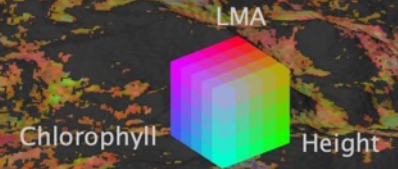


# BioCube: Integrating dimensions of Biodiversity in California and Wisconsin

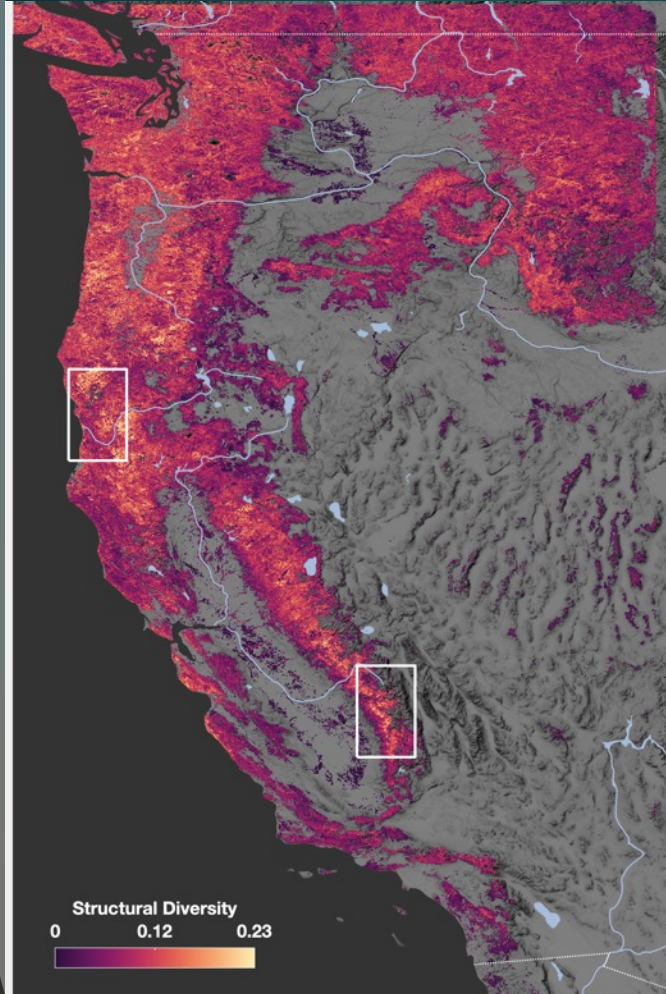
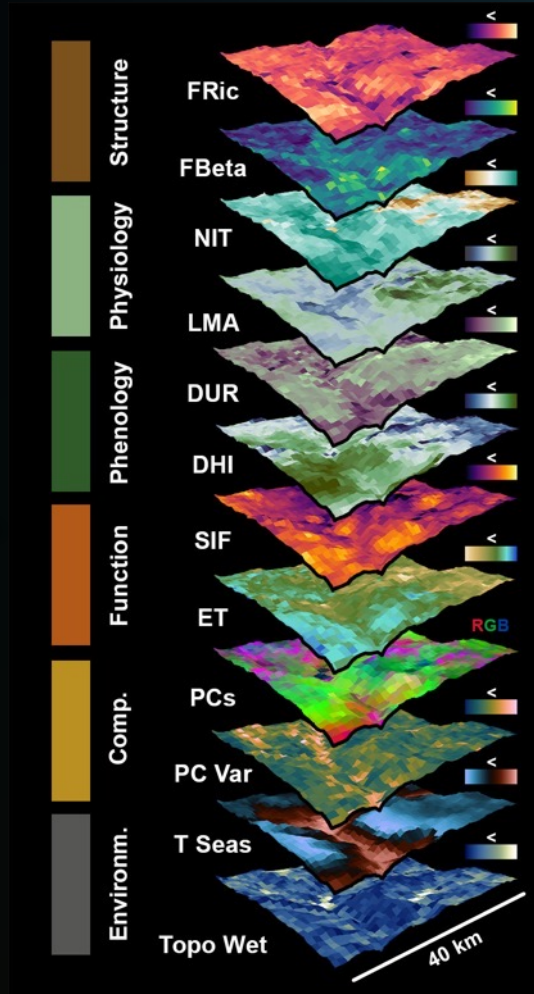
Philip Townsend, Ryan Pavlick, Laura Berman, Ethan Shafron, Ting Zheng, Zhiwei Ye, Natalie Queally, Kyle Kovach, Giulia Tagliabue, Fabian D. Schneider\*



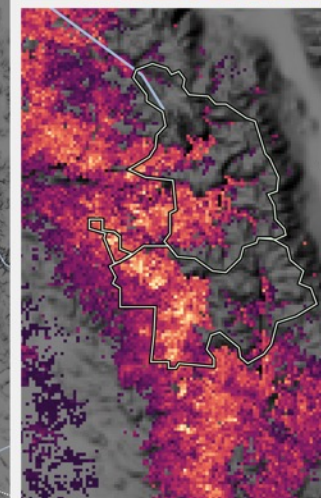
# What is BioCube?

A data cube to study relationships among dimensions of biodiversity at landscape scale

## Biodiversity Dimensions



**Structural Diversity**  
derived from GEDI  
Schneider et al. (in preparation)



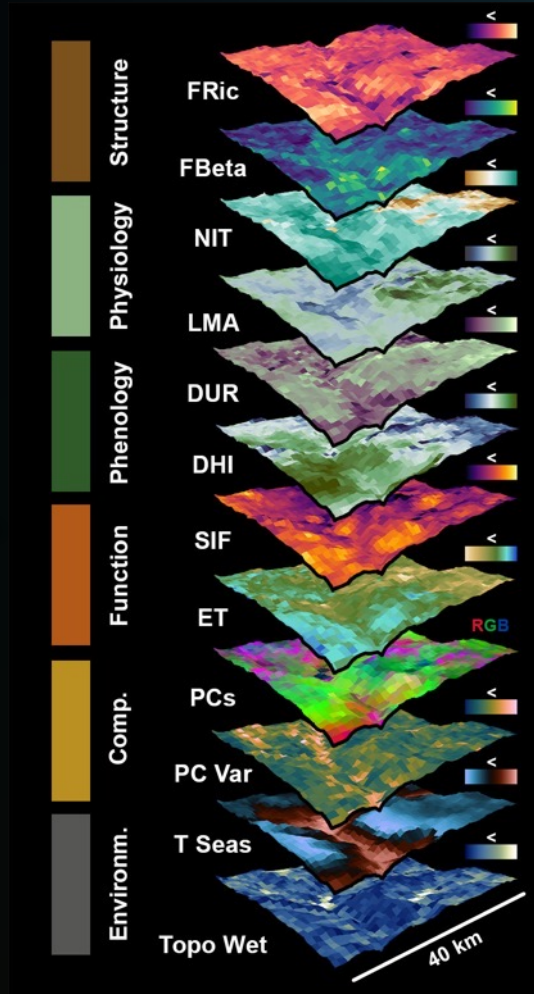
**Canopy Height** derived  
from GEDI and  
Sentinel-2  
Favrillon et al. (in review)



# What is BioCube?

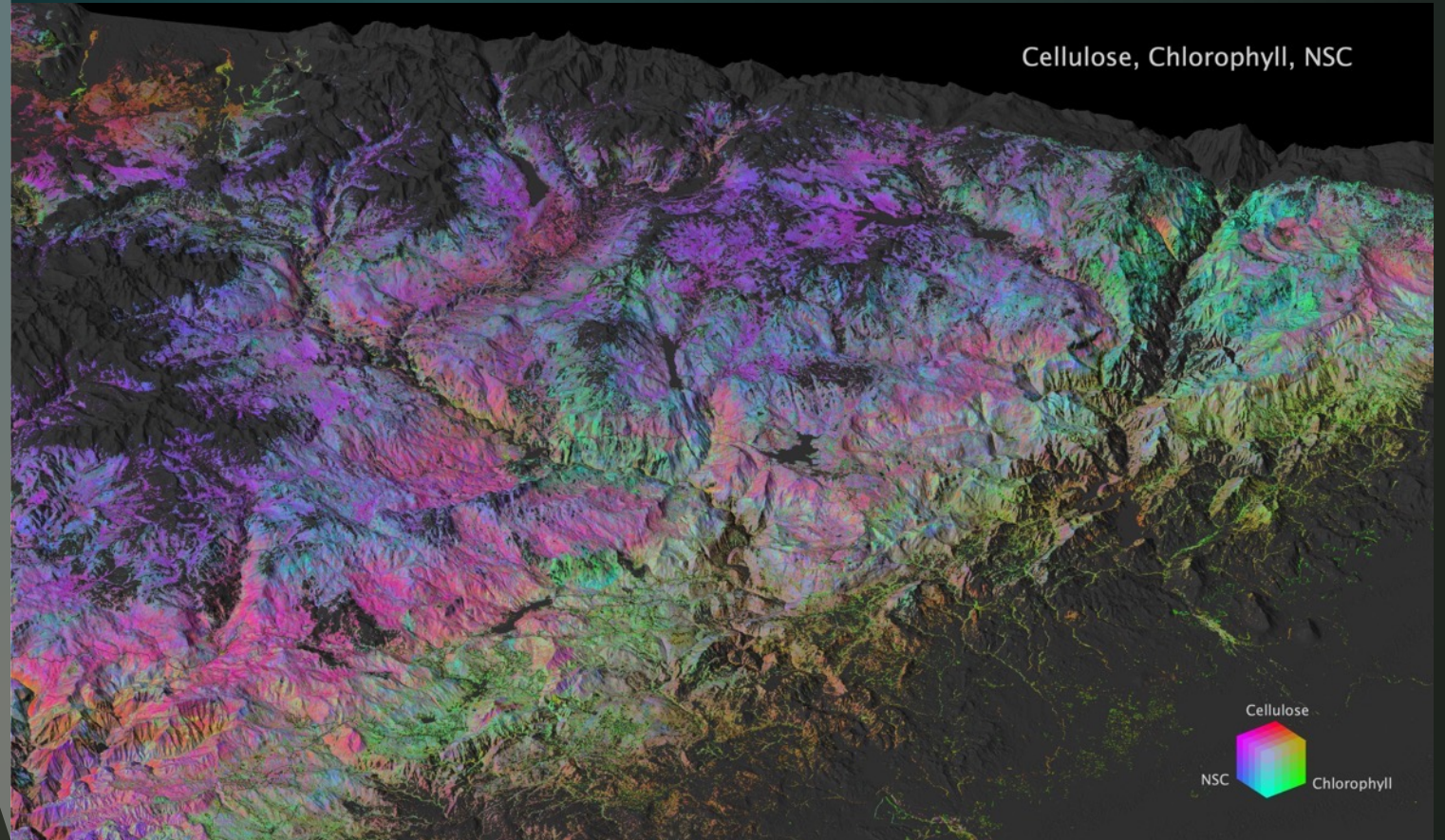
A data cube to study relationships among dimensions of biodiversity at landscape scale

## Biodiversity Dimensions



## Plant foliar traits and functional diversity derived from AVIRIS-Classic

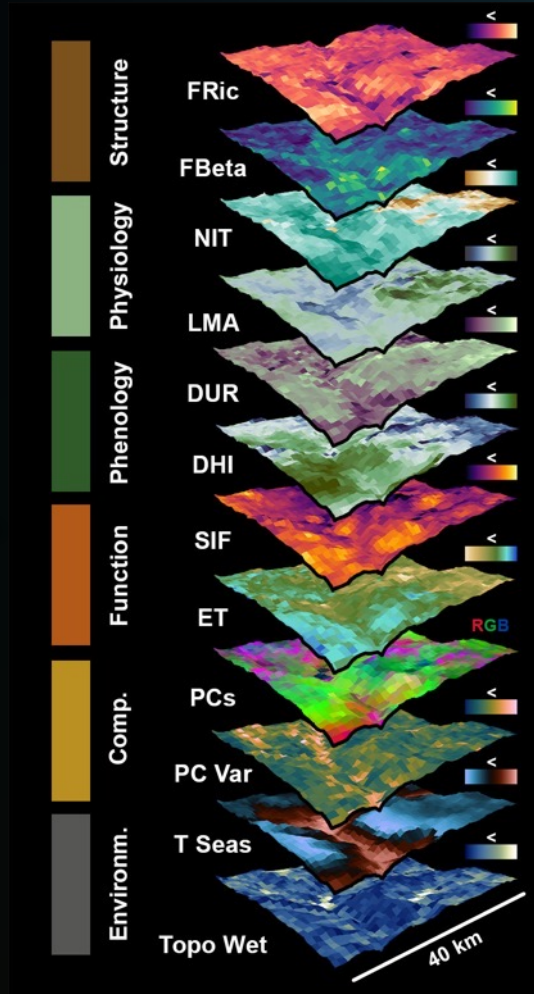
Zheng et al. (in preparation), Shafron et al. (in preparation), Schneider et al. (in preparation)



