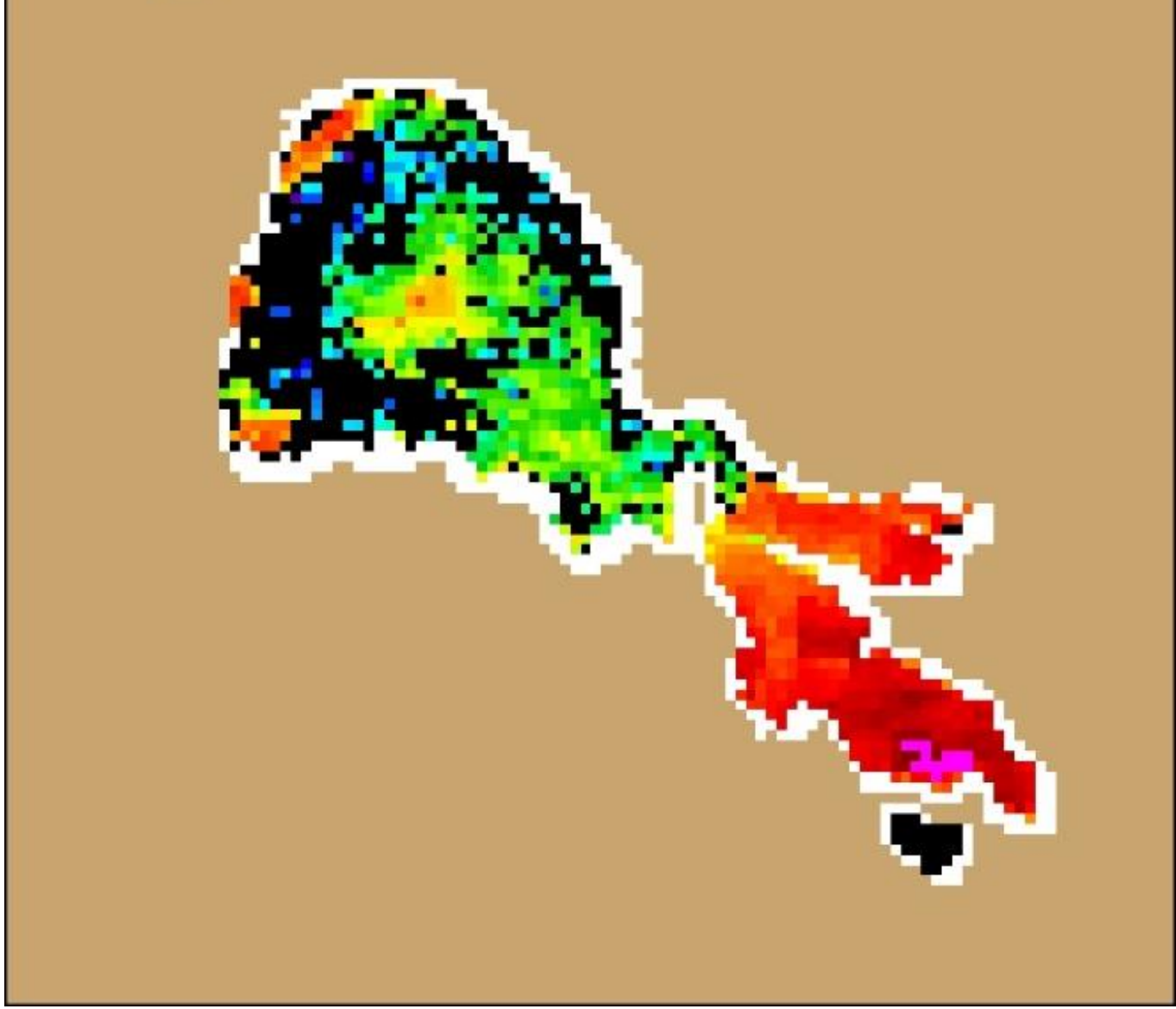
Use of Satellites to Examine CyanoHABs in California's Large Waterbodies

Randy Turner

San Francisco Estuary Institute



SWAMP contract with SFEI

Process, analyze and report on satellite imagery provided by NOAA to protect public health from cyanobacterial Harmful Algal Blooms (cyanoHABs)

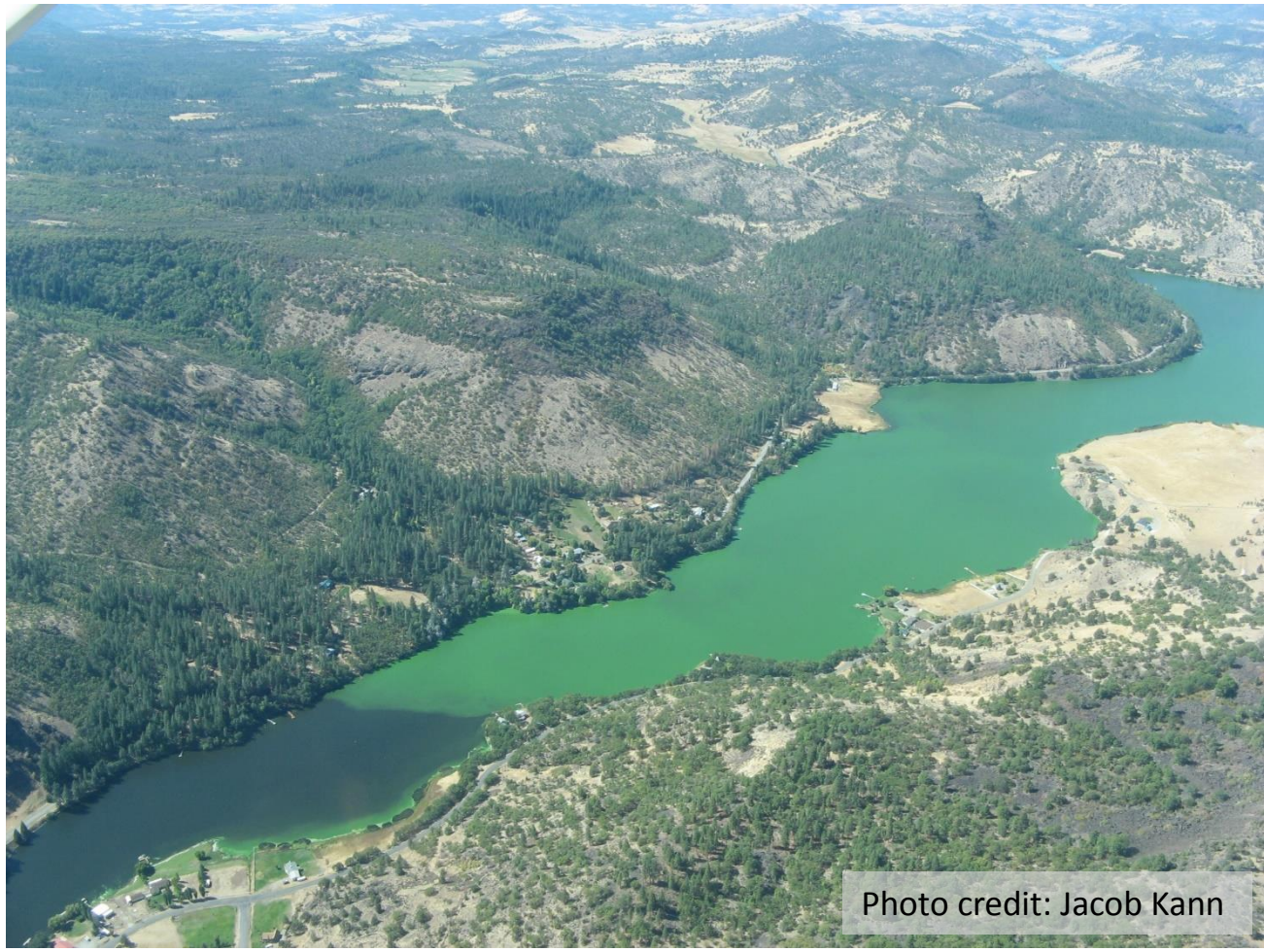


Photo credit: Jacob Kann

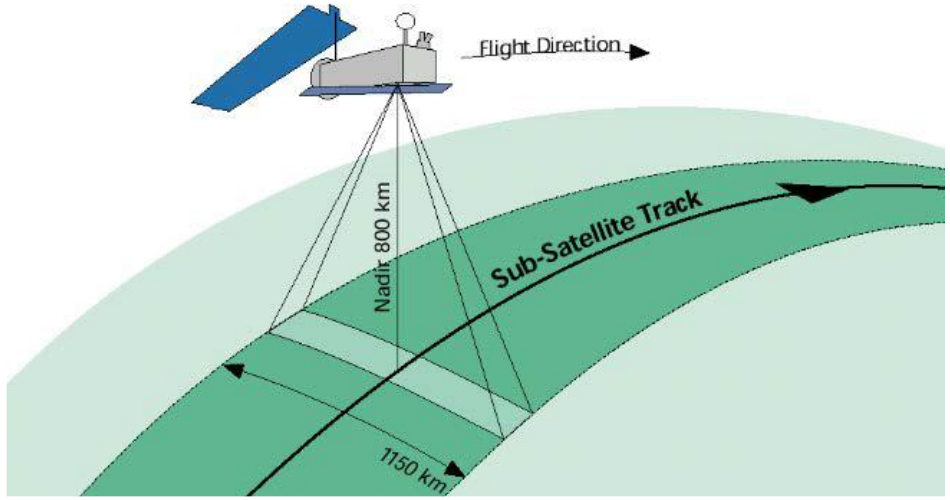
Deliverables

- Develop infrastructure and protocols for processing satellite imagery
- Analyze data from MERIS satellite (2002-2012)
  - Status and Trends Report on cyanoHABs in large lakes
- Analyze data from OLCI on Sentinel-3 satellite (launched in Feb 2016)
- Create web portal for viewing imagery and related data
- Issue bulletins and newsletters

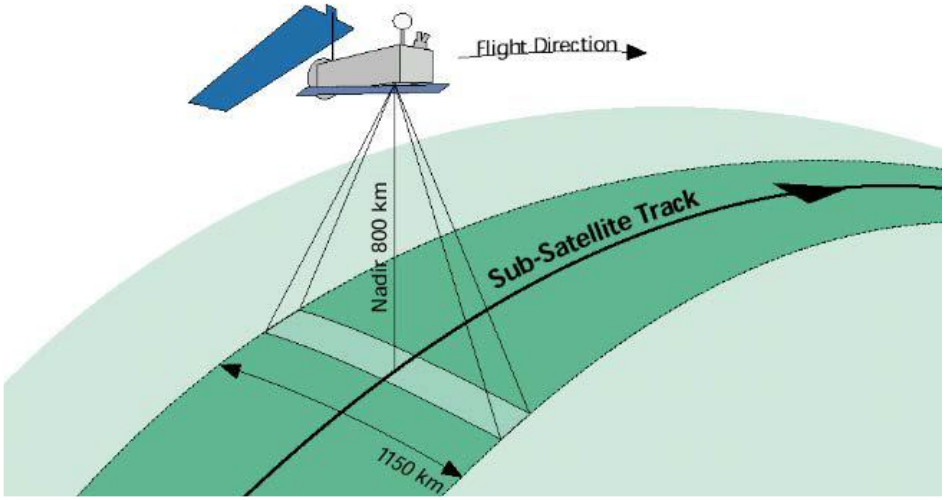

Photo credit: Susan Corum

Satellite basics

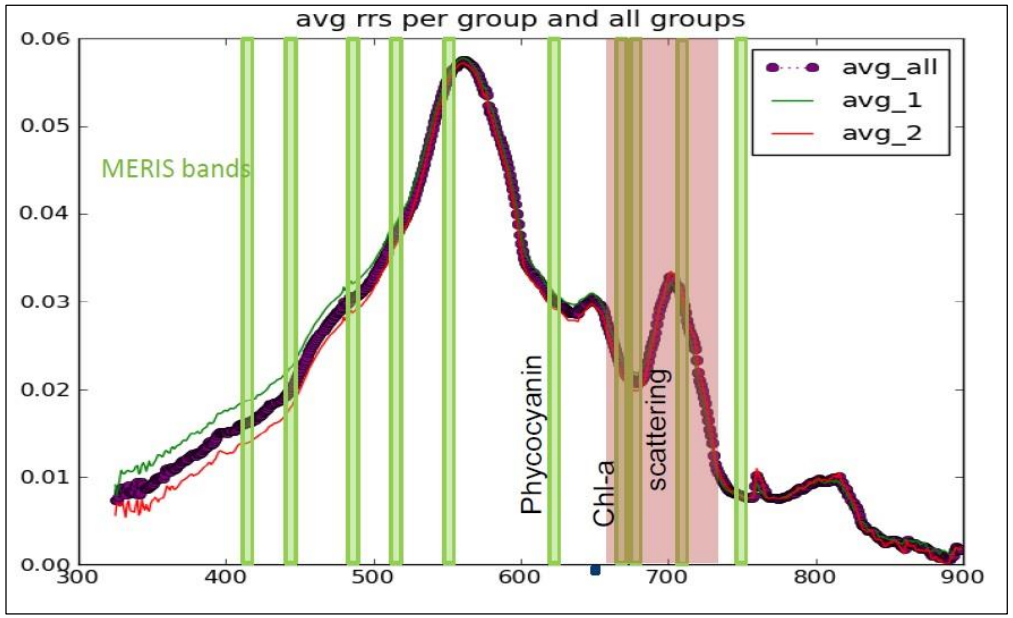
- Flyover every few days
  - Swath 1,150 km wide
  - Resolution is 300m x 300m (per pixel)



