The next frontier for remote sensing of freshwater HABs: Utilizing imaging spectroscopy data to identify cyanobacteria bloom types

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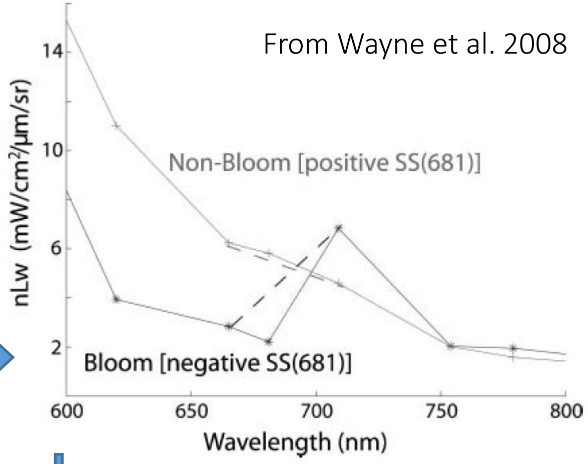
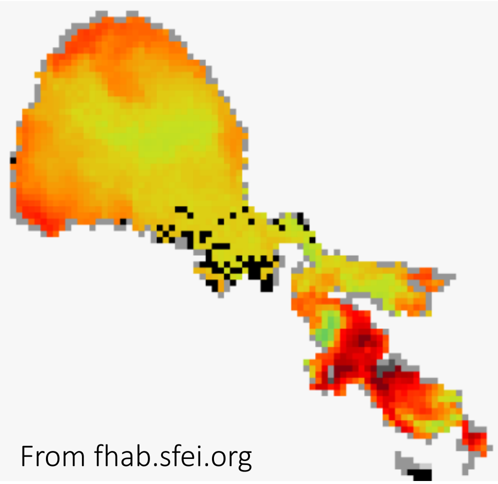
Background on cyanobacteria HABs

- Harmful algal blooms (HABs) are a water quality concern with impacts to ecosystem health and public health
- Some cyanobacteria can produce toxins including dermatoxins, hepatotoxins, and neurotoxins
- Cyanobacteria blooms are increasing in frequency and magnitude globally
- Cyanobacteria thrive in warm, calm, nutrient-rich waters
- HABs are expected to continue to increase with climate change