# What is BioCube?

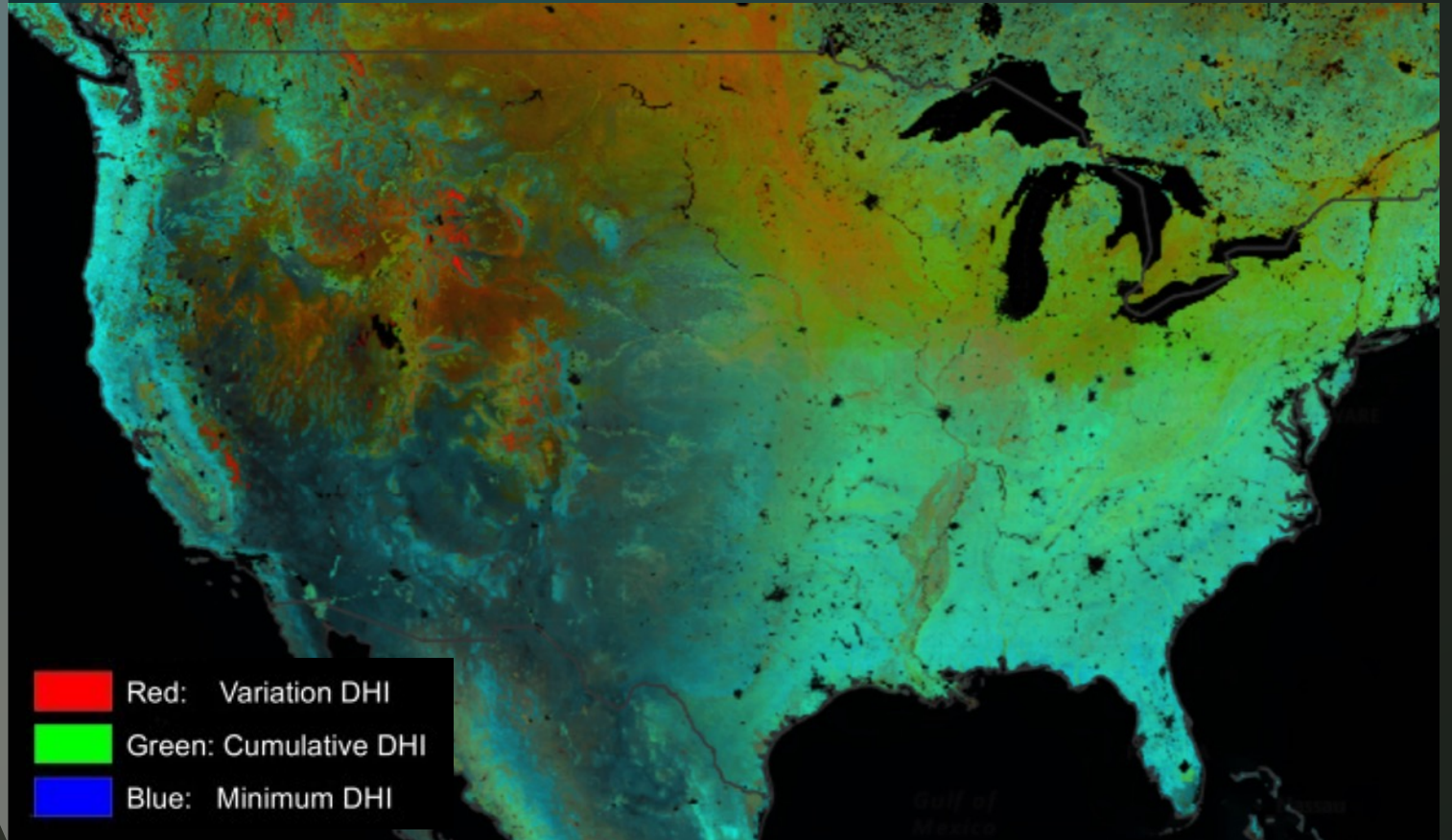
A data cube to study relationships among dimensions of biodiversity at landscape scale

## Biodiversity Dimensions



## Dynamic Habitat Indices produced by SILVIS LAB

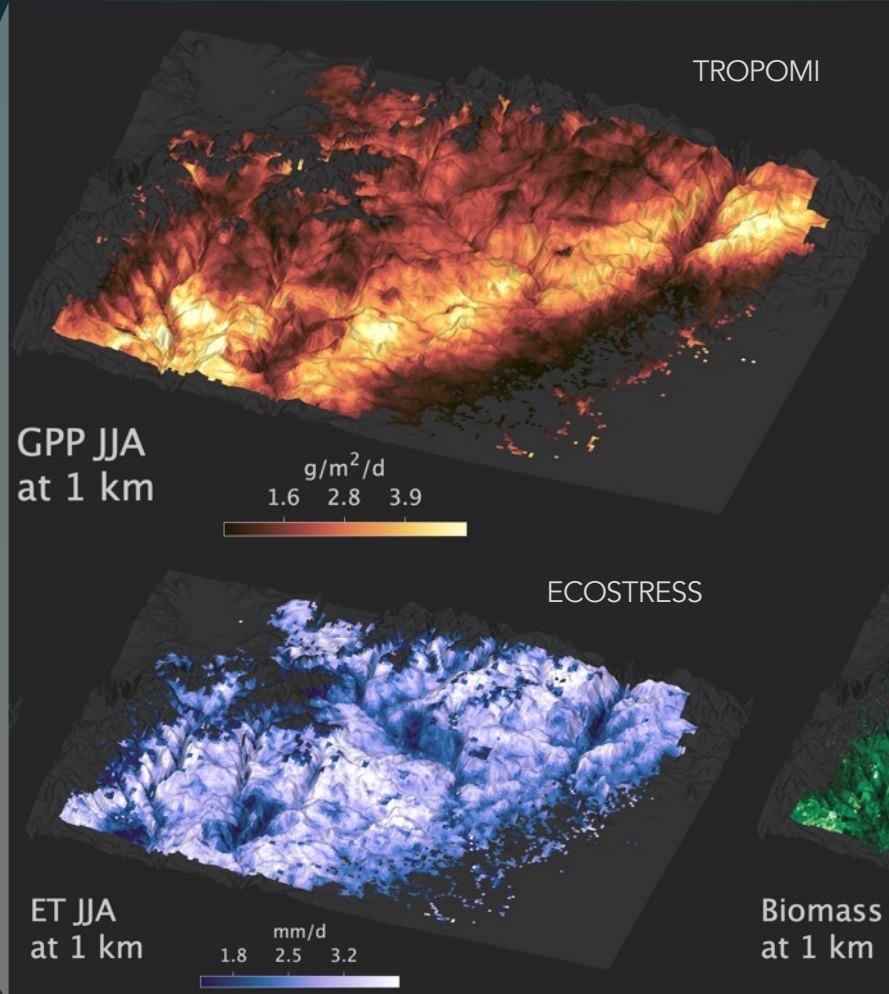
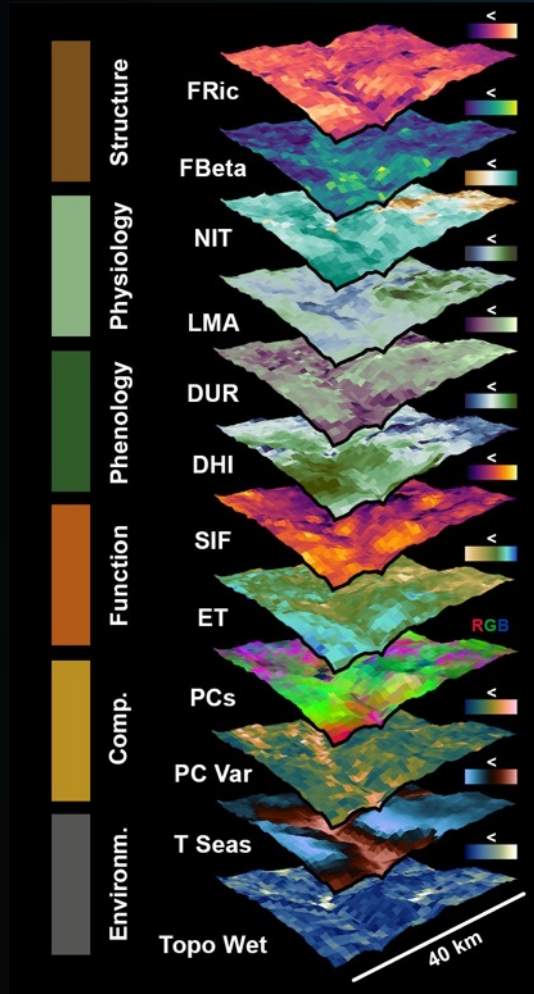
Radeloff et al. (2019), Hobi et al. (2017)



# What is BioCube?

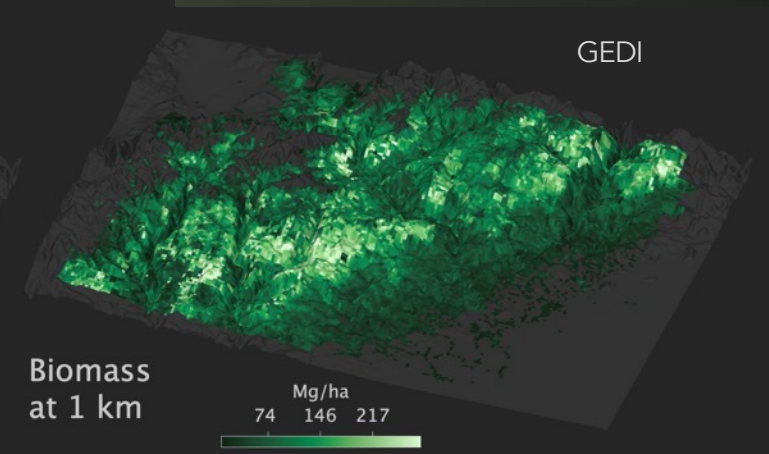
A data cube to study relationships among dimensions of biodiversity at landscape scale

## Biodiversity Dimensions



**Ecosystem productivity, evapotranspiration and Biomass derived from TROPOMI, ECOSTRESS and GEDI**

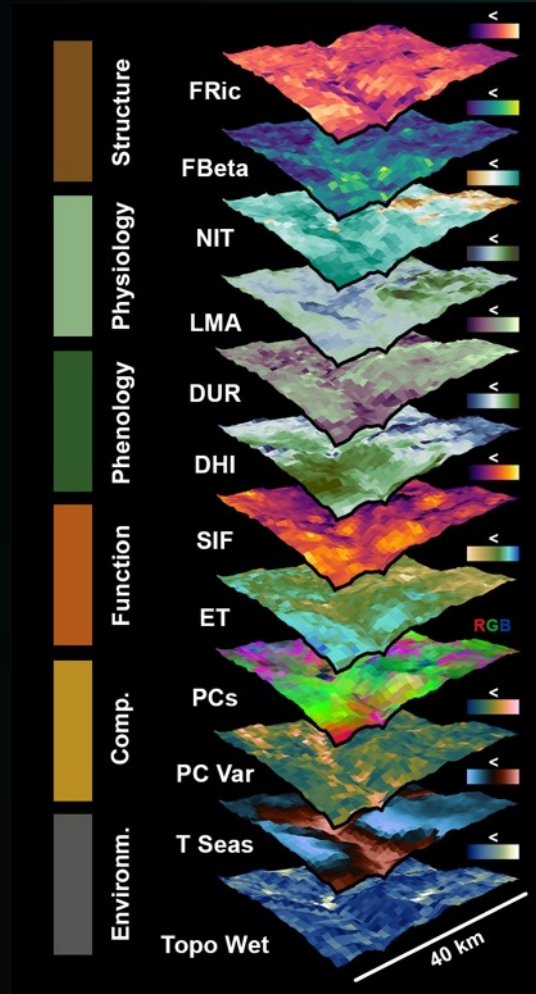
Gensheimer et al. (2022), Fisher et al. (2020) and Dubayah et al. (2022)



# What is BioCube?

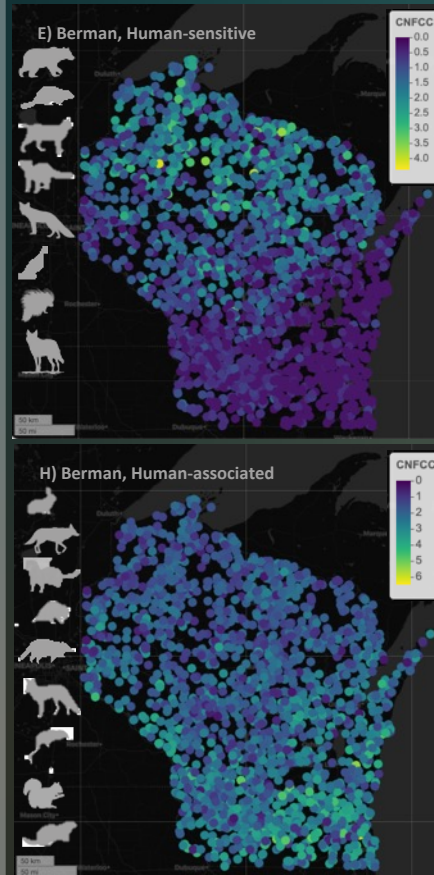
A data cube to study relationships among dimensions of biodiversity at landscape scale

## Biodiversity Dimensions



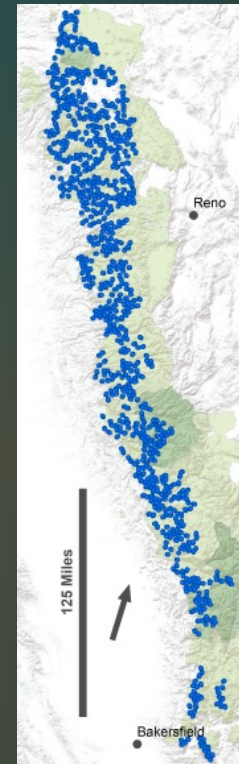
## Camera Trap Network from Snapshot Wisconsin

