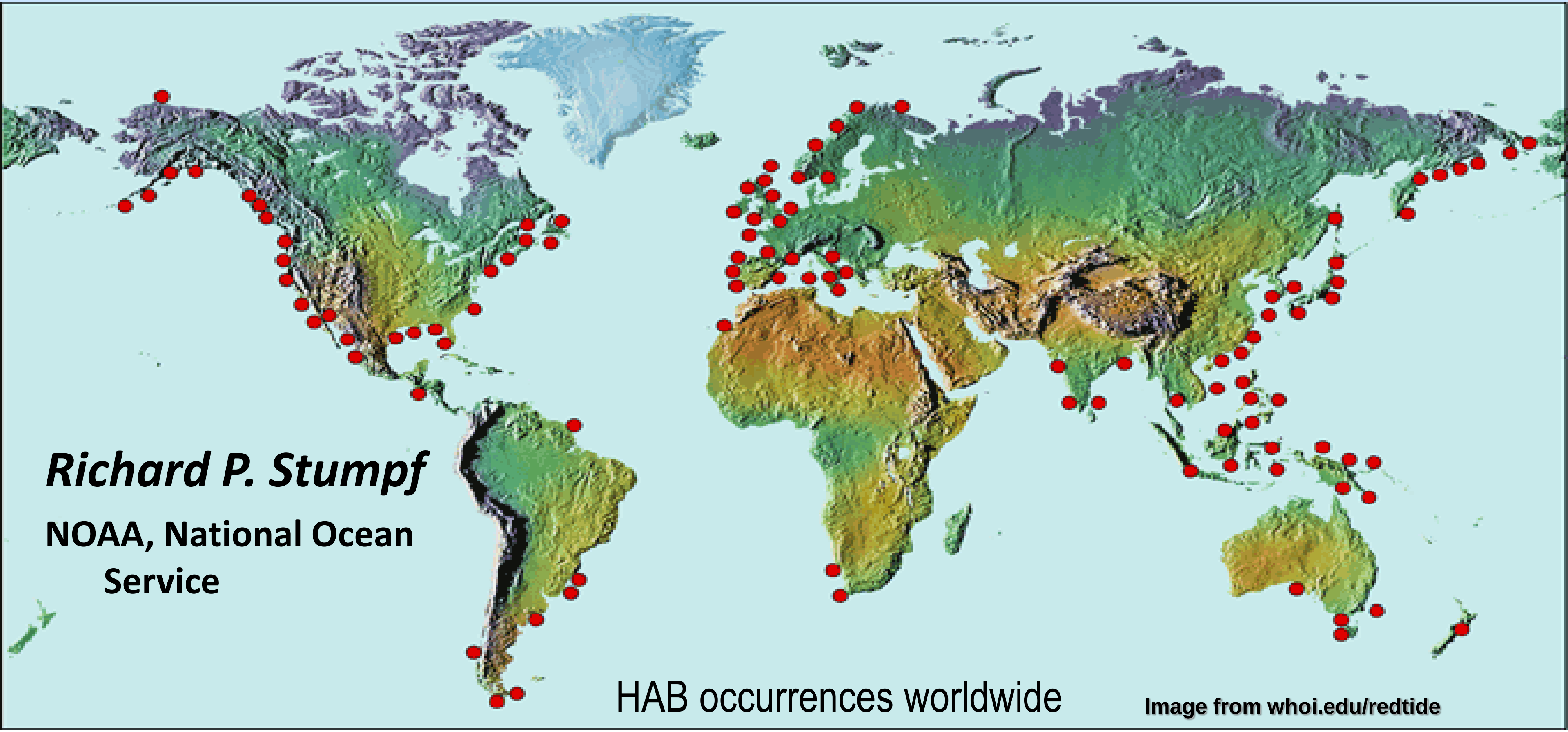
Harmful Algal Blooms (HABs) 2 methods



Richard P. Stumpf

NOAA, National Ocean Service

Remote Sensing for HAB Detection: Does the Bloom Change Water Color?

Yes? Optical techniques

- Can distinguish some bloom types in case 1 water
  - Difficult in coastal areas due to sediment and CDOM
- Use absorption, backscatter, and spectral shape, relative patterns
- Complements ecological detection techniques
- Many blooms are not unique (Pn is a diatom in a diatom system)

Bloom Ecology techniques, **Not just chl *a***

- Does it dominate/correlate biomass?
- Seasonality of blooms
- Relationship to environmental conditions

No? Physical Forcing

- Association between bloom and physical features, **use of SST**
  - (e.g., fronts, upwelling, wind events)
- Not direct bloom detection, difficult to view extent of bloom

Karenia can make strong blooms (major source of primary production on west Florida shelf). Pure *Karenia* blooms are great for Ocean Color Remote Sensing, gave illusion that “red tides” are easily solvable.

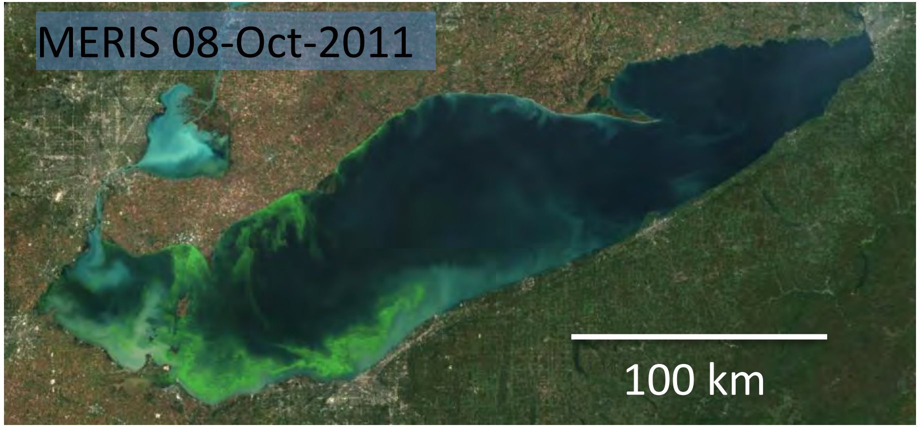
If you want a "red tide": *Nocticula*.
Visually striking; usually harmless, sometimes causes fish kills

Cyanos in many areas

Baltic

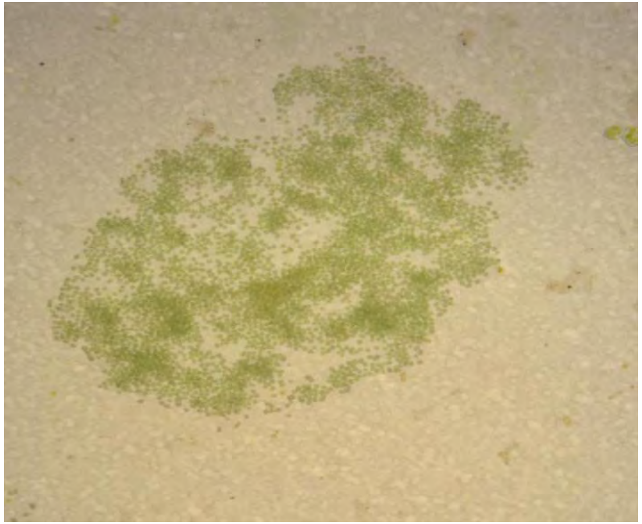
Large lakes (e.g. Lake Erie)

Small lakes

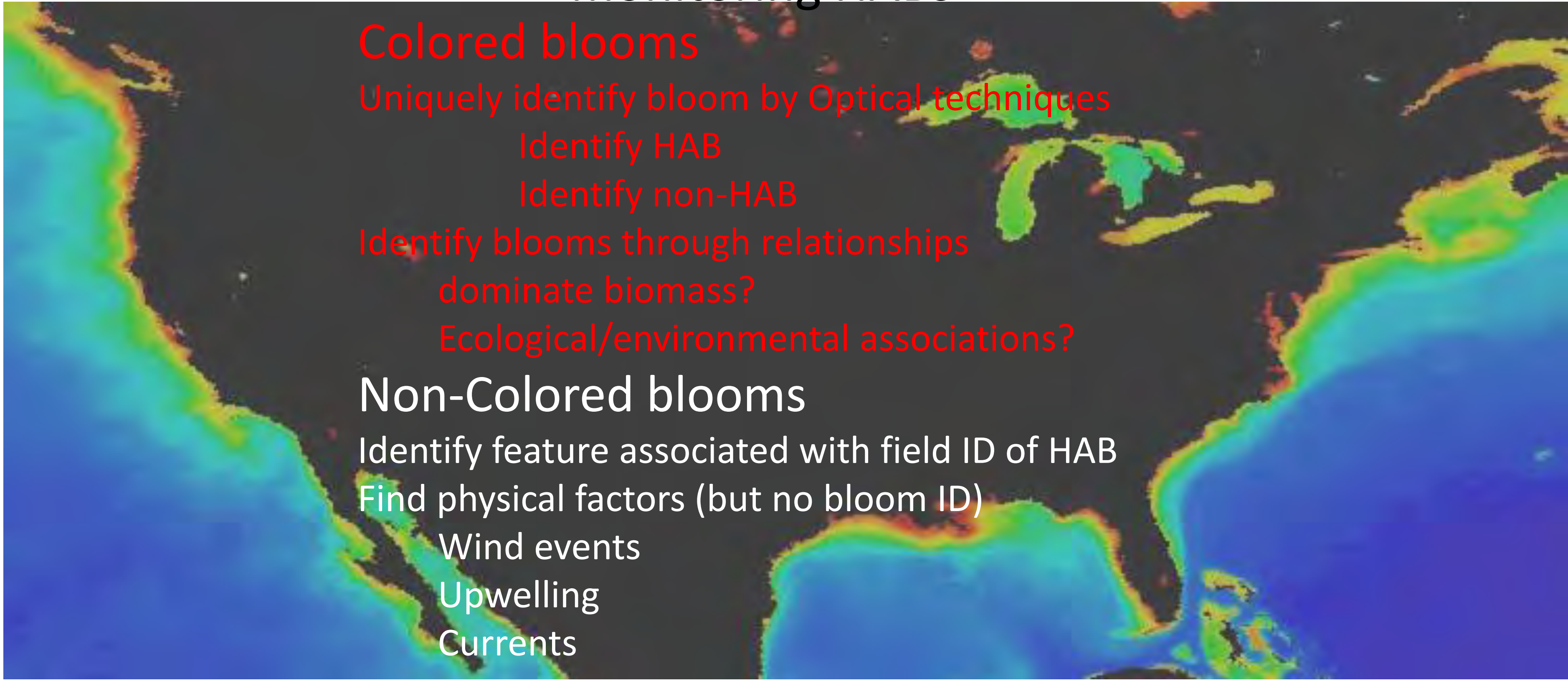


Microcystis as scum example

- Aug 2009, Lake Erie



Remote Sensing & Optical methods for detecting and monitoring HABs



Colored blooms

Uniquely identify bloom by Optical techniques
- Identify HAB
- Identify non-HAB

Identify blooms through relationships
- dominate biomass?
- Ecological/environmental associations?