Background on Satellite Detection of HABs



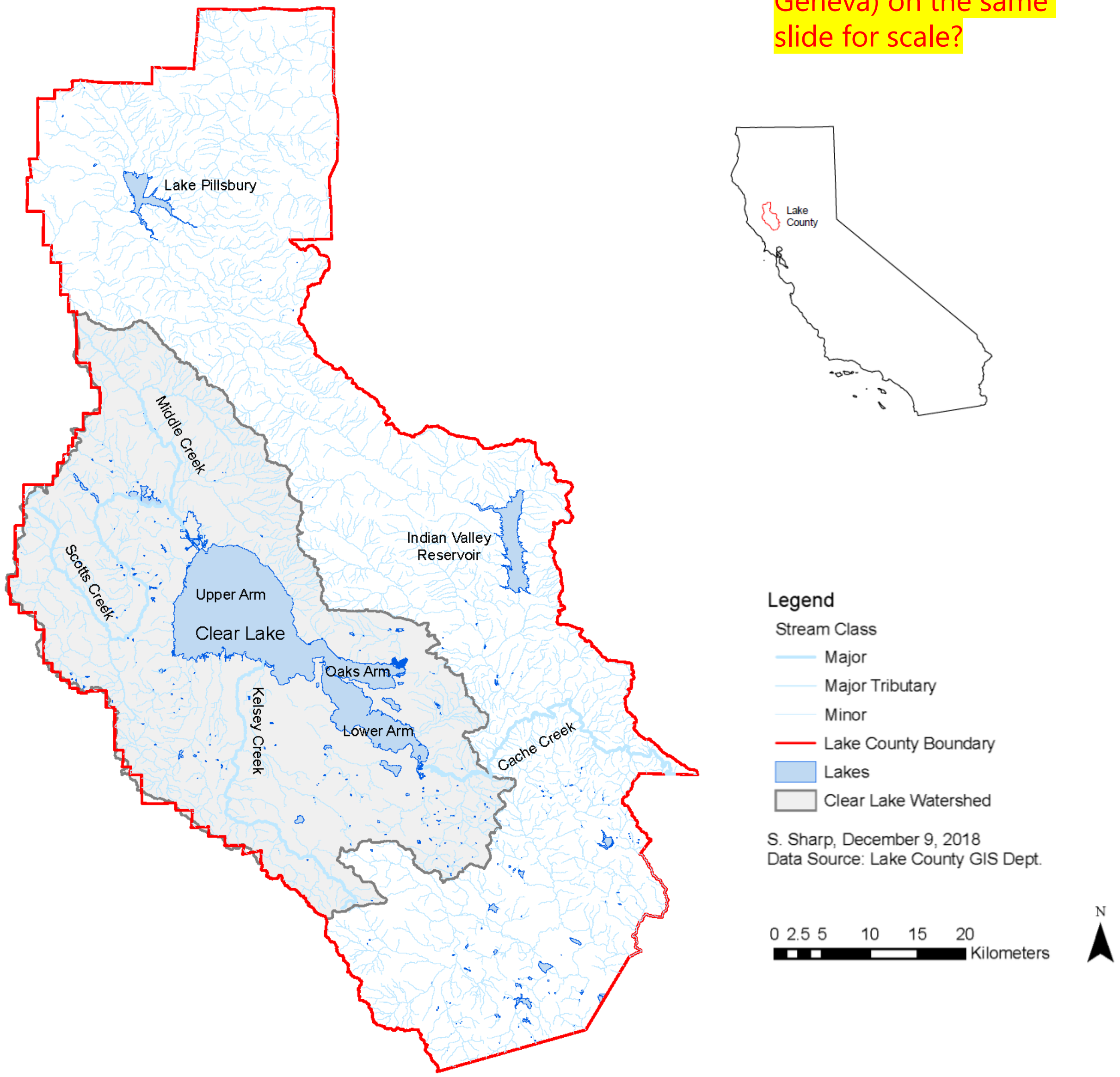


- Remote sensing of HABs is possible due to the unique spectral signature of cyanobacteria
- Advantages of satellite-based remote sensing:
  - Global observations
  - Large-scale sampling of entire waterbodies
  - Accessible sampling of remote and potentially hazardous sites
  - Frequent repeat samples
  - Cost effective

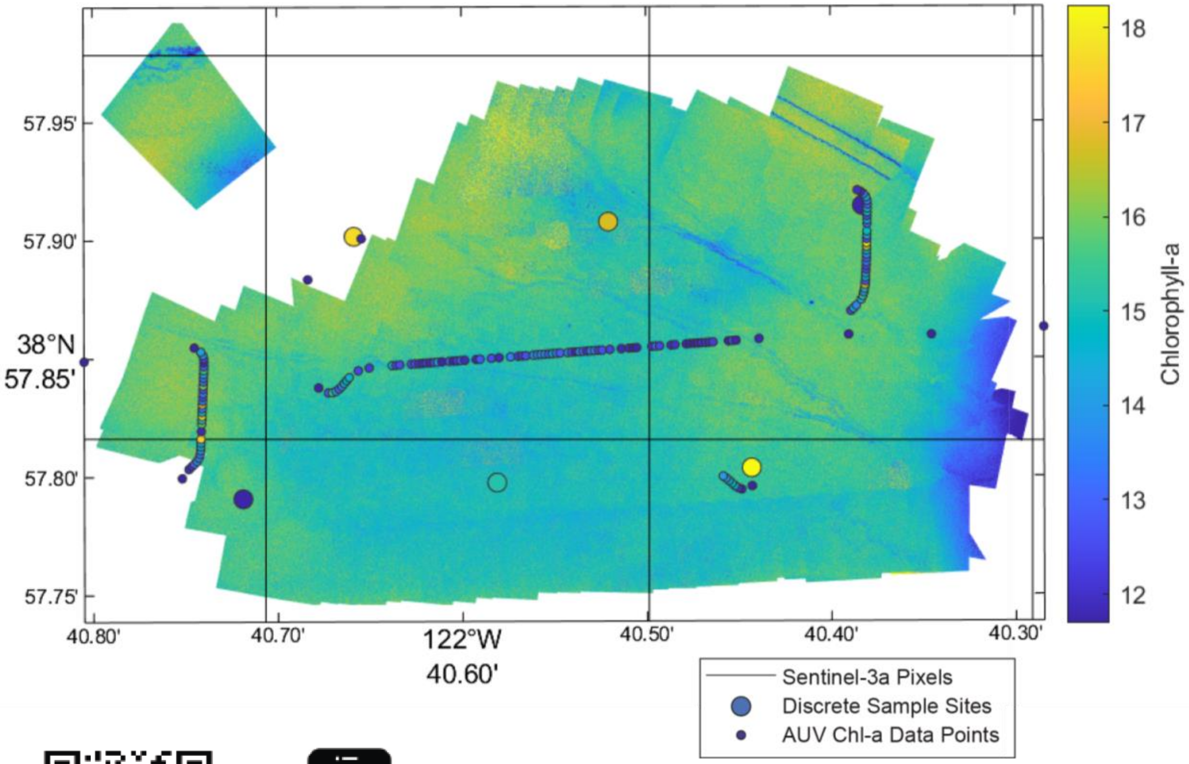
Study Site: Clear Lake, CA

Hard to see image / scale and might mean little to a European audience. Do you want to put a classic European lake (e.g. Geneva) on the same slide for scale?

- Large, shallow, polymictic lake
- Oldest lake in North America
- Naturally eutrophic
- Frequent cyanobacteria HABs
- Important water resource:
    - Recreational water uses
    - Cultural water uses
    - Drinking water supply