Satellite basics

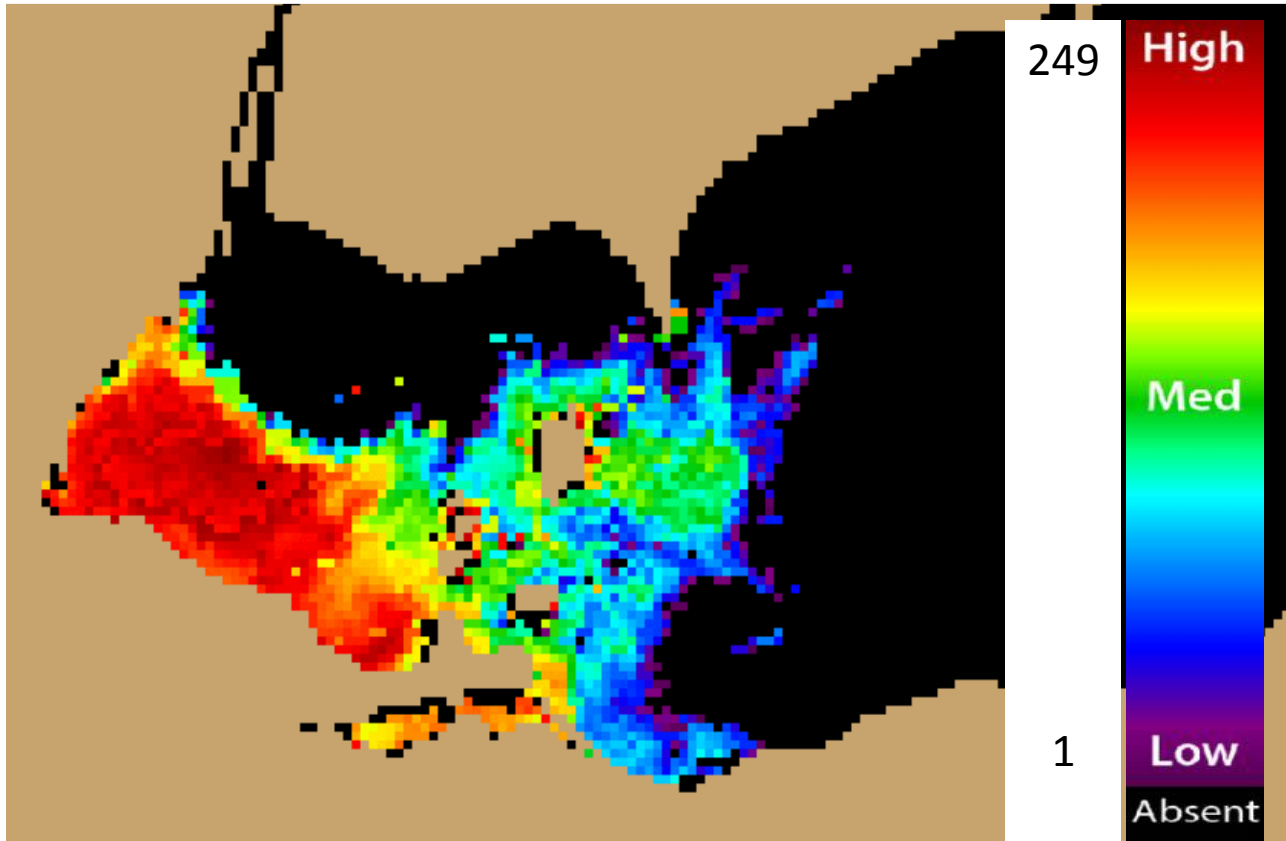


- Flyover every few days
  - Swath 1,150 km wide
  - Resolution is 300m x 300m (per pixel)
  - Satellite analyzes light absorption signature in each pixel
  - Shape in key spectral bands
  - Estimate concentration (N) for each pixel:
    - Cyanobacteria
    - Non-cyanos
    - All algae



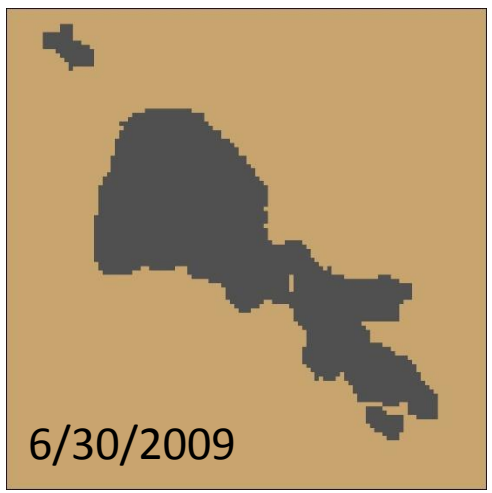
Satellite basics

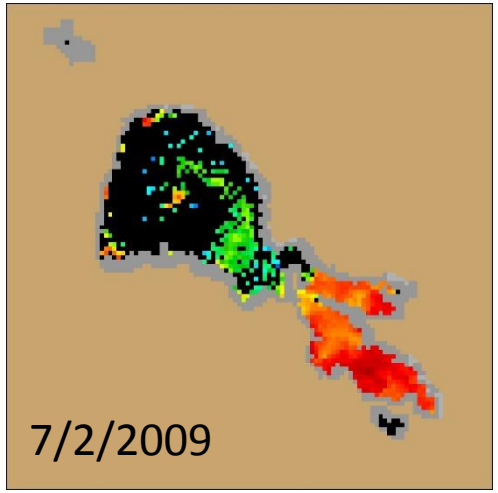
- Each pixel value N (1-249)
- Wind, clouds, etc. impact blooms
- Generate 10 day max composite

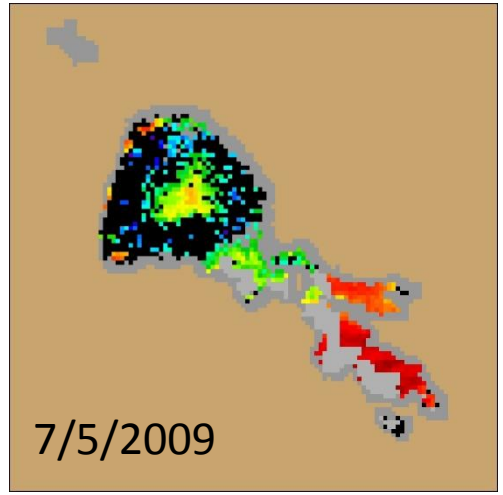


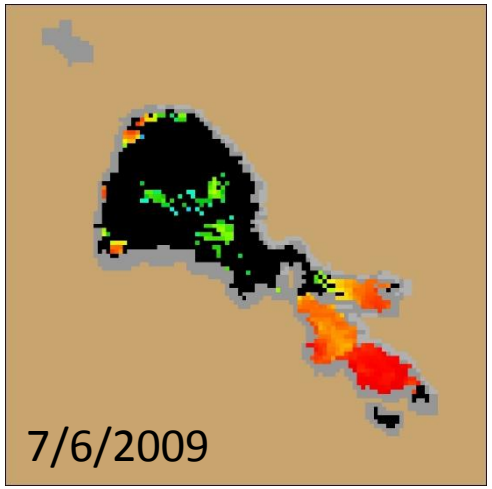
Data Processing

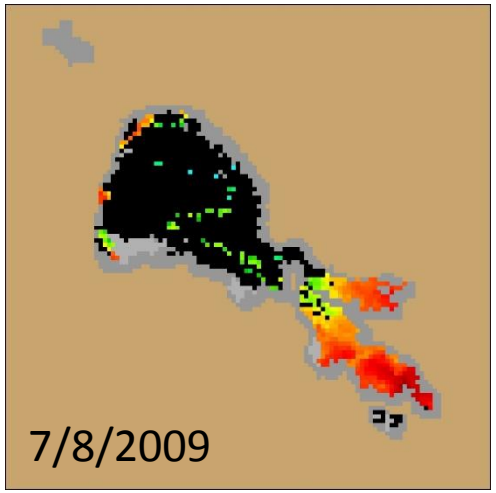
- Review all scenes for previous 10 days

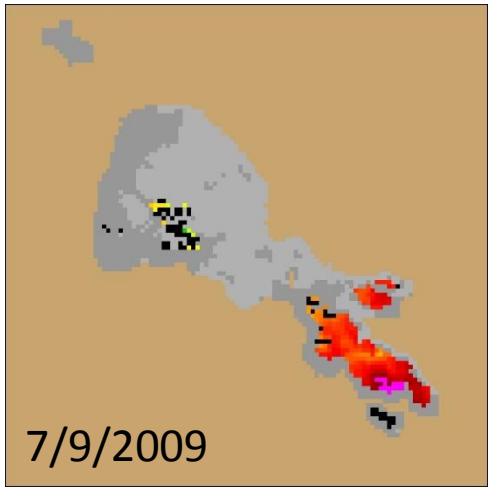






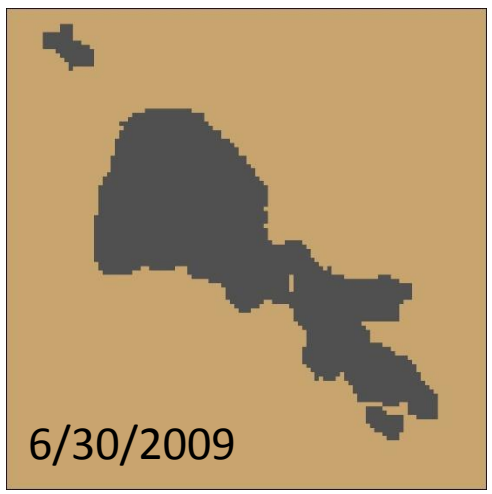


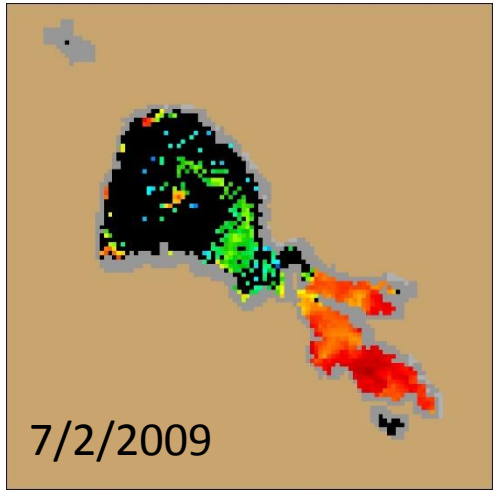


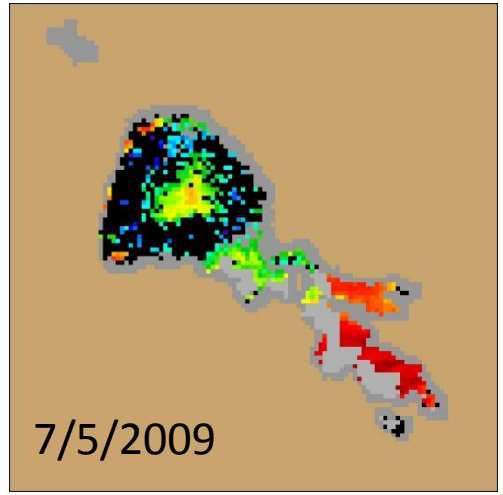


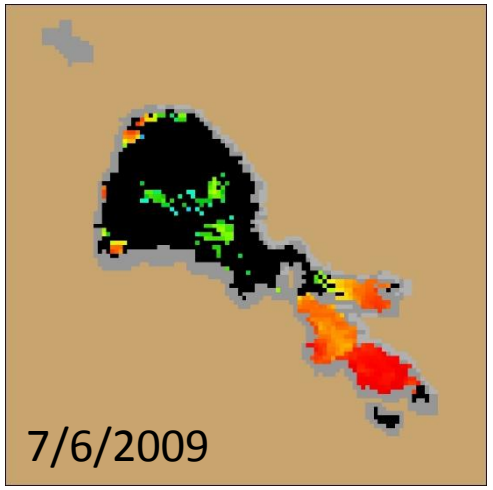
Data Processing

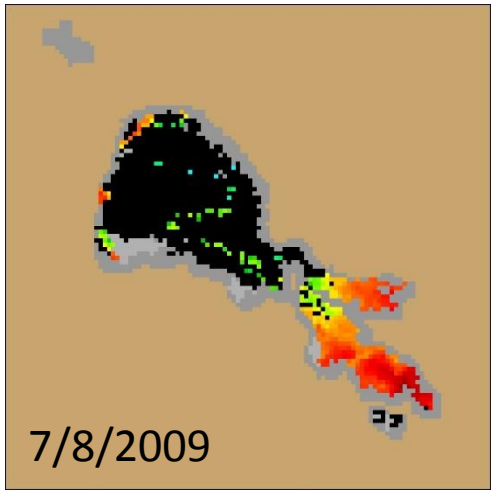
- Review all scenes for previous 10 days
- Determine maximum value for each pixel location

