SCOPING STUDY FOR BIODOVERSITY AIRBORNE CAMPAIGNS

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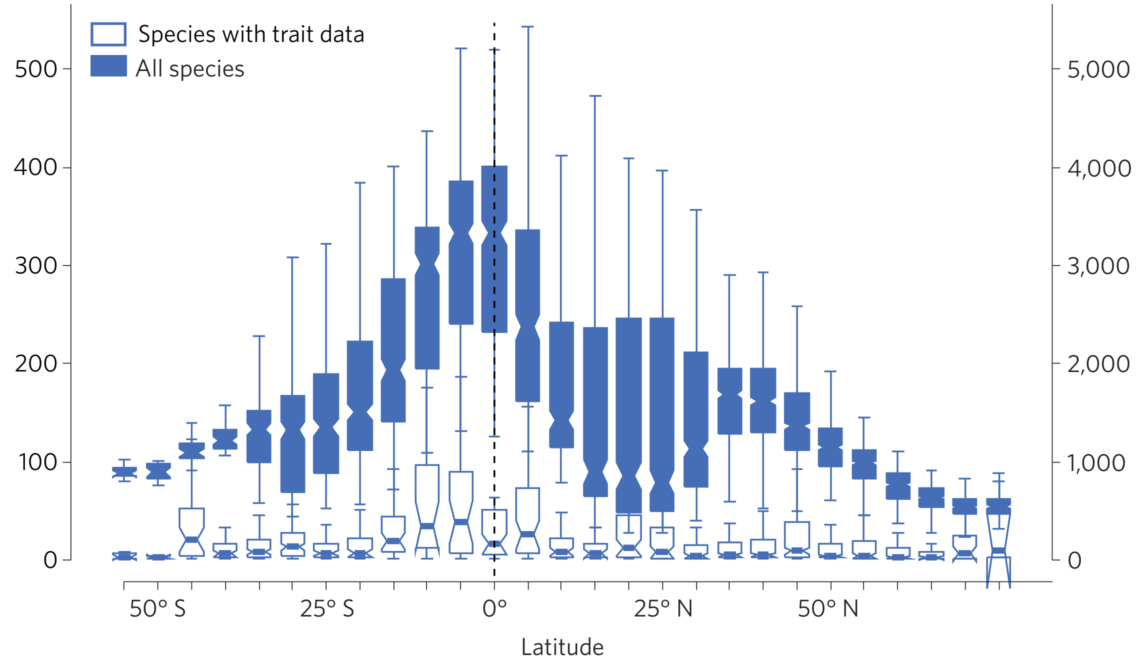
Grand Challenge Questions for Remote Sensing of Biodiversity

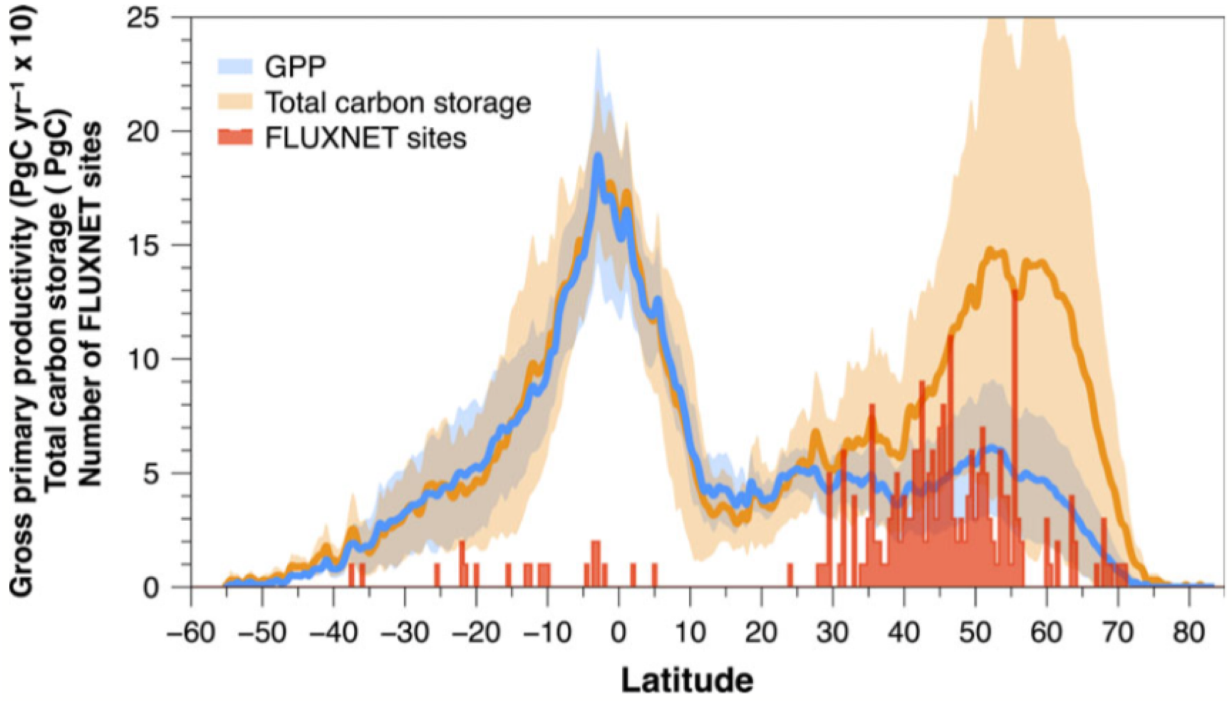
- Variation in fundamental traits between and within biomes?
- Variation in composition/diversity across organizational scales?
- Response of communities of differing functional diversity to environmental change (composition, ecosystem function)?
- Linkage across components of ecosystems:
    - Vegetation ~ belowground microbial diversity and function?
- Relevant phylogenetic resolution we can detect or need to detect?

Vegetation - Global Potential using Imaging Spectroscopy

Filling the data gap:



Trait Databases (Jetz et al. 2016)



Flux Data (Schimel et al. 2015)

Project Objectives

- Scoping study to design an airborne campaign to:
  - Characterize the global range of functional trait diversity, ecosystem structure, and corresponding scales of variation using airborne and in-situ data.
    - Identify target sites with existing data (and partners) and that capture range of diversity
    - Test generality of algorithms and evaluate existing data
    - Logistics and implementation concept
    - Imaging spectroscopy (hyperspectral) data and integration

