Using remote sensing to explore spatial and temporal variability of cyanobacteria blooms in Clear Lake

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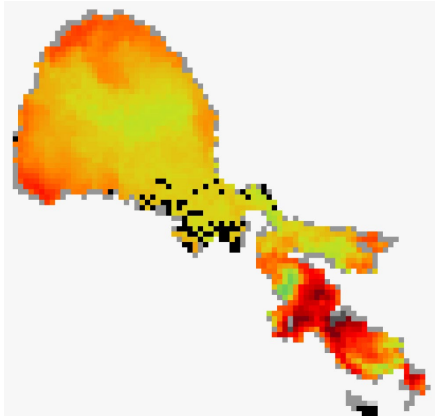
Outline

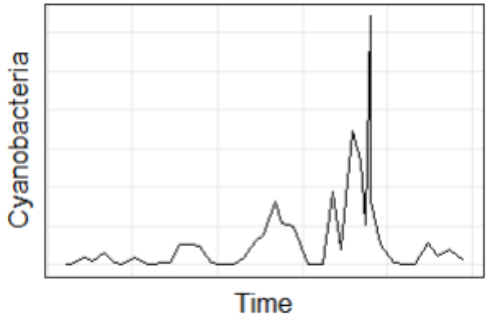
Remote Sensing Introduction

Spatial Variability of Cyanobacteria (Where?)

Temporal Variability of Cyanobacteria (When?)

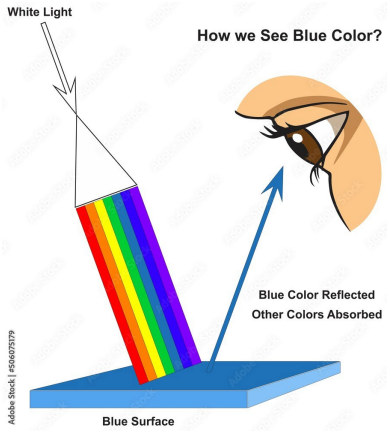
Importance for water users and managers





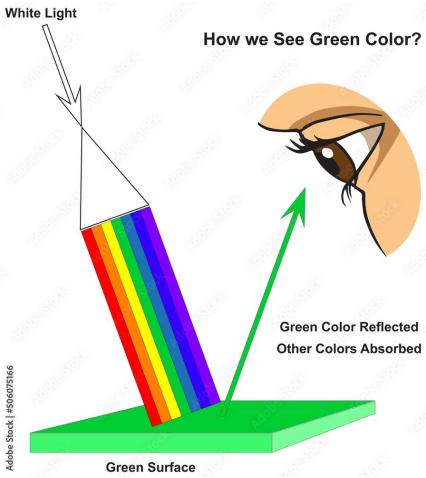
Introduction to Remote Sensing

- When a camera takes a photo, it measures **reflectance** of red, green, and blue light
- You can visually discern water (blue) from plants or phytoplankton (green)