Non-Colored blooms

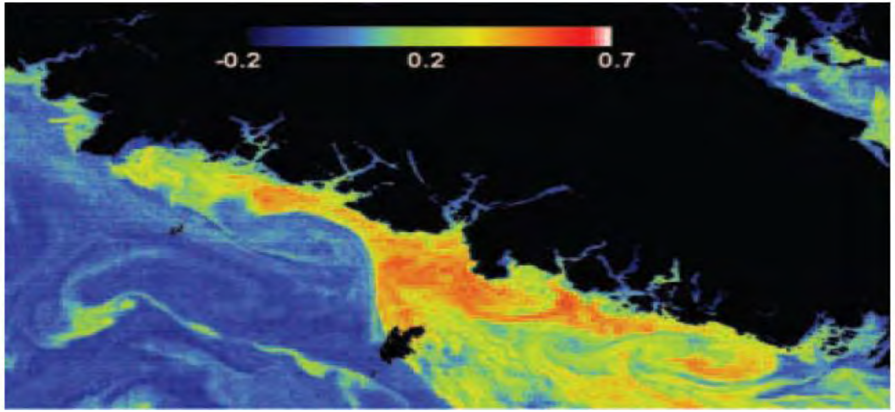
Identify feature associated with field ID of HAB

Find physical factors (but no bloom ID)
- Wind events
- Upwelling
- Currents

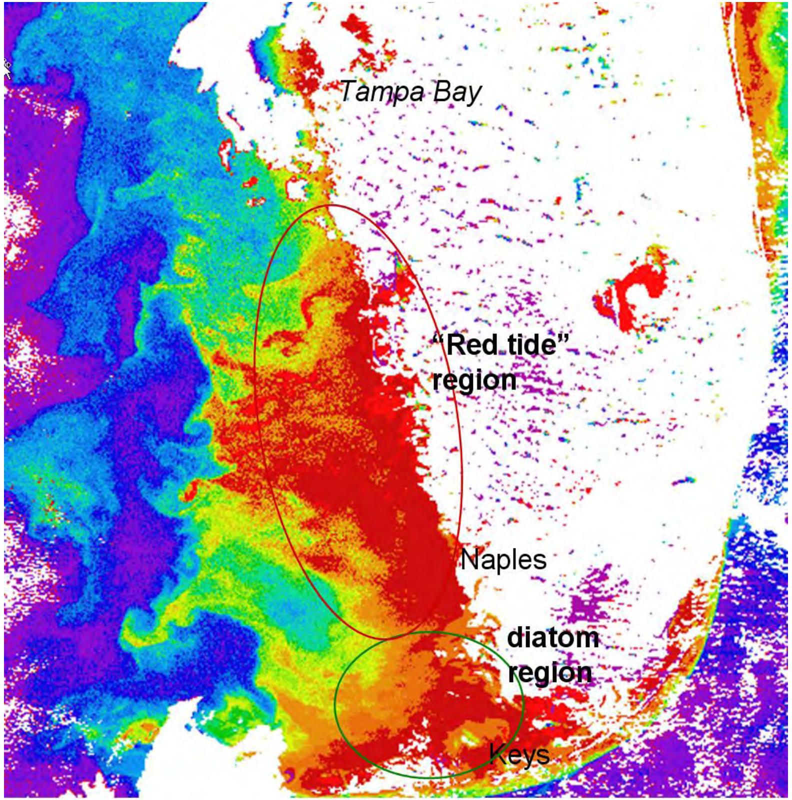
Chlorophyll

Generally not useful simply as chlorophyll

(Chlorophyll may be inferred from FLH)



Gower et al., 2005, MERIS FLH

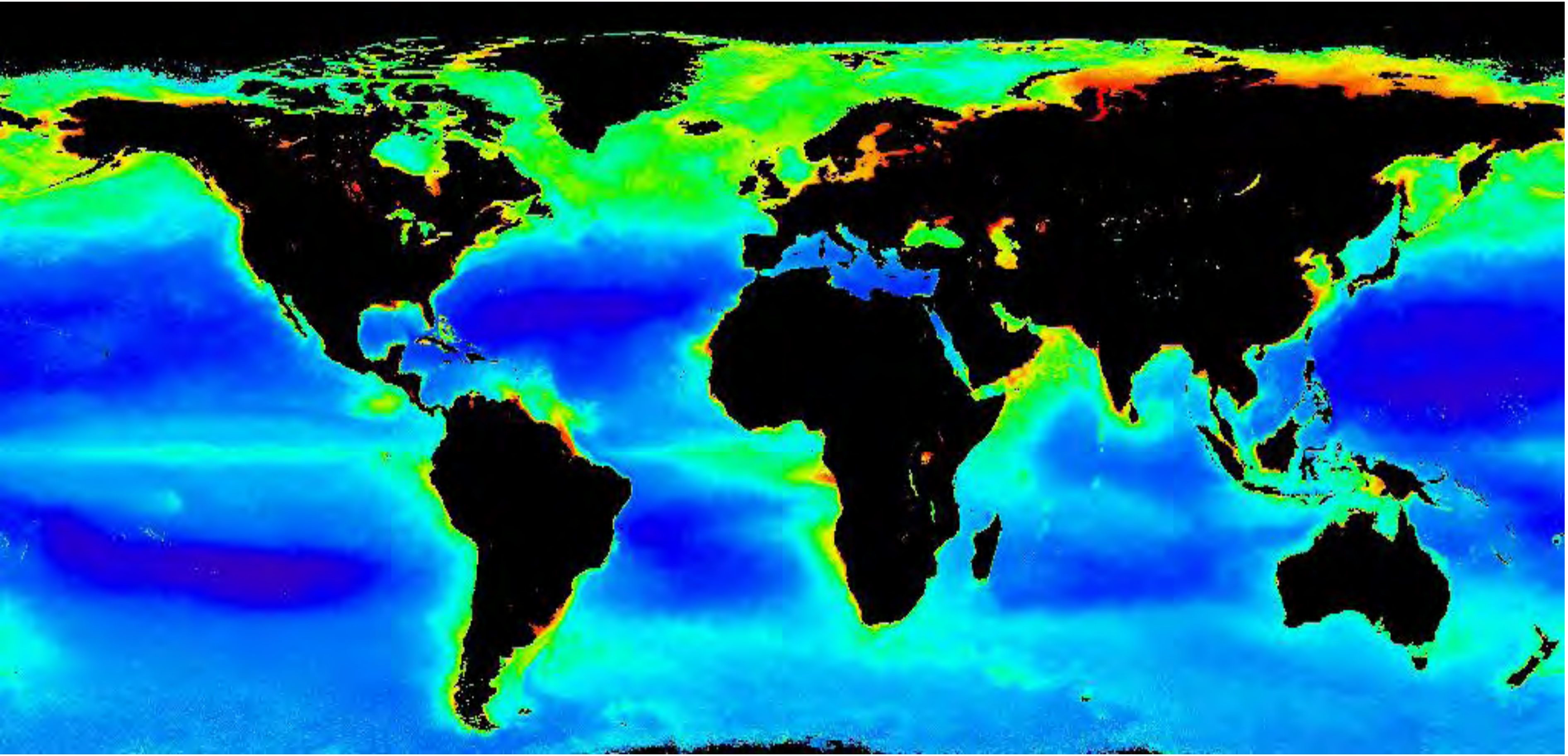


Exceptions, chlorophyll threshold is useful:

"red tide" in some bays in Japan (various species)

Brown tide in US, *Aureococcus*, *Aureoumbra*

Why not chl-a?

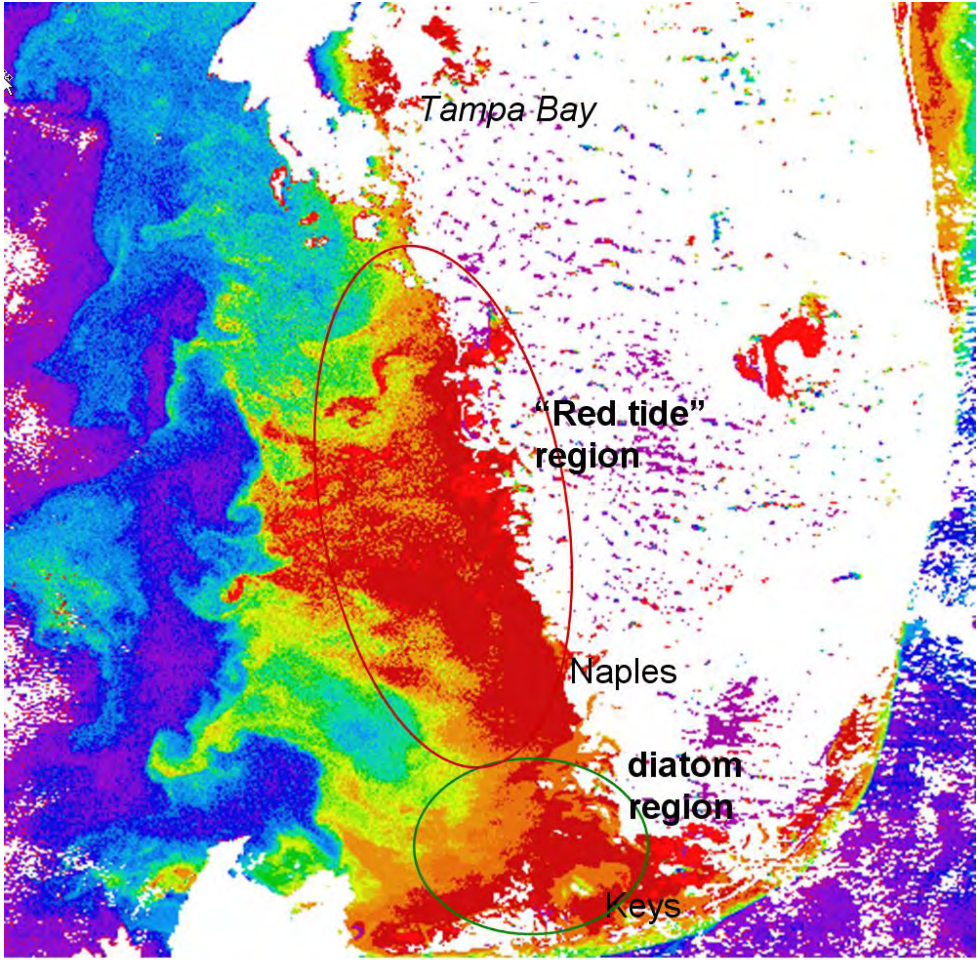


Chlorophyll is usually used in an anomaly or “delta” technique

Qualitative anomaly.

This area is a “red tide” because we infer concentration is much higher than normal.