Methodology and Outcome

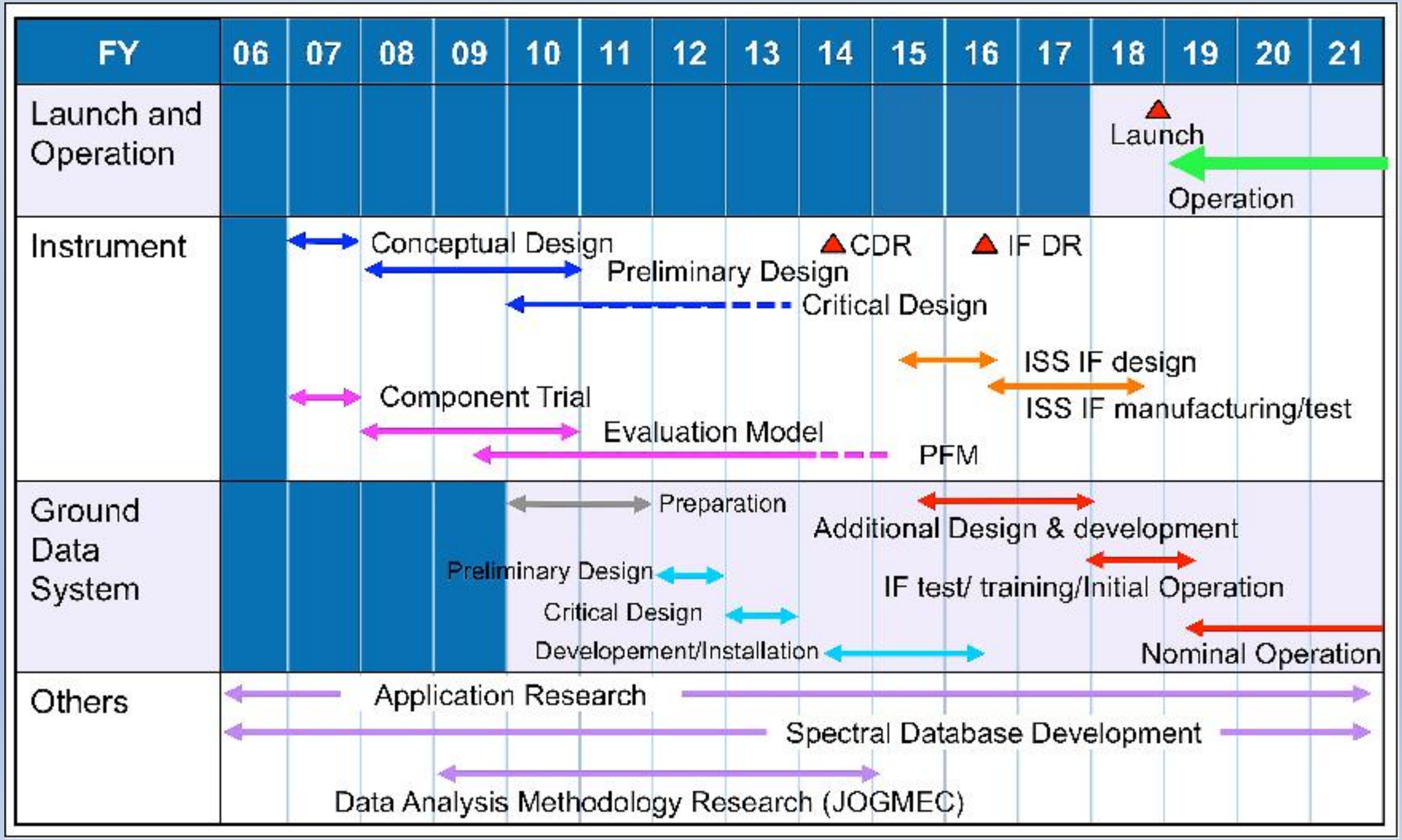
- Project meeting and telecons held in 2017
- Several concepts explored for mid-sized campaigns and EV-S3
- Japanese HISUI (ISS Imaging Spectrometer) announced (also EMIT)
  - Decadal survey missions (Surface Biology and Geology, SBG)

<u>Conclusions of Preliminary Work</u>

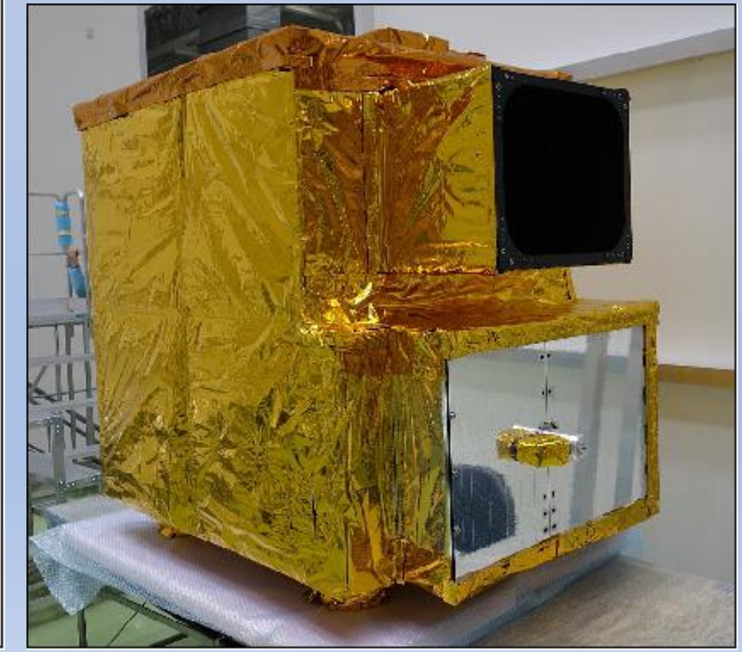
- Grand challenge question related to change cannot be addressed by a feasible and affordable airborne campaign. ***Limitations to snapshot sampling.***
- ***Airborne data are needed more broadly for inventory purposes and methods testing,*** but incrementally more data is insufficient to test hypotheses:
  - Effects of change on biodiversity
  - Phenological variability not captured
- Recommendation: An airborne experiment focused on key methodological and theoretical issues, complementary to global sampling by HISUI and potential Decadal Survey instruments, to address grand challenges.

HISUI

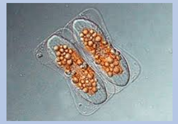
Ministry of Economy, Trade, and Industry (METI) of Japan
Mission focus: oil/gas/metal resources exploration

