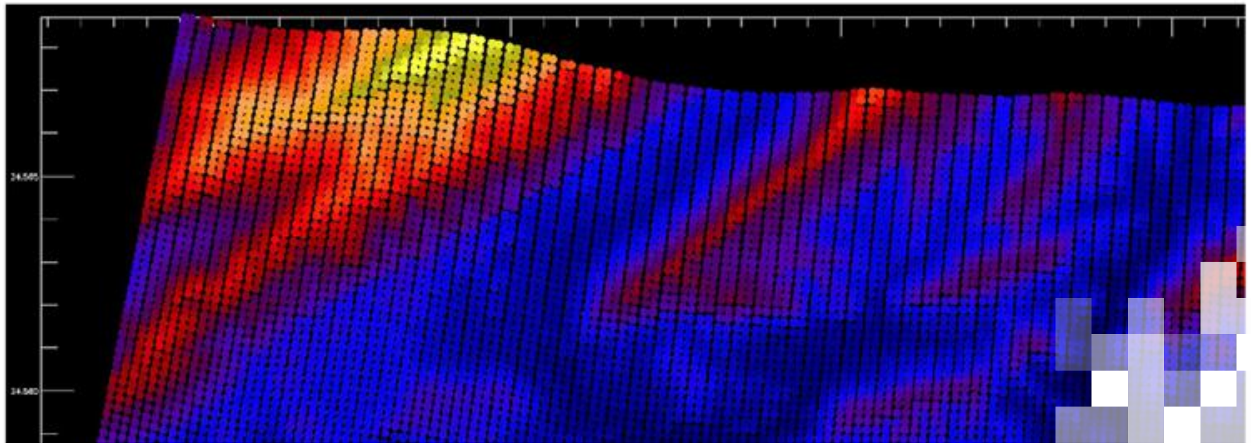
National Aeronautics and Space Administration



Biodiversity Applications for Airborne Imaging Systems

Juan L. Torres-Pérez, Britnay Beaudry, Sativa Cruz, Amber McCullum

Guest Speakers: Natasha Stavros

Invited contributors: Liane Guild, Jeremy Kravitz

April 5, 2023

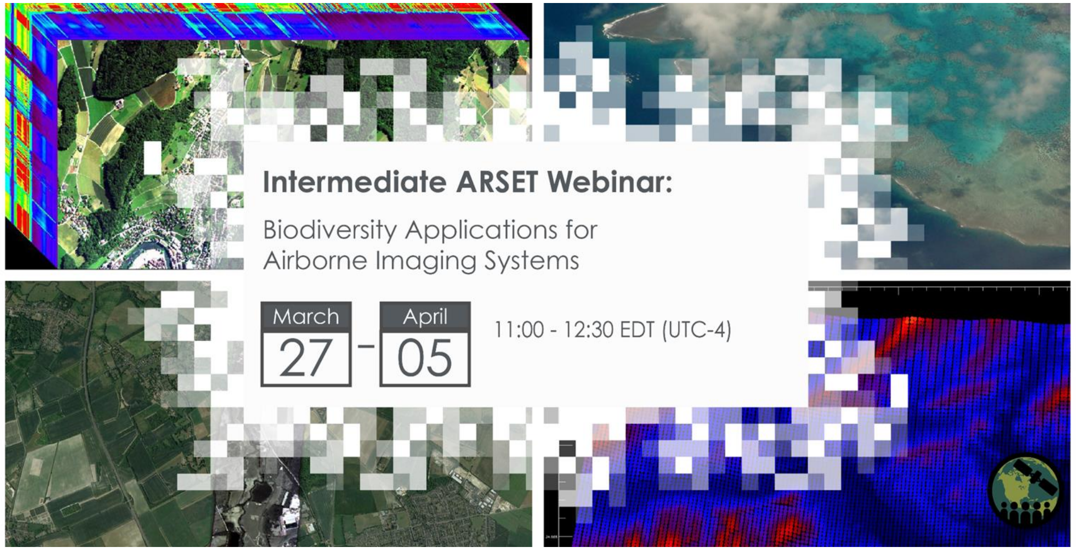
Course Structure and Information

- Four, 1.5-hour sessions on March 27, 29 & April 3, 5
  - 11:00 am - 12:30 pm EDT (UTC-4:00)

- Each session will feature a lecture and a Q&A session where instructors will be online to answer questions.

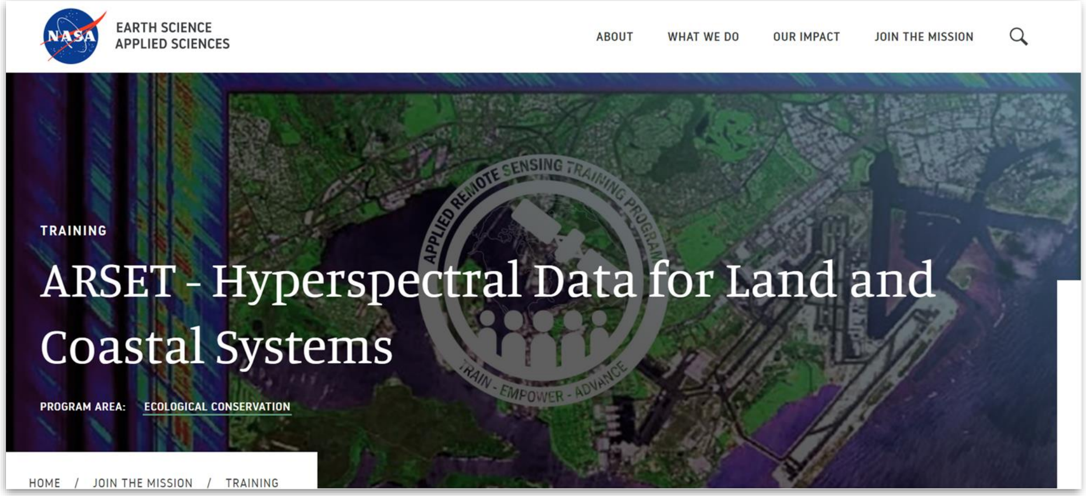
- Webinar recordings and PowerPoint presentations can be found after each session at: https://appliedsciences.nasa.gov/join-mission/training/english/arset-biodiversity-applications-airborne-imaging-systems

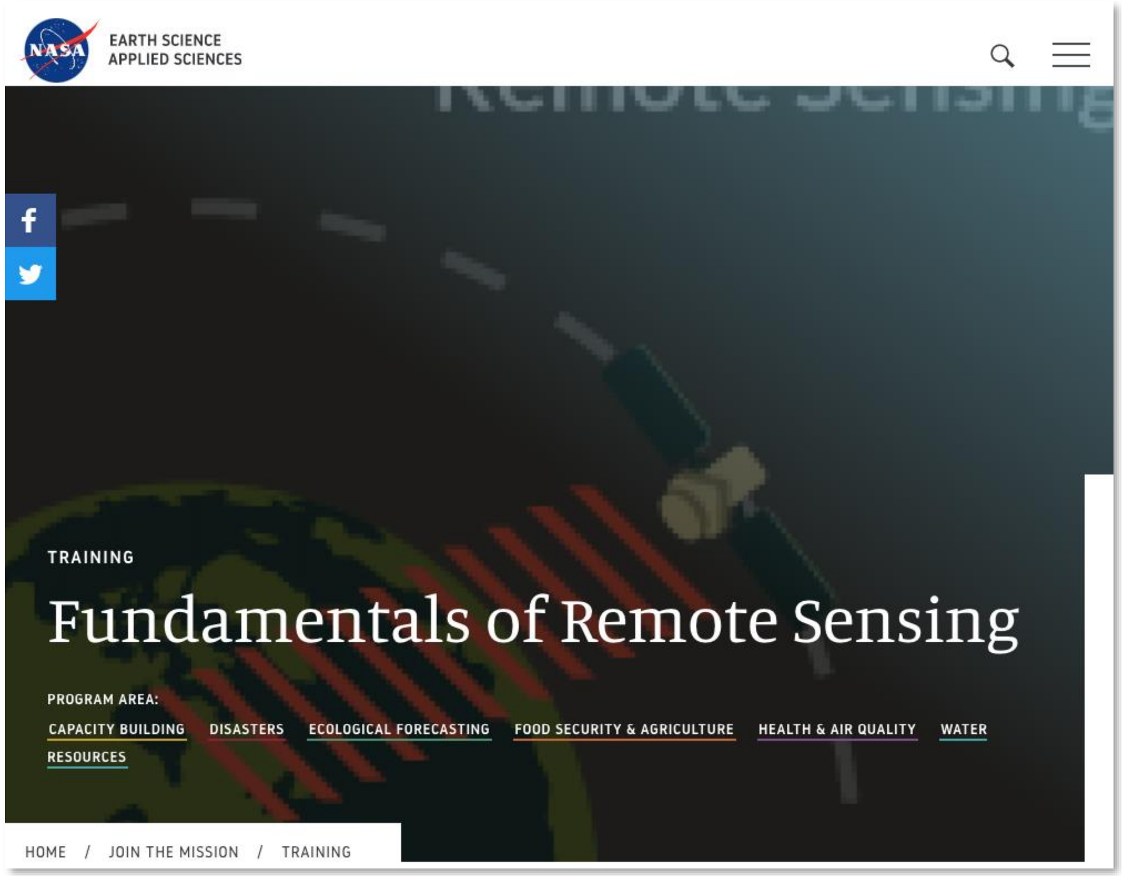
- For additional questions please email:
  - Juan L. Torres-Pérez (juan.l.torresperez@nasa.gov)
  - Amber McCullum (amberjean.mccullum@nasa.gov)
  - Britnay Beaudry (britnay.beaudry@nasa.gov)
  - Sativa Cruz (sativa.cruz@nasa.gov)



Prerequisites

- Prerequisites:
  - [Fundamentals of Remote Sensing]
  - [Hyperspectral Data for Land and Coastal Systems]
    - Or equivalent experience

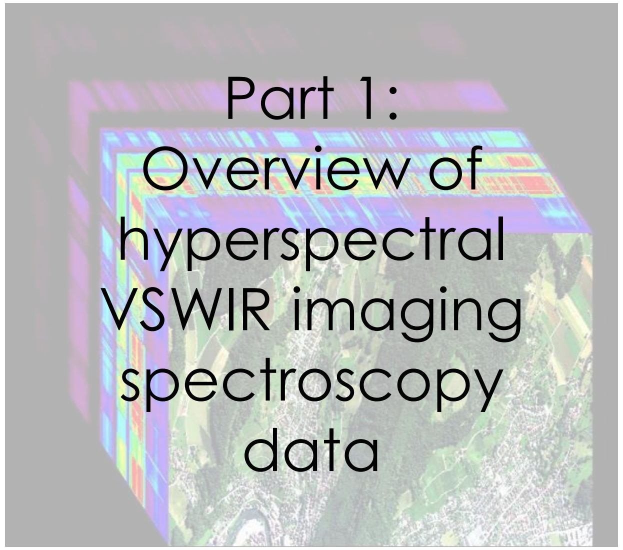




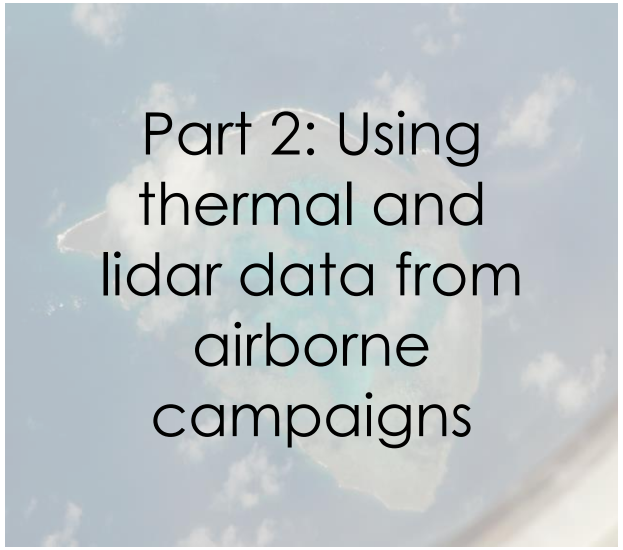
Homework and Certificates

- **Homework:**
  - One homework assignment (available at the end of session four of this webinar series)
  - Answers must be submitted via Google Forms
  - **HW deadline: April 19th**
- **Certificate of Completion:**
  - Attend all four live webinars
  - Complete the homework assignment by the deadline (access from ARSET website)
  - You will receive certificates approximately two months after the completion of the course from: marines.martins@ssaihq.com

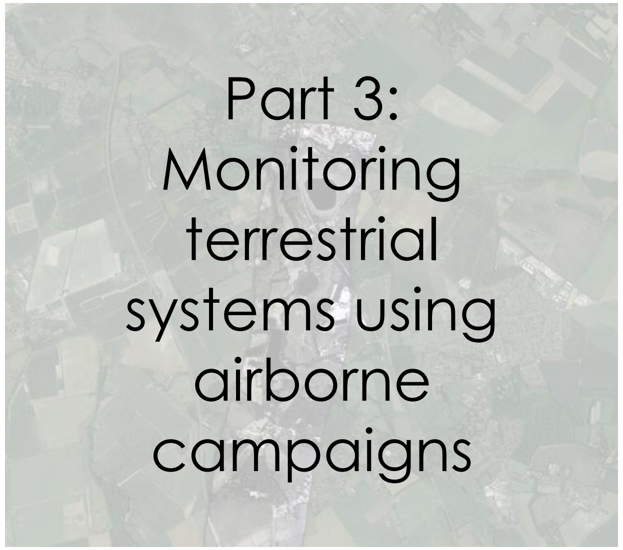
Course Outline



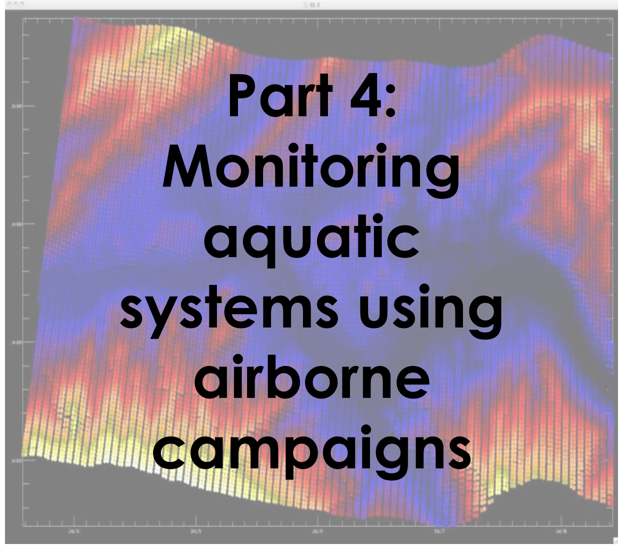
Part 1: Overview of hyperspectral VSWIR imaging spectroscopy data



Part 2: Using thermal and lidar data from airborne campaigns



Part 3: Monitoring terrestrial systems using airborne campaigns

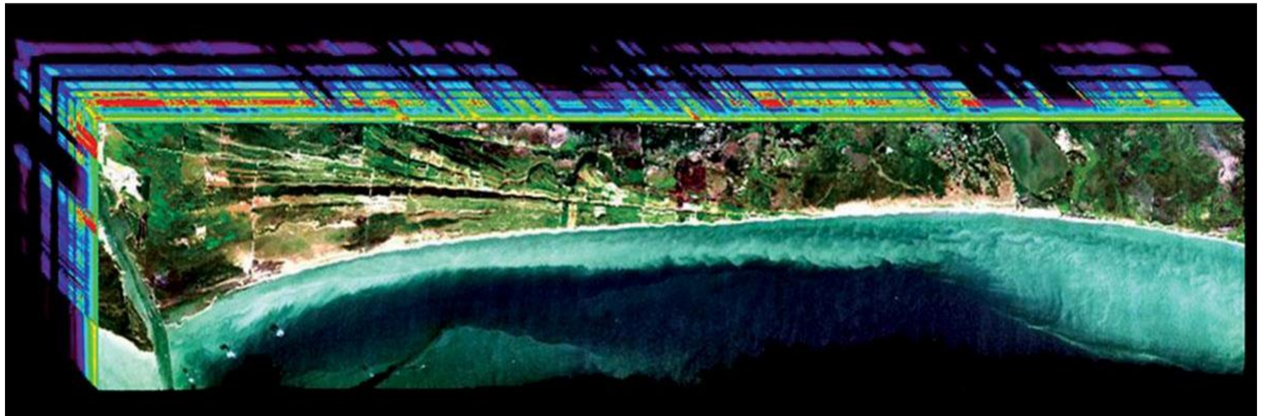


Part 4: Monitoring aquatic systems using airborne campaigns

Learning Objectives

By the end of this training attendees will be able to:

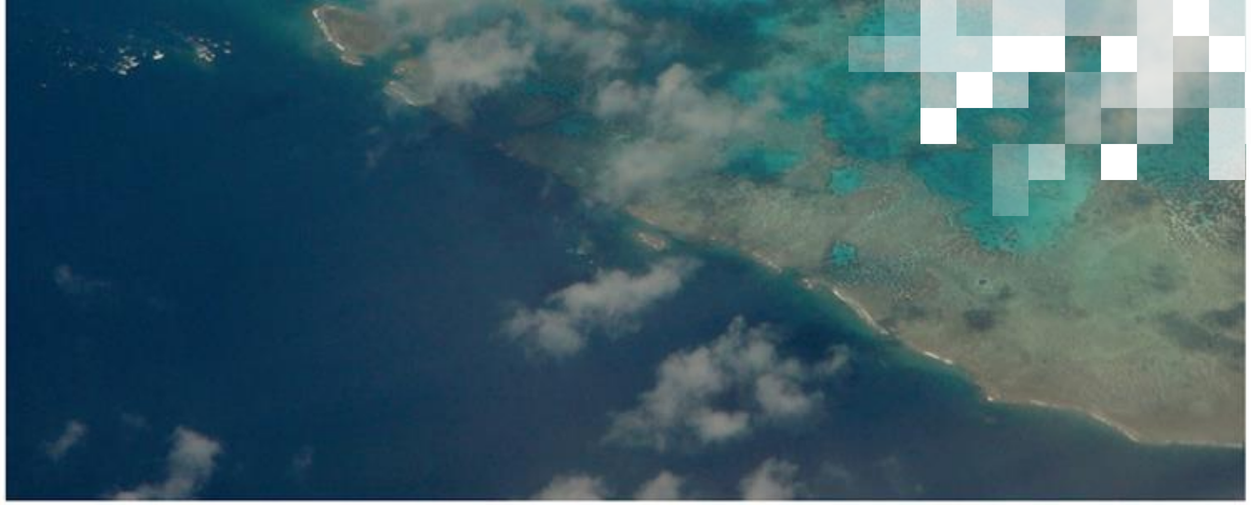
- Understand the applications of hyperspectral data, multispectral data, and LiDAR data for biodiversity monitoring and analysis
- Compare case studies that have used these datasets in preparation for upcoming NASA satellite missions and airborne campaigns

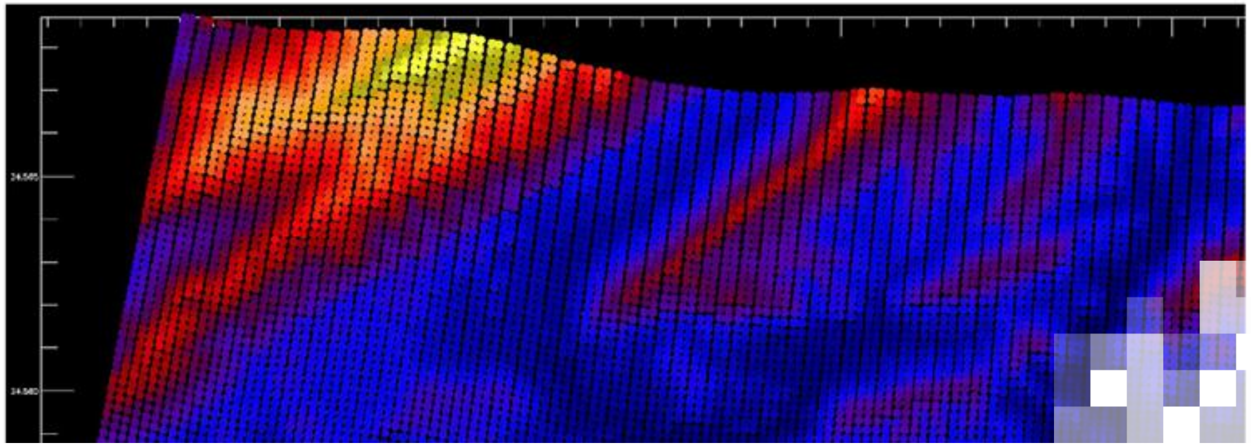


Source: NASA JPL

Part 4 Agenda

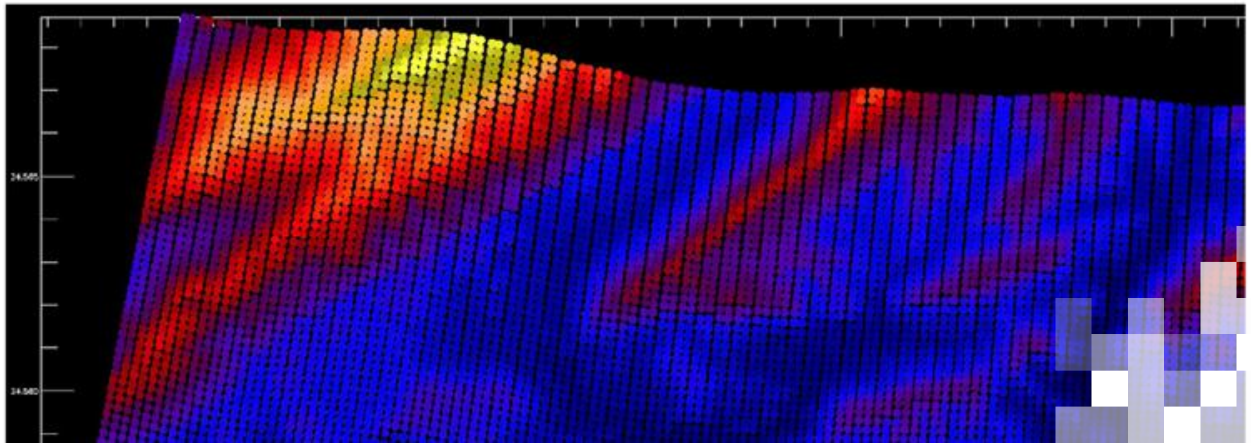
- Watershed scale monitoring of biodiversity at multiple scales using eDNA, remote sensing, and field sampling
  - Highlight of HyTES and AVIRIS-NG data and analogous satellite data from ECOSTRESS and EMIT
  - Overview of how spatial scale influences diversity metrics to inform how we can go from big data to manageable data
- Monitoring aquatic systems using imaging spectroscopy and airborne campaigns
  - Highlight of PRISM applications and the CyanoSCape project
  - Highlight of PACE preparatory data
- Q&A Session



Guest Speaker: Natasha Stavros, Director of the Earth Lab Analytics Hub, Cooperative Institute for Research in Environmental Studies (CIRES), University of Colorado Boulder

National Aeronautics and Space Administration



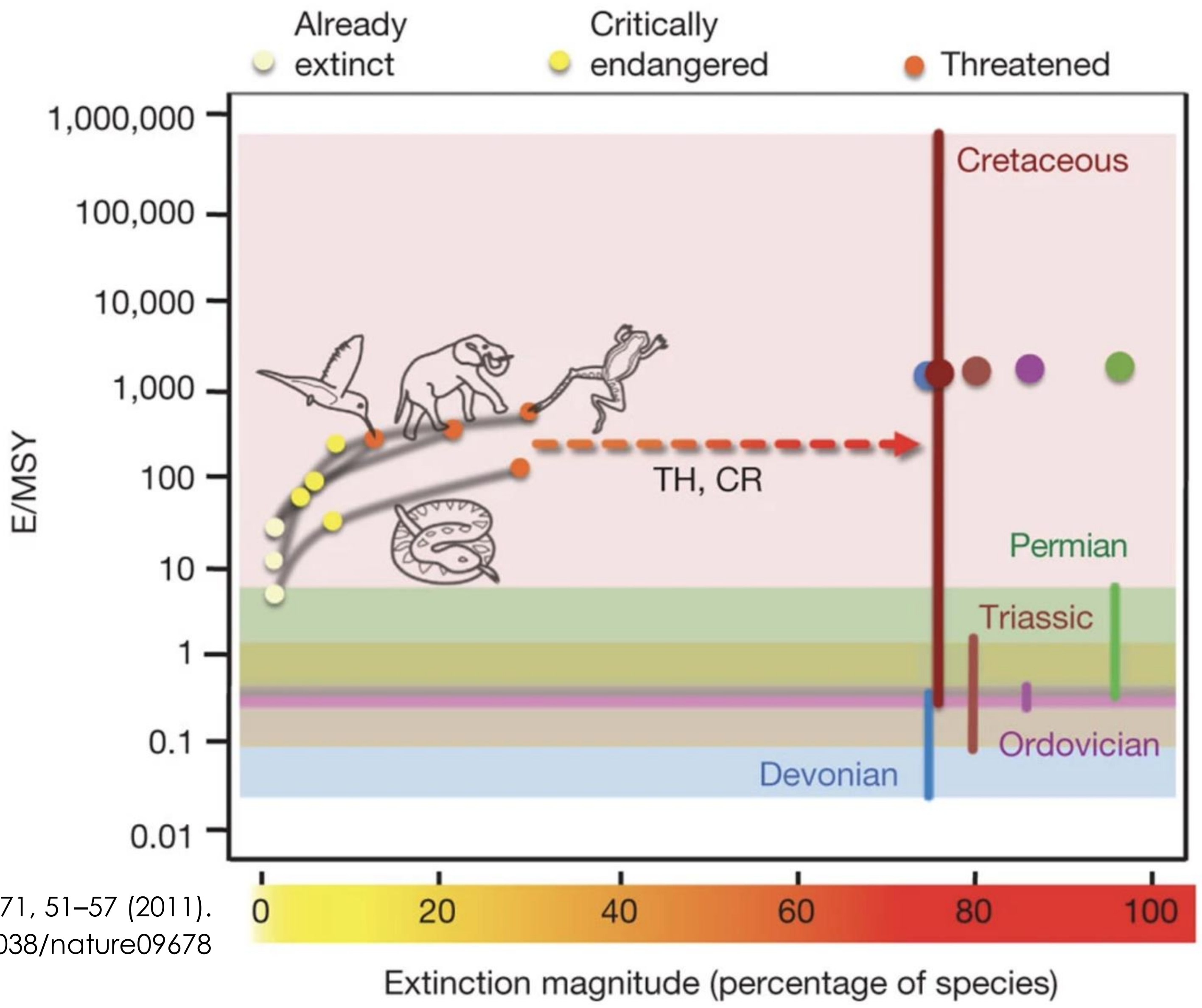
Biodiversity Applications for Airborne Imaging Systems