Most “chlorophyll” HABs are interpreted anomalies



Anomaly method can be quantified

Anomaly finds *New Blooms*

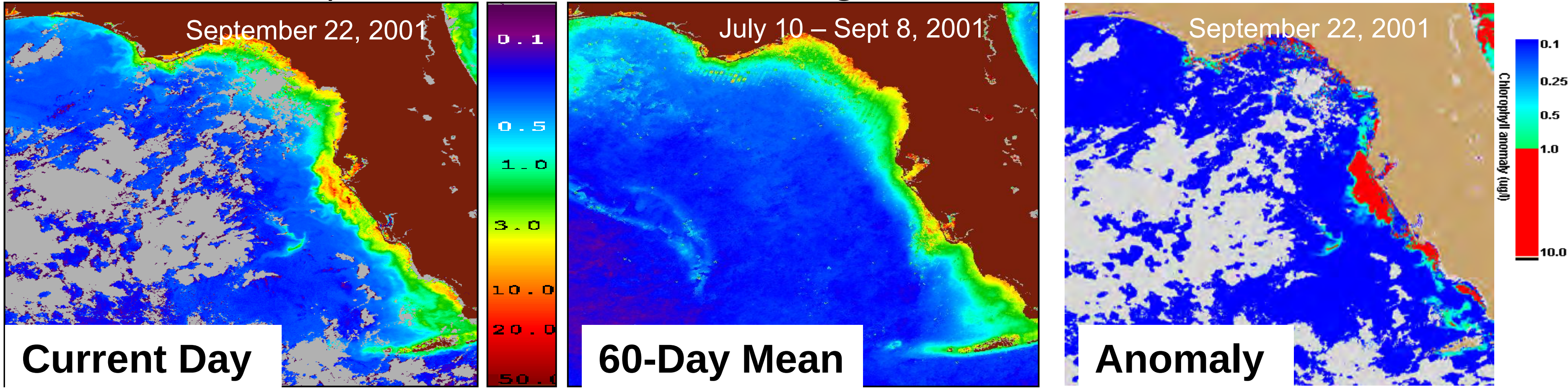
Demonstrated as effective for *Karenia brevis*

- *K. brevis* dominates biomass in late summer
- Better in case 2 water (with turbidity) than optical algorithms

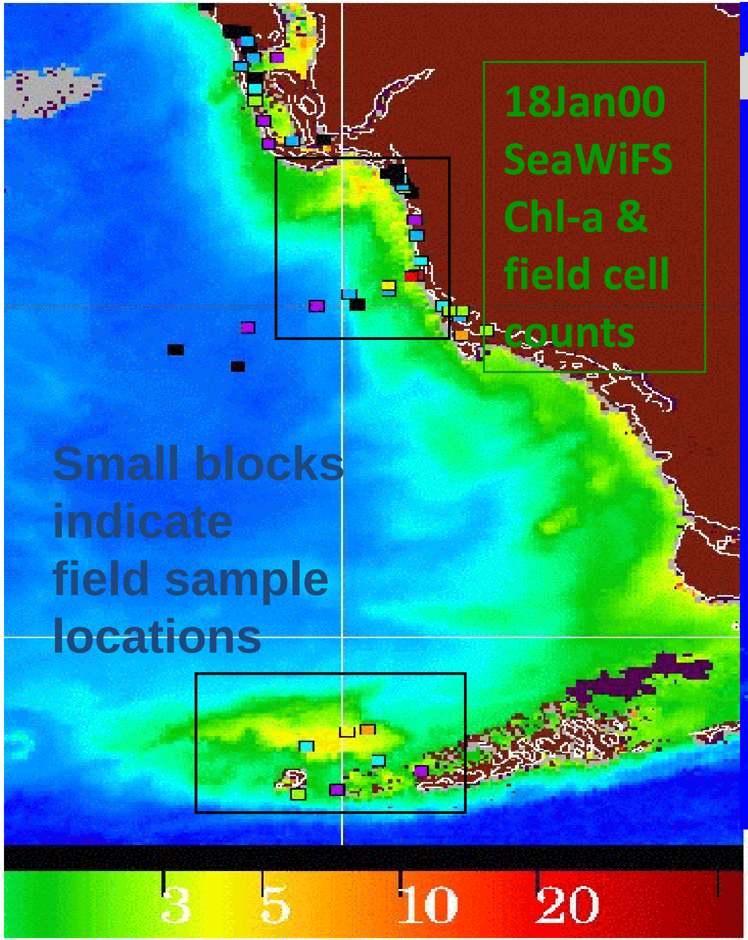
Accuracy > 80% during summer and fall

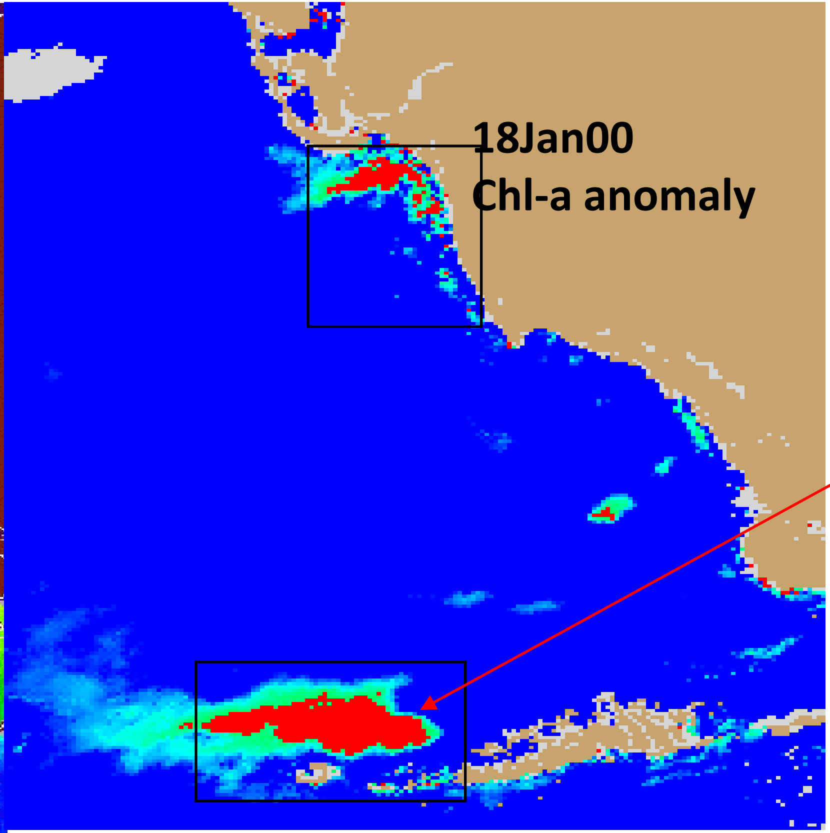
- False positives common, False negatives rare.

New Blooms



HAB Detection from SeaWiFS



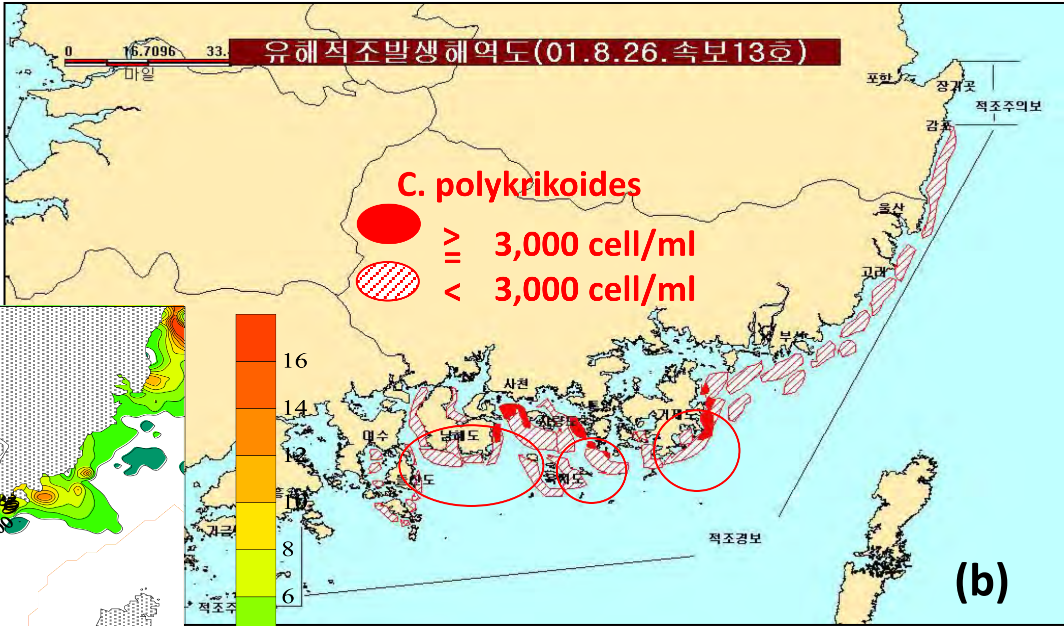


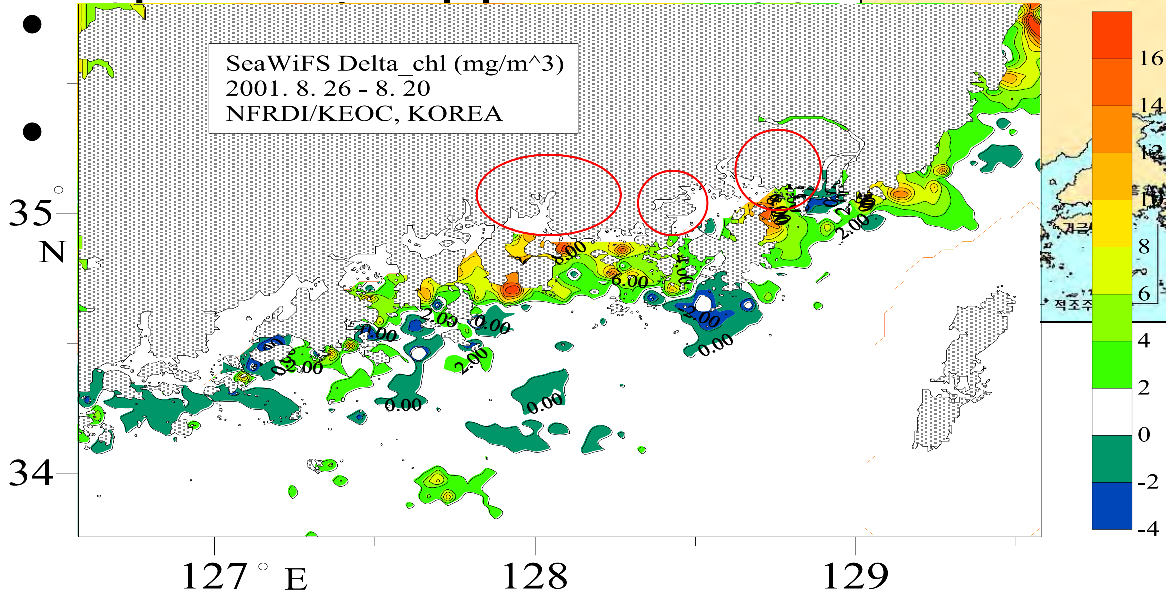
First HAB detected from satellite prior to field

- Bloom extent not identified by field sampling, but satellite provides full size