Clear blue water in Lake Tahoe

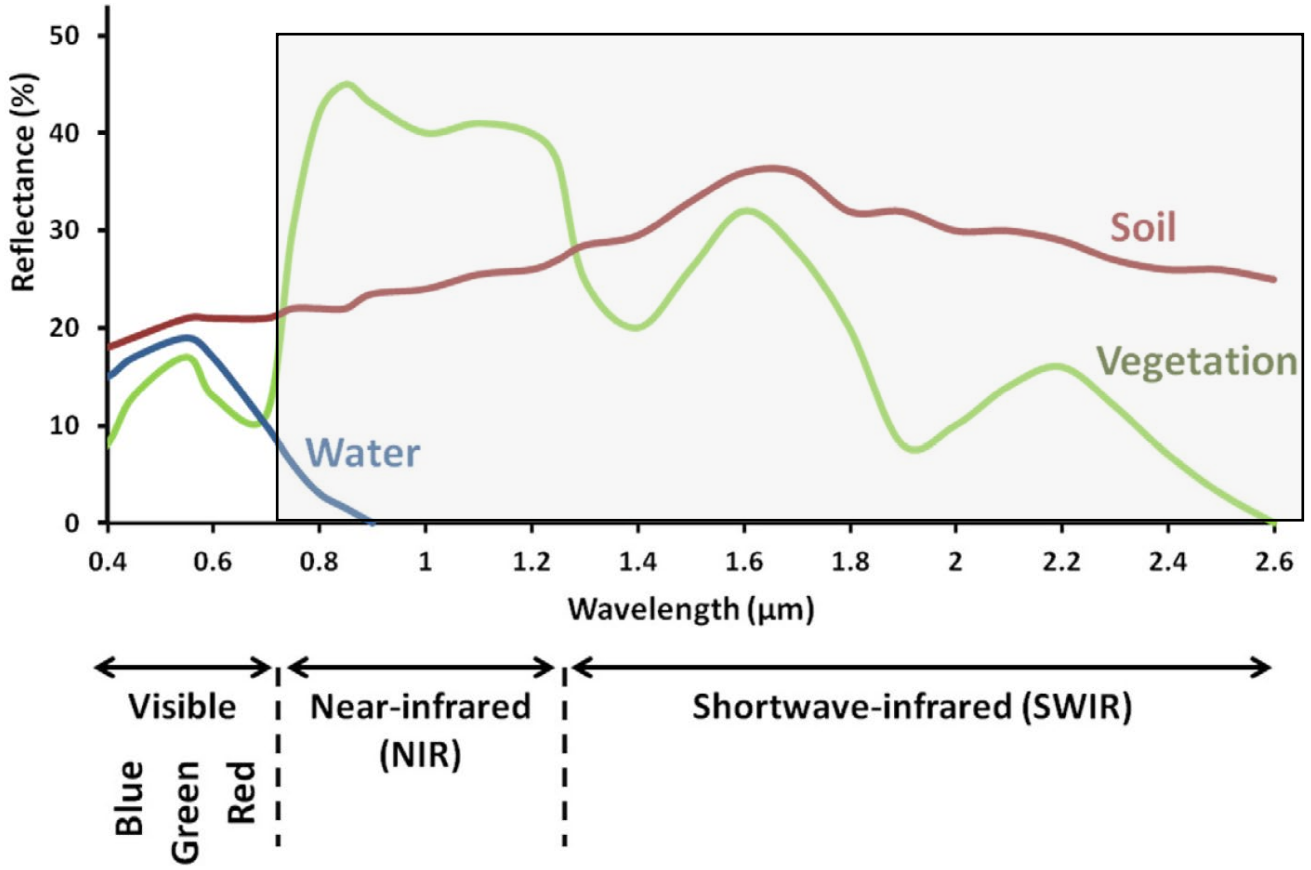
Highly productive water in Clear Lake



Introduction to Remote Sensing

Satellite sensors measures reflectance across **additional wavelengths of light**, used to:

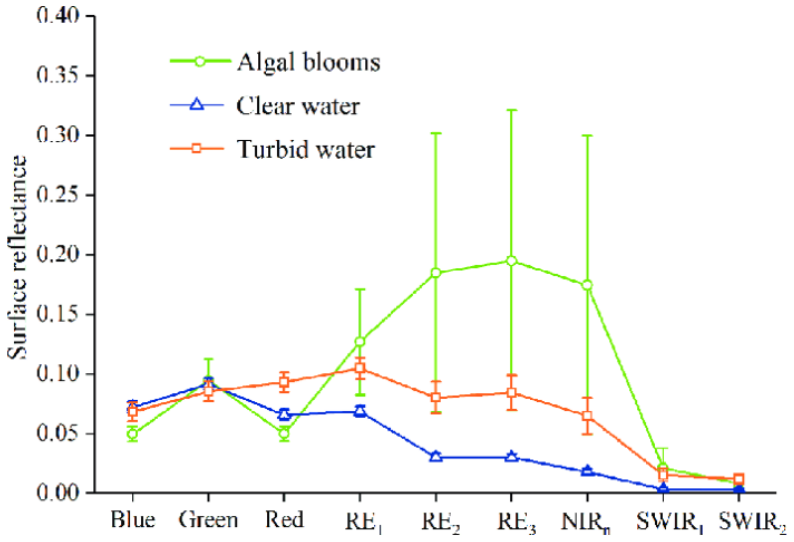
- Distinguish different land surface **features** (e.g. forest from water)
- Measure **optical properties** (e.g. chlorophyll-a concentration)



