Jet Propulsion Laboratory
California Institute of Technology

NCEAS

Scoping Study for Biodiversity Airborne Campaigns

Dave Schimel, Frank Davis, Greg Asner, Jeannine Cavender Bares, Paul Moorcroft, Stuart Davies, Phil Townsend, Ralph Dubayah, Liane Guild, Kyle Cavanaugh, Helene-Muller Landau, Michael Schaepmann, Forrest Hoffman, Jitendra Kumar, Daniel Jensen, Zhihui Wang

ROSES 2015 A.6 Biodiversity

- Scoping studies for potential biodiversity field campaigns that:
  - identify the **key scientific questions** to be addressed should the campaign be carried out
  - develop an **initial study design and implementation concept**

ROSES 2015 A.6 Biodiversity

- Plans for potential field campaigns should include:
  - ***in situ* surface sensors** that complement the airborne measurements (the airborne measurements must be the central focus and core observations of the campaign)
  - the **ER-2 aircraft** outfitted with at least two of the following three imaging spectrometers **PRISM**, **AVIRIS-NG**, and **HyTES**, along with the **LVIS** lidar
  - **relevant satellite datasets** from NASA and other sources (e.g., radars, other thermal infrared sensors, other lidars, etc.).

Key science questions should address one or both of:

- The **distribution and/or abundance of components of biodiversity** (focusing on one or more of ecosystems, species, and genes) and the **drivers and mechanisms of change** in the distribution and/or abundance of these components of biodiversity (ecosystems, species and genes)

- The **impacts of changing biodiversity** on the wider Earth System, e.g., the feedbacks from biodiversity to climate and/or other aspects of the Earth system