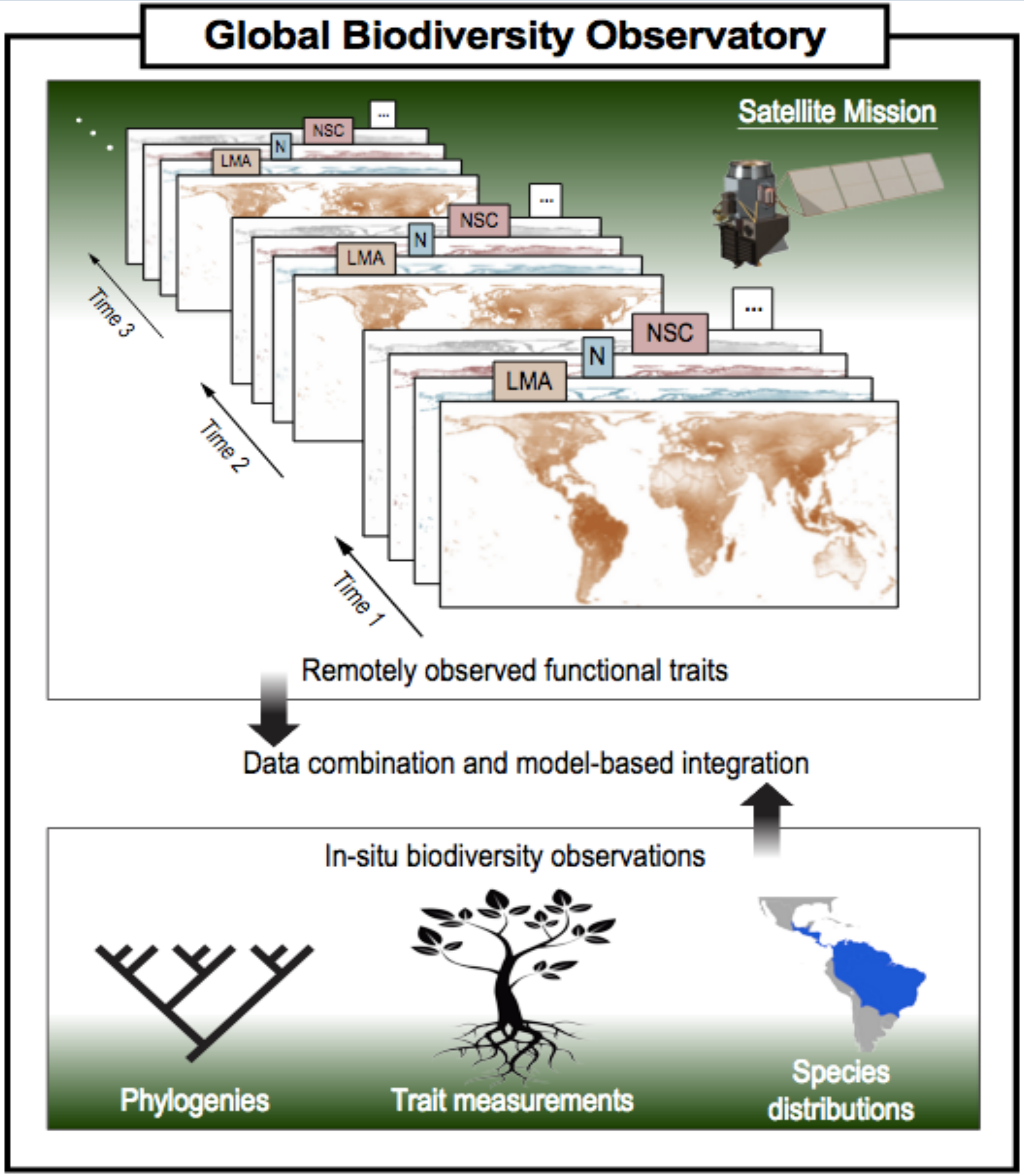


- 50° N to 50° S
- 400-2500 nm coverage
- 185 bands
- 20 km swath

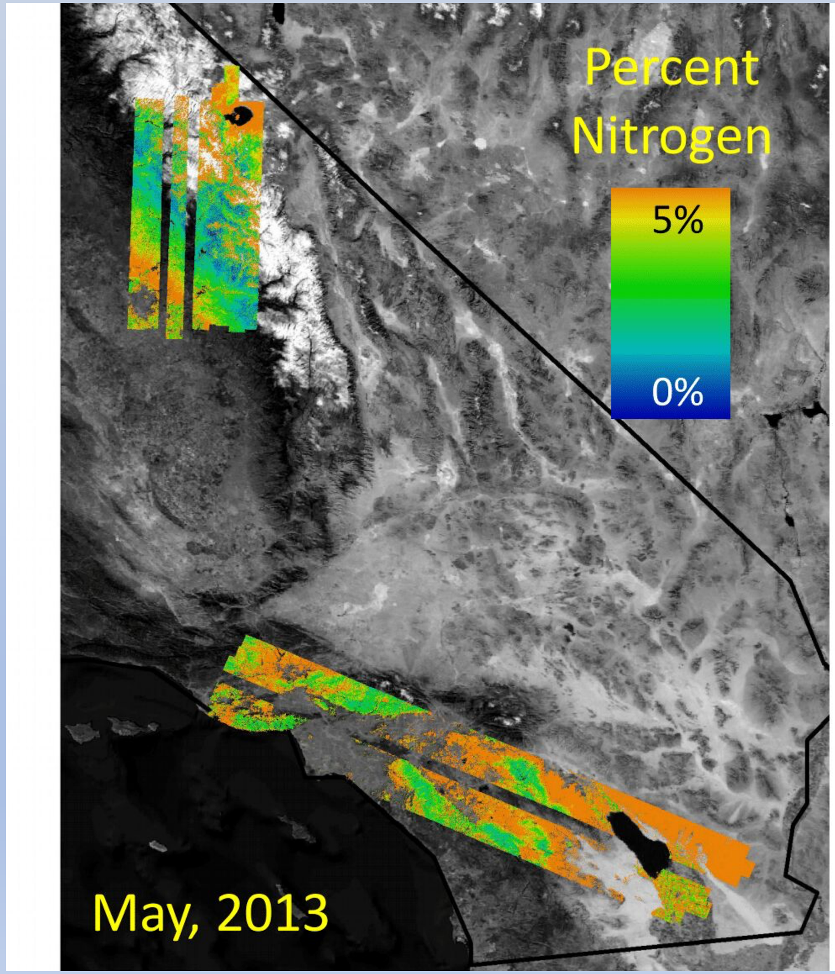


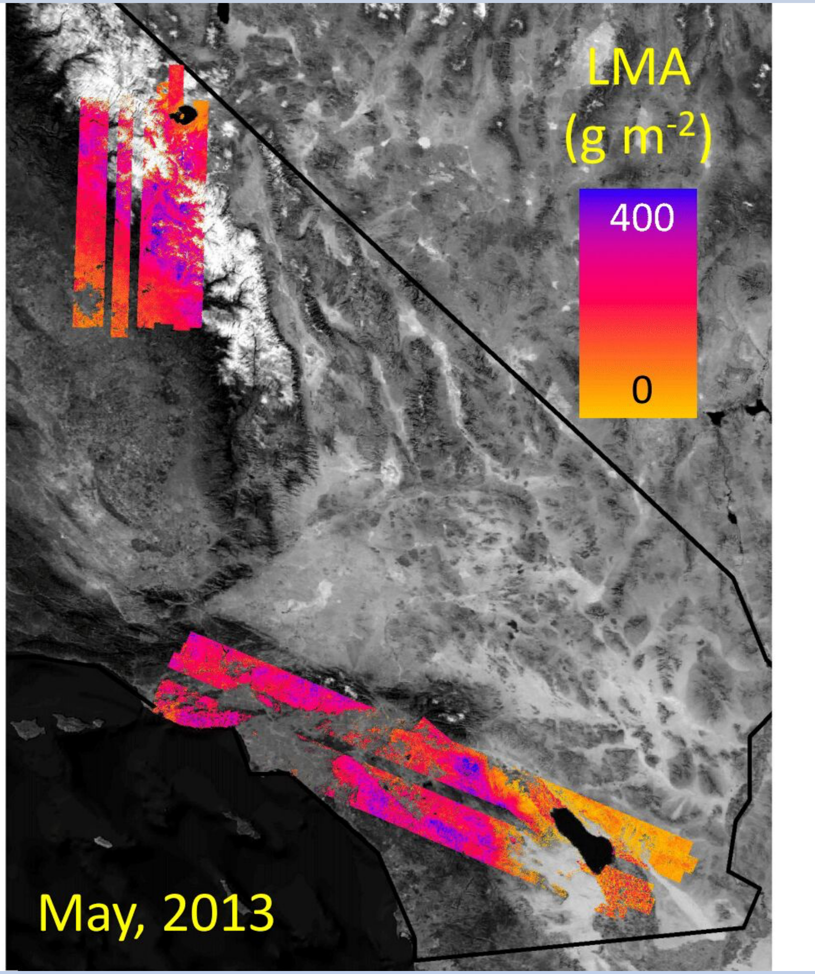
Key Challenges for Biodiversity from Space