Berman et al. (in review)



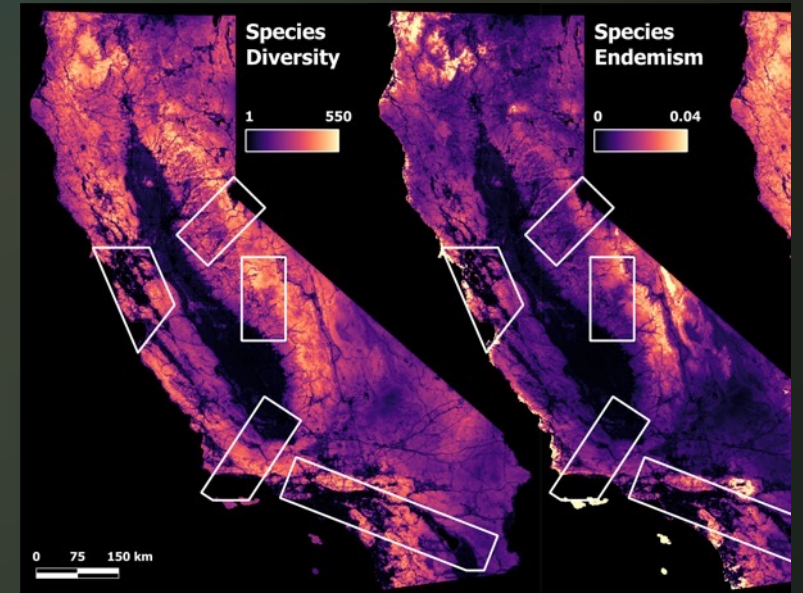
## Bioacoustic Monitoring in the Sierra Nevada

Wood et al. (2021)



## Plant Species Diversity from species distribution models in California

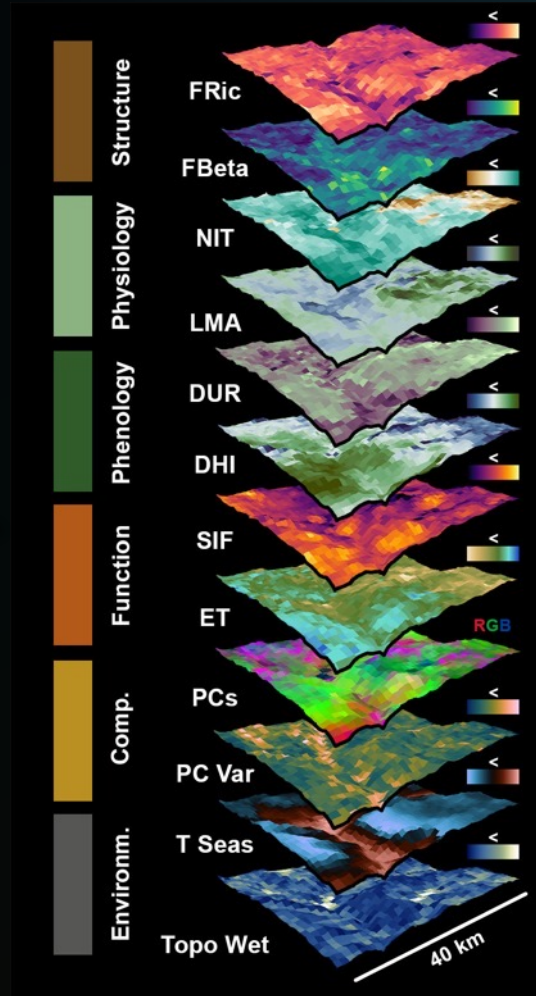
Kling et al. (2018)



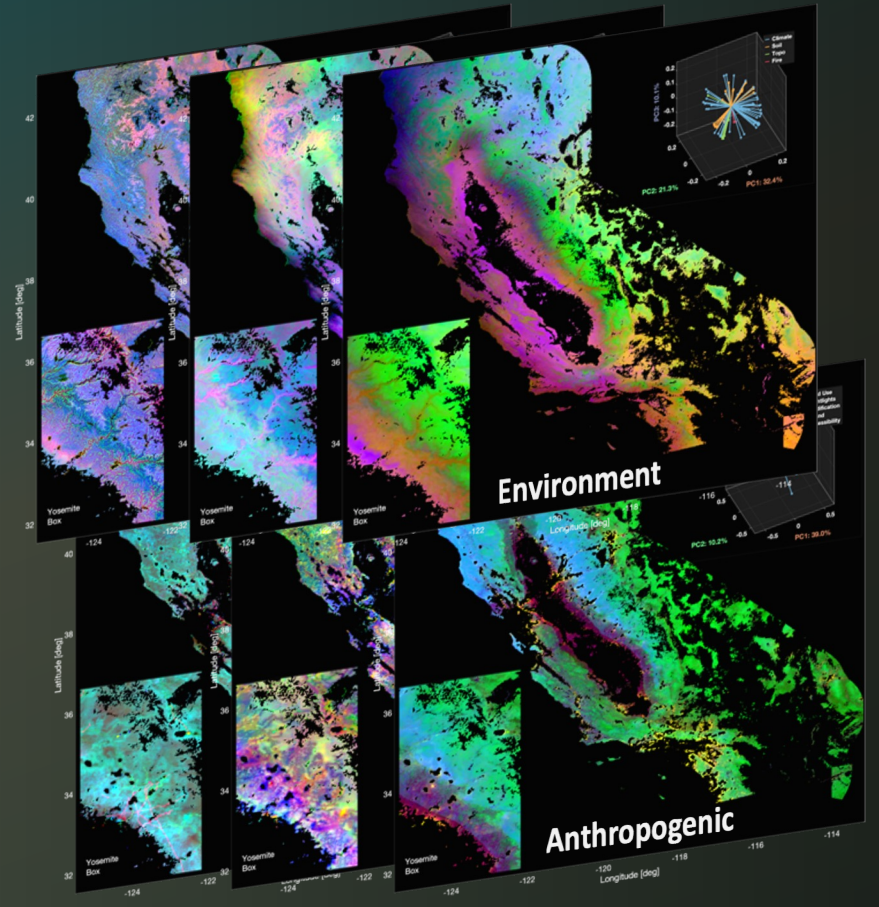
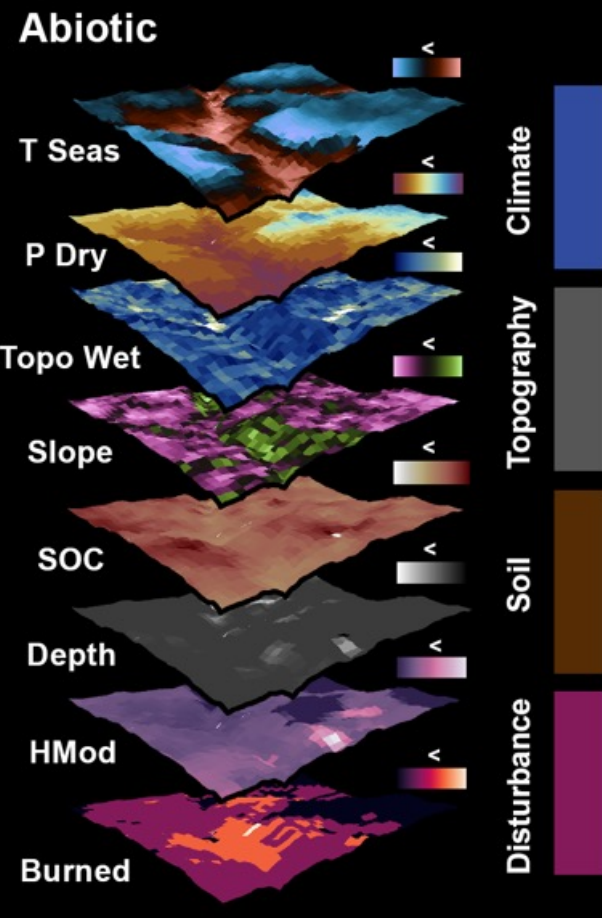
# What is BioCube?

A data cube to study relationships among dimensions of biodiversity at landscape scale