E. Natasha Stavros, CIRES, University of Colorado Boulder
Team: Rachel Meyer (UCSC), Matt Rossi (CIRES, CUB), Meghan Hayden (CUB), Madeline Slimp (UCSC)

March 27, 2023

Sixth Mass Extinction

Ordovician	~445M yrs ago	Moving supercontinent, sea level rise, Ordovician **ice age**, and changes in water chemistry
Devonian	~370M yrs ago	Cause Unknown
Permian	~252M yrs ago	**Climate Change**
Triassic	~201M yrs ago	**Climate Change**
Cretaceous	~66M yrs ago	**Climate Change**
Holocene	Now	Human-caused global warming, **climate change**, and land cover and land use that increases invasives

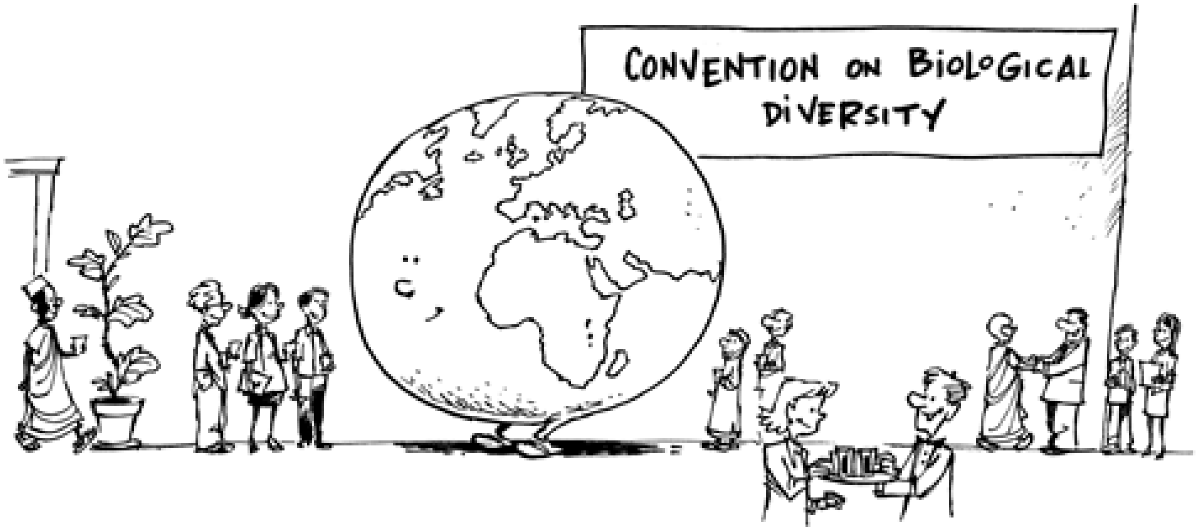


Barnosky et al. (2011), Nature 471, 51–57 (2011). https://doi.org/10.1038/nature09678

International Effort to Conserve Biodiversity

A multilateral treaty for "the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources"

- Legally binding document with an obligation to implement
- Ratified by 196 countries



https://www.cbd.int/ibd/2008/youth/cbd/

Success Relies on Metrics of Measurable Outcomes

In 2010, the International Year of Biodiversity, the UN declared 2011 to 2020 as the United Nations Decade on Biodiversity.

- Strategic Plan for Biodiversity 2011-2020
- Aichi Biodiversity Targets that Include 4 Strategic Goals; Each with Targets; Each Target has Indicators

No global observation system led the Group on Earth Observations Biodiversity Observation Network (GEO BON) to create Essential Biodiversity Variables (EBVs).

EBV class	EBV examples	Measurement and scalability	Temporal sensitivity
Genetic composition	Allelic diversity	Genotypes of selected species (e.g., endangered, domesticated) at representative locations.	Generation time
Species populations	Abundances and distributions	Counts or presence surveys for groups of species easy to monitor or important for ES, over an extensive network of sites, complemented with incidental data.	1 to >10 years
Species traits	Phenology	Timing of leaf coloration by RS, with in situ validation.	1 year
Community composition	Taxonomic diversity	Consistent multitaxa surveys and metagenomics at select locations.	5 to >10 years
Ecosystem structure	Habitat structure	RS of cover (or biomass) by height (or depth) globally or regionally.	1 to 5 years
Ecosystem function	Nutrient retention	Nutrient output/input ratios measured at select locations. Combine with RS to model regionally.	1 year

Pereira et al. (2013), Science, 339:6117 p 277-278. DOI: 10.1126/science.1229931

Remote sensing can be a valuable tool as it offers a top-down view with consistent information in time and space.

EBV class	EBV examples	Measurement and scalability	Temporal sensitivity
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Quick Check:

Screenshot from NCIS Season 16, Episode 2

How many have seen criminal shows that use a "mass spectrometer" to investigate the chemical compound of evidence?

Imaging Spectrometers do something very similar!

Rather than measuring mass, imaging spectrometers measure chemical compounds based on the structure of the compounds and how that absorbs and scatters the full spectral signature in the electromagnetic spectrum.

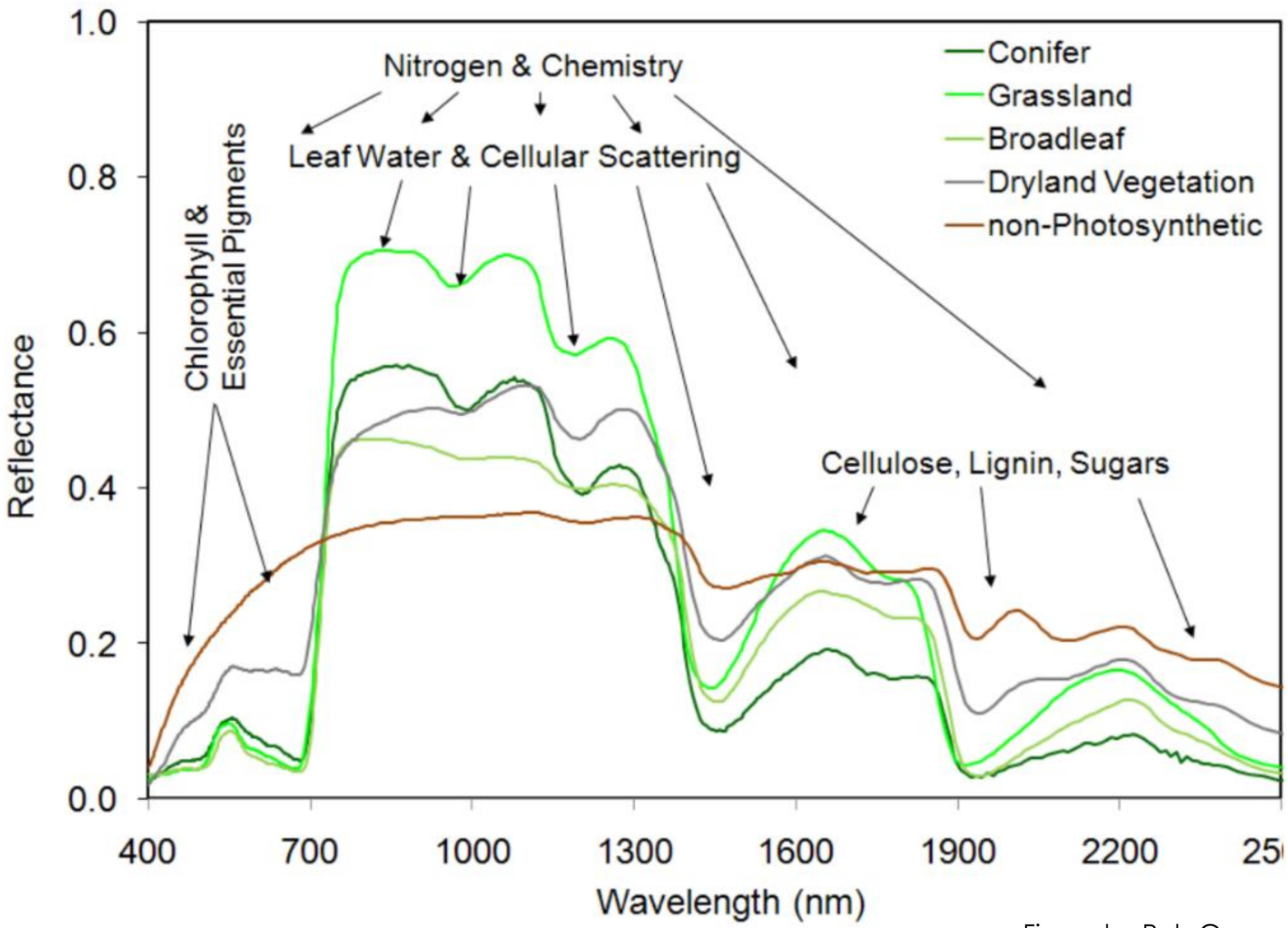
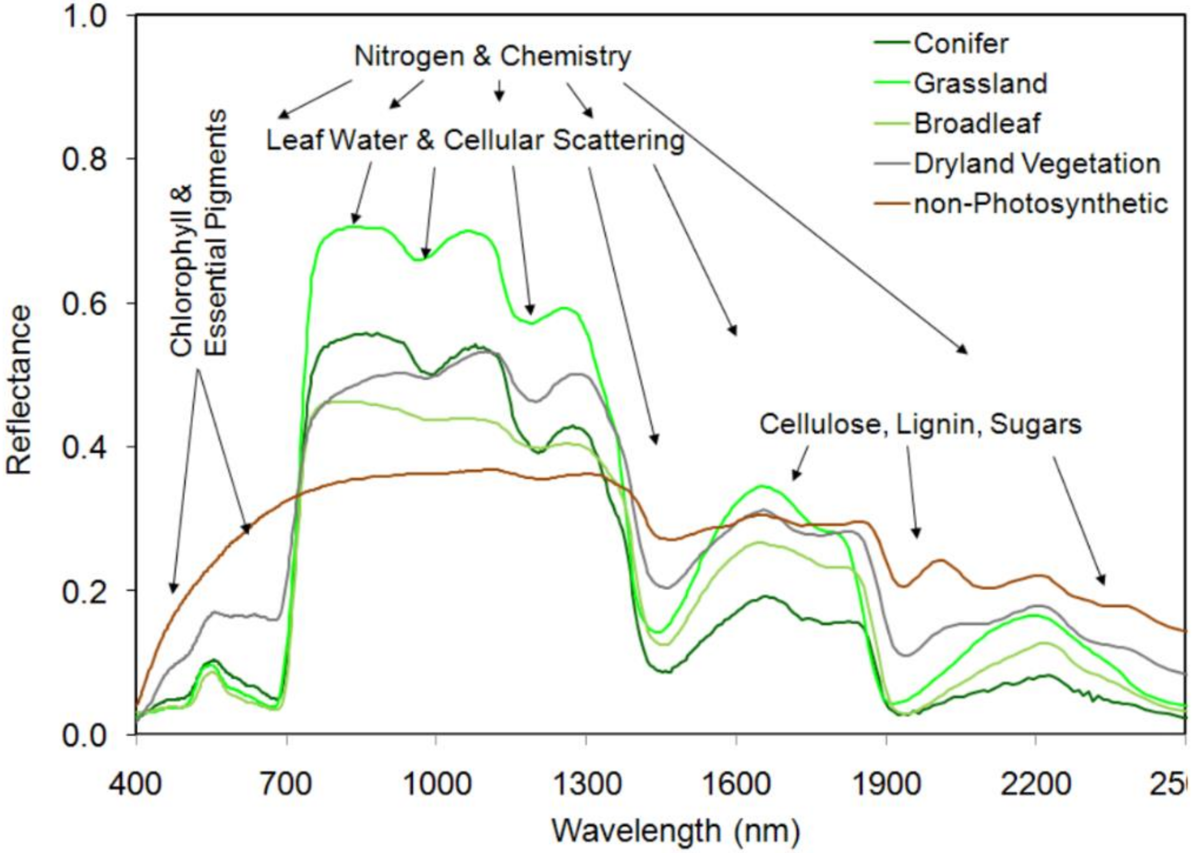
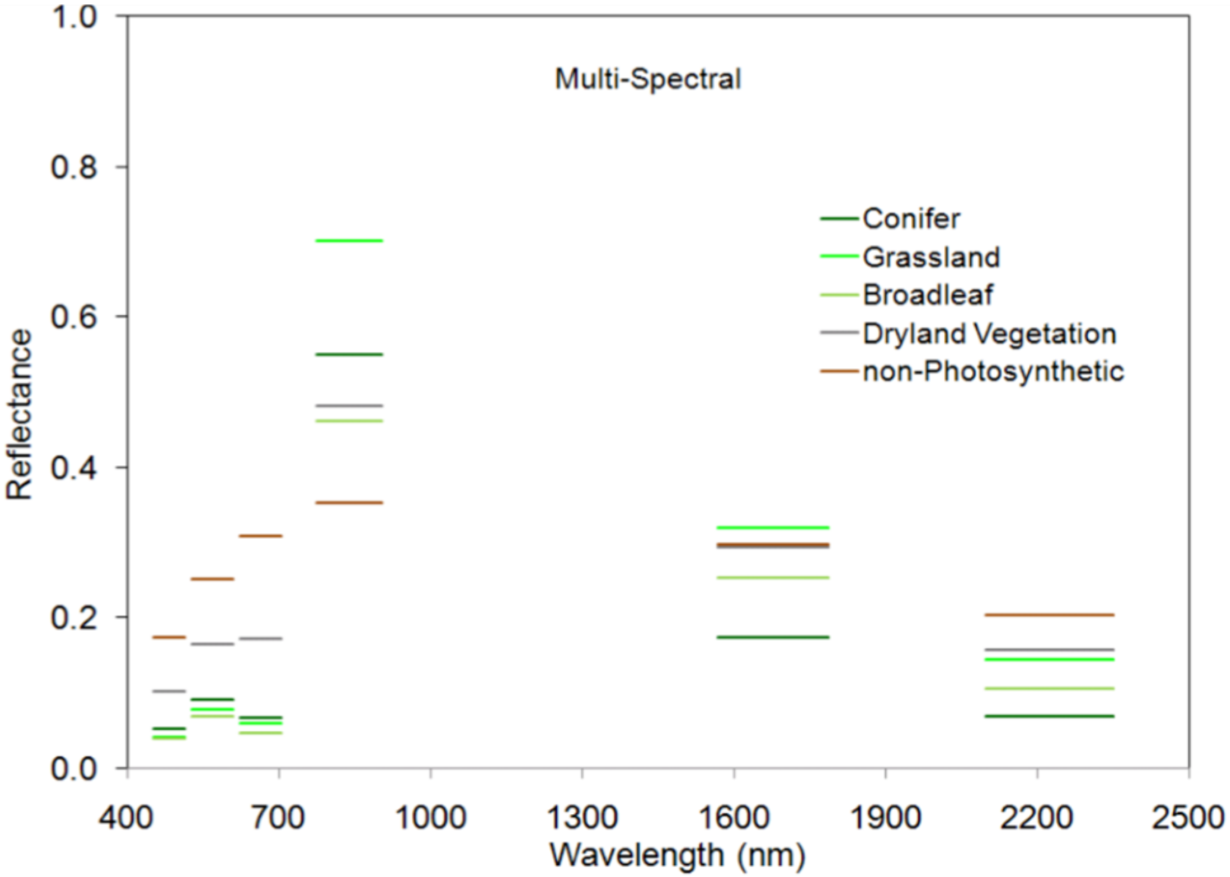


Figure by Rob Green

Compare this to multi-spectral, like what you see from Landsat.

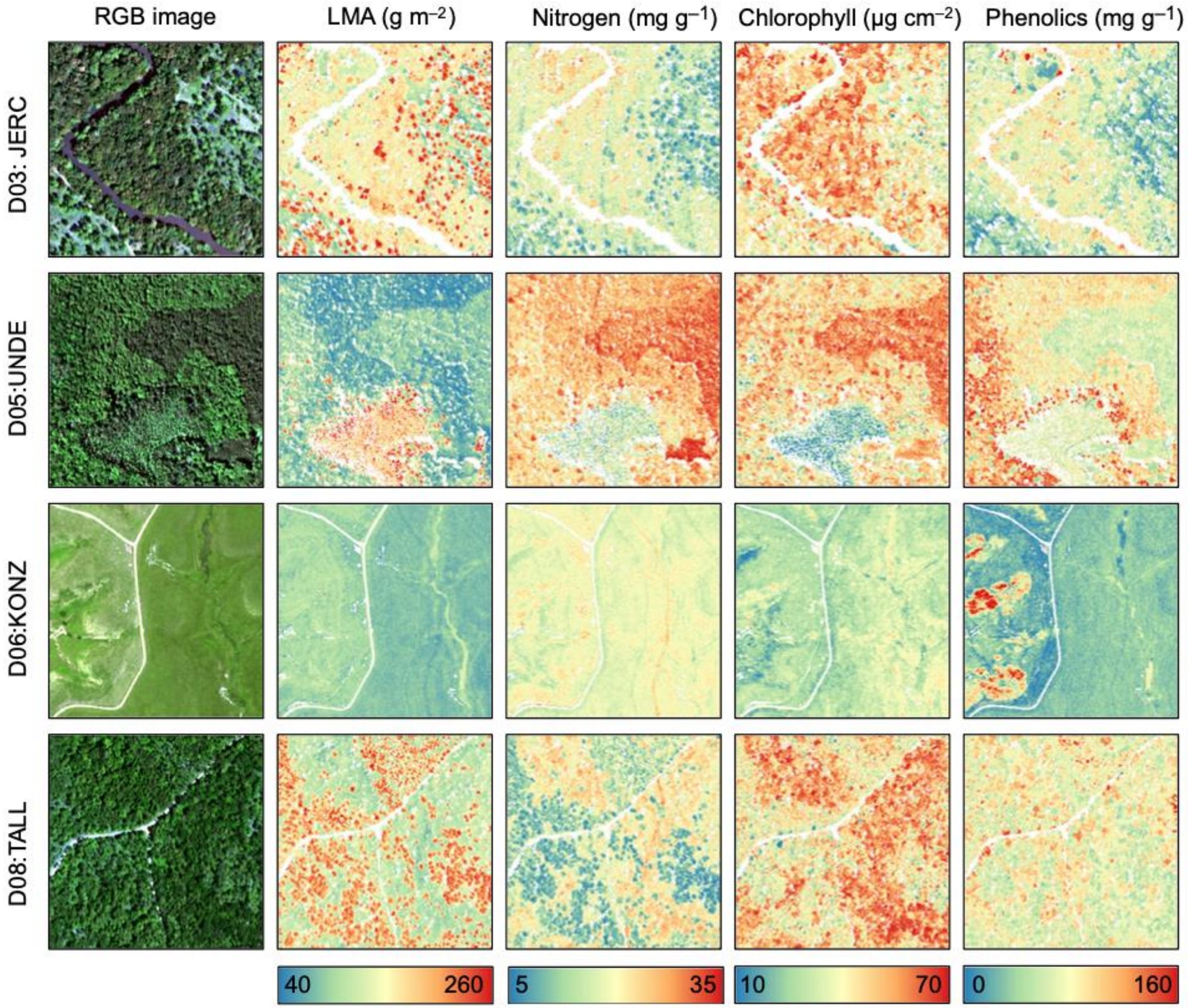




Modified Version of Figure by Rob Green

We can use imaging spectroscopy to map the biogeochemical “fingerprints” of the Earth’s Surface.

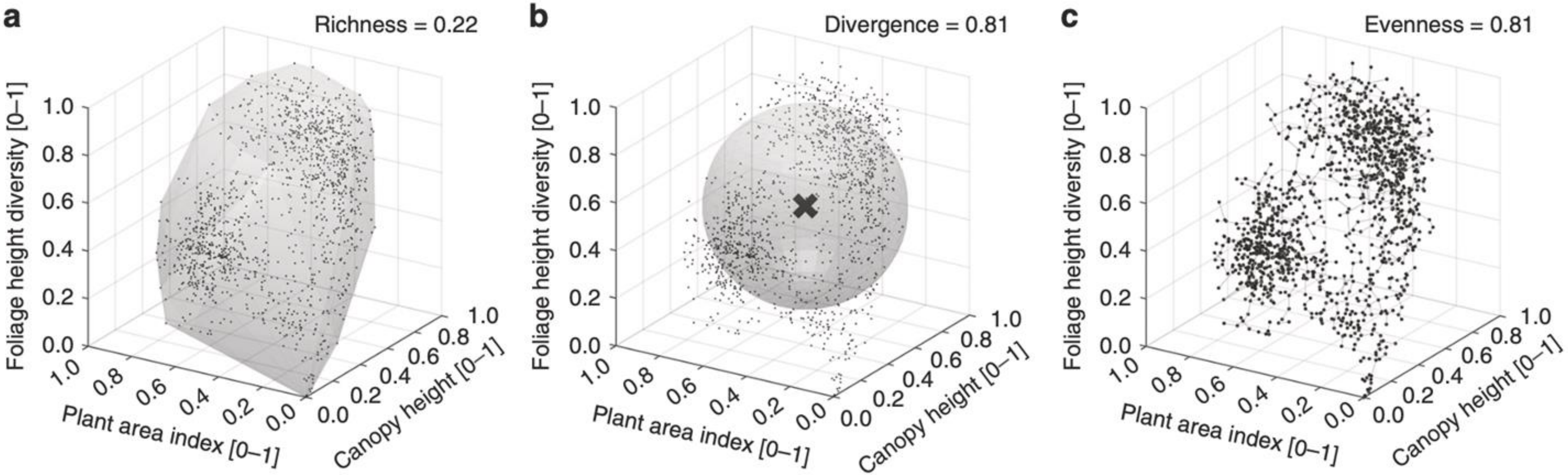
These fingerprints are “functional traits.”



Wang et al. (2020) new Phytologist. DOI: 10.1111/nph.16711

Functional Traits can be used to map Functional Diversity.

Richness = Volume of the space inhabited by all points
Divergence = Spread of points from center of gravity
Evenness = How evenly points are spaced



Schneider et al. (2017) Nature; http://www.nature.com/articles/s41467-017-01530-3

Also, functional traits represent key chemical processes (e.g., metabolism) that facilitate the cellular functions necessary to sustain life and can relate to specific species.