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NASA


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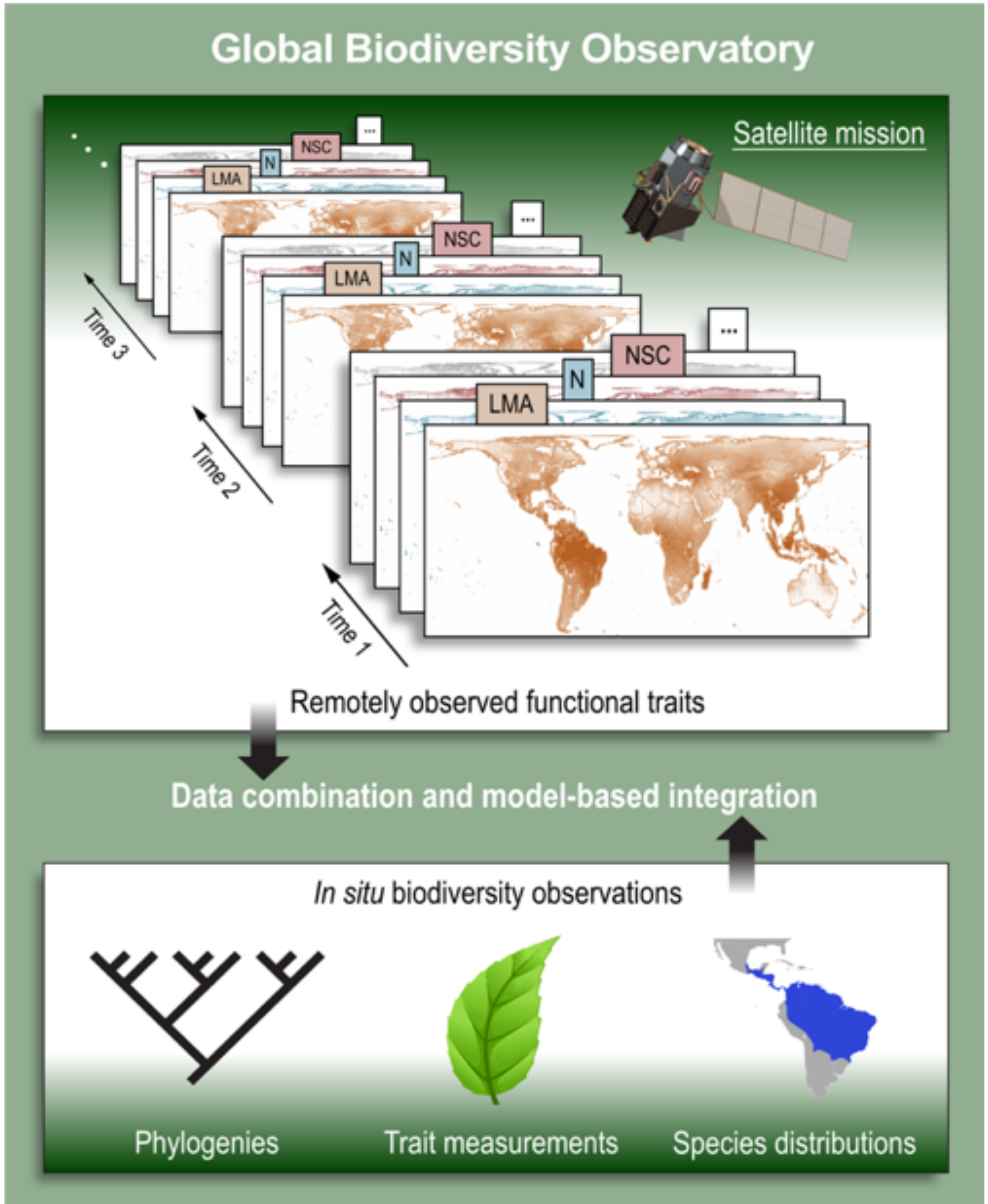