## Biodiversity Dimensions

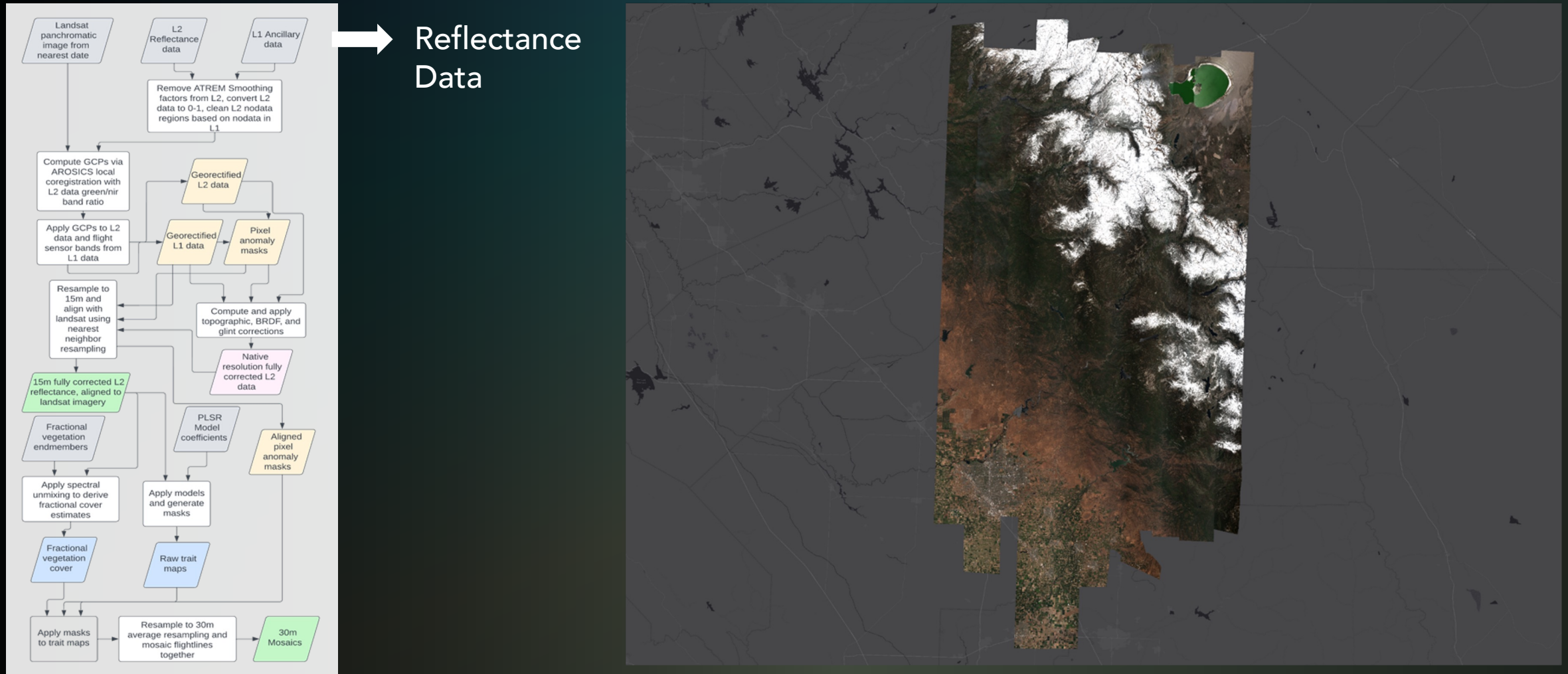


## Environmental Variables and Drivers of Biodiversity Change



# Progress towards a consistent plant trait time series

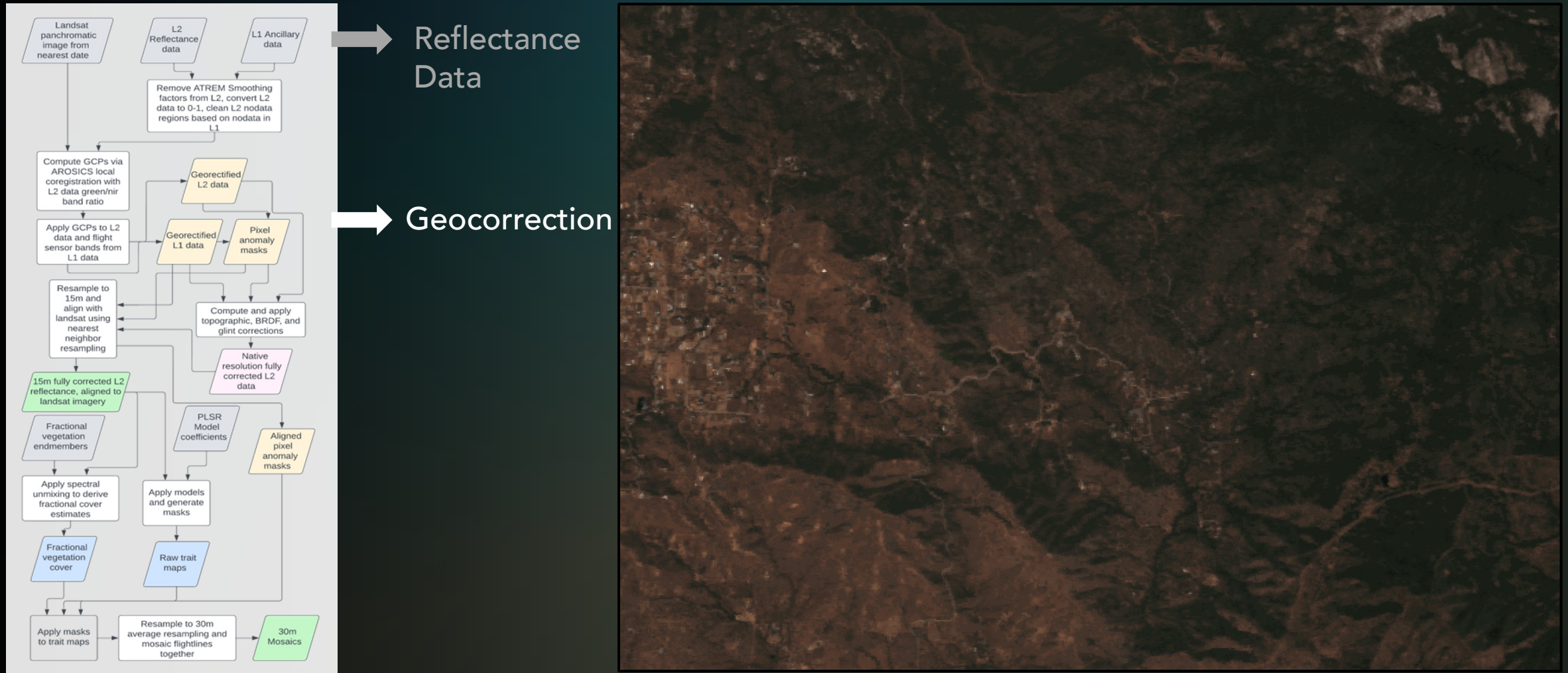
At landscape scale across California using the Western Diversity Time Series





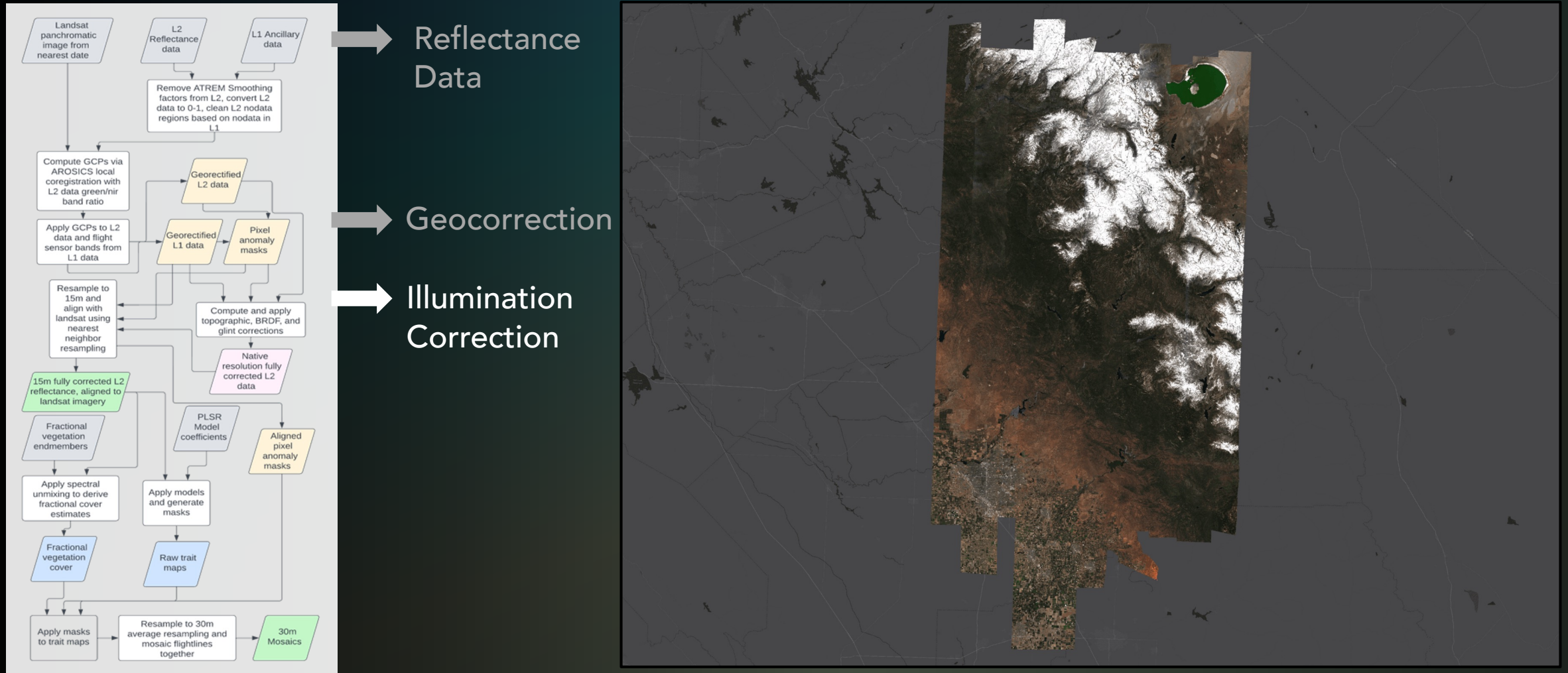
# Progress towards a consistent plant trait time series

At landscape scale across California using the Western Diversity Time Series



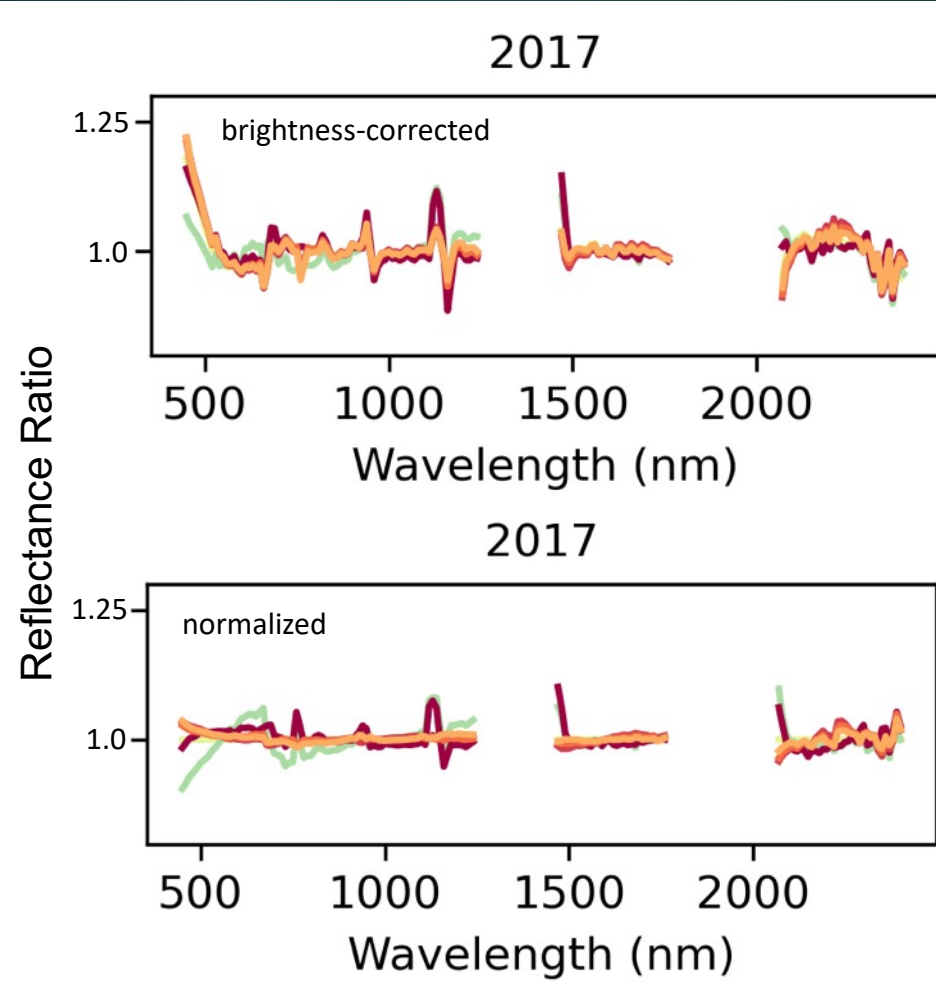
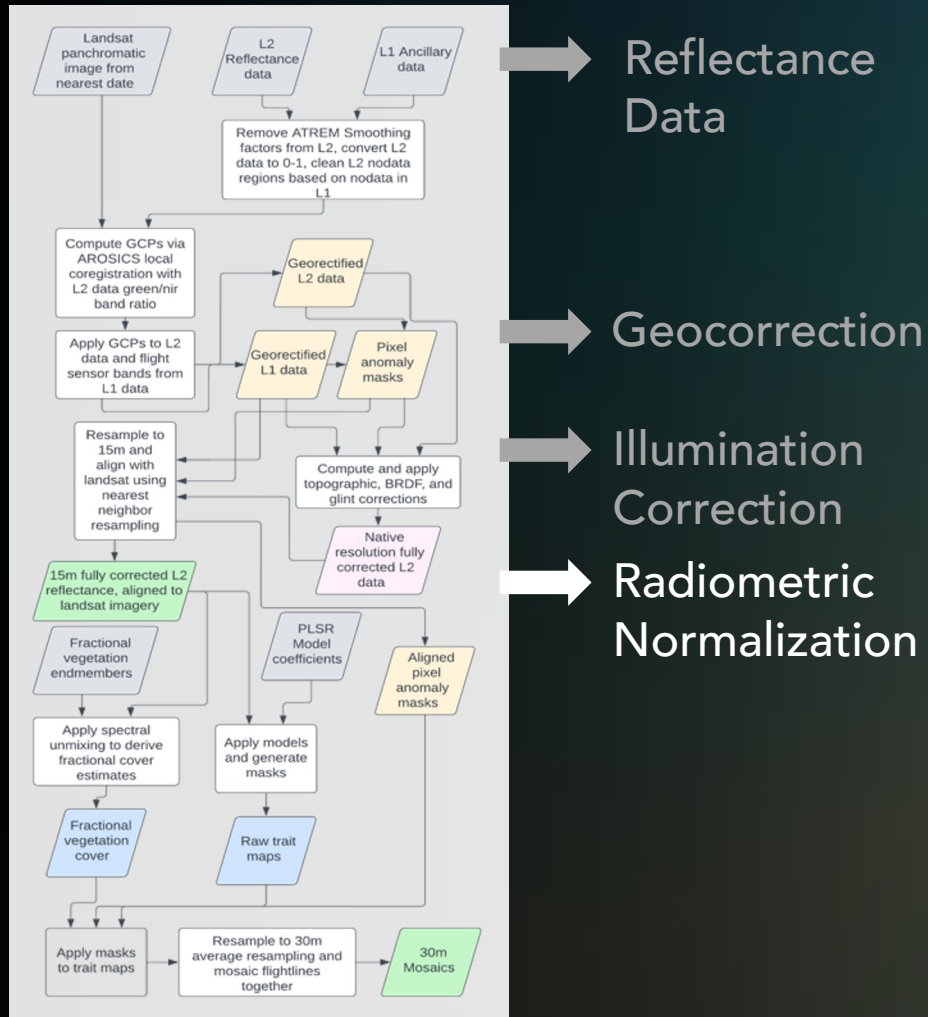
# Progress towards a consistent plant trait time series

At landscape scale across California using the Western Diversity Time Series



# Progress towards a consistent plant trait time series

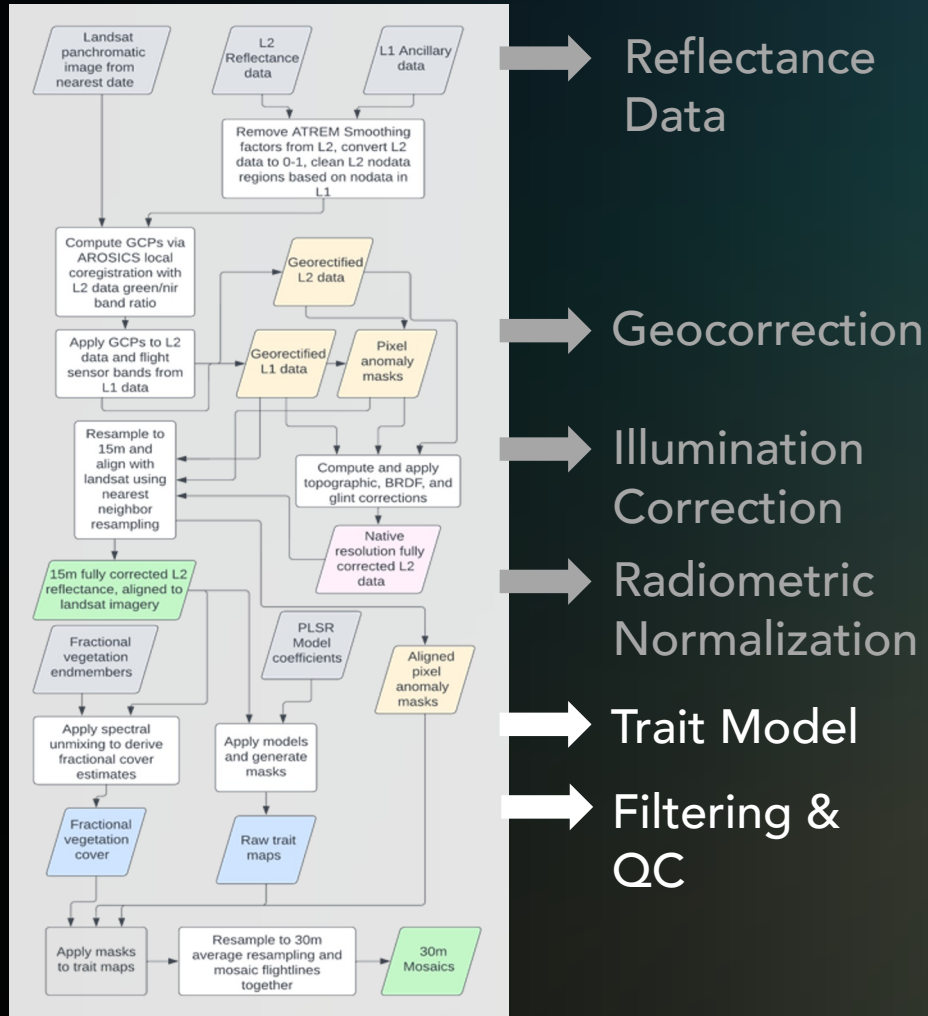
At landscape scale across California using the Western Diversity Time Series