Change in chlorophyll, example for Korea

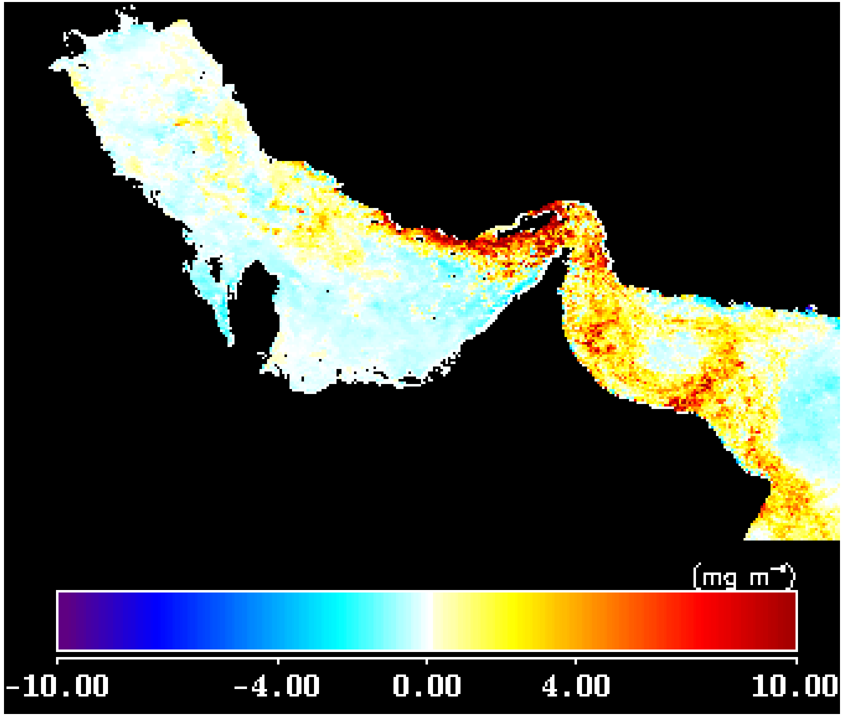
- Suh et al., 2004



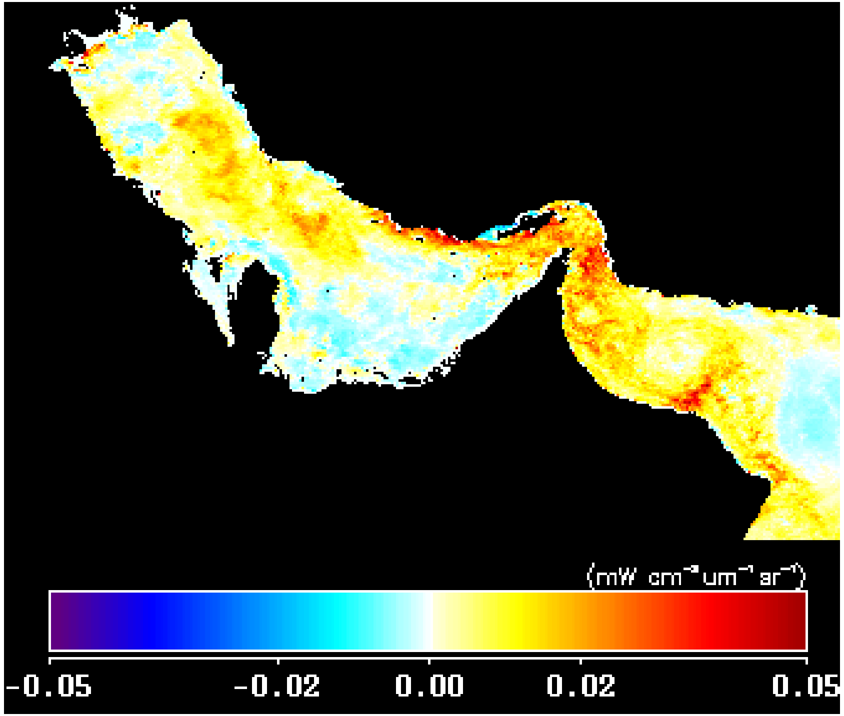


Persian Gulf during *Cochlodinium* bloom

MODIS Chlorophyll anomaly, Nov 2008

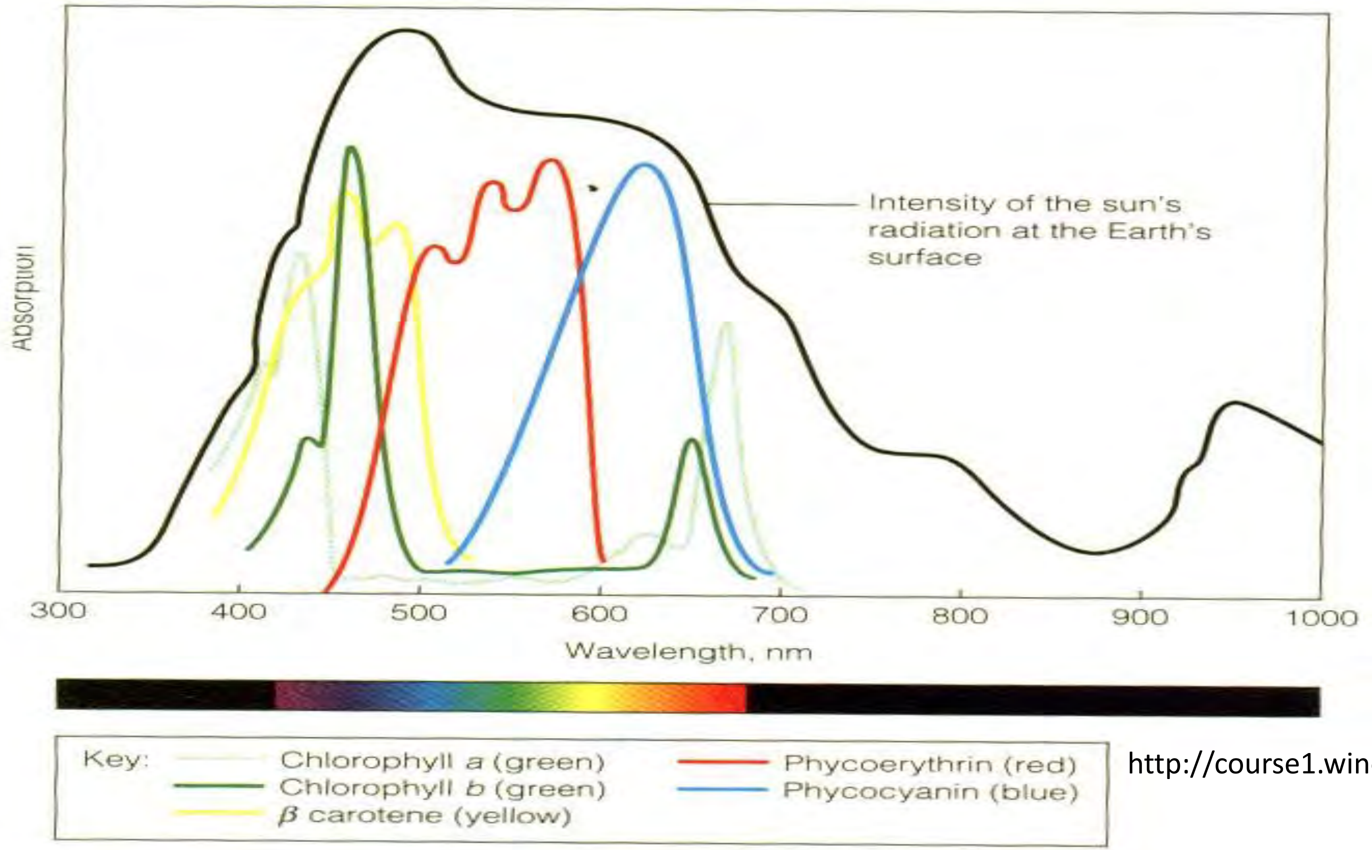


FLH anomaly



From: R. Kudela UCSC

Spectra: various pigments in algae



S. Berg Winona State
http://course1.winona.edu/sberg/Fac_sb.htm

Analytical algorithms

- Phycocyanin, from Simis, Gons and others
- QAA for absorption (Lee and others)
  - Solve for absorption at MODIS or SeaWiFS bands
- With good data, quite effective; demonstrated to work with radiometry; satellite depends on atmospheric correction

Analytical optics, example from cyanobacteria

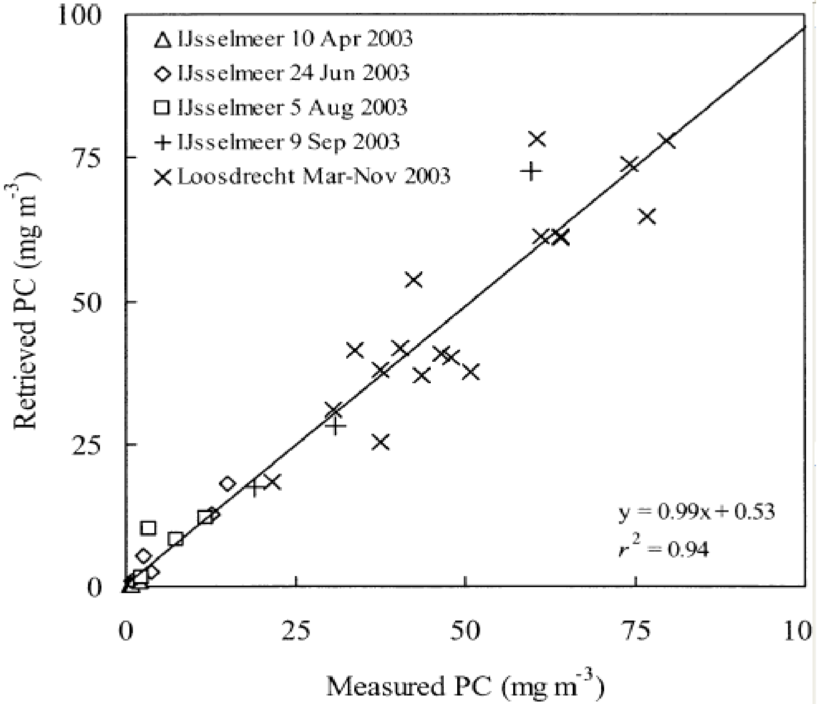
- Simis et al. (L&O, 2005) Netherlands, MERIS