Initial Study

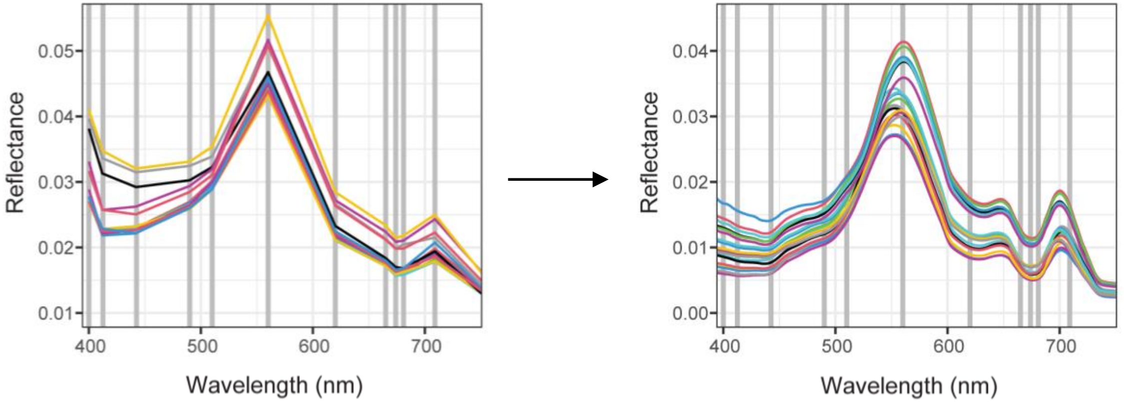


Multiplatform (boat-based, AUV, UAV, satellite-based) sampling of Clear Lake

- Quantify spatial variability of a cyanobacteria bloom
- Validate Cyanobacteria Index (CI) from Sentinel-3's OLCI sensor for Clear Lake

Take a picture to download the full paper of the initial study

What more can we learn as we move from multispectral to hyperspectral?

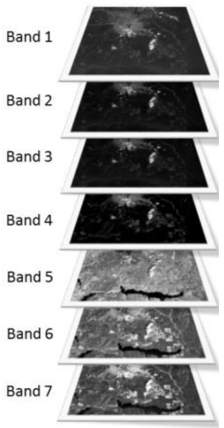


Sharp, S. L., Forrest, A. L., Bouma-Gregson, K., Jin, Y., Cortés, A., & Schladow, S. G. (2021). Quantifying scales of spatial variability of cyanobacteria in a large, Eutrophic lake using multiplatform remote sensing tools. *Frontiers in Environmental Science*, *9*, 612934.

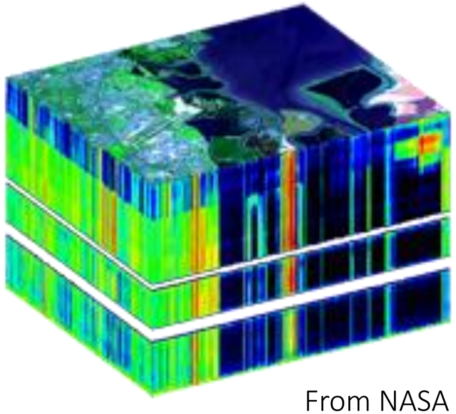
The Next Frontier: Hyperspectral Sensors

Multispectral
(up to tens of bands of data)

Hyperspectral
(hundreds of bands of data)



From Cal Poly Humboldt


From NASA JPL

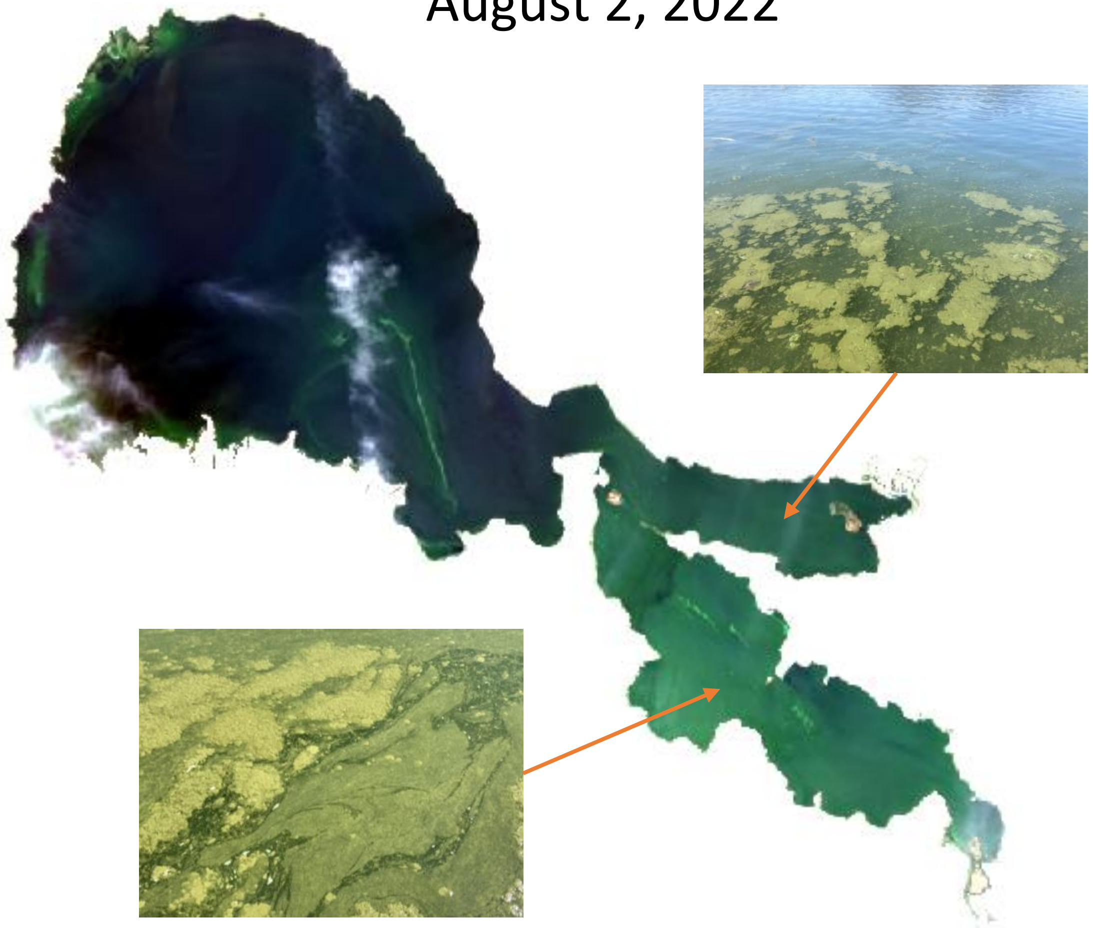
- NASA’s PACE, GLIMR, and SBG missions planned for this decade = frequent, repeat hyperspectral data acquisitions globally
- Pre-cursor missions have data available now:
  - Italian Space Agency’s PRISMA on-demand satellite-based hyperspectral sensor
  - German Space Agency’s DESIS on-demand ISS-based hyperspectral sensor
  - NASA’s EMIT on-demand ISS-based hyperspectral sensor

