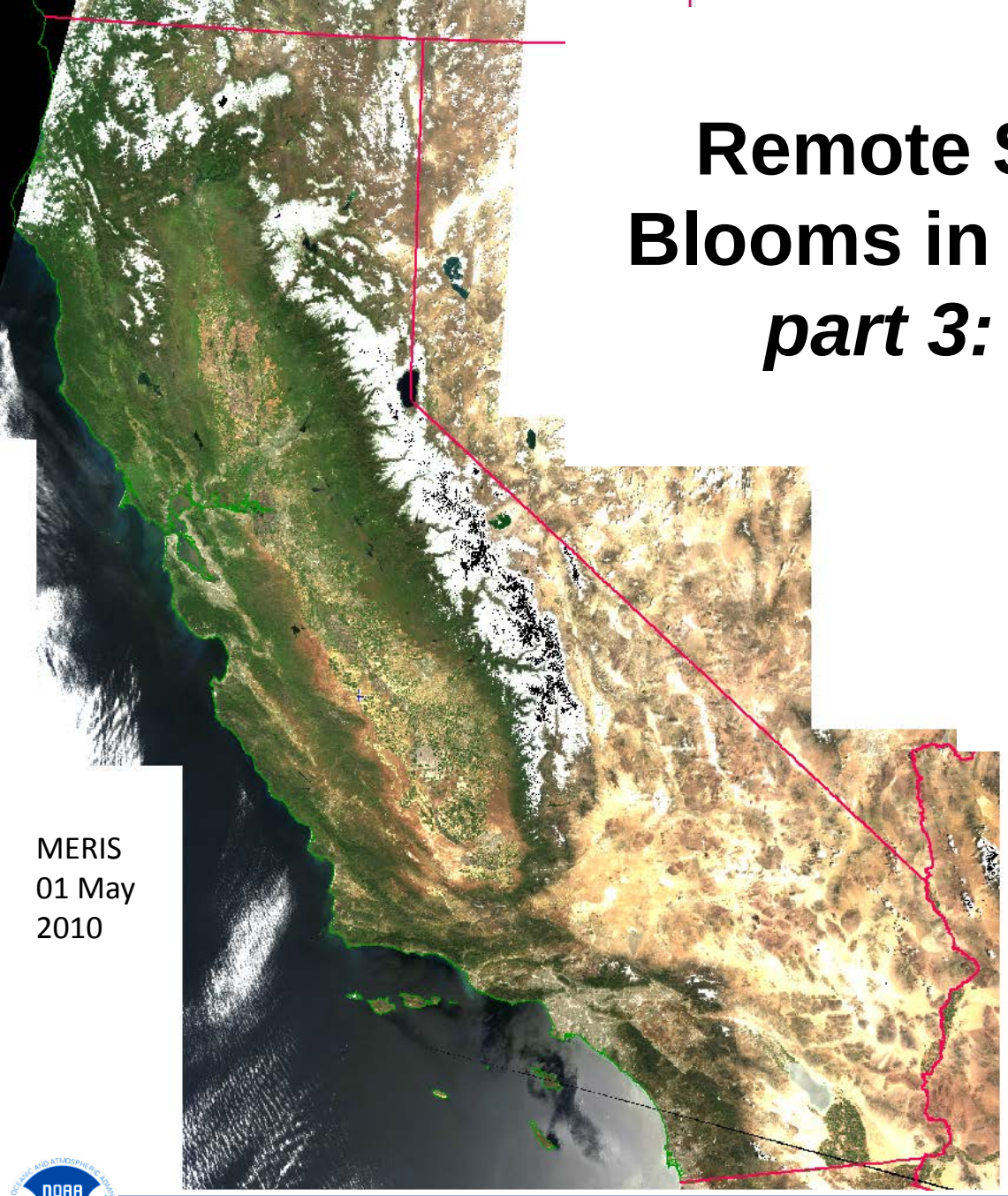
Remote Sensing for Algal Blooms in California Lakes
part 3: applications



MERIS
01 May
2010

Shelly Tomlinson
Rick Stumpf
Andrew Meredith

NOAA
National Centers for
Coastal Ocean Science

MERIS for monitoring (Lake Erie example)

Algorithm moved to 1 km MODIS in 2012

Experimental
Lake Erie Harmful Algal Bloom Bulletin
2011-008
08 September 2011
National Ocean Service
Great Lakes Environmental Research Laboratory
Last bulletin: 22 July 2011

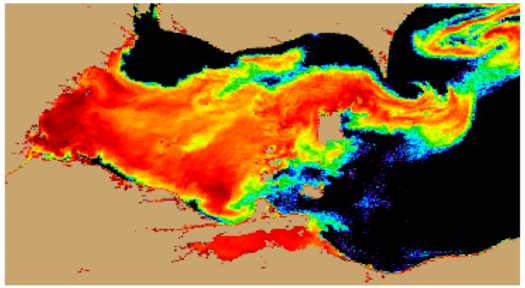


Figure 1. MERIS image from the European Space Agency. Imagery shows the spectral shape at 681 nm from September 03, where colored pixels indicate the likelihood of the last known position of the *Microcystis* spp. bloom (with red being the highest concentration). *Microcystis* spp. abundance data from shown as white squares (very high), circles (high), diamonds (medium), triangles (low) , + (very low) and X (not present).

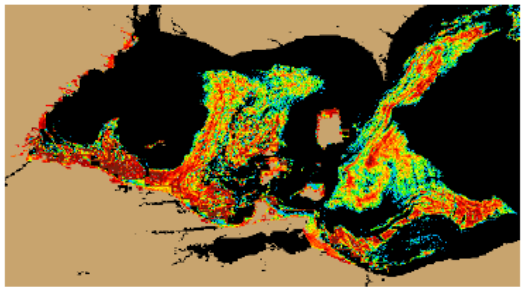


Figure 2. Nowcast position of *Microcystis* spp. bloom for September 08 using GLCFS modeled currents to move the bloom from the September 03 image.

Experimental Lake Erie Harmful Al
National Centers for Coastal Ocean Science anc
27 August 2012; Bulletin 13
In Maumee Bay, U.Toledo reports that *Anabaena* has re
and slightly intensified in Maumee Bay since last week's
- Dupuy, Wynne, Briggs

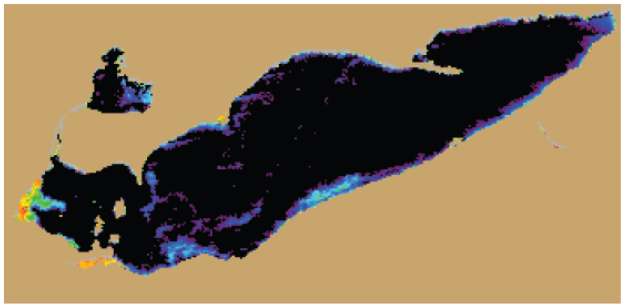


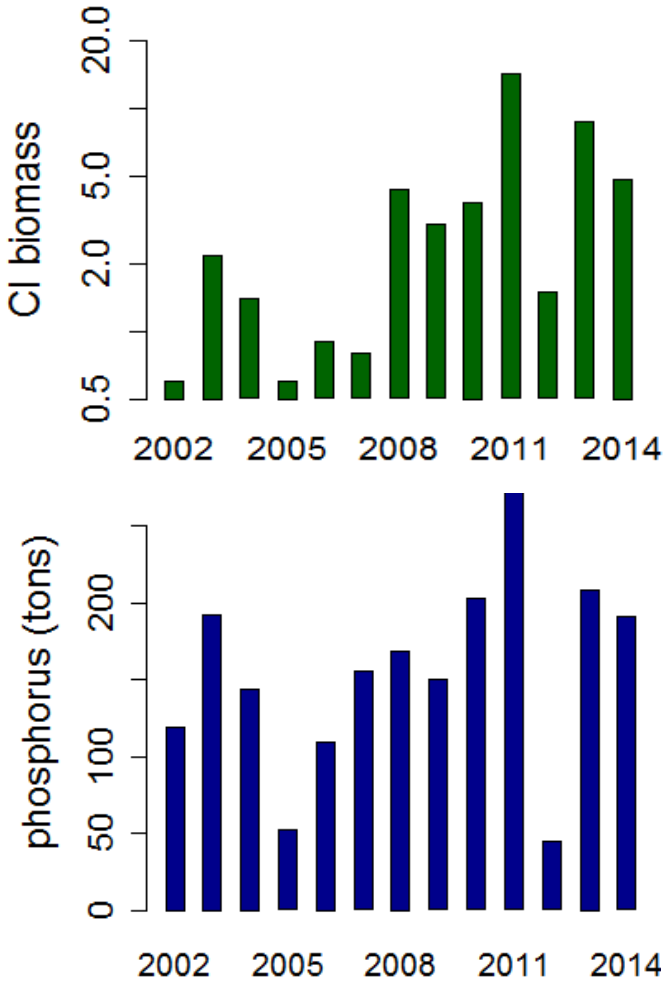
Figure 1. MODIS Cyanobacterial Index from 24 August 2012.

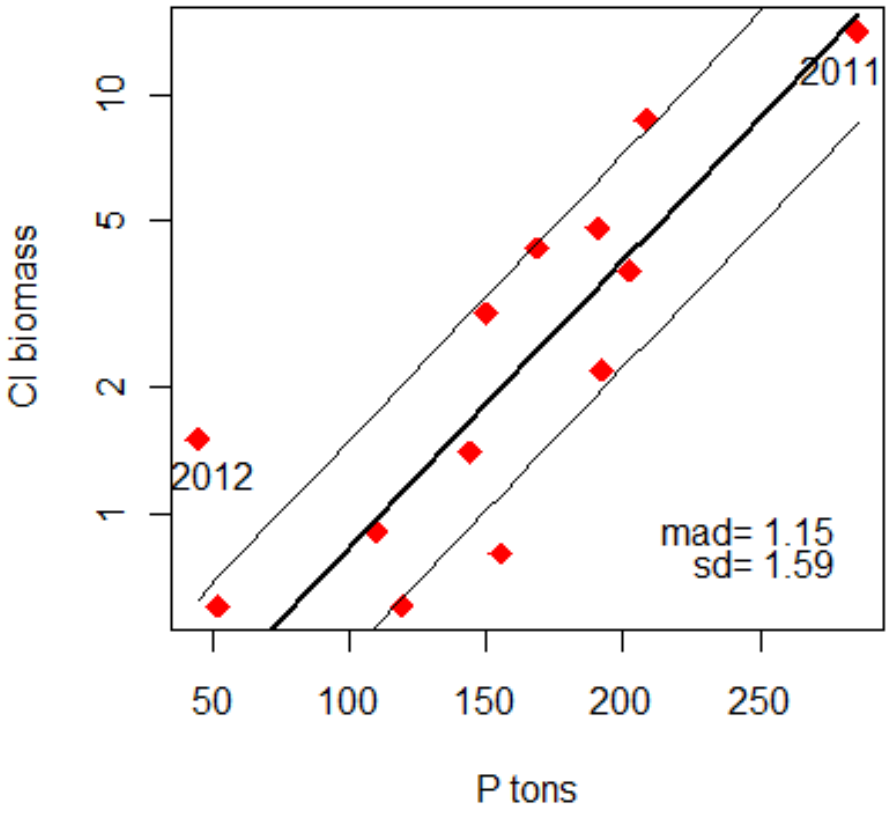
Figure 3. Forecast position of bloom for 30 August 2012 using GLCFS modeled currents to move the bloom from the 24 August 2012 image.