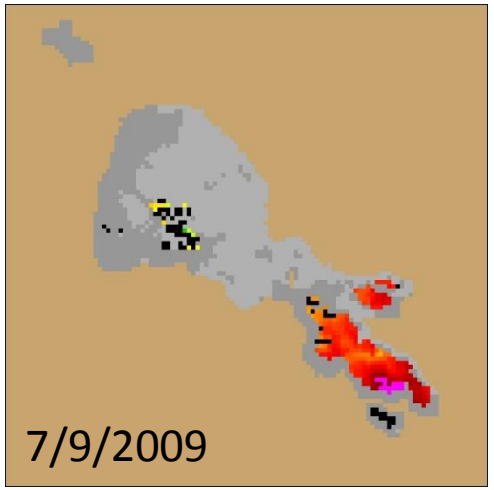












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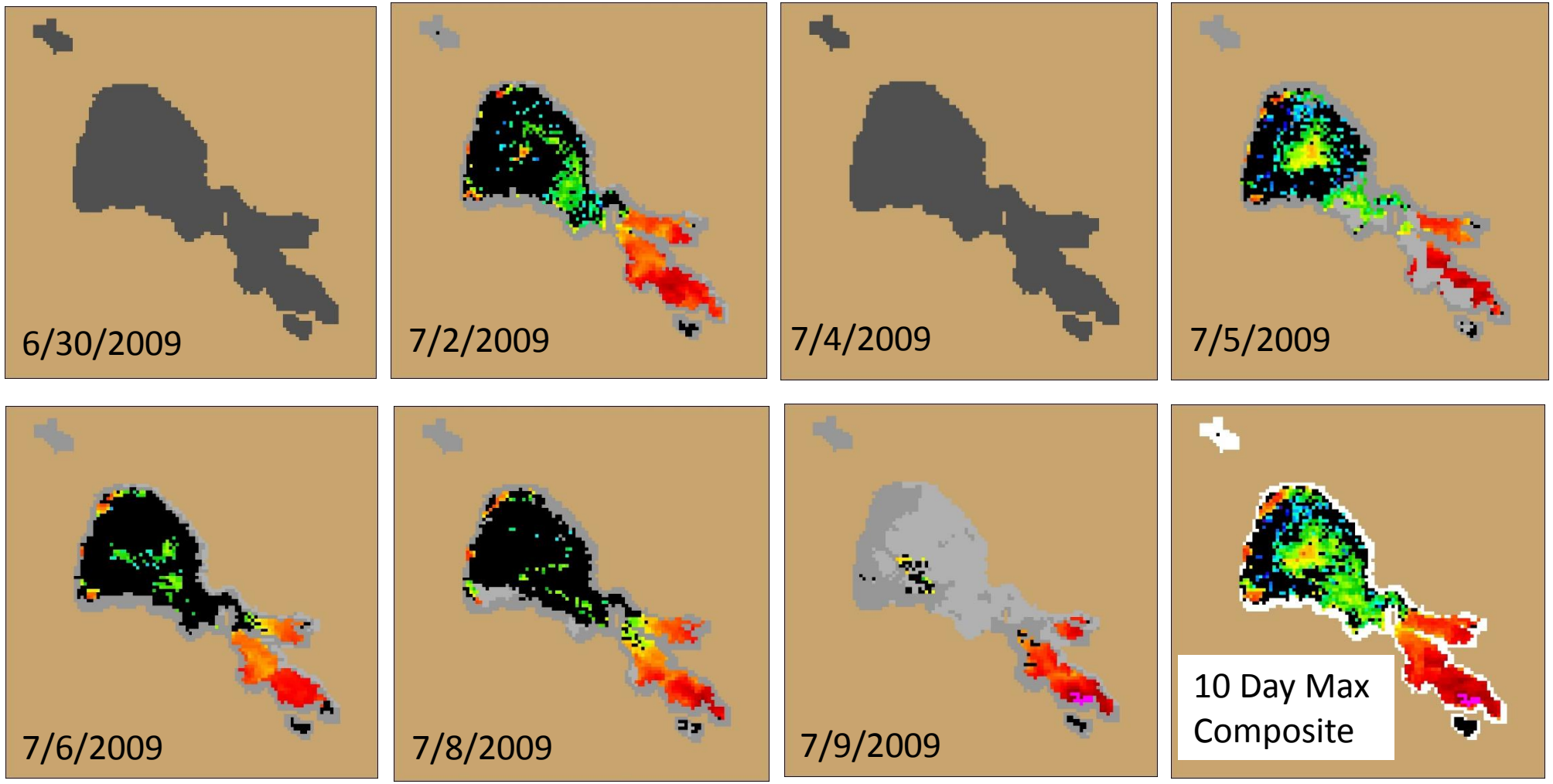
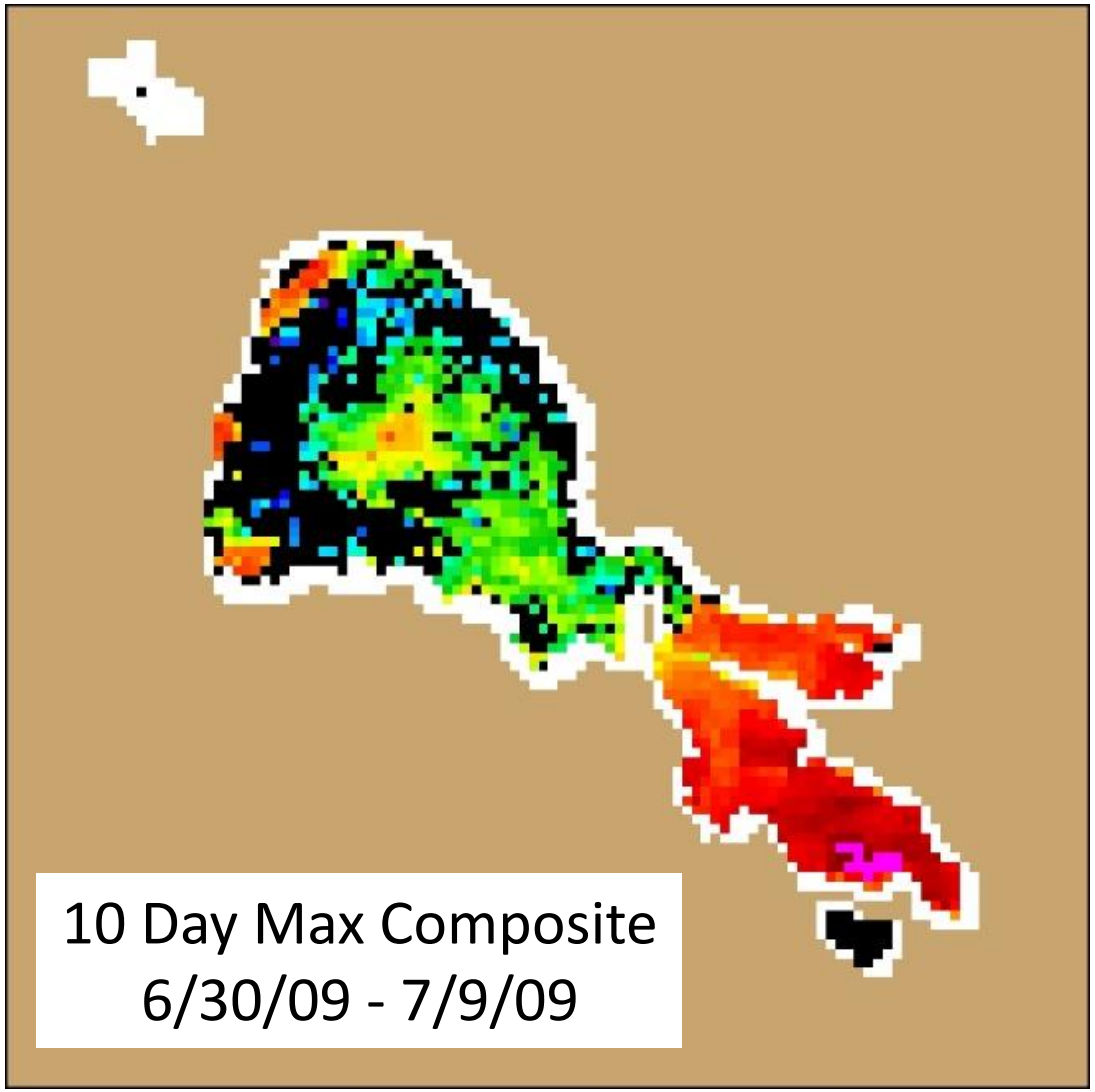
- Generate 10 day max composites



Generate Statistics

- From each 10 day max composite, generate lake-wide estimates for:
  - Mean
  - Median
  - 90th percentile of max
- For each ‘portion’ of bloom:
  - Cyano / Non-Cyano / Total
- NOAA derived algorithms to convert N to:
  - Cyanobacterial Index (CI)
  - Chlorophyll-a (ug/L)
  - Microcystis sp. (cells/mL)
- Where composites:
  - >17 pixels (NOAA recommended)
  - >0 pixels



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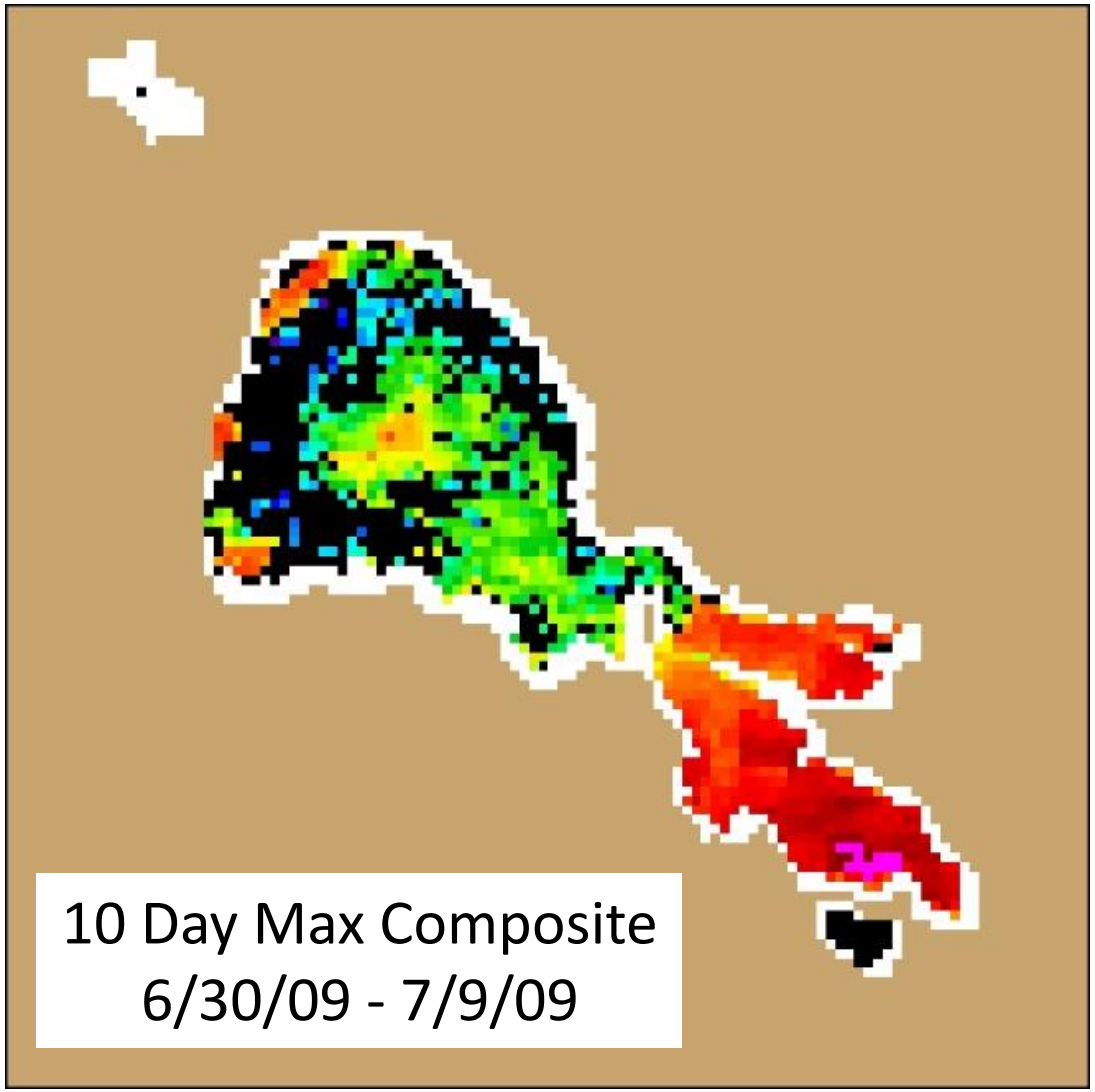
			Cyano Mean >17	Cyano Median >17	Cyano 90th % >17
start_date	end_date	Pixels	MC (cells/mL)	MC (cells/mL)	MC (cells/mL)
6/22/2009	7/1/2009	1757	109,648	131,826	1,995,262
6/23/2009	7/2/2009	1779	123,027	154,882	1,949,845
6/24/2009	7/3/2009	1739	109,648	134,896	1,949,845
6/25/2009	7/4/2009	1739	109,648	134,896	1,949,845
6/26/2009	7/5/2009	1721	134,896	181,970	1,778,279
6/27/2009	7/6/2009	1709	125,893	186,209	1,548,817
6/28/2009	7/7/2009	1709	125,893	186,209	1,548,817
6/29/2009	7/8/2009	1733	134,896	194,984	1,584,893
6/30/2009	7/9/2009	1721	125,893	186,209	1,621,810

10 Day Max Composite
6/30/09 - 7/9/09

Generate 81 columns of data for each day for each lake!

