Scales of variability of cyanobacteria in Clear Lake

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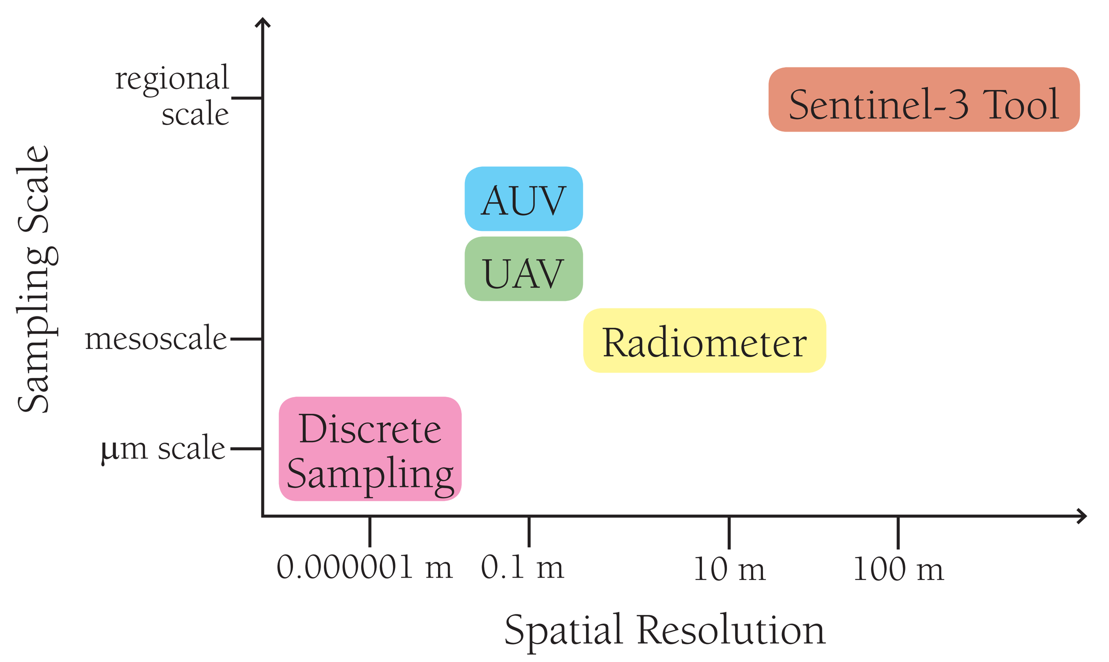
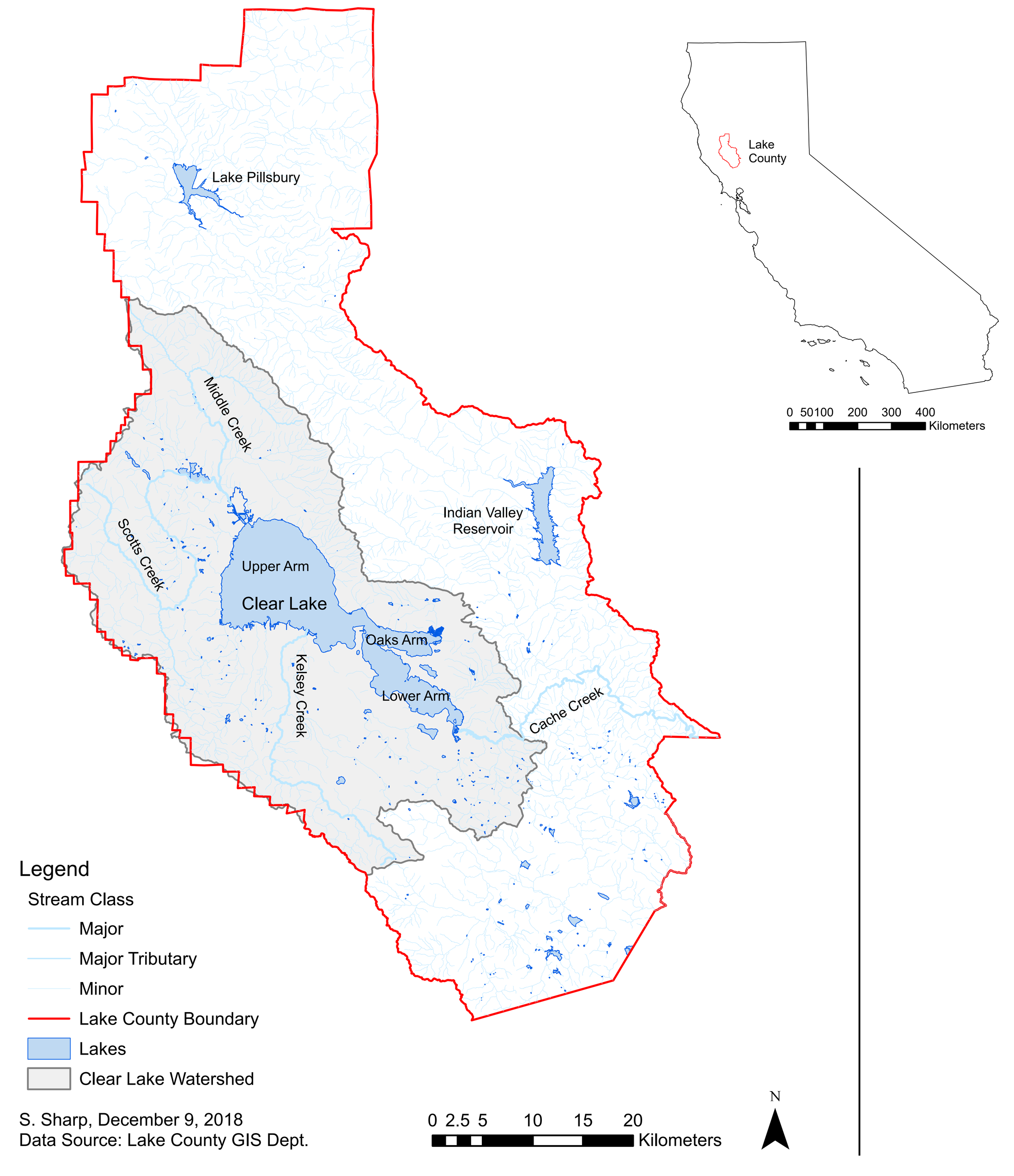
Core Question:

