Biodiversity from Space: Observing life in the earth system

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


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
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10% of species occurrence data
15% of trait data

Latitude

Plant species richness

Percent of in-situ trait observations per 1° bin
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 atelectchnological 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

Remote sensing can quantify key traits

Spectral and structural measurements

Plant traits

Lineages

Phylogenetic organization of traits into lineages

Technology: imaging spectroscopy can resolve chemical and leaf structure differences between species, and defines key chemical properties affecting animal and microbial species. LIDAR can resolve structural, demographic and community attributes, as well as defining key habitat variables for animal species.

Traits: the emerging trait paradigm links phenotypes and function to phylogeny.

The assembly of large plant phenology data bases organizes information about plant species and reveals evolutionary defined linkages between seemingly independent plant traits.

Traits link to ecosystem function
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
Combining Phylogeny, Traits, and Observational Methods

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

Phylogeny
Traits
Remote Sensing

Advances in Theory

‘Seeing’ the Tree of Life Globally

Globally

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Traits linking spectra/structure and phylogeny

Reflectance spectra -> traits

LIDAR point clouds -> traits

Estimates of leaf N, leaf area/area and Vcmax
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 informatics can 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 produce 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.