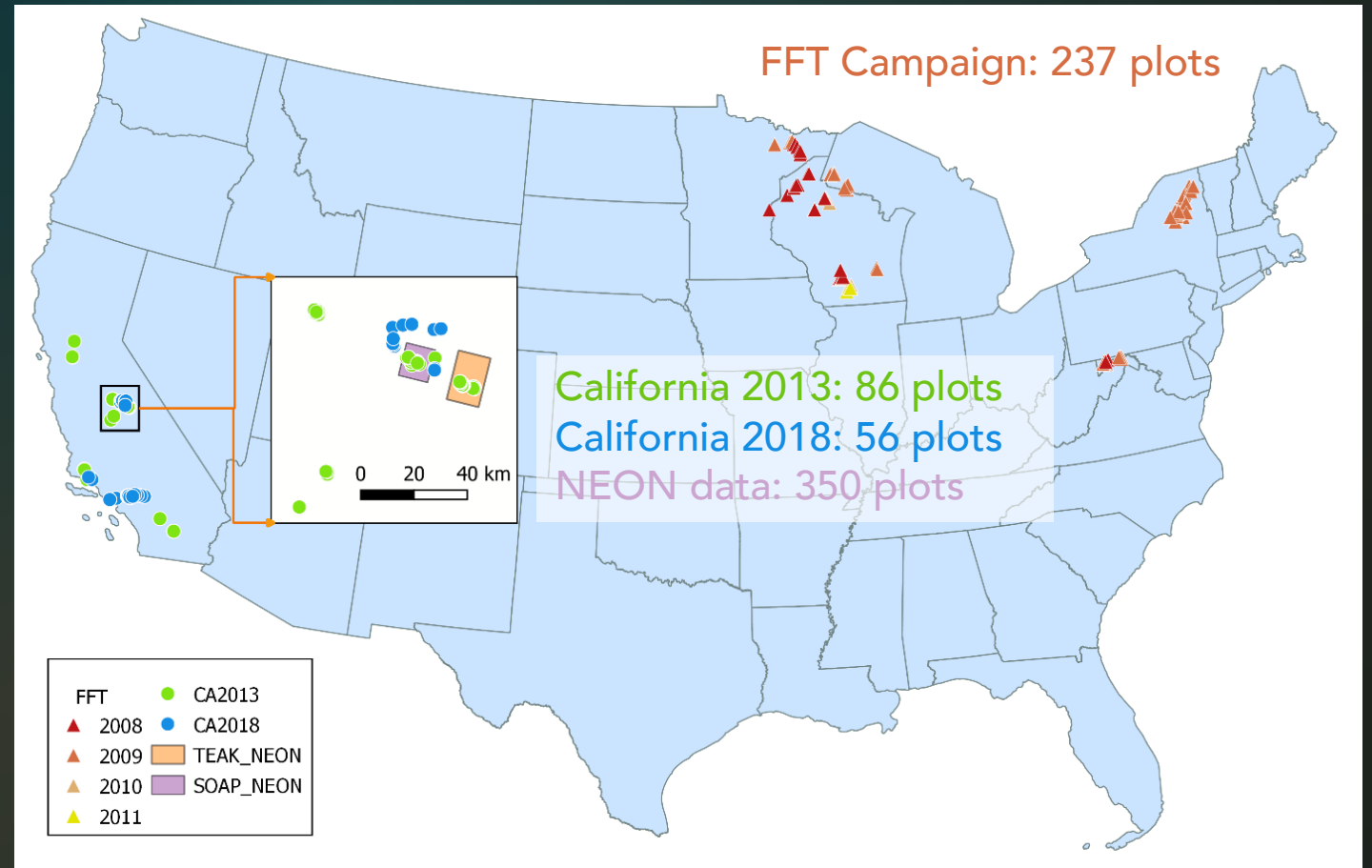
Spectral anomalies of stable image targets before and after correction

# Progress towards a consistent plant trait time series

At landscape scale across California using the Western Diversity Time Series

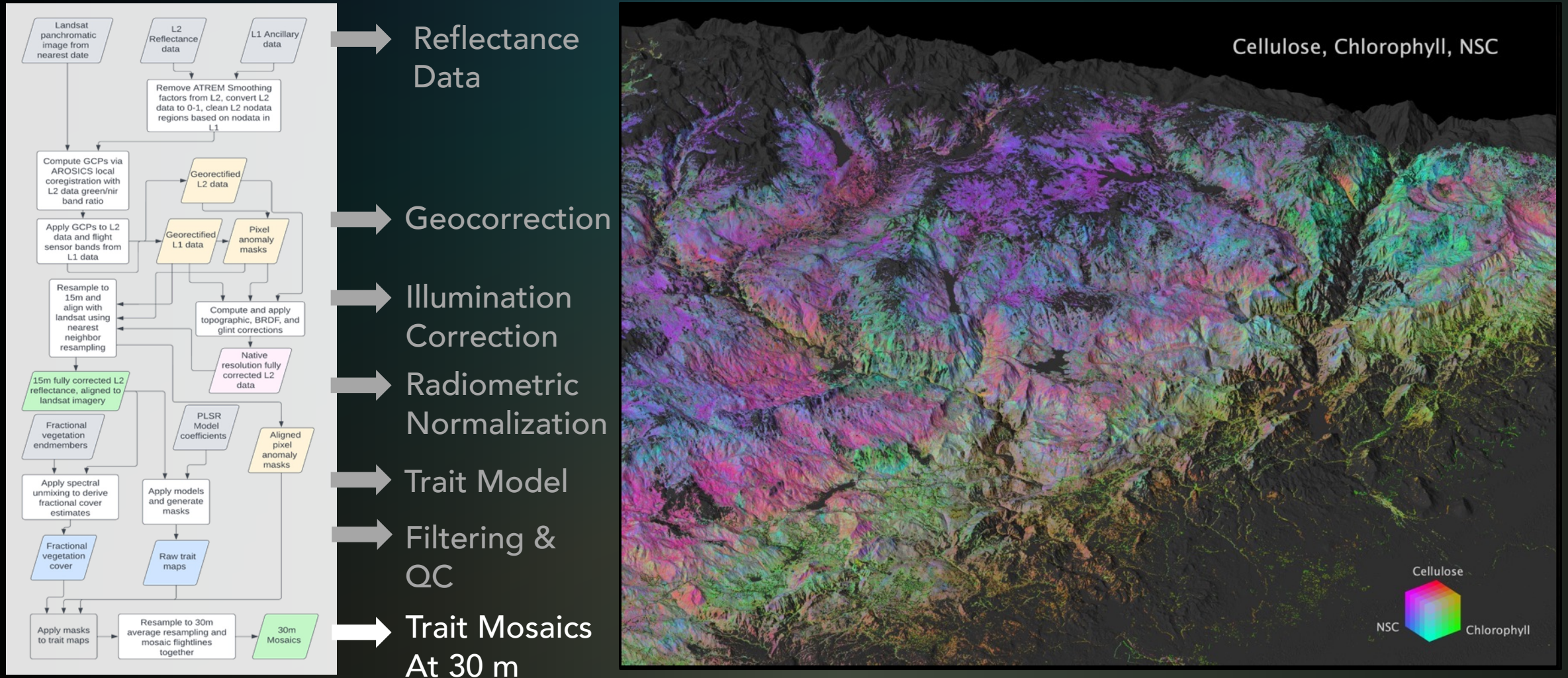


Field data and plot locations for training, testing and validation



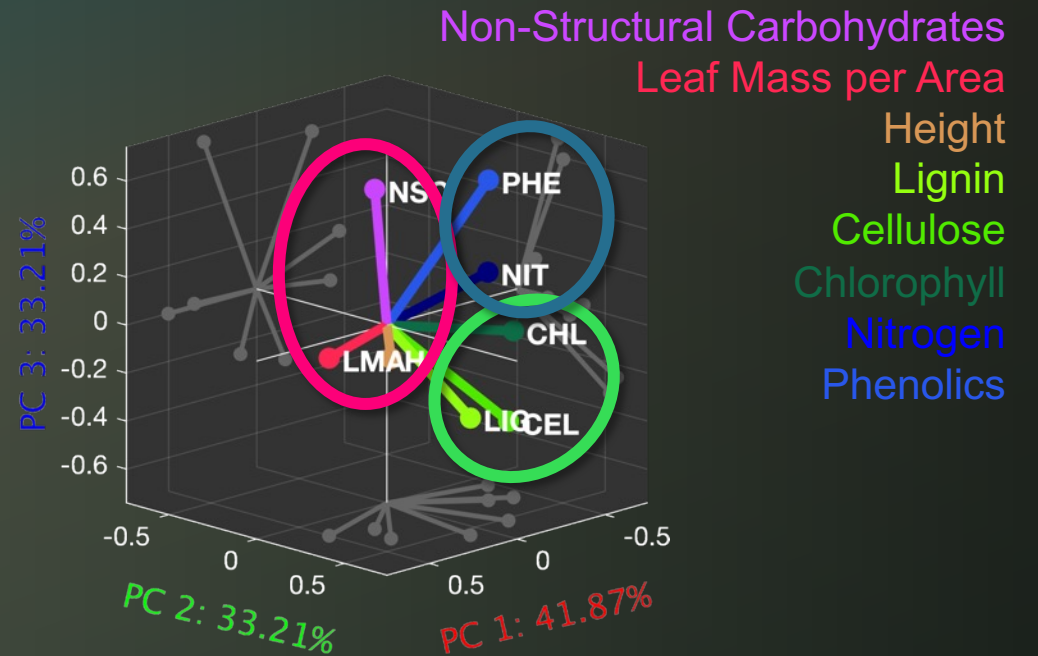
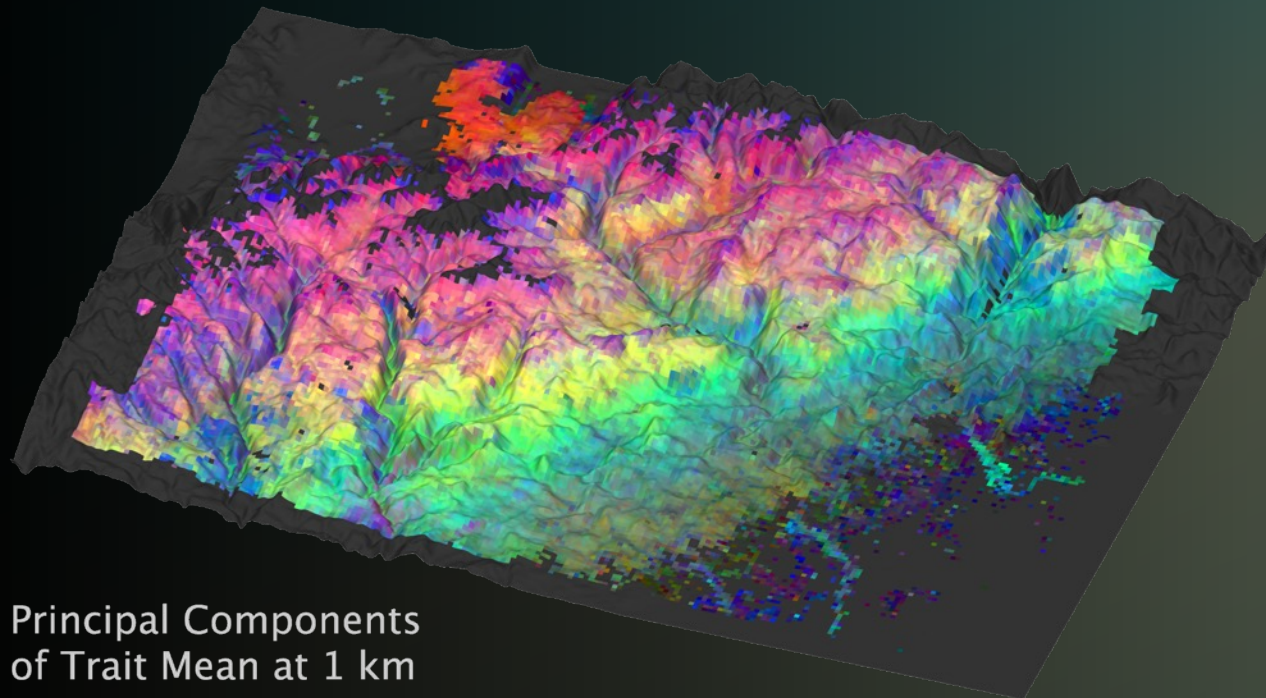
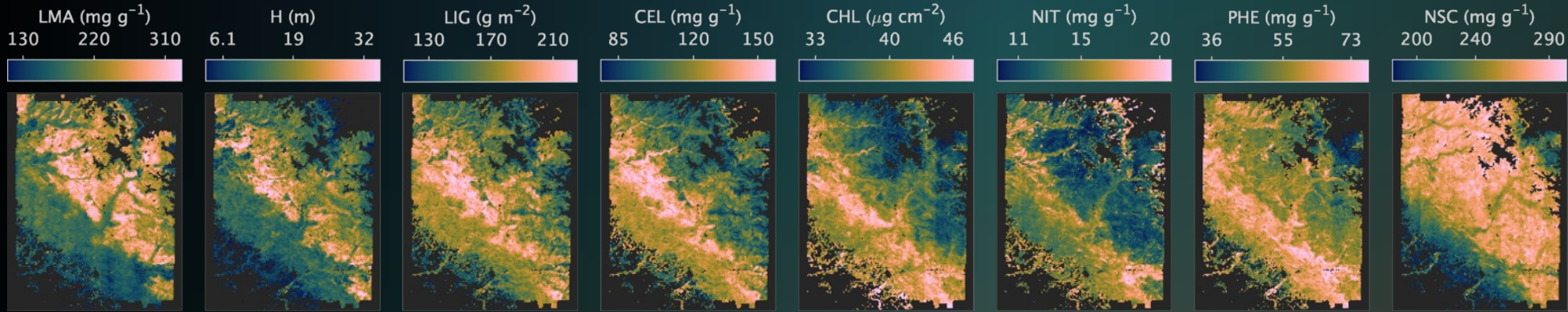
# Progress towards a consistent plant trait time series