Can we use sampling methods at varying scales and resolutions to understand the spatial and temporal variability of cyanobacteria blooms in Clear Lake?



Clear Lake Background

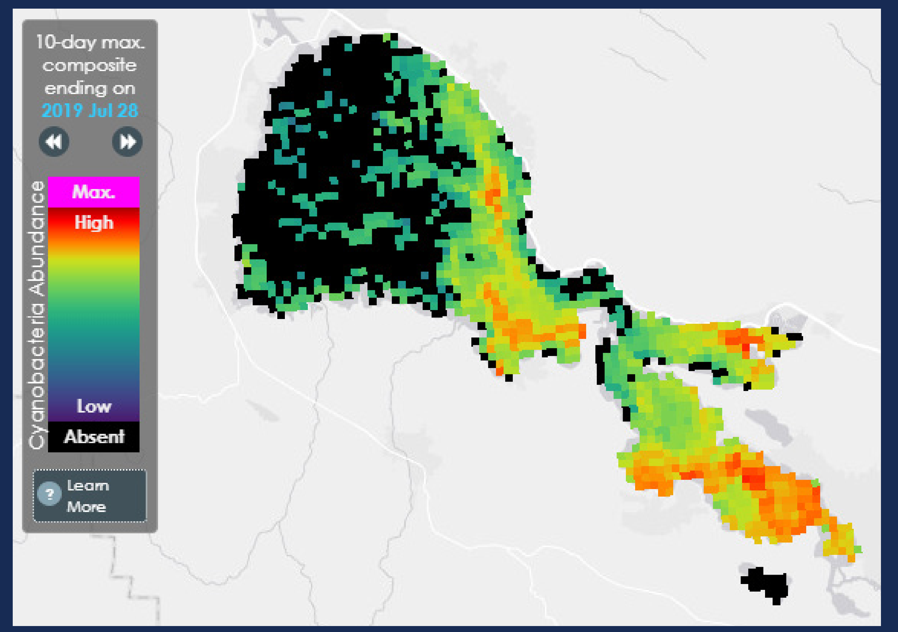
- Shallow, polymictic, naturally eutrophic lake
- Surface area of 160 sq. km., maximum depth of 18 meters
- Ancient lake, formed 1.8 - 3 million years ago
- Supports large fish and wildfowl populations
- Algal blooms occur naturally
- Blooms have increased in recent years including harmful algal blooms of cyanobacteria are a public and environmental health concern
- Several observed species of cyanobacteria including microcystis and dolichospermum, with cyanotoxins observed including microcystin, anatoxin-a, and saxitoxin
- Clear Lake beneficial uses include drinking water (18 municipal drinking water companies), irrigation water in Yolo County, recreation uses including boating and fishing, and traditional uses



