Biodiversity from Space:
Observing life in the earth system

David Schimel +

NCEAS BFS participants +

Merton Initiative participants

GLOBAL IGBP CHANGE International Geosphere-Biosphere Programme

NCEAS

NASA

Building on the IGBP-Diversitas-IHDP Merton Report and the NCEAS Biodiversity from Space working Group:

The Merton Initiative: Towards a Global Observing System for the Human Environment

ANDELMAN, SANDY	Conservation International
BACKLUND, PETER	National Center for Atmospheric Research
CHAVEZ, FRANCISCO	Monterey Bay Aquarium Research Institute
COOK, ROBERT	Oak Ridge National Laboratory
COX, PETER	University of Exeter
DE SHERBININ, ALEX	CIESIN, The Earth Institute at Columbia University
GREENWOOD, GREG	Mountain Research Initiative
GUIBERT, GREG	National Center for Atmospheric Research
HELD, ALEX	CSIRO Office of Space Science and Applications
HIBBARD, KATHY	Pacific Northwest National Laboratory
HOFFMAN, FORREST	Oak Ridge National Laboratory
MONKS, PAUL	University of Leicester/IGAC
NIGHTINGALE, JOANNE	NASA GSFC
REICHSTEIN, MARKUS	Max-Planck-Institute for Biogeochemistry
SCHIMEL, DAVID	National Ecological Observatory Network/NCAR
SEITZINGER, SYBIL	IGBP
SPEHN, EVA	Institute of Botany, University of Basel/Diversitas
WALTERS, MICHELE	GEO Biodiversity Observation Network (GEO BON)
PLUMMER, STEPHEN	ESA
DOWNY, CAT	

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September 2011

http://www.igbp.net/publications/themertoninitiative.4.7815fd3f1437 3a7f24c256.html

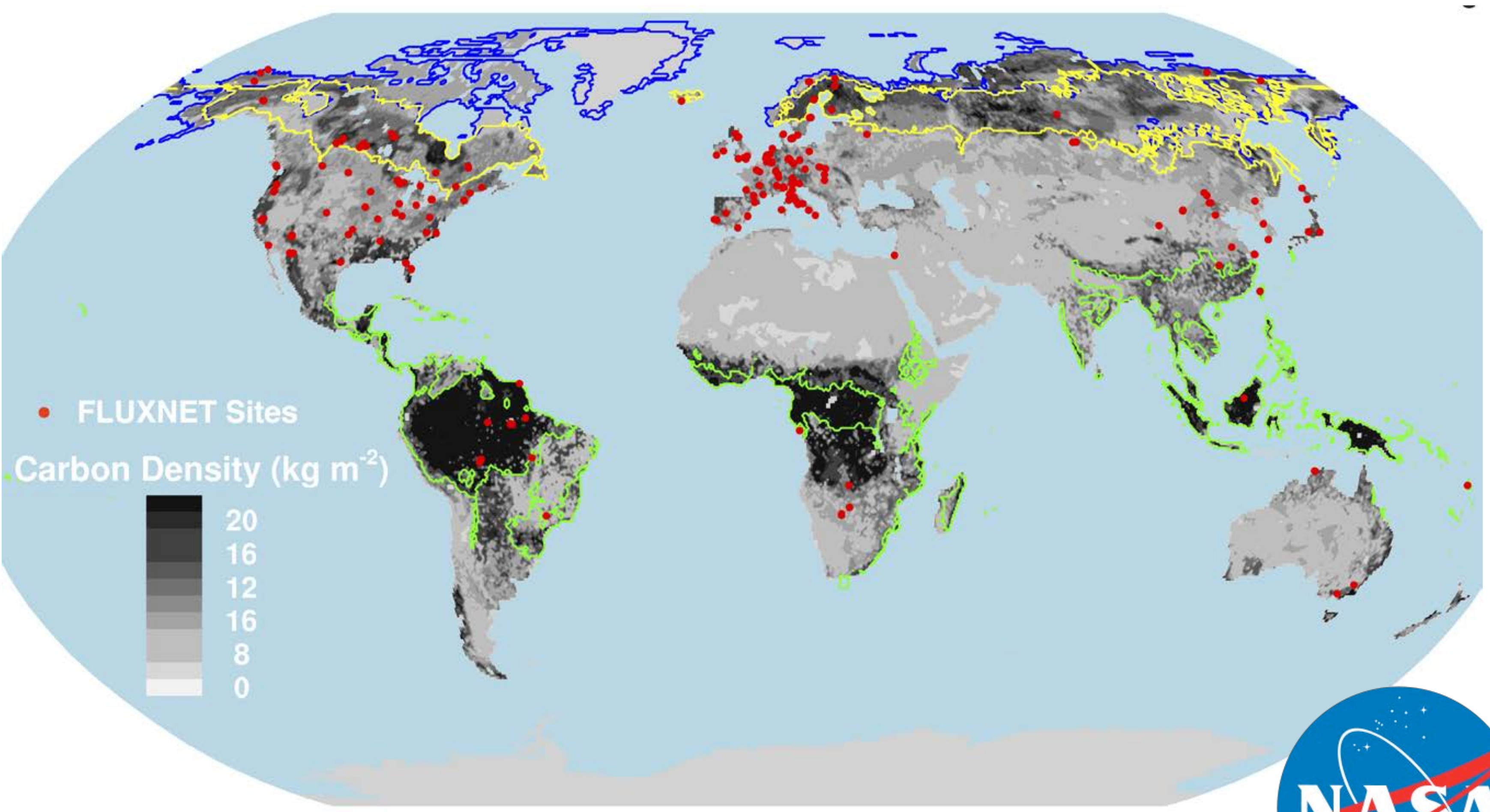
Merton Conclusions (related to this talk)

- *Current and new systems must be integrated into a planetary observatory…*
- *Coverage of global observing systems is highly variable in density and large regions of the planet are inadequately observed.*
- *Space-based data are critical for understanding global and globally-distributed processes. New and improved technical and programmatic strategies for coordinating in situ and space based observations are needed to ensure a continuing increase in the value of global data products.*