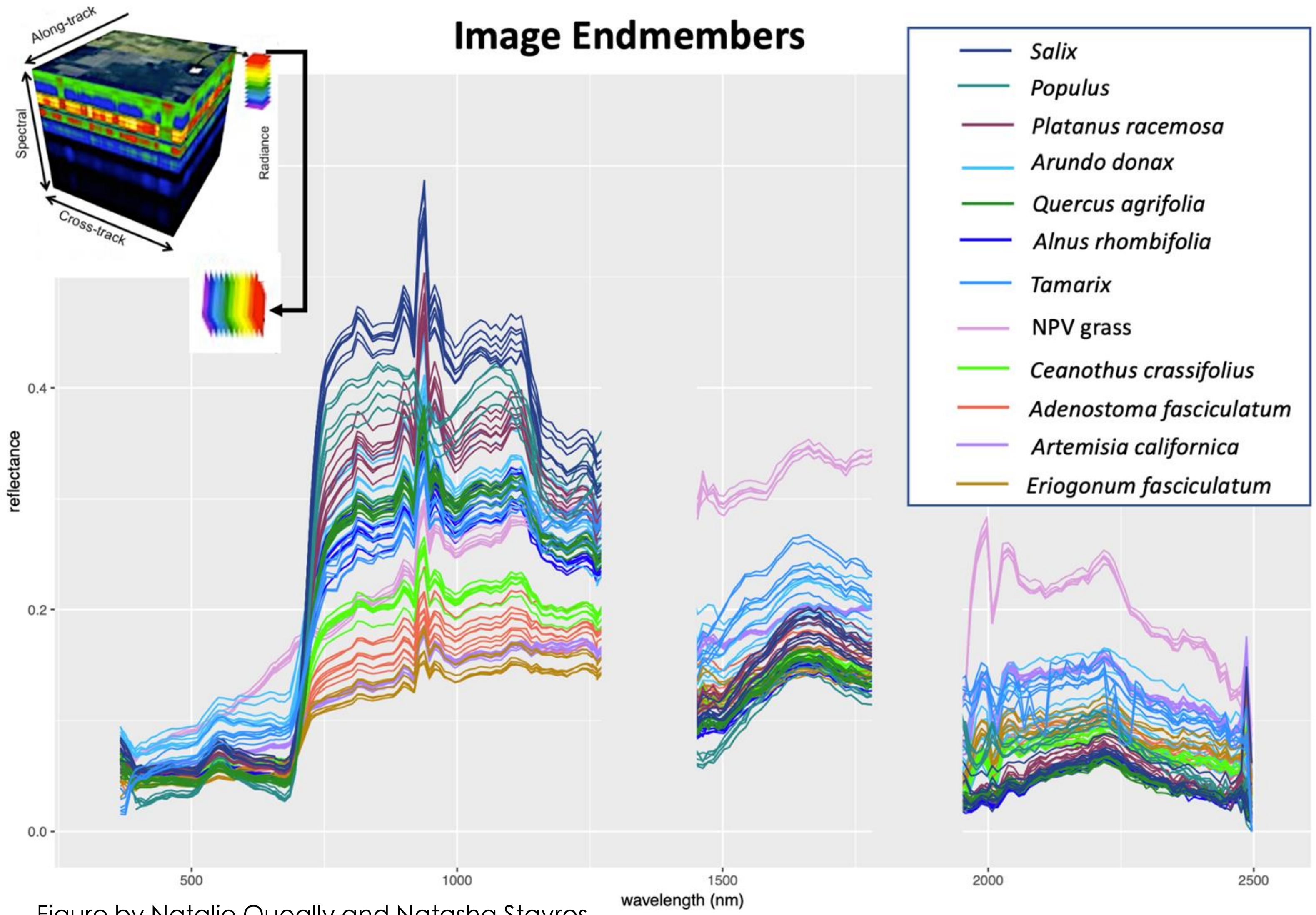
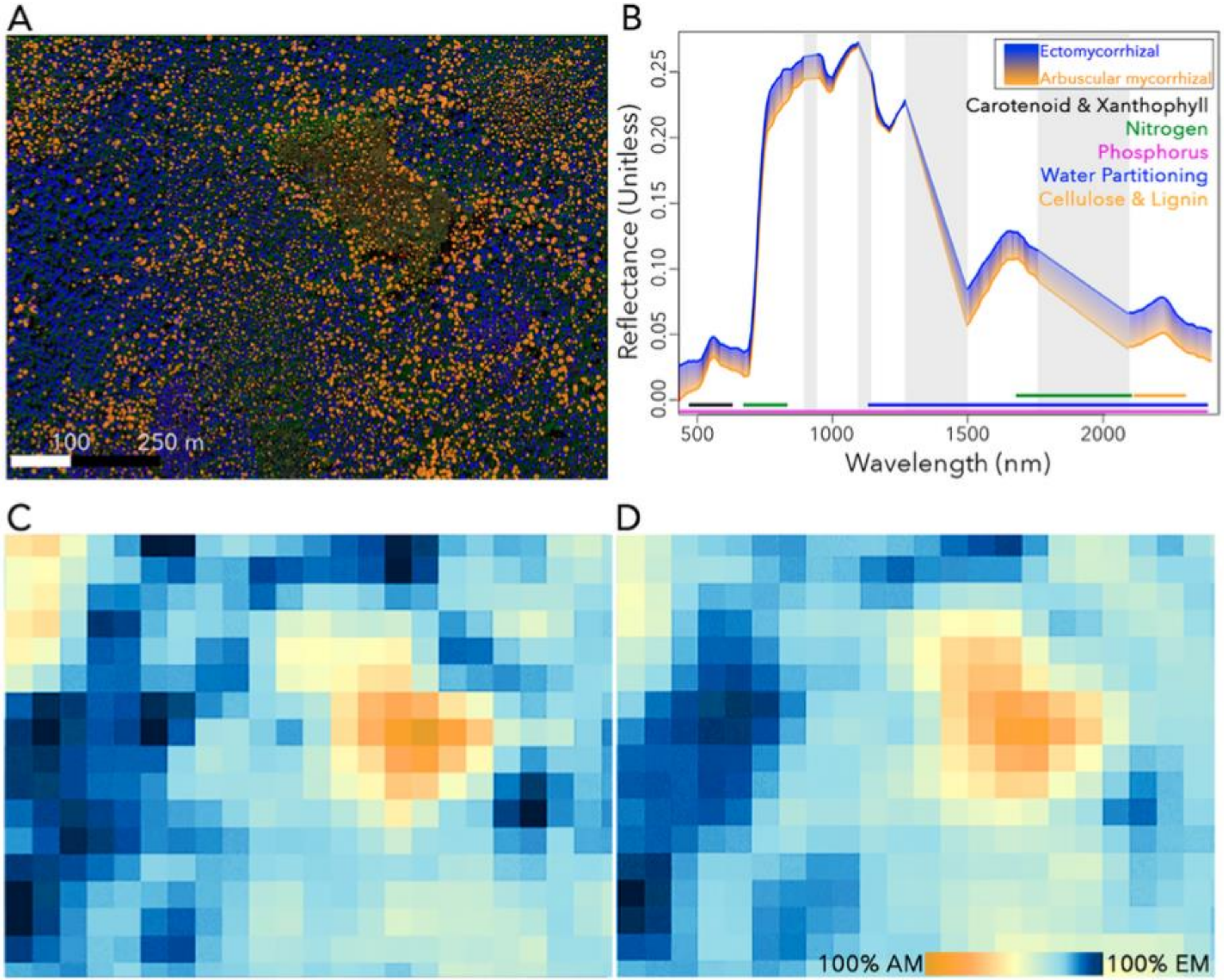


Figure by Natalie Queally and Natasha Stavros

Not just in the top of canopy, but also below ground in mycorrhizal fungi and microbial communities.

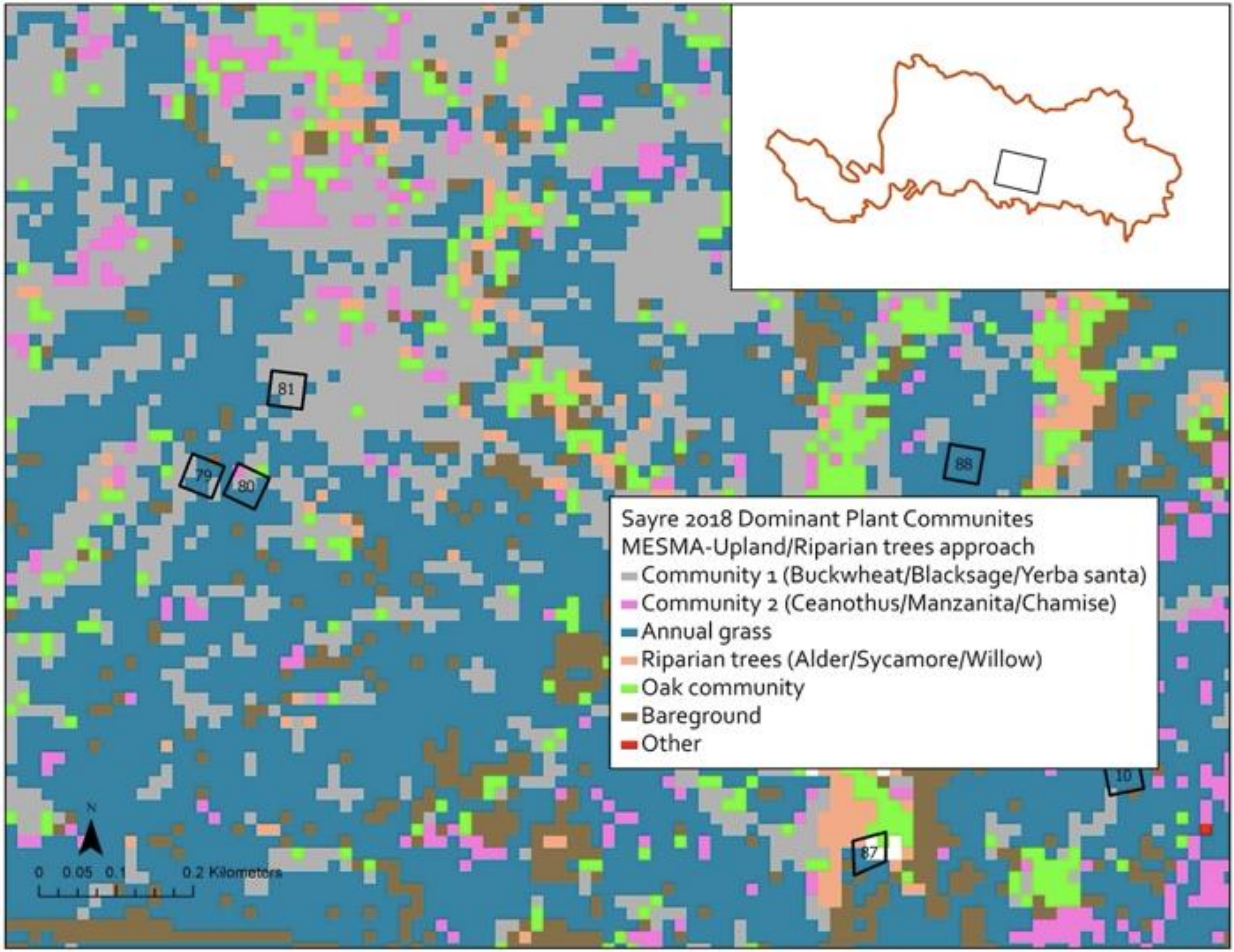


Sousa et al (2021) Geophysical Research Letters, 48, e2021GL0922764. DOI: 10.1029/2021GL092764

This allows us to map dominant species in the canopy and how they relate to plant communities.

Community	Producer's accuracy	User's accuracy
Community 1	72%	72%
Community 2	0%	0%
Bare ground	0%	0%
Annual grass	75%	71%
Oak Community	100%	80%

Overall accuracy = 66%

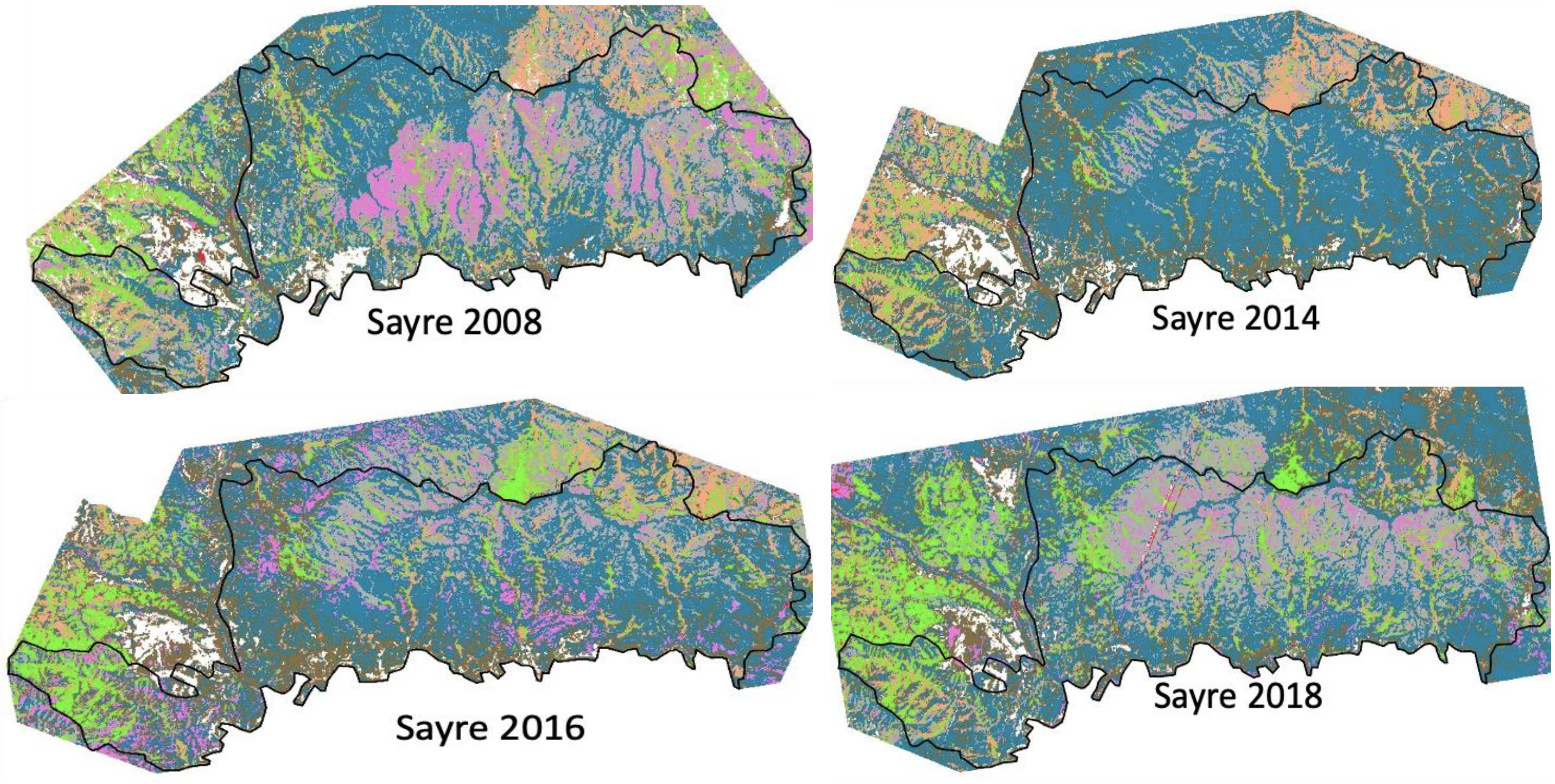


Bonfield et al. (2019) Assessment, prioritization, and planning for restoration and conservation activities on the Angeles National Forest. Final Report to USFS.

We can even go beyond mapping plant communities to mapping habitat.

Bird surveys determined species richness inside and outside of the fire.

Results indicated that breeding bird community composition differed significantly between points inside vs. outside of the fire perimeter.



Bonfield et al. (2019) Assessment, prioritization, and planning for restoration and conservation activities on the Angeles National Forest. Final Report to USFS.

This helps bridge the gap between remote sensing and what we see on the ground.

Traditional Observations:
- Collections,
- Photographs, and
- Acoustic Biomonitoring

Rely on the subjective expertise of the observer, and overrepresent the:
- Visible,
- Collectable,
- Culturable, and
- Resident rather than Transient

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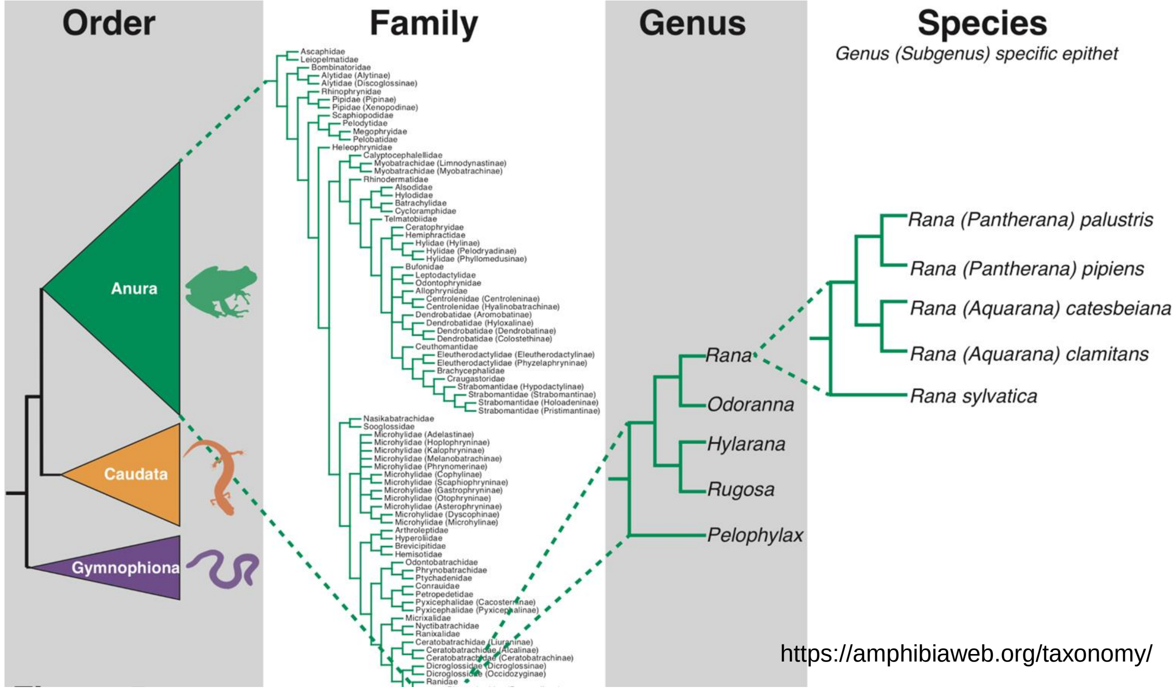
Pereira et al. (2013), Science, 339:6117 p 277-278. DOI: 10.1126/science.1229931

But conservation management targets focus on not just select species, but species richness or phylogenetic diversity and ecosystem services.

Taxonomic Diversity - The diversity of taxa within an evolving hierarchical nomenclature **constructed by taxonomists that have historically grouped organisms based on morphology, ecological or economic function, or genetic similarity.**

Phylogenetic Diversity - The evolutionary relationships among taxa where distance is calculated from differences in molecular or morphological characters that separate clades and contribute to branch lengths of phylogenetic trees. **On these clades, we can calculate how redundant (regular) communities are in clades, clade richness, divergence, and extinction/loss.**



https://amphibiaweb.org/taxonomy/

So how do we get there?

Environmental DNA (eDNA) from soil, sediment, water, and even dust in air (easy for volunteers)

- Geo-tagged samples processed in the lab (Deiner et al., 2016)
- Processed sequences within days to weeks

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Environmental DNA (eDNA)

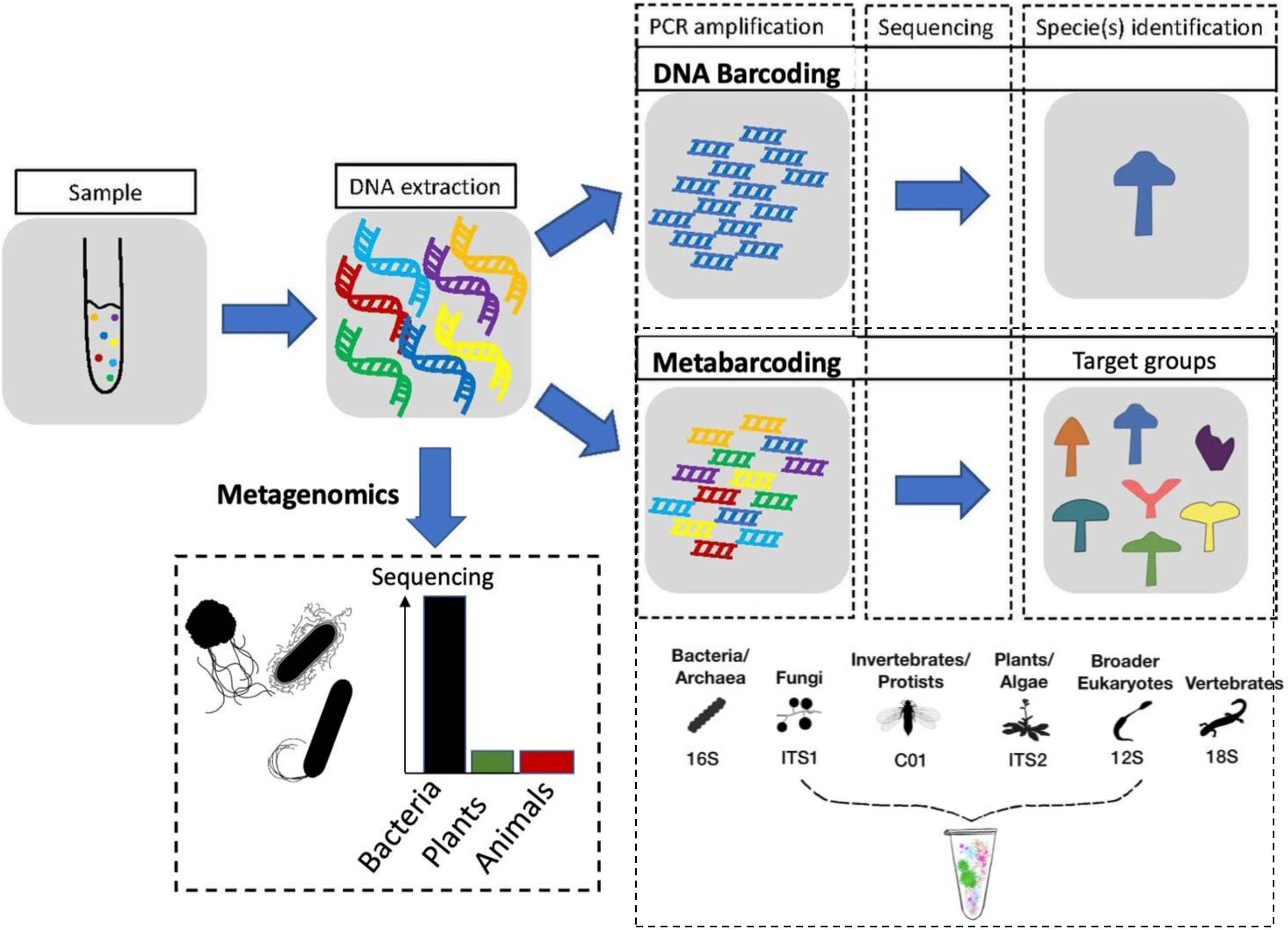
- Advantages:
  - Find microbes and small organisms easily, which are hard to inventory in traditional surveys
  - Considered a gap-filling method
- Challenges:
  - Still ‘zero-inflated’ data, so many samples are needed for inventories
  - Some species still missing reference DNA barcoding data
- Even with imperfections, eDNA data is a ‘biodiversity barometer’ of ecological change (DiBattista et al., 2020).

Slide Credit: Rachel Meyer, UCSC

How does eDNA work?

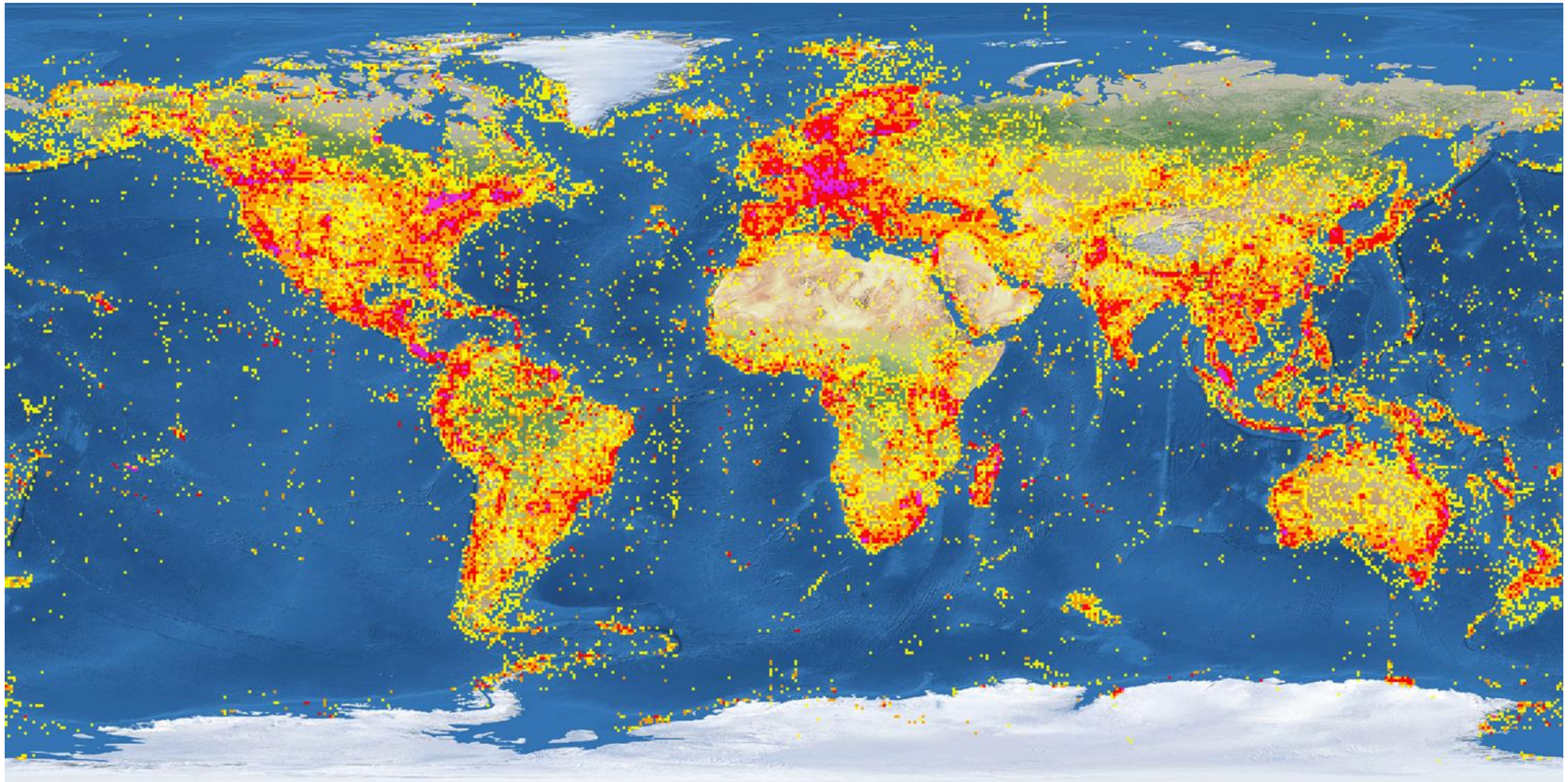
Metabarcoding and Metagenomics find signatures of 100s-1000s of species per sample.