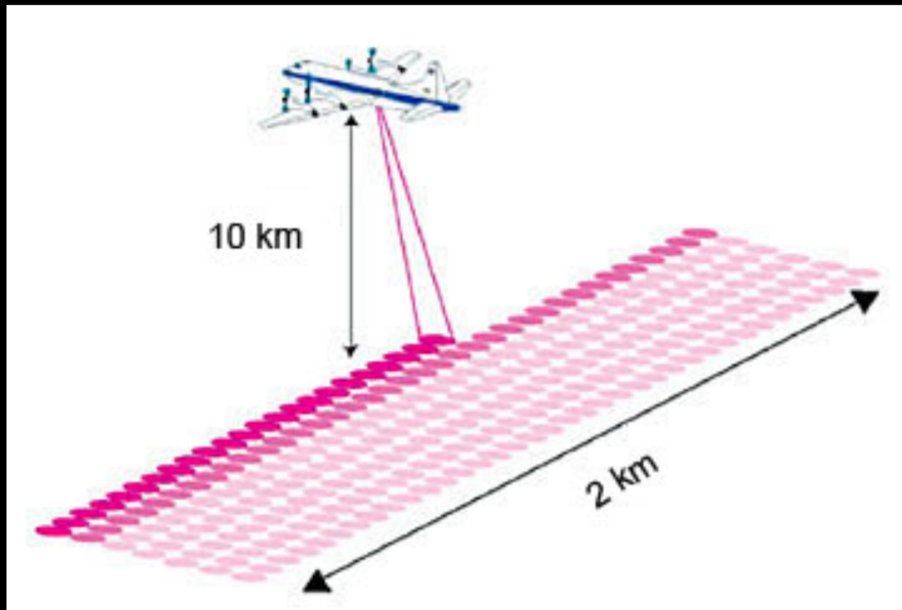
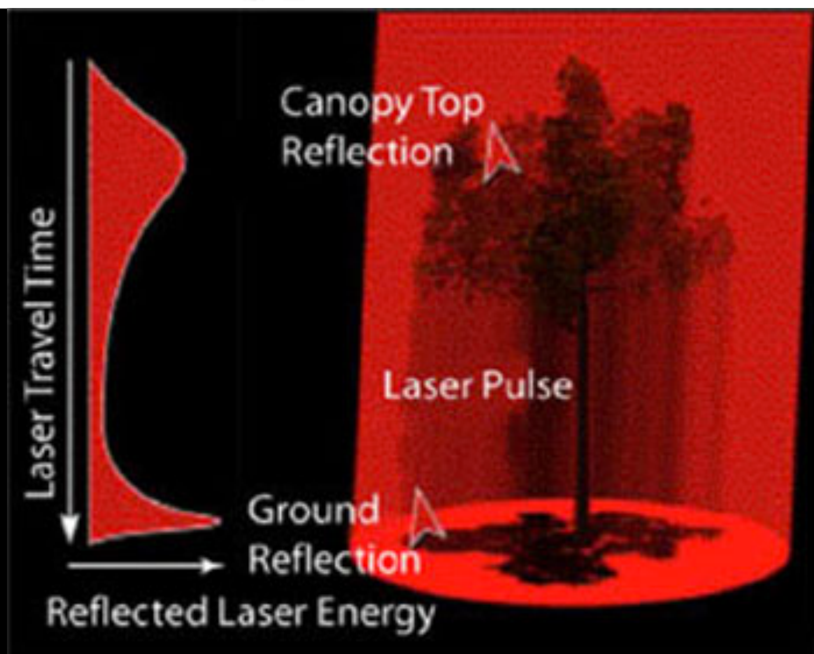
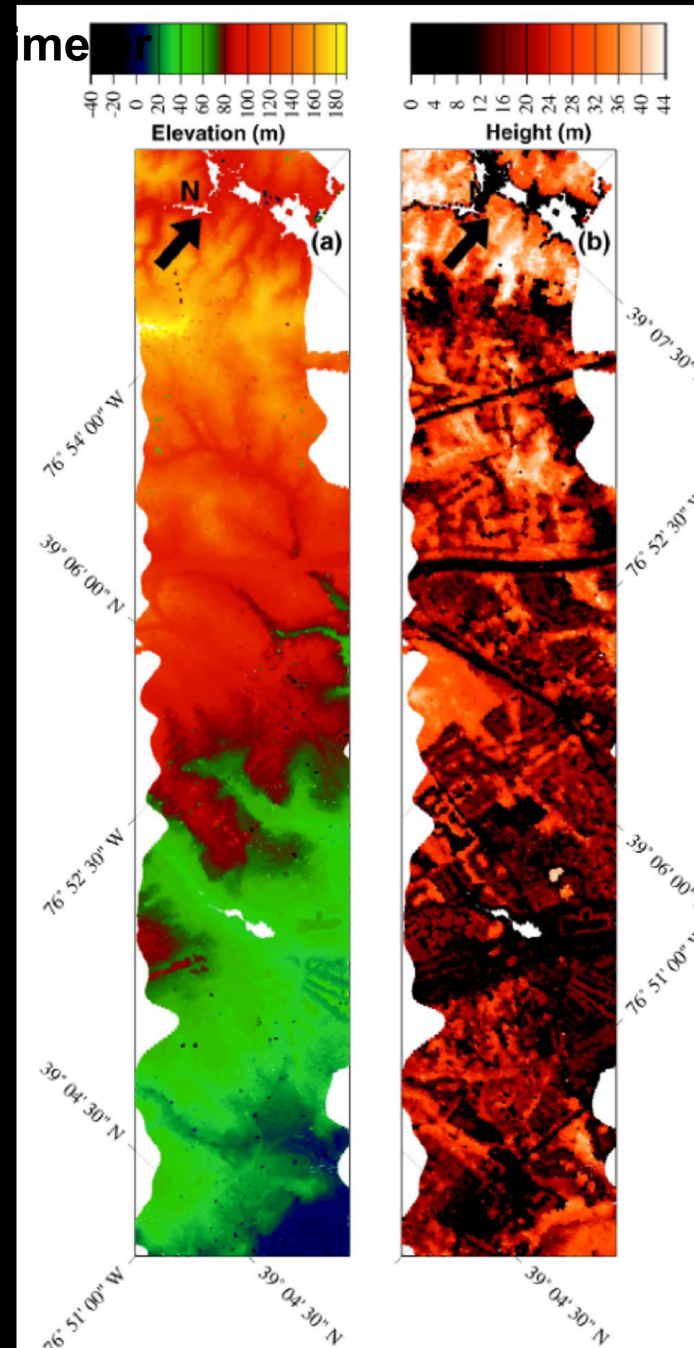