Solve for ***a_{pc}(620)*** from

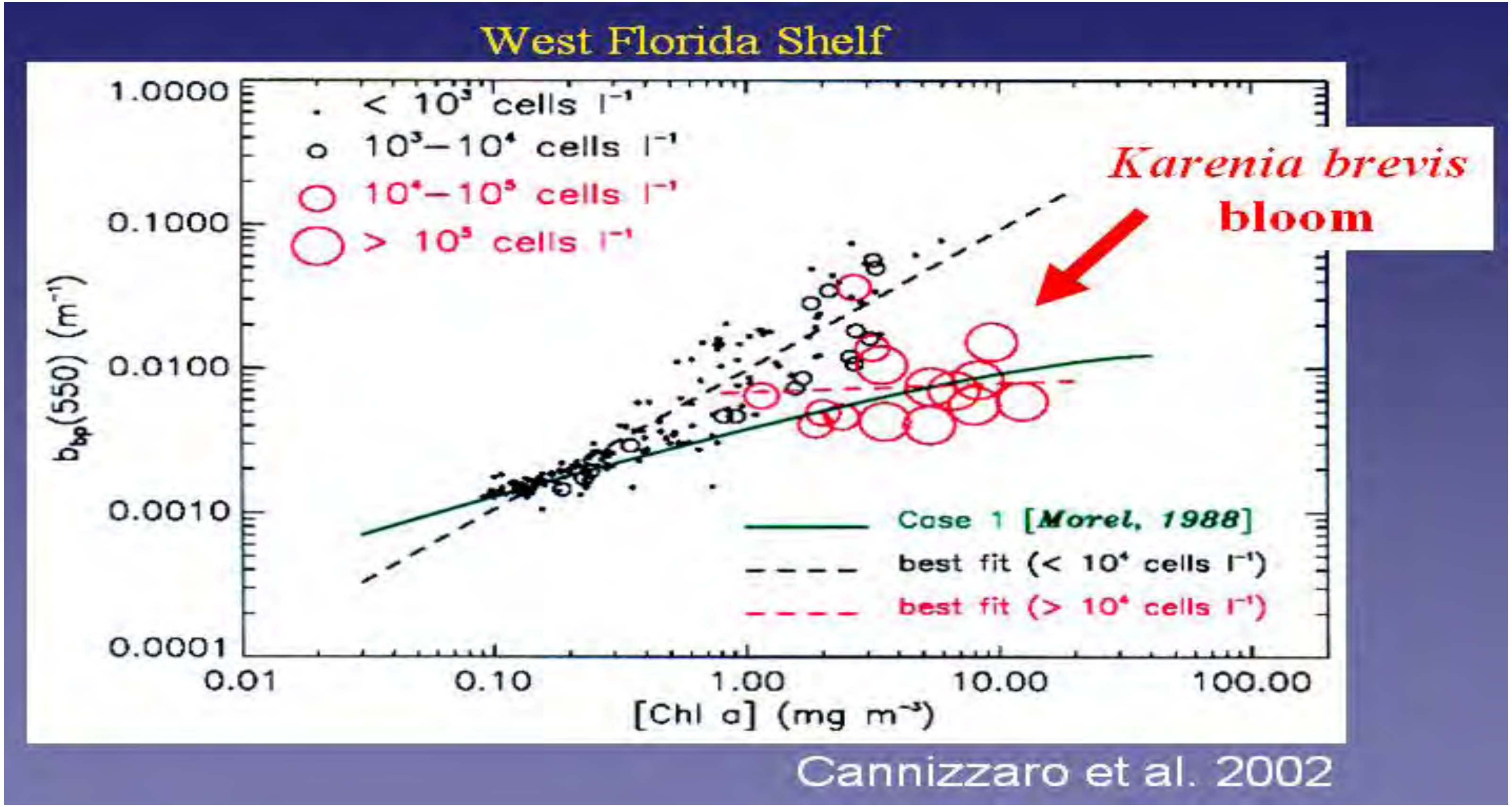
R(709)/R(620)

With ***b_b, a_w , a_{phi}***

$$[PC] = a(620)_{pc}/a^*_{pc}(620)$$



Empirical, backscatter against absorption, example from *Karenia*, less scatter from cells and from cellular detritus



Spectral shape algorithms

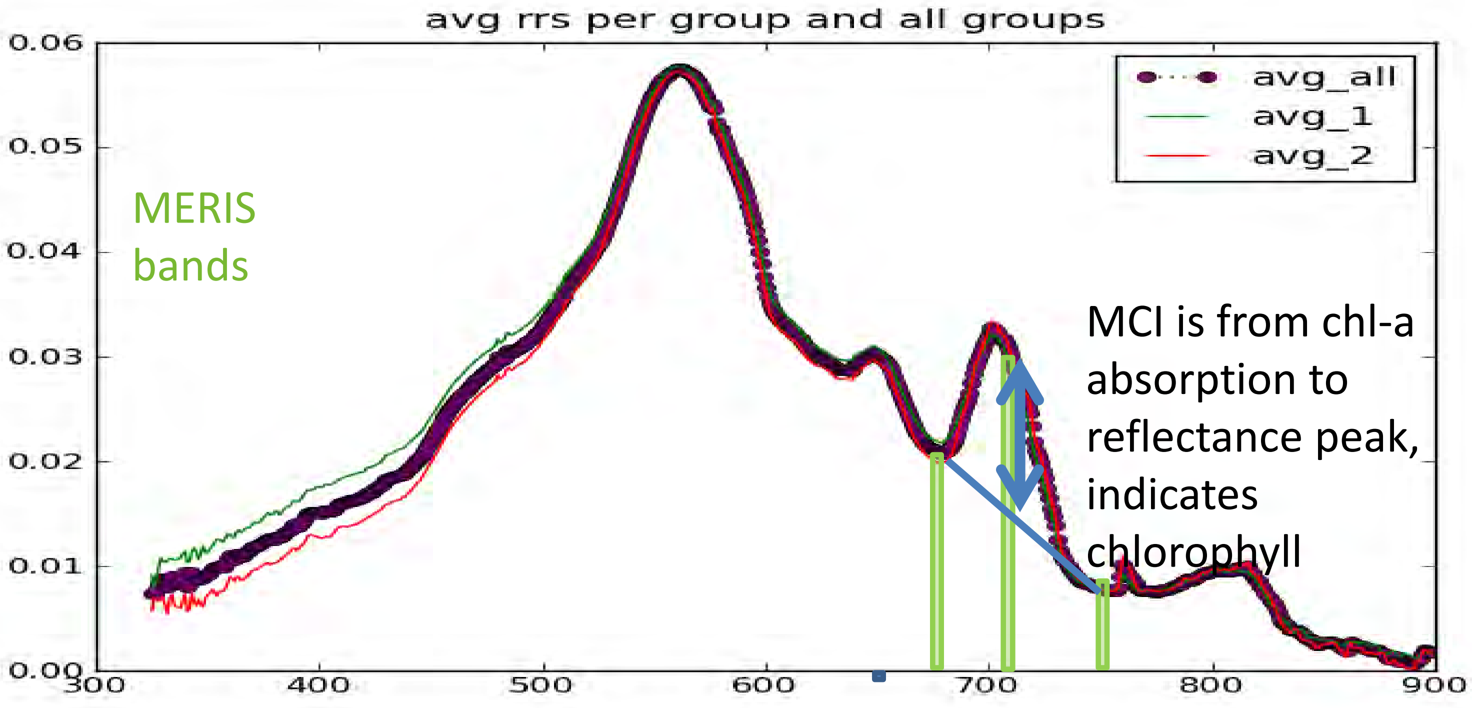
MCI on MERIS (Gower 2005); (quantify by Binding 2011)

CI on MERIS (Wynne et al., 2010)

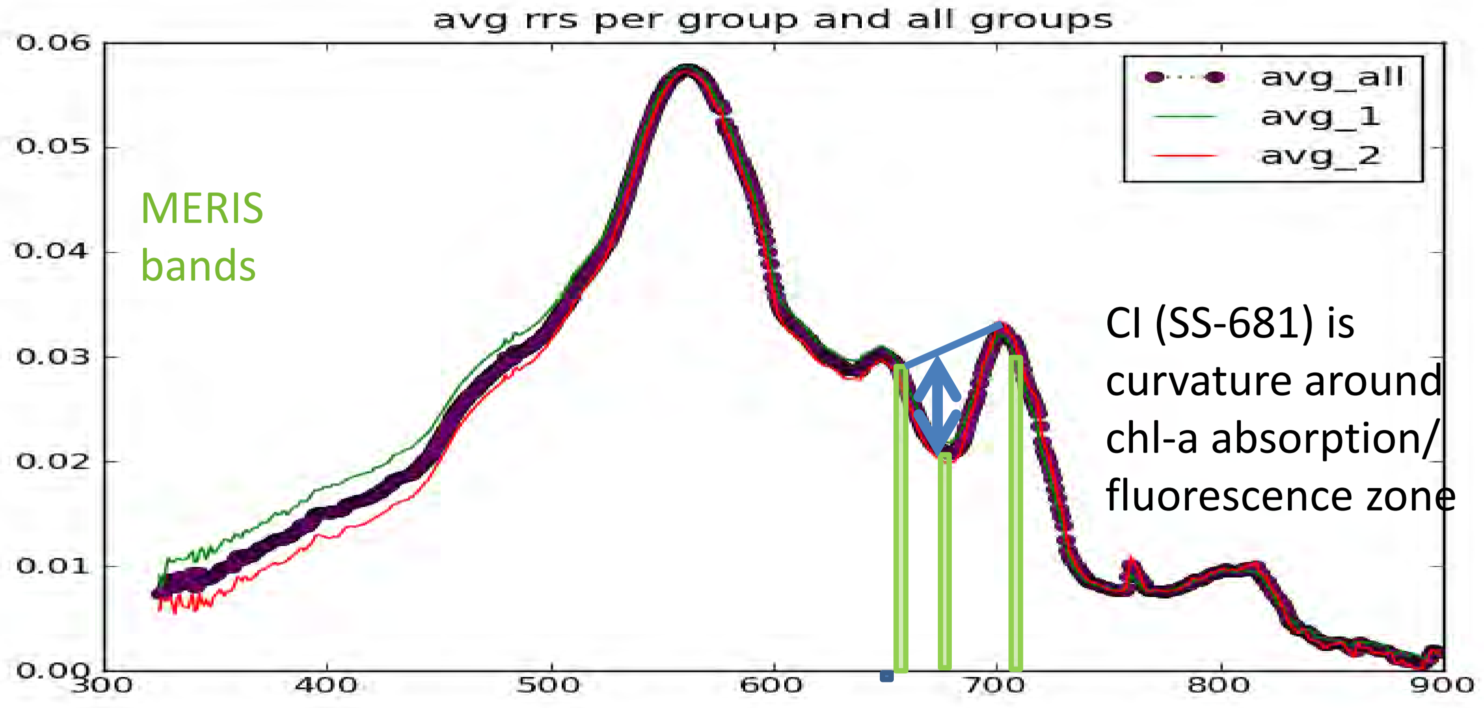
FLH MODIS (applied to a HAB, Hu et al., 2008)

Other shape algorithms (SeaWiFS or MODIS; Tomlinson et al., 2010)