Molecular Techniques



Slide Credit: Rachel Meyer, UCSC

Reference DNA barcoding libraries are vast (>10 million specimens)



Slide Credit: Rachel Meyer, UCSC

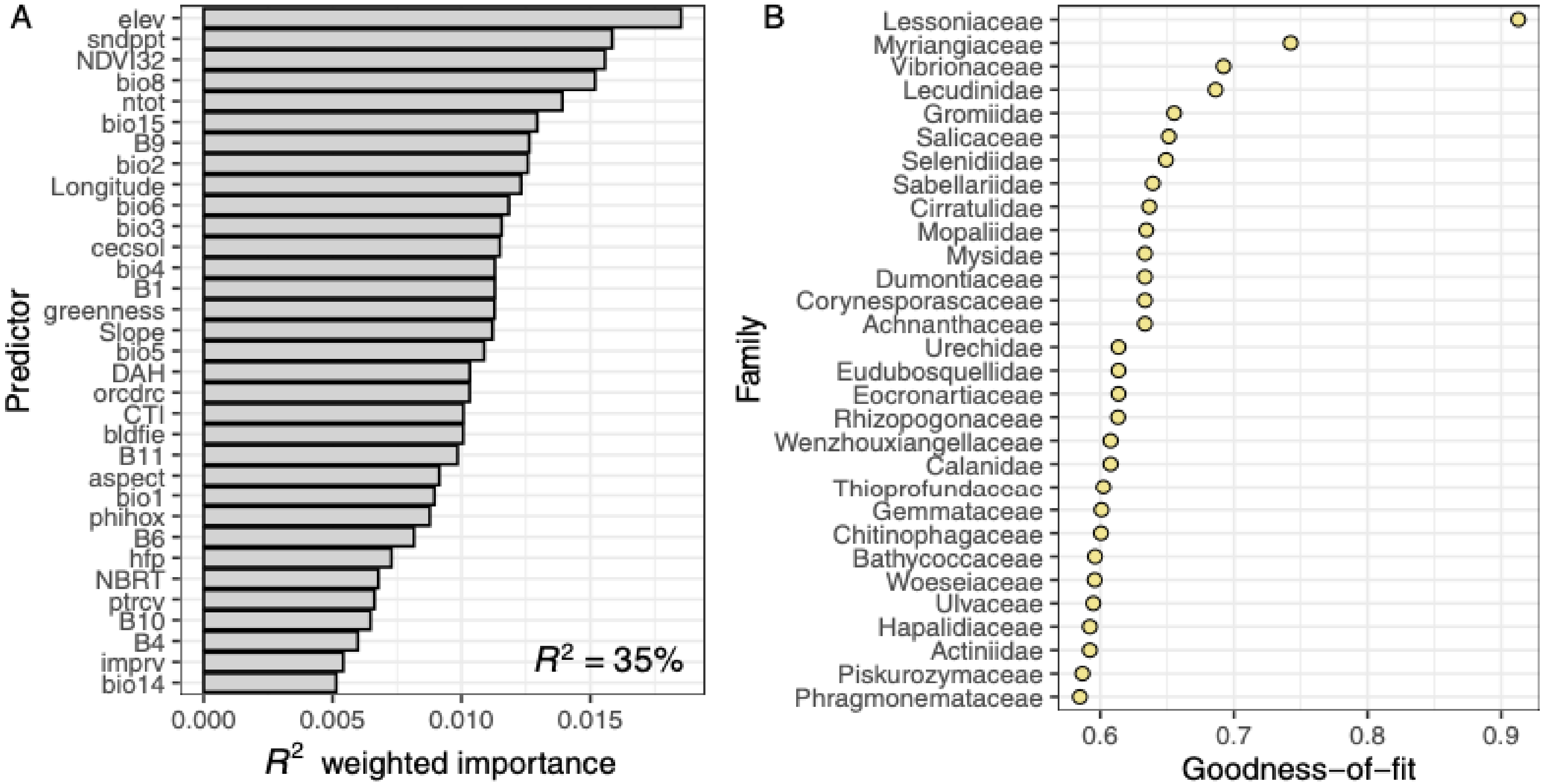
We know that traditional *and* citizen ("Community") science work together to tell the status of biodiversity on the ground.

Traditional Surveys		Community Science
Many months to years to coordinate many expert taxonomists	Bioindicators, rather than direct species measurements, but these "wash out" the details needed to study complex biological systems	Usually non-experts or local experts, but involves more data science with more samples in space and time

And we know that eDNA and remote sensing relate.

We can measure remote sensing predictor values and which families across the tree of life are the most predictable.

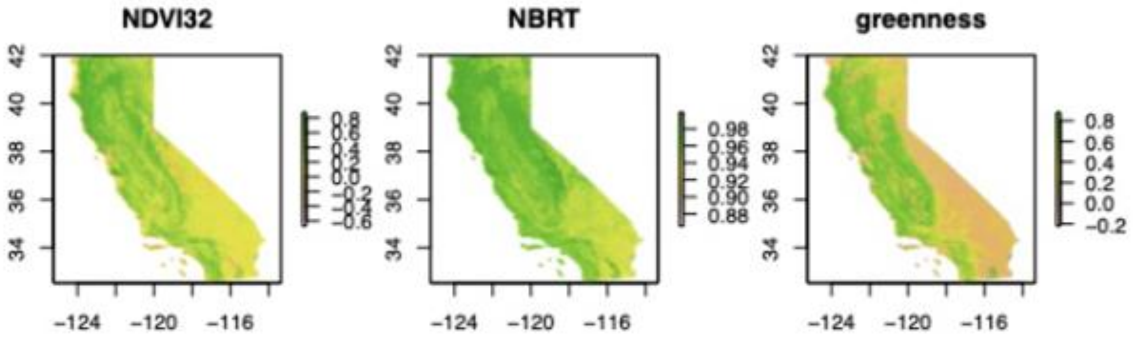
R2 = 35% across ~700 families

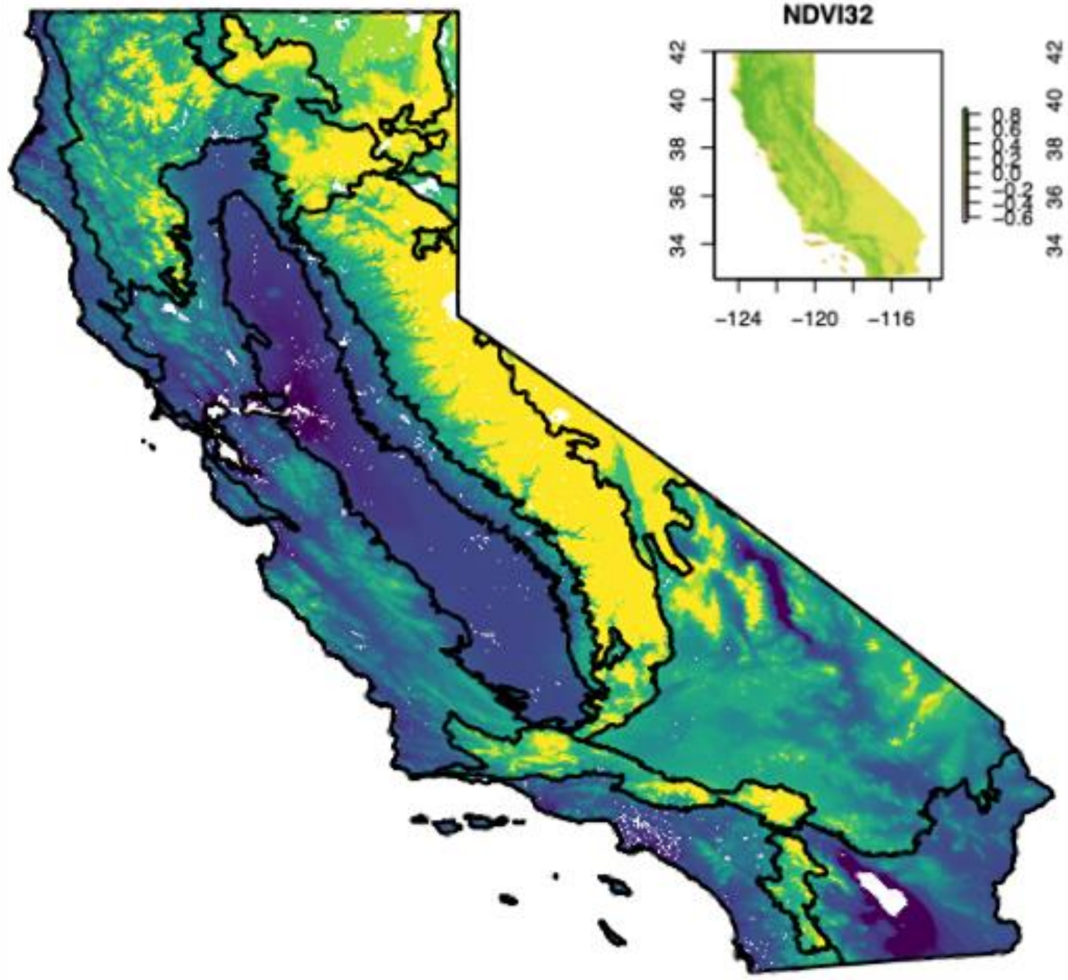


Lin et al. (2021) Ecological Applications; DOI: 10.1002/eap.2379

And that those relationships generally follow biotic and abiotic drivers of ecosystem and environmental patterns (ecoregions).

*3 of 33 of the Remote Sensing Layers:





eDNA Communities by Ecoregion, Level 13

Lin et al. (2021) Ecological Applications; DOI: 10.1002/eap.2379

But what we need to know is how eDNA, traditional field, and remote sensing observations of biodiversity relate across space and time.

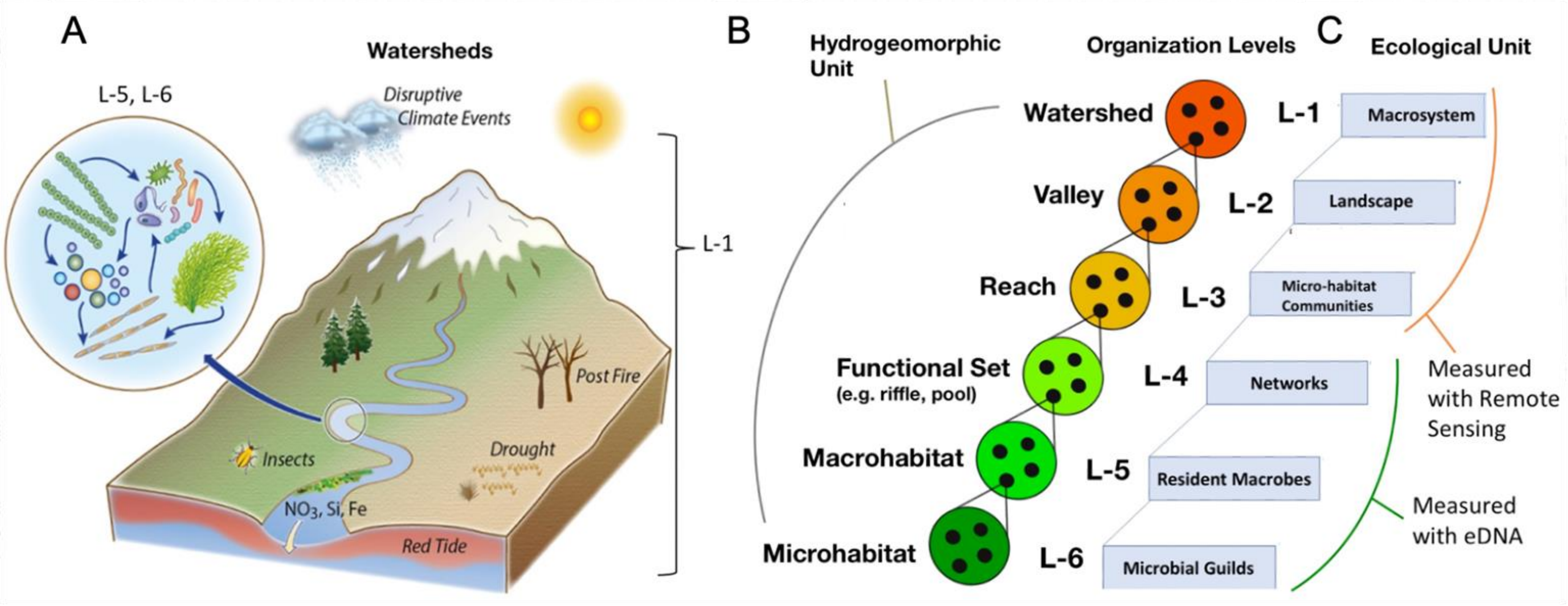


Figure 1A credit to M. Newcomer and D. Swantek (LBNL) as part of collaborations for similar work in the California Russian River watershed. LBNLFigure EESA19-011

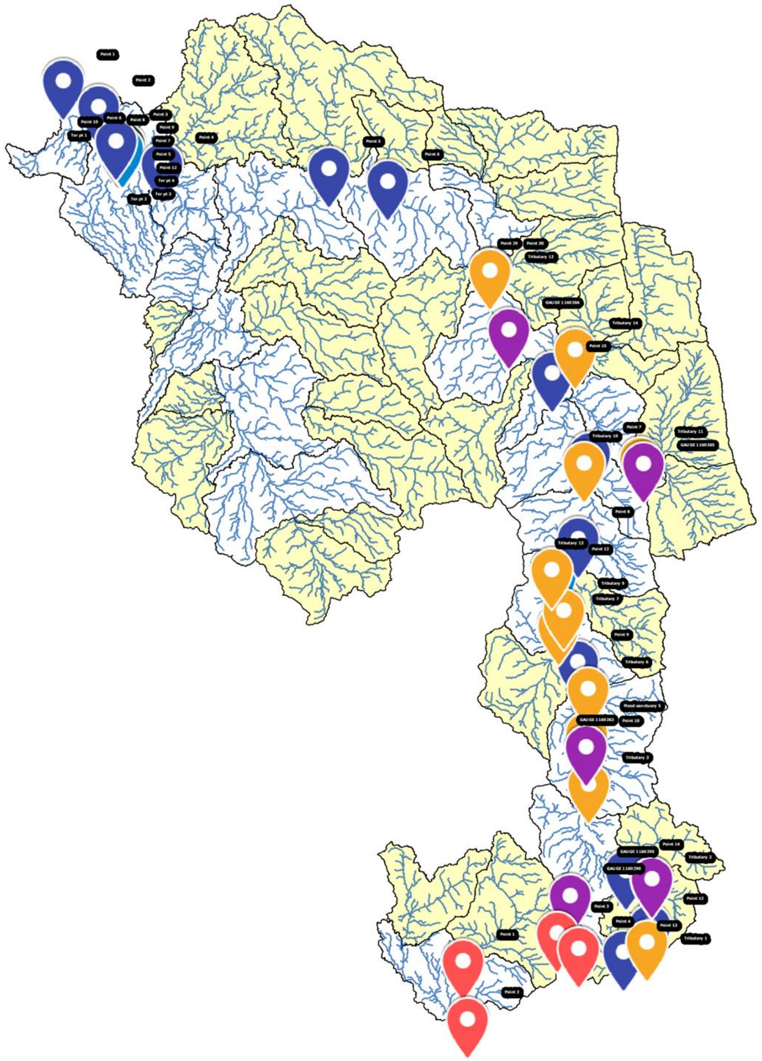
Question	Hypothesis	Significance
<u>RELATED:</u> Are phylogenetic, taxonomic, and functional diversity directly related to each other?	(H1) Phylogenetic, taxonomic, and functional diversity are directly related to each other along the Berg and Eerste River systems.	We could map biodiversity consistently, globally, and at regular intervals.
<u>SPACE:</u> Does the hydrologic structure of watersheds, phylogenetic, taxonomic, and functional diversity self-organize spatially dependent on scale?	(H2) Due to the hydrologic structure of watersheds, phylogenetic, taxonomic, and functional diversity self-organize spatially and are scale dependent.	Life organizes along understood processes of water movement and possibly, how water moves can predict how biodiversity will move.
<u>TIME:</u> Do hydrometeorological processes influence the temporal signal of functional and phylogenetic and taxonomic diversity that enable dynamic mapping of biodiversity?	(H3) Hydrometeorological processes influence the temporal signal of functional and phylogenetic and taxonomic diversity that enable dynamic mapping of biodiversity.	How we use and interpret use of eDNA data in combination with remote sensing.

We’ve analyzed the Berg and Eestre River Watersheds in South Africa and visited our sites collecting data for the first time in fall 2022.

Clear = Conveyance Watersheds (influenced by other watersheds)

Yellow = Headwaters of Tributaries Feeding the Berg and Eestre (true watersheds)

** Units are similarly sized using Strohler order (4th order to ID headwaters)



Berg (sampled 2x)
- 14 locations, each with:
  - 2 clusters in river
  - 1 cluster across river
  - 2 inland samples

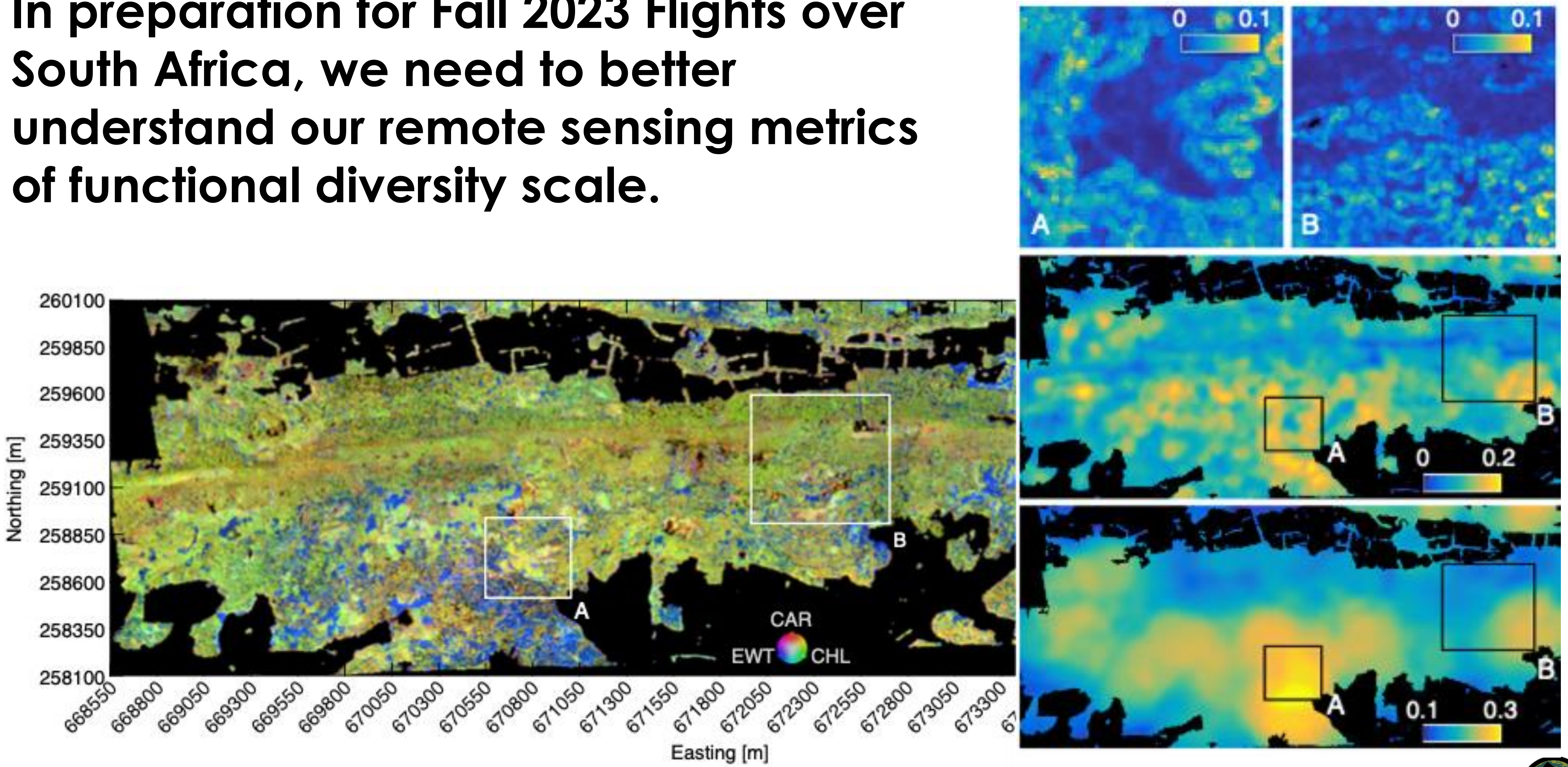
Eerste (sampled 2x) Off-site control
- 4 locations, each with:
  - 2 clusters in river
  - 1 cluster across river
  - 2 inland samples

Berg Tributaries (sampled 2x)
- 12 locations, each with:
  - 1 cluster in river

Gauge (sampled 4x)
- 5 locations, each with:
  - 2 water samples
  - 2 sediment samples

1 cluster = 3 samples

In preparation for Fall 2023 Flights over South Africa, we need to better understand our remote sensing metrics of functional diversity scale.



Schneider et al. (2017) Nature; http://www.nature.com/articles/s41467-017-01530-3

How can our work benefit you?

Established framework for better understanding how different observations of biodiversity relate to inform conservation management and improve monitoring

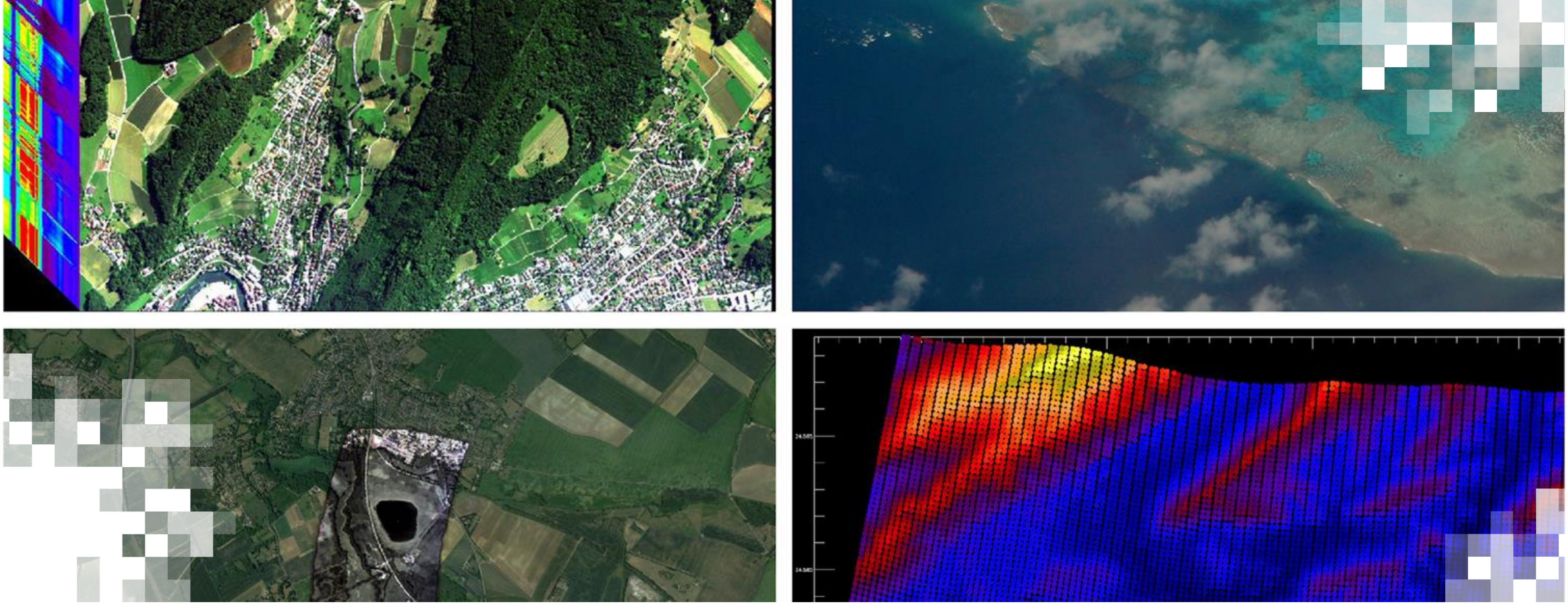
By better understanding the phenomenon that drive spatial and temporal patterns of different observation types, we can better account for them in biodiversity reporting.

Tangible Outcome (Spring 2024): An open-source software package that enables anyone with access to imaging spectroscopy and thermal infrared data (coming globally, and freely available in late 2020s through the NASA Surface Biology and Geology mission) to extract remotely-sensed, spatially-consistent metrics of functional diversity.

Many Thanks!