Global Biodiversity Observatory
Satellite mission
NSC
N
LMA
...
Time 3
Time 2
Time 1
Remotely observed functional traits
Data combination and model-based integration
In situ biodiversity observations
Phylogenies
Trait measurements
Species distributions


10 km
2 km

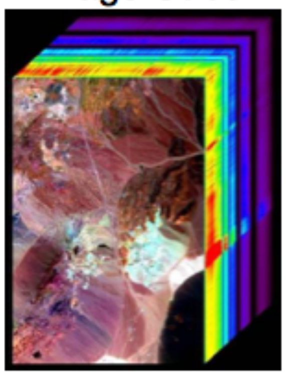

Canopy Top
Reflection
Laser Pulse
Ground
Reflection
Laser Travel Time
Reflected Laser Energy


-40 -20 0 20 40 60 80 100 120 140 160 180
Elevation (m)
0 4 8 12 16 20 24 28 32 36 40 44
Height (m)
N
(a)
(b)
76° 54' 00" W
39° 06' 00" N
76° 52' 30" W
39° 04' 30" N
76° 51' 00" W
39° 07' 30" N
39° 06' 00" N
76° 51' 00" W
39° 04' 30" N

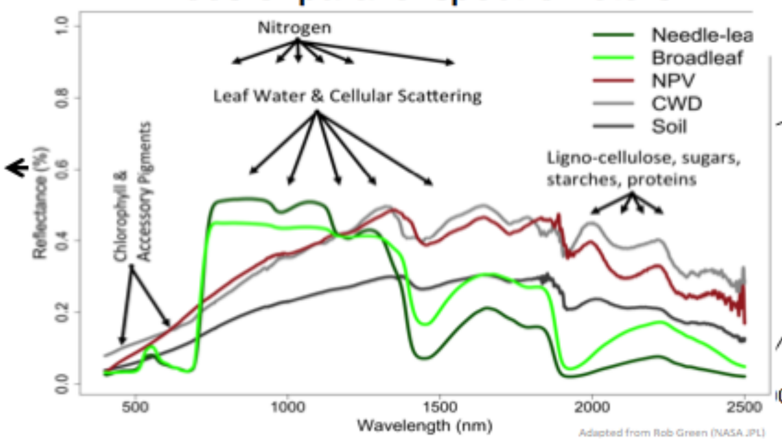
AVIRIS

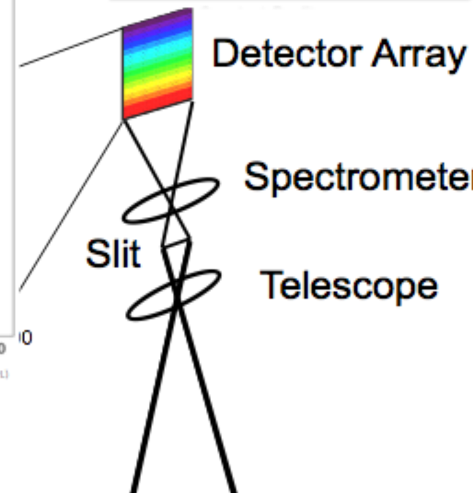
Airborne Visible / Infrared Imaging Spectrometer