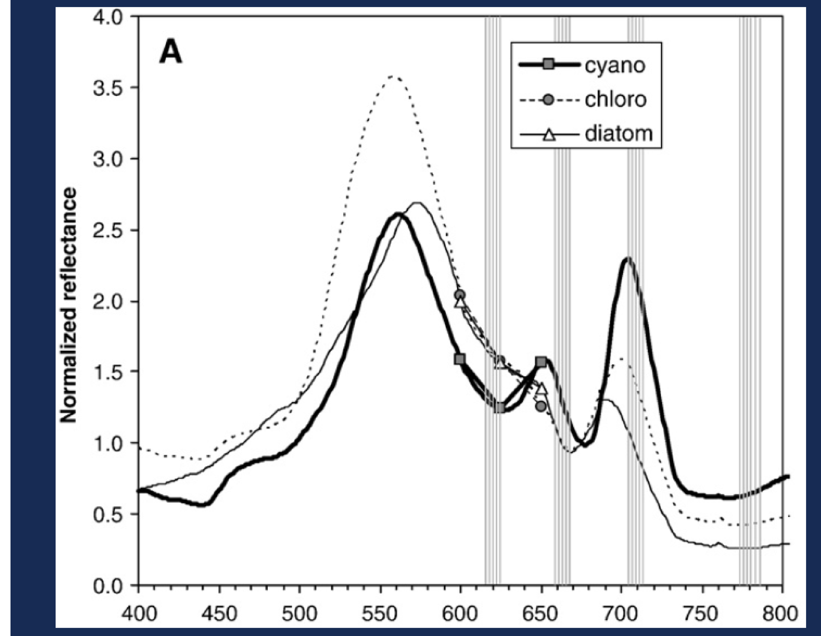
Satellite Tool Background

NOAA developed a satellite tool for detecting Harmful Algal Blooms (HAB) in the Great Lakes using MERIS and then Sentinel-3 after the end of the MERIS Satellite program. The San Francisco Estuary Institute (SFEI) has applied the HAB Tool to lakes in California. The HAB Tool calculates a cyanobacteria index (CI) from satellite imagery for water bodies in California. The CI is based on unique spectral shape (SS) for cyanobacteria compared to other algae species.

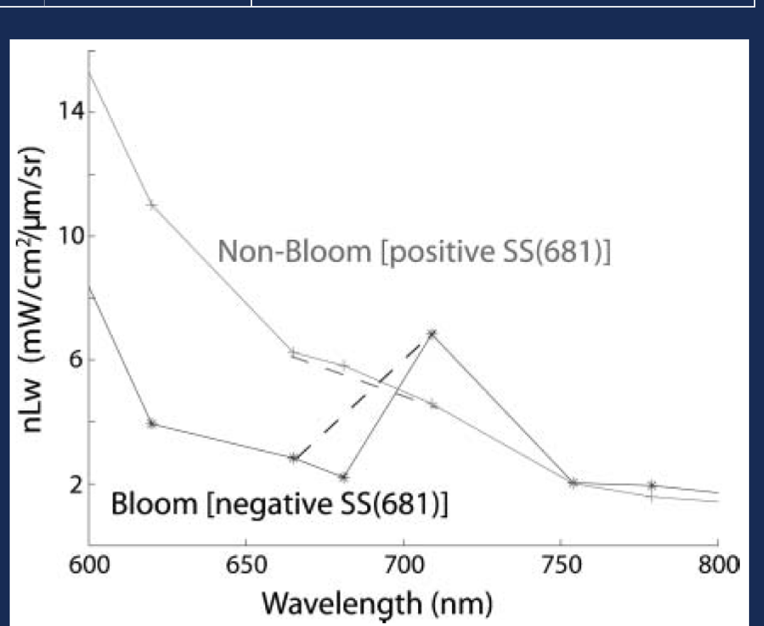
Satellite	Agency	Operating Period	Spatial Res.	Temporal Res.	Spectral Res.
MERIS	ESA	2002 - 2012	300 m	3 days	390-1040 nm (15 bands)
Sentinel-3	ESA	2016 - present	300 m	<2 days	400-1020 nm (21 bands)