At landscape scale across California using the Western Diversity Time Series



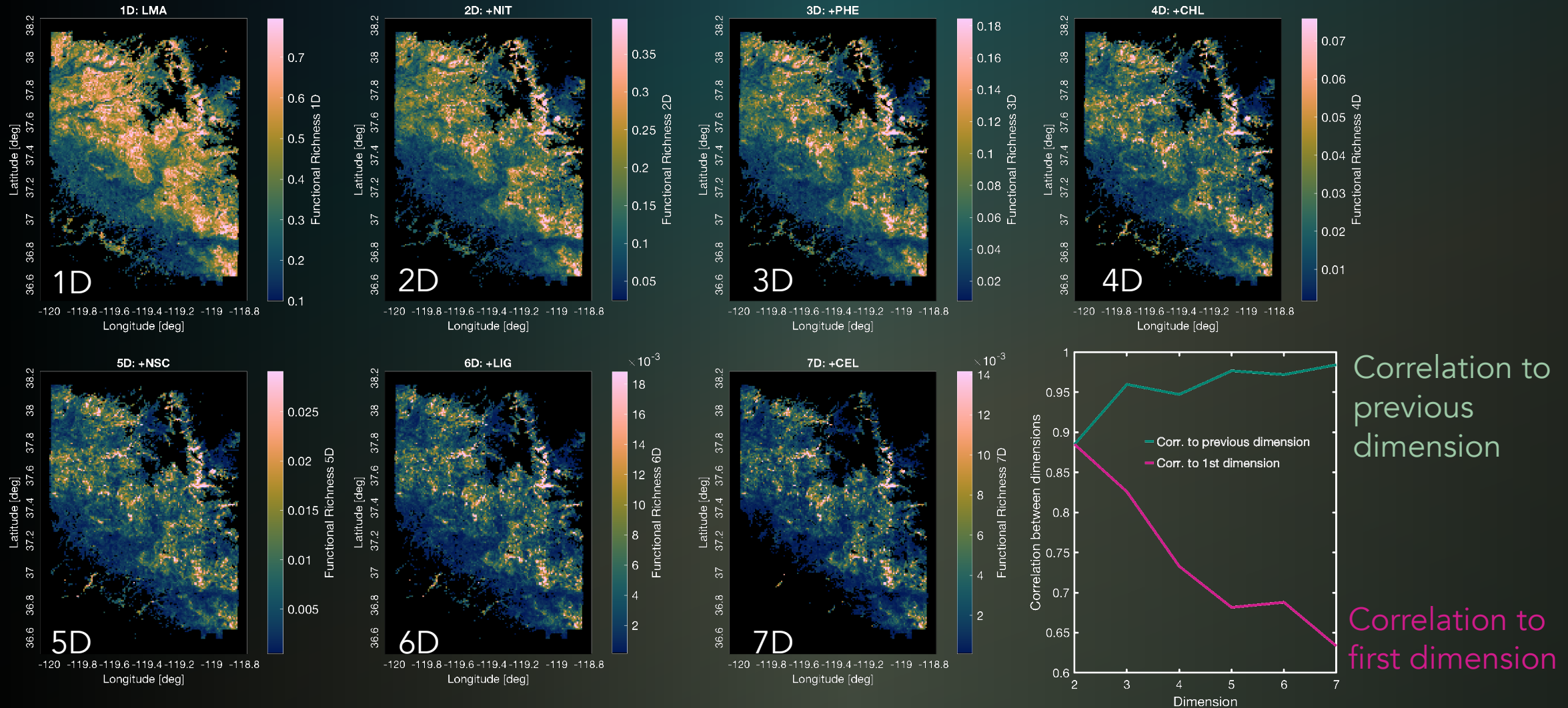
# Understanding axes of plant functional diversity

What are trait-trait relationships and important tradeoffs?



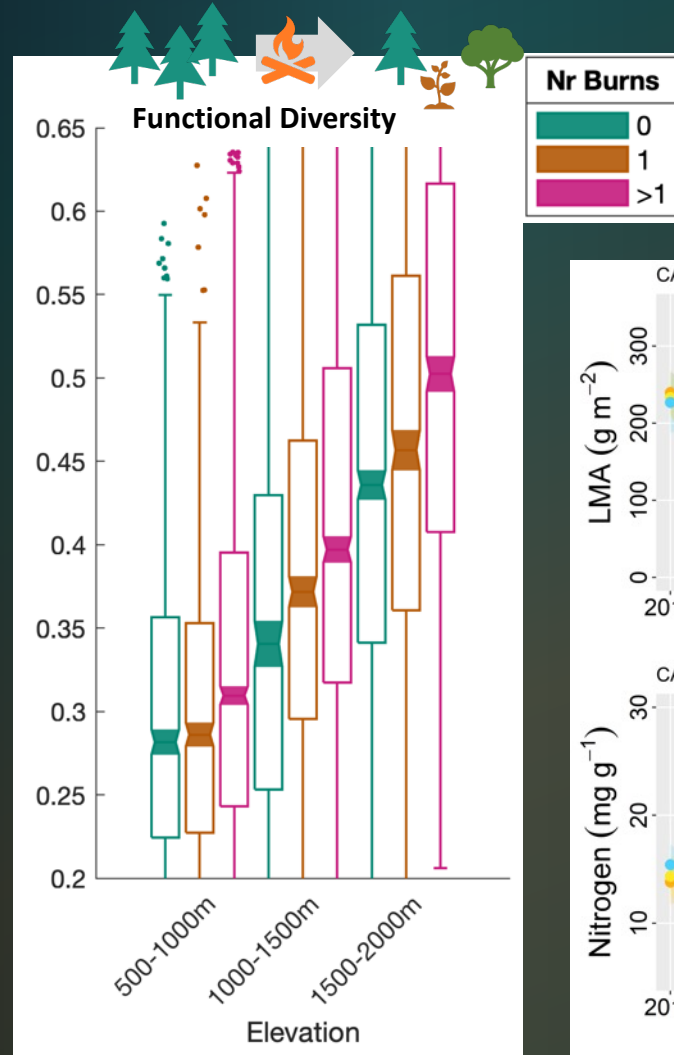
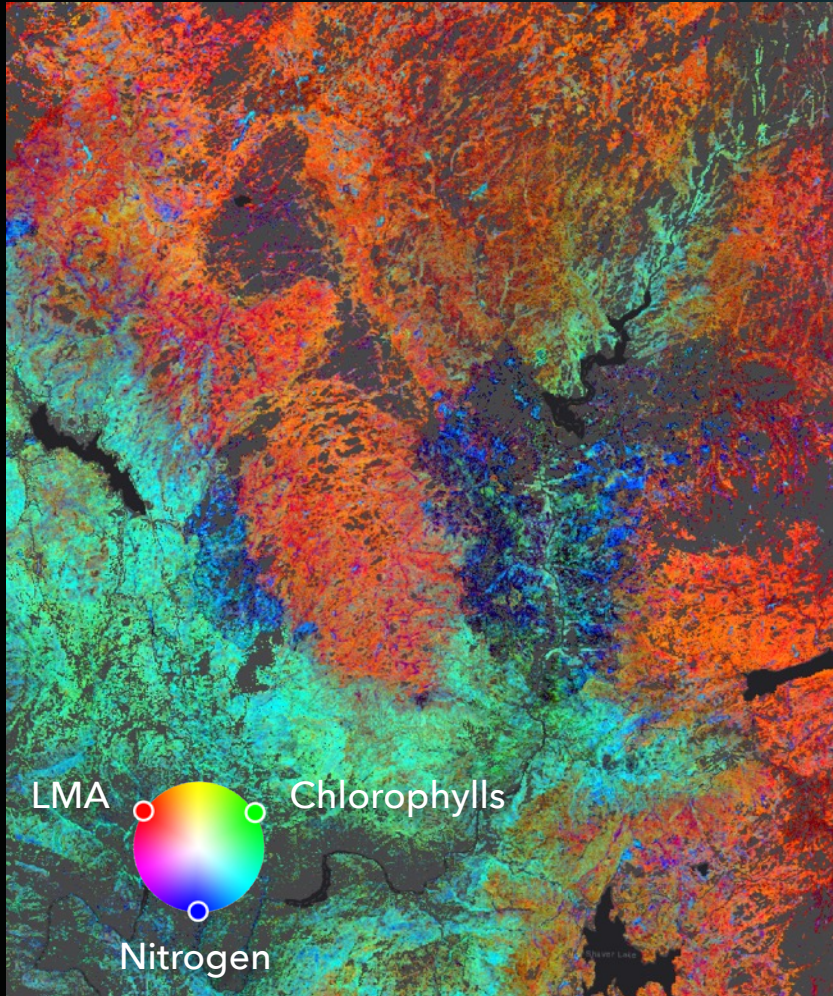
# Understanding axes of plant functional diversity

Convergence of diversity patterns at 3-5 dimensions

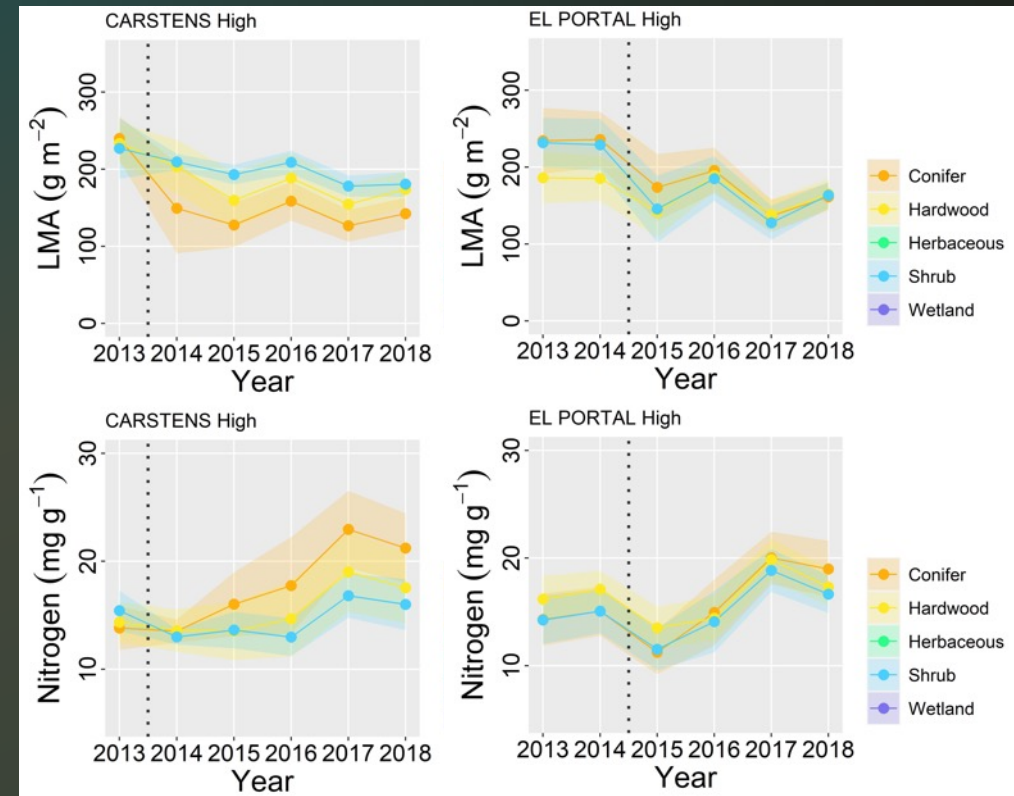


# Understanding the impact of wildfires on trait turnover

What is the resilience of ecosystems to wildfires, and what is the role of functional diversity?