Current Study

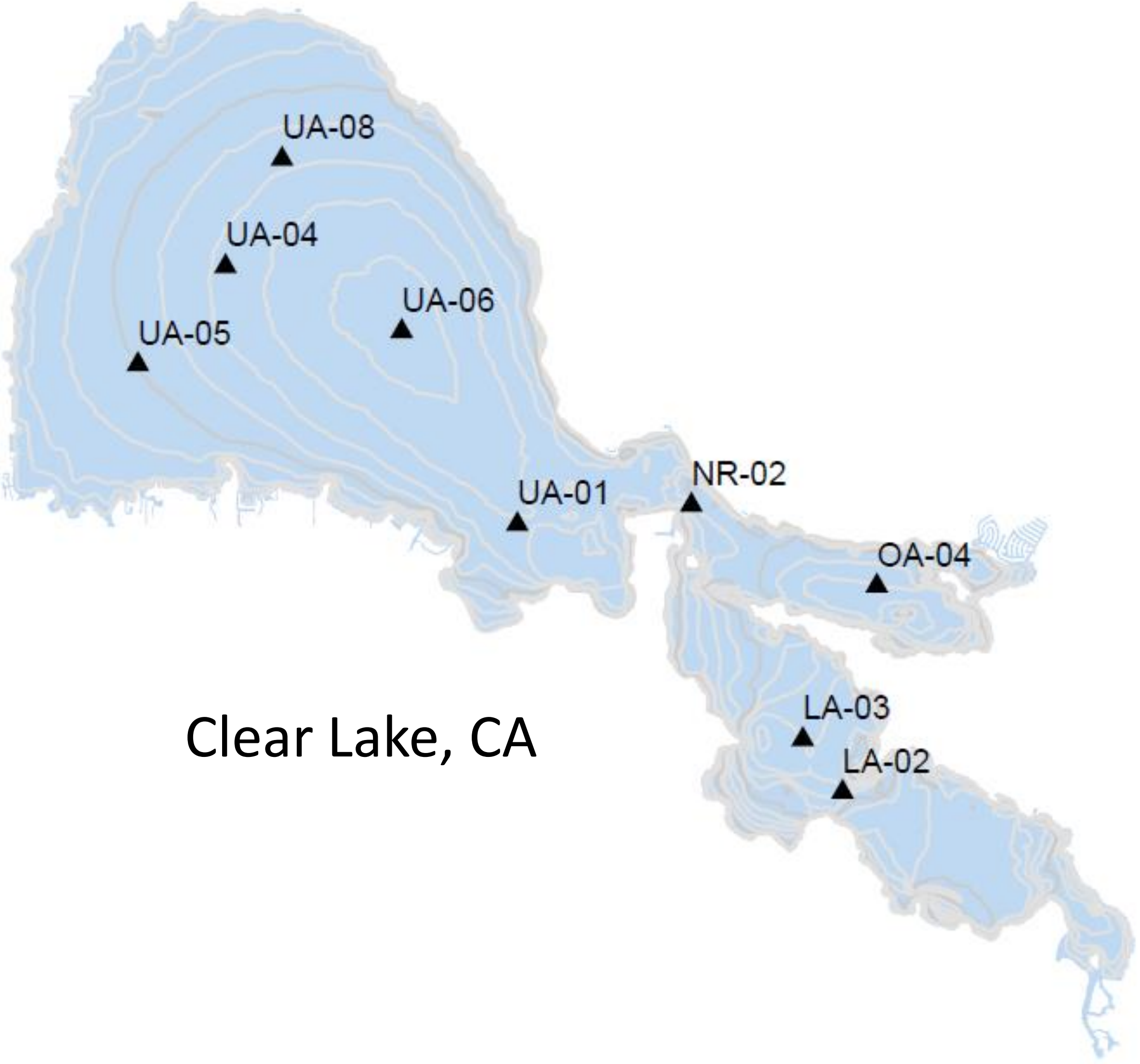
Detecting cyanobacteria bloom types from imaging spectroscopy data

- *In situ* lake sampling to characterize cyanobacteria blooms
- Coincident field radiometry measurements
- Coincident DESIS scene captures (SBG-precursor datasets) for three sampling events