MCI determined at red-edge, related to chlorophyll

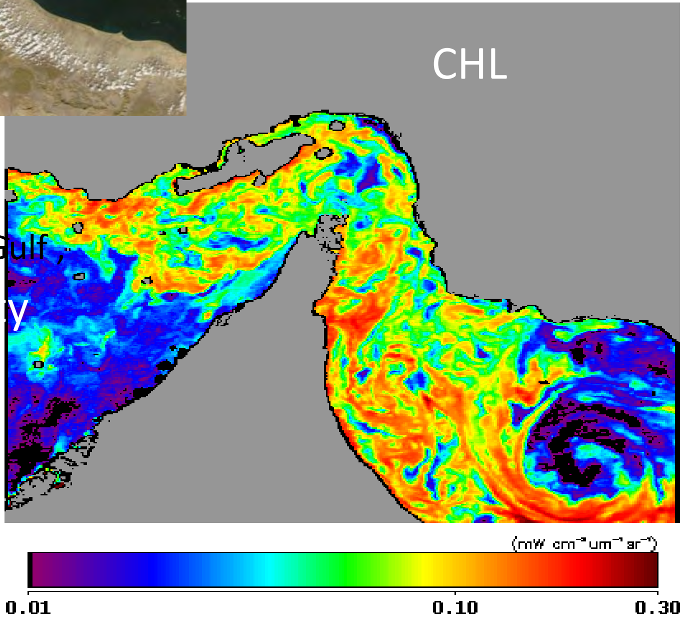


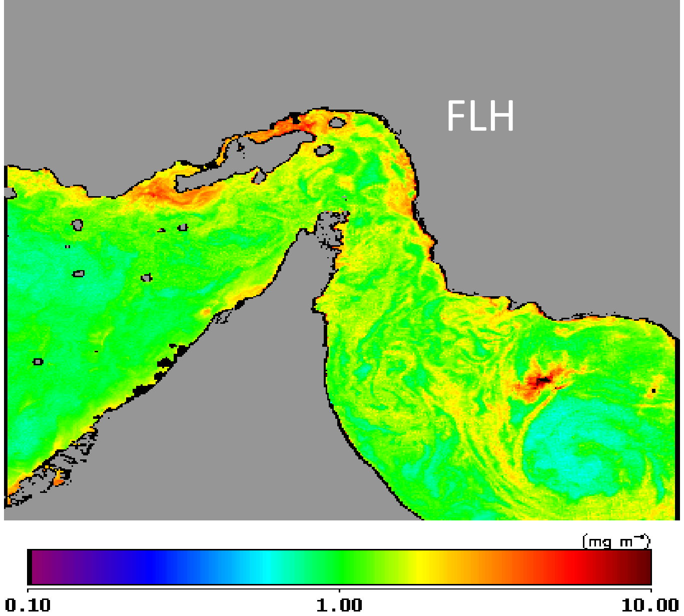
CI/SS681, intense blooms, more cyano sensitive

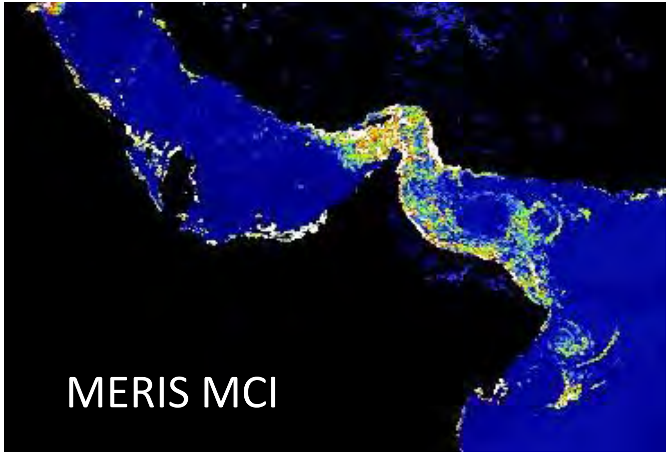


MODIS 19 November 2008;
Cocchlodinium bloom, Persian Gulf ,
impacting water supply .

chlorophyll, FLH.
Figures from Raphe Kudela

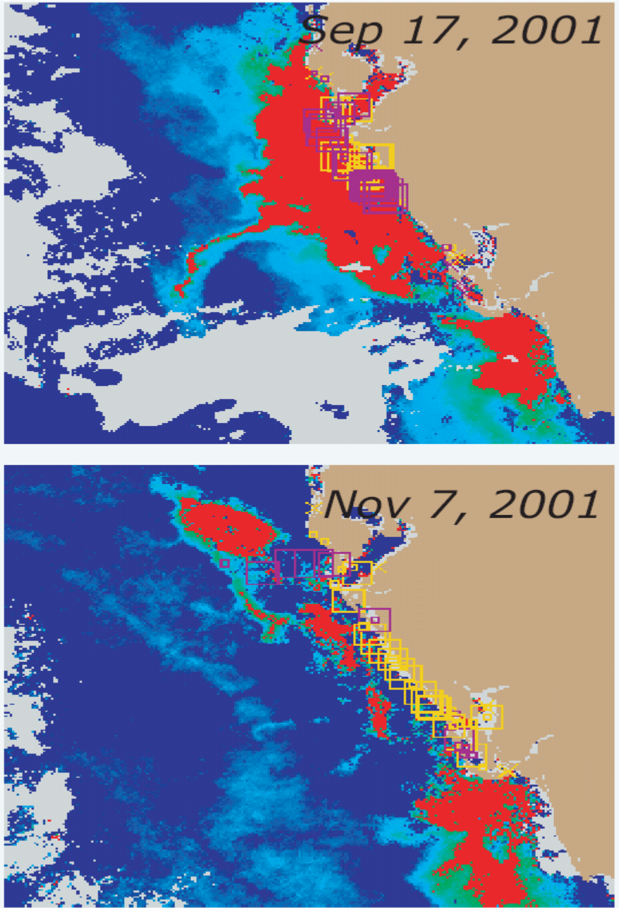




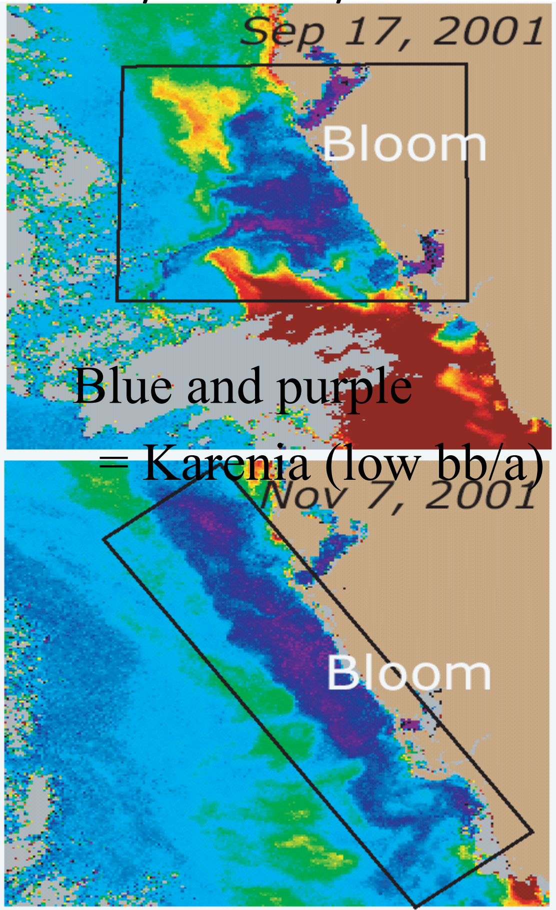


Other Optical Algorithms

Chl Anomaly



Bb/a Carder/Cannizzaro



Bb/a (Cannizzaro/Carder

Karenia blooms scatter less than diatom & *Trichodesmium*.

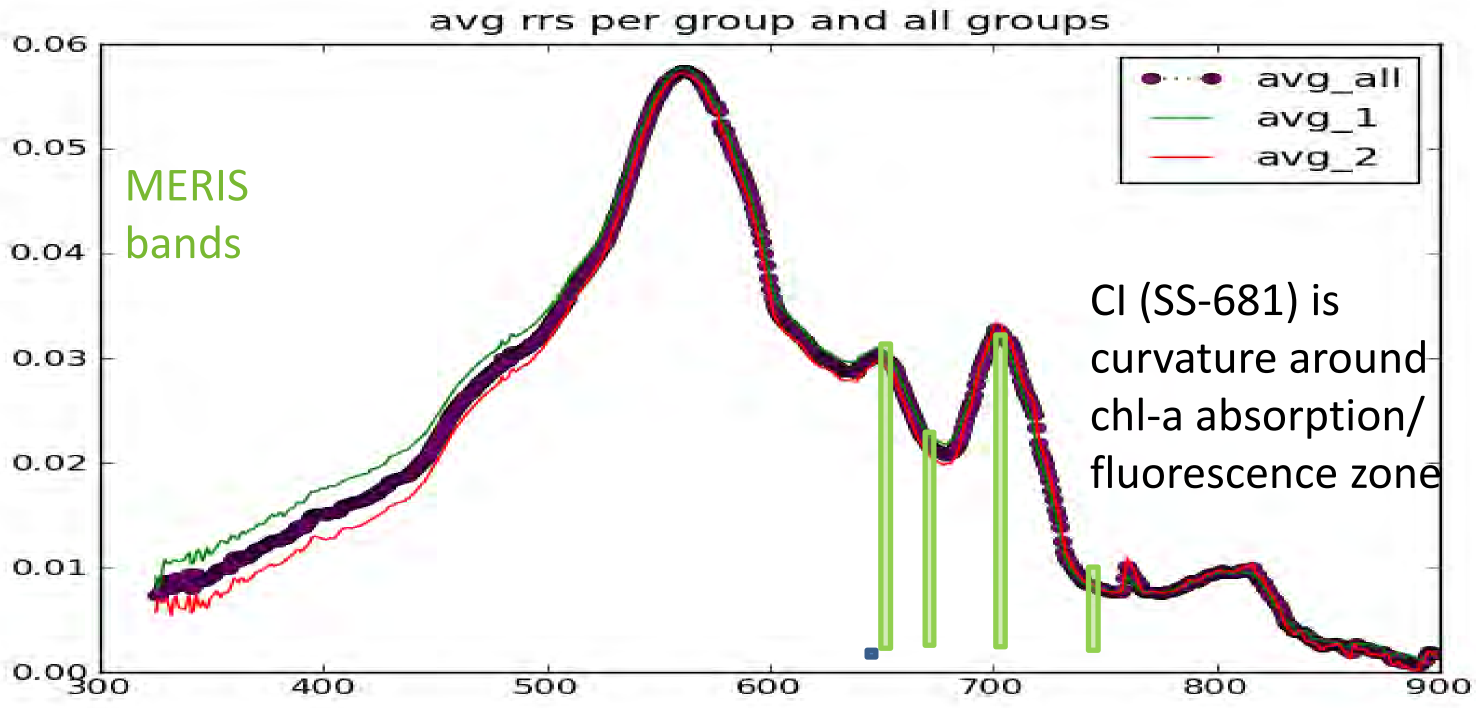
Use Morel bb for reference. *Karenia* bloom when

(bb/a) < Morel bb/a).