Example output from SFEI/NOAA HAB Tool (from: fhab.sfei.org)



From Ruiz-Verdú, et al. (2008), Hyperspectral profiles



From Wayne, et al. (2008), Multispectral profiles from MERIS data

Cyanobacteria Index calculated from Sentinel-3 data (from Wayne et al. 2008 and 2010):

$$CI = -SS\{681\}$$

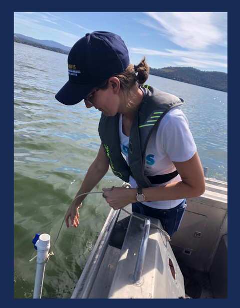
$$SS\{\lambda\} = reflec\{\lambda\} - reflec\{\lambda^-\} - (reflec\{\lambda^+\} - reflec\{\lambda^-\}) \times \frac{\lambda - \lambda^-}{\lambda^+ - \lambda^-}$$

Where, $\lambda = 681\ nm, \lambda^+ = 709\ nm,$ *and* $\lambda^- = 665\ nm$

Data Collection

UC Davis completed cyanobacteria data collection in Clear Lake on three dates during the Summer 2019.

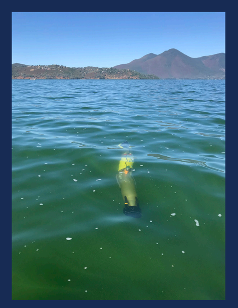
Discrete Sampling

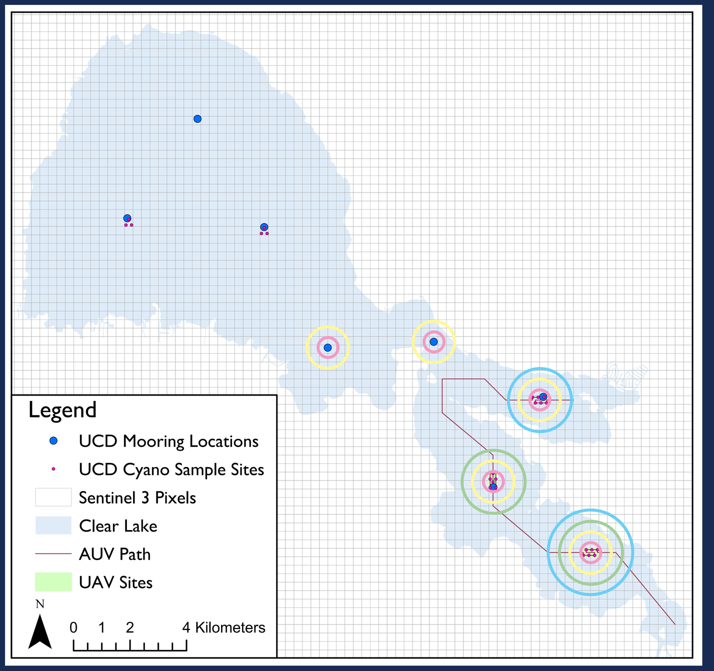


Radiometer

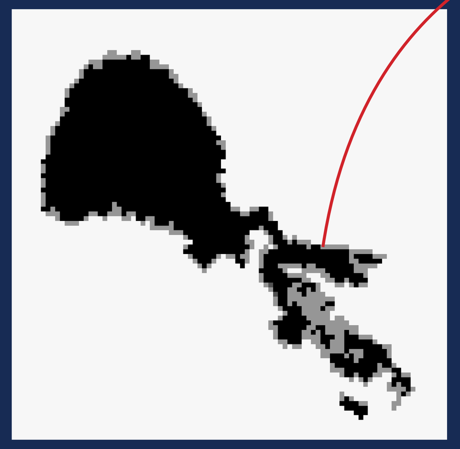
UAV

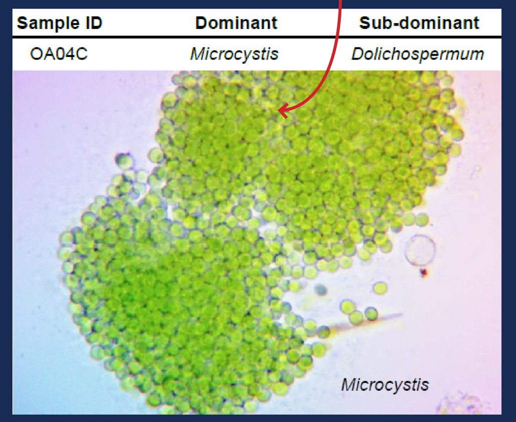
AUV