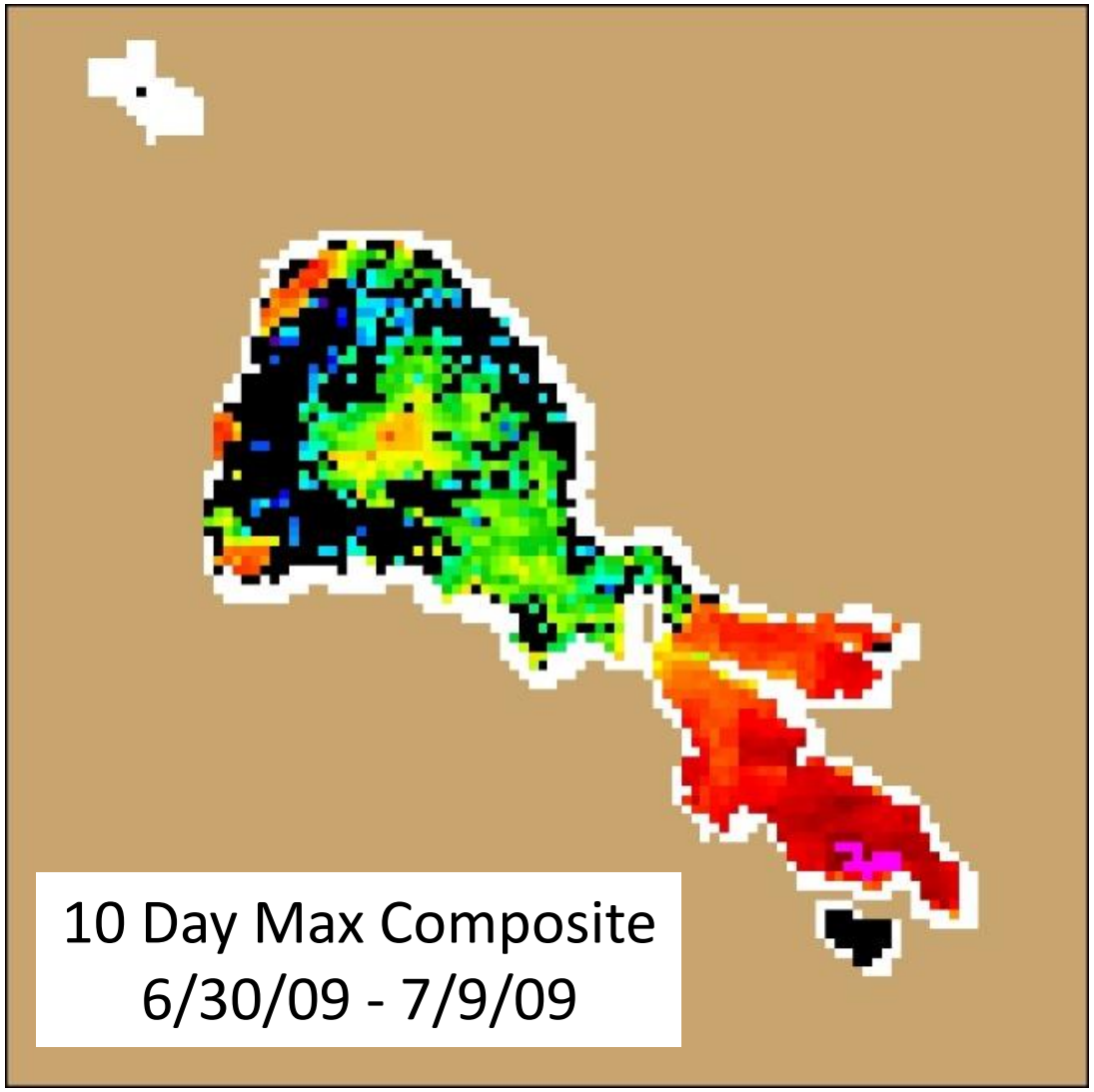
Historic Data

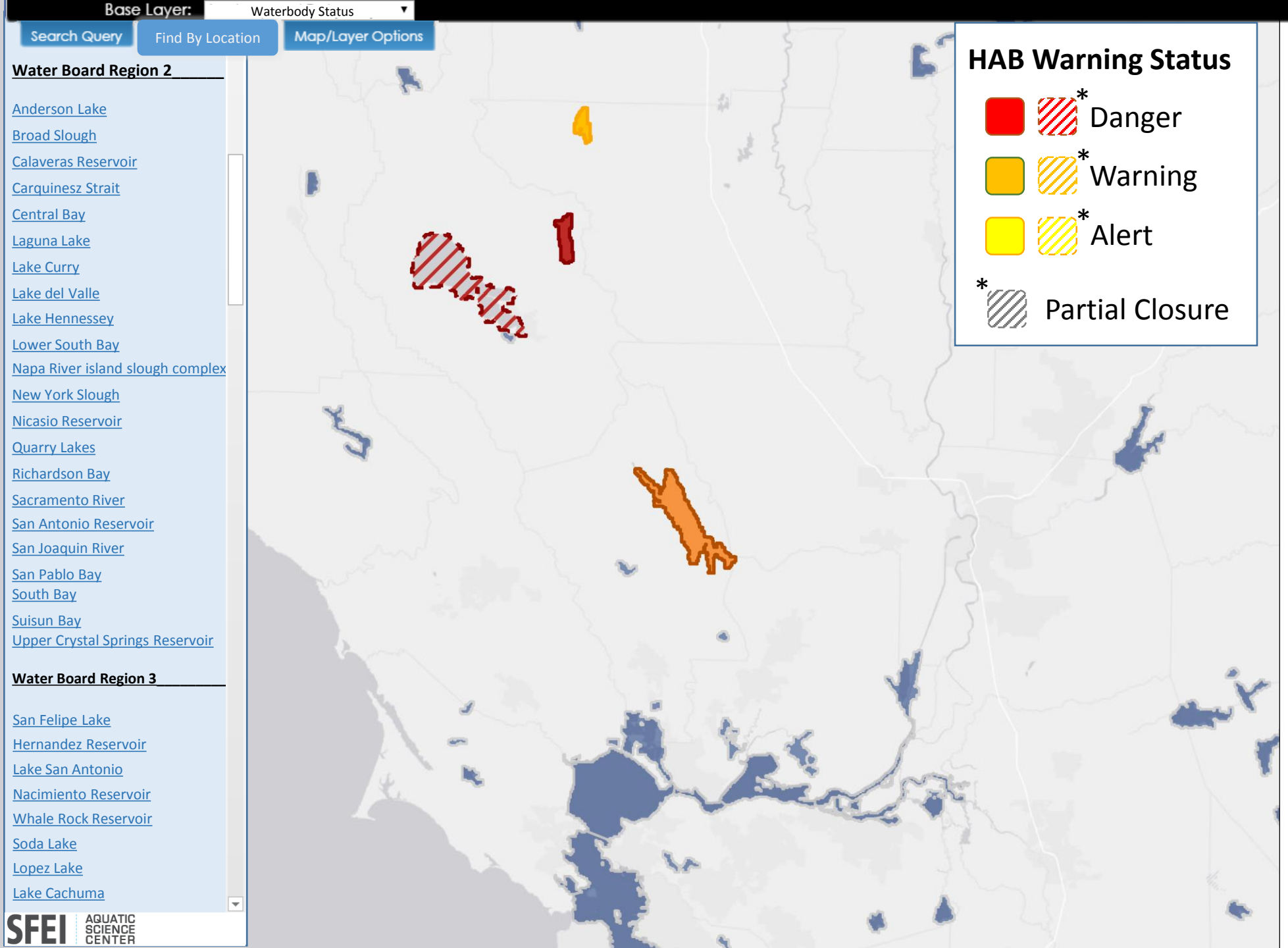
- Status and Trends report
- 269 waterbodies in and upstream of CA
- Rank waterbodies
- Select ~20 lakes
  - Corrections and analysis
- Final report by September 2016
- More extensive S&T report to follow

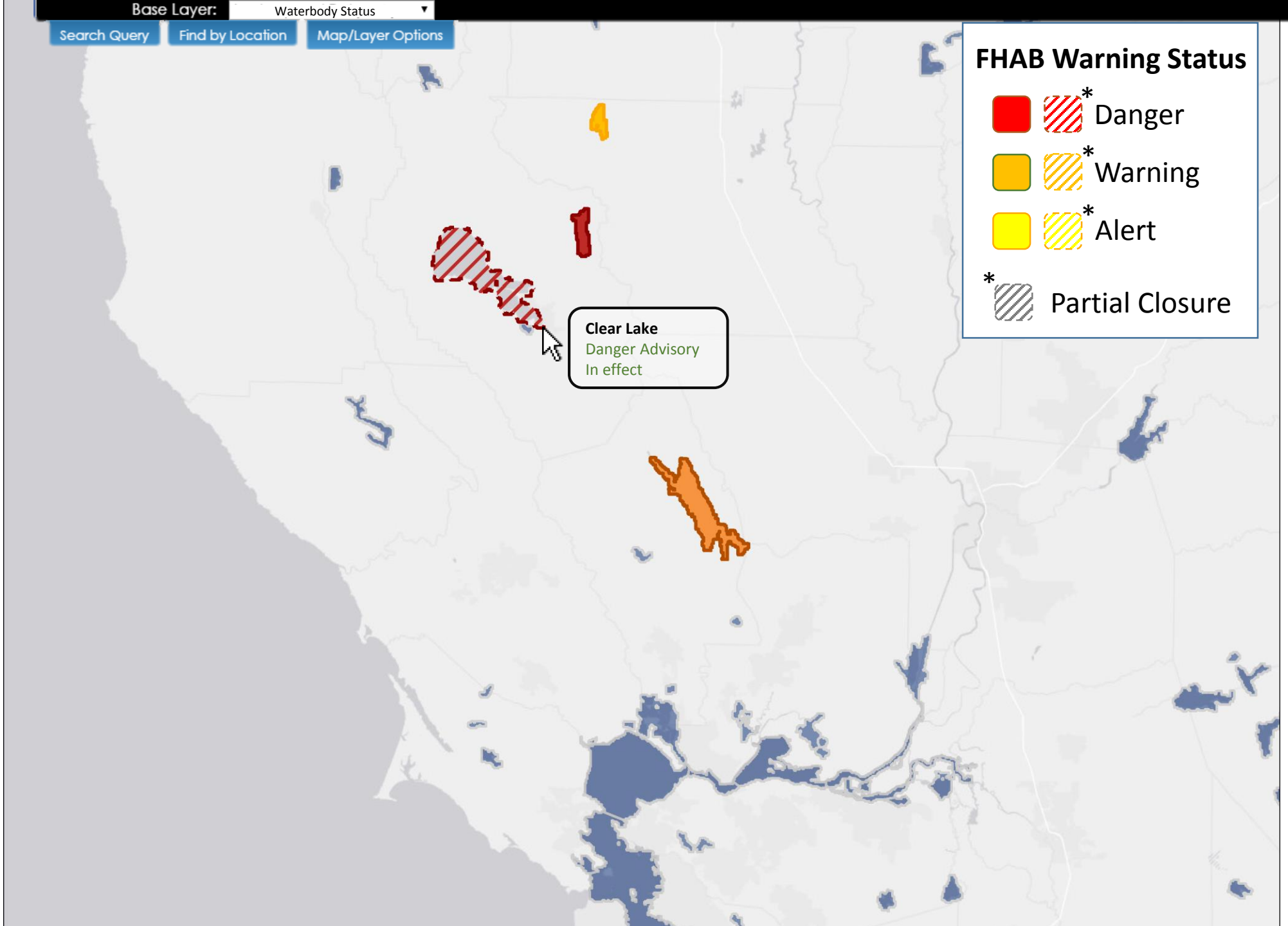


Future Data

- OLCI/Sentinel-3 satellite
  - Data available from NOAA by this fall?
- Download and analyze new data regularly
- Screening tool
- Communicate data to guide event response monitoring by:
  - Lake managers
  - County public health officials
  - Regional Board/SWAMP
- Publish:
  - Bi-weekly bulletins
  - Quarterly newsletter
  - Web maps and data

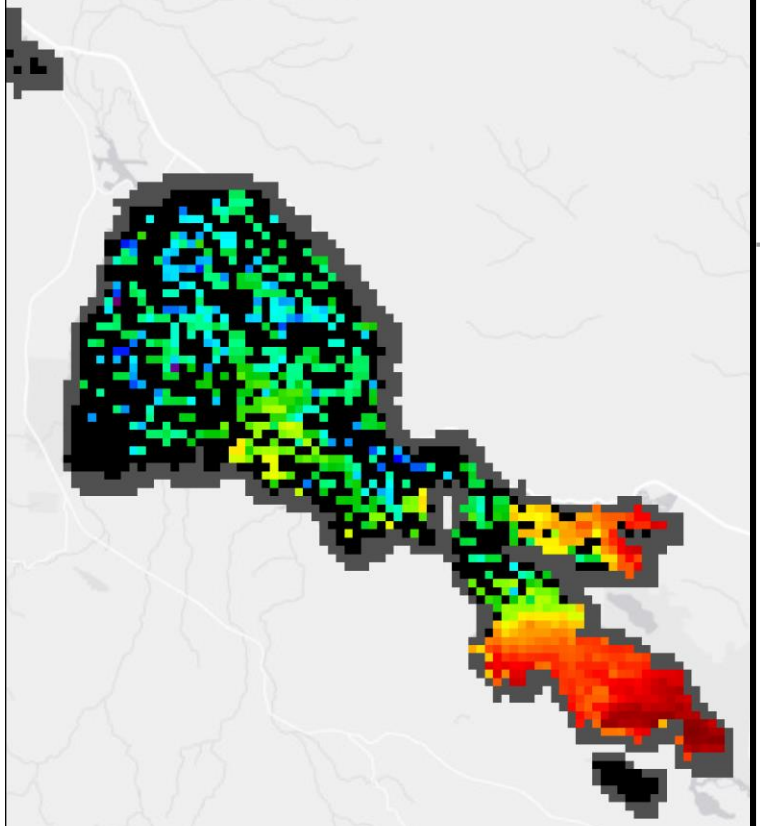



Base Layer:
Waterbody Status
Search Query
Find By Location
Map/Layer Options
Water Board Region 2
Anderson Lake
Broad Slough
Calaveras Reservoir
Carquinesz Strait
Central Bay
Laguna Lake
Lake Curry
Lake del Valle
Lake Hennessey
Lower South Bay
Napa River island slough complex
New York Slough
Nicasio Reservoir
Quarry Lakes
Richardson Bay
Sacramento River
San Antonio Reservoir
San Joaquin River
San Pablo Bay
South Bay
Suisun Bay
Upper Crystal Springs Reservoir
Water Board Region 3
San Felipe Lake
Hernandez Reservoir
Lake San Antonio
Nacimiento Reservoir
Whale Rock Reservoir
Soda Lake
Lopez Lake
Lake Cachuma
SFEI
AQUATIC SCIENCE CENTER
HAB Warning Status
Danger
Warning
Alert
Partial Closure