To subscribe to this bulletin, go to :
http://www.glerl.noaa.gov/res/Centers/HABS/lake_erie_hab/signup.php

Example of evaluation, western Lake Erie

Max biomass each year vs spring P load





Where Are We With Satellite

- We can find algal blooms
- Cyano blooms are detectable,
  but usable method currently produces many false positives
    - We are examining strategies to reduce these
    - We bias against false negatives
- All sensors can find scum
- Most sensors have limitations
  – Resolution trade-offs: spatial, spectral, temporal
- We are also examining portable radiometers for small lakes

Sampling scale

Field samples against satellite have uncertainty:

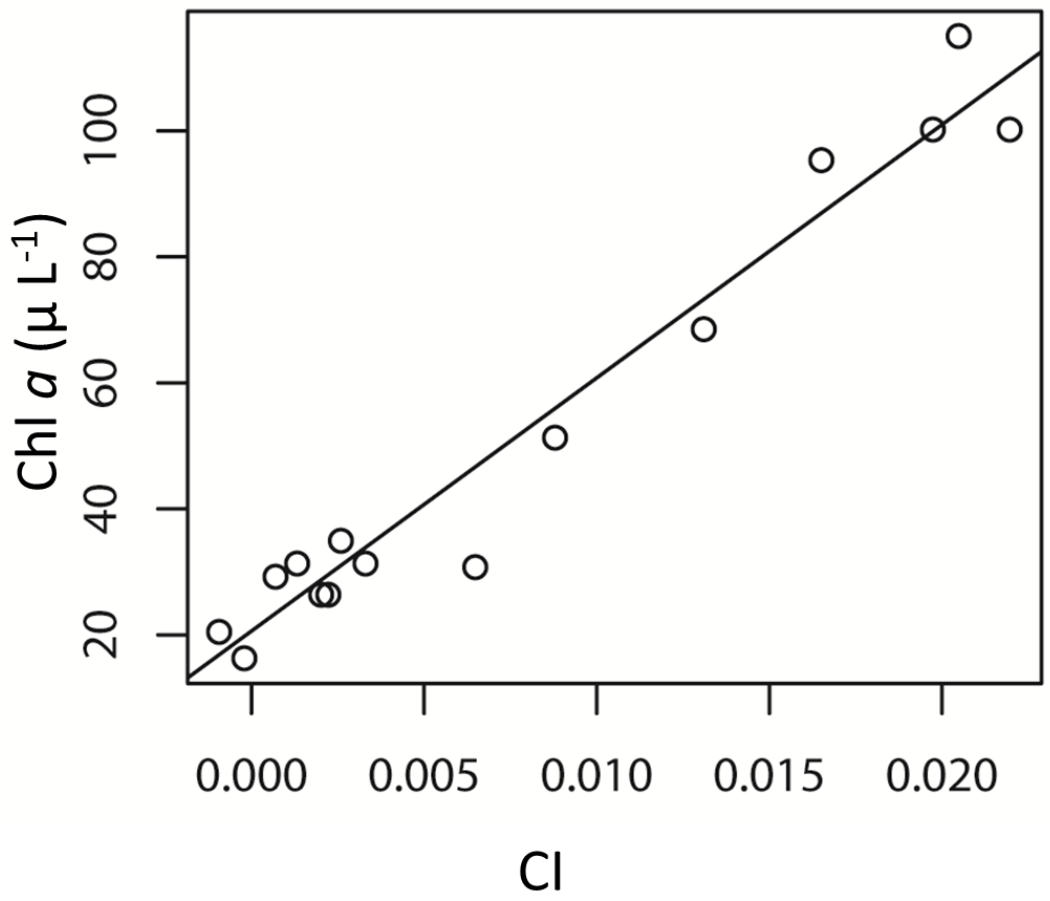
Compare the contents of any cup at random to the average of all cups in Levi's Stadium;

Satellite tells you the average; water sample is akin to one cup.

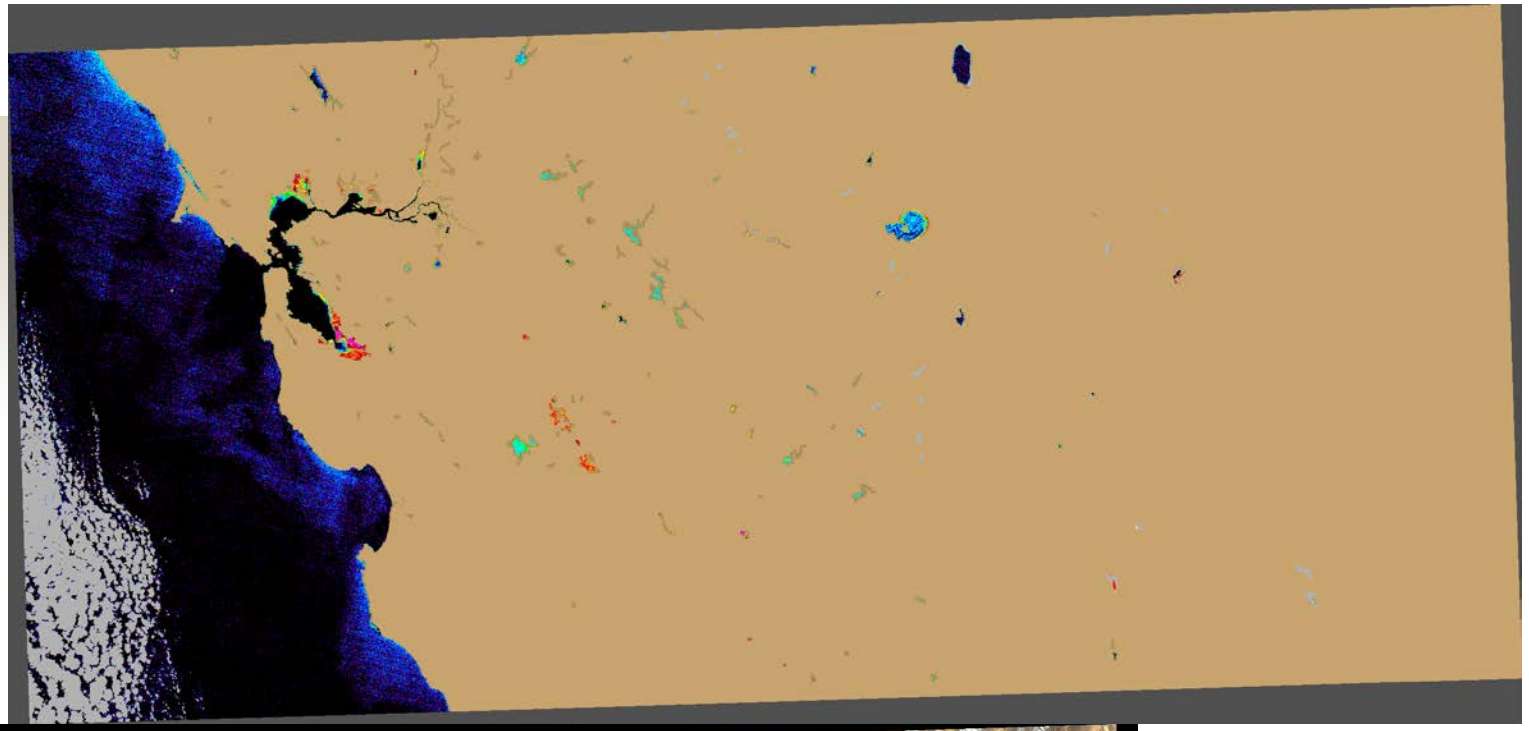
Emphasis on Detection of Cyanobacteria blooms

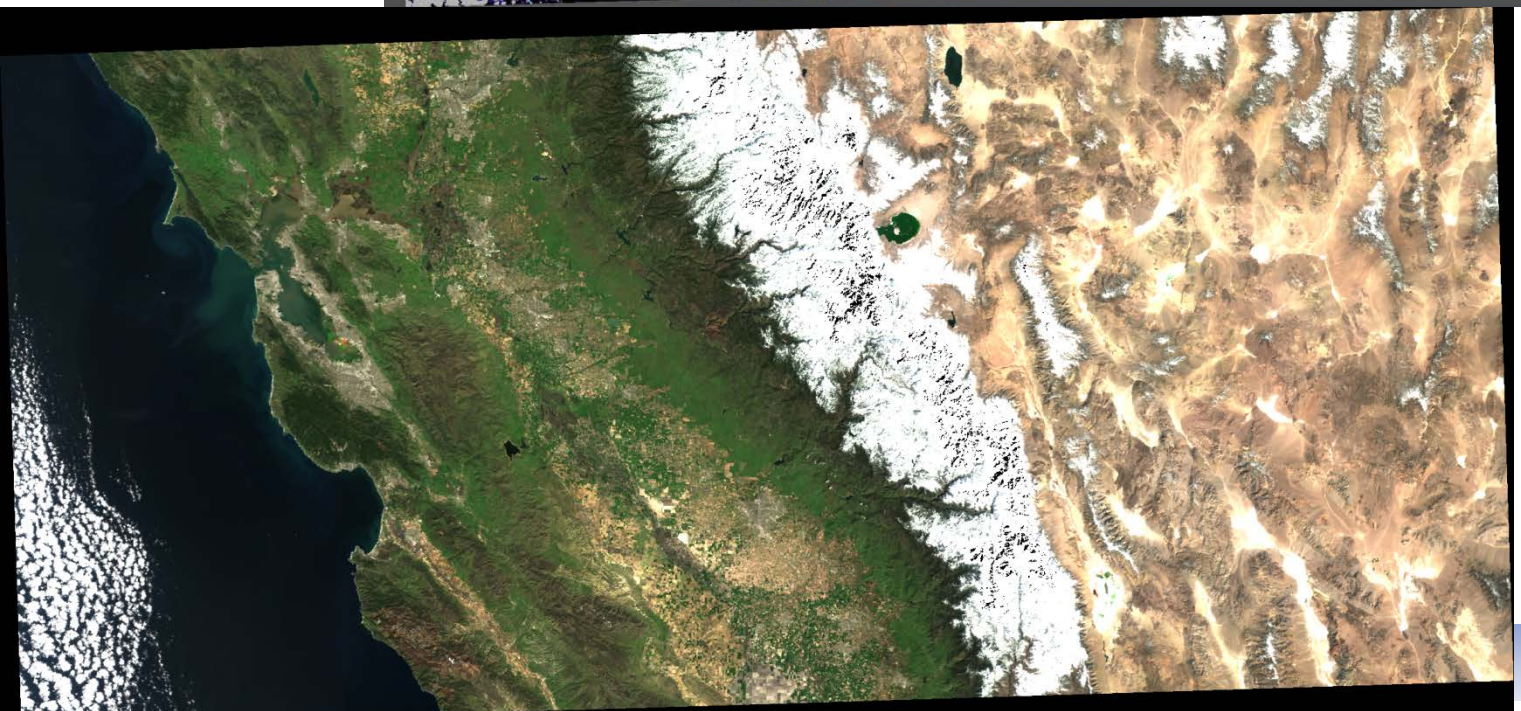
Chlorophyll relationship

Detects some other blooms; we can use an algorithm to discriminate cyanos from other blooms