In-situ data collected will be used to validate the satellite remote sensing model. Initial observations show inaccuracies of the HAB tool underestimating cyano abundance at lower concentrations.





References

Jensen, J.R. (2014). *Remote Sensing of the Environment An Earth Resources Perspective* (2nd Ed.). Pearson Education Limited.

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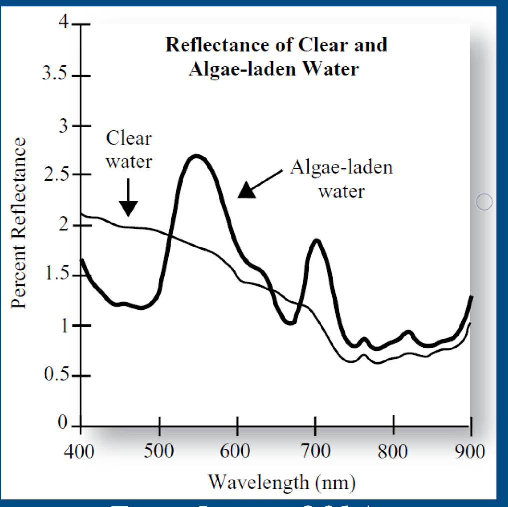
Wynne, T. T., Stumpf, R. P., Tomlinson, M. C., & Dyble, J. (2010). Characterizing a cyanobacterial bloom in western Lake Erie using satellite imagery and meteorological data. *Limnology and Oceanography*, 55(5), 2025-2036.

Data Analysis

Statistical comparison of phycocyanin concentrations [PC] derived from these five sampling methods, where PC is a proxy for cyanobacteria

Discrete Sampling:

[Chl-a]
[PC] → [Chl-a]:[PC]



From Jensen 2014

AUV:

[Chl-a] → [PC]
[CDOM]
[Turbidity]

UAV:

reflec{Blue λ = 475 nm}
reflec{Green λ = 560 nm}
reflec{Red λ = 668 nm}
reflec{NIR λ = 940 nm}
reflec{Red Edge λ = 717 nm}