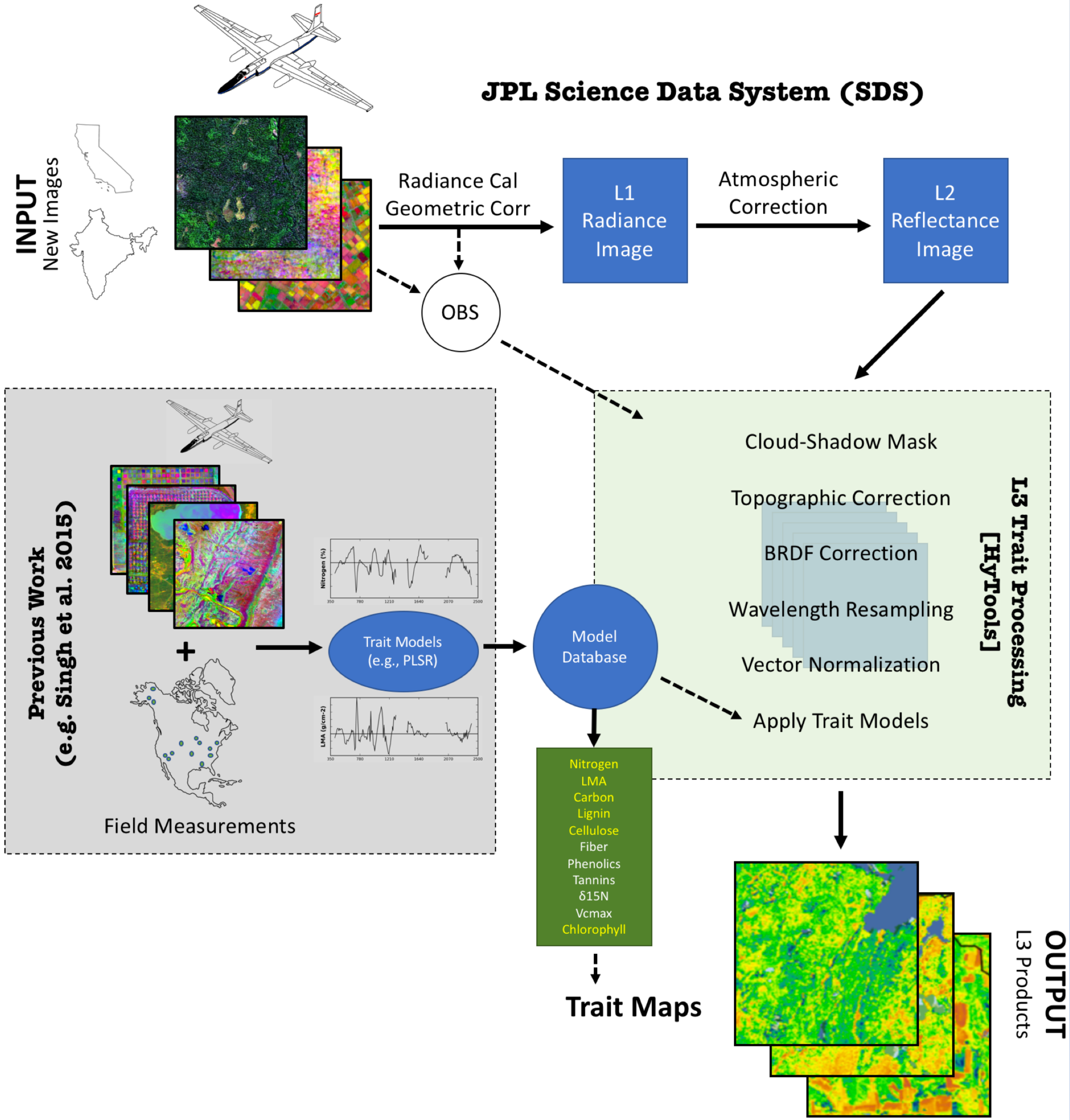
- Robust algorithms
- Change over time
- Scale   
- Data fusion (composition, function and structure)
- Remote and in situ data integration



[Robust Algorithms] Use Existing Data to Mature Algorithms Pre-Hyspiri Flights, AVIRIS India and Hawai'i