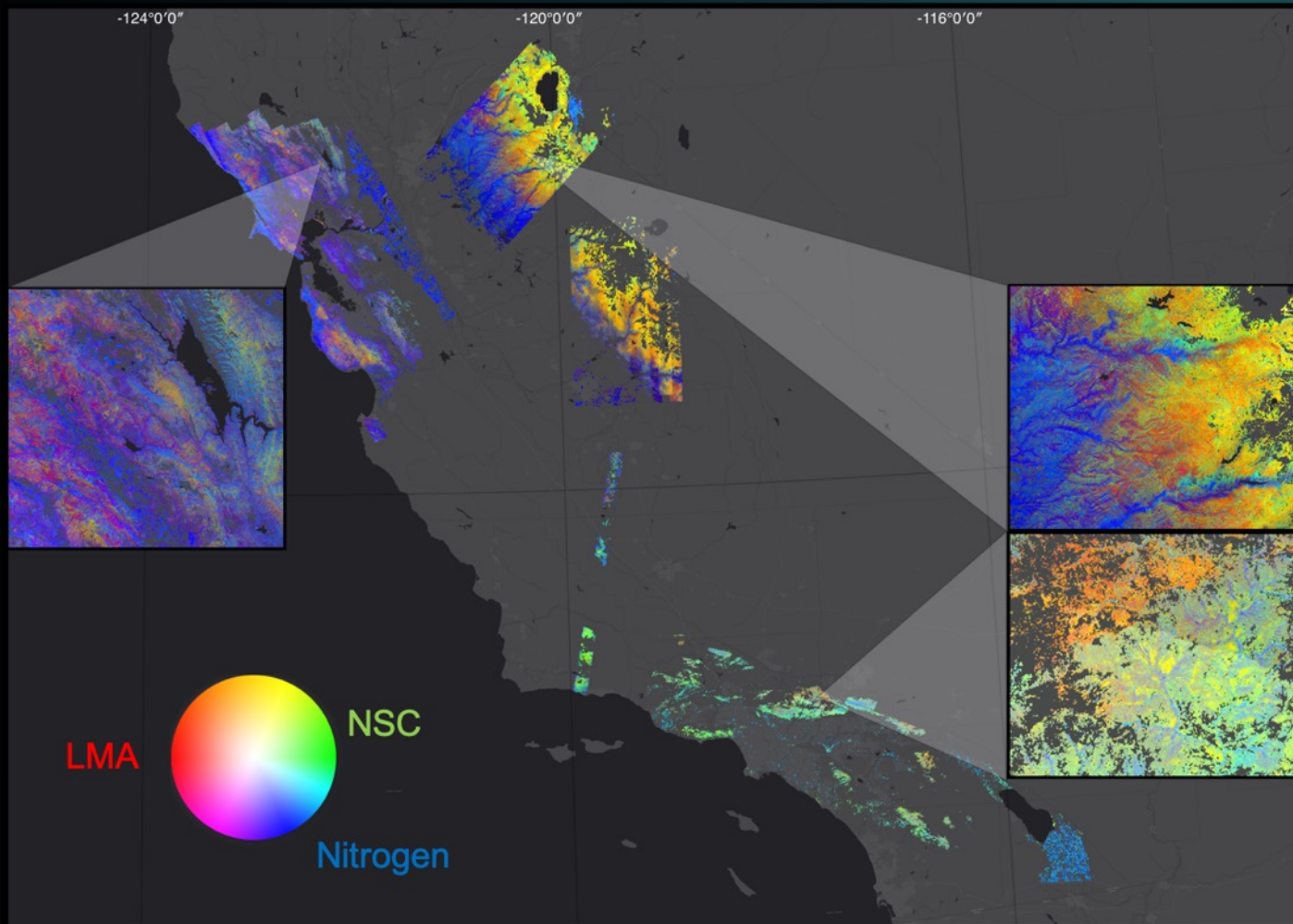
Impact of high-intensity fires on leaf mass per area and nitrogen





# Understanding large-scale patterns of functional diversity

Outlook: California-wide analysis across the Western Diversity Time Series



What are the predictors of plant functional diversity at the landscape scale?

**Goal:** Predict functional diversity across California using the BioCube, and assess the predictor importance.

What is the relationship between plant functional, structural and species diversity?

**Goal:** Assess the strength and shape of the relationships, and how they are varying across ecosystems.

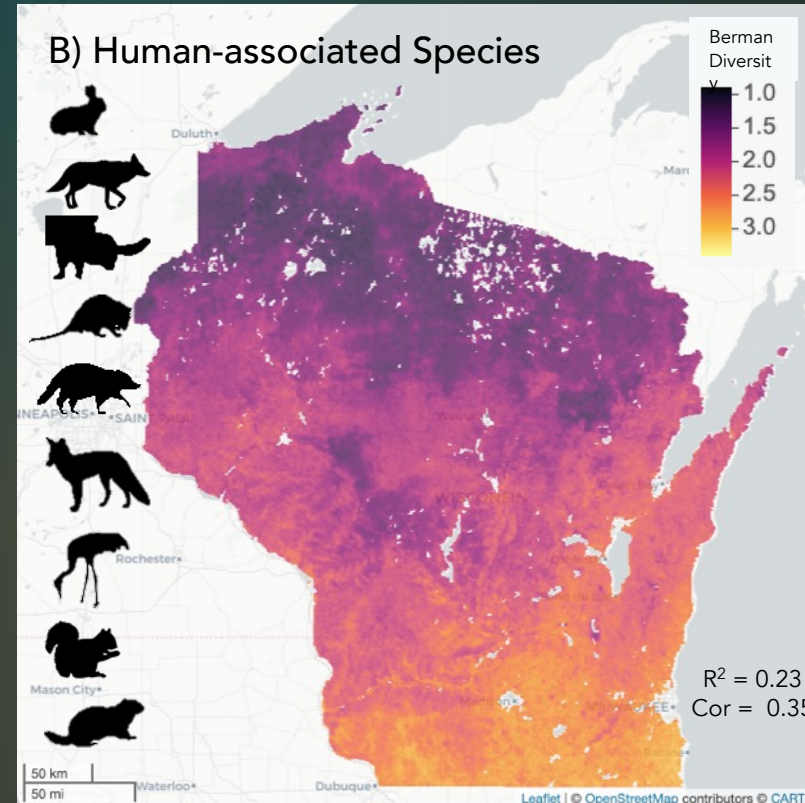
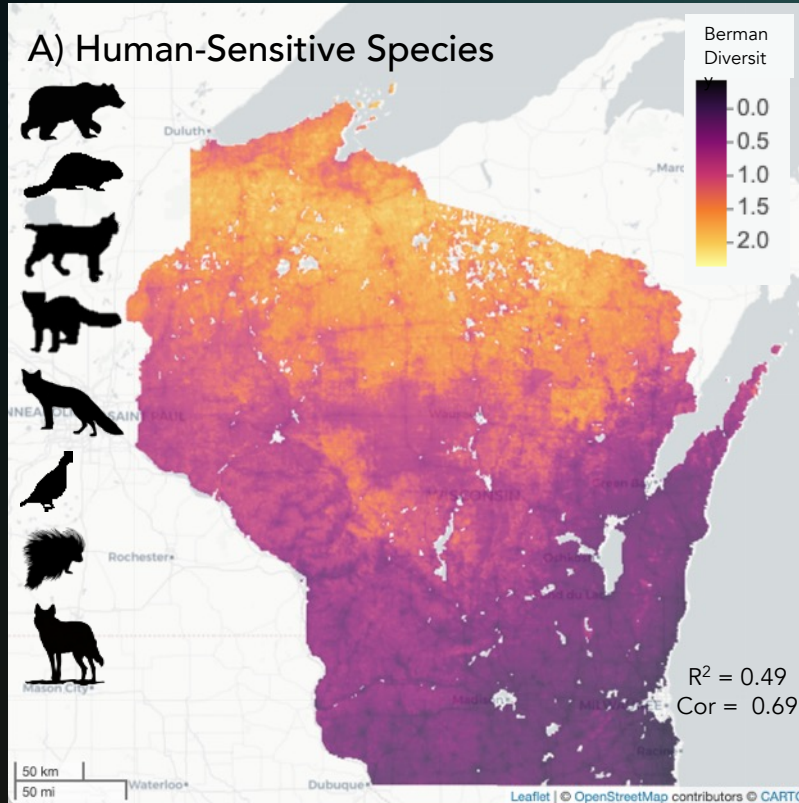
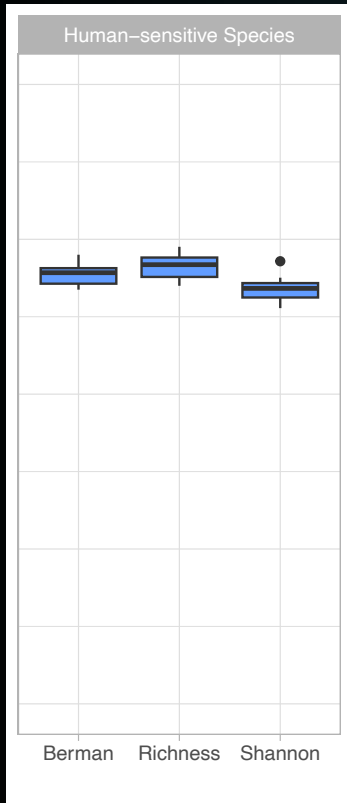
# Understanding large-scale patterns of animal diversity

Wisconsin-wide analysis using Snapshot Wisconsin and BioCube

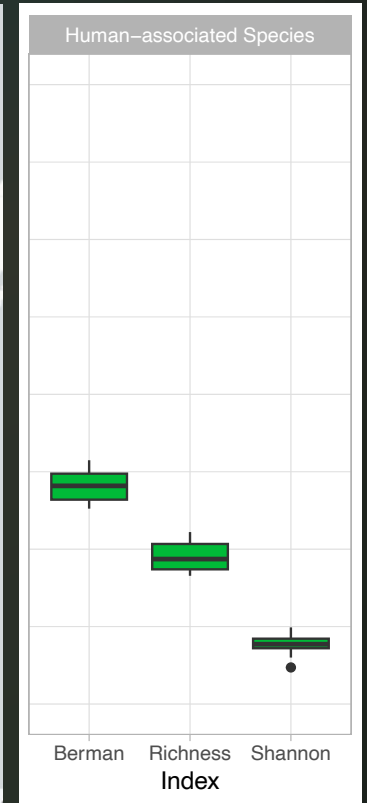
$$Diversity_{site} = \sum_{i=1}^n \left( \frac{d_{site,i}}{d_{max,i}} \right)^{\frac{\log 0.5}{\log \left( \frac{d_{site,i}}{d_{max,i}} \right)}}$$

**Berman Diversity:** A diversity index for camera trap networks

Accuracy



Accuracy



# Understanding large-scale patterns of animal diversity

## Outlook: Animal diversity and activity in the California Sierra Nevada

### Poster by Laura Berman

BioCube

Integrating remote sensing and in-situ dimensions of biodiversity to understand plant and animal community composition and dynamics at large scales

Laura M. Berman<sup>1</sup>, Fabian D. Schneider<sup>2</sup>, Ryan P. Pavlick<sup>2</sup>, Zach Peery<sup>1</sup>, Connor Wood<sup>3</sup>, Jennifer Stenglein<sup>4</sup>, Ryan Bemowski<sup>4</sup>, Morgan Dean<sup>5</sup>, Ting Zheng<sup>1</sup>, ZhiWei Ye<sup>1</sup>, Ethan Shafron<sup>2</sup>, Natalie Queally<sup>1</sup>, Jason Winiarski<sup>1</sup>, Anu Kramer<sup>1</sup>, Philip A. Townsend<sup>1</sup>

#### Hyperspectral foliar traits and bioacoustics

BioCube includes 200+ geospatial data layers across California and Wisconsin, including landcover, topography, soils, forest structure, anthropogenic variables, and foliar traits like LMA and nitrogen.

**BIRDNET bioacoustic species detection**

+100 MILLION OBSERVATIONS
~900 ARU LOCATIONS
101 SPECIES
3 YEARS

Research questions:

- What is the relationship between BioCube measures of forest structure and function and avian vocal behavior?
- Do birds allocate more energy towards song at sites with higher primary productivity, as derived from remotely sensed measures of productivity and vegetation traits?
- Does functional diversity in forests impact the species composition or diversity of birds?

#### A new diversity index for real wildlife communities

$$Diversity_{site} = \sum_{i=1}^n \left( \frac{d_{i(site)}}{d_{i(max)}} \right)^{\log 0.5}$$

Our diversity index better reflects ecological patterns in real datasets where detectability and maximum population densities vary by species, as compared to Shannon diversity.