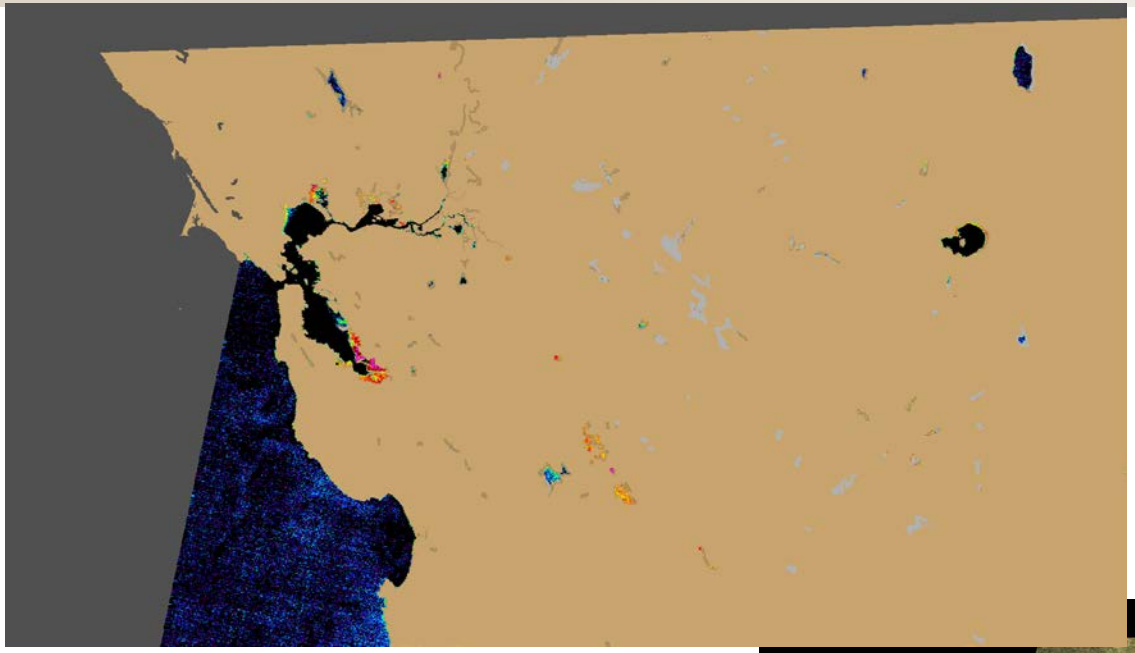


Clear Scene Example



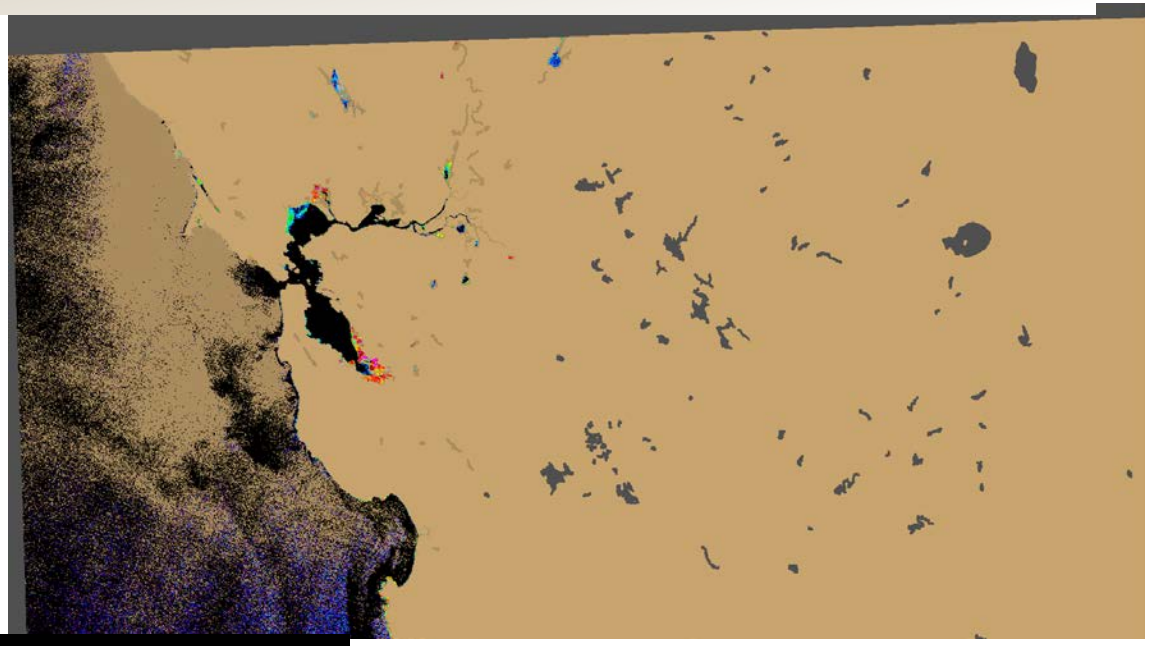


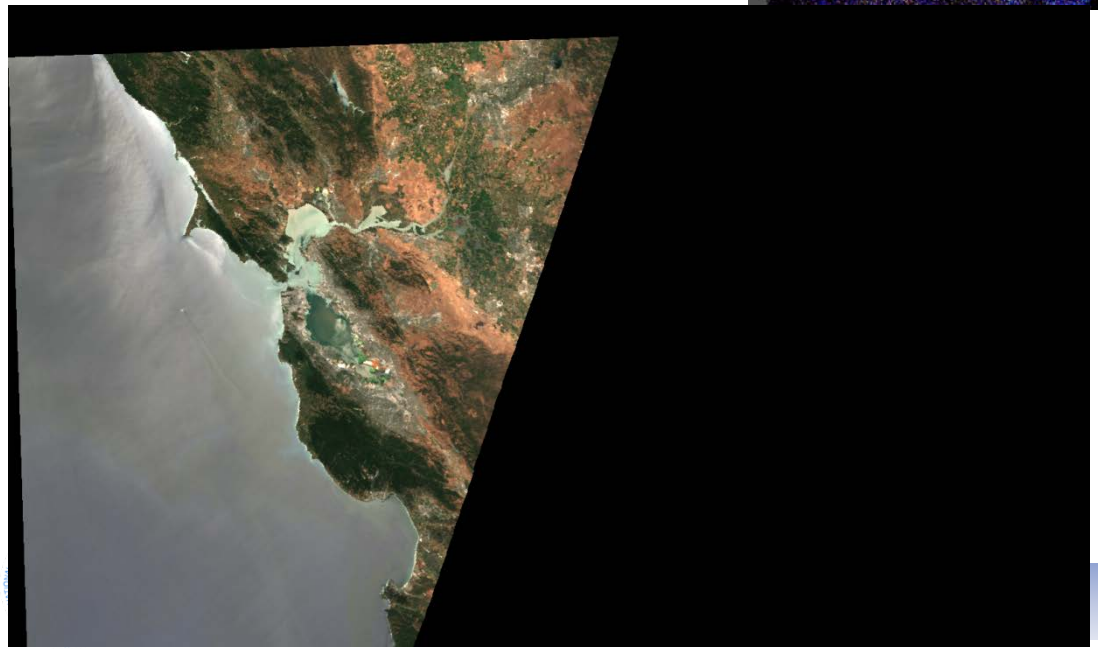
Masking/Issues within imagery



- Edge of Swath
- Land
- Snow
- Clouds
- Marsh?

Issues con't: Glint

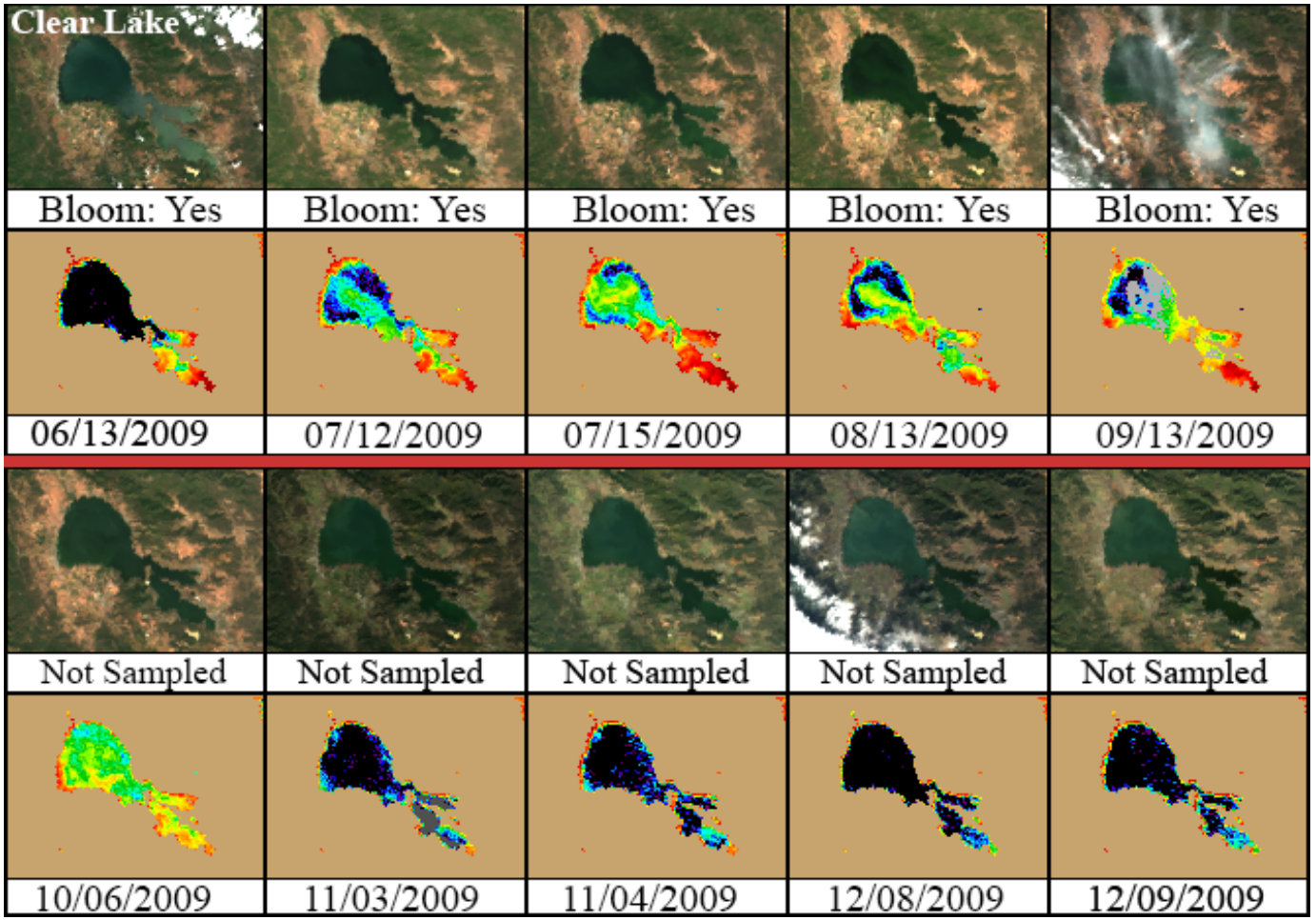




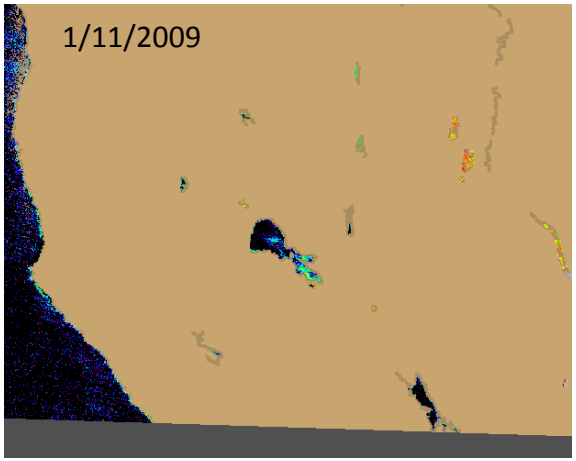
Time-series analysis, Clear Lake

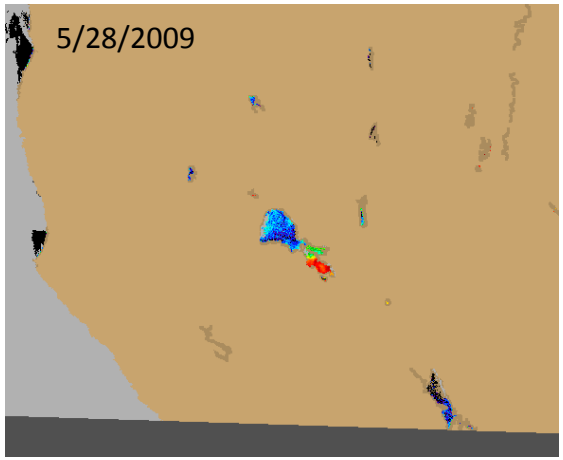
Imagery flags confirmed bloom

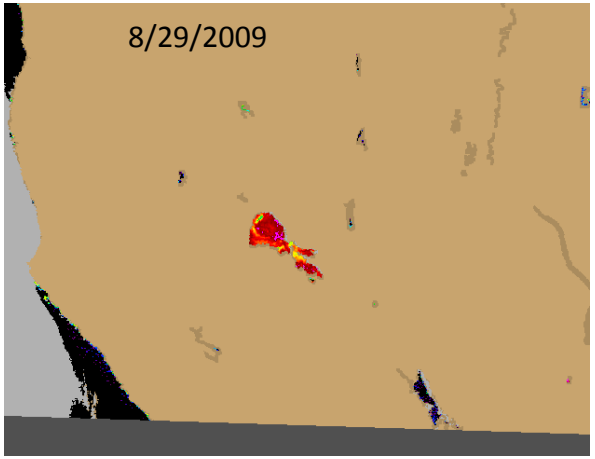
Bloom disappears during winter (unconfirmed)

