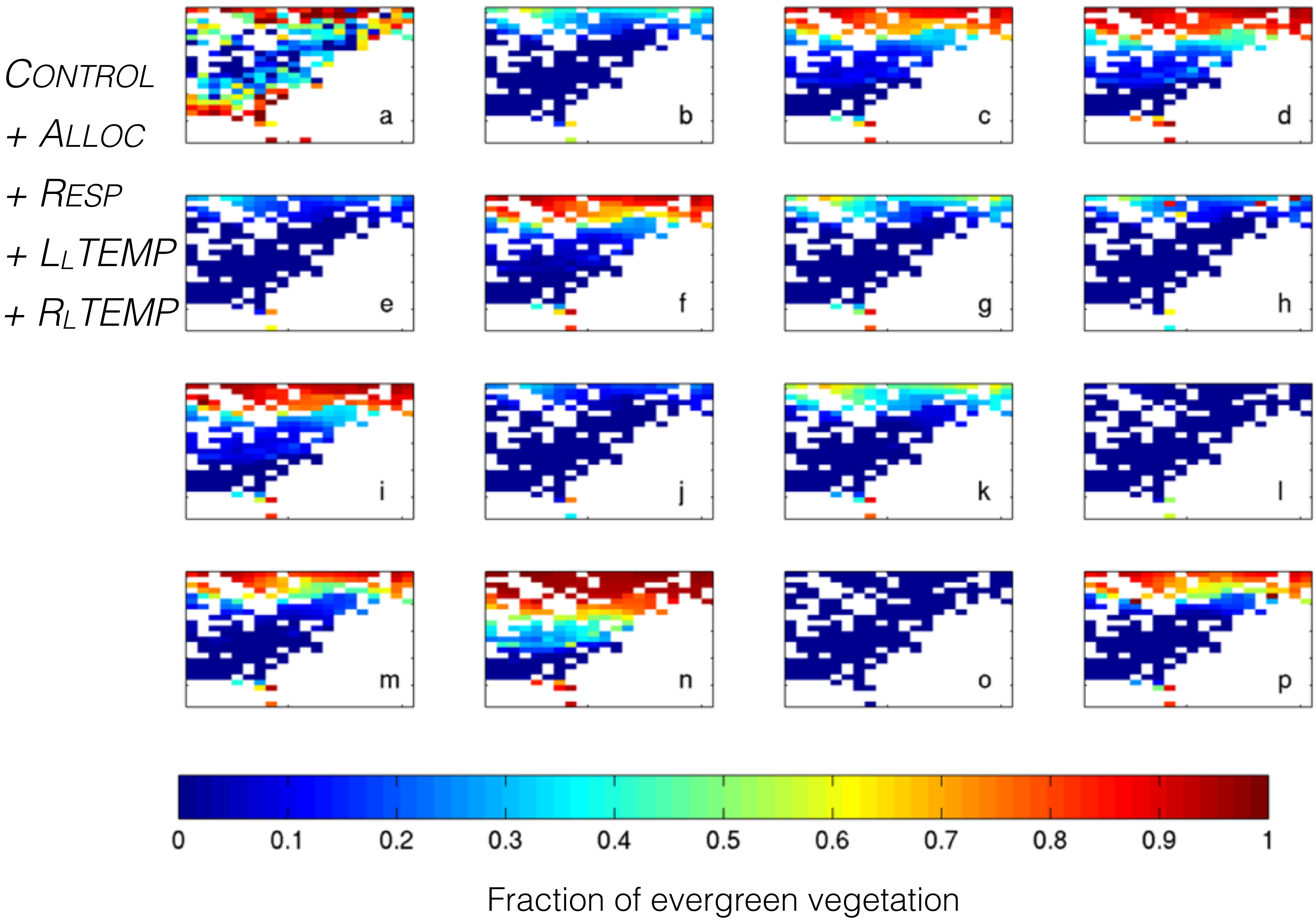

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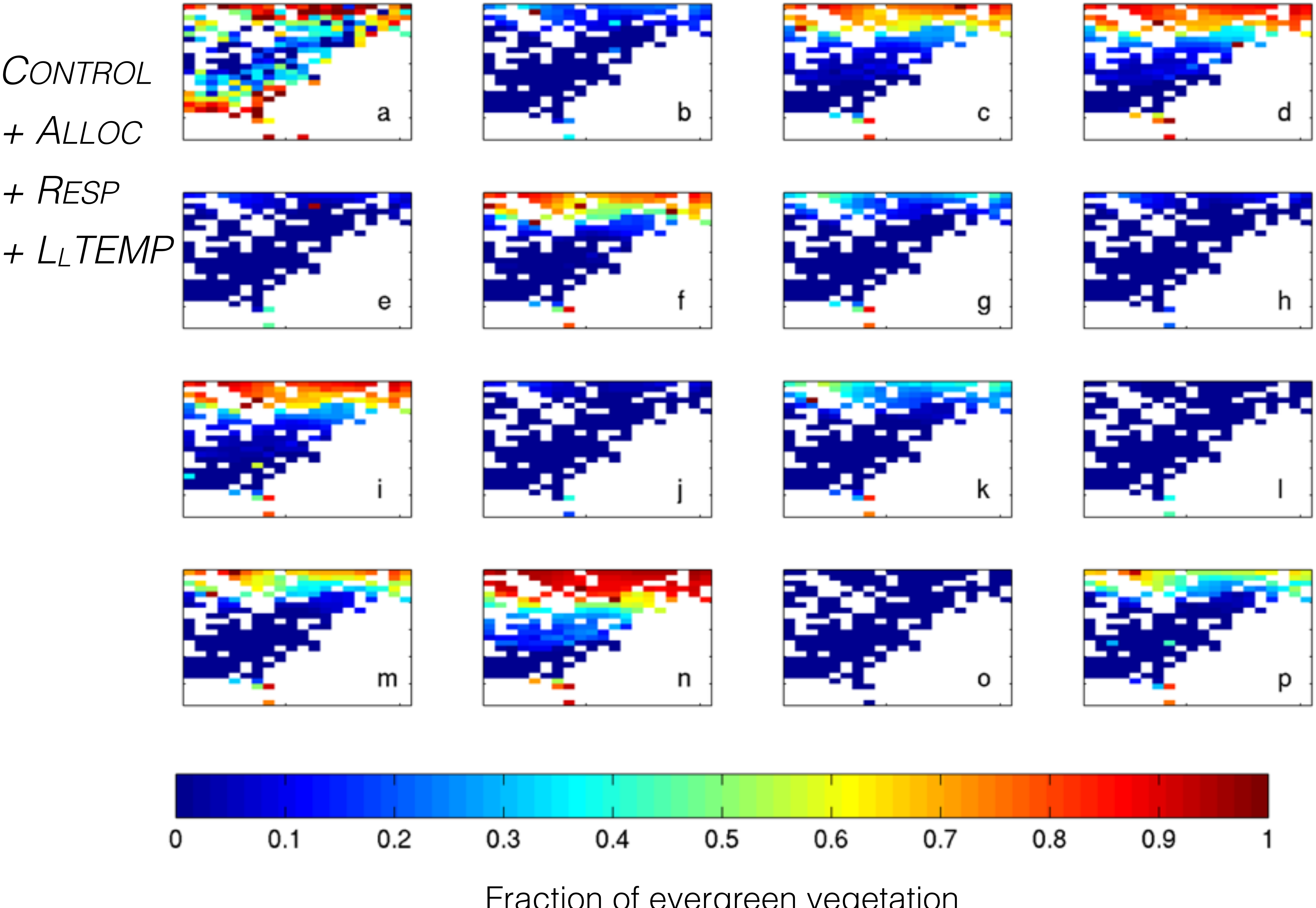

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Fraction of evergreen vegetation

Conclusions

- Carbon economy of leaf habit can, in some cases, predict biome boundaries
- How we use plant trait data matters for vegetation dynamics predictions.
- Naïve use of plant trait databases does not necessarily lead to skillful prediction
- Parametric and structural ensembles are both informative for understanding cause & effect in model predictions.