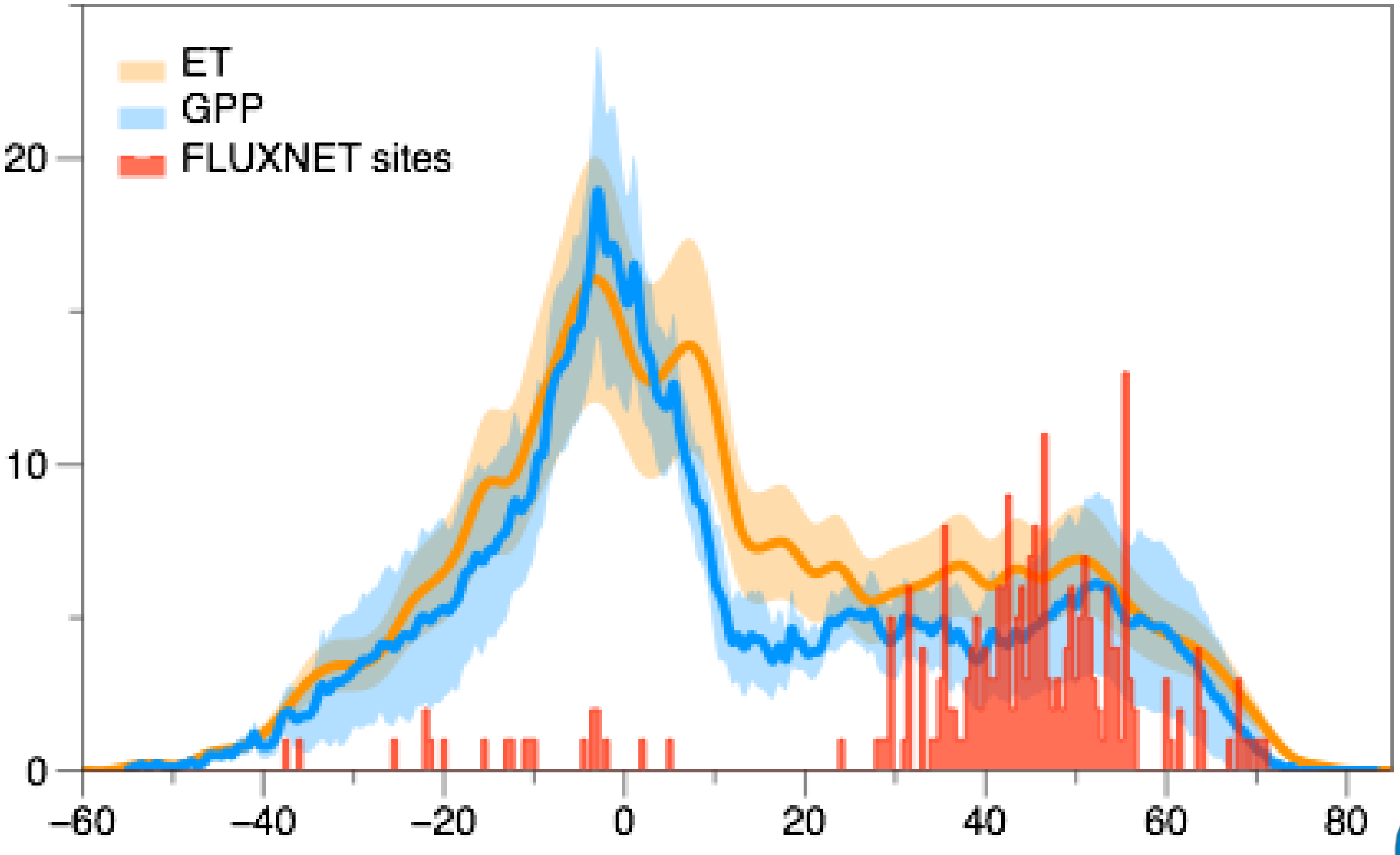
Biodiversity os a vital dimension of the Earth System

- Biodiversity underpins global-scale ecosystem services, in addition to supporting local ecosystem services.
- Functional diversity is central to understanding and predicting the response of the biosphere to climate and other environmental change over the next century.
- Credible models on all scales must address functional diversity.
- The *big leaf* is wilting if not yet fully abscissed!