DESIS Scene from August 2, 2022



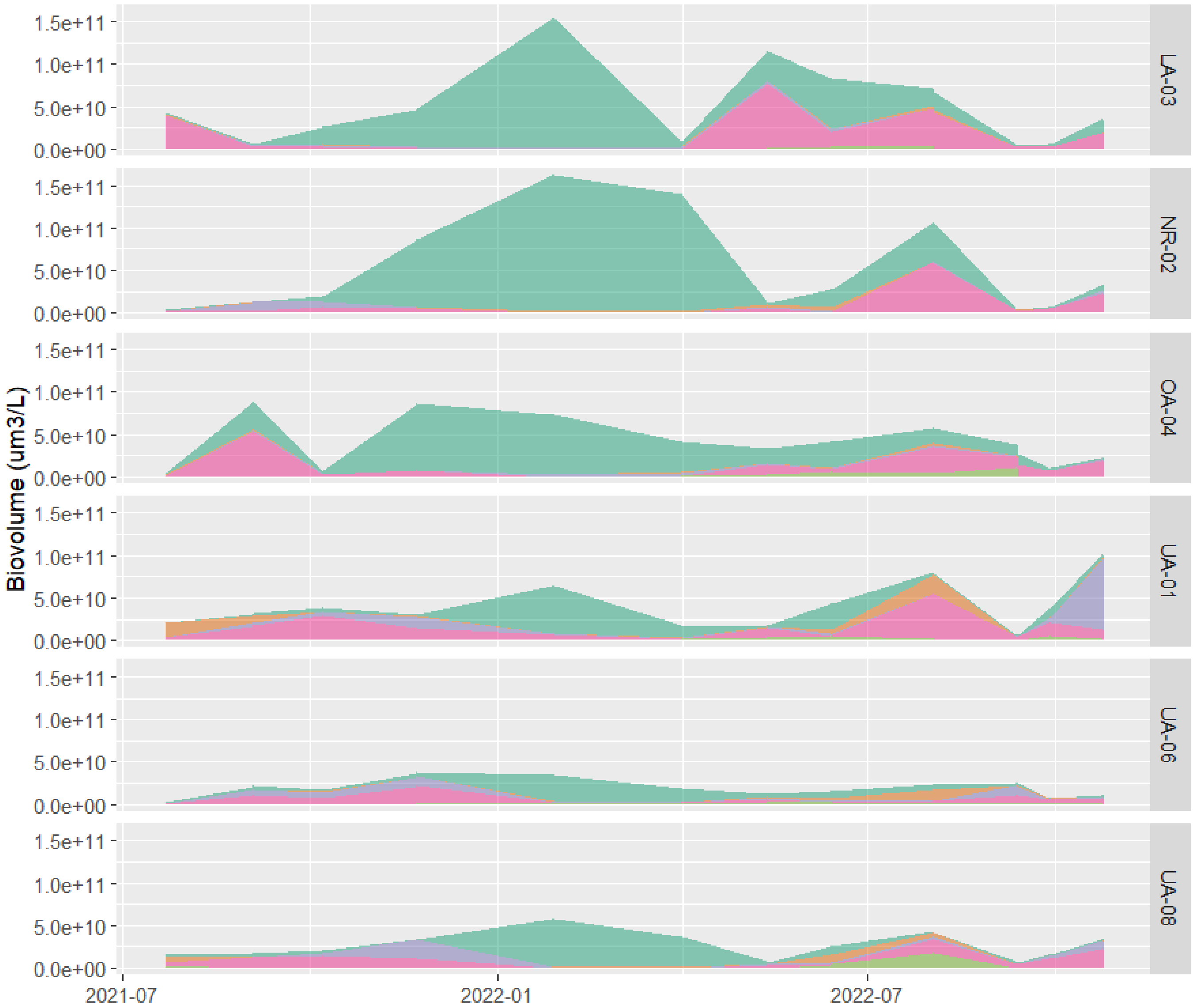
Field Sampling



Clear Lake, CA

- 12 sampling events (2021 – 2022, across all seasons)
- Optical measurements:
  - Optical water profiles
  - Above-water spectrometer
  - CDOM and particulate absorption
- Biological measurements:
  - Taxonomy (speciation and enumeration)
  - Cyanotoxins
- Pigments:
  - HPLC
  - Chlorophyll-*a*
  - Phycocyanin
- Additional chemical and physical measurements from our existing water quality monitoring program