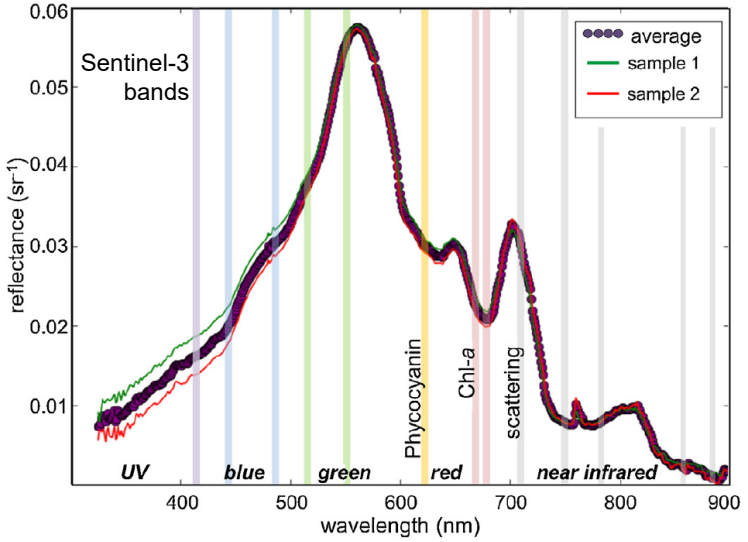
Introduction to Remote Sensing

- Early satellite missions (Landsat) measured **few wavelengths of light** in the visible spectrum – measure chlorophyll-a (measure of **algal biomass**) ➔ Good for the ecosystem
- More recent satellite missions (Sentinel-3) measure **more wavelengths of light** – measure phycocyanin (measure of **cyanobacteria biomass**) ➔ Potential production of toxins that may compromise water uses

Landsat data

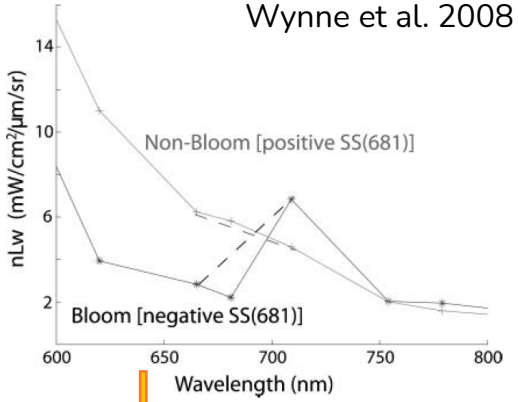


Sentinel-3 data

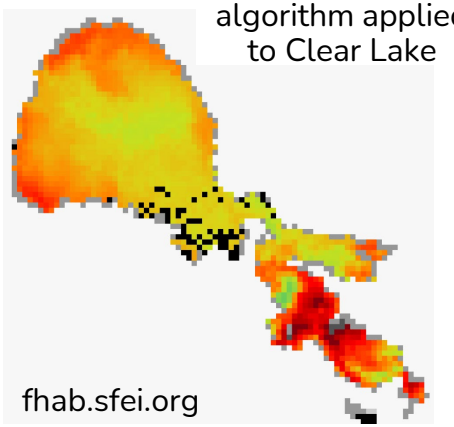


Introduction to Remote Sensing

Cyanobacteria Index algorithm
Wynne et al. 2008



Cyanobacteria Index algorithm applied to Clear Lake



Advantages

- **Global** observations
- Large-scale sampling of **entire waterbodies**
- **Accessible sampling** of remote and potentially hazardous sites
- Fill **historical** data records
- **Frequent** repeat samples
- **Cost effective**