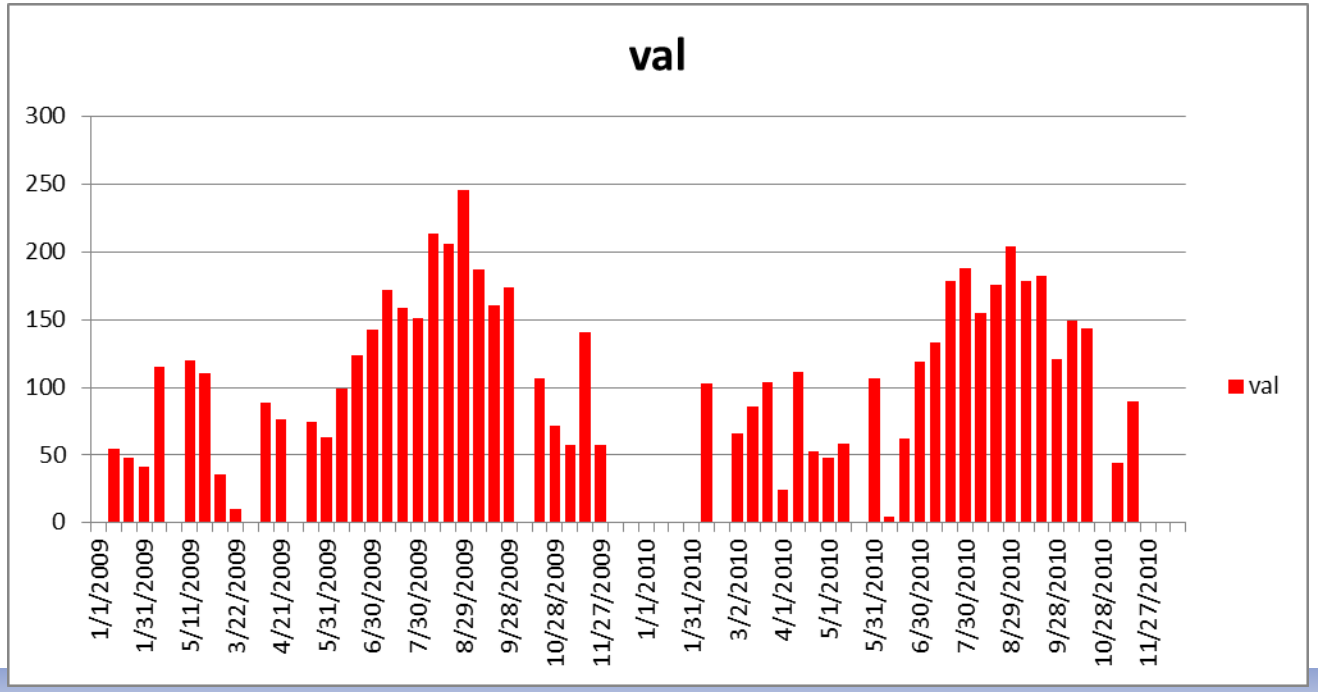


Time series example from Clear Lake





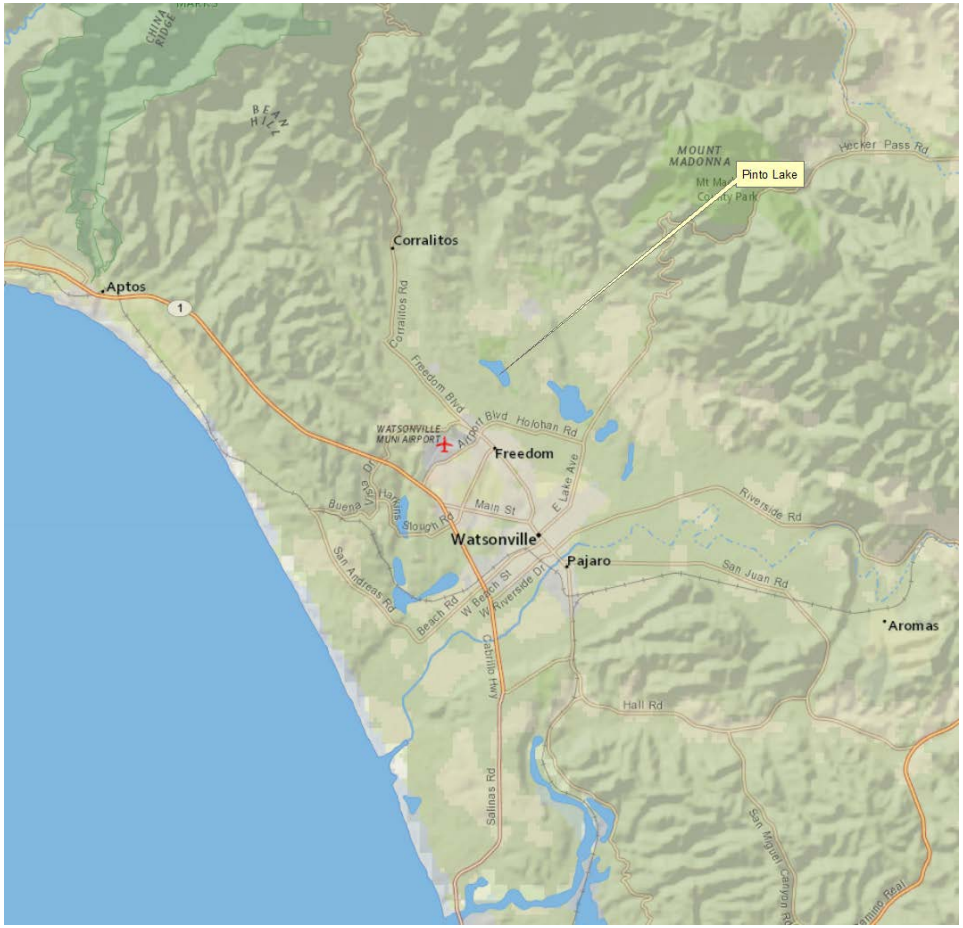




Pinto Lake

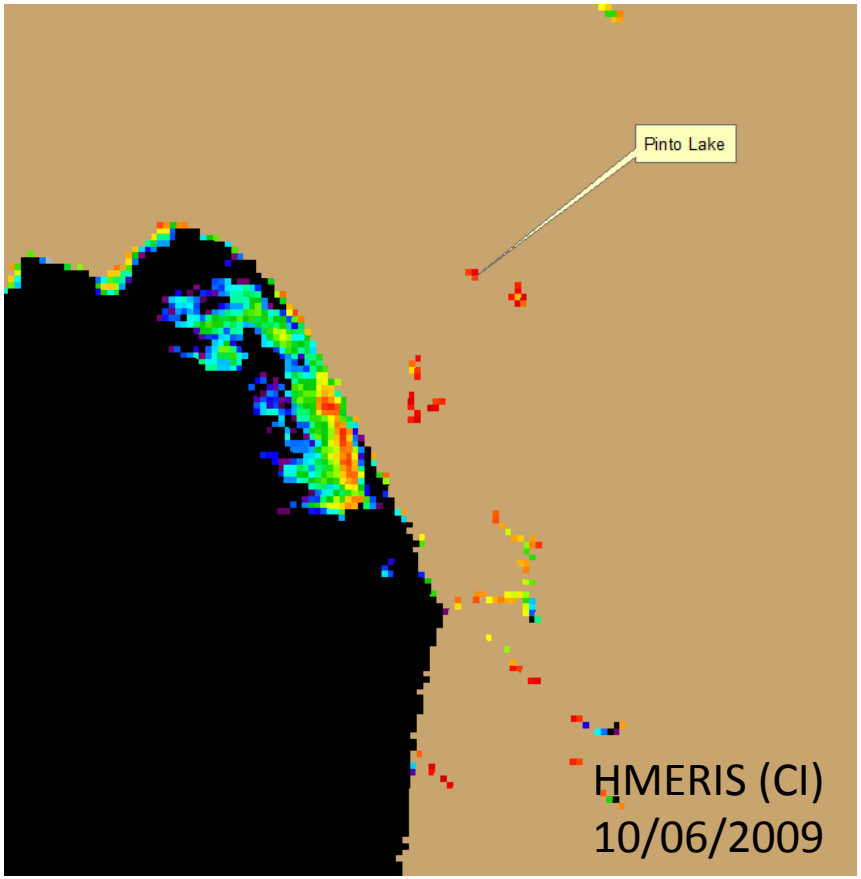
(Too Small; 3 pixels)

To retrieve usable data, need 3 pixel width and at least 6-8 pixels in length



Pinto Lake (Too Small; 3 pixels)

Toxic bloom in Monterey Bay at this time (MBARI & UCSC).

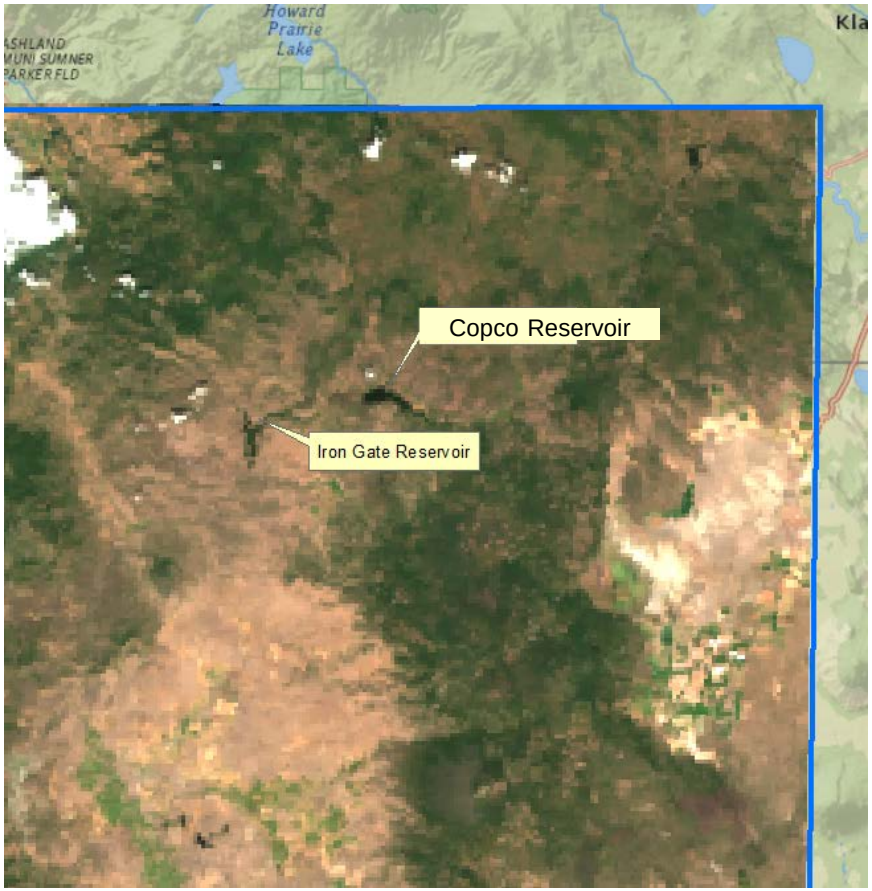


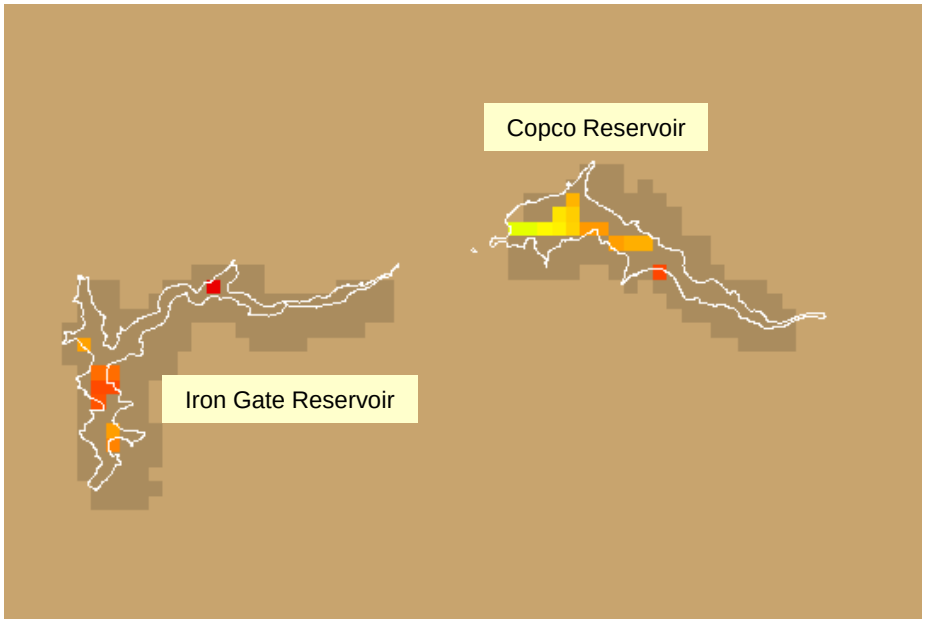
Iron Gate & Copco Reservoirs

on Klamath River

Iron Gate & Copco Reservoirs

what can be resolved in narrow reservoirs?