Base Layer:
Waterbody Status
Search Query
Find by Location
Map/Layer Options
FHAB Warning Status
Danger
Warning
Alert
Partial Closure
Clear Lake
Danger Advisory
In effect

Base Layer: 10 Day Biomass estimate

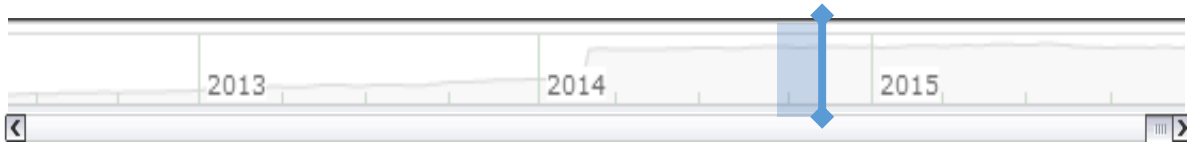
Search Query | Find by Location | Map/Layer Options



MERIS 10-Day Composite Biomass Estimate
May 20, 2014 – May 30, 2014

Clear Lake, Lake County, CA

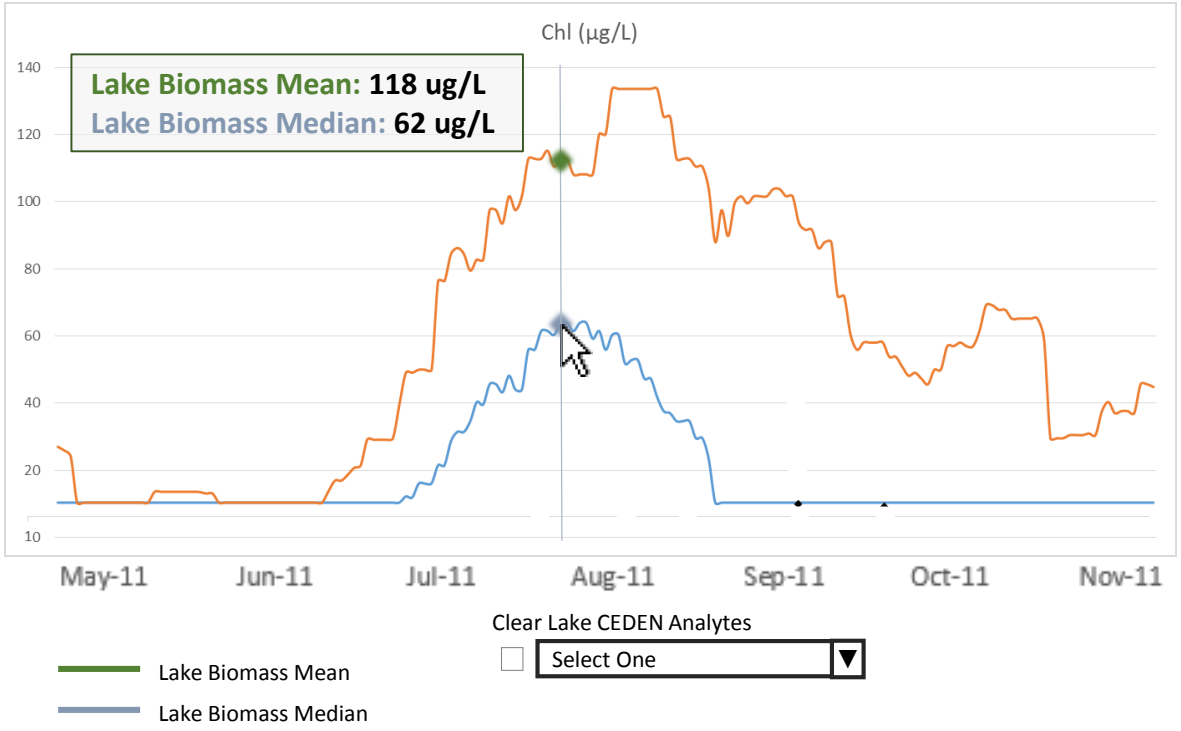
Current Advisory: State and county agencies are urging swimmers, boaters and recreational users to avoid contact with blue-green algae now blooming in Clear Lake located in Lake County, CA. The lake has been posted with advisories warning of any contact with the water because of possible toxins associated with the algae. (Read More)

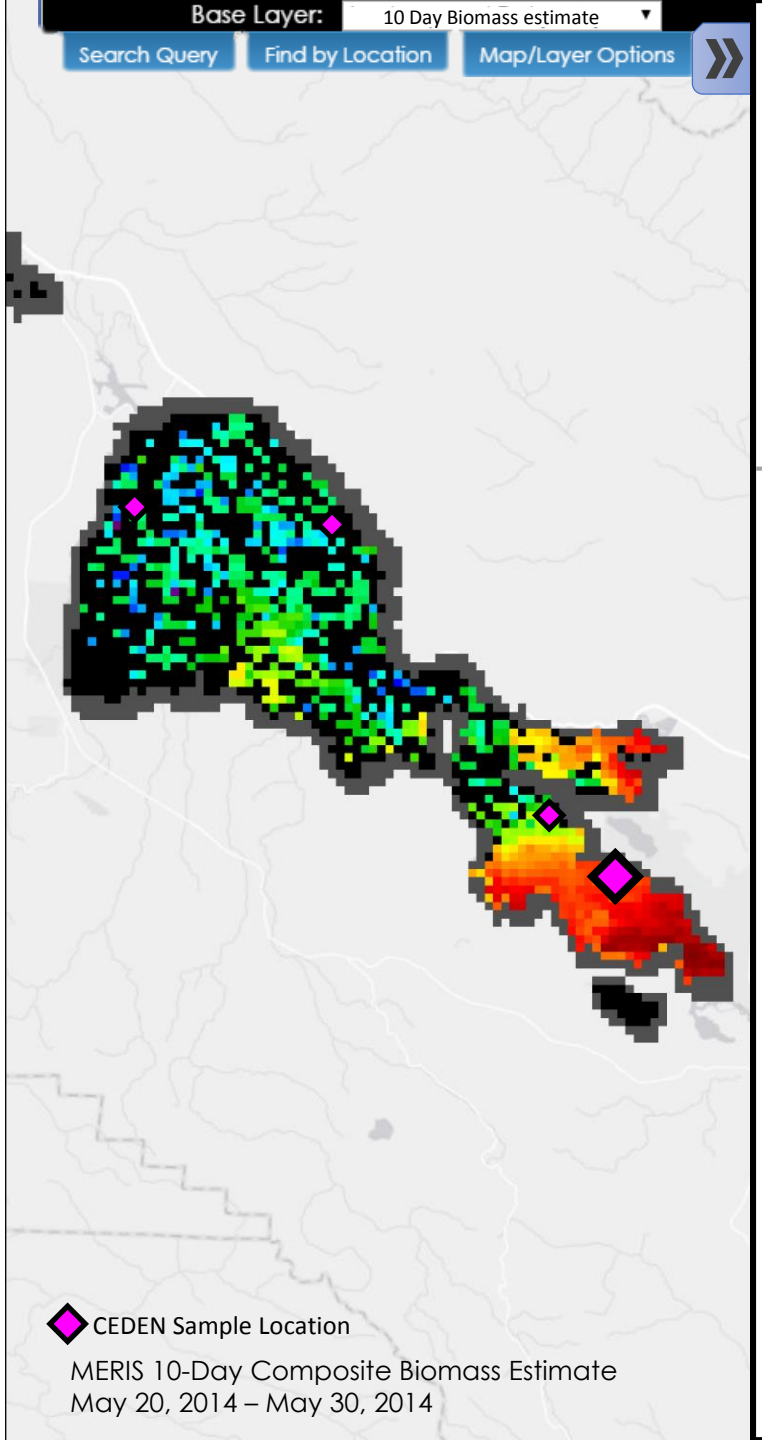


Display Last 10 Days

Trends | Water Quality | Data Table

Cyanobacteria Estimated Biomass & Toxicity





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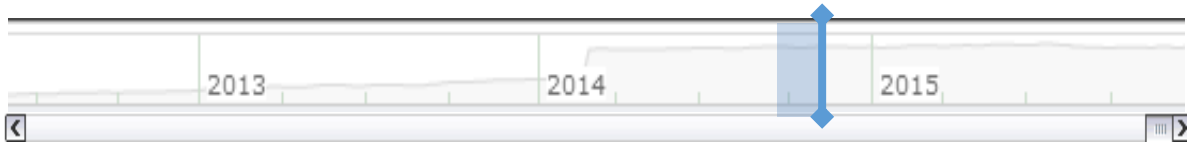

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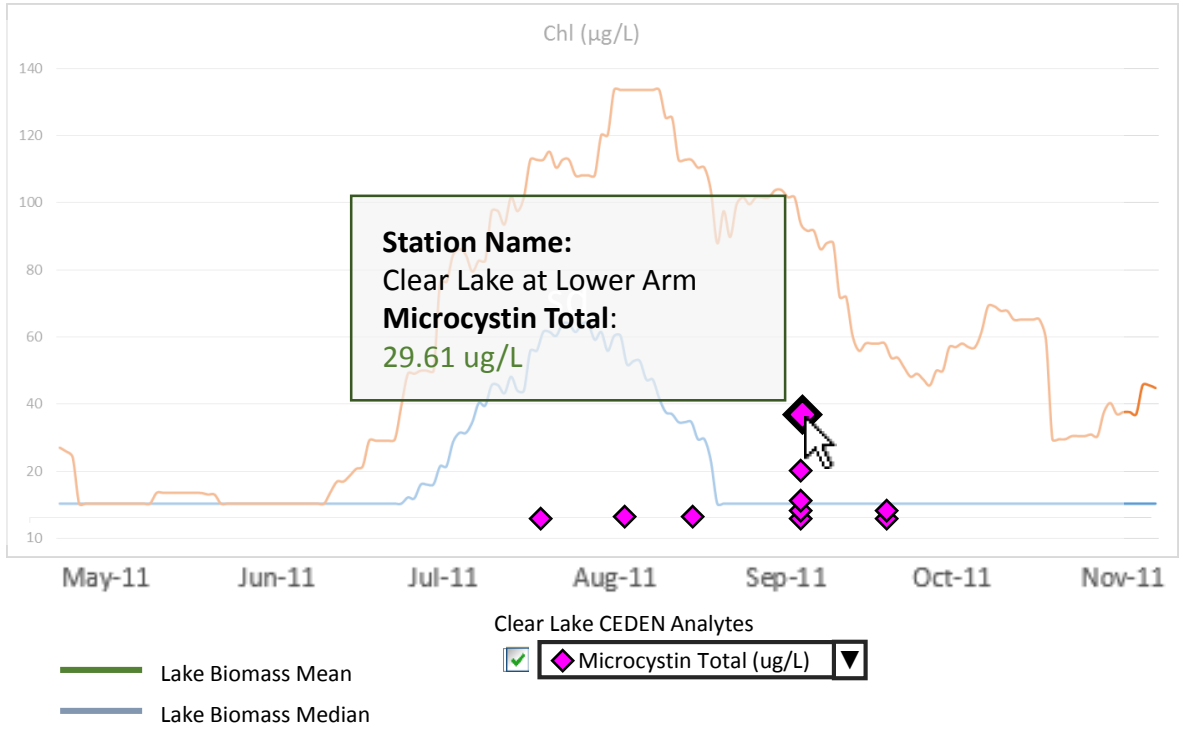
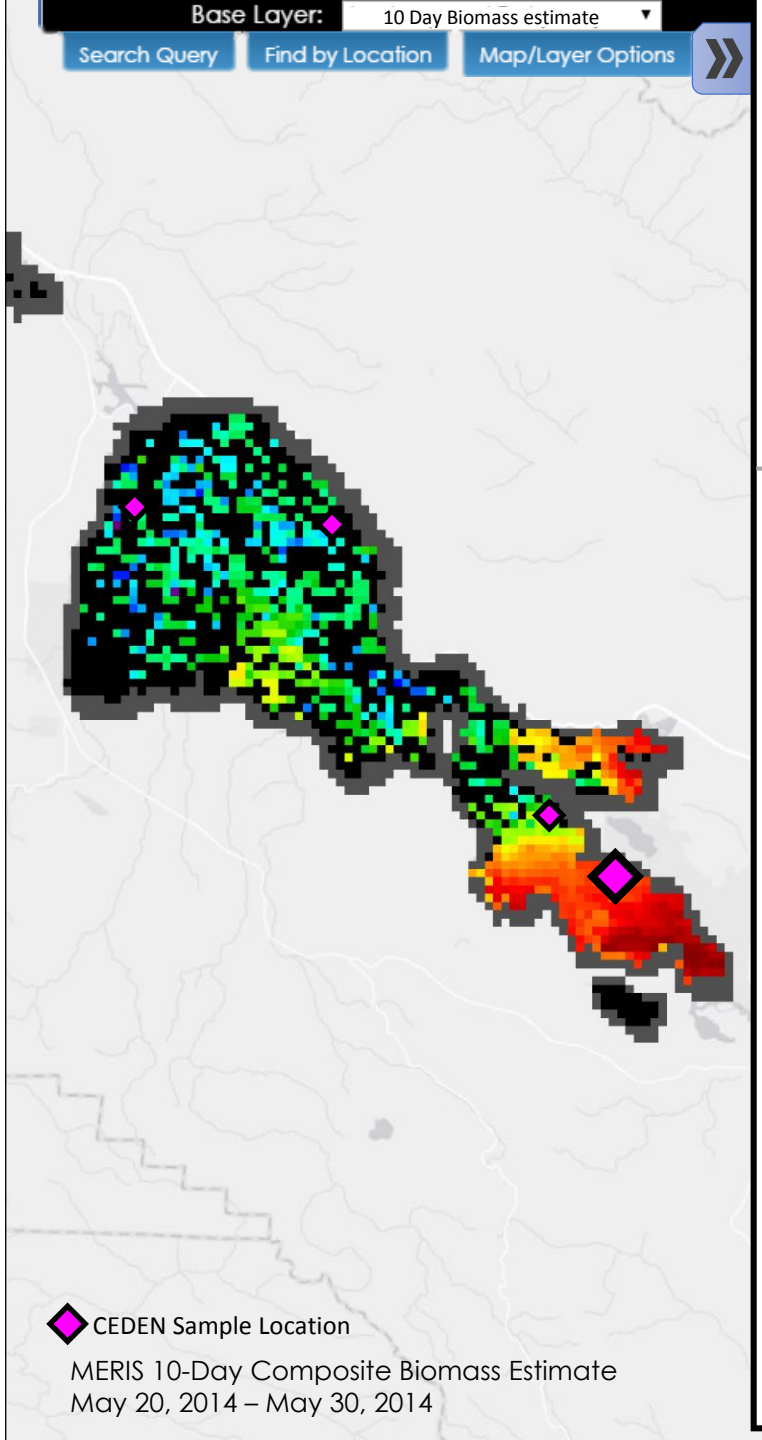
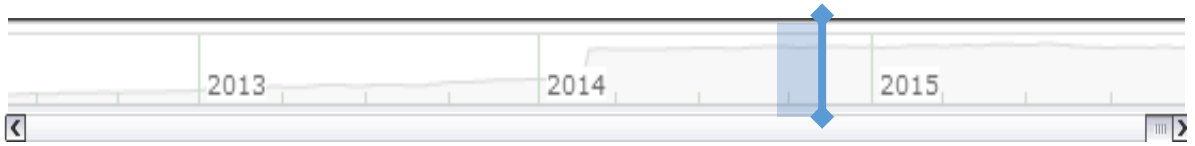