Field Team
John Rourke Retired (Compton Herbarium, Kirstenbosch Gardens)
Tony Cunningham Retired (Independent Ethnobotanist, U. of Stellenbosch)
Rachel Meyer & Madeline Slimp U. of California - Santa Cruz
Jabulile Malindi UWC Masters Student, Volunteer
Ayesha Hargey UCT Masters Student, Volunteer
Julia Smith Retired (Afrikaans language expert, farmer), Volunteer

Collaborators
Douglas Yu, Andrew Briscoe & Vere Ross-Gillespie (NatureMetrics)
Fabian Schneider (JPL, Caltech)
Philip Townsend (U. of Wisconsin-Madison)
Tony Verboom (U. of Cape Town)



Examples of PRISM Applications in Coastal Waters

COral Reef Airborne Laboratory (CORAL)

- Airborne mission flown using the Portable Remote Imaging Spectrometer (PRISM) to evaluate health and conditions of coral reef ecosystems
- Date Range: 2016-2019
- Spectral Resolution: 349.9-1053.5 nm (3.5 nm sampling)

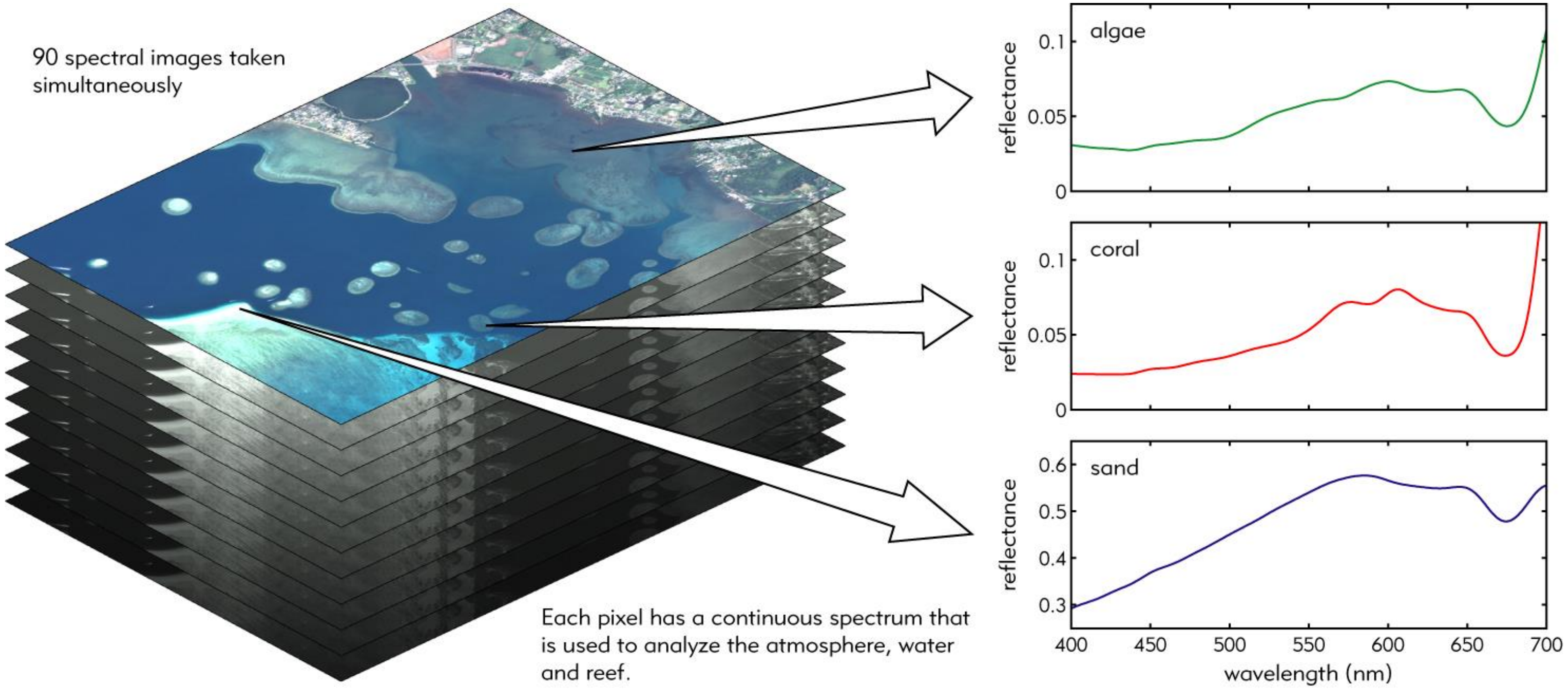
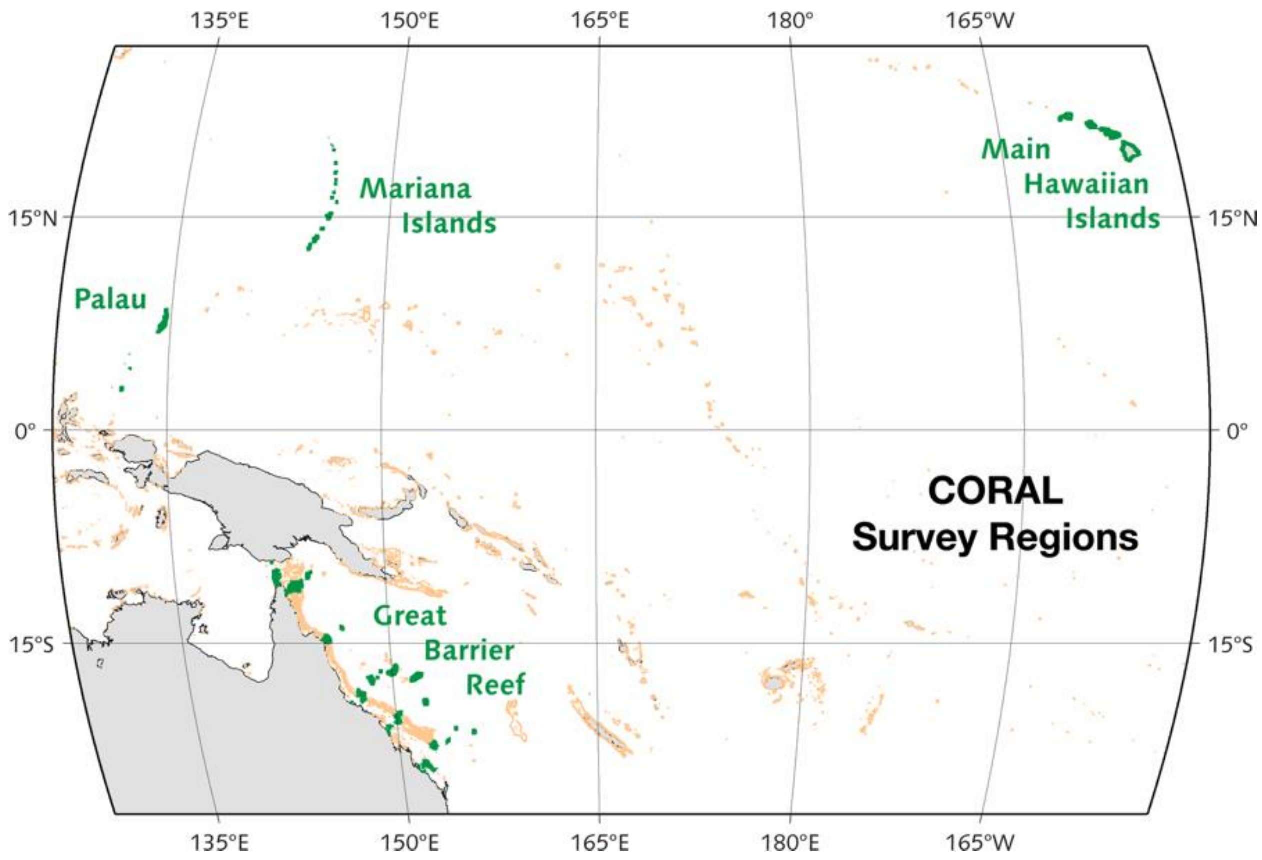


Image Credit: Eric Hochberg (CORAL PI)

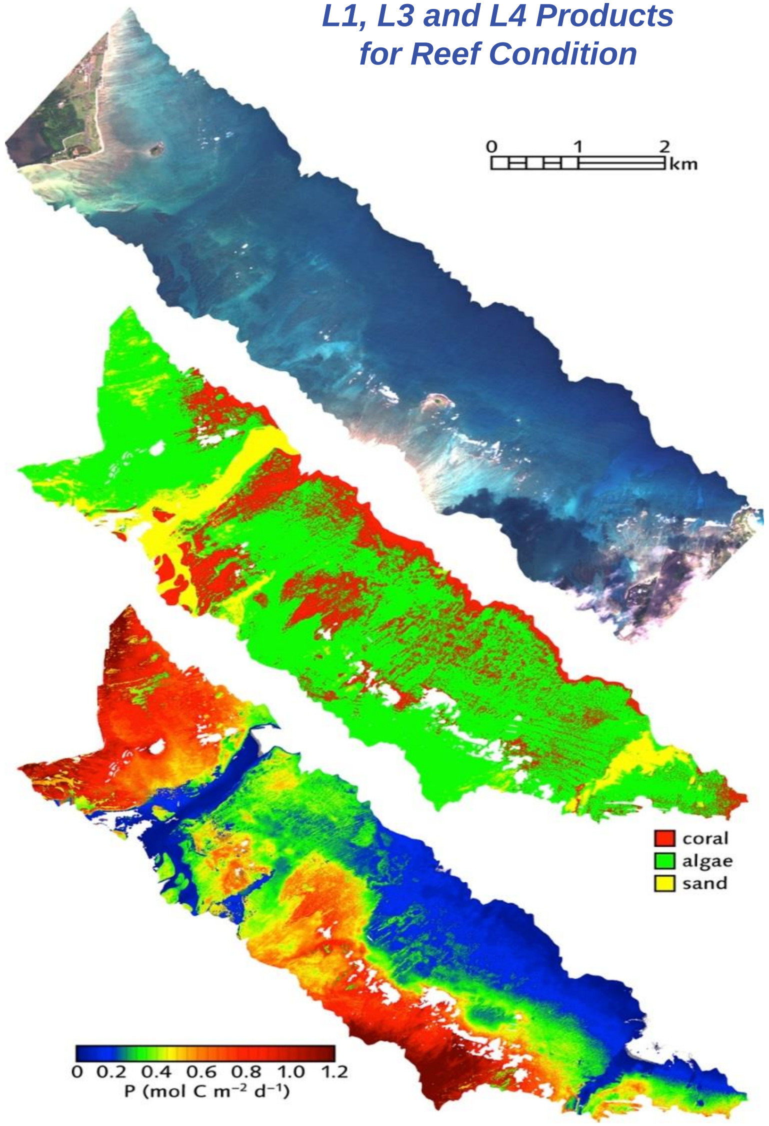
COral Reef Airborne Laboratory (CORAL)



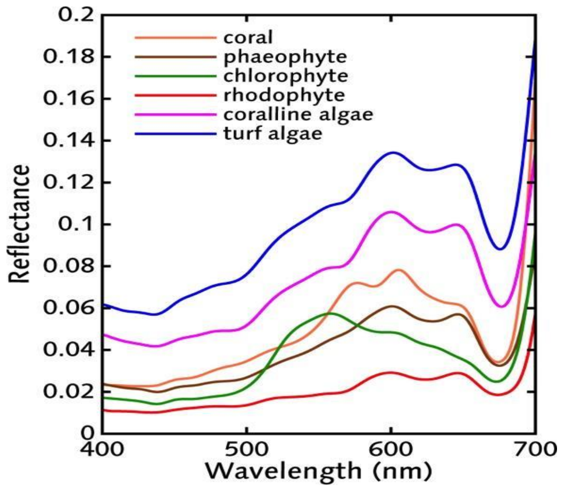
Six sub-campaigns near the Mariana Islands, Palau, portions of the Great Barrier Reef, and the Hawaiian Islands (top). CORAL image and classification (right) from the French Frigate Shoals in Northwestern Hawaii. Image Credit: NASA

COral Reef Airborne Laboratory (CORAL)

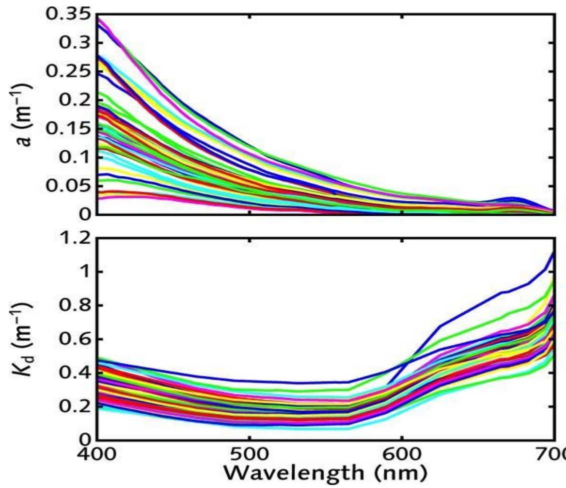
L1, L3 and L4 Products for Reef Condition



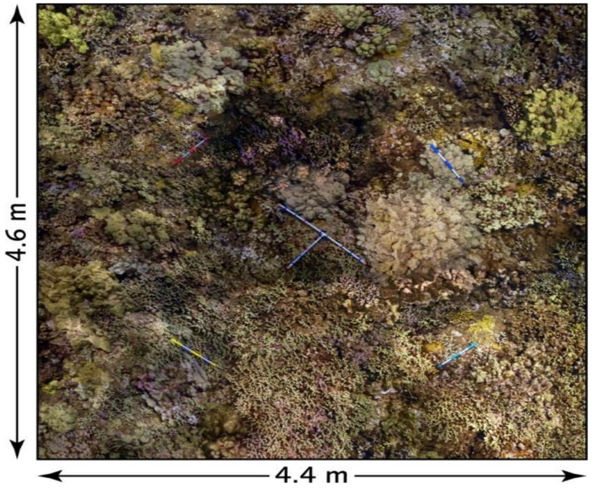
Benthic Reflectance Cal/Val



Water IOP/AOP Cal/Val



Benthic Cover Cal/Val via Photomosaic



Benthic Productivity Cal/Val via Gradient Flux

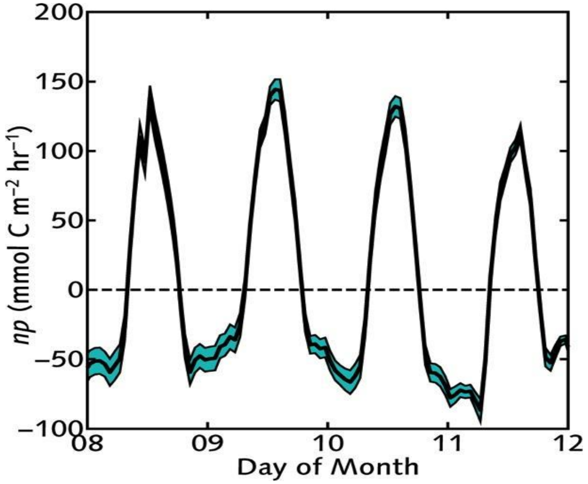
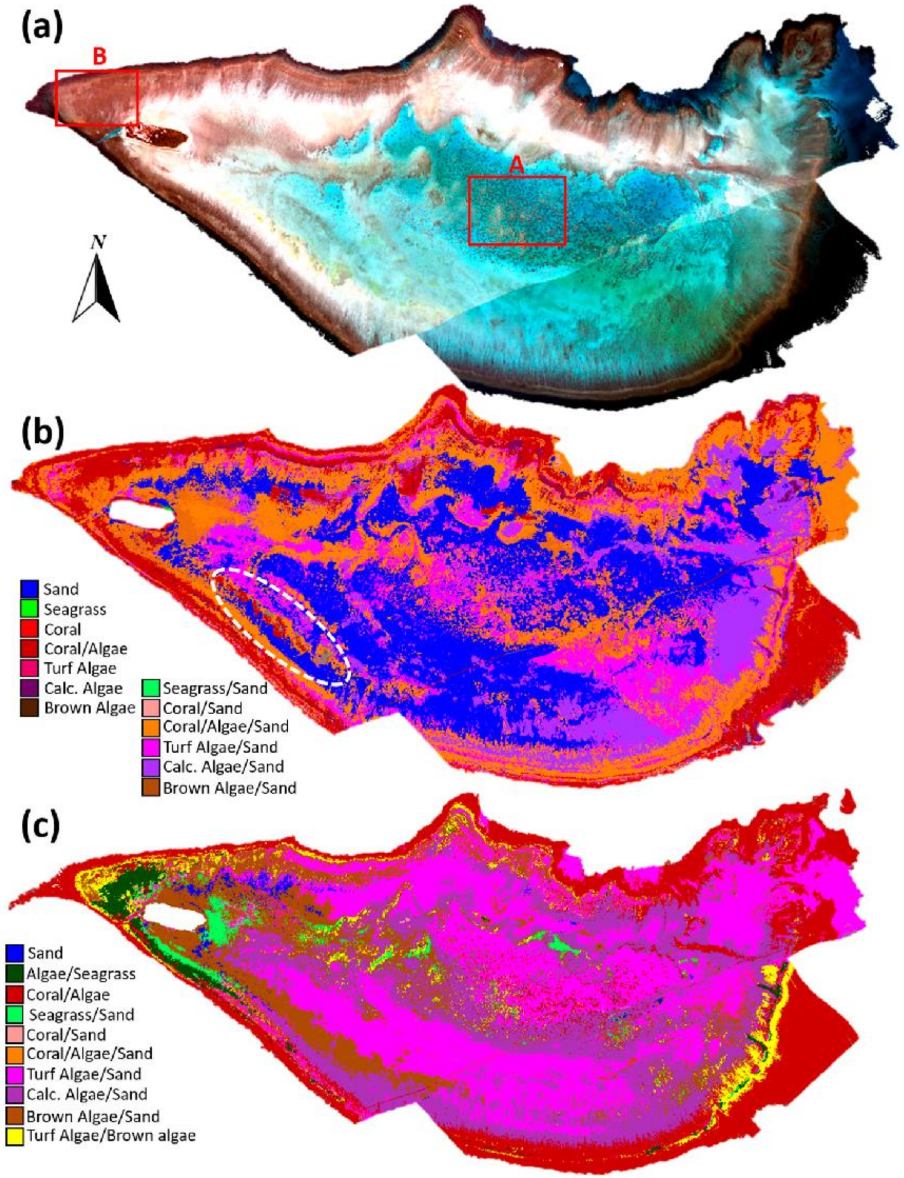


Image Credit: Eric Hochberg (CORAL PI)

COral Reef Airborne Laboratory (CORAL)

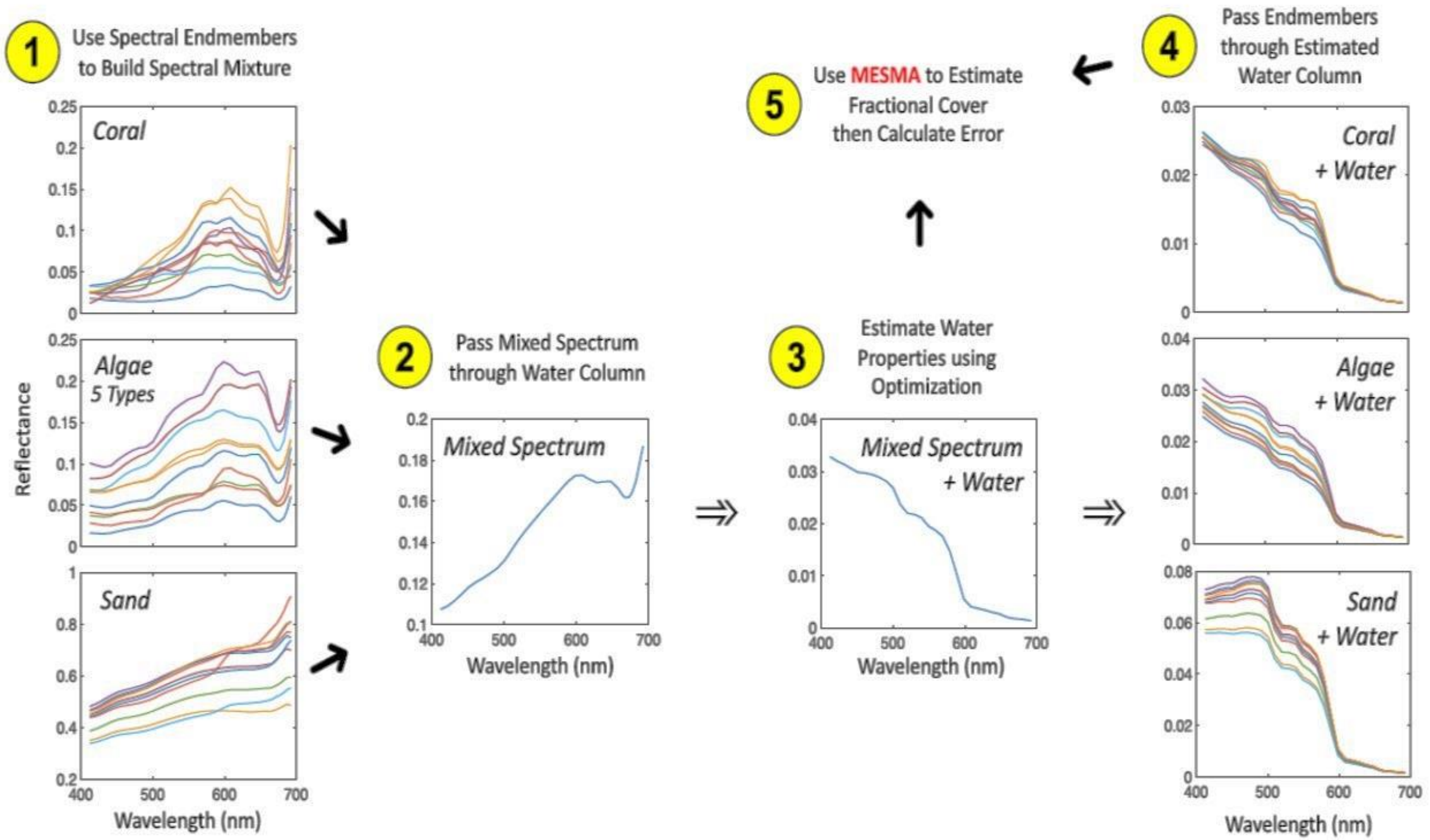
- Experimented with different approaches for benthic mapping using the PRISM hyperspectral data
- Methods differed in highlighting areas dominated by diverse benthic components
  - Also differed in required computational time
  - Demonstrated the versatility of PRISM data and improved classification of spectrally similar benthic features



Credit: Garcia et al (2018) Remote Sens

Discrimination of Benthic Cover (CORAL)

- Benthic organisms have somewhat similar spectral signatures.
- Robust end-members data can aid in validating hyperspectral imagery.
- Fractional cover of coral and algae should be >25% for accurate estimates with current hyperspectral sensors.
  - Due to heterogeneity of reef substrate cover and current sensors' spatial resolutions