Bloom Composition

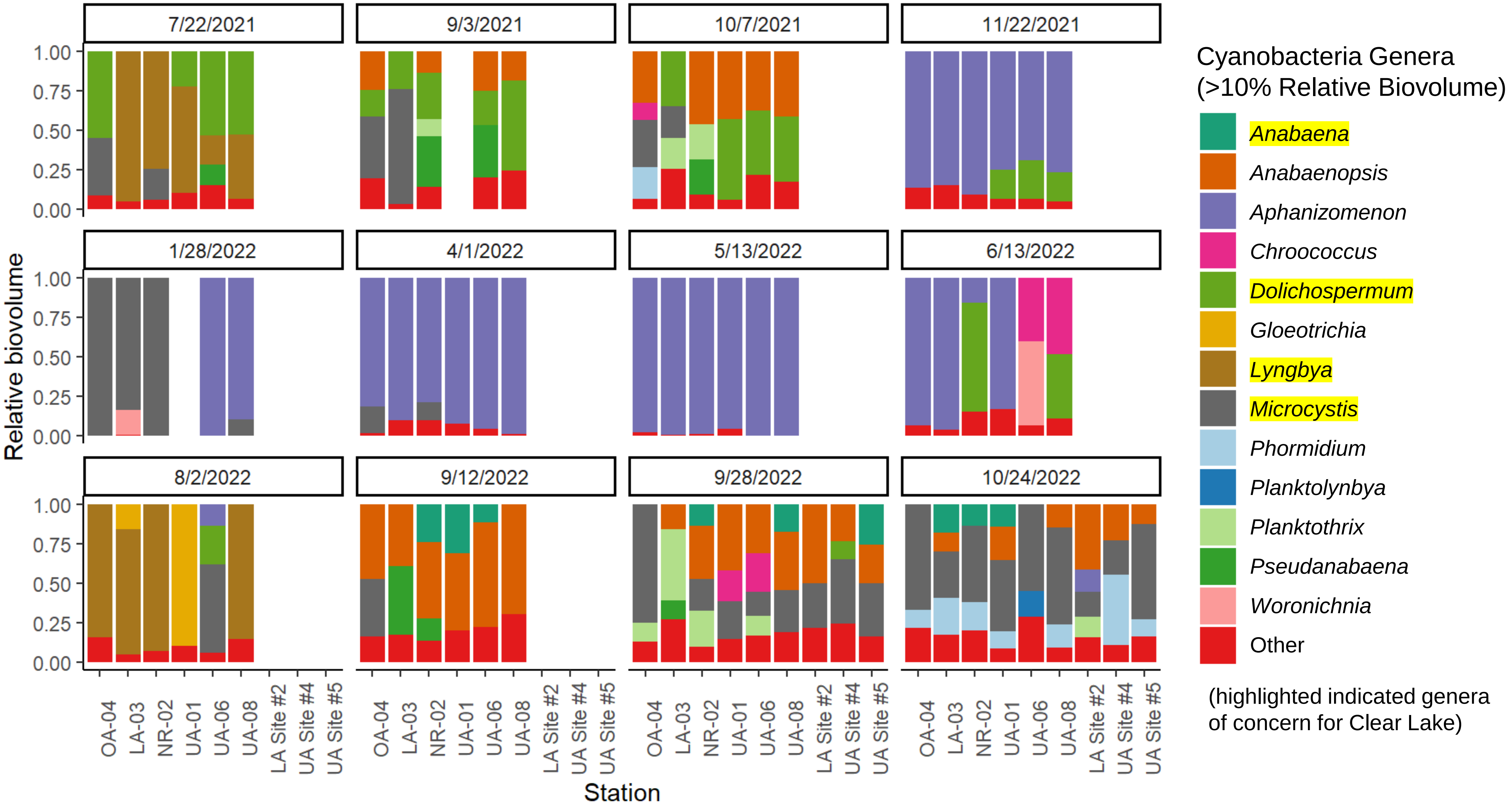


- Inter-season variability of bloom conditions:
  - Summer 2021 – mixed bloom of primarily diatoms, green algae, and cyanobacteria
  - Fall 2021 – cyanobacteria dominance
  - Winter 2022 – shift to dominance of diatoms
  - Spring and Fall 2022 – two cyanobacteria blooms which is typical for Clear Lake
- Inter-basin variability