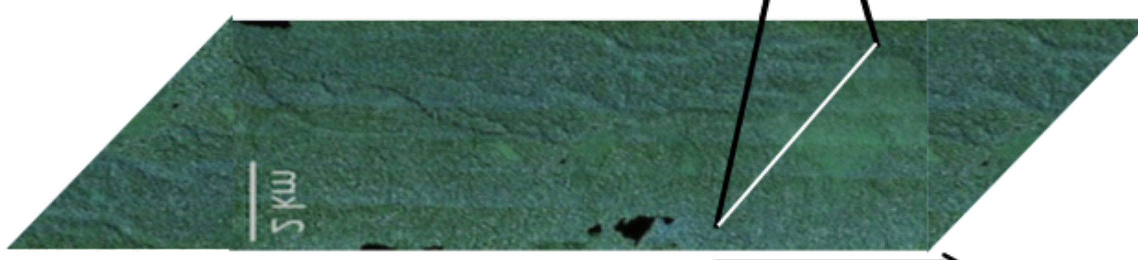
Calibrated Image Cube

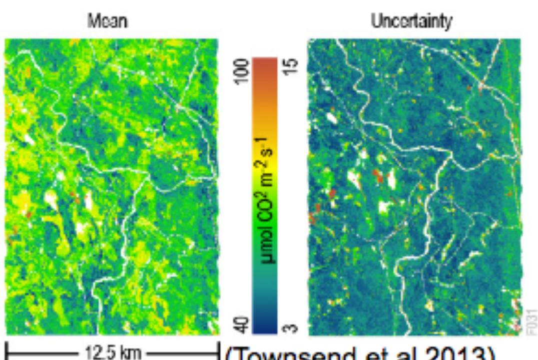


100s of parallel spectrometers







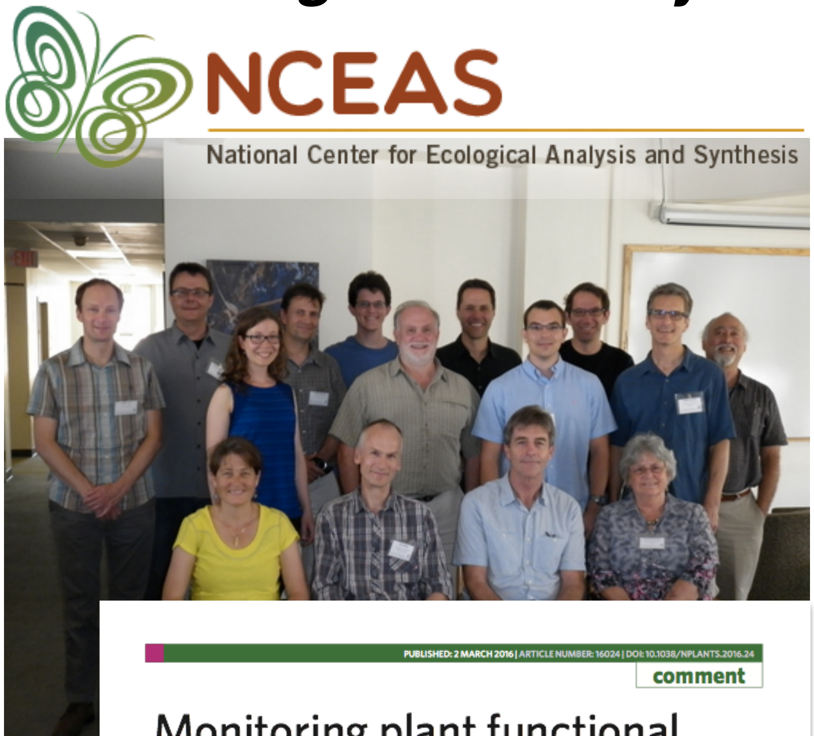


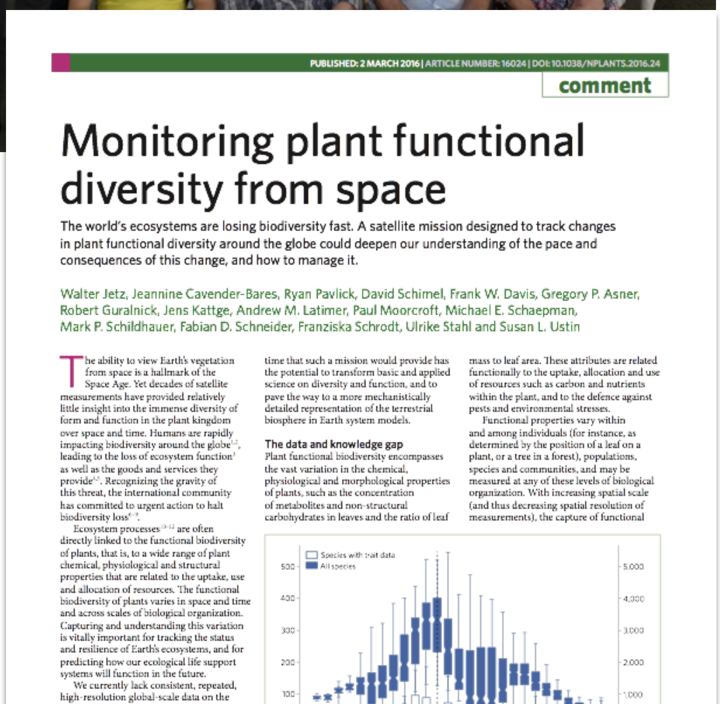
(Townsend et al 2013)

Plant trait maps

Source: Rob Green

Observing Biodiversity From Space workshop series





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comment

Monitoring plant functional diversity from space

The world's ecosystems are losing biodiversity fast. A satellite mission designed to track changes in plant functional diversity around the globe could deepen our understanding of the pace and consequences of this change, and how to manage it.

Walter Jetz, Jeannine Cavender-Bares, Ryan Pavlick, David Schimel, Frank W. Davis, Gregory P. Asner, Robert Guralnick, Jens Kattge, Andrew M. Latimer, Paul Moorcroft, Michael E. Schaepman, Mark P. Schildhauer, Fabian D. Schneider, Franziska Schrodt, Ulrike Stahl and Susan L. Ustin

The ability to view Earth's vegetation from space is a hallmark of the Space Age. Yet decades of satellite measurements have provided relatively little insight into the immense diversity of form and function in the plant kingdom over space and time. Humans are rapidly impacting biodiversity around the globe[1,2], leading to the loss of ecosystem function[3] as well as the goods and services they provide[4,5]. Recognizing the gravity of this threat, the international community has committed to urgent action to halt biodiversity loss[6–9].

Ecosystem processes[10–12] are often directly linked to the functional biodiversity of plants, that is, to a wide range of plant chemical, physiological and structural properties that are related to the uptake, use and allocation of resources. The functional biodiversity of plants varies in space and time and across scales of biological organization. Capturing and understanding this variation is vitally important for tracking the status and resilience of Earth's ecosystems, and for predicting how our ecological life support systems will function in the future.

We currently lack consistent, repeated, high-resolution global-scale data on the functional biodiversity of the Earth's time that such a mission would provide has the potential to transform basic and applied science on diversity and function, and to pave the way to a more mechanistically detailed representation of the terrestrial biosphere in Earth system models.