Spatial Variability of Cyanobacteria (patchiness)

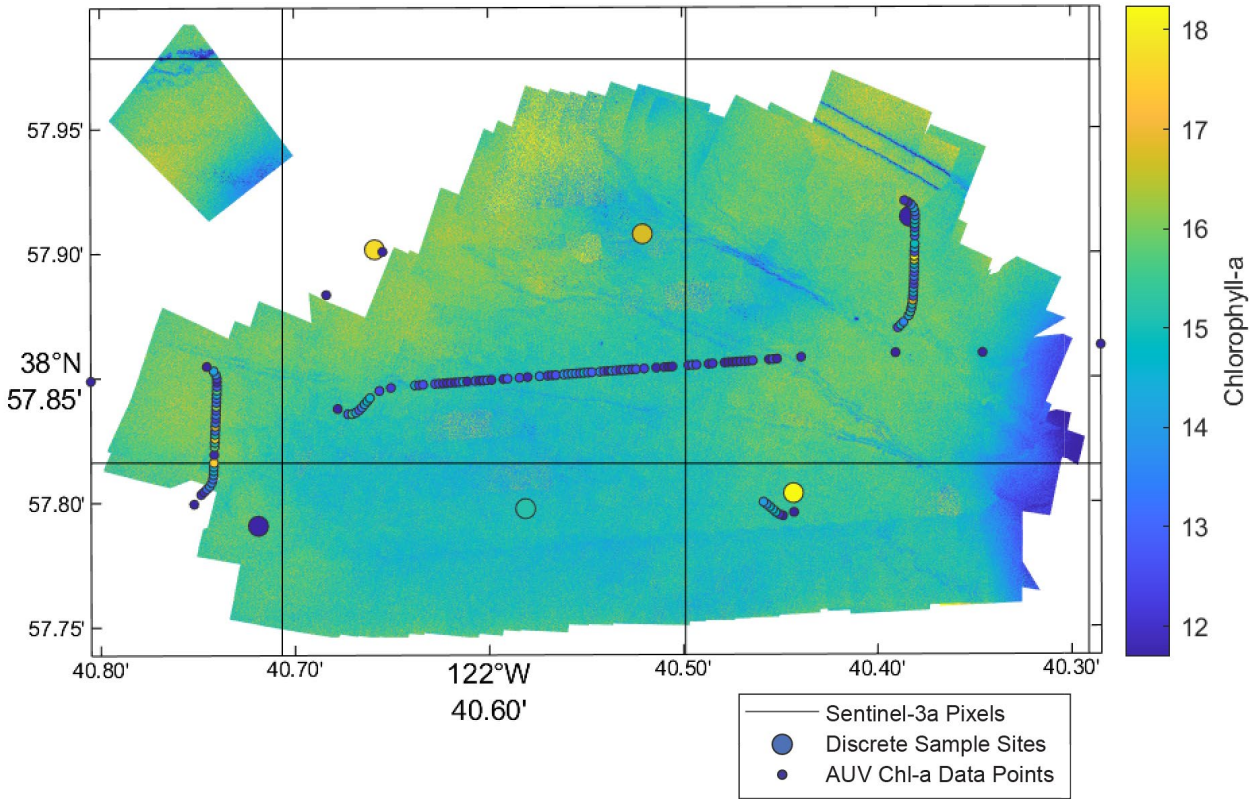
Importance:

- Designing adequate **sampling plans**
- **Identifying areas at risk vs. risk-free for community and wildlife use**
- Informing **spatial resolution** requirements for future satellite missions
- Justifying spatial **averaging** of data