→ [Chl-a] Band Ratio:
- Green:Red
- NIR:Red
- Green:Blue
- Blue:Red

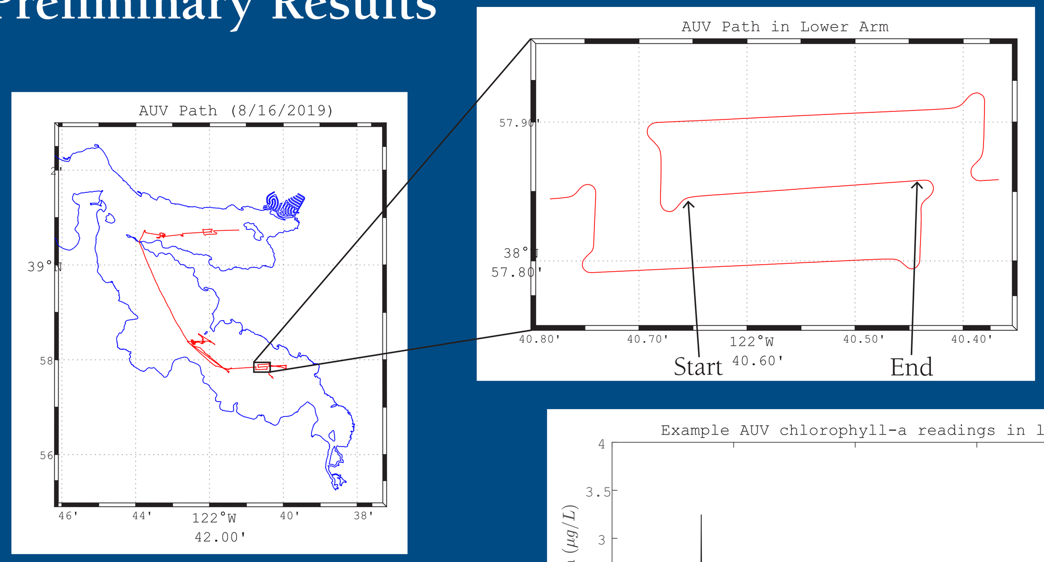
→ [PC]

Radiometer: & **Sentinel-3 Tool:**

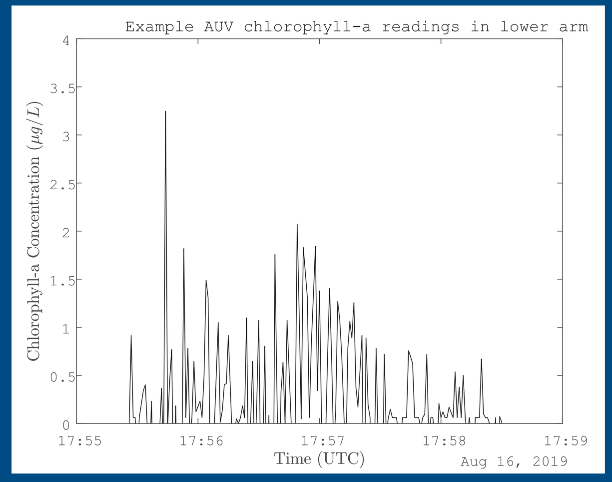
reflec{λ = 681 nm}
reflec{λ⁺ = 709 nm}
reflec{λ⁻ = 665 nm}

→ *CI* → [PC]

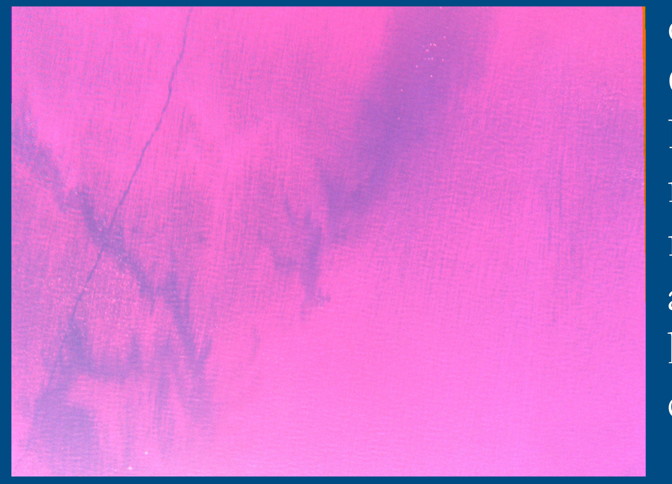
Preliminary Results



Spatial variability of chlorophyll-a concentration observed in AUV data



Example color-infrared imagery from UAV flight in Clear Lake on 8/16/2019 (R = NIR G = red, B = green). Brighter magenta regions represent higher reflectance of green and NIR indicating higher chlorophyll-a concentration



Acknowledgements

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