Clear Lake, Lake County, CA

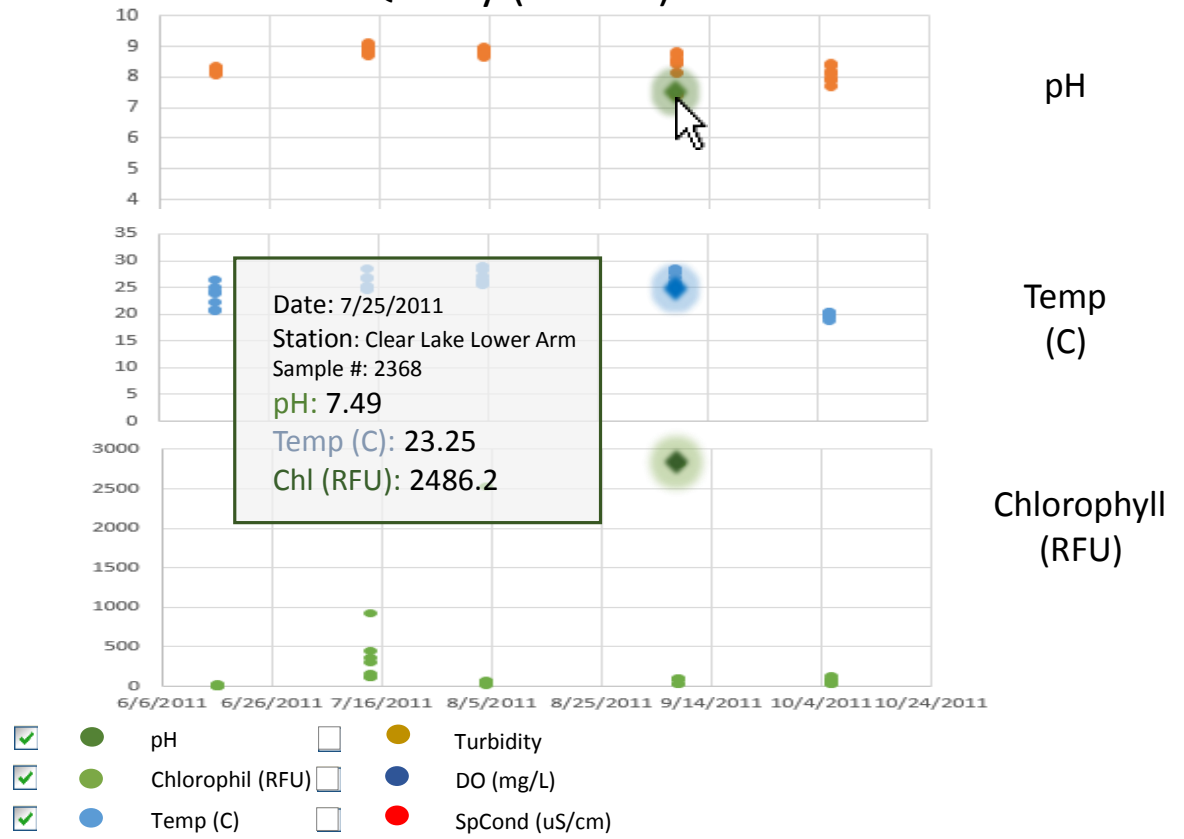
Current Advisory: State and county agencies are urging swimmers, boaters and recreational users to avoid contact with blue-green algae now blooming in Spring Lake located in Spring Lake Regional Park in Santa Rosa, CA. The lake has been posted with advisories warning of any contact with the water because of possible toxins associated with the algae. (Read More)

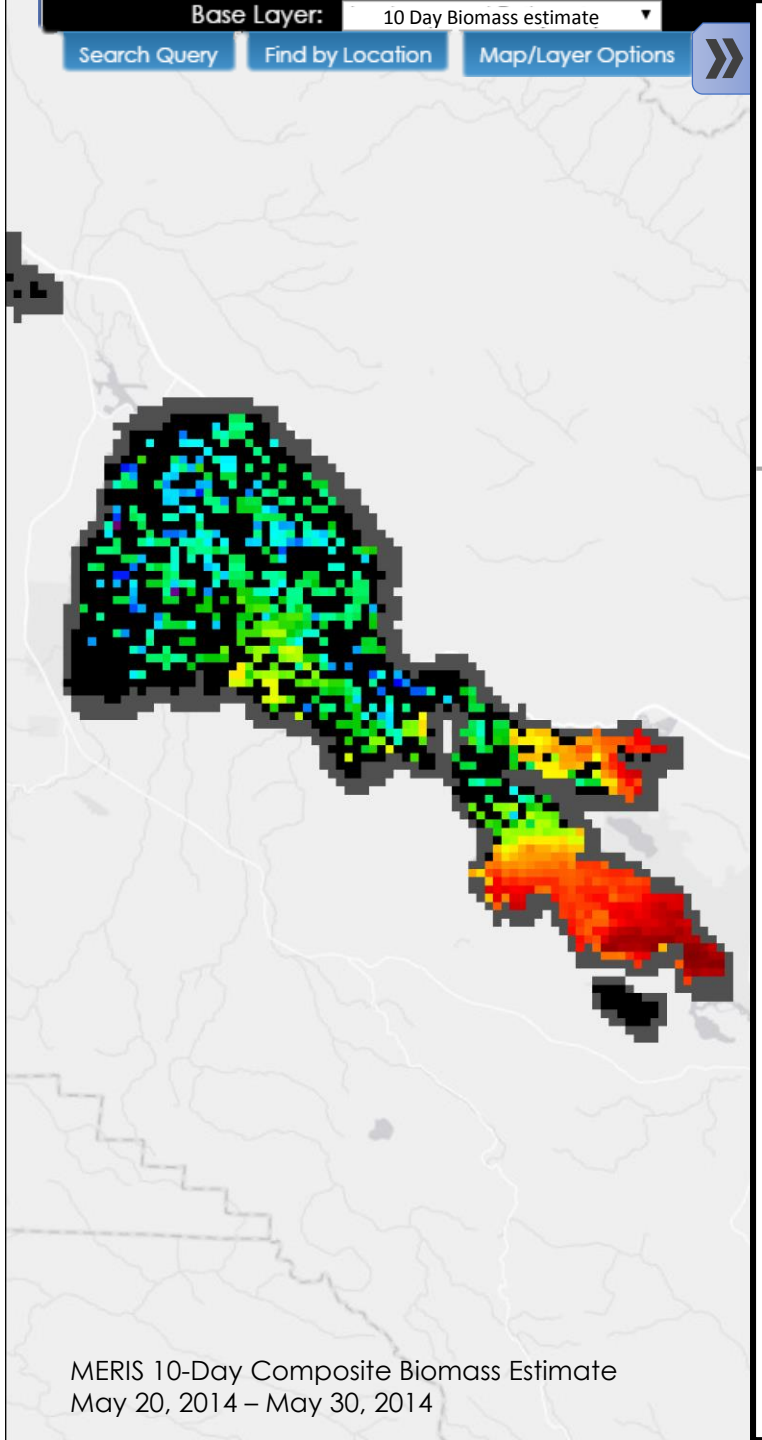


Display Last 10 Days

Trends | **Water Quality** | Data Table

Clear Lake Water Quality (CEDEN)