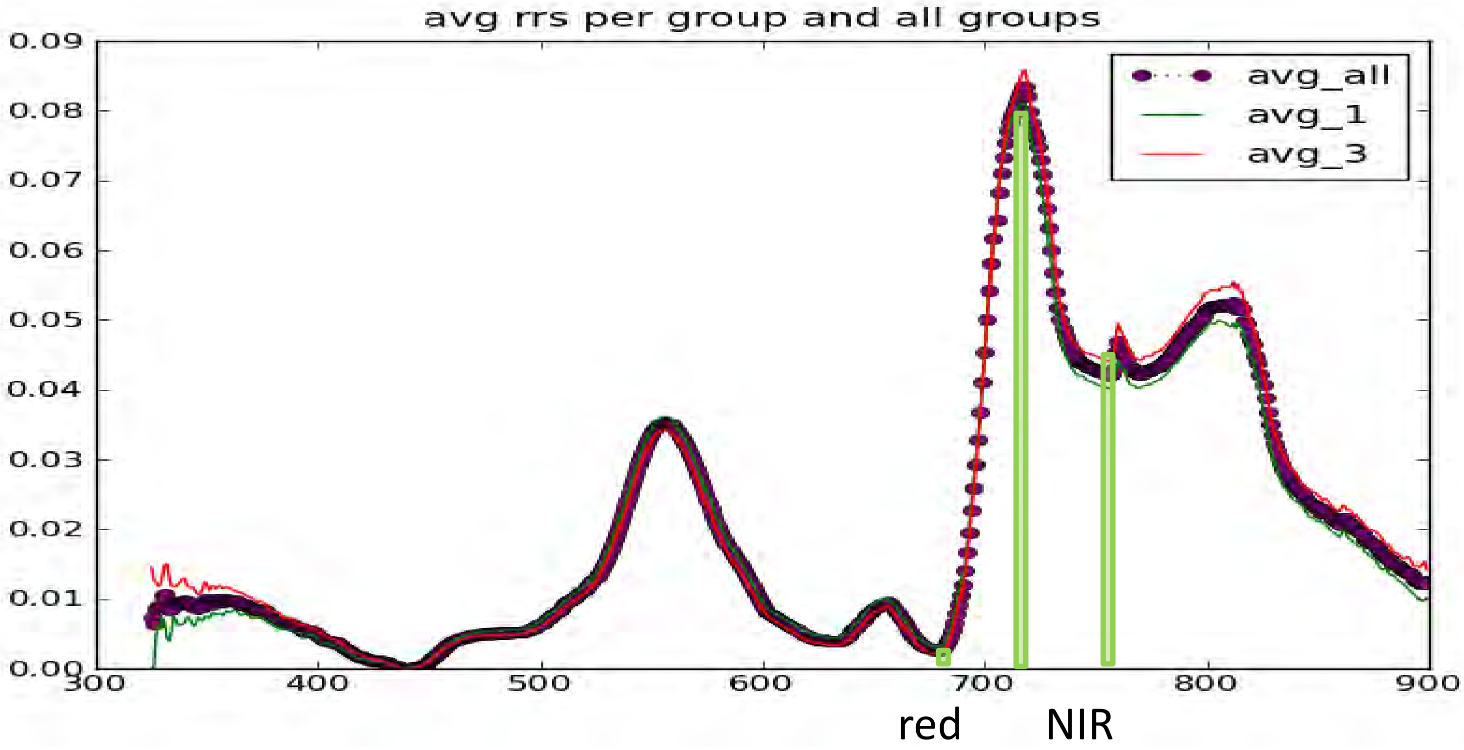
bb from Rrs or Qaa, chl or FLH as surrogate for a.

Low is *Karenia* bloom.

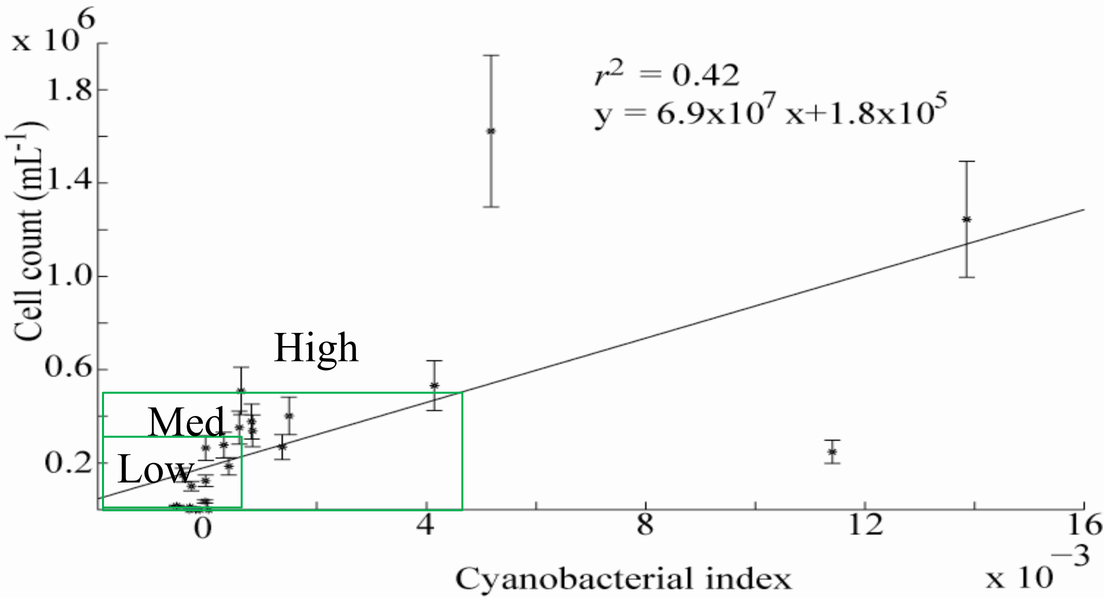
intense blooms in water



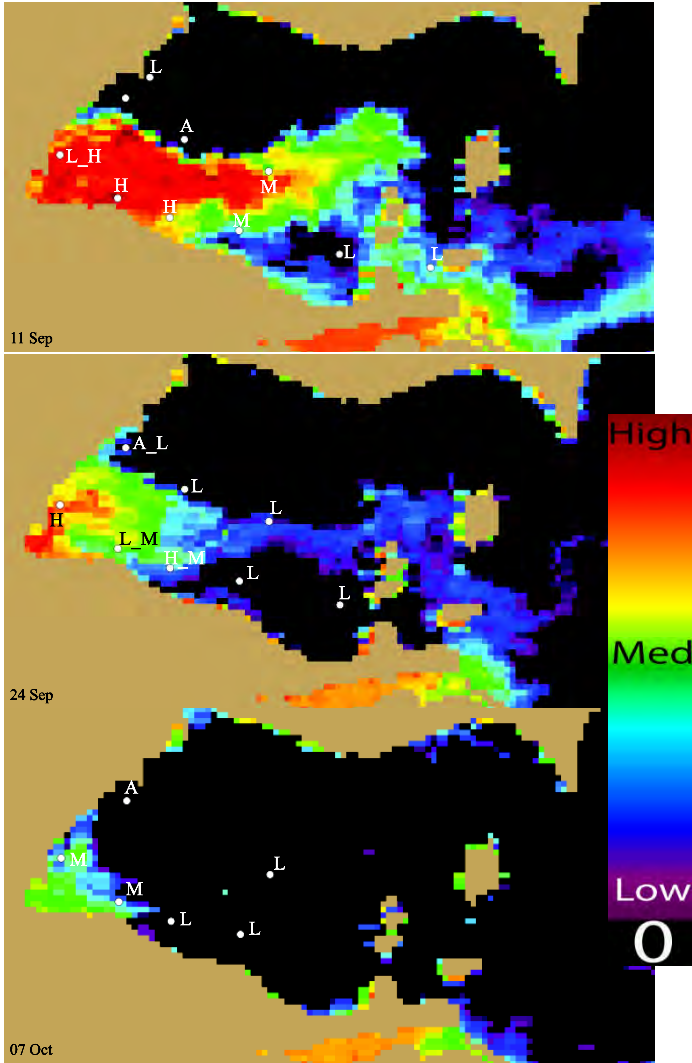
Spectra of *Microcystis* “scum”, bloom on water
High in NIR, low in red



Obtaining cell counts from satellite

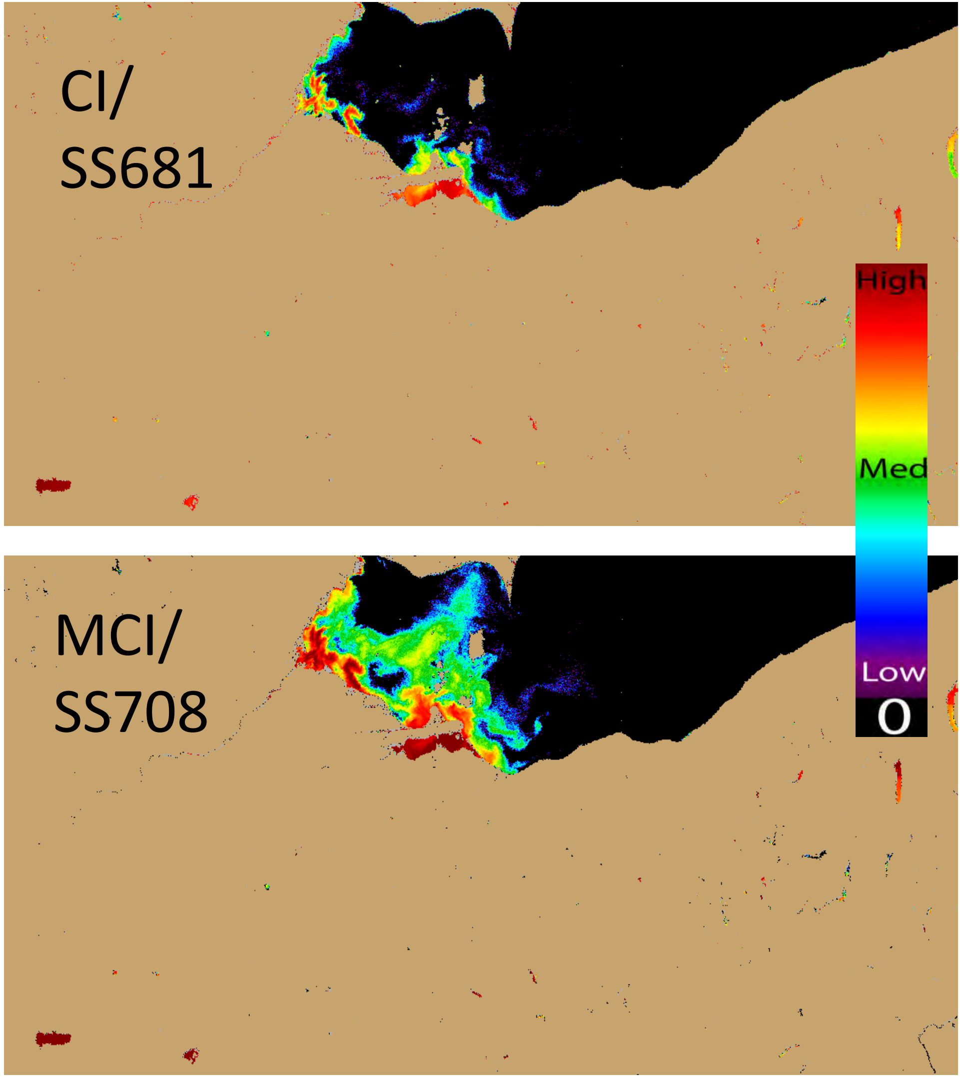


Satellite against field cell counts (now working on field radiometry)