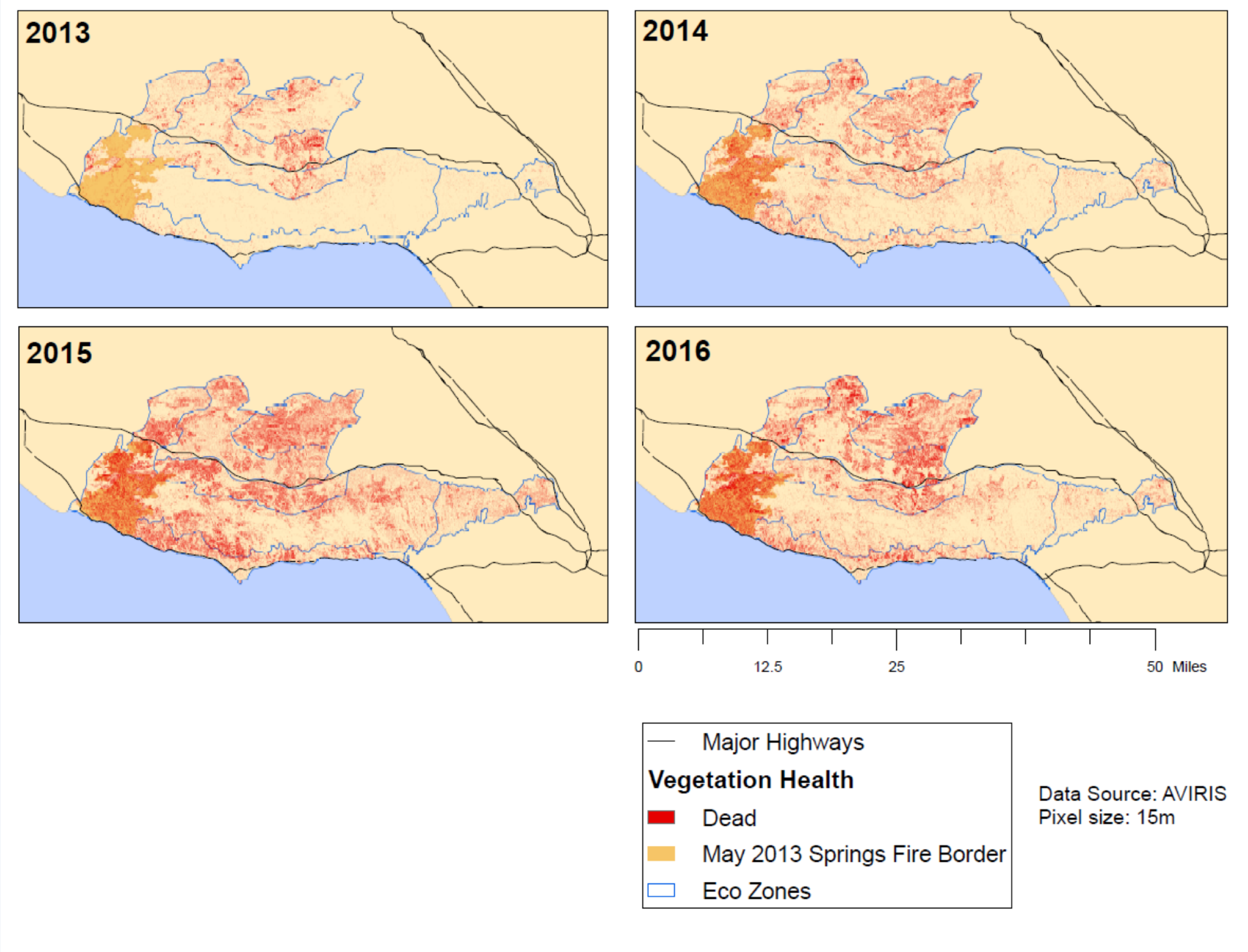






JPL Science Data System (SDS)
INPUT
New Images
Radiance Cal
Geometric Corr
L1
Radiance
Image
Atmospheric
Correction
L2
Reflectance
Image
OBS
Previous Work
(e.g. Singh et al. 2015)
+
Field Measurements
Trait Models
(e.g., PLSR)
Model
Database
Cloud-Shadow Mask
Topographic Correction
BRDF Correction
Wavelength Resampling
Vector Normalization
Apply Trait Models
L3 Trait Processing
[HyTools]
Nitrogen
LMA
Carbon
Lignin
Cellulose
Fiber
Phenolics
Tannins
δ15N
Vcmax
Chlorophyll
Trait Maps
OUTPUT
L3 Products

[Change over Time] Change over time: Santa Monica Dieback Prototype (DEVELOP)



Imaging Spectroscopy can quantify change over time despite uncertainties

[Data Synergism] Mammoth Lakes Case Study

- Volcanoes emit CO_2 and produce landscapes where CO_2 is chronically high, mimicking a future high-CO_2 world.
- Area can be located with similar soils and slope/aspect and normal CO_2 as controls.
- Airborne remote sensing is an ideal way to study these expansive and variable landscapes.

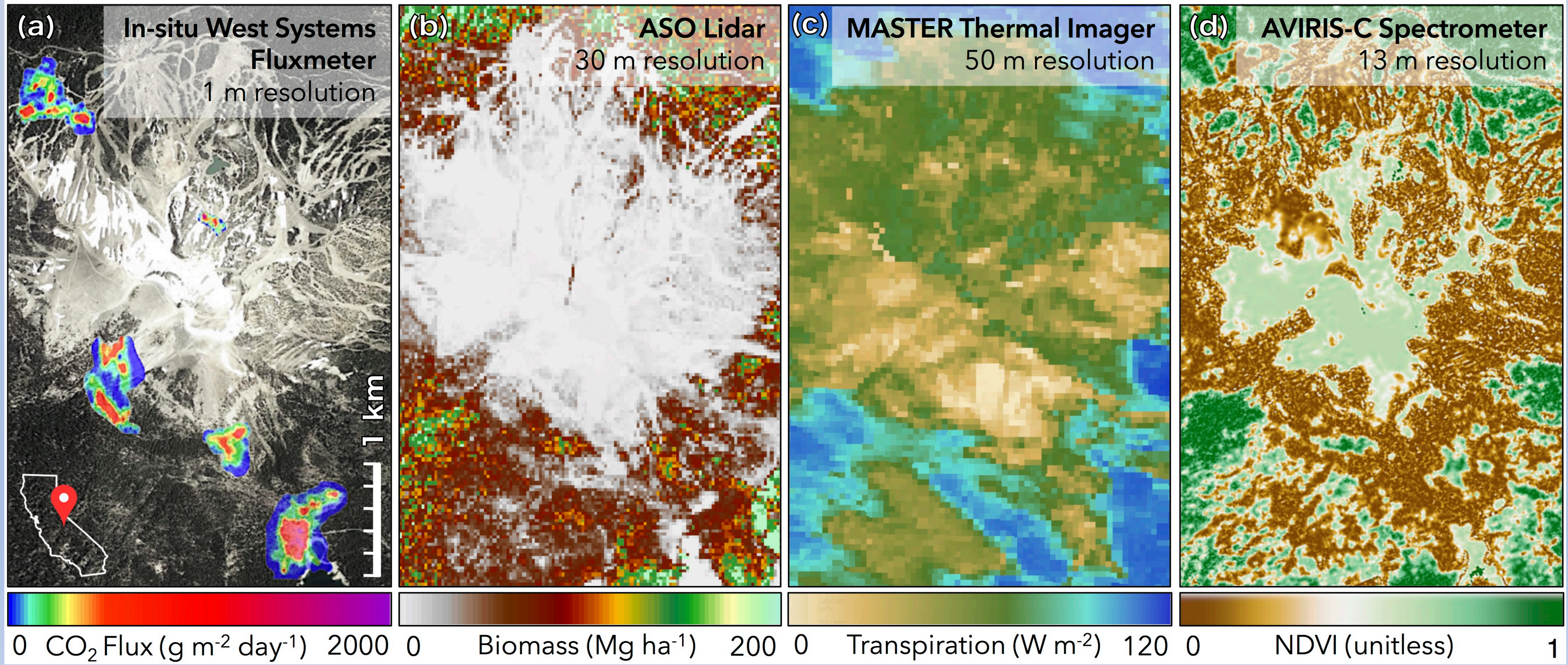
Data from AVIRIS, HyTES, ASO Lidar, CFIS

Characterize key diagnostics of long-term CO_2 response

- Plant functional traits, greenness (AVIRIS)
- Evapotranspiration (MASTER)
- Biomass and height (ASO Lidar)
- Photosynthesis (CFIS)
- Water use efficiency (CFIS/MASTER)
- Nitrogen Use Efficiency (CFIS/AVIRIS)