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2013 2014 2015

Trends | Water Quality | **Data Table**

Select Data for Waterbody

CEDEN Data

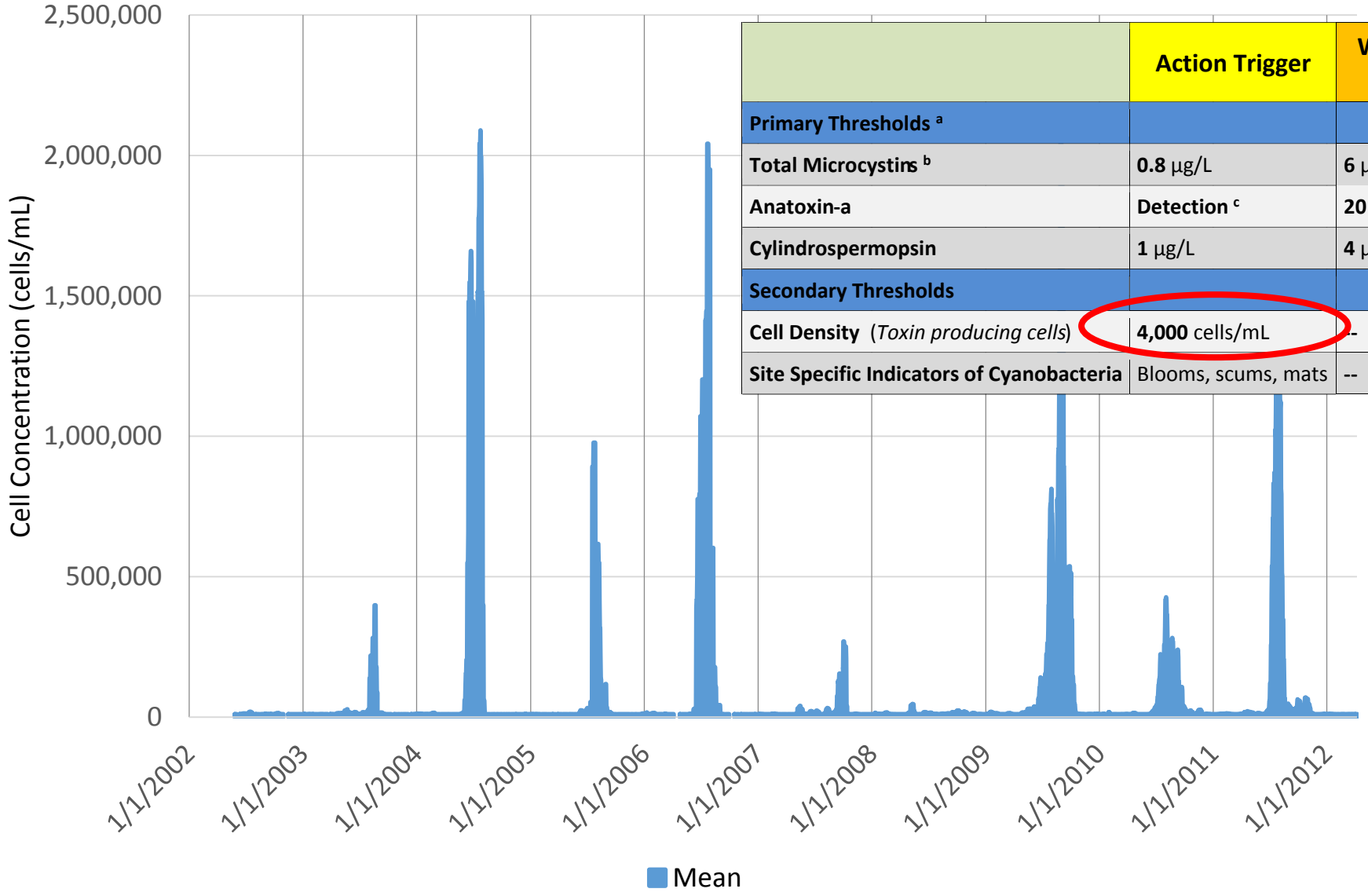
MERIS Analysis Data

From Jan 8, 2016 To Feb 8, 2016 **Download Table**

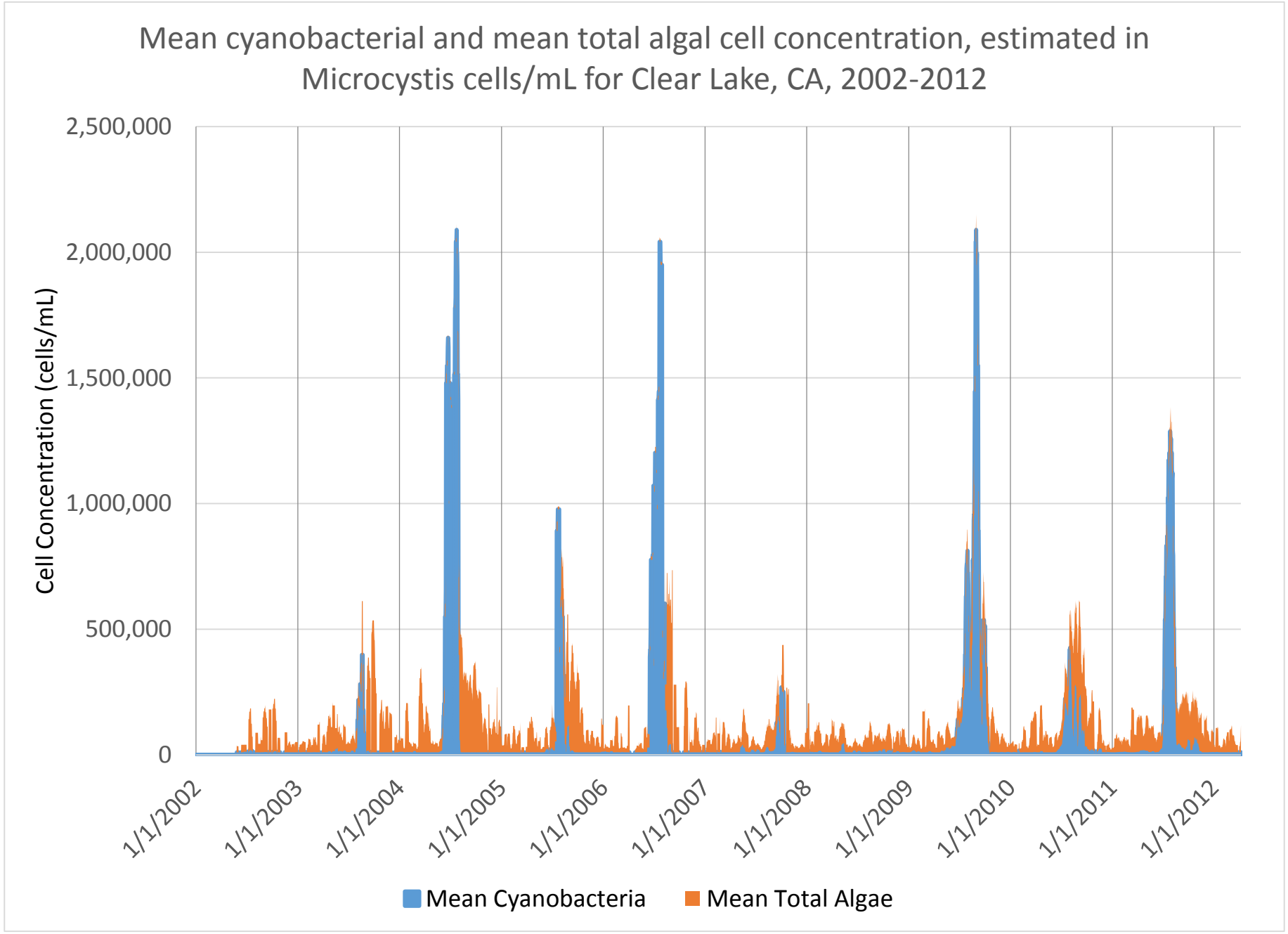
	H	I	J	K	L	M	N	O	P	Q	R
	Pixel Values							ug/L			
	median	mean	perc90	var	min	max	stdev	median	mean	perc90	var
	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
5	12/25/2010	1/3/2011	1638	1638	1	176	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
6	12/26/2010	1/4/2011	1638	1638	1	176	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
7	12/27/2010	1/5/2011	1638	1638	1	176	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
8	12/28/2010	1/6/2011	1638	1638	1	176	5	1	1	24	1	10.41	33.02	10.44	10.41	10.41	10.70	10.41
9	12/29/2010	1/7/2011	1708	1708	1	176	6	1	1	31	1	10.41	33.02	10.45	10.41	10.41	10.80	10.41
10	12/30/2010	1/8/2011	1708	1708	1	176	6	1	1	31	1	10.41	33.02	10.45	10.41	10.41	10.80	10.41
11	12/31/2010	1/9/2011	1674	1674	1	108	5	1	1	30	1	10.41	14.81	10.45	10.41	10.41	10.80	10.41
12	1/1/2011	1/10/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
13	1/1/2011	1/11/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
14	1/2/2011	1/12/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
15	1/3/2011	1/13/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
16	1/4/2011	1/14/2011	1675	1675	1	123	7	1	1	46	1	10.41	16.79	10.46	10.41	10.41	11.13	10.41
17	1/5/2011	1/15/2011	1727	1727	1	137	15	1	1	211	3	10.41	19.38	10.55	10.41	10.41	61.53	10.43
18	1/6/2011	1/16/2011	1727	1727	1	137	15	1	1	211	3	10.41	19.38	10.55	10.41	10.41	61.53	10.43
19	1/7/2011	1/17/2011	1727	1727	1	137	15	1	1	211	3	10.41	19.38	10.55	10.41	10.41	61.53	10.43
20	1/8/2011	1/18/2011	1713	1713	1	147	19	1	1	374	5	10.41	21.80	10.62	10.41	10.41	133.61	10.44
21	1/9/2011	1/19/2011	1713	1713	1	147	19	1	1	374	5	10.41	21.80	10.62	10.41	10.41	133.61	10.44
22	1/10/2011	1/20/2011	1698	1698	1	147	19	1	1	368	5	10.41	21.80	10.62	10.41	10.41	133.61	10.44
23	1/11/2011	1/21/2011	1742	1742	1	147	20	1	1	411	6	10.41	21.80	10.63	10.41	10.41	133.61	10.45
24	1/12/2011	1/22/2011	1742	1742	1	147	20	1	1	411	6	10.41	21.80	10.63	10.41	10.41	133.61	10.45
25	1/13/2011	1/23/2011	1746	1746	1	147	21	1	1	431	6	10.41	21.80	10.63	10.41	10.41	133.61	10.45
26	1/14/2011	1/24/2011	1746	1746	1	147	21	1	1	431	6	10.41	21.80	10.63	10.41	10.41	133.61	10.45
27	1/15/2011	1/25/2011	1722	1722	1	147	17	1	1	281	4	10.41	21.80	10.58	10.41	10.41	133.61	10.44
28	1/16/2011	1/26/2011	1731	1731	1	147	24	1	1	562	8	10.41	21.80	10.68	10.41	10.41	133.61	10.47
29	1/17/2011	1/27/2011	1731	1731	1	147	24	1	1	562	8	10.41	21.80	10.68	10.41	10.41	133.61	10.47
30	1/18/2011	1/28/2011	1715	1715	1	146	20	1	1	418	6	10.41	21.54	10.63	10.41	10.41	133.61	10.46
31	1/19/2011	1/29/2011	1715	1715	1	146	20	1	1	418	6	10.41	21.54	10.63	10.41	10.41	133.61	10.46
32	1/20/2011	1/30/2011	1660	1660	1	146	20	1	1	417	6	10.41	21.54	10.63	10.41	10.41	133.61	10.46
33	1/21/2011	1/31/2011	1576	1576	1	146	20	1	1	417	6	10.41	21.54	10.63	10.41	10.41	133.61	10.45

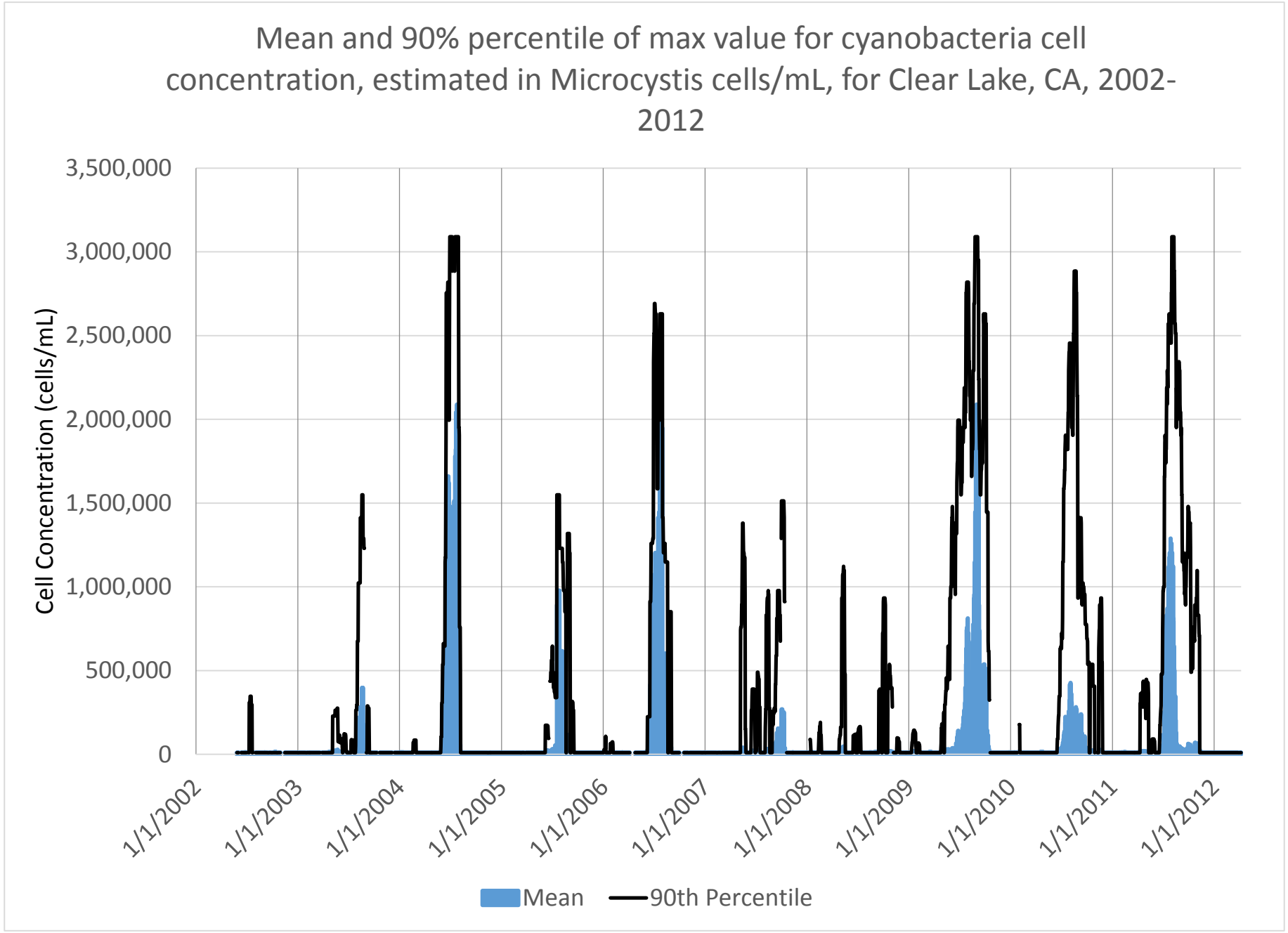
Example of Historic Satellite Data for Clear Lake

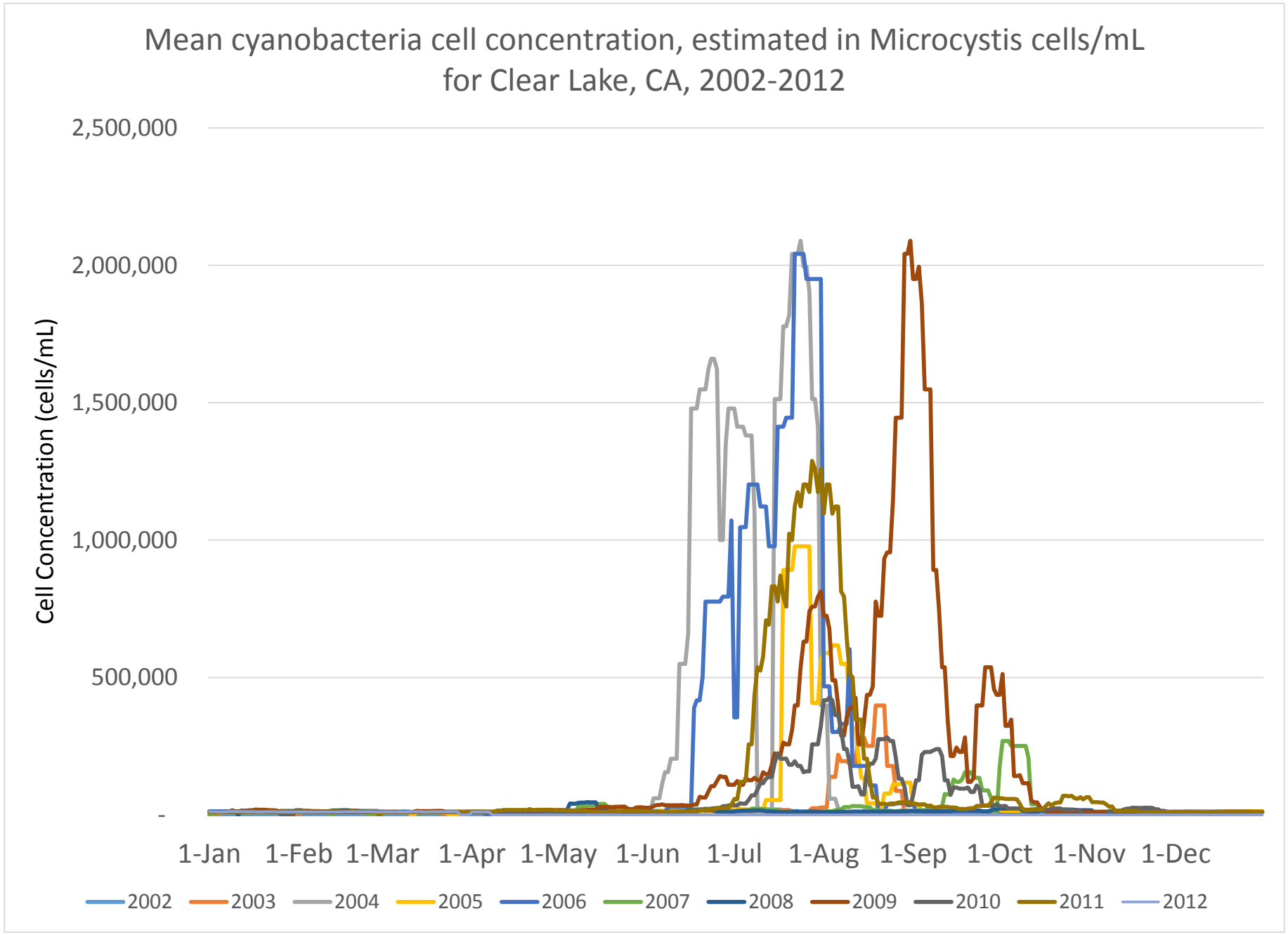
Mean cyanobacteria cell concentration, estimated in Microcystis cells/mL for Clear Lake, CA, 2002-2012