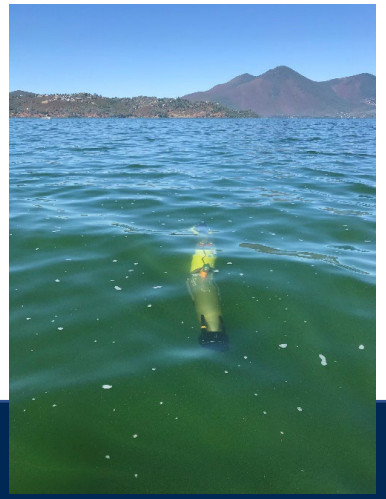
Spatial Variability of Cyanobacteria

Multiplatform robotics remote sensing sampling of Clear Lake in 2019

Link to download full paper



Drone “sUAS”-based multispectral remote sensing measurements



Autonomous Underwater Vehicle “AUV”-based optical measurements

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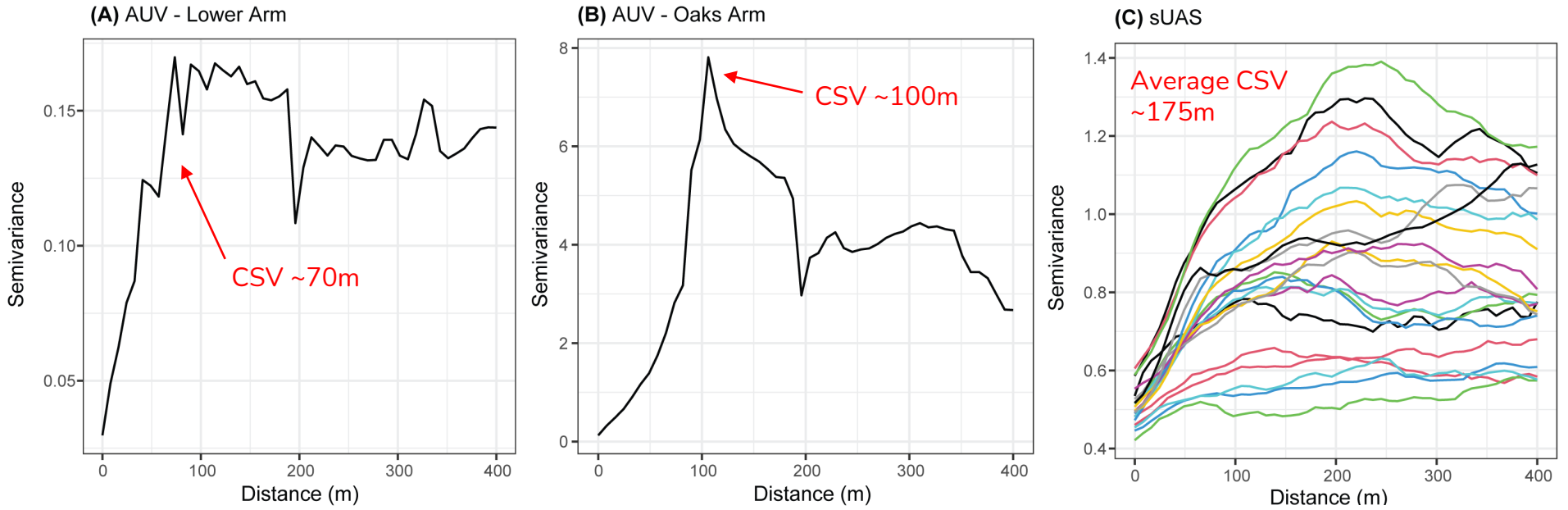
Quantifying Spatial Variability

- Quantified the **Critical Scale of Variability "CSV"** – length-scale necessary to **resolve a bloom**
- CSV for a cyanobacteria bloom in Clear Lake ~**70-175m**



Temporal (over time) Variability of Cyanobacteria

- Goals
  - Identifying **environmental drivers** of blooms
  - Identifying **areas at risk vs. risk-free** for community and wildlife use
- Why satellite **remote sensing** tools? **Frequent** measurements of cyanobacteria blooms across the **entire water body**.
- Evaluate the **Cyanobacteria Index (CI)** algorithm for Clear Lake, CA
  - CI calculated from reflectance measurements made by the Sentinel-3 satellite
  - Critical to inform community water uses and management decisions
  - Requires ground truthing with field measurements