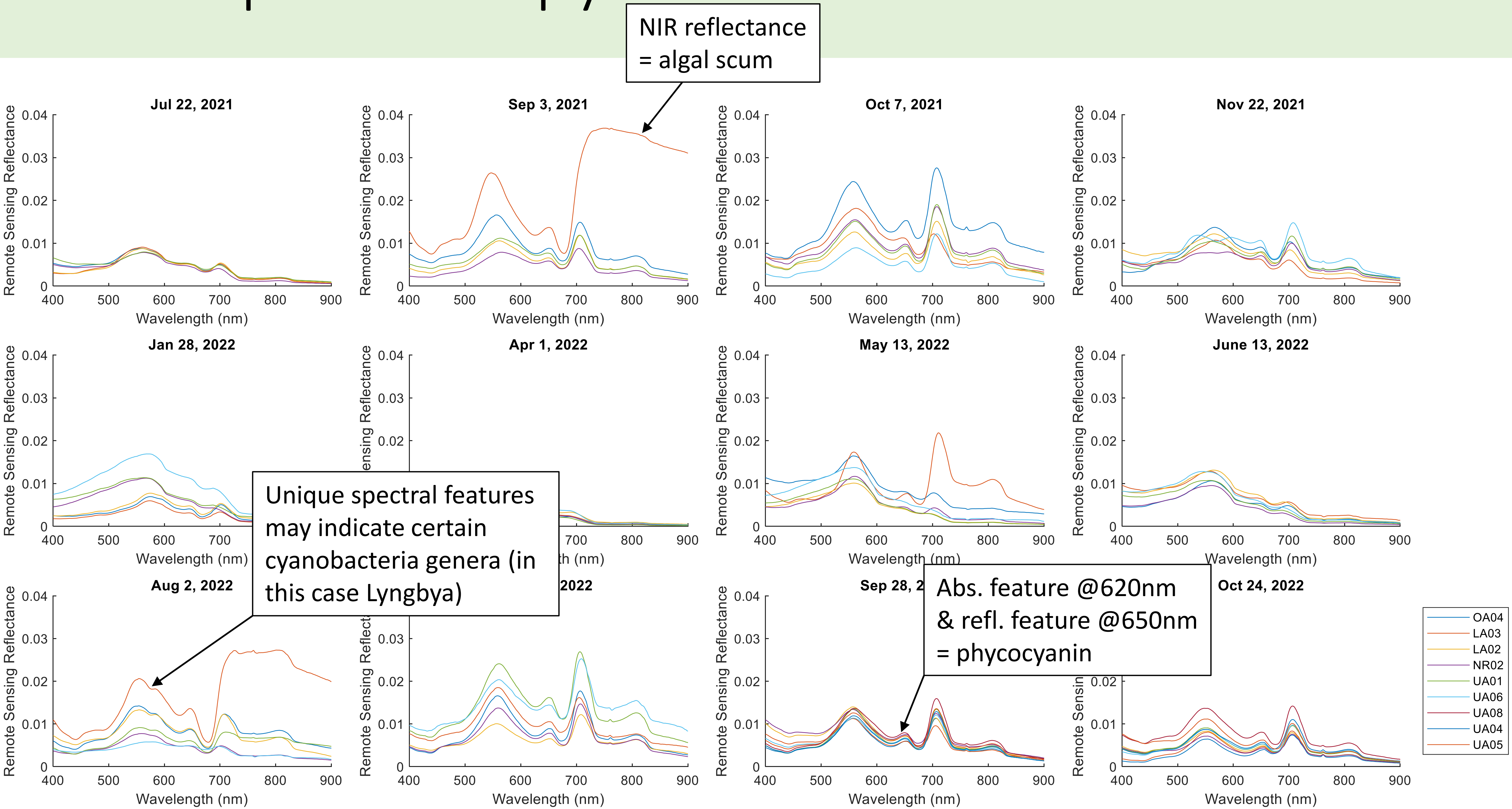
Primary Divisions

- Bacillariophyta (Diatoms)
- Chlorophyta (Green Algae)
- Cryptophyta
- Cyanobacteria
- Miozoa (Dinoflagellates)

Bloom Composition



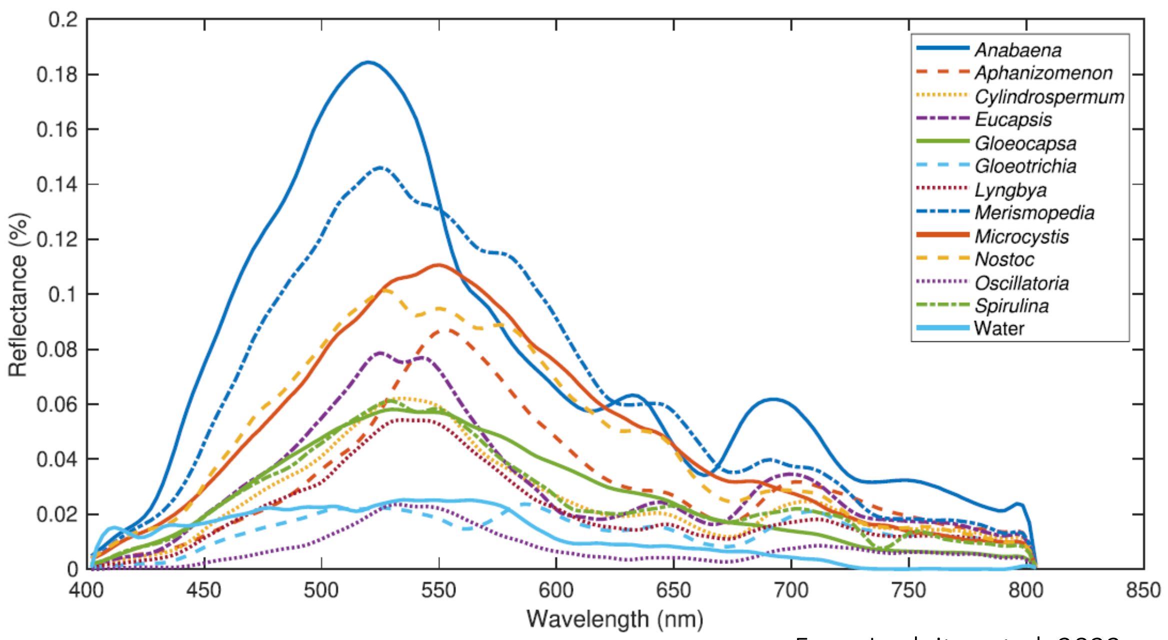
Field Spectroscopy



Next Steps

- Complete data post-processing
- Evaluate atmospheric correction of DESIS scenes
- Apply existing cyanobacteria differentiation algorithms to dataset:
  - USGS's **SMASH** (Spectral Mixture Analysis for Surveillance of Harmful algal blooms) algorithm – cyanobacteria genera
  - NASA's Jeremy Kravitz's **SWIPE** (Spectral Water Inversion Prototype Emulator) algorithm – phytoplankton functional types
  - Explore other classification approaches