The data and knowledge gap

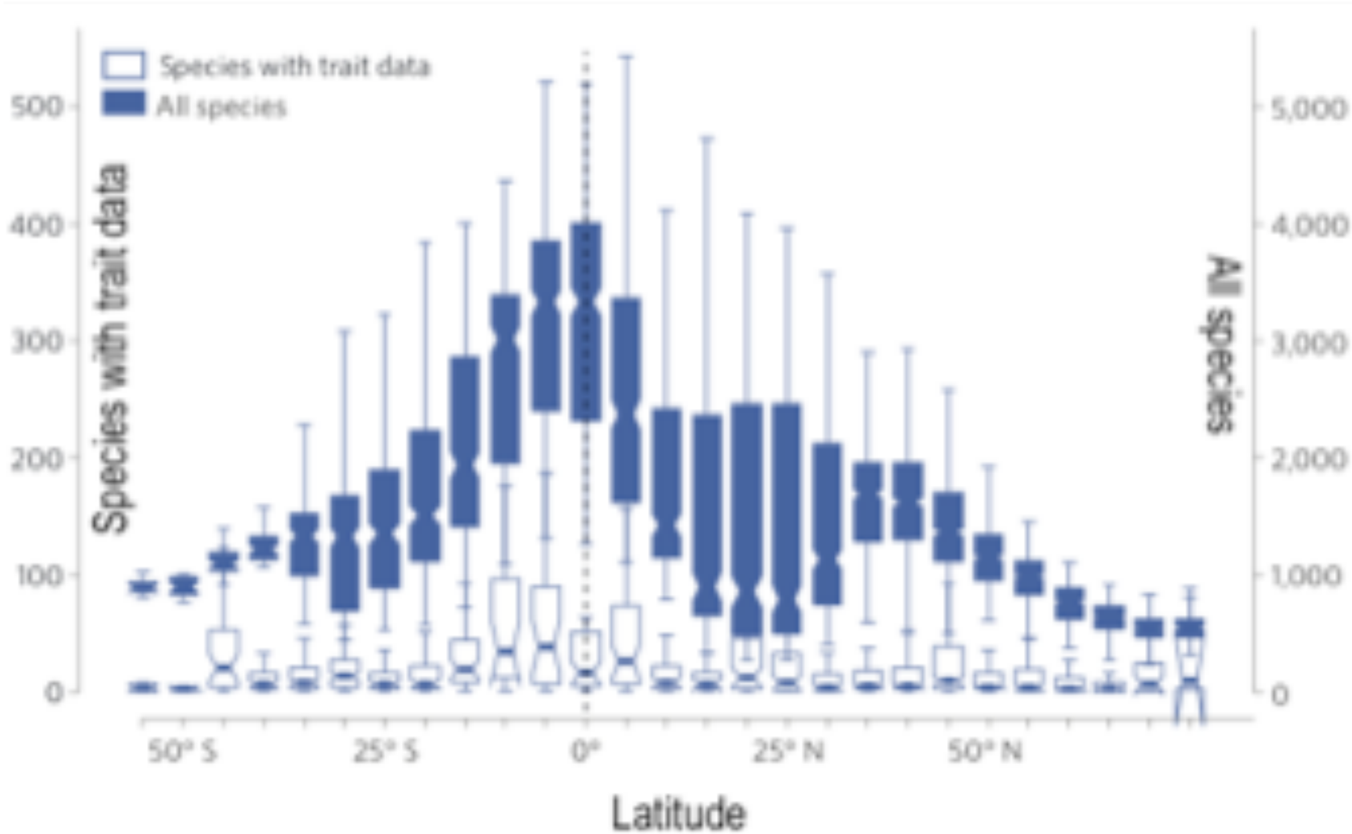
Plant functional biodiversity encompasses the vast variation in the chemical, physiological and morphological properties of plants, such as the concentration of metabolites and non-structural carbohydrates in leaves and the ratio of leaf mass to leaf area. These attributes are related functionally to the uptake, allocation and use of resources such as carbon and nutrients within the plant, and to the defence against pests and environmental stresses.

Functional properties vary within and among individuals (for instance, as determined by the position of a leaf on a plant, or a tree in a forest), populations, species and communities, and may be measured at any of these levels of biological organization. With increasing spatial scale (and thus decreasing spatial resolution of measurements), the capture of functional

Species with trait data
All species
500
400
300
200
100
5,000
4,000
3,000
2,000
1,000

- 2 workshops on terrestrial biodiversity in December 2014 and July 2015
- Outlining urgent policy needs and fundamental science questions
- Quantifying massive data gap
- Limitations of existing in-situ networks and satellites
- Maturity of airborne VSWIR algorithms
- Vision for a Global Biodiversity Observatory supported by a spectroscopic satellite mission
- RFIs to the NRC Decadal Survey
- Marine biodiversity workshop in June 2016

Observing Biodiversity From Space workshop series



The data gap

Observing Biodiversity From Space workshop series

Table 1 | Key functional plant traits that are remotely observable from space (see Supplementary Table 1 for more traits).

Trait	Trait definition	Trait functions	Trait role (refs)	Remote observation (refs)
Leaf mass per area (LMA) ($g\,m^{-2}$)	The dry mass of a leaf divided by its one-sided area measured when fresh. The reciprocal is specific leaf area (SLA).	A primary axis of the global leaf economics spectrum[11]	49,66,67	34,35,68–70
Nitrogen (N) (%)	Concentration of elemental nitrogen in a leaf or canopy.	Important for photosynthesis and other metabolic processes as a constituent of plant enzymes.	67,71,72	34,35,73–75
Non-structural carbohydrates (NSC) (%)	Direct products of photosynthesis (sugars and starches), not yet incorporated into plant structural components and thus readily assimilable.	Useful as an indicator of tolerance to environment stress	76	77
Chlorophyll ($mg\,g^{-1}$)	Green pigments.	Responsible for capturing light in the process of photosynthesis.	78,79	35,80,81
Carotenoids ($mg\,g^{-1}$)	Orange and yellow pigments.	Involved in the xanthophyll cycle for dissipating excess energy and avoiding oxygen radical damage under stress conditions (drought, chilling, low nutrients).	82,83	31,35
Lignin (%)	A complex organic polymer.	Provides mechanical support and a barrier against pests and pathogens; negatively correlated with tree growth rate and microbial decomposition.	84,85	32,35,73,86