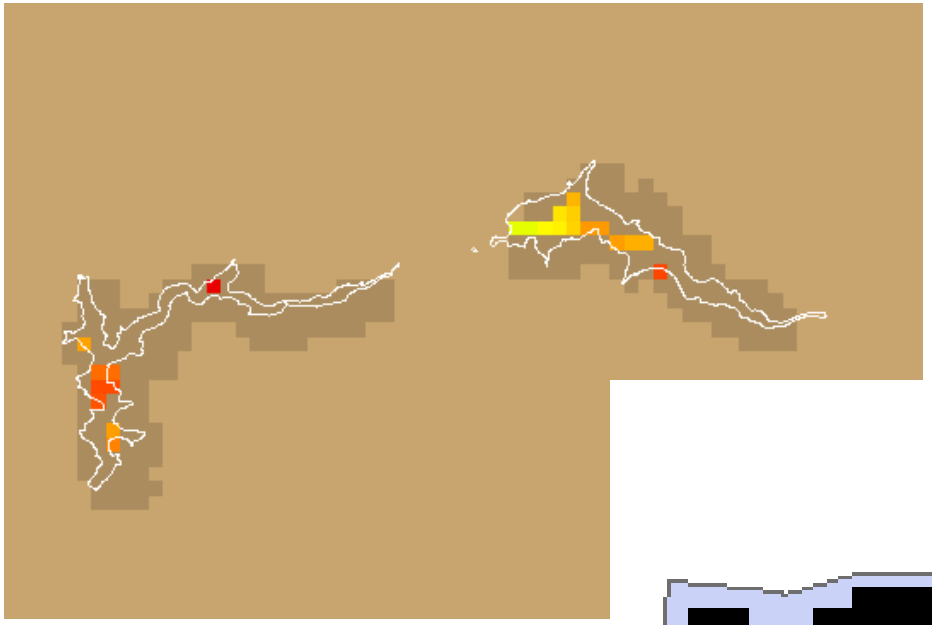




MERIS (CI)
08/13/2009

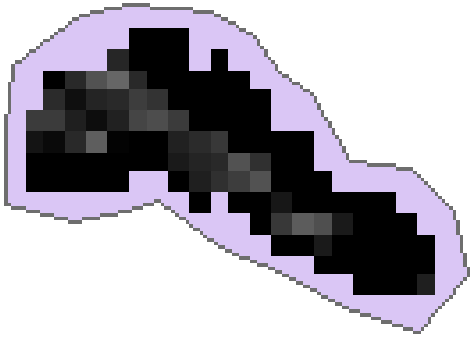
Iron Gate & Copco Reservoirs

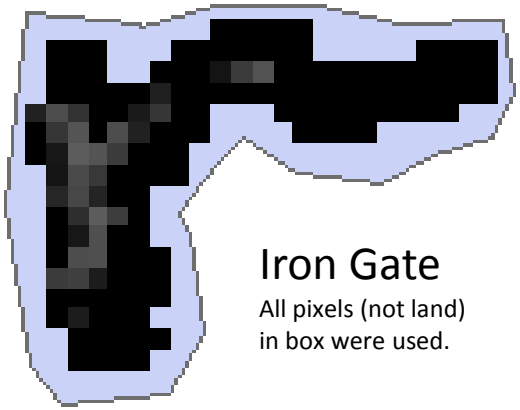
combine pixels for analysis.



Copco Res.

All pixels in white box were used.

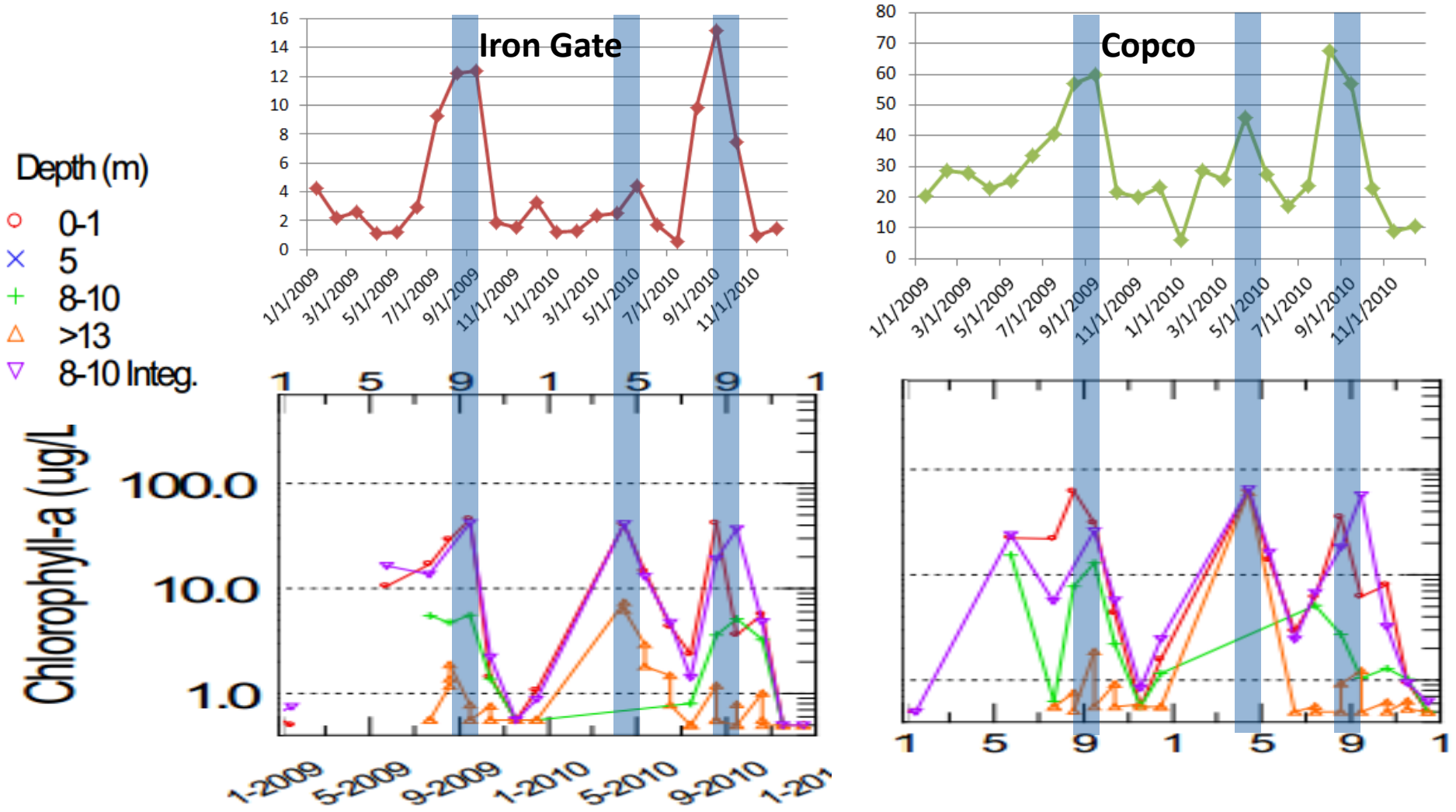




Iron Gate

All pixels (not land)
in box were used.

Monthly means extract information from small lakes



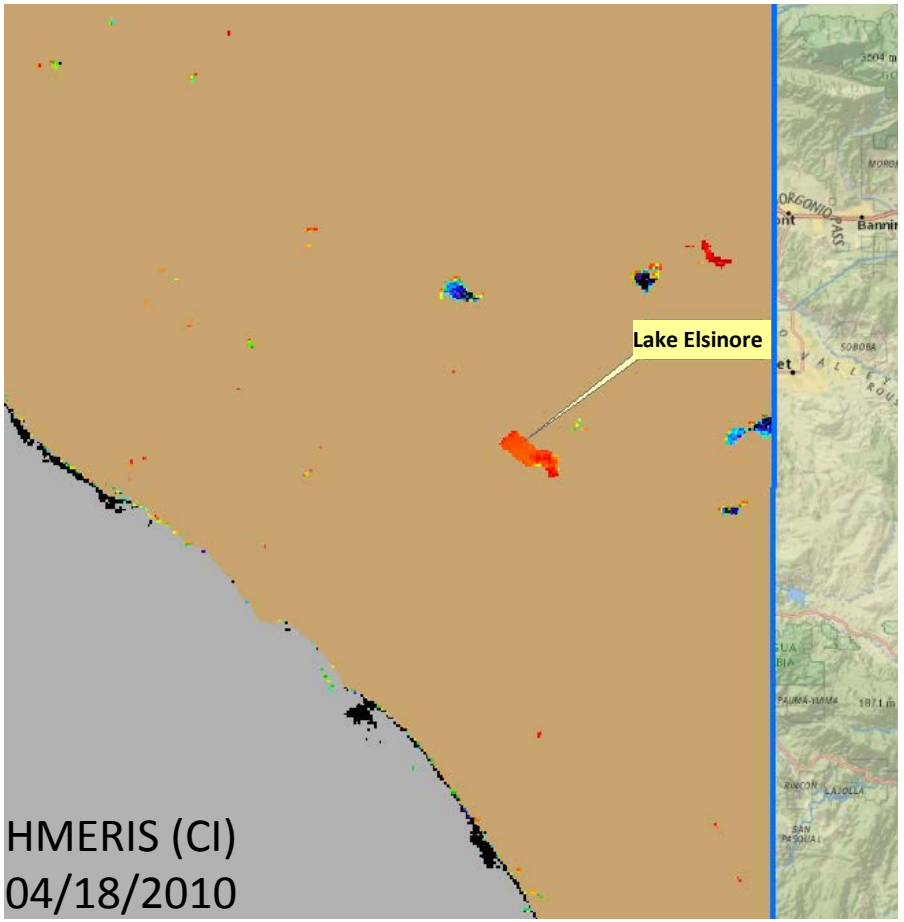
http://www.klamathwaterquality.com/documents/asarian_kann_2011_CopIG_res_2005_2010_rpt.pdf

Lake Elsinore

(Data available: once every other month in 2010)

Lake Elsinore

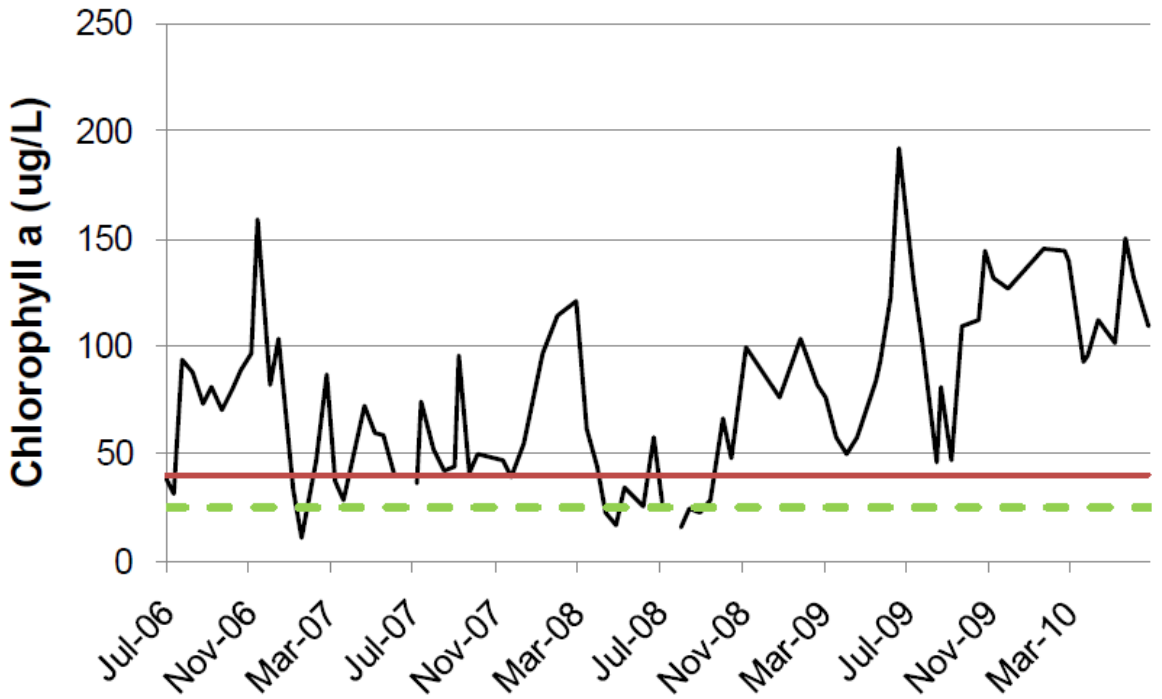
(Adequate size, little field data available)