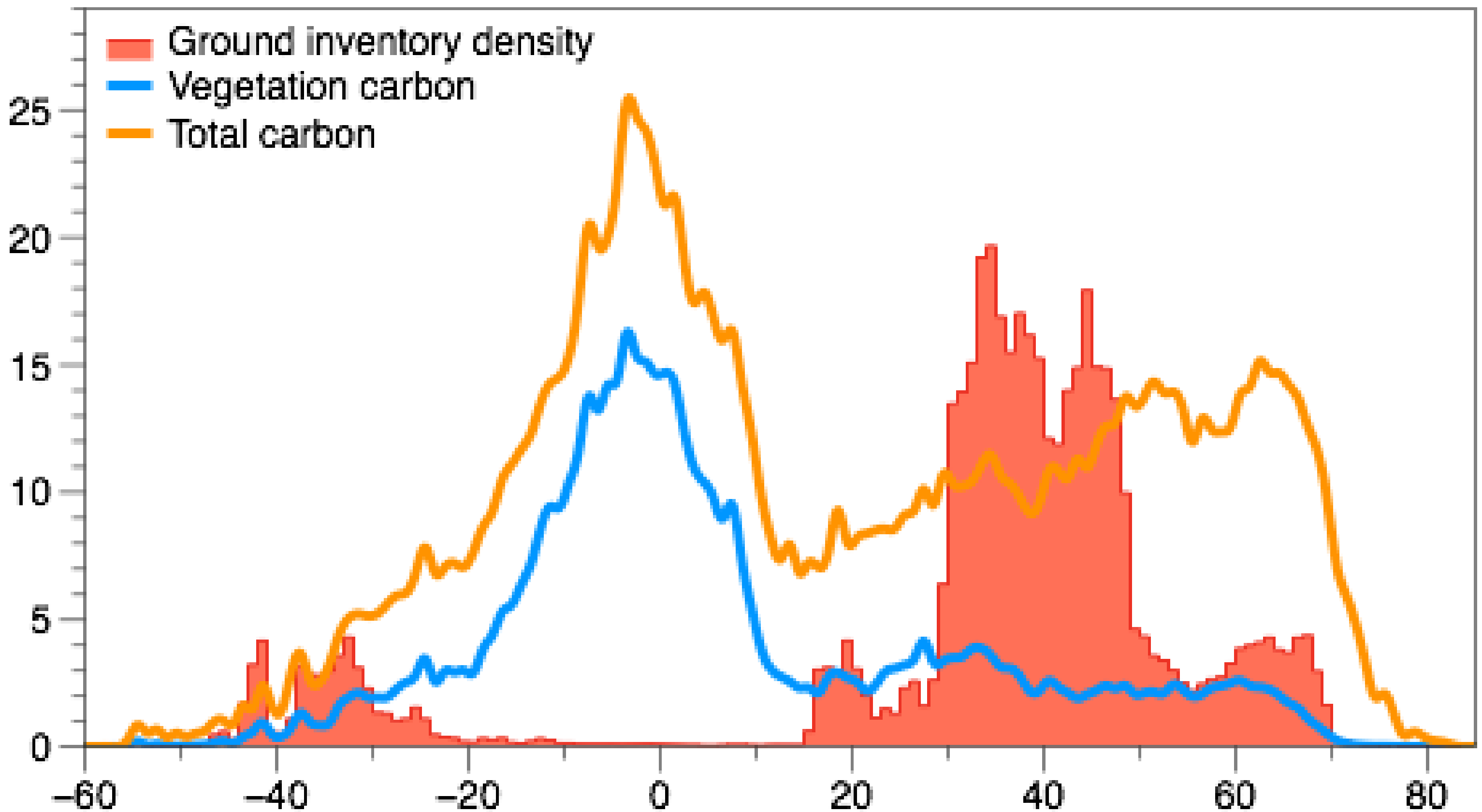
The dimensions of the data gap



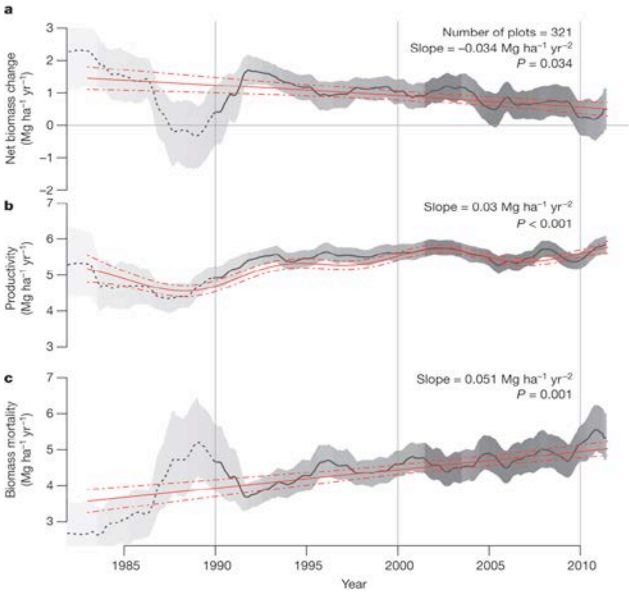
The data gap: Global estimates of GPP and NPP



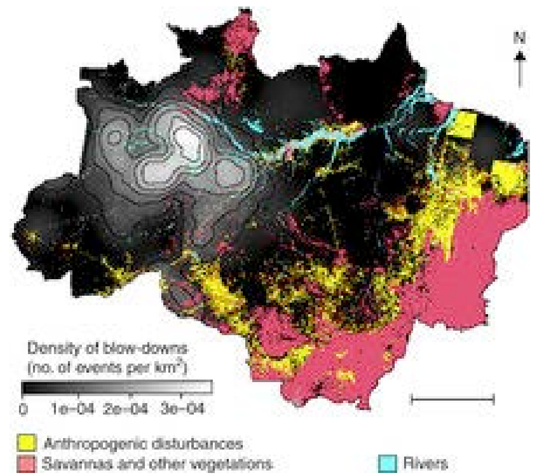
The data gap: Biomass, forest structure and carbon storage



Tropical forests play crucial roles in the carbon cycle, climate and global biodiversity

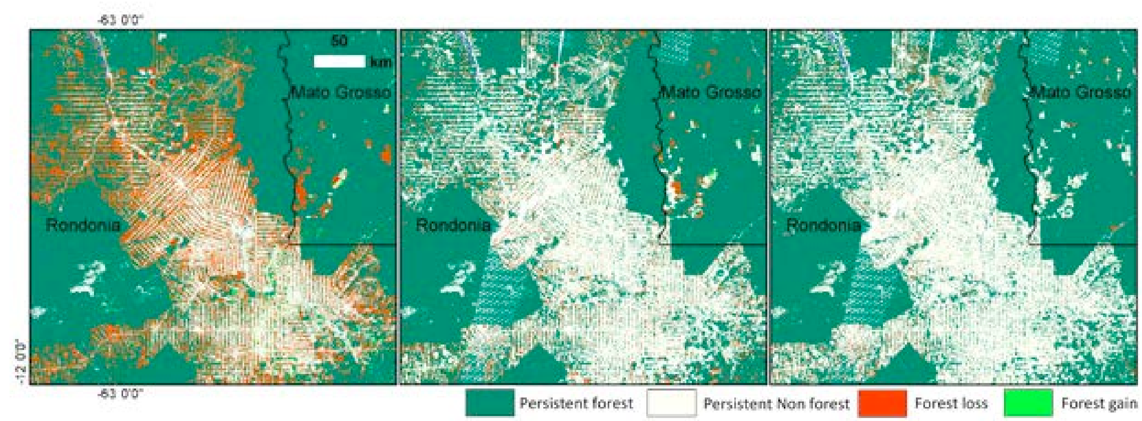


Wang, Xuhui, et al. "A two-fold increase of carbon cycle sensitivity to tropical temperature variations." Nature 506.7487 (2014): 212-215.