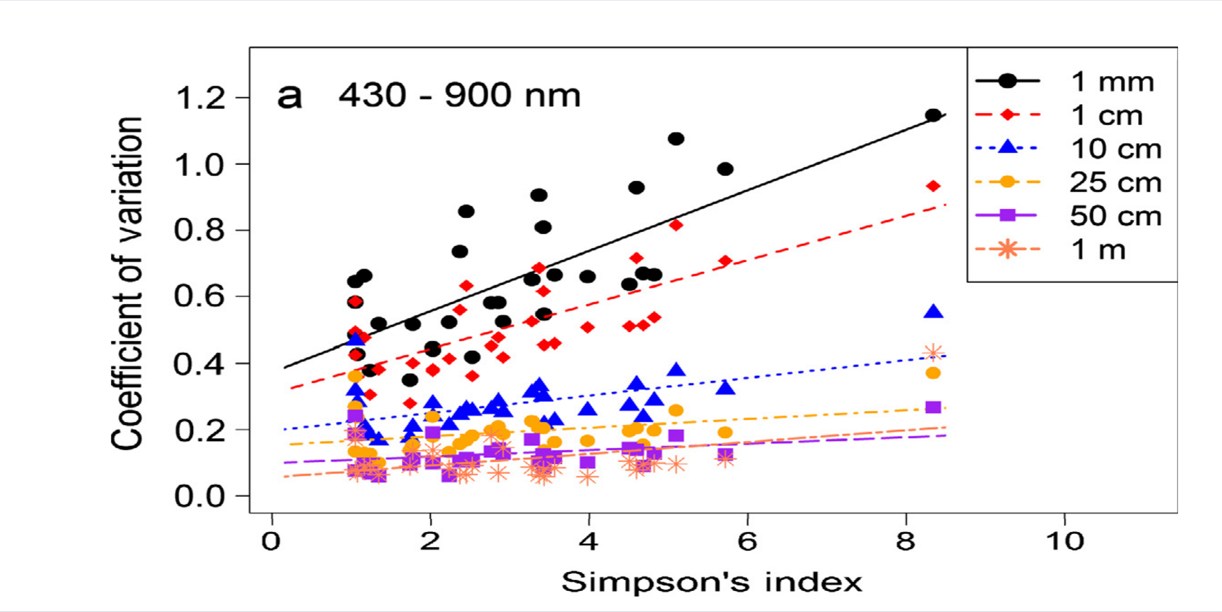
Preliminary Data for Mammoth Lakes

We combined several airborne measurements to show that plants are smaller and less green in areas with increasing CO_2, and show higher levels of stress (Cawse-Nicholson et al. *in review*)



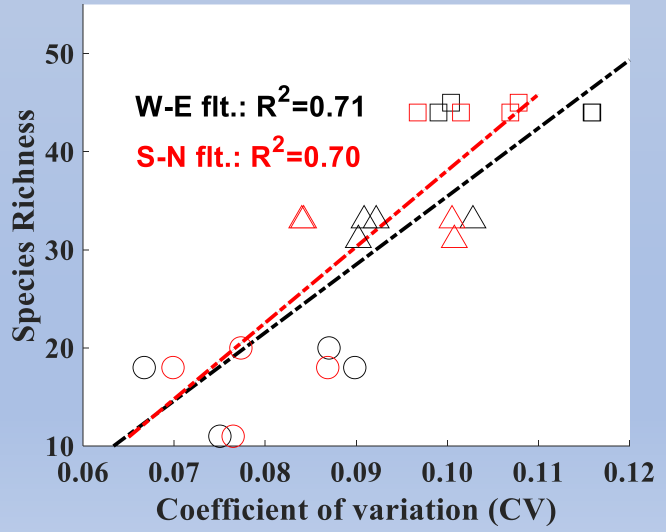
[Spatial Scale]

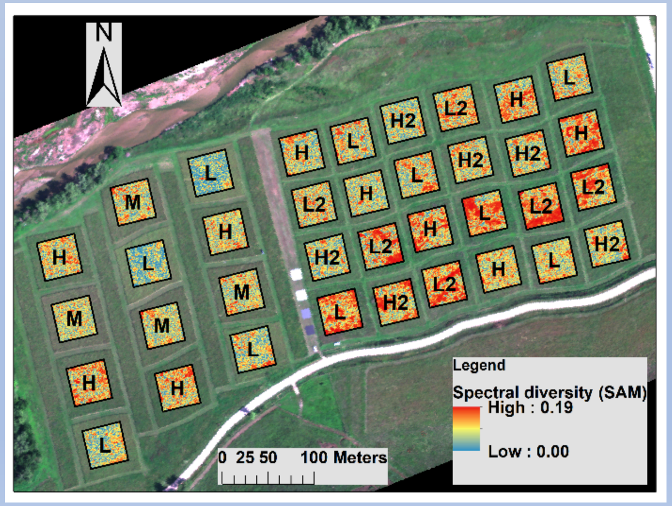
Scale matters and continued empirical and theoretical work on organisms versus pixels is urgently required



Wang R, Gamon JA, Cavender-Bares J, Townsend PA, Zygielbaum AI. 2018. The spatial sensitivity of the spectral diversity–biodiversity relationship: an experimental test in a prairie grassland. Ecological Applications 28(2):541-56.

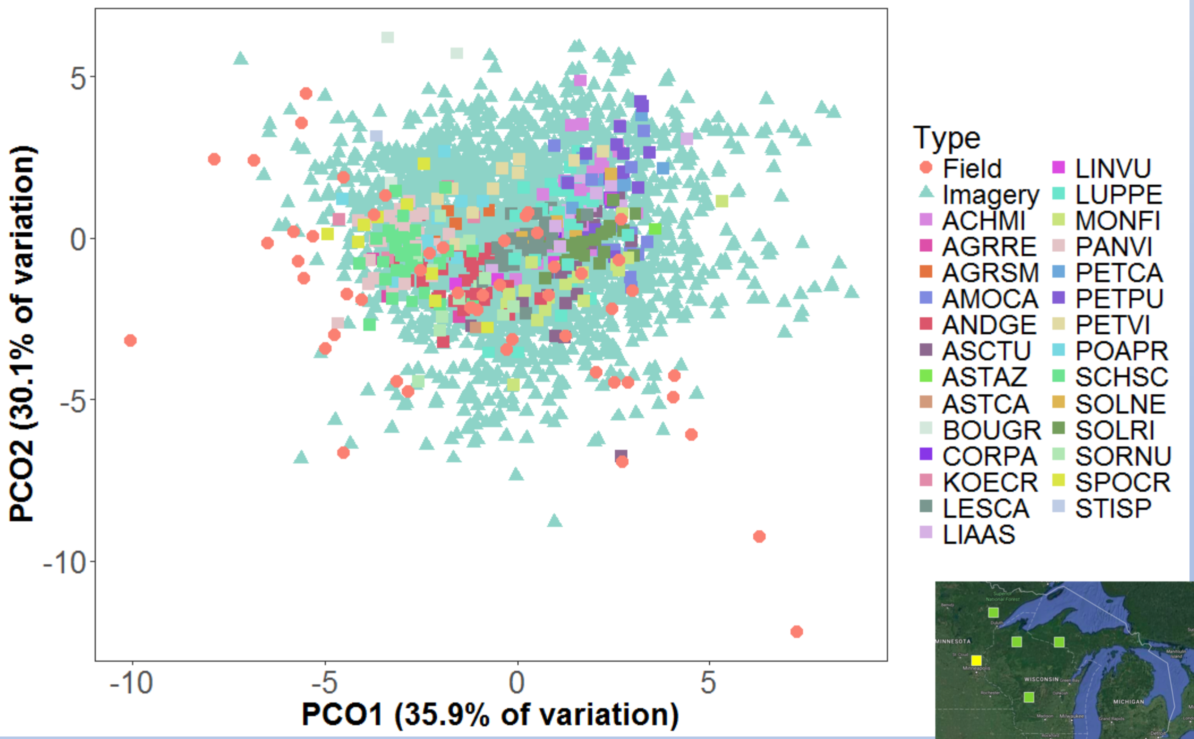
Gholizadeh H, Gamon JA and others. Detecting biodiversity in restored prairie with airborne remote sensing. In prep.