Lake Elsinore Chlorophyll *a*

(High chlorophylls were present in Lake Elsinor in 2010)

Figure 3-6. Lake Elsinore Chlorophyll a (ug/L)
3 Stations Integrated Samples - July 2006 to June 2010

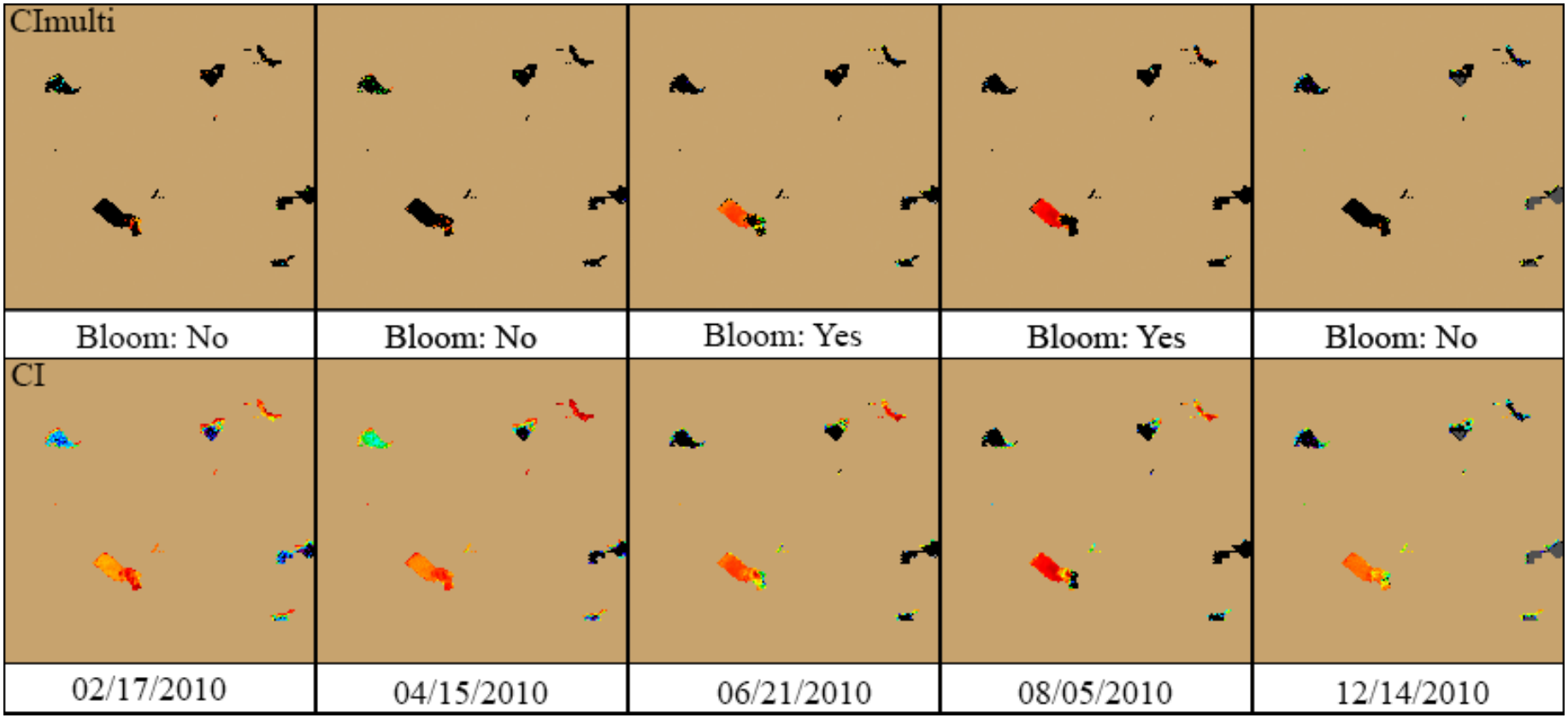


Note: TMDL 2015 Chlorophyll a objective is summer average 40 µg/L and the 2020 objective is summer average 25 µg/L.

http://www.waterboards.ca.gov/rwqcb8/water_issues/programs/tmdl/docs/elsinore/implemetation/TMDL_Annual_Report_FY_09-10_Final.pdf

Lake Elsinore

(CI Imagery shows elevated chlorophylls throughout 2010, while Cimulti imagery flags bloom as likely cyanobacteria in June and August.)

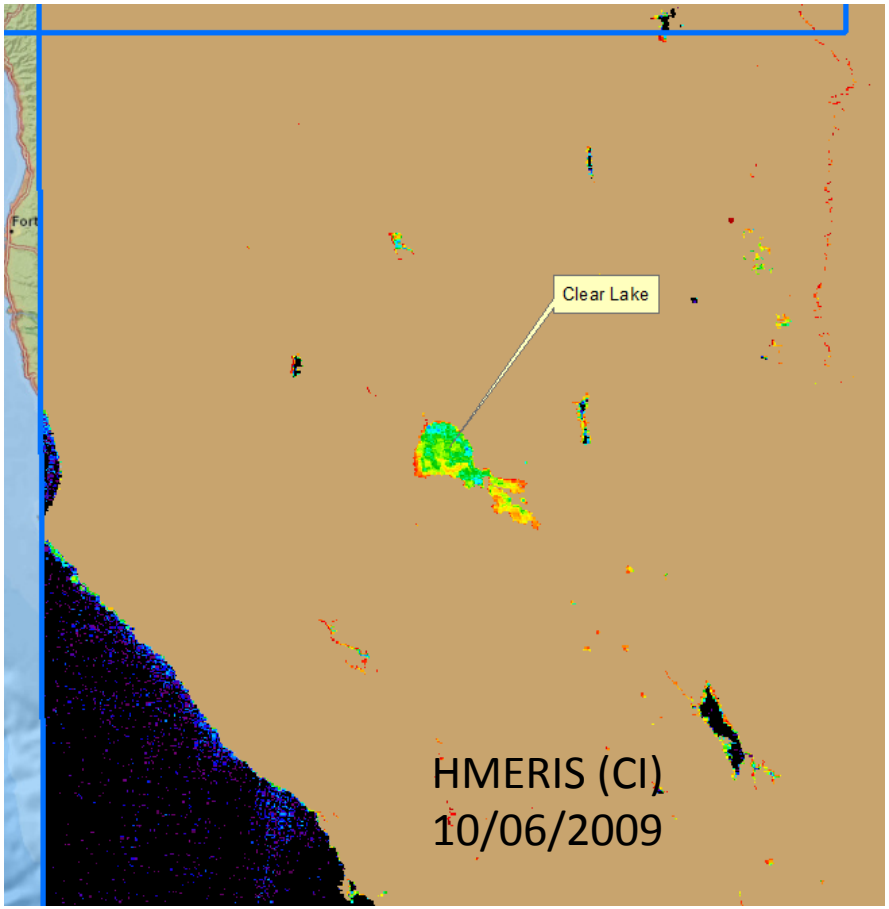


Clear Lake

(Adequate size; data available for most of 2009, 2010, and 2011)

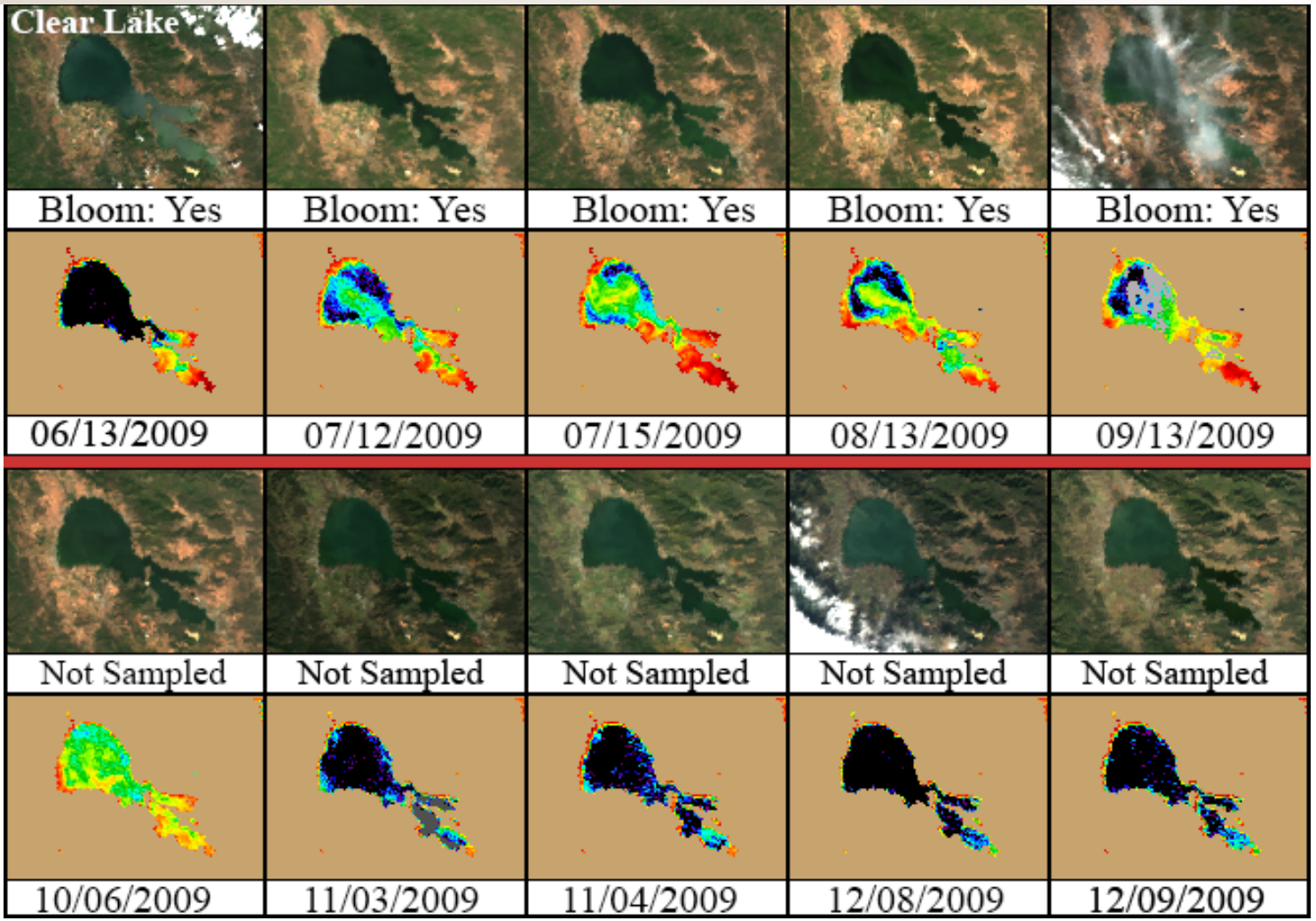
Clear Lake

(Adequate size; data available for most of 2009, 2010, and 2011)



Clear Lake

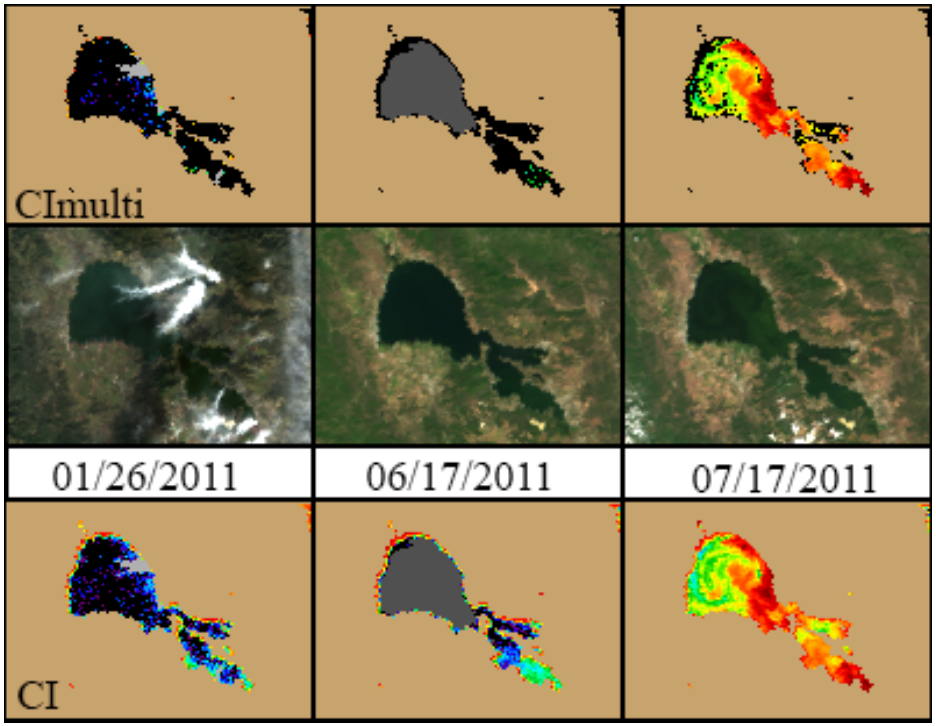
(Imagery flags a bloom when field data confirms a bloom; bloom disappears during winter, although not confirmed by in situ data).