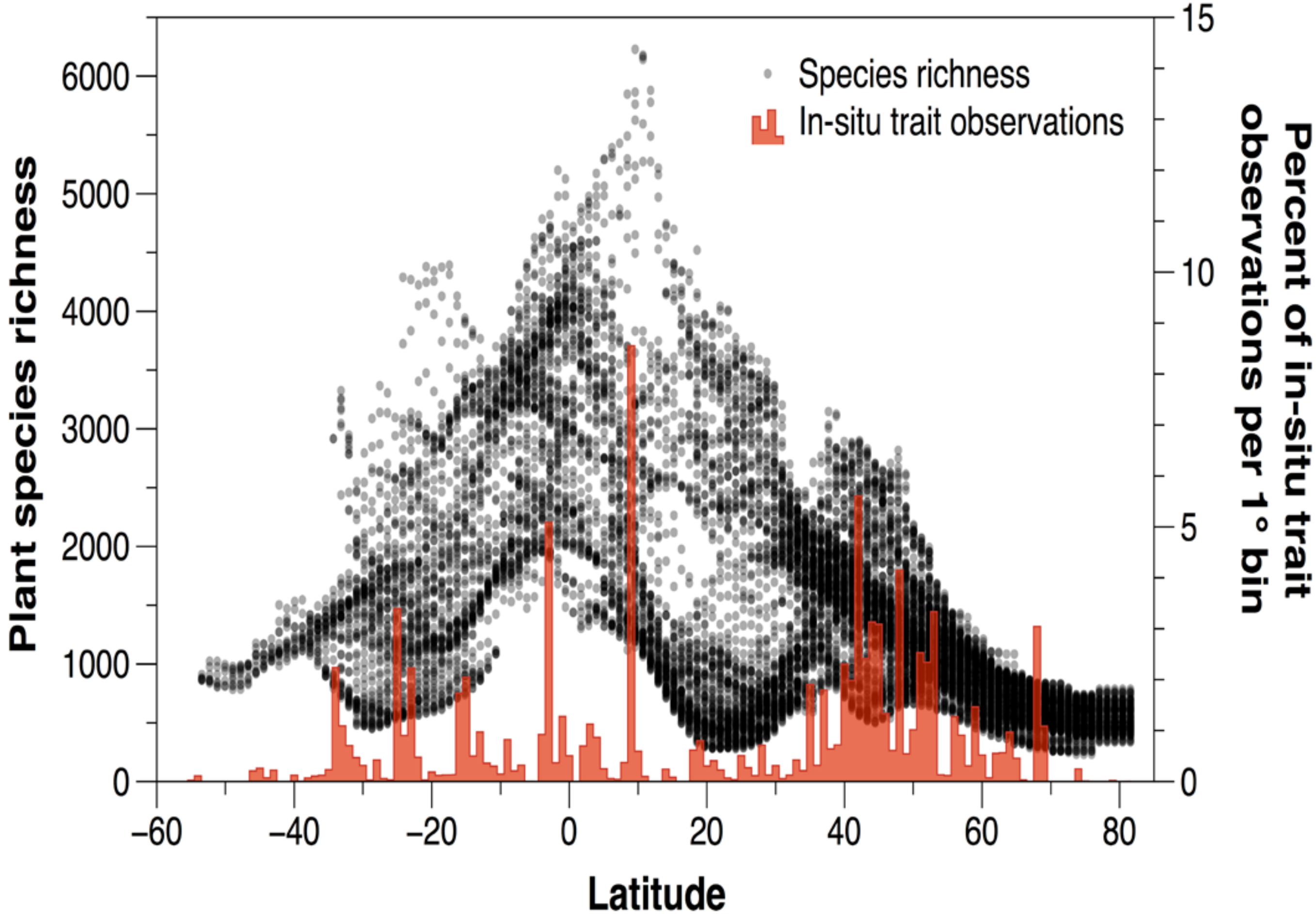
Espírito-Santo, Fernando DB, et al. "Size and frequency of natural forest disturbances and the Amazon forest carbon balance." Nature communications 5 (2014).

Fauset, Sophie, et al. "Hyperdominance in Amazonian forest carbon cycling." Nature Communications 6 (2015).