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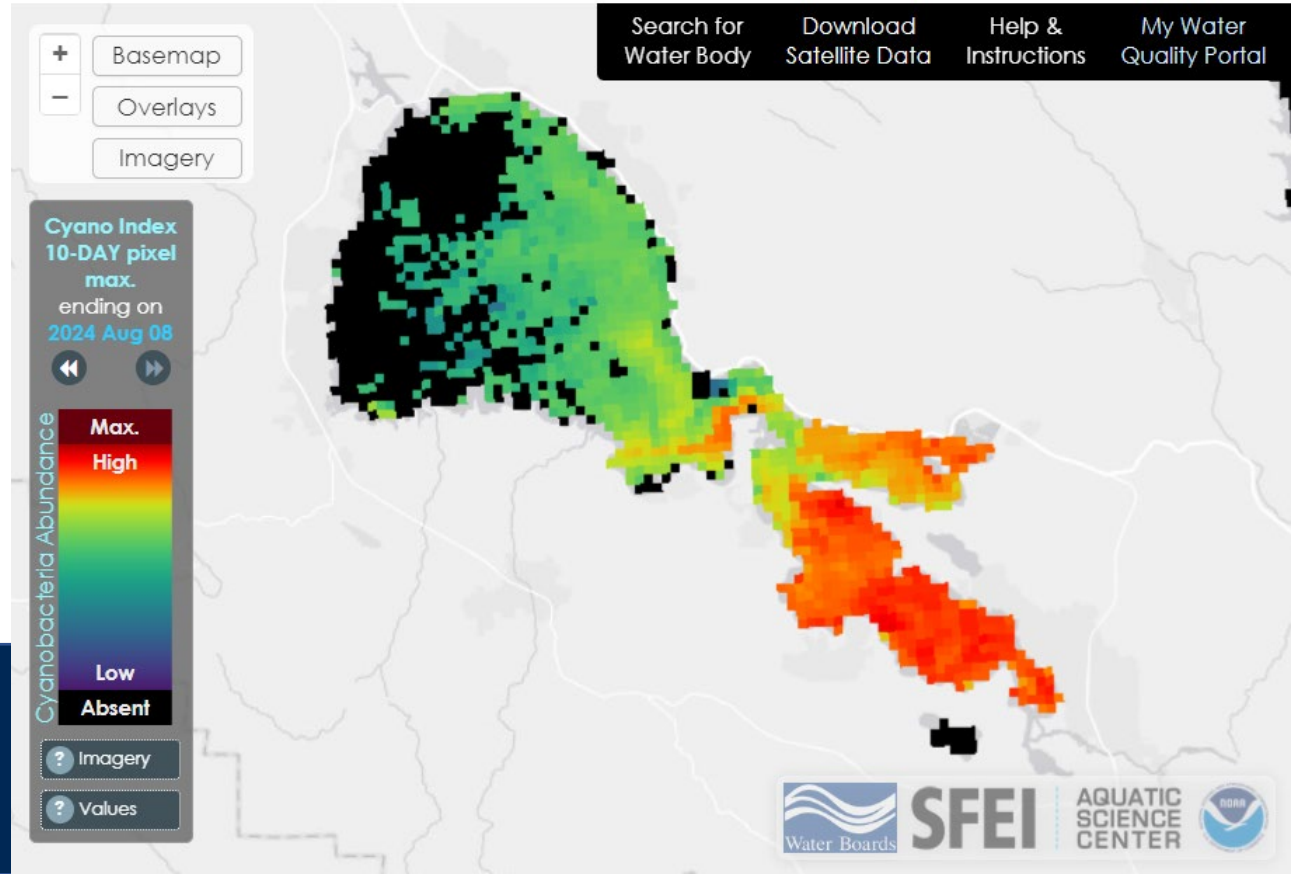