Clear Lake

(Imagery shows intensification of chlorophyll-a in June)

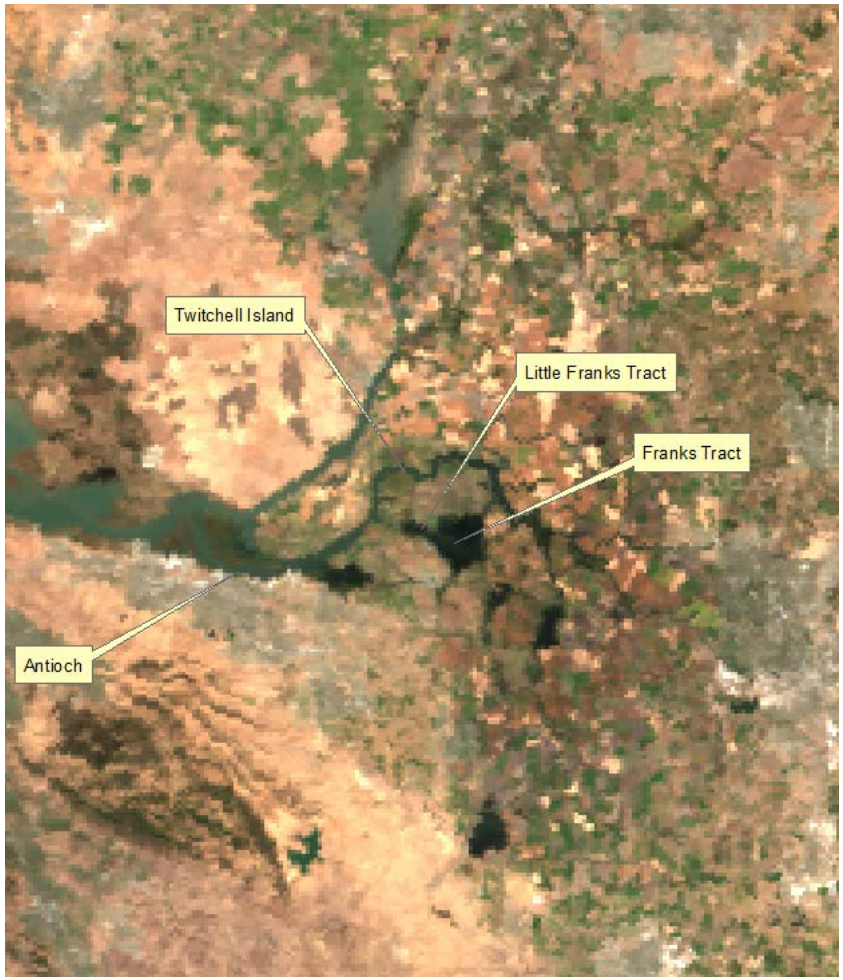
- In mid June chlorophyll increased dramatically Clear Lake Lower Arms on June 16th, 2011. Clear Lake subsequently suffered a devastating cyanobacteria bloom that continue through the summer. Early June chlorophyll ~3 ug/L in NW, 15 ug/L in Lower Arms.
- 60 and 130 ug/L in mid July.

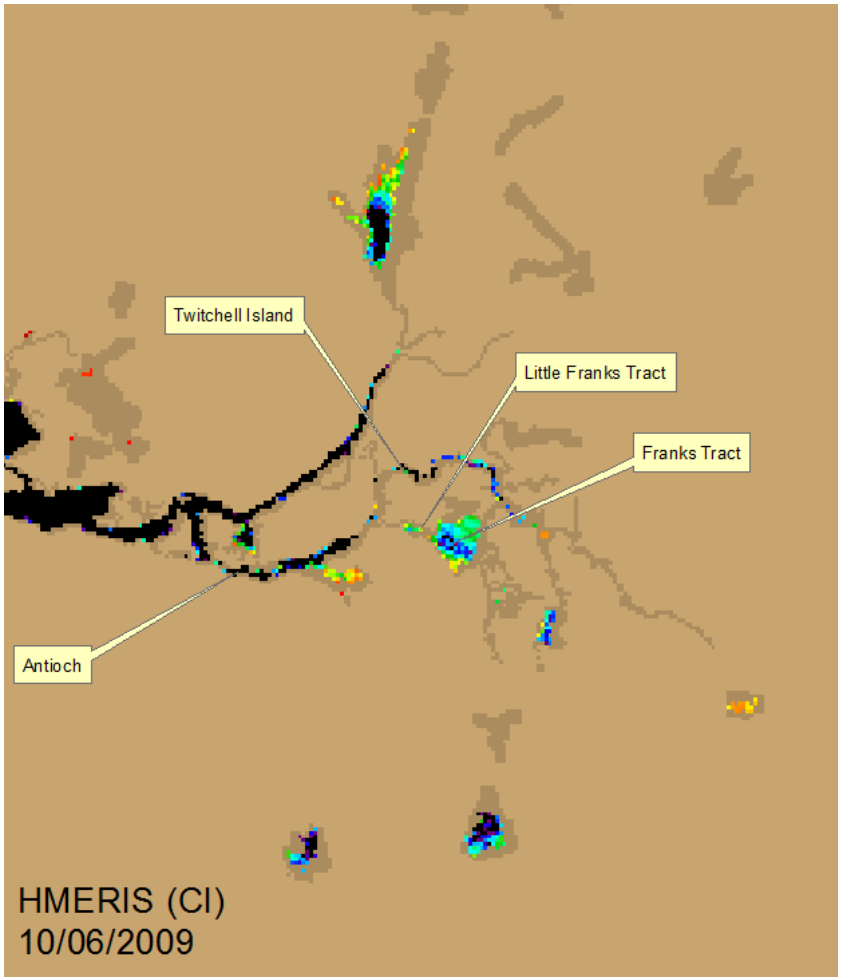


Delta Region

Delta Region

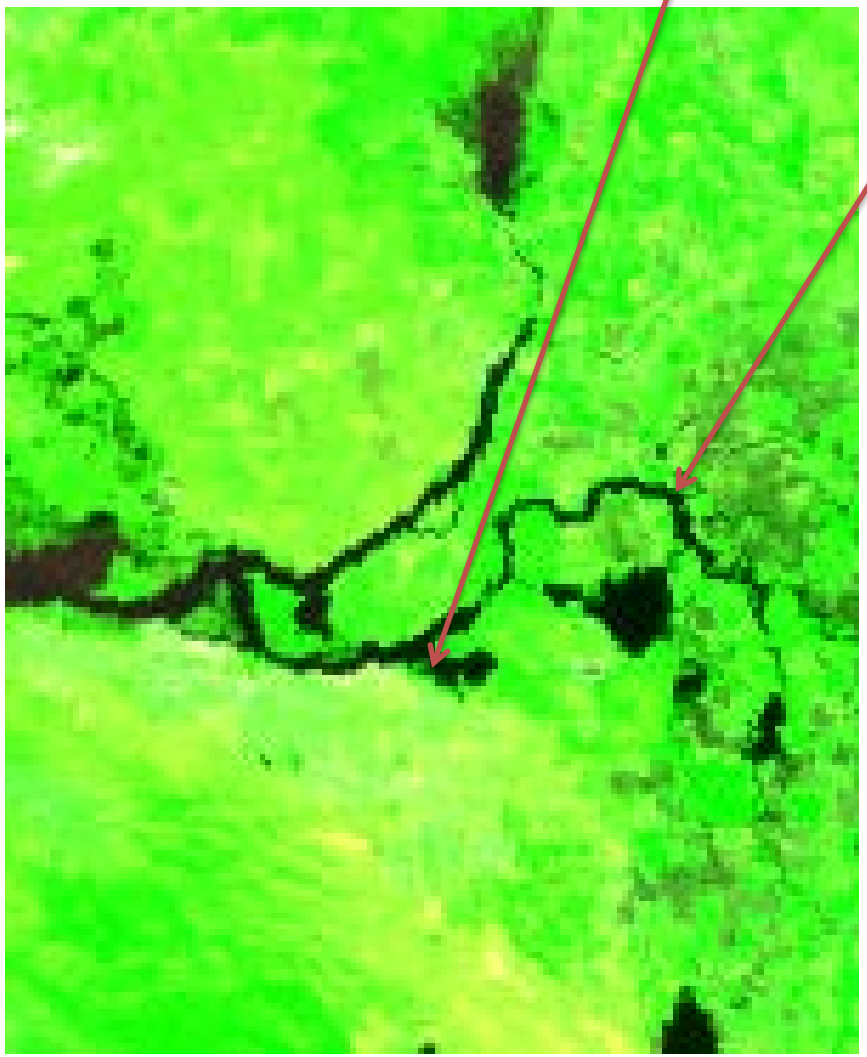
(Franks Tract is adequate size;
Twitchell Island and Antioch are narrow, time average may return information)





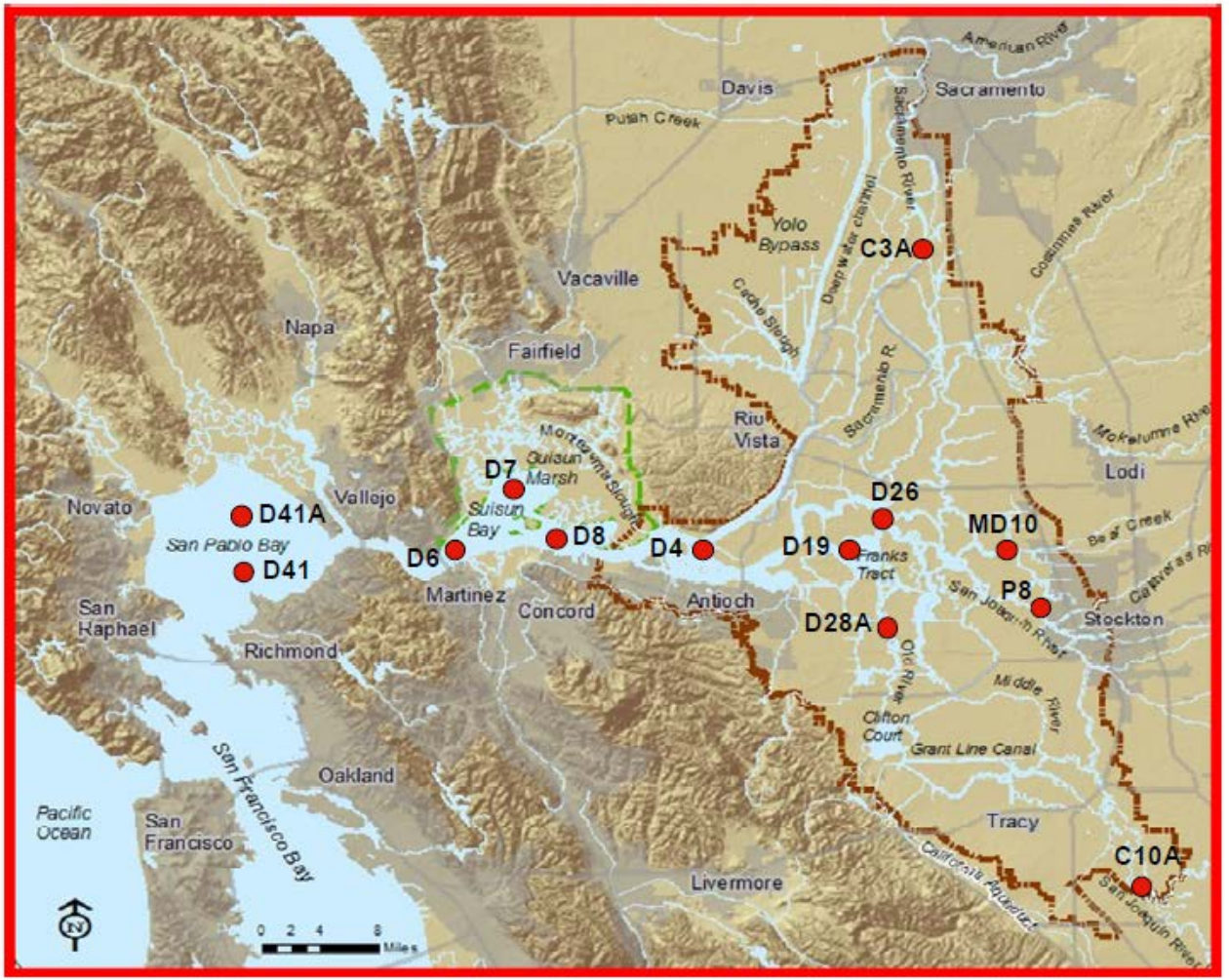
Delta Region, NIR to separate land & water