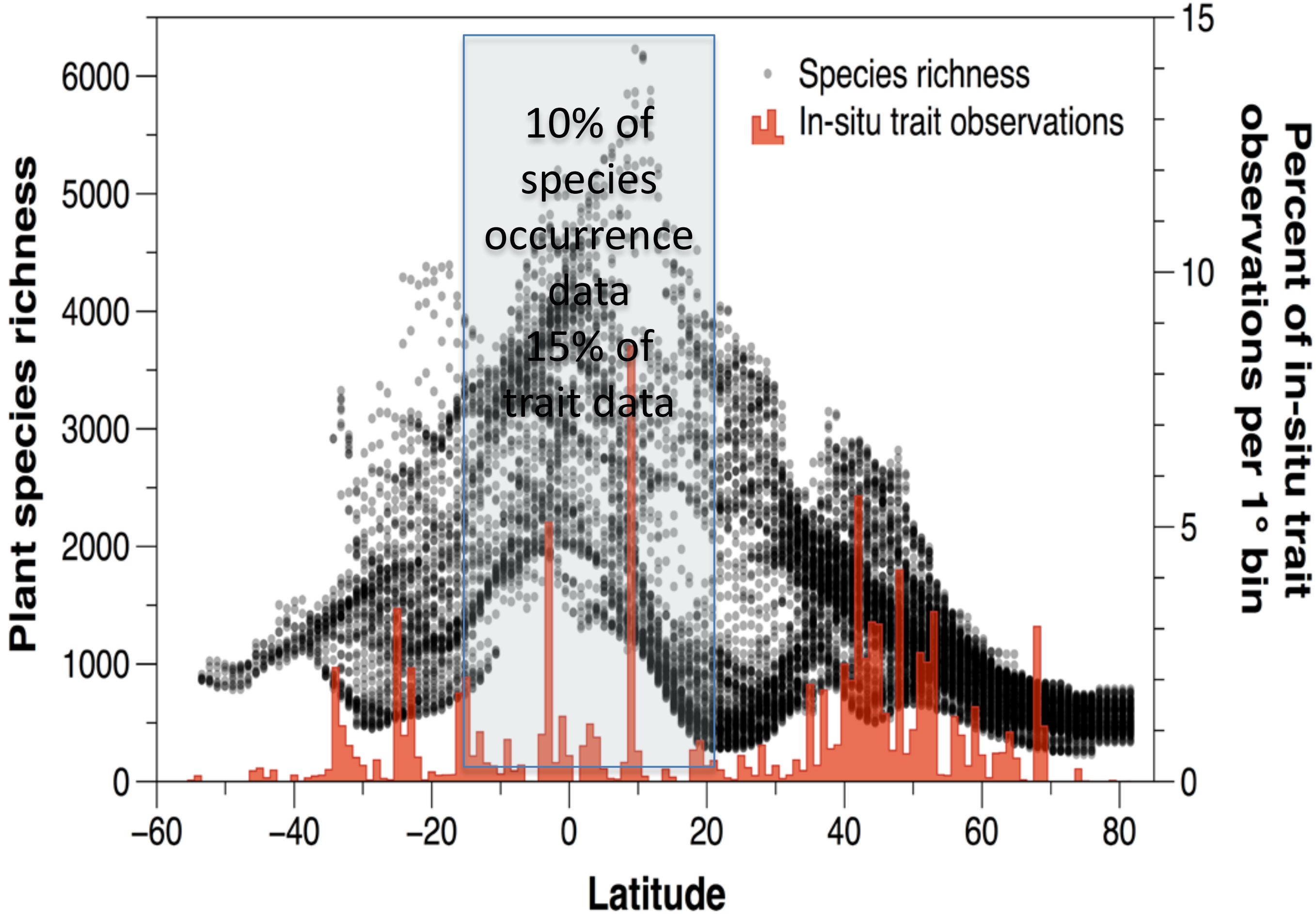


Landsat-based forest cover change map for 1990-2000 (left), 2000-2005 (middle) and, 2005-2010 (right) in Rondonia and Mato Grosso, Brazil.

The data gap: Estimated plant diversity, density of diversity observations and distribution of corresponding trait observations



The data gap: Estimated plant diversity, density of diversity observations and distribution of corresponding trait observations



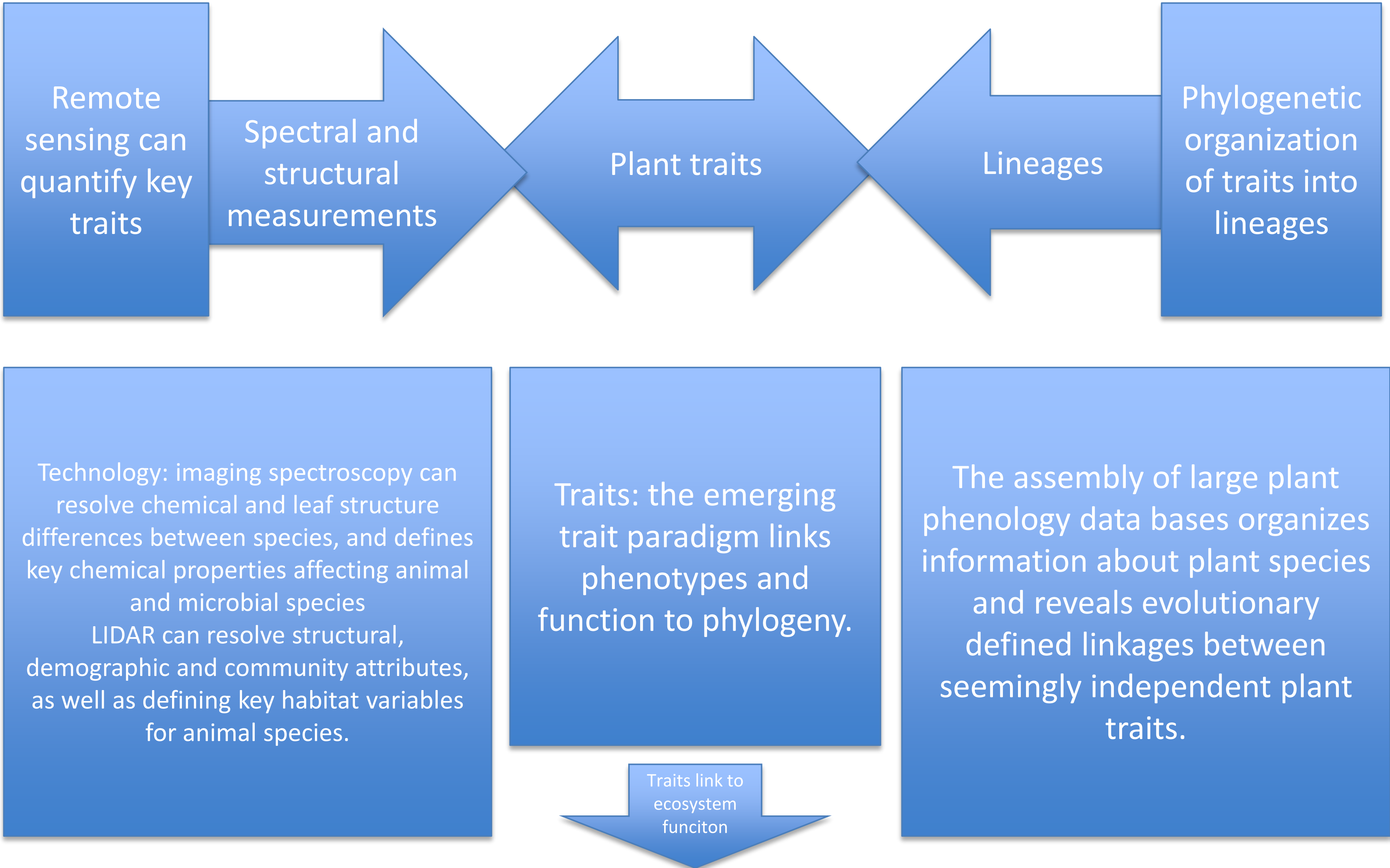
The most diverse regions are the least observed.

- The data gap means many attributes of today’s baseline plant diversity are highly uncertain.
- The data gap means that we lack a comprehensive baseline against which to measure change.
- The pace of data gathering means we have limited ability to observe change, except in select regions
- The data gap means we have no way of including functional diversity in global ecosystem models.

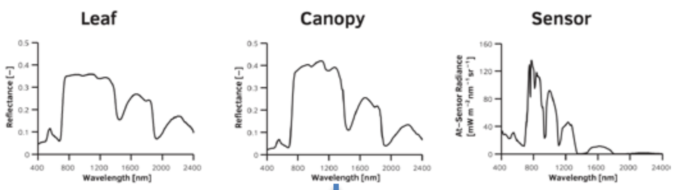
Other disciplines faced with this same challenge (insufficient coverage) have adopted technological solutions.