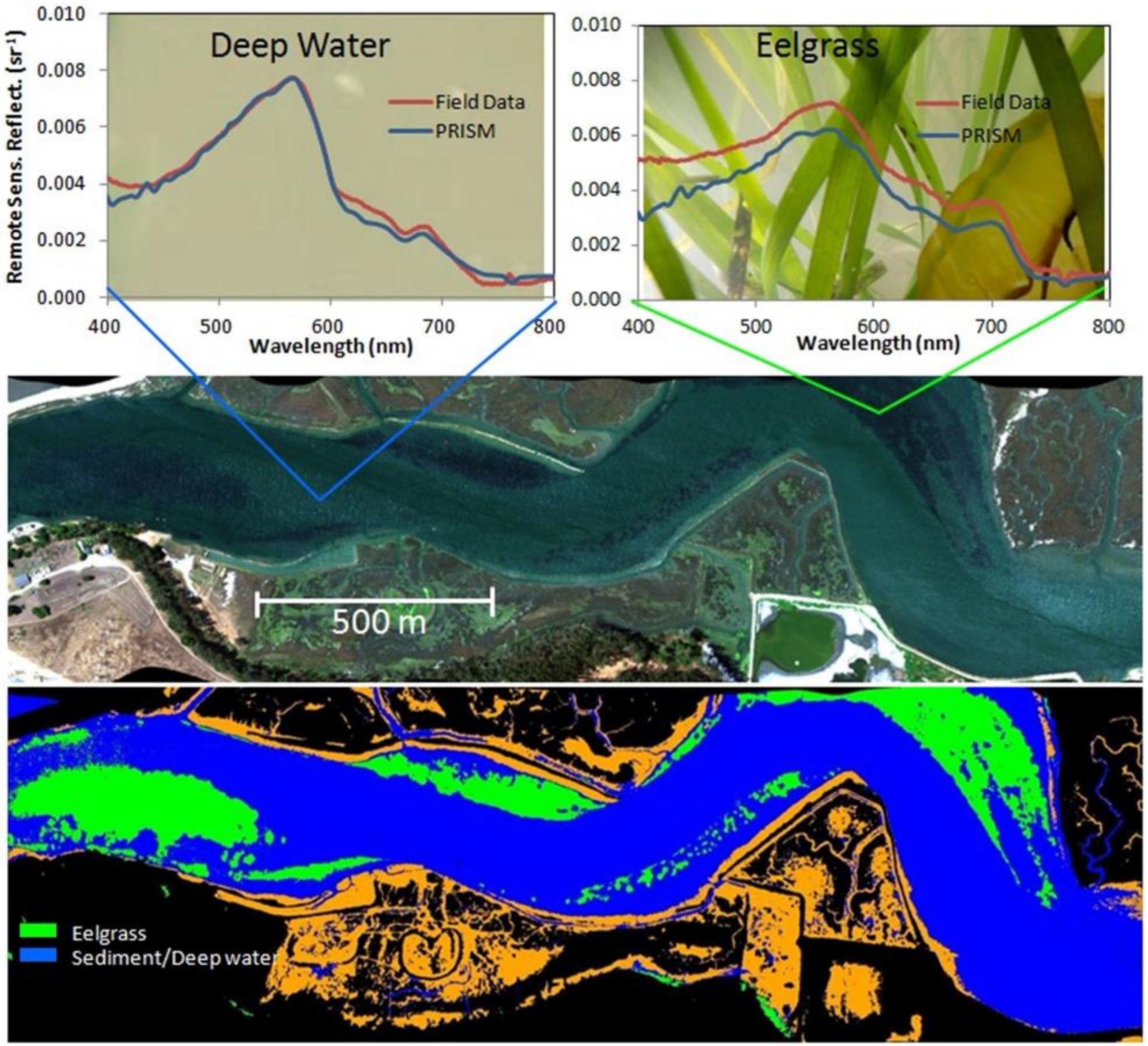


Credit: Bell et al (2020) RSE

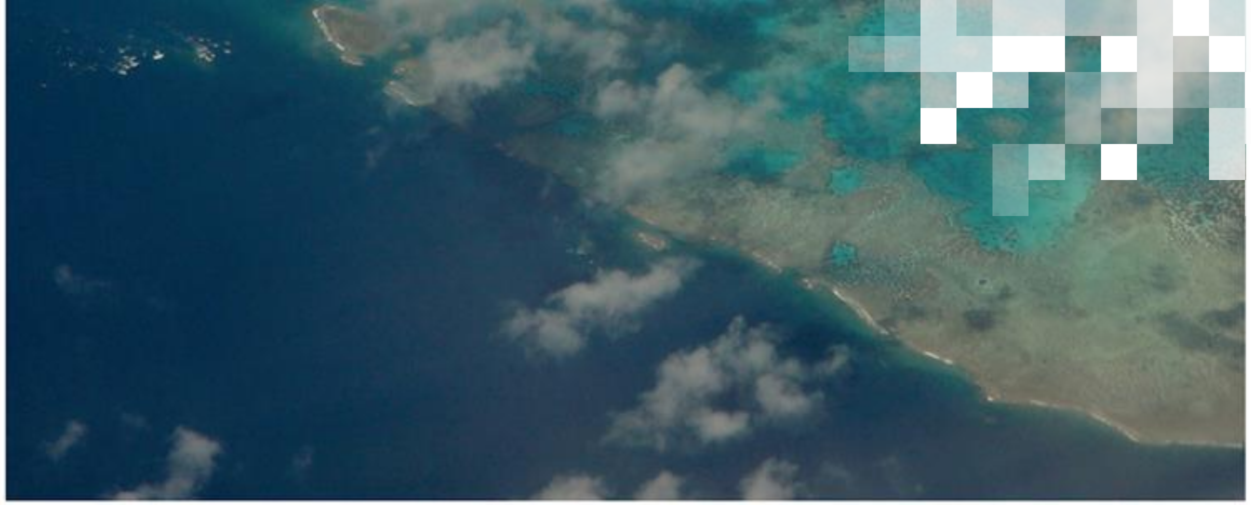
Mapping Seagrasses with PRISM

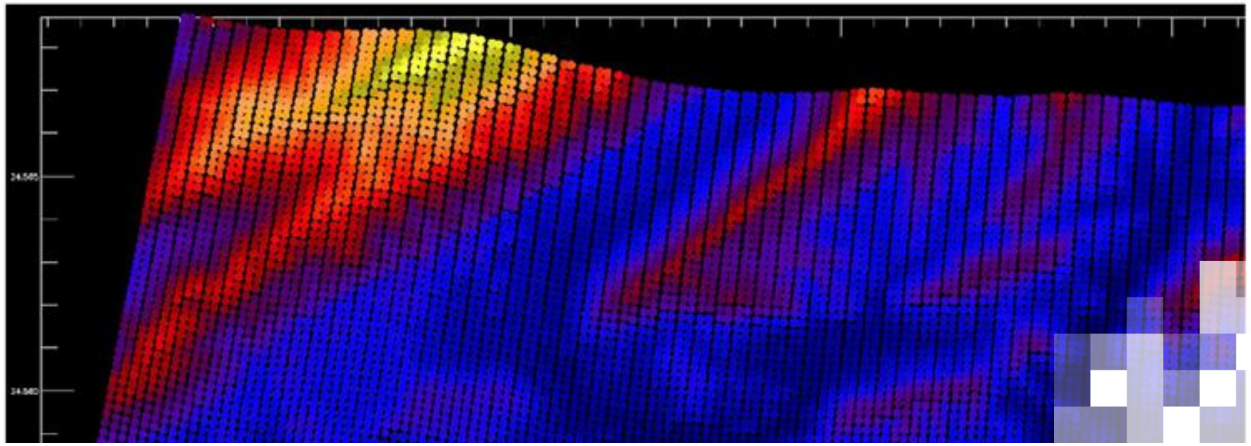
- Dierssen (2013) and Dierssen et al (2019) applied the Hyperspectral Optimization Processing Exemplar (HOPE) model to map eelgrass in the optically complex waters of the Elkhorn Slough in Monterey Bay in California

- Subtle spectral differences between the eelgrass and sediments allowed for the characterization of both components using PRISM data



Credit: Dierssen (2013) Proc SPIE



Monitoring Inland Aquatic Biodiversity Using Airborne Imaging Systems

CyanoSCape

Freshwater Phytoplankton and Floating Aquatic Vegetation Biodiversity

Liane Guild, Jeremy Kravitz, and Juan Torres-Pérez, NASA Ames Research Center, Moffett Field, CA

Marie Smith and Lisl Lain, Council for Scientific and Industrial Research, Cape Town, SA

Wilson Mugera Gitari, Rabelani Mudzielwana, and Glynn Pindihama, Univ. of Venda, Thohoyandou, SA

Ames Research Center

CSIR Touching lives through innovation

University of Venda Creating Future Leaders

CyanoSCape Importance

- The phytoplankton biodiversity of SA freshwater systems is not well characterized. Anthropogenic practices have compromised riverine and aquatic ecosystems.
- The biodiversity of freshwater phytoplankton includes cyanobacteria, some that are harmful.
- Harmful cyanobacteria can produce toxins (e.g., Microsystin) that cause hepatoxic (liver disease) and neurotoxic effects in humans and animals and can lead to mortality.
- Eutrophic conditions are also conducive to invasive floating aquatic vegetation (FAV), like water hyacinth.

CyanoSCape **Goal**

Goal: Utilize hyperspectral data with recently developed and next-generation algorithms to:

- Determine the biodiversity of freshwater systems phytoplankton assemblage with emphasis on genus level distinction, including potentially toxic cyanobacteria and;
- Monitor the prevalence and diversity of FAV that favor these environments.

CyanoSCape Objectives

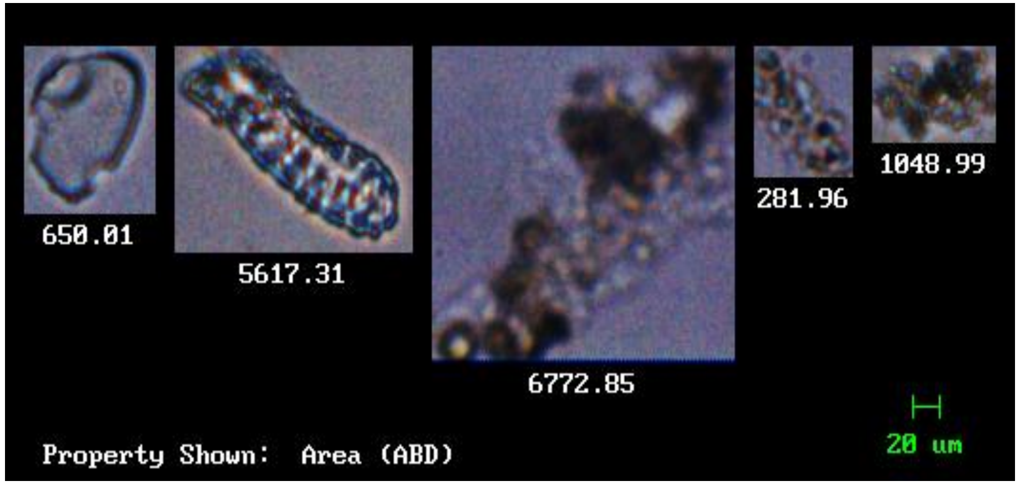
Objective 1: Apply and test the capability of published and next-generation algorithms for hyperspectral delineation of the phytoplankton assemblage and FAV biodiversity

- Remote sensing
  - **Seasonality of phytoplankton and FAV.** Build on historic time series (MERIS, Mathews 2014) with Landsat 8 OLI, and Sentinel 2 MSI, Sentinel 3 OLCI. Review MODIS, VIIRS for scale.
  - **Opportunistic satellite data collection during airborne campaign** (+/- 1 hr of airborne flight over field sites) Landsat and Sentinel (possibly MODIS, VIIRS).
  - **AVIRIS-NG and PRISM hyperspectral data.**
- Radiative Transfer Modeling will produce a synthetic dataset to train an emulator to output water quality and Phytoplankton Functional Type (PFT) products
- Machine learning and artificial neural network will be used for Phytoplankton Class/PFT level
- Mapping floating aquatic vegetation and connection with cyanobacteria blooms
- Errors and uncertainties

CyanoSCape Objectives

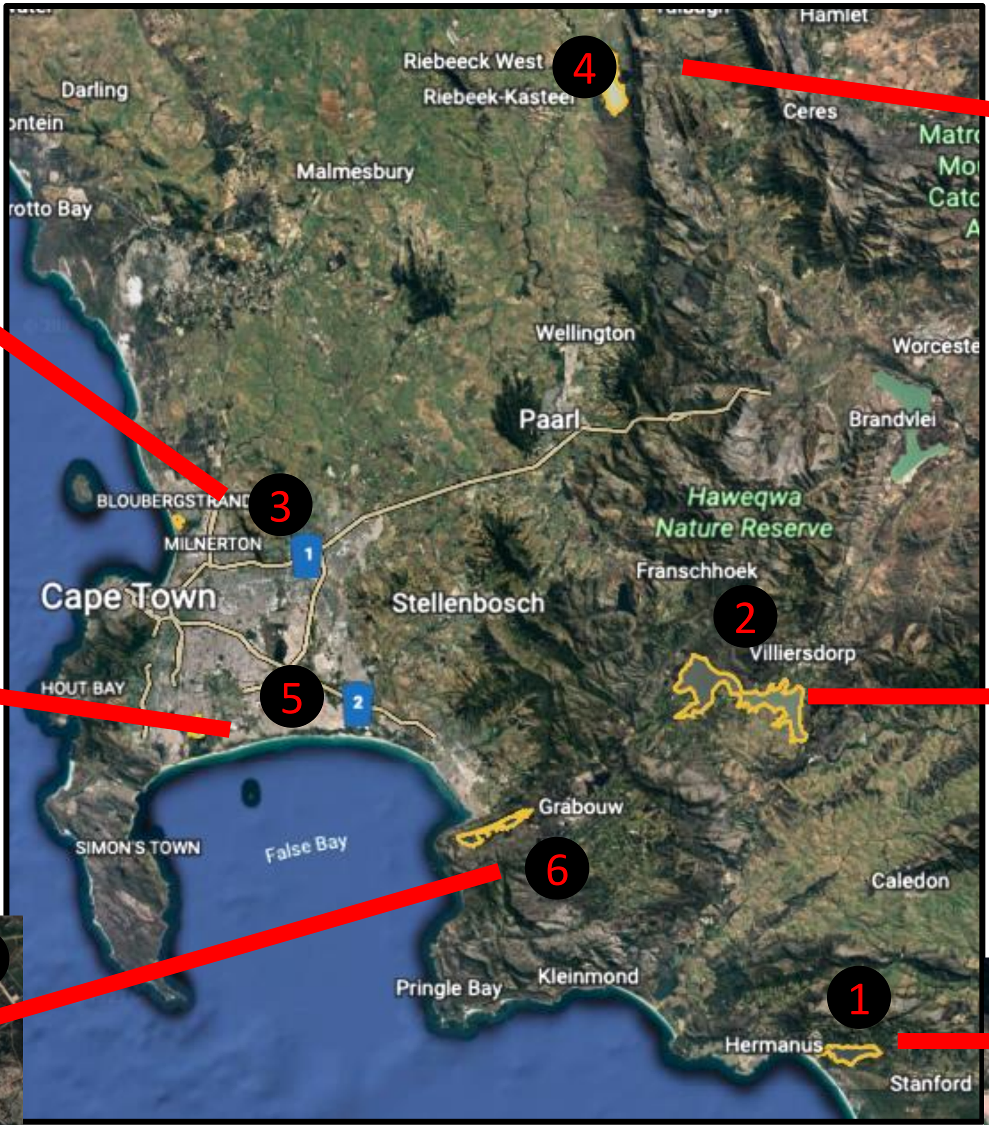
Objective 2: Phytoplankton community and FAV diversity

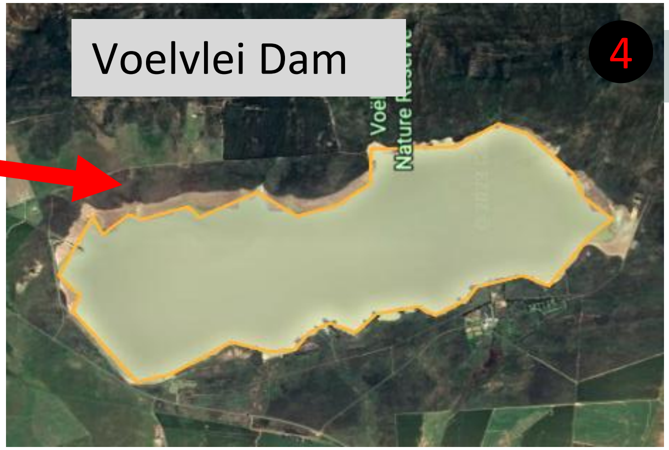
- Field - 4-5 stations during overflights:
  - Field spectroscopy
  - Apparent optical properties (AOPs)
  - Water sampling for microscopic analysis of phytoplankton and cyanobacteria
  - Aerosol optical thickness (AOT) for atmospheric correction
- Flow imaging microscopy (FlowCAM)
  - Phytoplankton enumeration and cyanobacterial identification
- Chlorophyll a fluorometric and HPLC pigment analysis

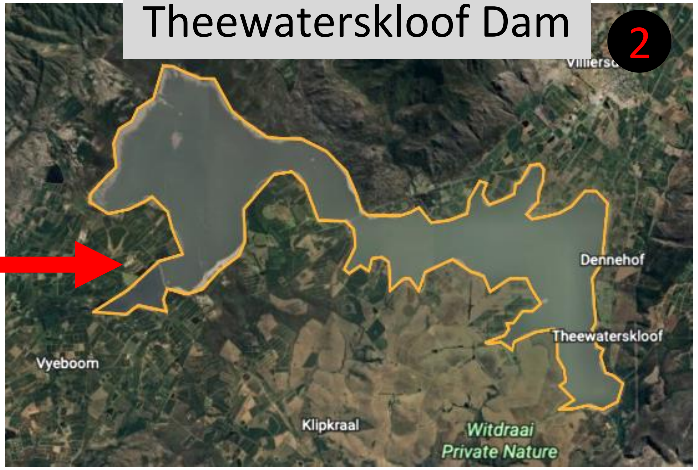


Example of harmful cyanobacteria identified using FlowCam microscopy: *Anabaena* (650.01); Dinoflagellate spp. (5617.31); *Microcystis* (6772.85, 281.96, 1048.99). Credit: Univ. of Venda.

CyanoSCape Sites





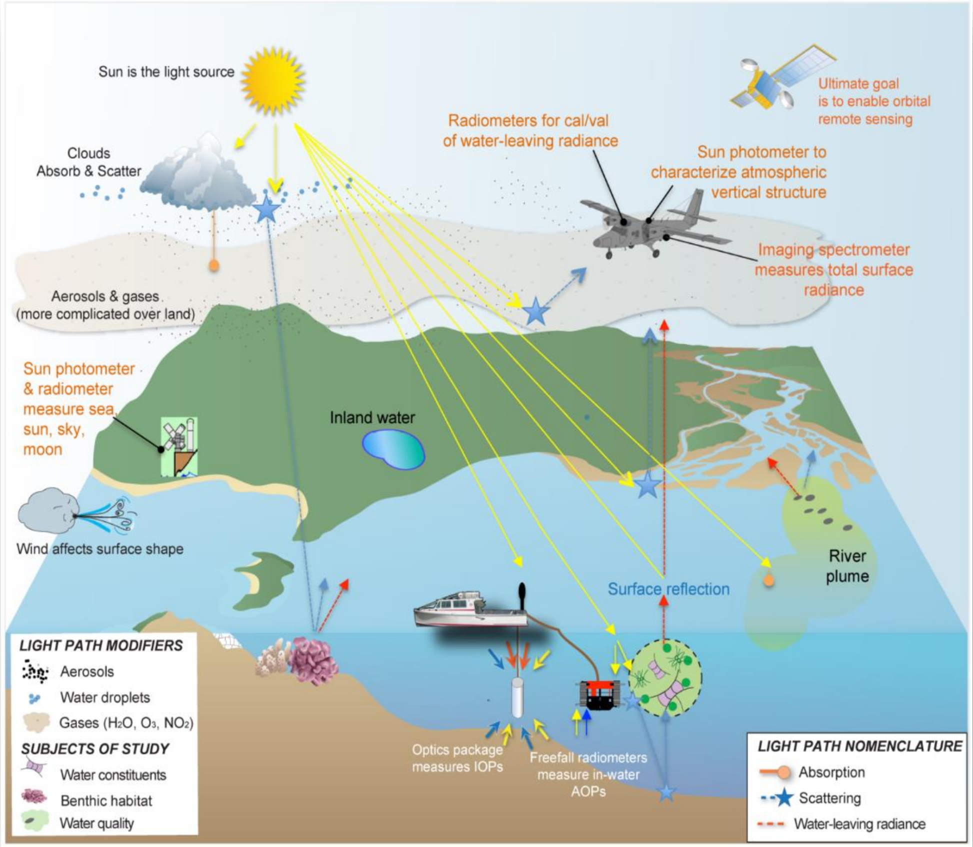


Note: Numbers in order of priority.

Flight Planning

- Avoidance of sunglint
- Avoidance of rough waters with white caps
- Cloud-free data, or nearly so
- Optimizing flight lines for science quality data
- Other considerations
  - Satellite matchup: overpass timing aligned with +/- 1 hr of aquatic field sampling

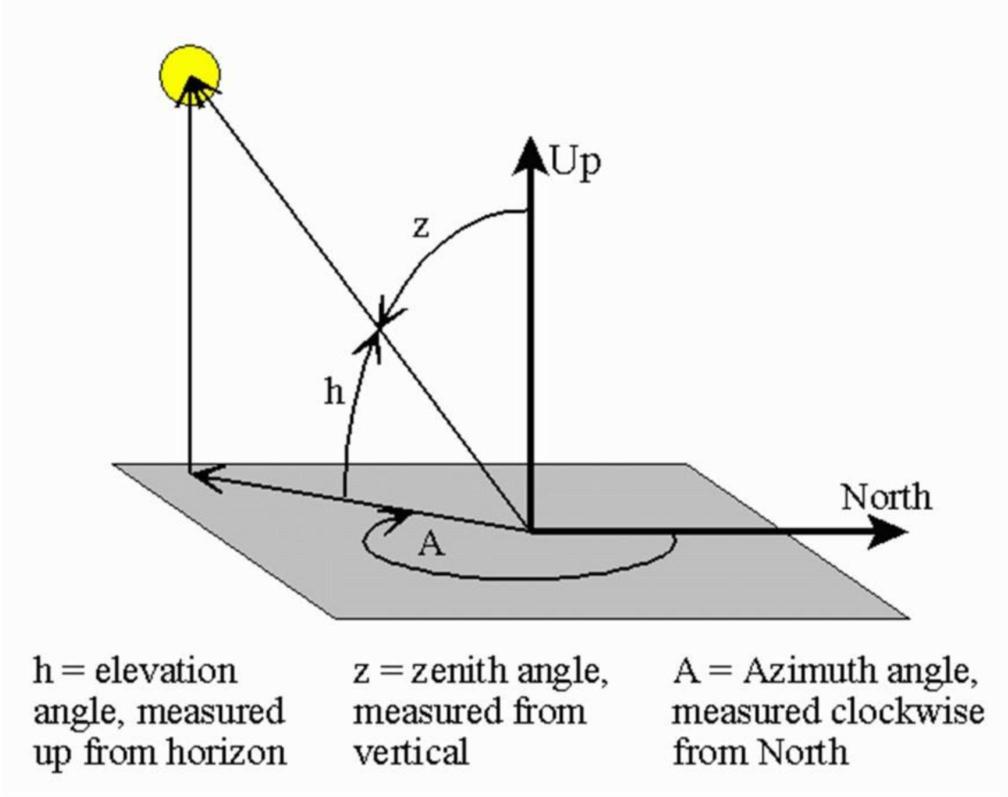
Credit: Guild et al (2020), Airborne Radiometry for Calibration, Validation, and Research in Oceanic, Coastal, and Inland Waters. Front. Environ. Sci. 8:585529. DOI: 10.3389/fenvs.2020.585529.



Concept of operations. Credit: Raphe Kudela (UC Santa Cruz)

Flight Planning

- Consider solar geometry
- Aircraft flying the nose of the aircraft into and out of the Sun mitigates sunglint
- Aircraft pitch (nose up/down), roll (wings up/down), and yaw (aircraft heading and influenced by wind) may impact some airborne sensor performance.



Credit: Guild et al (2020), Airborne Radiometry for Calibration, Validation, and Research in Oceanic, Coastal, and Inland Waters. Front. Environ. Sci. 8:585529. DOI: 10.3389/fenvs.2020.585529.

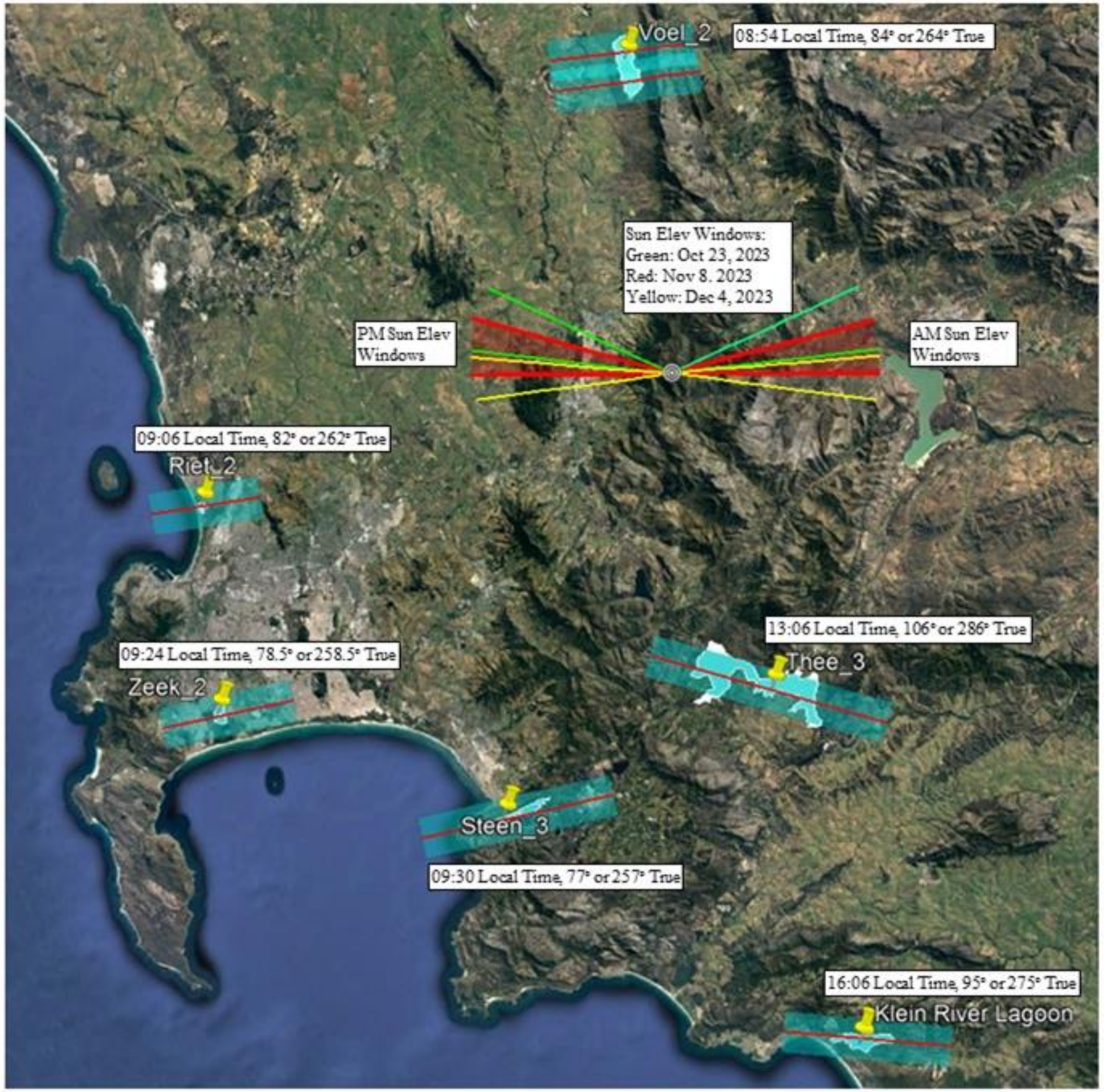
Flight Planning Window

Acceptable Sun Elevation Range: 30 to 50 deg.

Example dates: 23 Oct (green), 8 Nov (red), & 4 Dec 2023 (yellow)
Magnetic Variation Used: 25 deg W

Morning Sun Elevation Window using 8 Nov:
- Start: 08:12 Local Time, Solar Az = 89.83 True, 114.83 Magnetic
- End: 09:42 Local Time, Solar Az = 75.08 True, 100.08 Magnetic

Afternoon Sun Elevation Window:
- Start: 15:06 Local Time, Solar Az = 285.96 True, 310.96 Magnetic
- End: 16:42 Local Time, Solar Az = 270.0 True, 295.0 Magnetic



Credit: Jim Eilers (NASA Ames)

Flight Planning by Date

Acceptable Sun Elevation Range: 30 to 50 deg.