SMASH Spectral Library

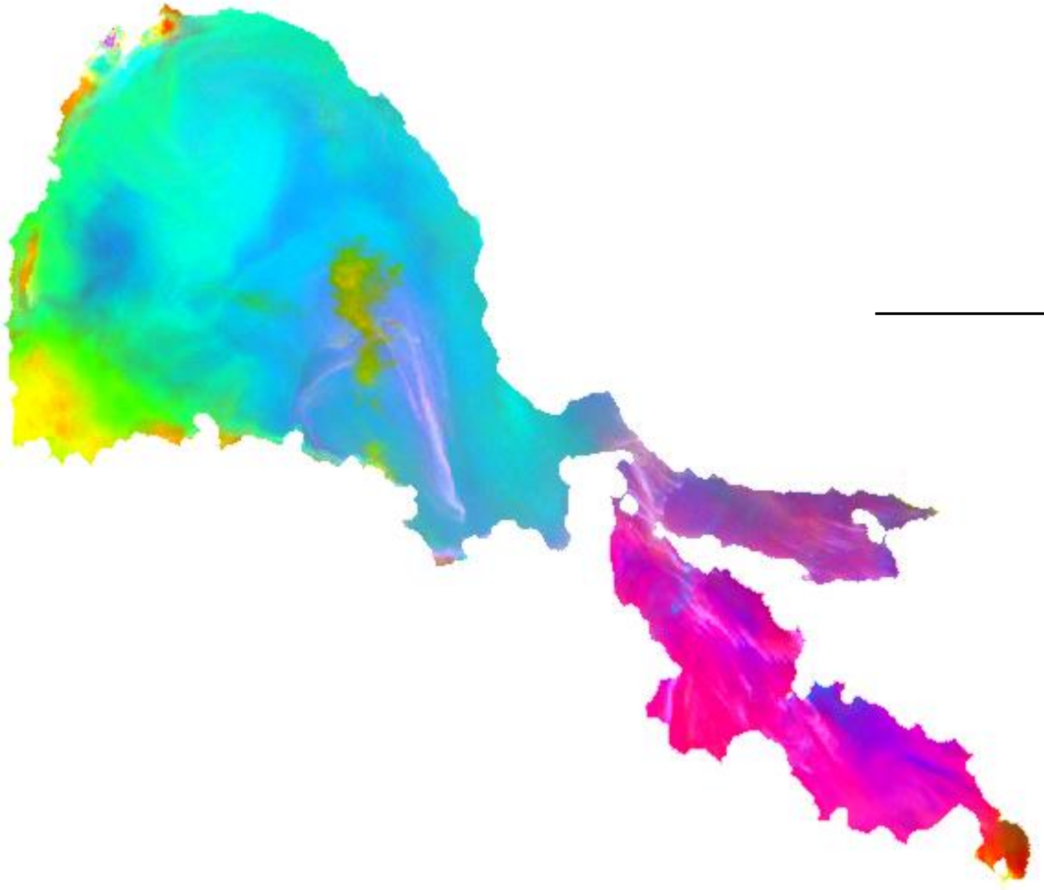


From Legleiter et al. 2022

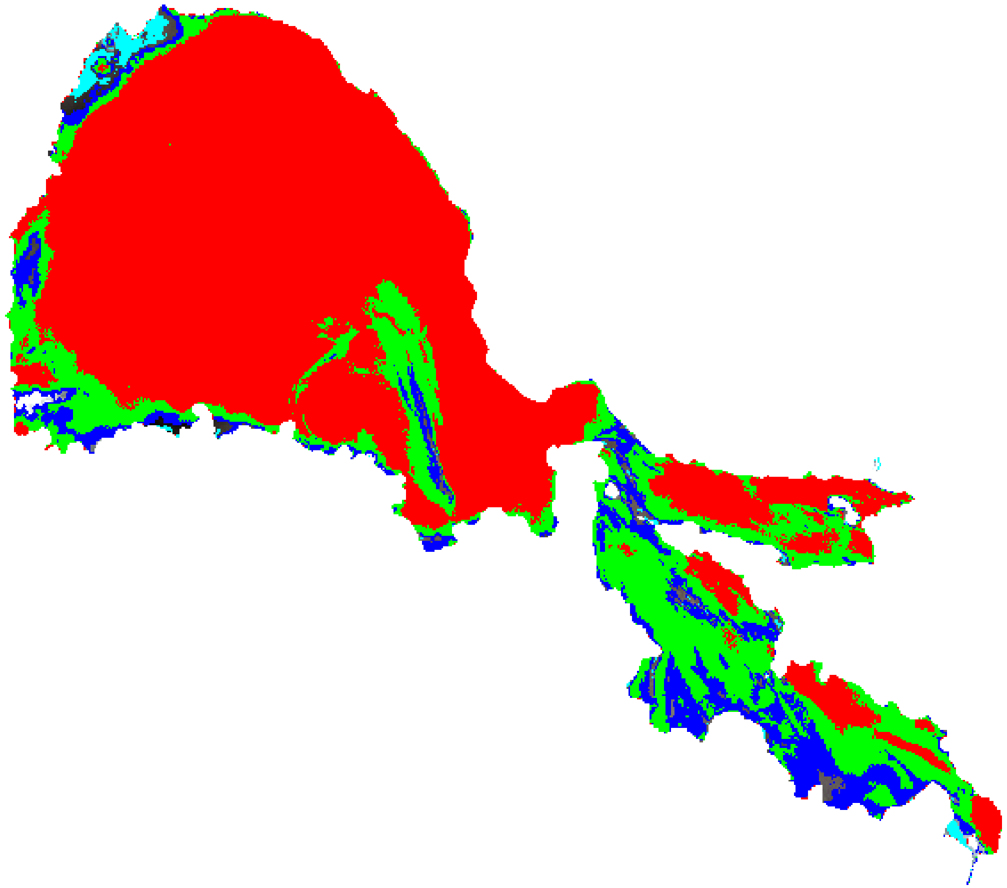
From Jeremy Kravitz

Next Steps – explore other classification approaches

Principal Component Analysis:
Image for first three principal
components



Unsupervised classification
(5 classes)



Acknowledgements

NASA

BIG VALLEY RANCHERIA

COUNTY OF LAKE WATER RESOURCES

USGS
science for a changing world

UC DAVIS
Tahoe Environmental Research Center

Questions?

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