- Ecologists have historically been atechnological and have mainly adopted technology developed first in other fields (e.g. genomics, flux measurements, isotopes).
- Simultaneous developments in theory, informatics and technology create a technological option for direct, as opposed to multisensor, observation of plant diversity.
- Many other approaches are required, e.g., citizen science, but may not address sampling bias.

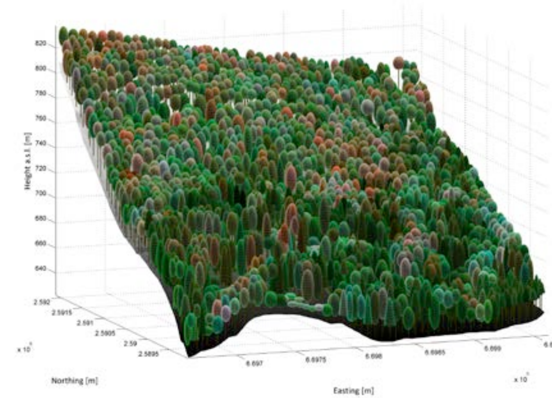
Advances in theory and technology link phylogeny and plant function to global observables



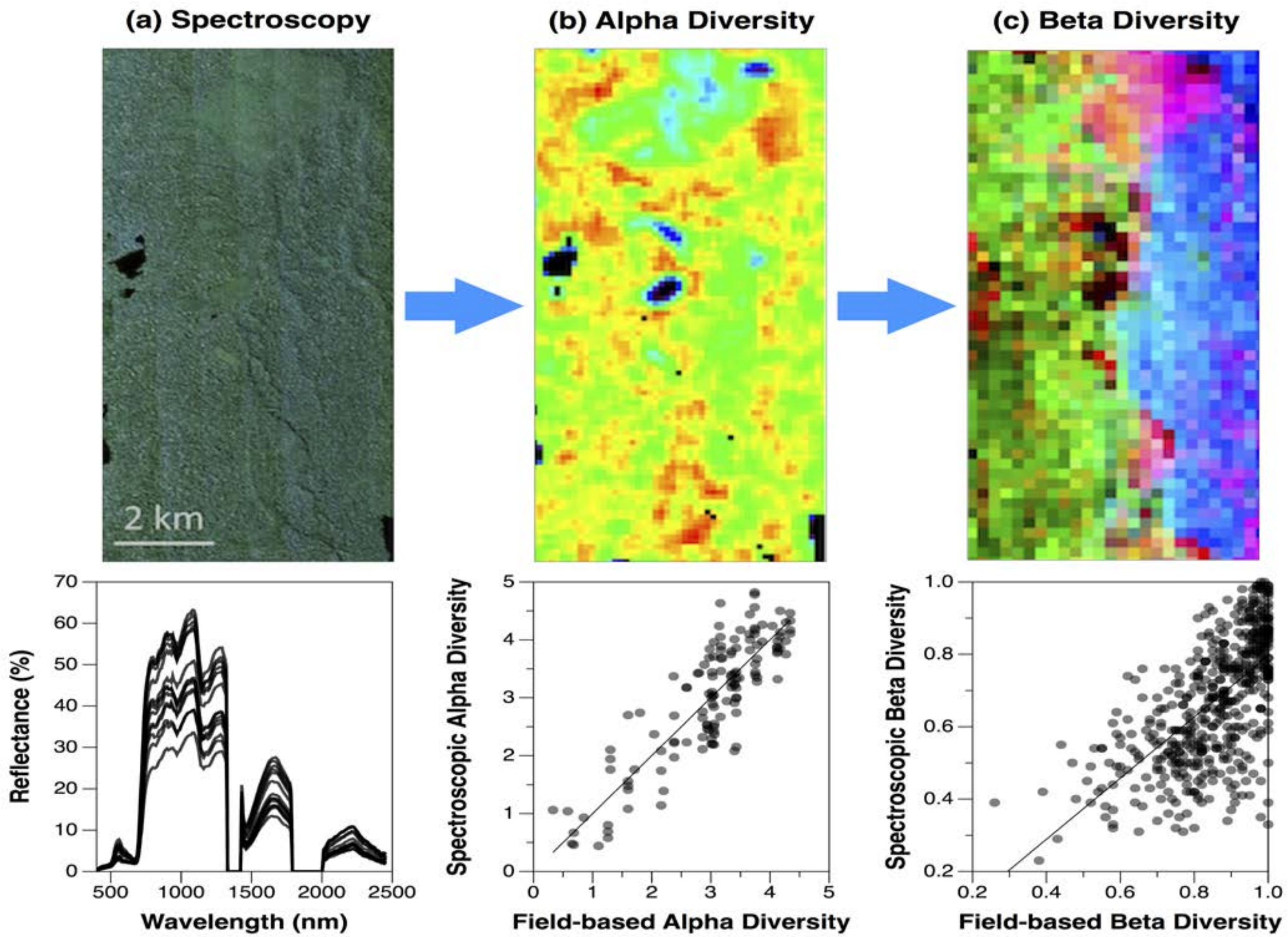
New remote sensing technologies can observe plant traits:
N, Chlorophyll. LMA, Vcmax, defense, architecture,