Conceptual framework for selecting regions

- Gradients that capture ranges of:
  - **Organism sizes** from microscopic phytoplankton to large canopy trees **(need to understand scaling)**
  - **Alpha diversity** from agricultural monocultures to highly diverse rainforests; species-poor mid-ocean gyres to diverse upwelling regions **(are algorithms robust across diversity gradients?)**
  - **Ecosystem structure** including the degree of fragmentation due to human-disturbance

What are the

patterns, causes, and consequences

of plant functional biodiversity?

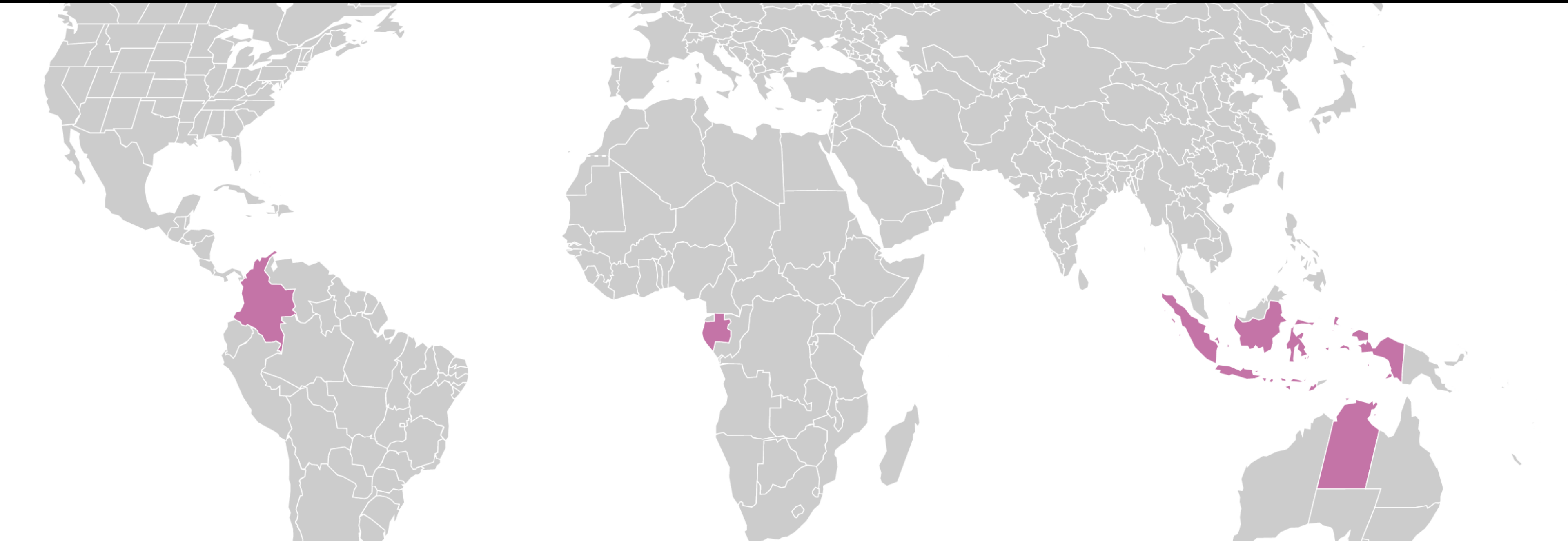
What are the dominant controls on the distribution of plant functional traits and their diversity within biomes?

Is it abiotic environment, evolutionary contingencies, biotic context, or historical human influences? (yes)