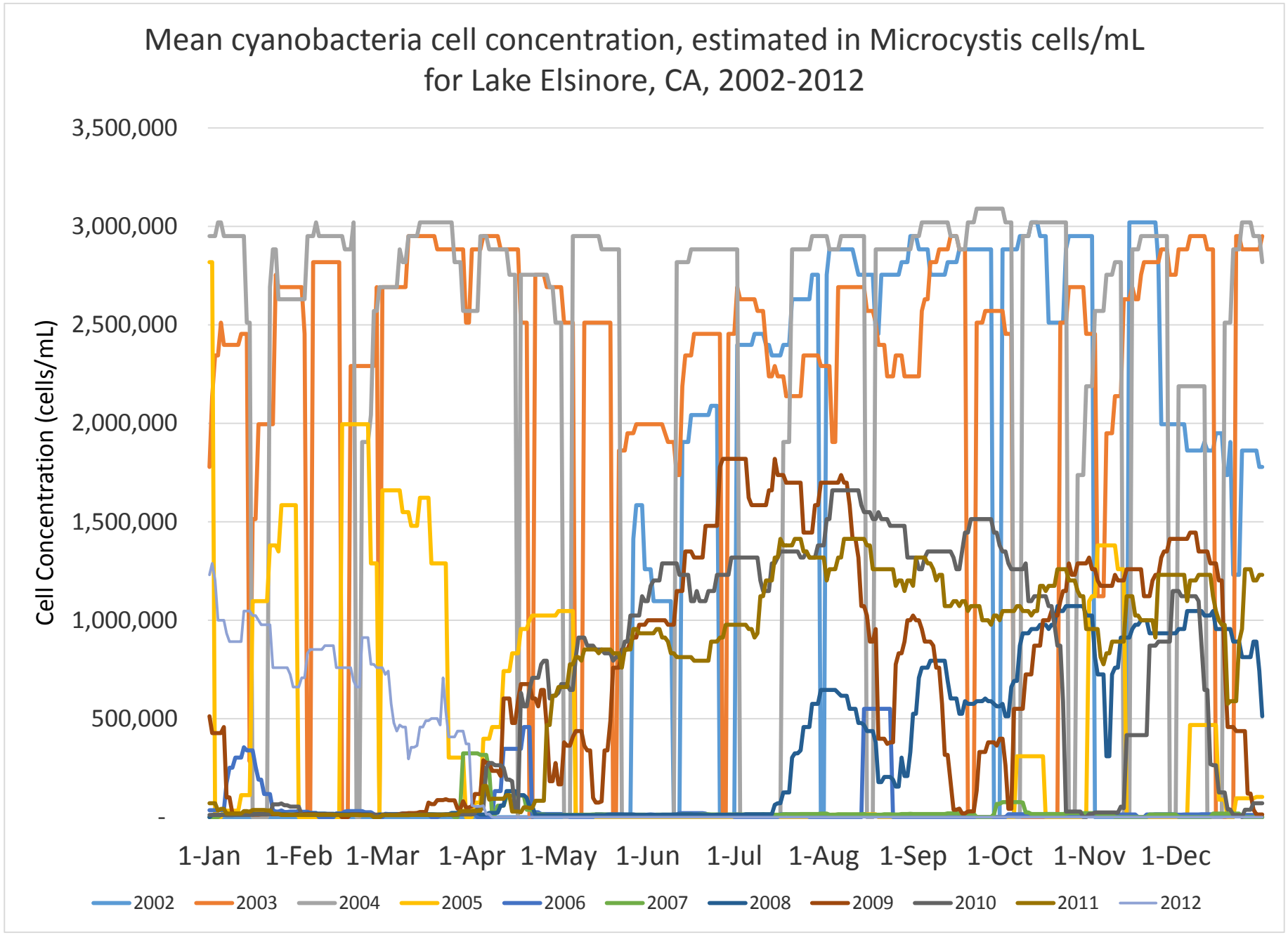


	Action Trigger	Warning TIER 1	Danger TIER 2
Primary Thresholds [a]			
Total Microcystins [b]	**0.8** µg/L	**6** µg/L	**20** µg/L
Anatoxin-a	**Detection** [c]	**20** µg/L	**90** µg/L
Cylindrospermopsin	**1** µg/L	**4** µg/L	**12** µg/L
Secondary Thresholds			
Cell Density (*Toxin producing cells*)	**4,000** cells/mL	--	--
Site Specific Indicators of Cyanobacteria	Blooms, scums, mats	--	--


Mean cyanobacterial and mean total algal cell concentration, estimated in Microcystis cells/mL for Clear Lake, CA, 2002-2012
Cell Concentration (cells/mL)
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1/1/2002
1/1/2003
1/1/2004
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
Mean Cyanobacteria
Mean Total Algae

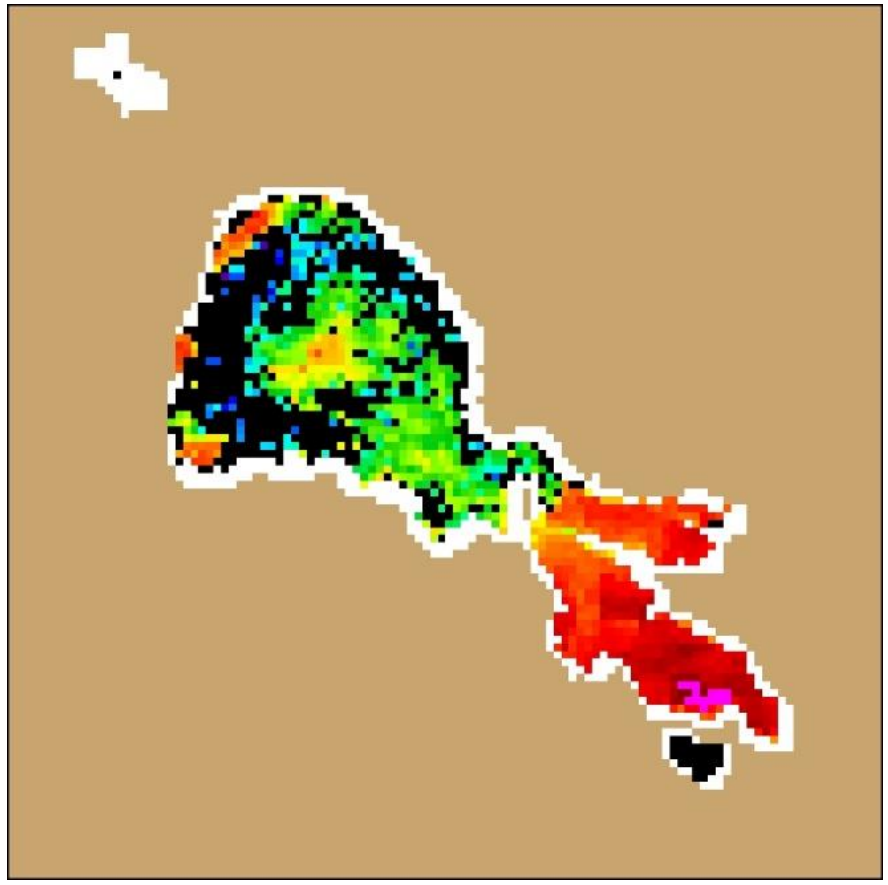

Mean and 90% percentile of max value for cyanobacteria cell concentration, estimated in Microcystis cells/mL, for Clear Lake, CA, 2002-2012
Cell Concentration (cells/mL)
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1/1/2002
1/1/2003
1/1/2004
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
Mean
90th Percentile


Mean cyanobacteria cell concentration, estimated in Microcystis cells/mL for Clear Lake, CA, 2002-2012
Cell Concentration (cells/mL)
2,500,000
2,000,000
1,500,000
1,000,000
500,000
-
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012


Mean cyanobacteria cell concentration, estimated in Microcystis cells/mL for Lake Elsinore, CA, 2002-2012
Cell Concentration (cells/mL)
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
-
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

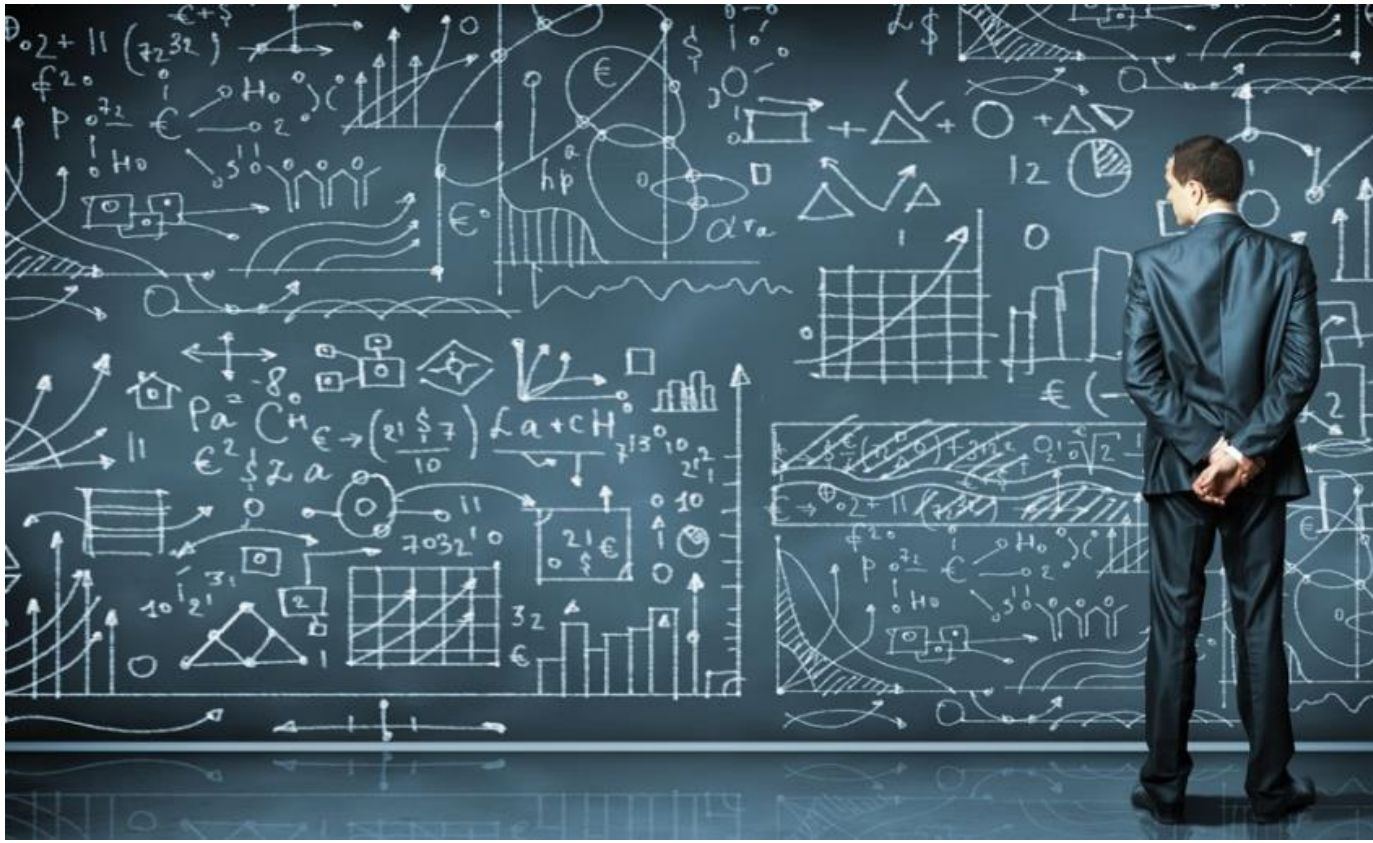
Satellites- What They Can't Do

- Cyano blooms can be detected…but…
  - Clouds block images
  - Not very sensitive at low concentrations
  - False positives can occur
  - Also measures non-toxin producing cyanos
  - Don't measure toxin levels
  - No direct comparisons to HAB thresholds
  - Limited to large lakes (currently)



Further Research Needed

- Satellite data will be available to compare to:
  - Nutrients
  - Algae
  - Water temp
  - Weather
  - Inflow/lake levels
  - Geology
  - Etc.



Questions?

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