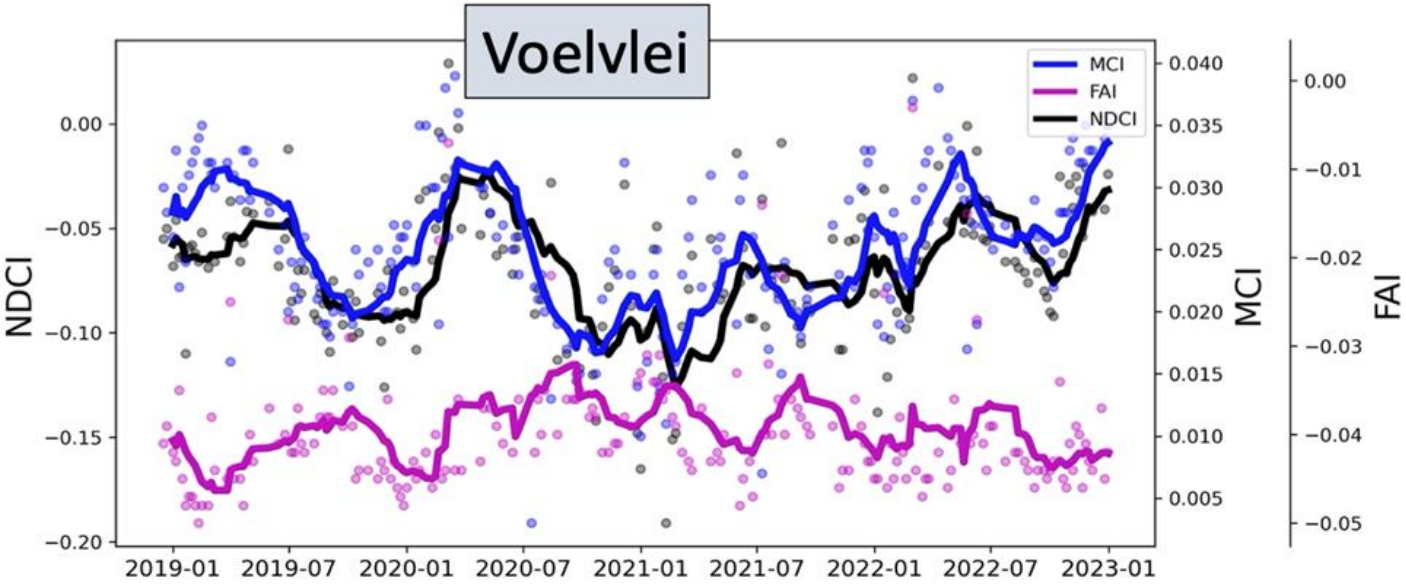
Example date: 15 Oct 2023
Magnetic Variation Used: 25 deg W

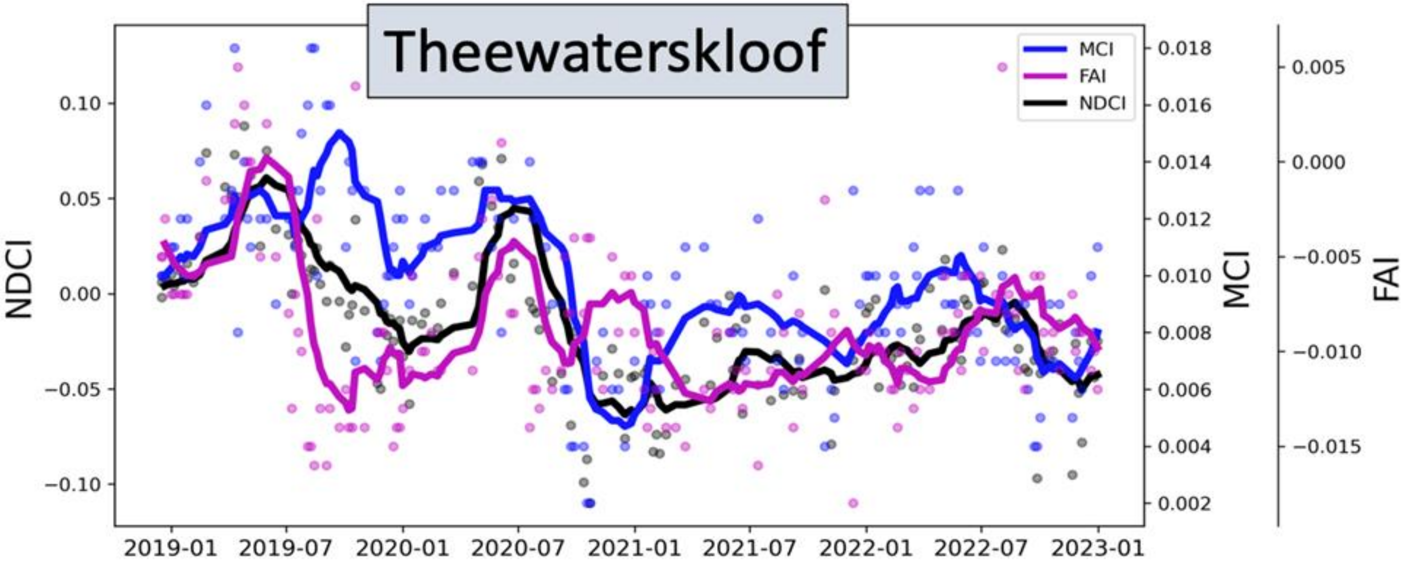
Morning Sun Elevation Window:
- Start: 08:36 Local Time, Solar Az = 78.58 True, 103.58 Magnetic
- End: 10:12 Local Time, Solar Az = 58.90 True, 83.90 Magnetic

Afternoon Sun Elevation Window:
- Start: 12:48 Local Time, Solar Az = 300.46 True, 325.46 Magnetic
- End: 16:24 Local Time, Solar Az = 20.95 True, 305.95 Magnetic

Credit: Jim Eilers (NASA Ames)

Rationale for sites selection





Normalized Difference Chlorophyll Index (NDCI)

$$\mathrm{NDCI} = \frac{\mathrm{Red\ edge\ 1} - \mathrm{Red}}{\mathrm{Red\ edge\ 1} + \mathrm{Red}}$$

Maximum Chlorophyll Index (MCI)

Floating algal Index (FAI)

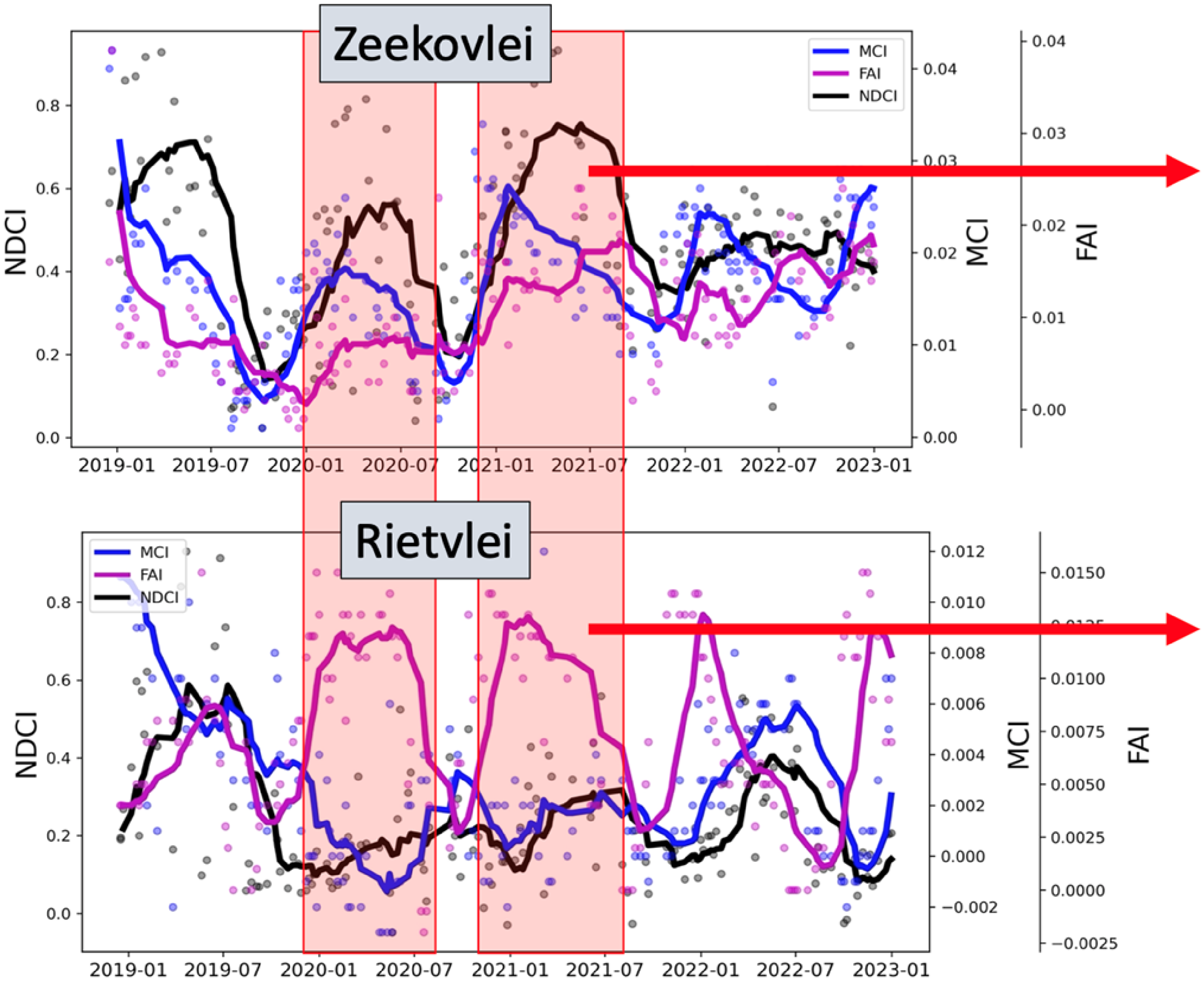
MCI bands : B4, B5, B6

FAI bands : B4, B6, B8

$$\mathrm{Chl-a} \propto R(\lambda_2) - R(\lambda_1) + \left(R(\lambda_1) - R(\lambda_3) \frac{(\lambda_2 - \lambda_1)}{(\lambda_3 - \lambda_1)} \right)$$

- Four year time series (2019- 2022) of algal indices for all 6 potential sites.
- Average value of entire dam for each overpass
- Cloud and land masked

Credit: Kravitz (unpublished)

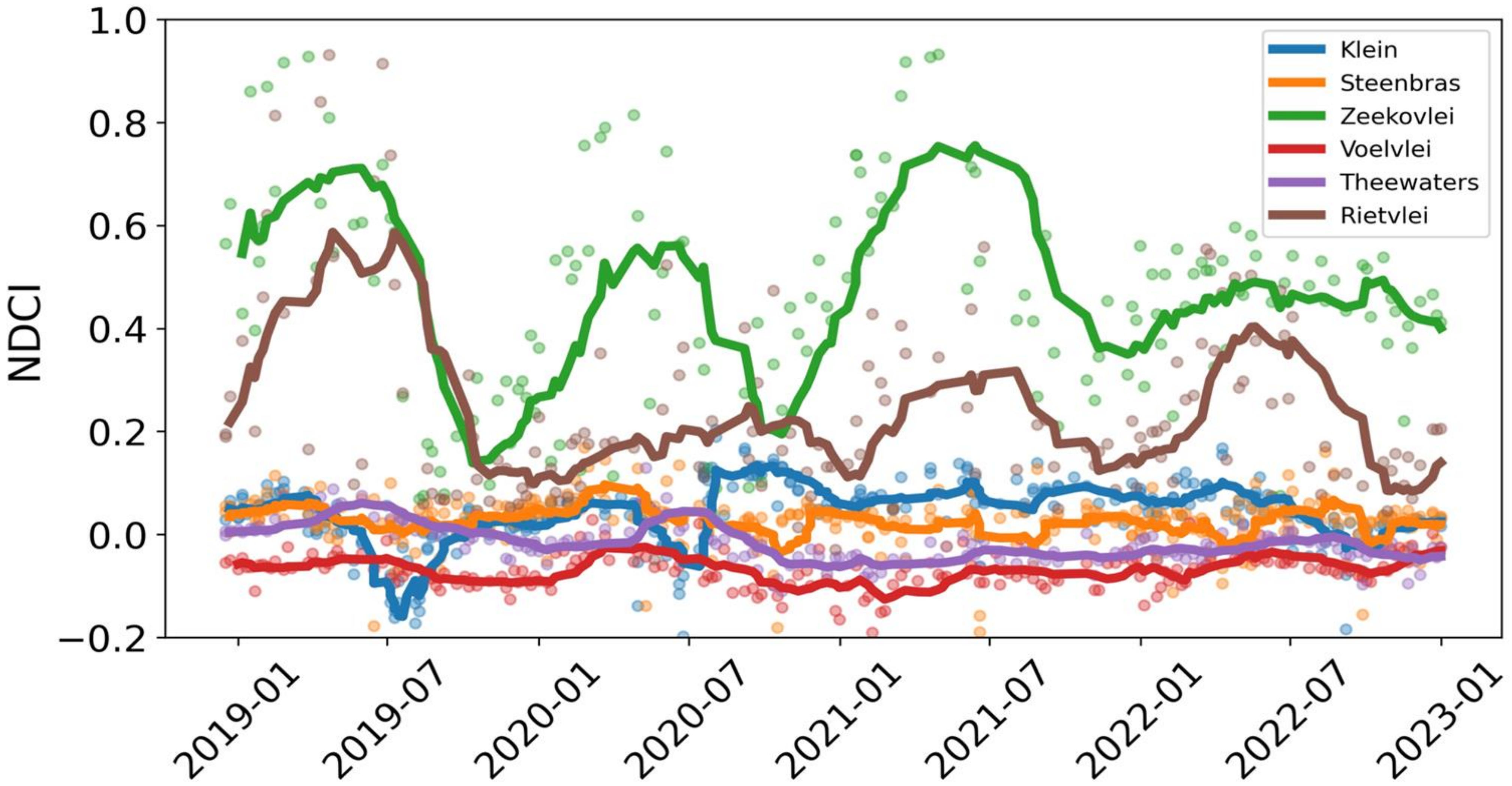


Algal blooms during and after the hot summer months and receding into the rainy winter season.

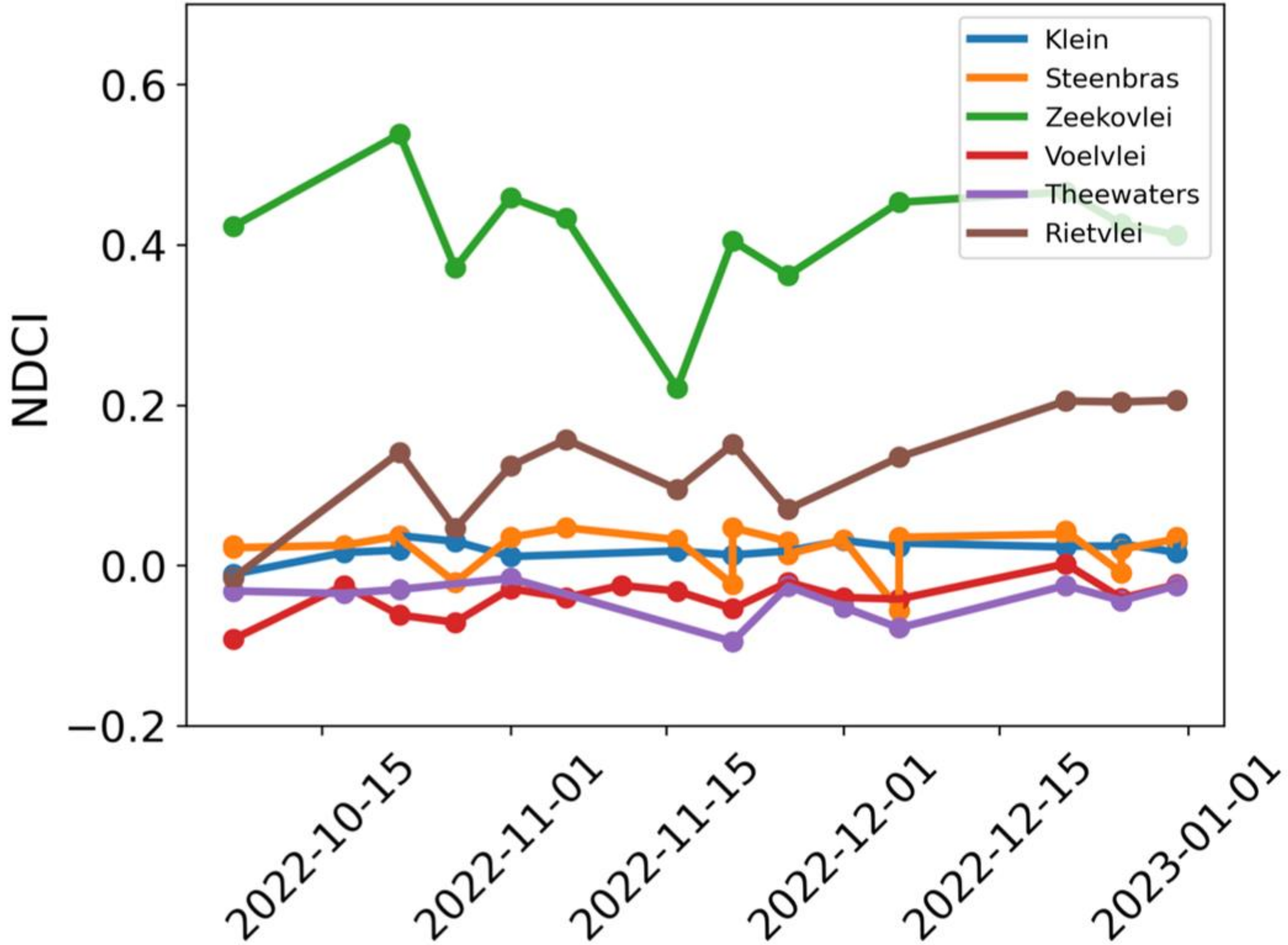
FAI only bloom could imply floating vegetation or benthic influence from water level change

Credit: Kravitz (unpublished)

NDCI Comparison of All Dams



Credit: Kravitz (unpublished)



Short time series for timeframe of Airborne campaign in 2023

Credit: Kravitz (unpublished)

Fieldwork During Sensor Overpass

Sample Collection

- Inland: 4-5 stations, water collection by bucket/sample bottles

Matchups

- +/- 1 hour of overpass (PRISM, AVIRIS-NG)
- Solar elevation angle of 30-50 deg to avoid sunglint
- Nose of aircraft to fly into and out of solar azimuth

Radiometric Validation

- Simultaneous radiometric measurements with diverse instruments
- Mooring systems: Trios Ramses radiometers

Pigments:

- Chl-a, Phycocyanin

Optics

- Field: ACS, BB9 – Absorption, Attenuation, Backscatter
- Lab: Particulate/Dissolved Absorption with spectrophotometry

Phytoplankton ID

- Inland: FlowCam flow cytometry

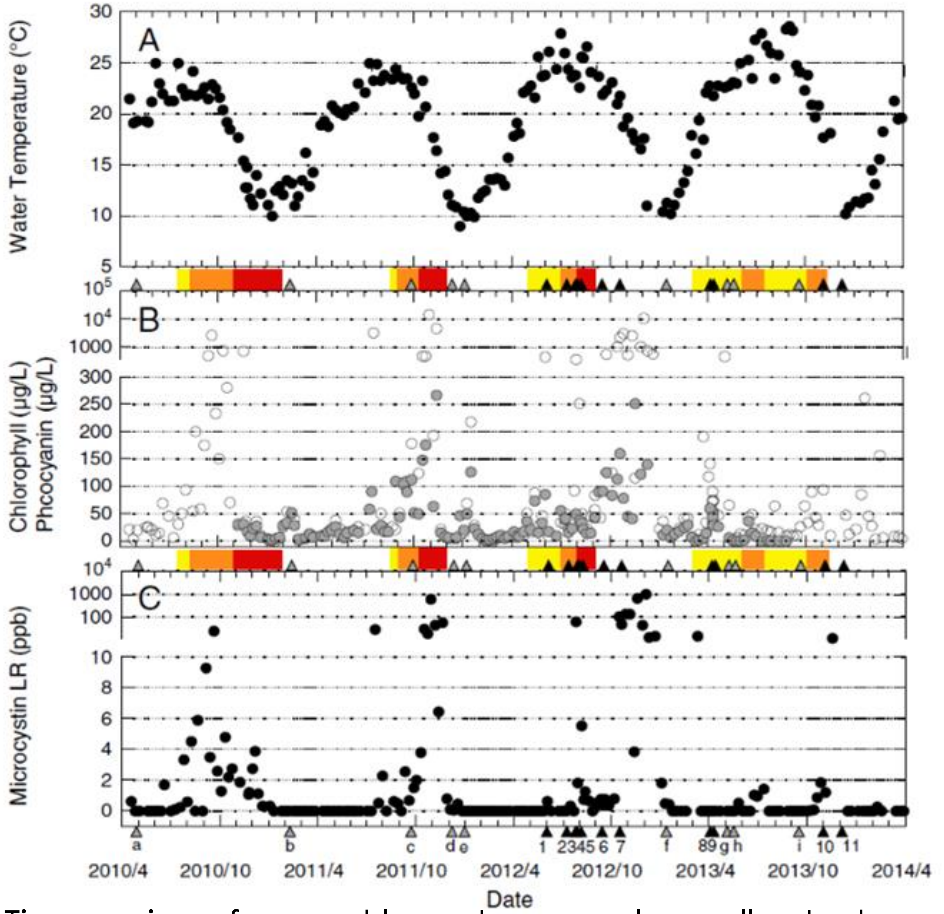
Pinto Lake, California.
Credit L. Guild & S. Palacios.

Example of previous Hyperspectral Coastal Observations with Hyperspectral Imagery - Pinto Lake, CA, USA

Algorithms developed/applied to spectral data.
CI = Cyanobacteria Index, SLH = Scattering Line Height,
AMI = *Aphanizomenon-Microcystis* Index. Kudela et al. 2015.