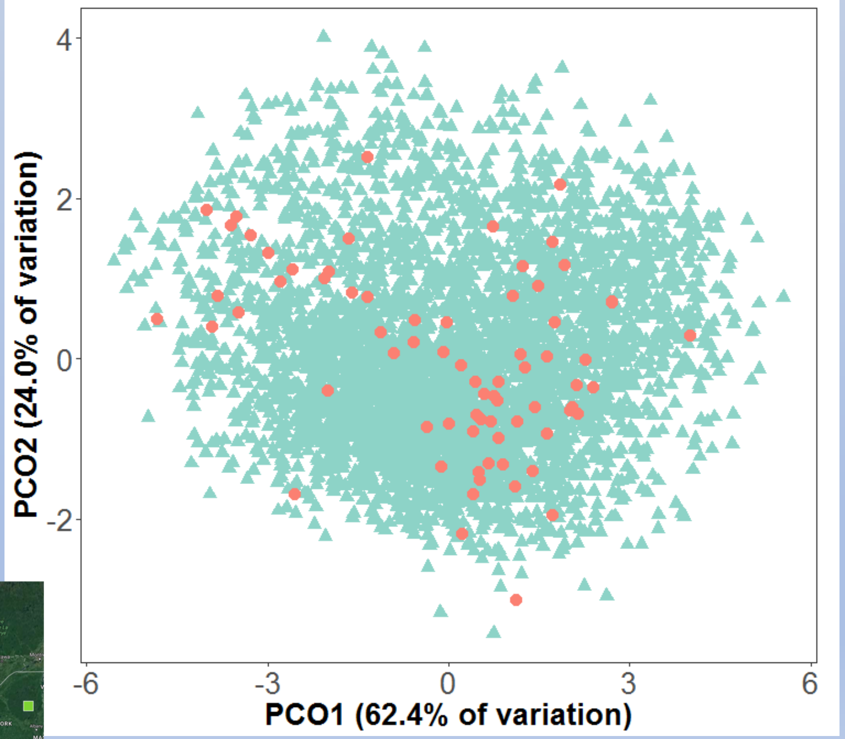


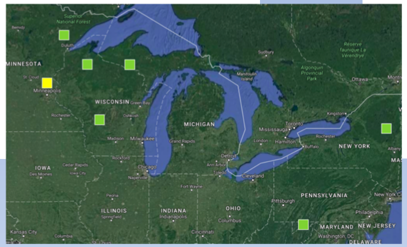
[In situ Data Integration] Imaging Spectroscopy Derived Trait Space vs. Field Measurements – "Filling the Gaps"