**Berman diversity differs from Shannon diversity in these ways:**

1. All species are valued equally.
2. Diversity increases linearly with species richness.
3. An increase in richness or abundance always results in an increase in diversity.
4. Population decline results in a loss of diversity.
5. Species detectability does not bias the index.
6. Multiple sites are required.

Site	Species	Abundance	Shannon	Berman
A	4.51	8.36	2.36	28.67
B	0.88	0.52	2.08	1.8
C	0.11	0.35	2.08	0
D	0	0.35	2.36	23.51
E	0.11	0.35	2	23.51
F	0.0011	0.0025	0.0228	0.205

MULTIPLE TROPHIC LEVELS

DIFFERENT BODY SIZES

DIFFERENT DETECTABILITY

DIFFERENT MAX DETECTION RATES

Does Berman diversity outperform Shannon diversity in real datasets?

We used species detection rates at 4,000+ camera traps in the Snapshot Wisconsin network and ~200 BioCube geospatial layers to model Berman diversity, Shannon diversity, and species richness in Wisconsin.

Berman diversity models produced better validated models of spatial patterns than simple species richness, while Shannon diversity models were significantly worse than species richness, suggesting that Berman diversity adds ecologically relevant information, while Shannon diversity may be introducing stochasticity.

Contact: Dr. Laura Marie Berman  
lberman6@wisc.edu

<sup>1</sup>University of Wisconsin – Madison; <sup>2</sup>CalTech Jet Propulsion Lab; <sup>3</sup>Cornell University; <sup>4</sup>Wisconsin Department of Natural Resources; <sup>5</sup>University of California, Los Angeles

Acknowledgment: Funding to support this research was provided by a NASA Biodiversity Program grant. JPL work was conducted under a contract with the NASA (80NM0018D0004) with a subaward to UW-Madison (1669379). Aspects of this research have also received support from NASA Ecological Forecasting (NNX14AC36G) program as well as the NSF ASCEND Biology Integration Institute (BII) through DBI award 2021896.

What is the relationship between BioCube measures of forest structure and function and avian vocal behavior?

Do birds allocate more energy towards song at sites with higher primary productivity, as derived from remotely sensed measures of productivity and vegetation traits?

Does functional diversity in forests impact the species composition or diversity of birds?



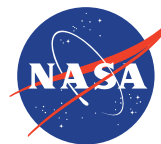
Sierra Nevada Mountains

Photo: Fabian Schneider, July 2023

# Thank you

Adam Chlus (JPL), Alex Turner (UW),  
Camila Cortez (UW Madison/JPL), John  
Clare (UC Berkeley), Morgan Dean  
(UCLA/JPL), and many others

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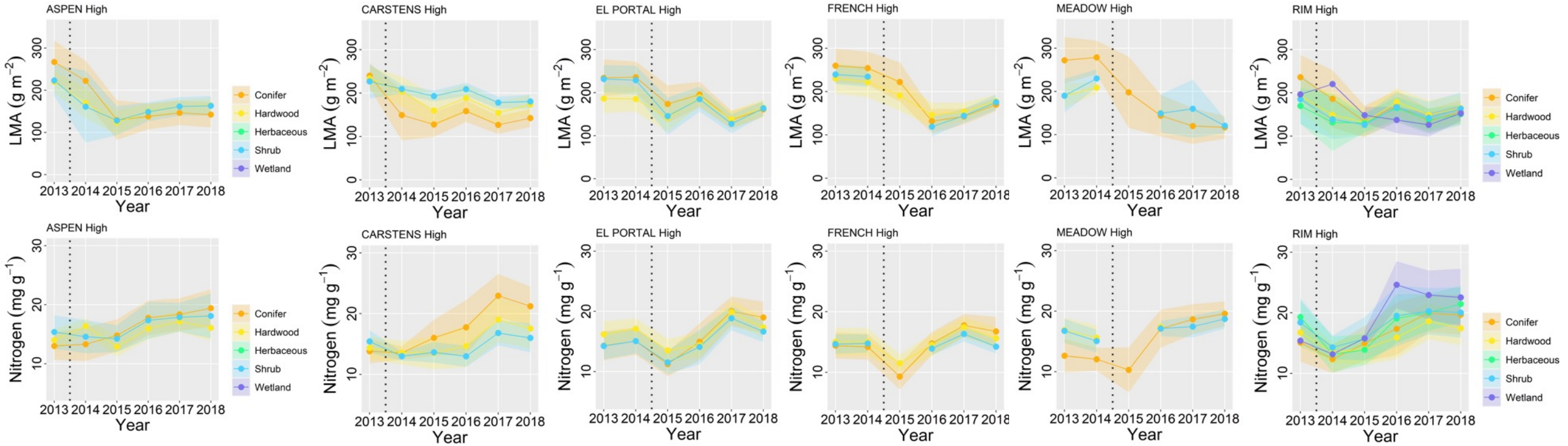


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# High intensity fires



# California Foliar Trait Mapping



Using AVIRIS Classic as precursor to SBG

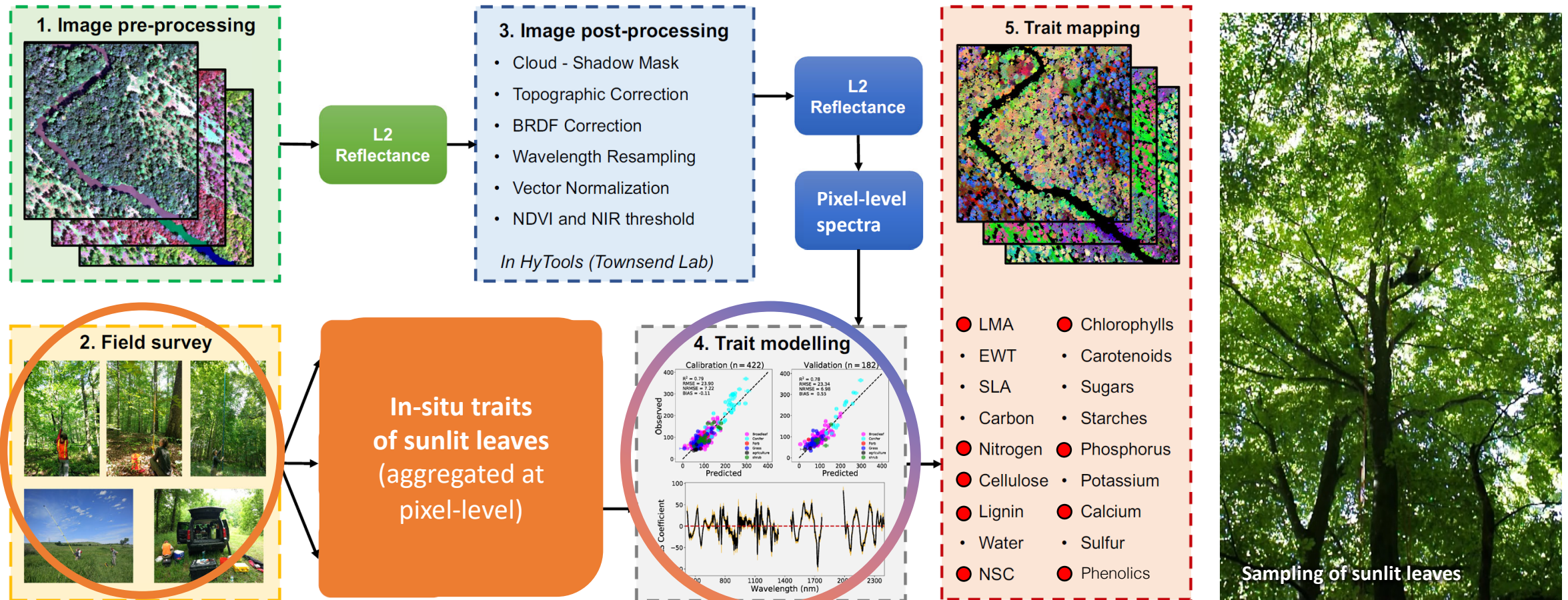


Fig. 2 Trait mapping workflow using NEON AOP images and field data. LMA, leaf mass per area; EWT, equivalent water thickness; SLA, specific leaf area; NSC, nonstructural carbohydrate.

Leaf Mass per Area

Yosemite  
Valley

Grant Grove

Mariposa  
Grove

(mg g<sup>-1</sup>)

96.4 192.9 289.3

24

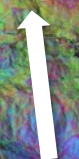


LMA, Height, Chlorophyll

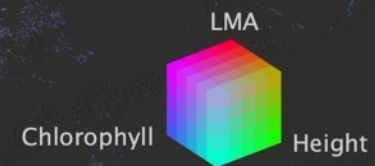
Yosemite Valley



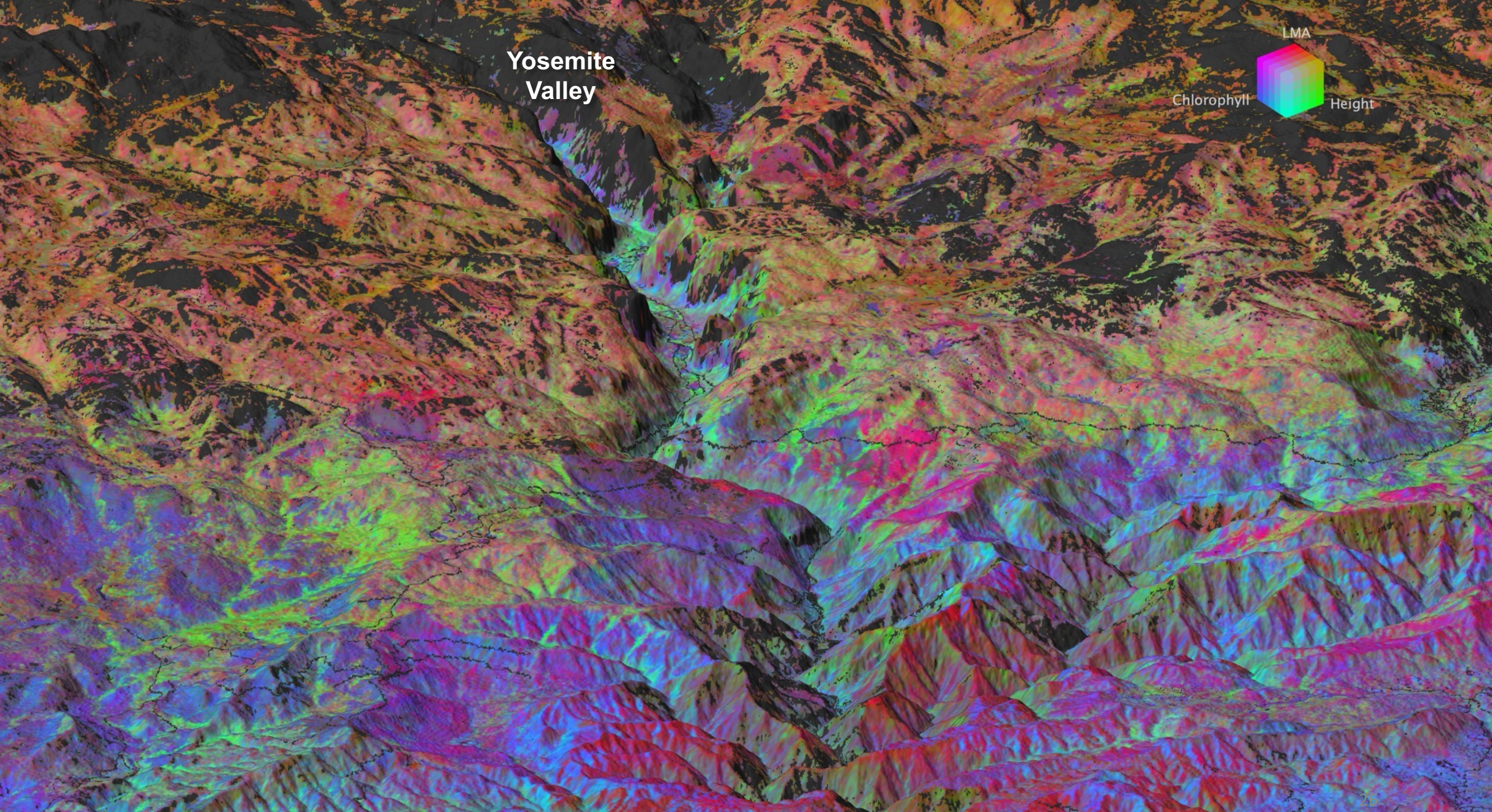
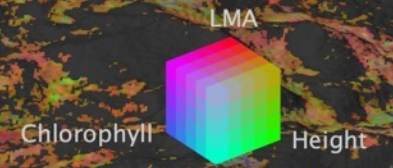
Mariposa Grove



Grant Grove



# Yosemite Valley

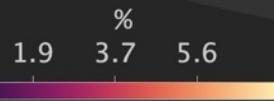


# Functional Diversity and Ecosystem Functions

NASA BioCube

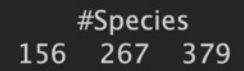
Functional Richness at 1 km

Schneider et al. (in prep)



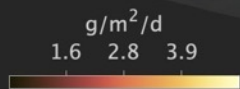
Species Richness at 1 km

Kling et al. 2019



GPP JJA at 1 km

TROPOMI



ET JJA at 1 km

ECOSTRESS



Biomass at 1 km

GEDI



Schneider et al. (in prep)