Algorithm	Formulation
CI	$CI = -SS(681)$
	$SS(681) = Rrs_{681} - Rrs_{665} - [Rrs_{709} - Rrs_{665}] \times \frac{(681\ \text{nm} - 665\ \text{nm})}{(709\ \text{nm} - 665\ \text{nm})}$
SLH	$SLH = Rrs_{714} - [Rrs_{654} + \frac{Rrs_{754} - Rrs654}{754nm - 654nm}(714\ \text{nm} - 654\ \text{nm})]$
AMI	$AMI = \text{peak width/dip width} = [640 - 510\ \text{nm}] / [652 - 625\ \text{n}$

Cyanobacterial layer formed at the water surface in Pinto Lake, CA. Credit: Liane Guild (NASA Ames)



Time series of ~ weekly water samples collected showing (A) water temp, (B) chlorophyll (open circles) and phycocyanin (shaded circles) concentration, and microcystin LR concentrations. Kudela et al. 2015

Example of previous Hyperspectral Coastal Observations with Hyperspectral Imagery - Pinto Lake, CA, USA

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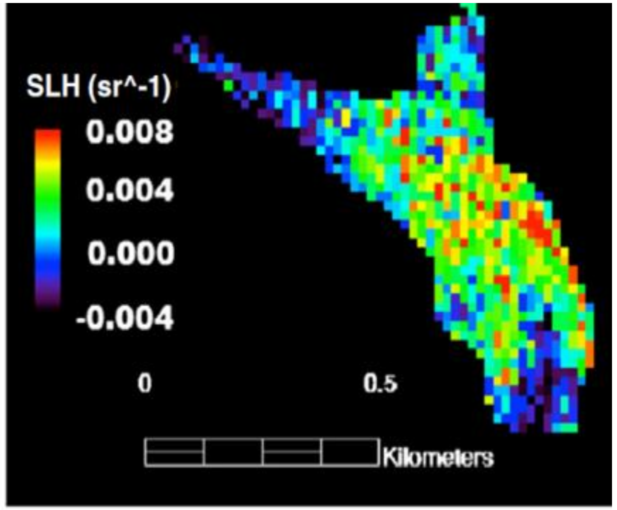
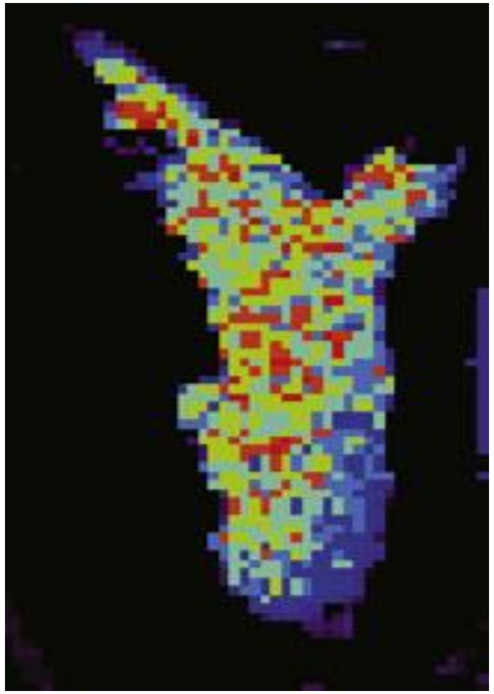
SLH	$SLH = Rrs_{714} - [Rrs_{654} + \frac{Rrs_{754} - Rrs654}{754nm - 654nm}(714\ \text{nm} - 654\ \text{nm})]$
AMI	$AMI = \text{peak width/dip width} = [640 - 510\ \text{nm}] / [652 - 625\ \text{nm}]$



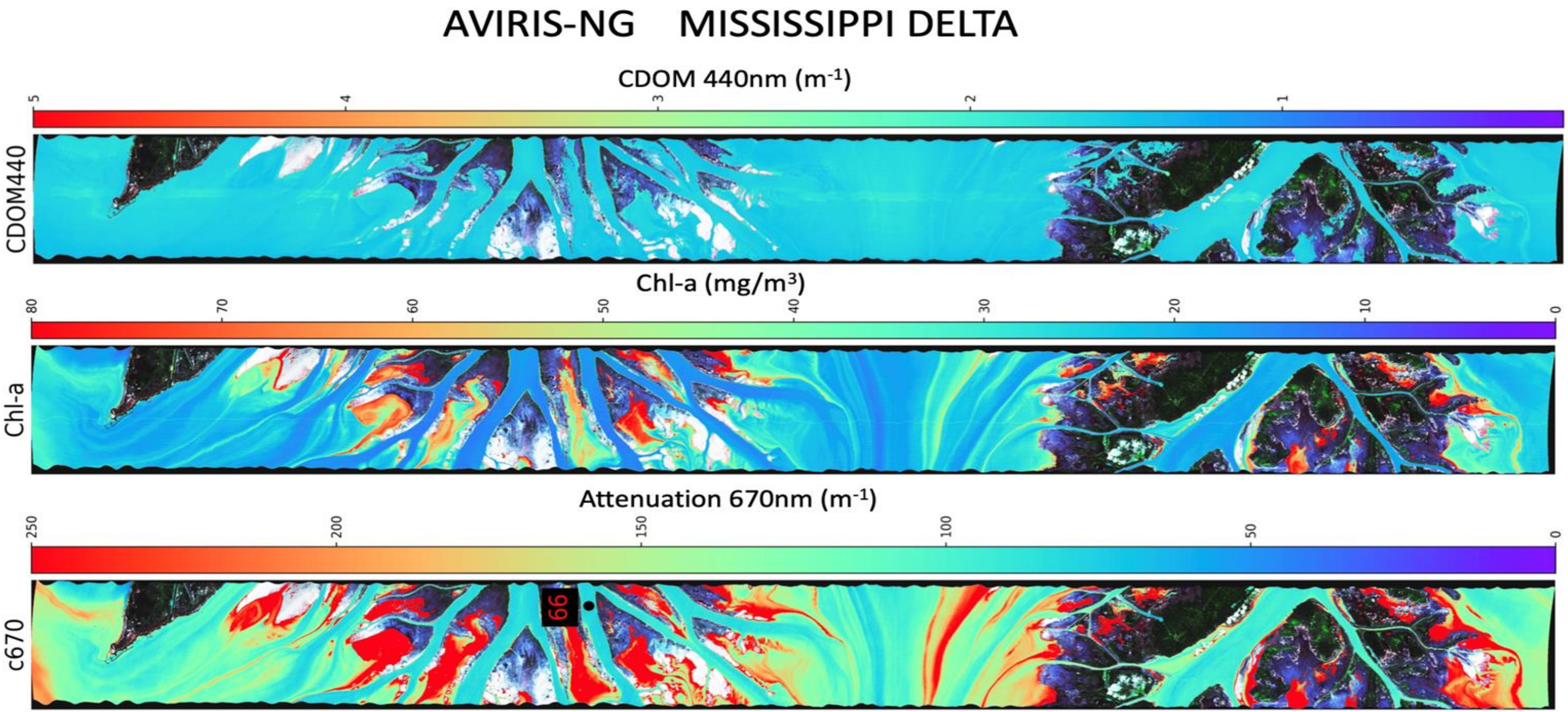
Scattering Line Height (SLH) for Pinto Lake, CA. Warm colors indicate the probability of a cyanobacterial bloom and validated with in situ observations. Kudela et al. 2015.



Cyanobacteria Index (CI) for Pinto Lake, CA using AVIRIS imagery for 31 October 2013. Kudela et al. 2015.

Credit: Kudela, Raphael M., Sherry L. Palacios, David C. Austerberry, Emma K. Accorsi, Liane S. Guild, Juan Torres-Perez, 2015, *Application of Hyperspectral Remote Sensing to Cyanobacterial Blooms in Inland Waters*, Remote Sensing of Environment, DOI: 10.1016/j.rse.2015.01.025.

Example of previous Airborne Hyperspectral Coastal Observations with AVIRIS-NG



Credit: Kravitz et al. (unpublished)

Modeling of Laboratory Data for PFTs Derivation

75 species of laboratory Culture Measurements of chl-a Specific absorption

↓

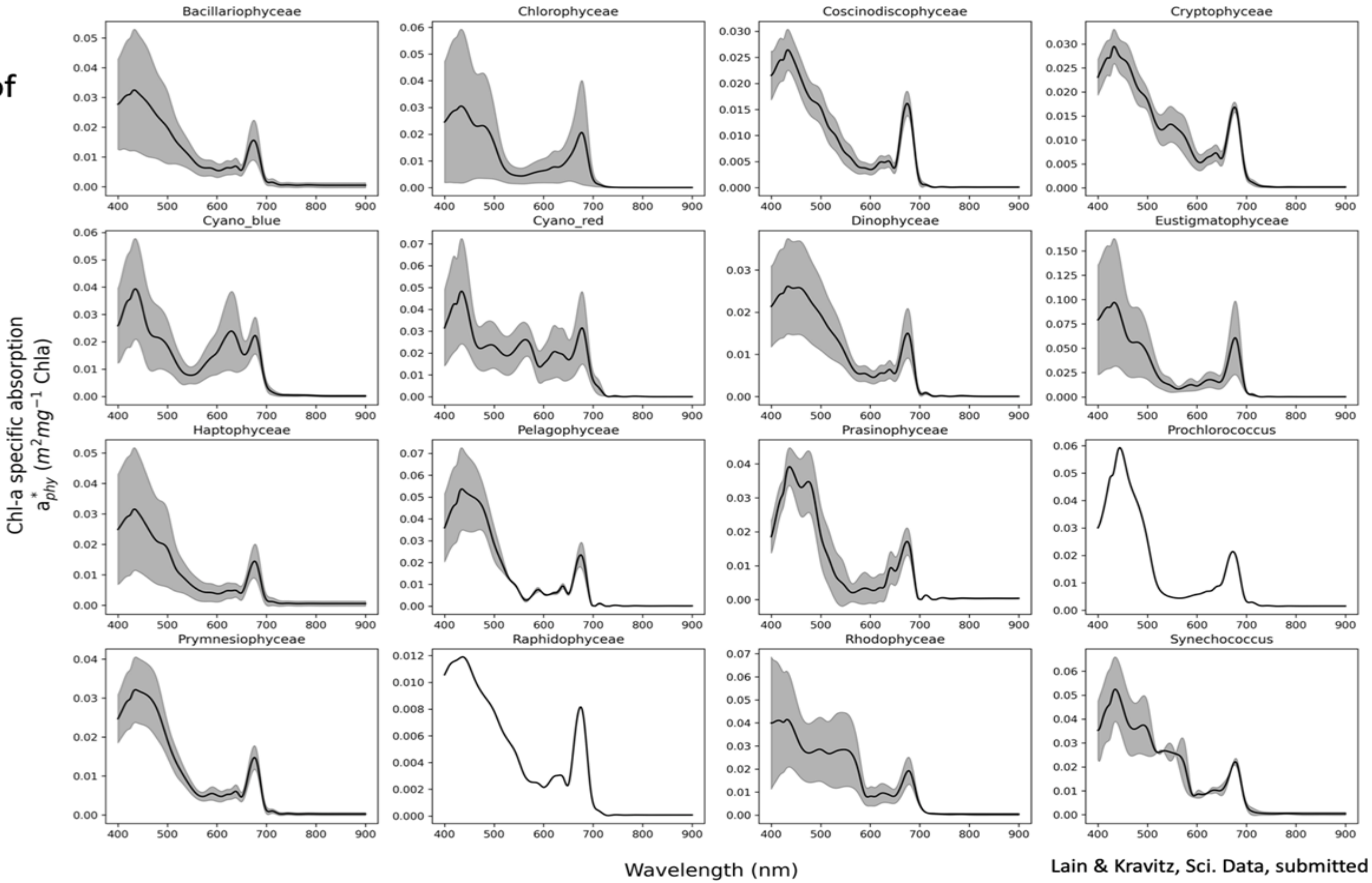
Calculate imaginary Refractive indices (absorption)

↓

Kramers-Kronig Eqs. Derive real Refractive indices (scatter)

↓

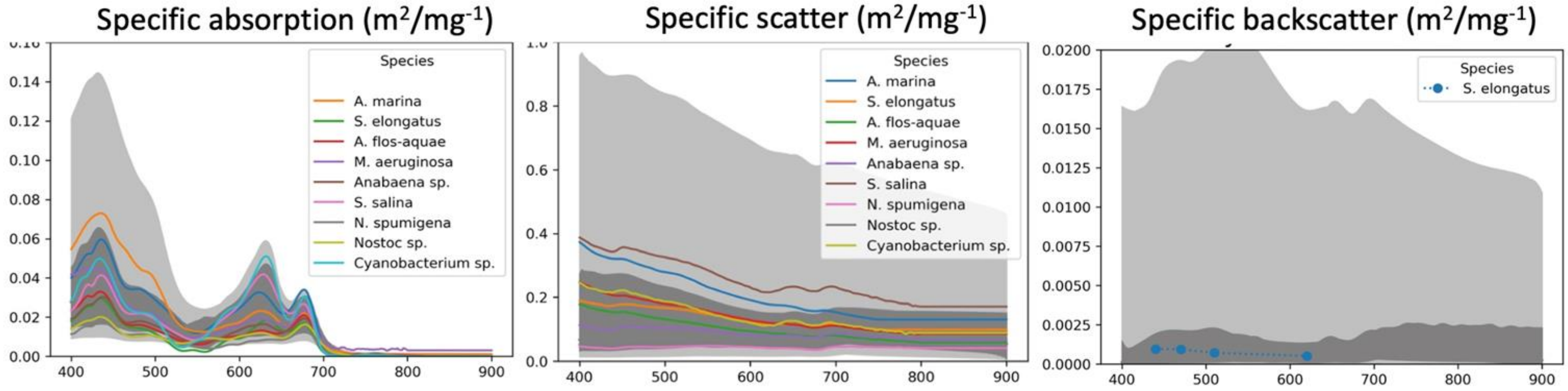
Derive species Specific IOPs (absorption, scatter, Backscatter)



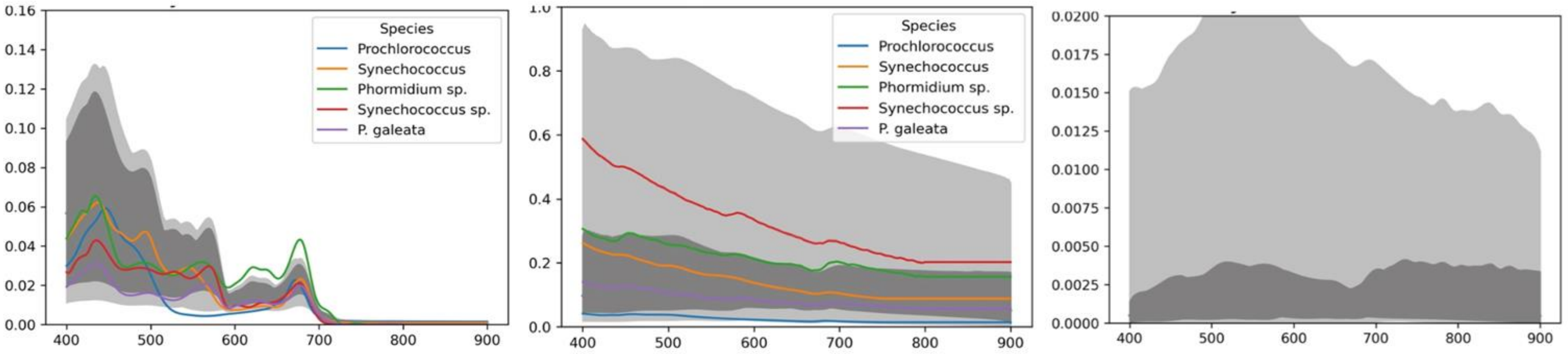
Lain & Kravitz, Sci. Data, submitted

Identification of Dominant Cyanobacterial Groups

Cyanobacteria – “Blue mode” – Phycocyanin dominant

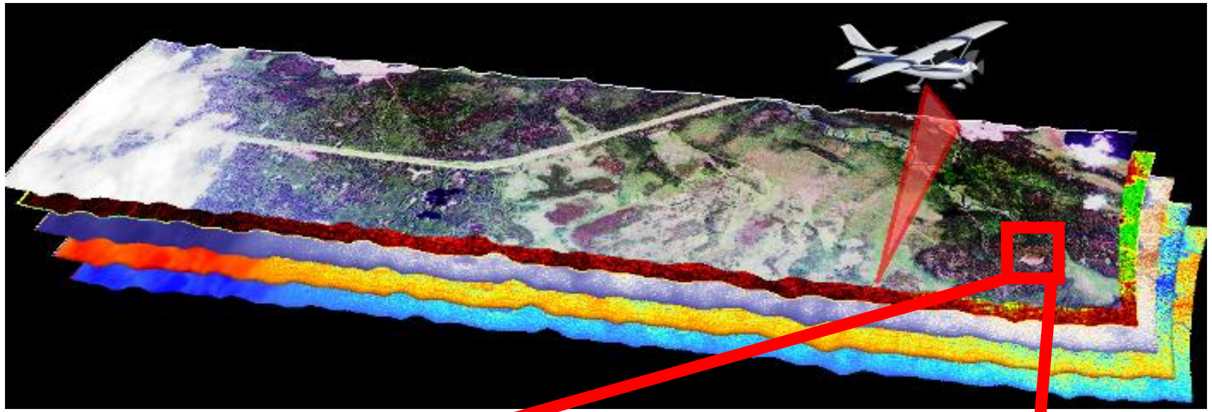


Cyanobacteria – “Red mode” – Phycoerythrin dominant

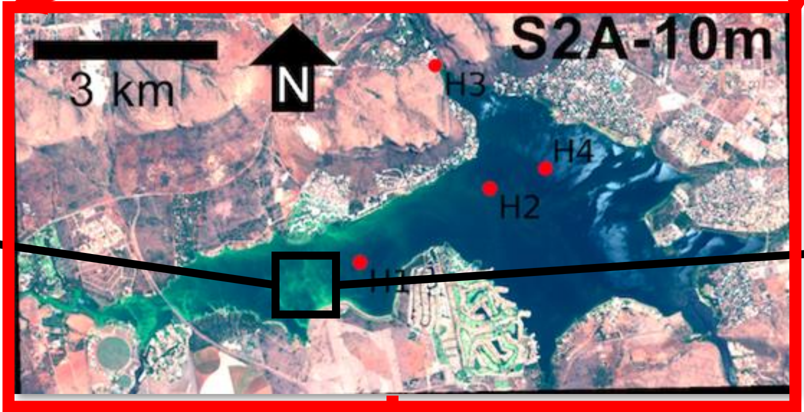


Credit: Kravitz (unpublished)

Hartbeespoort Dam, SA

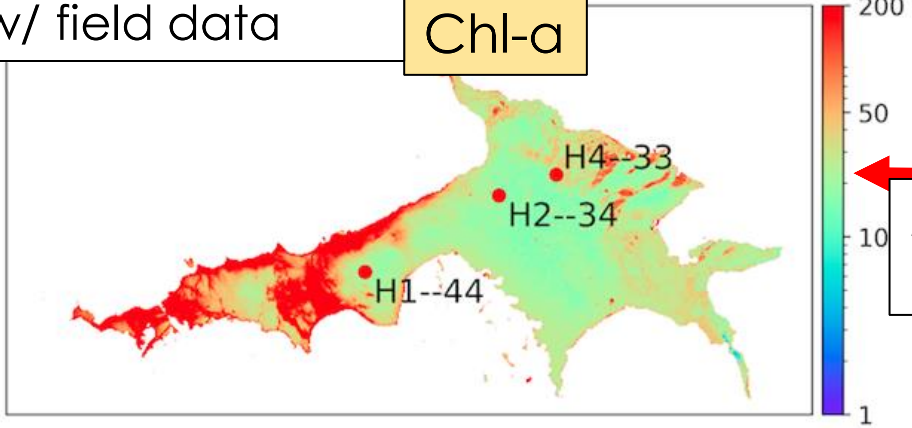


Airborne Data



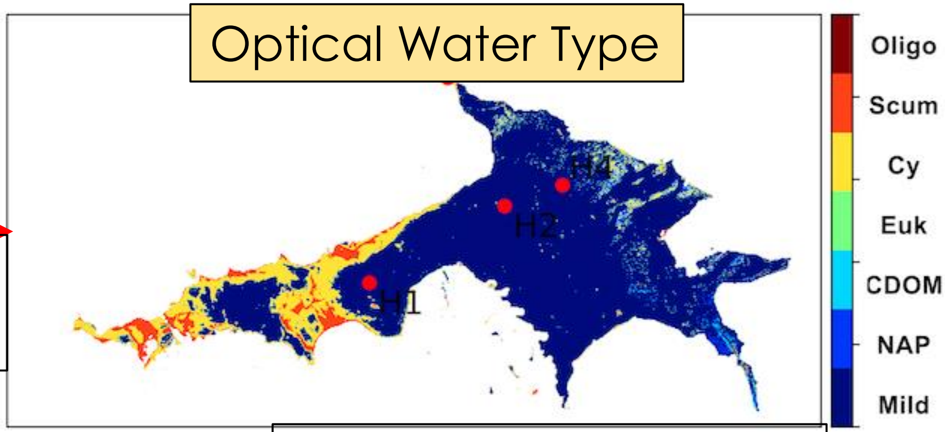
Matchup validation w/ field data

Chl-a



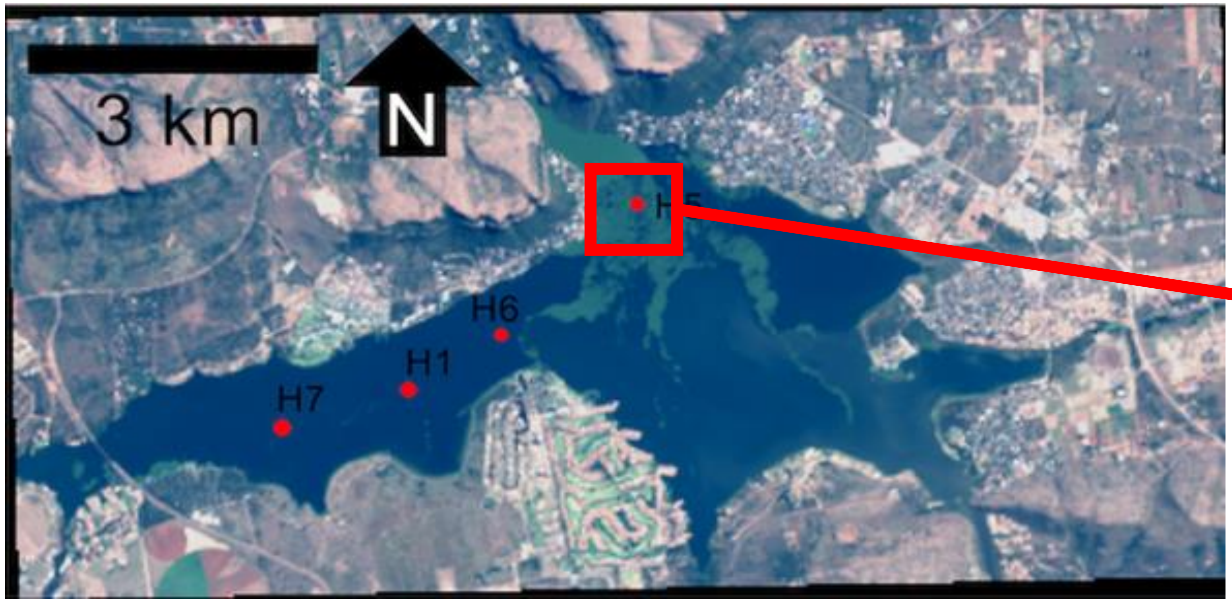
Machine Learning

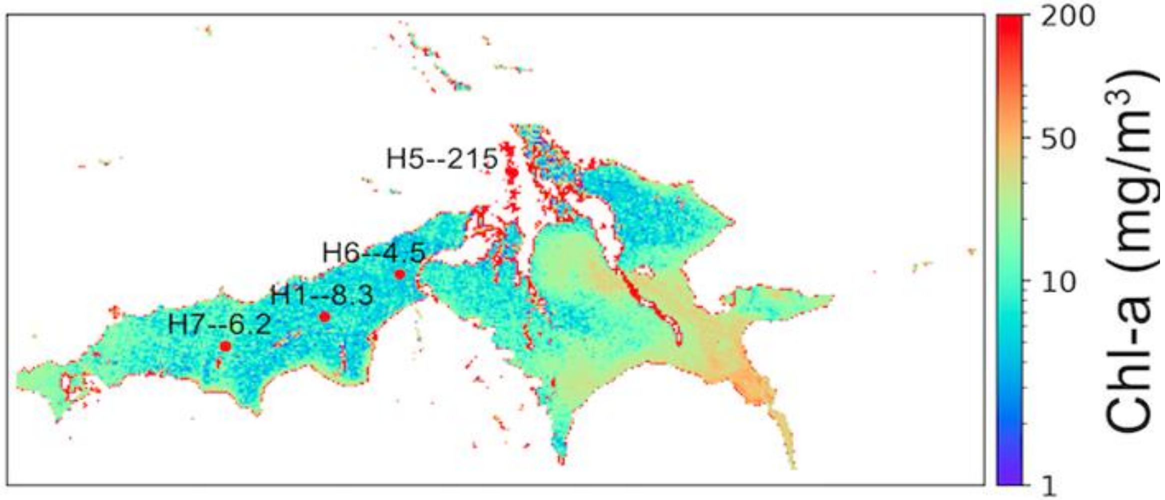
Optical Water Type

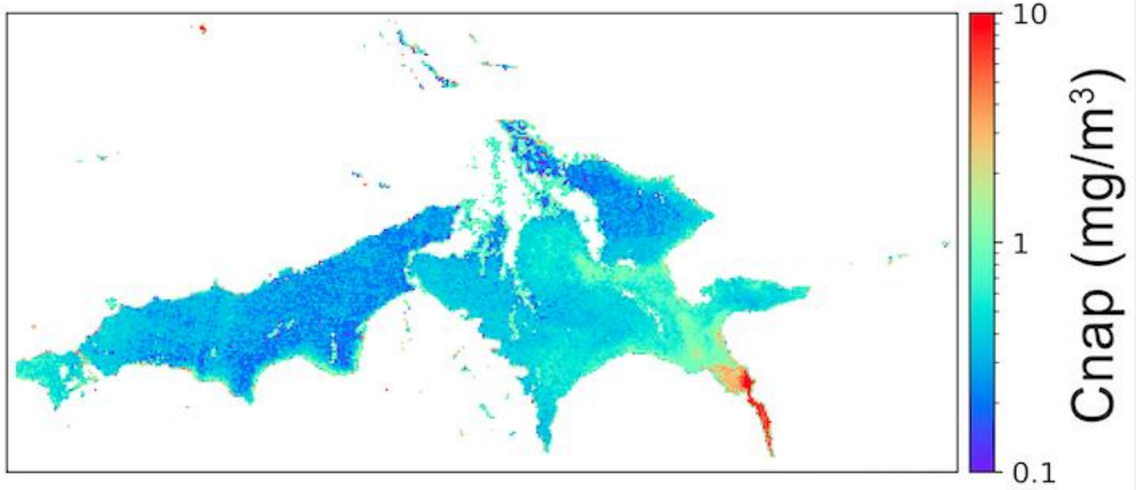


Credit: Kravitz et al. (2021)

Mapping Floating Aquatic Vegetation and Cyanobacterial Blooms







Credit: Kravitz et al. (2021)

Summary

- Airborne campaigns tied with intensive field efforts provide unique opportunities for the characterization of terrestrial and aquatic ecosystems.
- Sites selection are usually based on needs and accessibility.
- Flight Planning is critical as it may present particular challenges especially for aquatic targets.
- Consideration of phenology, seasonality, atmospheric conditions, etc.
- For aquatic targets, the fieldwork needs to be aligned with the airborne campaign and opportunistic satellite overpasses due to the constant changes in water column composition.
- Analyses and modeling facilitated by machine learning techniques help processing such large datasets collected by airborne sensors.

Resources

- https://airbornescience.nasa.gov/
- https://hytes.jpl.nasa.gov/
- https://aviris.jpl.nasa.gov/
- https://ecostress.jpl.nasa.gov/
- https://earth.jpl.nasa.gov/emit/
- https://prism.jpl.nasa.gov/
- https://pace.gsfc.nasa.gov/

Contacts

- Trainers:
  - Juan L. Torres-Pérez: juan.l.torresperez@nasa.gov
  - Amber McCullum: amberjean.mccullum@nasa.gov
  - Britnay Beaudry: britnay.beaudry@nasa.gov
  - Sativa Cruz: sativa.cruz@nasa.gov

- Training Webpage: https://appliedsciences.nasa.gov/join-mission/training/english/arset-biodiversity-applications-airborne-imaging-systems

- ARSET Webpage: https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

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TRAIN - EMPOWER - ADVANCE

Thank You!