Grasslands – Cedar Creek LTER
PCA of 16 Traits



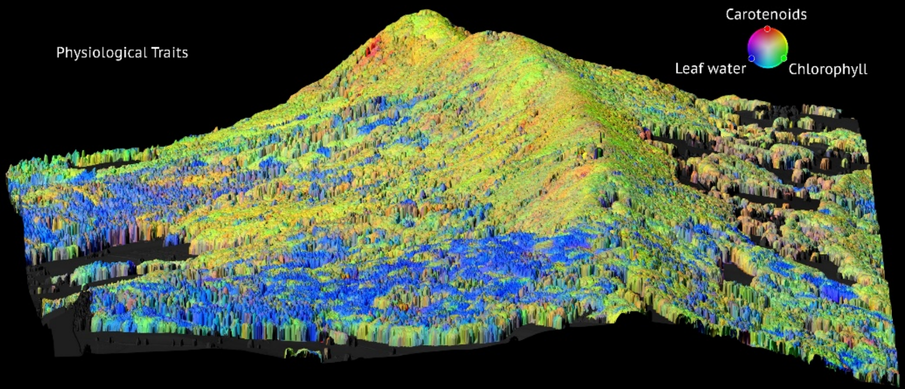
Eastern US Forests
PCA of 8 Traits

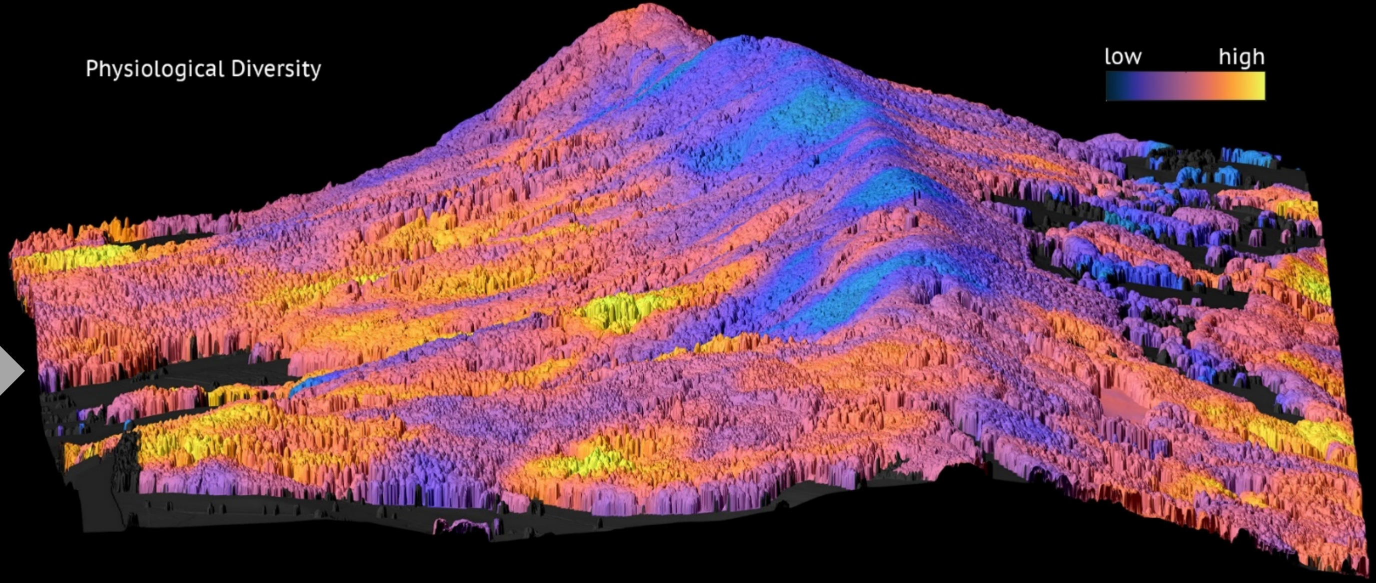




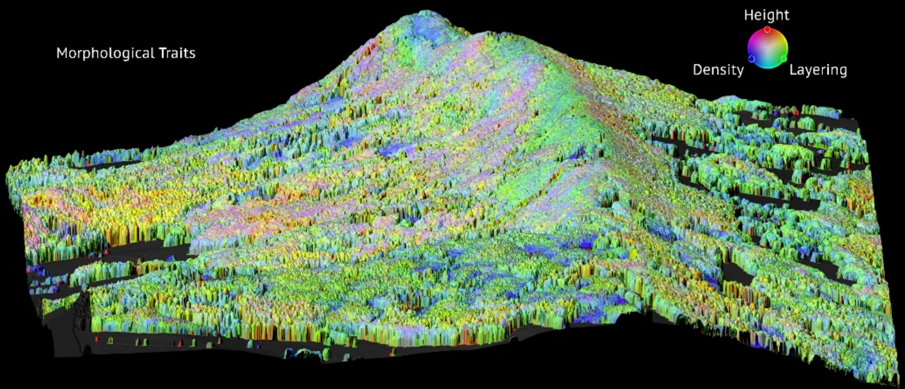
Mapping of Plant Functional Diversity

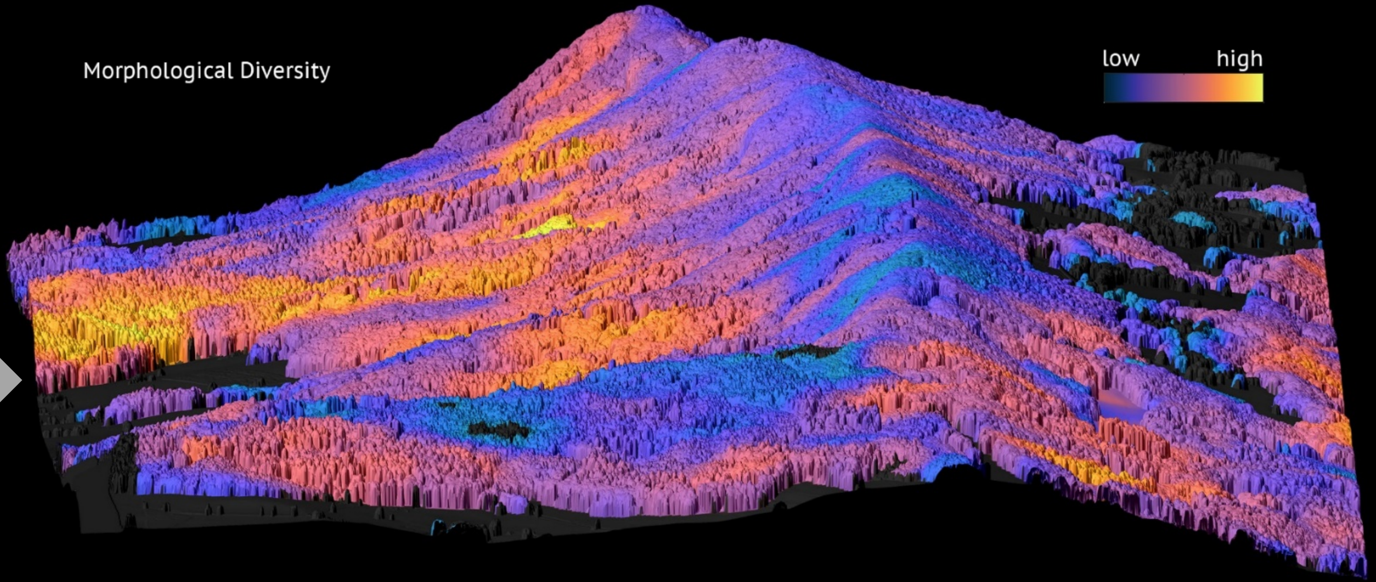
Leaf Biochemistry from Spectroscopy





Canopy Structure from LiDAR





Schneider, et al. (2017) Nature Communications

Conclusions – Continued Work Needed

- Grand challenges of global biodiversity <u>change</u> require repeat spaceborne measurements, but….
- Evidence is that we have instruments necessary to detect important components of biodiversity, including change; and
- Airborne studies are still urgently needed to:
  - Validate retrieval algorithms
  - Data integration (thermal, spectroscopy, SIF, active)
  - Scale studies
- Spaceborne work is needed to capture dynamics.

SBG: What are the structure, function, and biodiversity of Earth’s ecosystems, and how and why are they changing in time and space?

- **(VI) E-1a.** Quantify the distribution of the functional traits, functional types and composition of terrestrial and shallow aquatic vegetation and marine biomass, spatially and over time
- **(MI) E-1b.** Quantify the three dimensional (3-D) structure of terrestrial vegetation and 3-D distribution of marine biomass within the euphotic zone, spatially and over time.
- **(MI) E-1c.** Quantify the physiological dynamics of terrestrial and aquatic primary producers.

Surface Biology and Geology

TO-18 **Surface Biology & Geology**	• Surface geology & biology • Active geologic processes • Ground & water temperature • Gross Primary Production (GPP) • Snow spectral albedo • Functional traits of terrestrial vegetation and inland & near-coastal aquatic ecosystems	- **H-1c**, 2a, 2b, 3a, 3b, 3c, 4a, 4c, 4d - W-3a - **S-1a**, 1c, 2b, 4b, 4c, 7a - E-1a, **1c**, 1d, **2a**, **3a**, 5a, 5b, 5c - C-3a, 3c, 3d, 6b, 7e, 8f	***ESAS 2007:*** HyspIRI ***POR:*** ASTER/Terra, MODIS, Landsat, AIRS, PACE, Hyperion, ECOSTRESS	POR does not include hyperspectral imagery in the visible or shortwave infrared	***Similar to:*** **HyspIRI, combination of ASTER, MODIS, Landsat, AIRS; airborne instrument AVIRIS-NG** • Hyperspectral imagery in the visible and shortwave infrared and multi- or hyperspectral imagery in the thermal infrared • Spatial resolution of 30-60 m (vis-SWIR) and 60 m (TIR) with 14-19 day (SWIR) and 5 day (TIR) temporal resolution	**DESIGNATED** PROGRAM ELEMENT Maximum development cost $650M

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Wang, Ran, et al. "The spatial sensitivity of the spectral diversity–biodiversity relationship: an experimental test in a prairie grassland." *Ecological Applications* 28.2 (2018): 541-556.

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Schneider, Fabian D., et al. "Mapping functional diversity from remotely sensed morphological and physiological forest traits." *Nature communications* 8.1 (2017): 1441.