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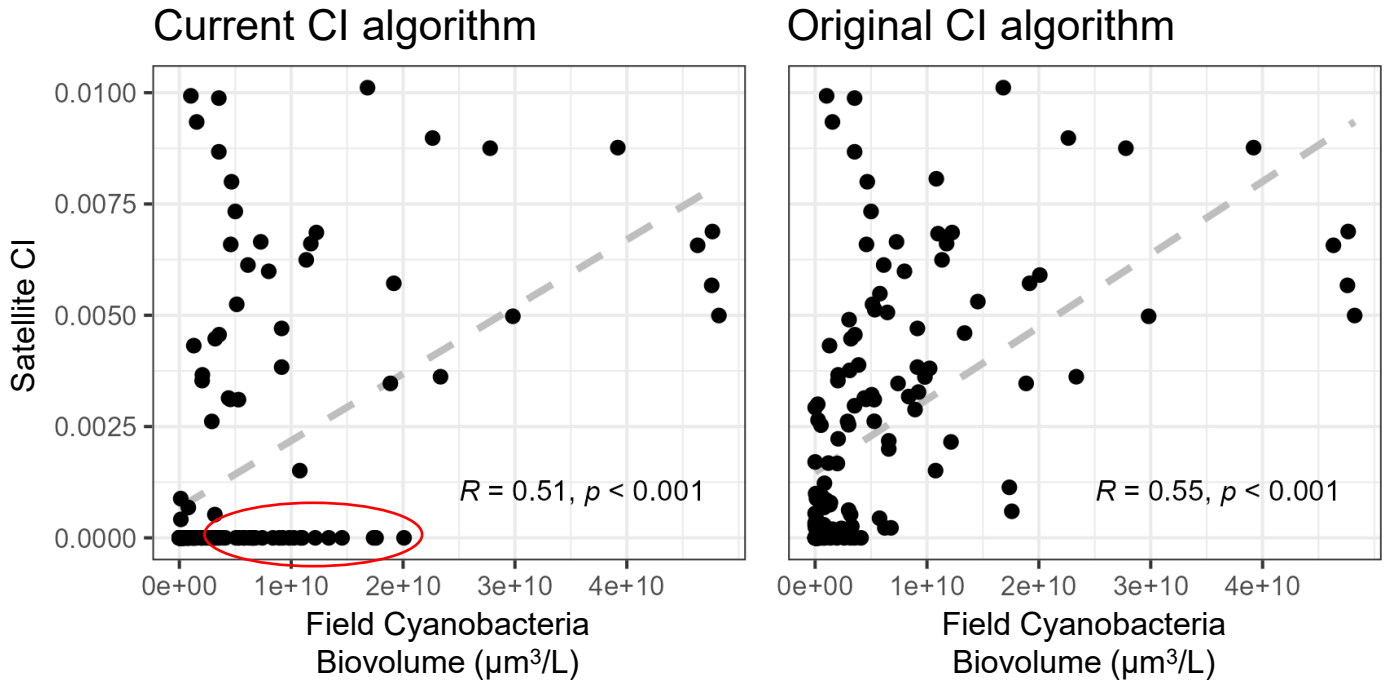
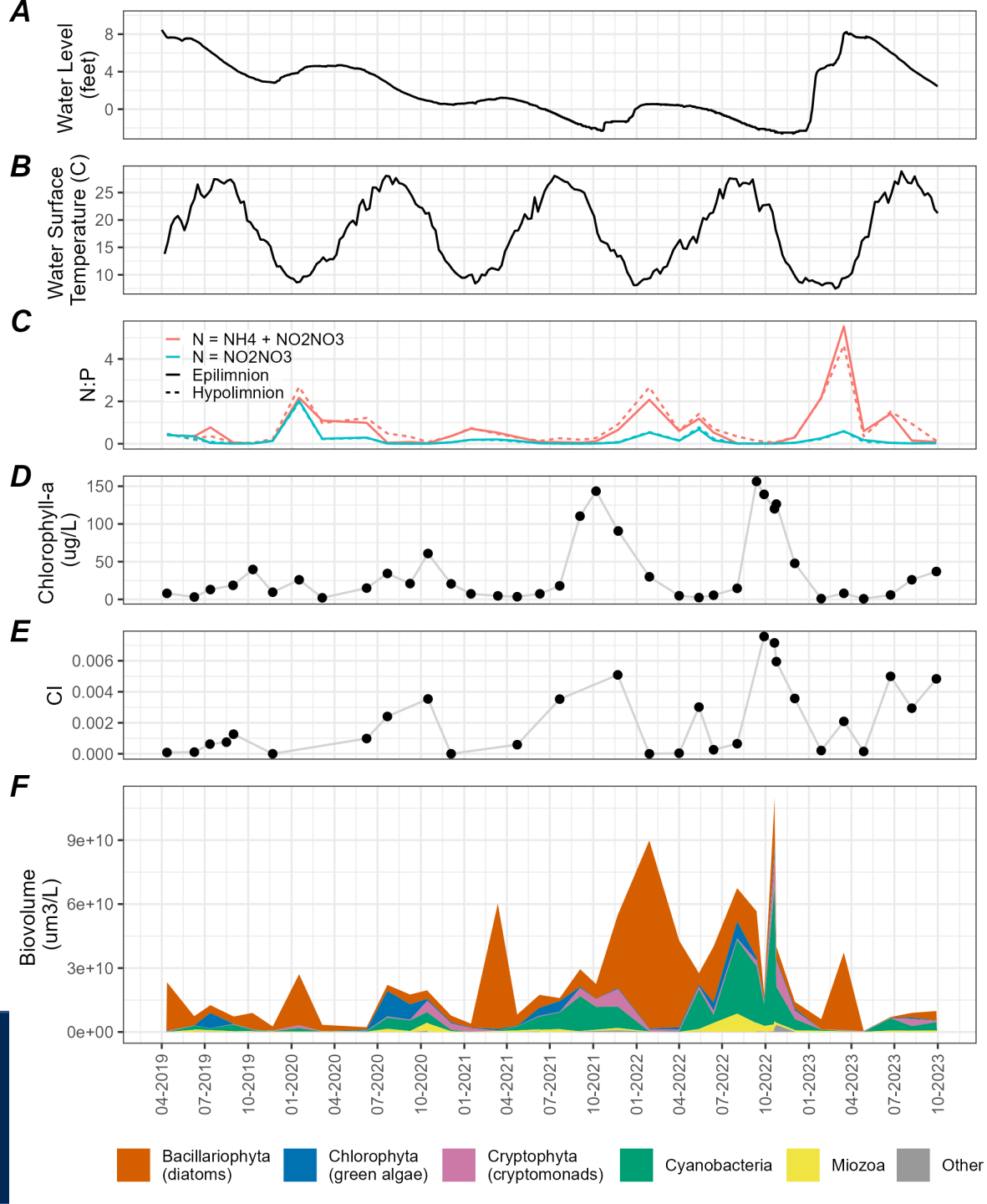
Cyanobacteria Index (CI) algorithm ground truthing for Clear Lake, CA

- Current CI algorithm includes a secondary step to reduce false warnings of blooms
- However, we found the current CI values do not always capture blooms occurring in Clear Lake
- We found better results for CI when using the original algorithm



Bloom Trends in Clear Lake (2019-2023)

- Seasonal patterns: diatoms in winter, followed by green algae, Cyanobacteria, and Miozoa in summer, and cryptomonads in fall
- **Cyanobacteria did not dominate in high concentrations except in the summer 2021 and 2022**
- Cyanobacteria is correlated with high temperature and low N:P nutrient ratio



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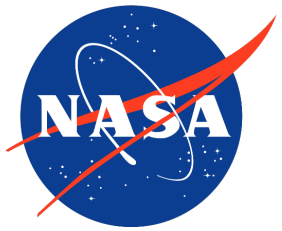
Conclusions

- Cyanobacteria have high spatial and temporal variability – important for designing sampling plans to inform community water uses and management decisions
- Remote sensing is useful because of large-scale, frequent sampling
- Ground truthing of remote sensing tools is important
- Future satellite missions may provide more useful data for measuring cyanobacteria blooms

Acknowledgments




Questions?