Imaging
Spectroscopy
&
LiDAR



Spectroscopy can also directly constrain richness and turnover



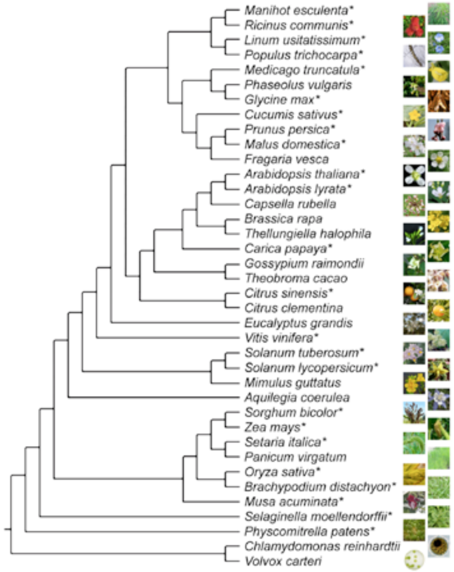
Feret and Asner 2015

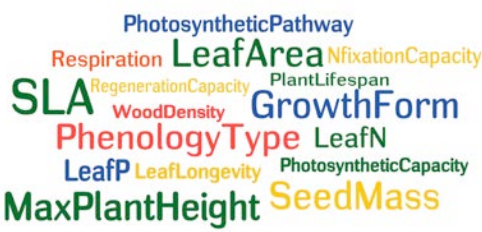
Phylogeny
Traits
Remote Sensing

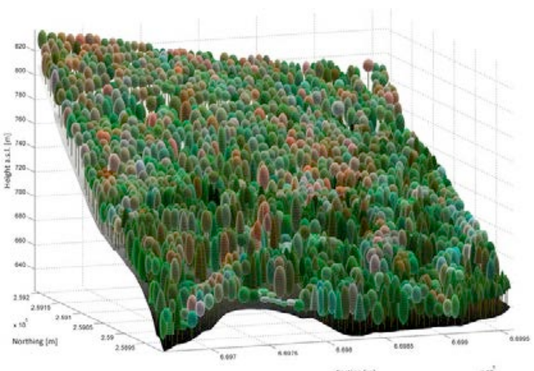
Advances in Theory
Combining Phylogeny,
Traits, and
Observational Methods

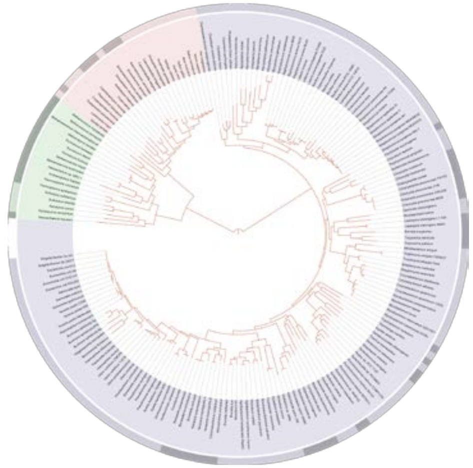
'Seeing' the
Tree of Life
Globally

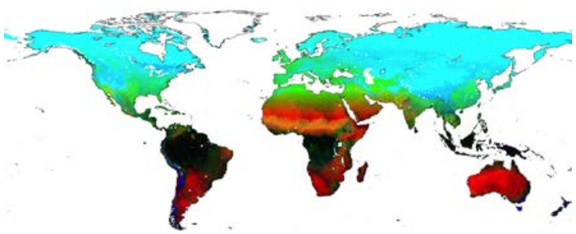
Adding Biodiversity
as a Key Component of
Earth System Science
Facilitated by
'Big Data' Research



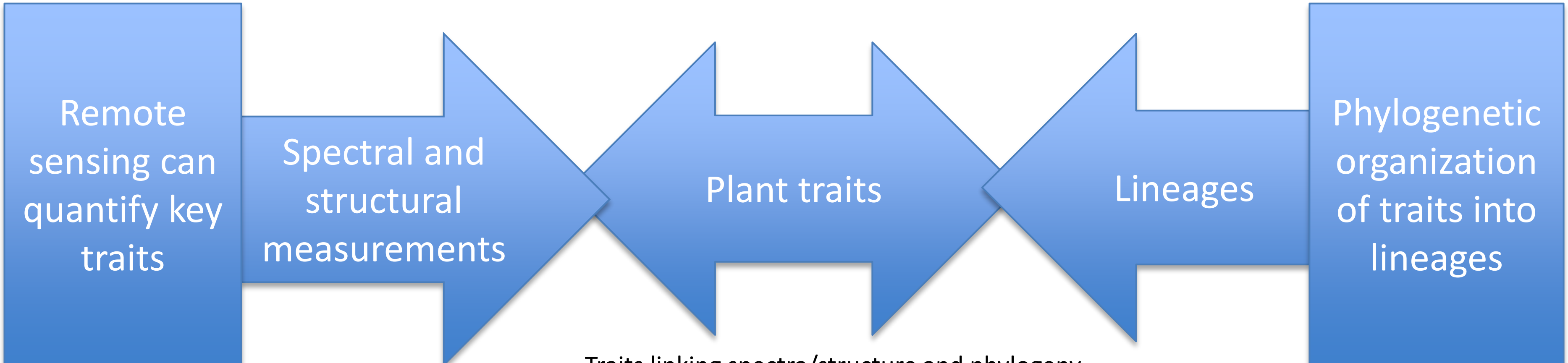




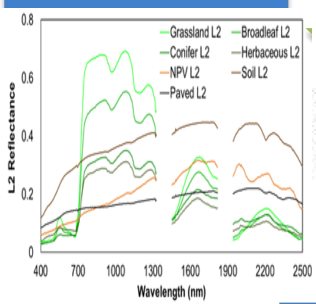


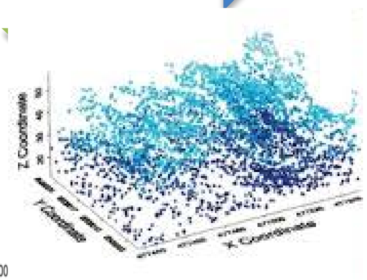


Advances in theory and technology link phylogeny and plant function to global observables



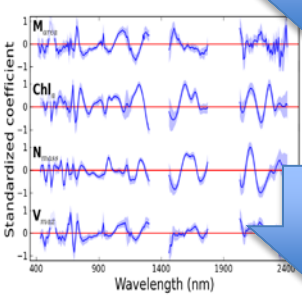
Traits linking spectra/structure and phylogeny