(NIR demonstration of narrowness at Antioch and Twitchell Island)



Delta Region
(Sampling locations)

Figure 4-1 Map of chlorophyll *a* and phytoplankton monitoring sites



Delta Region

(Pigment concentration < 3 ug/L observed at D19, consistent with imagery not flagging bloom)

Figure 4-8a Pigment concentrations at D19, 2009

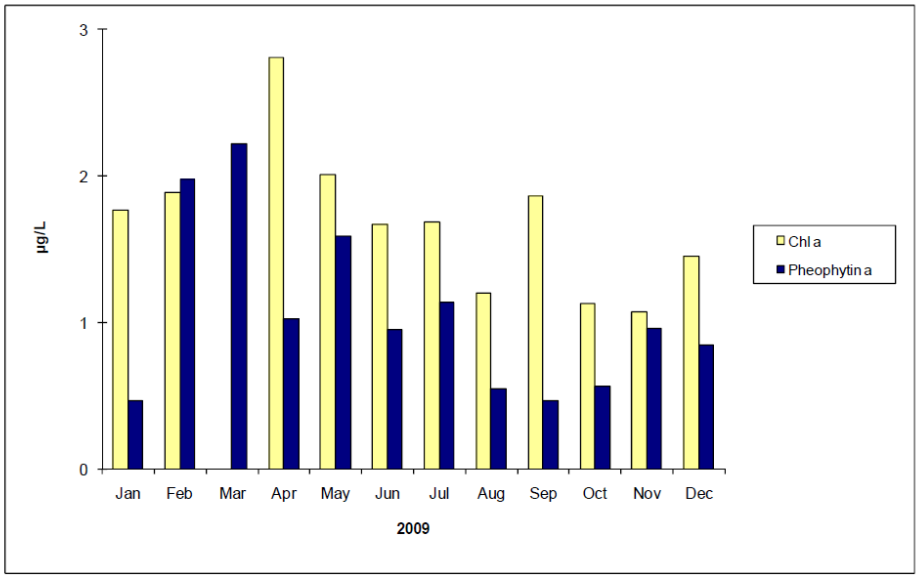
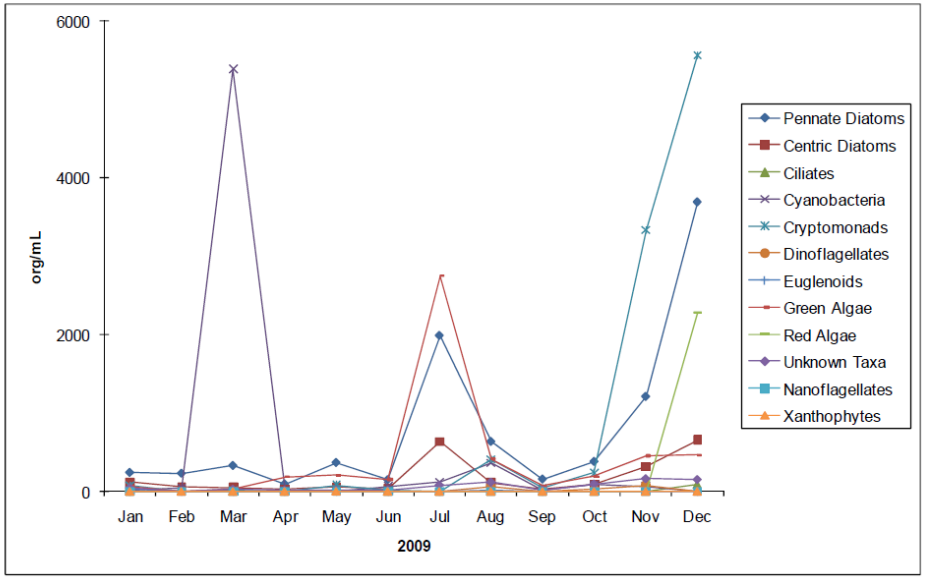


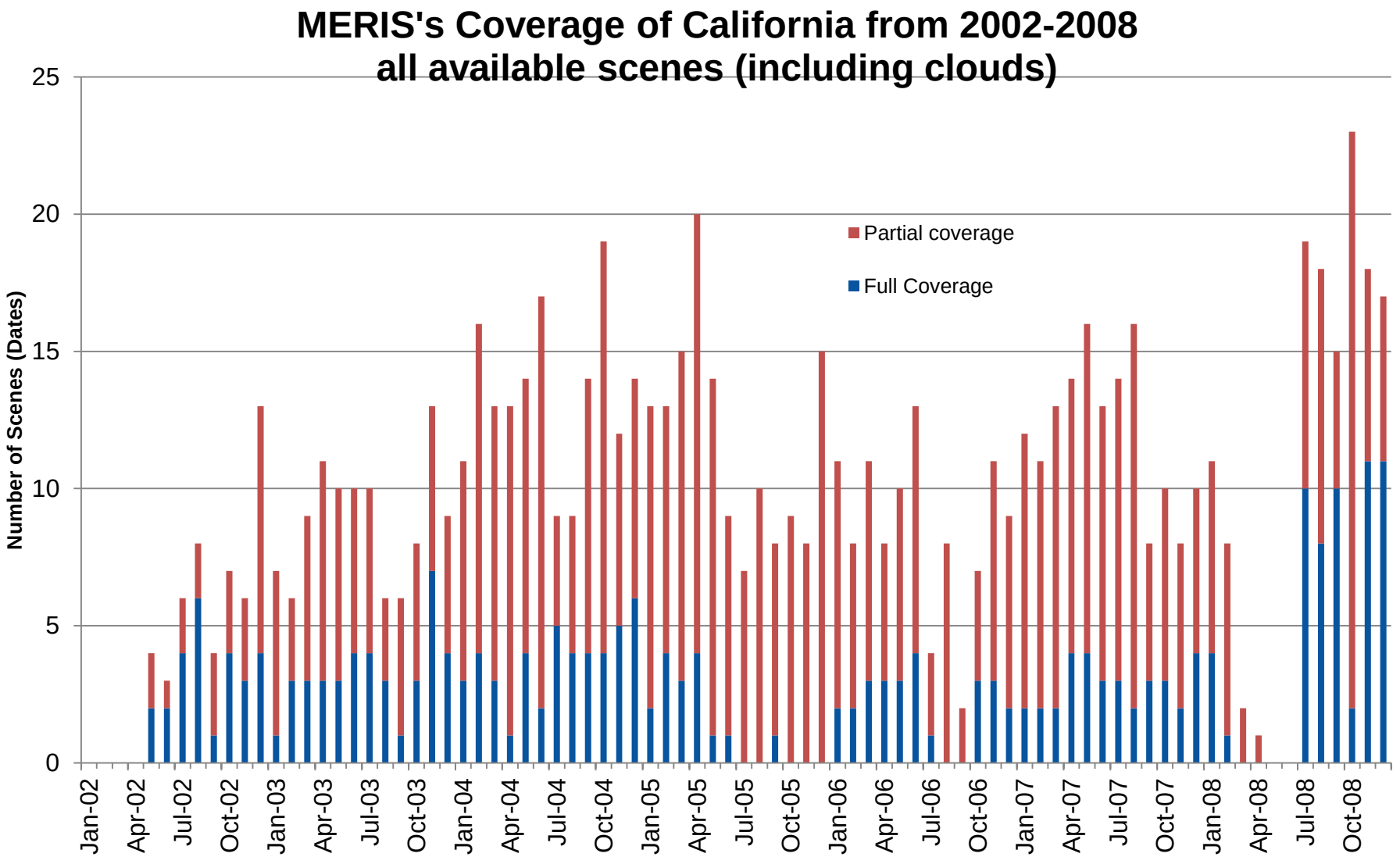
Figure 4-8b Phytoplankton composition, D19 in 2009



Franks Tract

(Imagery suggests a moderate bloom in eastern Franks Tract from August to November)
(At D19, cyanobacteria was relatively abundant in March; and greens and diatoms in August. These “blooms” had chlorophyll < 3 ug/L. 2009 WQ Report)

Frequency of full res MERIS imagery



About higher resolution sensors

- Sentinel-2, launch in 2015 will provide 10-day repeat with 20-30 m resolution. Bands may be good for algal bloom detection (not cyano-specific). Two-years later Sentinel-2b launch. Case study simulation of Sentinel-2 is possible with RapidEye, commercial satellite with 5 m resolution.
  - Has Landsat bands + one additional band.
- Landsat may provide eutrophication measure (8-16 days). Case study in Deschutes basin, central Oregon (Turner for ODEQ), showed promise. Potential of several scenes per summer. Not consistent for biomass
- Higher resolution are commercial.

Non-Commercial Satellites

Sensors	detail	Resol.	repeat	1980s	1990s	2000s	2010s
MERIS	Cyano presence, biomass, Chl-a; scum, eutrophic.	300 m	3-6 days *2 days*** *2009-2012*			7/2002 –	–4/2012
MERIS	"	1 km	2 days			7/2002 –	–4/2012
OLCI on Sentinel-3a/*3b**	*(same as MERIS)*	300 m	2 days *1 day**				2015 3a 2018* *3b*
MODIS on Aqua Terra	Eutrophication *Scum*	500 m *300 m*	1*-2 days		1999– Terra	7/2002 – Aqua	continue
Landsat (5, 7, 8)	Eutrophication Scum	30 m	16 days 8 days*	1984 – (L5)	1999– (L7)ǂ		2013– L8 –2013 L5
MSI on Sentinel-	Chl-a, scum, eutrophication	10-20 m	10 days *5 days**				2015 2a *2017**

*frequency based on two satellites operating.

ǂLandsat7 has gaps of 22% of the scene area, not all areas are covered on each pass.

Summary

MERIS can find high-chlorophyll cyano blooms in California lakes in all regions examined.

Time series assessment: comprehensive coverage from 2009-April 2012; thinner coverage from 2002 to 2009.

The smallest lakes cannot be resolved in individual MERIS scenes.

Chlorophyll of > 10-20 ug/L (WHO threshold) detectable.
(algorithm under study may achieve 3-10 ug/L)

Separation of cyano blooms and other blooms with MERIS/OLCI.

Future

OLCI/Sentinel-3 continues MERIS coverage after launch in 2015.

Potential for higher-resolution, less-frequent, chlorophyll with Sentinel-2 after 2015.

Contact information

Rick Stumpf and Shelly Tomlinson
National Centers for Coastal Ocean Science, NOS
301-713-3028

Andrew Meredith, CSS-Dynamac
843-762-8616

Richard.stumpf@noaa.gov
Michelle.tomlinson@noaa.gov
Andrew.Meredith@noaa.gov