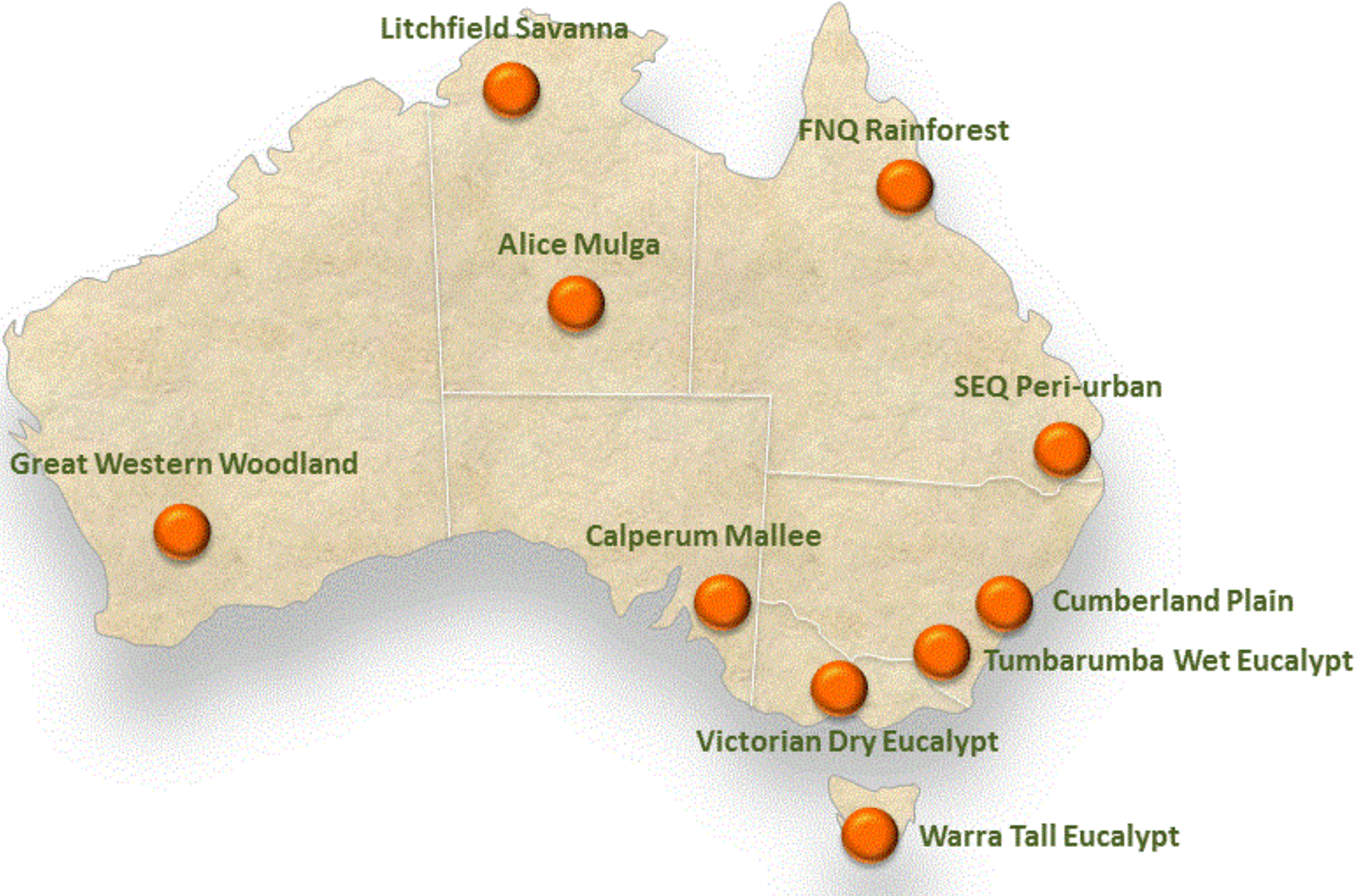
How will the projected loss of plant functional diversity affect Earth system functioning through changes in carbon, water, and nutrient cycling?

How do the distribution and diversity of animal, plant, and fungal species vary with plant functional composition and diversity?


CAO
C-GJPY
Carnegie Airborne



Scotty Creek
Wabikon Lake Forest
Michigan Big Woods
Haliburton Forest
Wind River
UMBC
Harvard Forest
Lilly Dickey
Yosemite
SERC
Santa Cruz
SCBI
Tyson Research Center
Cedar Breaks
Laupahoehoe
Palamanui
Luquillo
San Lorenzo
Cocoli
Barro Colorado Island
La Planada
Yasuni
Amacayacu
Manaus
Ilha do Cardoso
Wytham Woods
Speulderbos
Zofin
Ngel Nyaki
Korup
Rabi
Ituri
Mpala
Mudumalai
Sinharaja
Daxing'angling
Dinghushan
Donlingshan
Changbaishan
Baotianman
Badagongshan
Heishiding
Gutianshan
Tiantongshan
Baishanzu
Fushan
Lienhuachih
Nanjenshan
Nonggang
Xishuangbanna
Doi Inthanon
Huai Kha Khaeng
Hainan
Hong Kong
Palanan
Mo Singto
Danum Valley
Kuala Belalong
Khao Chong
Lambir
Pasoh
Bukit Timah
Wanang



Litchfield Savanna
FNQ Rainforest
Alice Mulga
SEQ Peri-urban
Great Western Woodland
Calperum Mallee
Cumberland Plain
Tumbarumba Wet Eucalypt
Victorian Dry Eucalypt
Warra Tall Eucalypt

Scoping study timeline

- First workshop (March 2017)
- Present at NASA biodiversity meeting (May) and ESA (August)
- Post written draft on cce.nasa.gov and advertise for comments (August)
- Final workshop (Fall 2018)
- Final report to Woody Turner (Feb 2018)