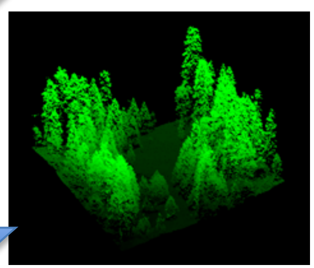




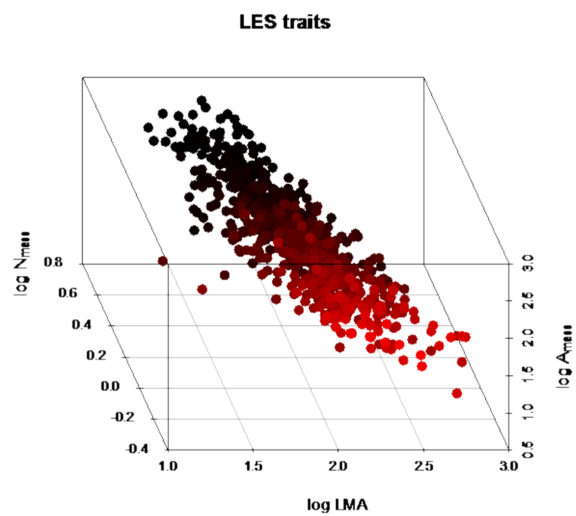
Reflectance spectra -> traits

LIDAR point clouds ->traits



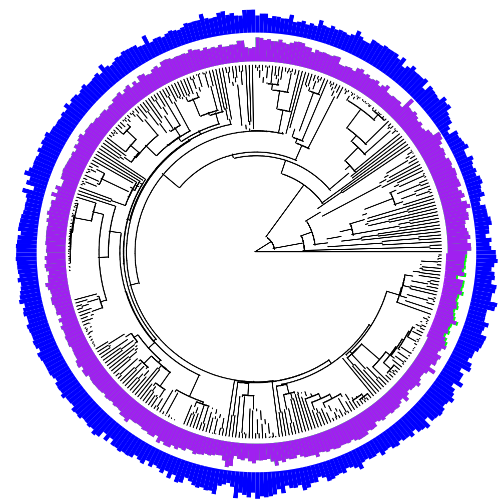


Estimates of leaf N, leaf area/area and V_{cmax} From spectra and LIDAR



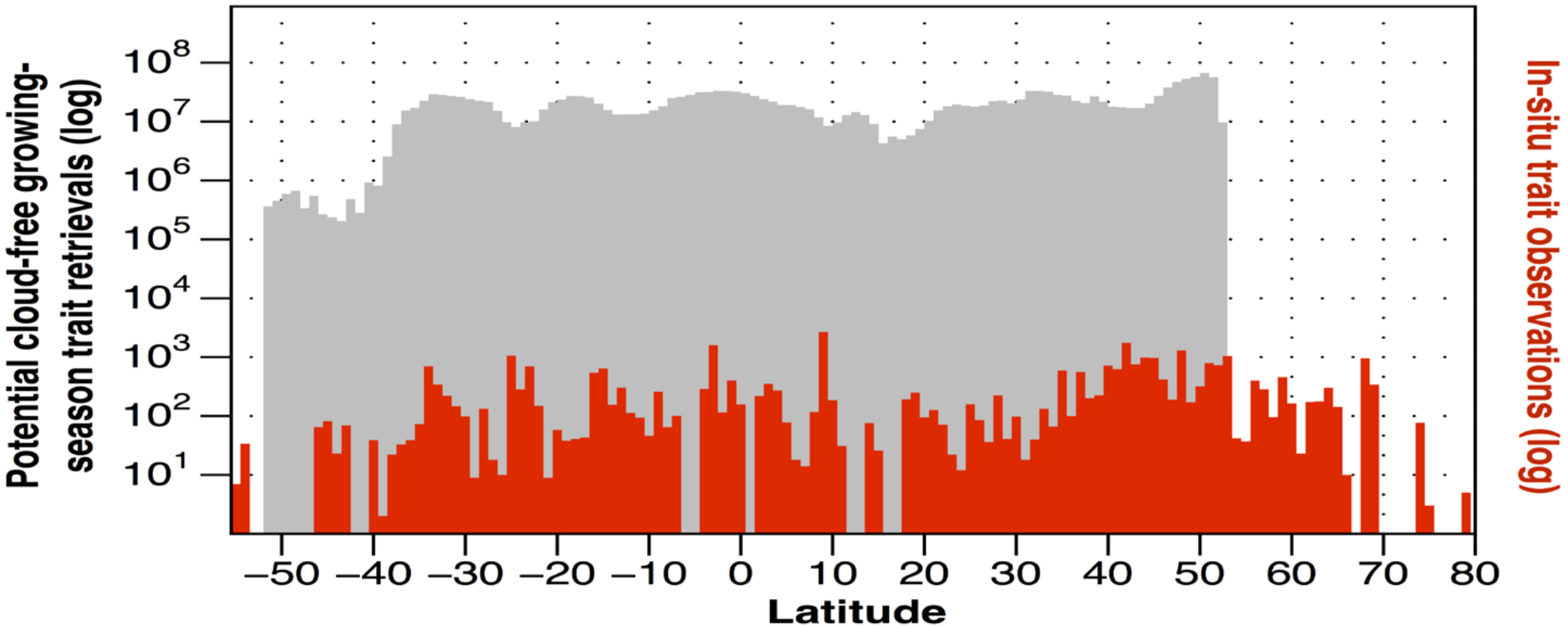
Traits and their correlation affect plant function and reflect phylogeny,

Traits are organized by phylogeny



Traits are organized by phylogeny and data bases and novel informaticscan link observable and unobservable traits (Zanne et al 2014). Blue shows N by species, purple is leaf mass/area

Data density from a space-based sensor: 6 orders of magnitude more data per degree latitude.



Space-based measurements will complement *in situ* techniques by providing comprehensive coverage and change detection.

All of the earth sciences from geology to climatology extend process knowledge at fine scales to large regions or globally.

Environmental understanding at larger scales requires observations that capture dimensions of the entire system to place the microscopic measurements in context.

Conclusions

- Biodiversity data, while numerous, doesn’t sample the distribution of species on earth very well.
- These sampling biases cannot be addressed by simply gathering more of the same data.
- At current rates of change, human-mediated data gathering is too slow to either prduce a baseline against which further change may be measured, and too slow to monitor change.

Conclusions

- The challenges of biodiversity are too crucial to leave to “chance” observations and non-systematic sampling.
- Technology can provide a partial solution.
- Parallel developments in theory, informatics and technology allow observation of plant and habitat diversity from space.
- Remote sensing can quantify plant traits and their diversity globally.
- Trait observations link remote observations to phylogeny and ultimately evolution at a planetary scale.

Conclusions

Management is local but diversity issues are “teleconnected” globally so we must think globally when we act locally.