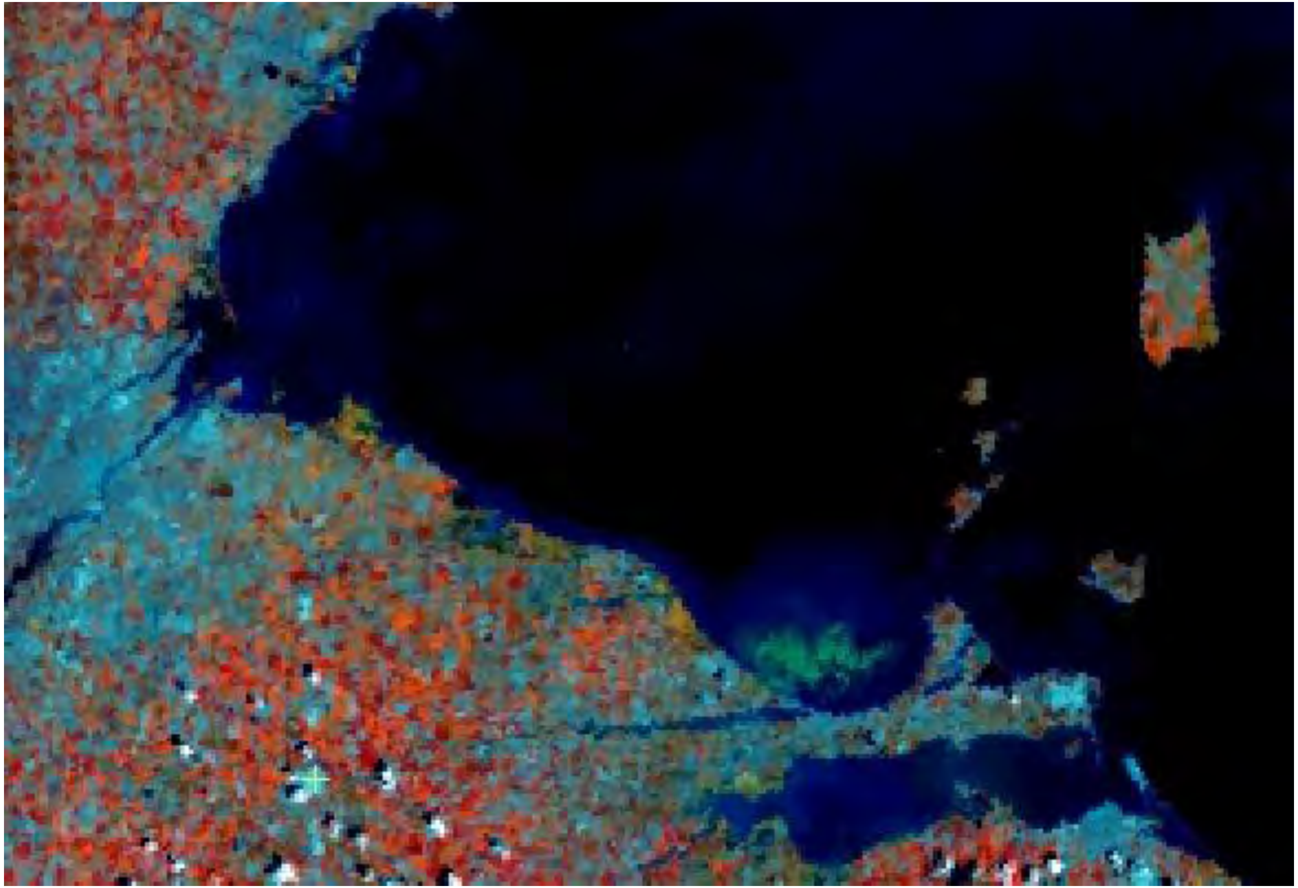
MERIS spectral shapes, cyano & other bloom

MCI sensitive to lower chl-a, but also sensitive to high sediment concentration



A side note, true color is valuable but hard to interpret: Find the scum, July 27, 2010

NIR and red

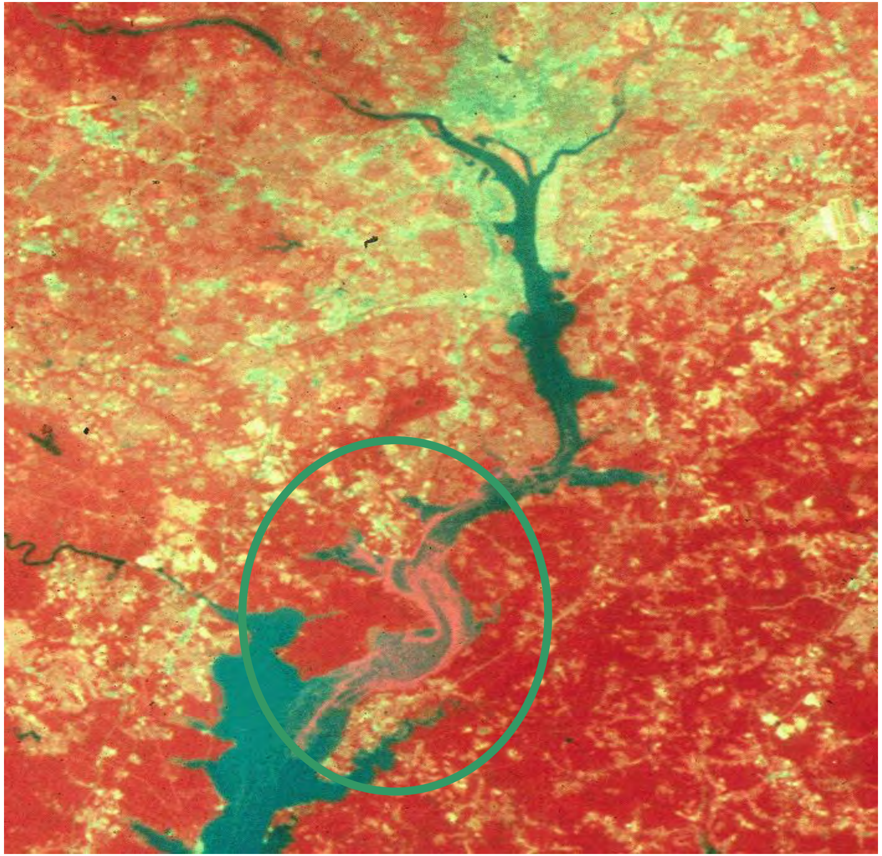


Other sensors

Cyanobacteria under high concentrations and low winds produce scum, high NIR reflectance

NIR assigned red color

False-color IR Landsat, Potomac River, 1982



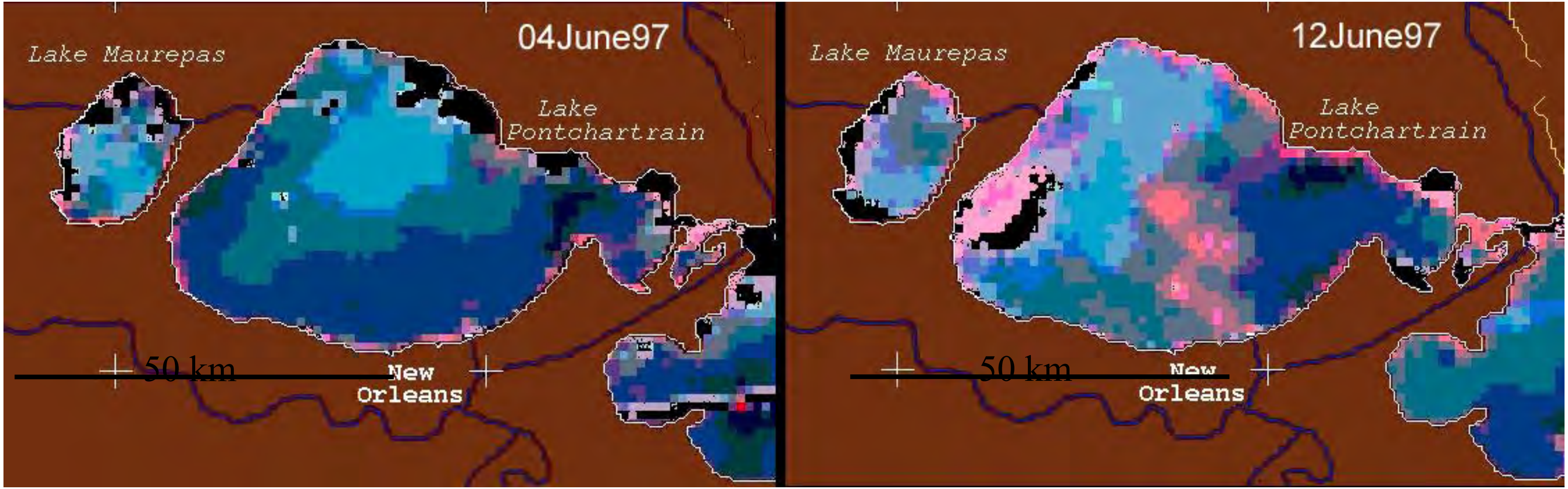
Anabaena bloom, AVHRR (only red and NIR)

Lake Pontchartrain, Louisiana, USA

(Blue-green algae can produce surface scums)

False Color infrared (pink indicates high NIR reflectance)

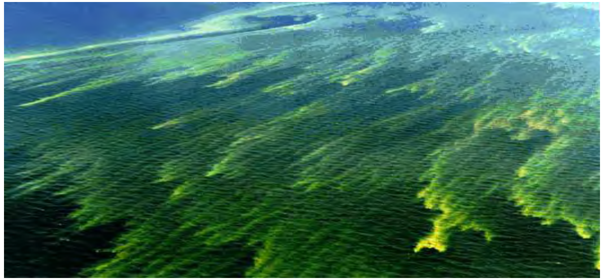
Cell counts < 10^3 mL^{-1} > 10^5 mL^{-1}

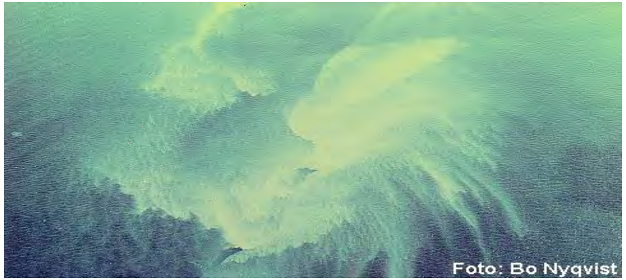


Extensive work done on blue-green blooms in the Baltic.

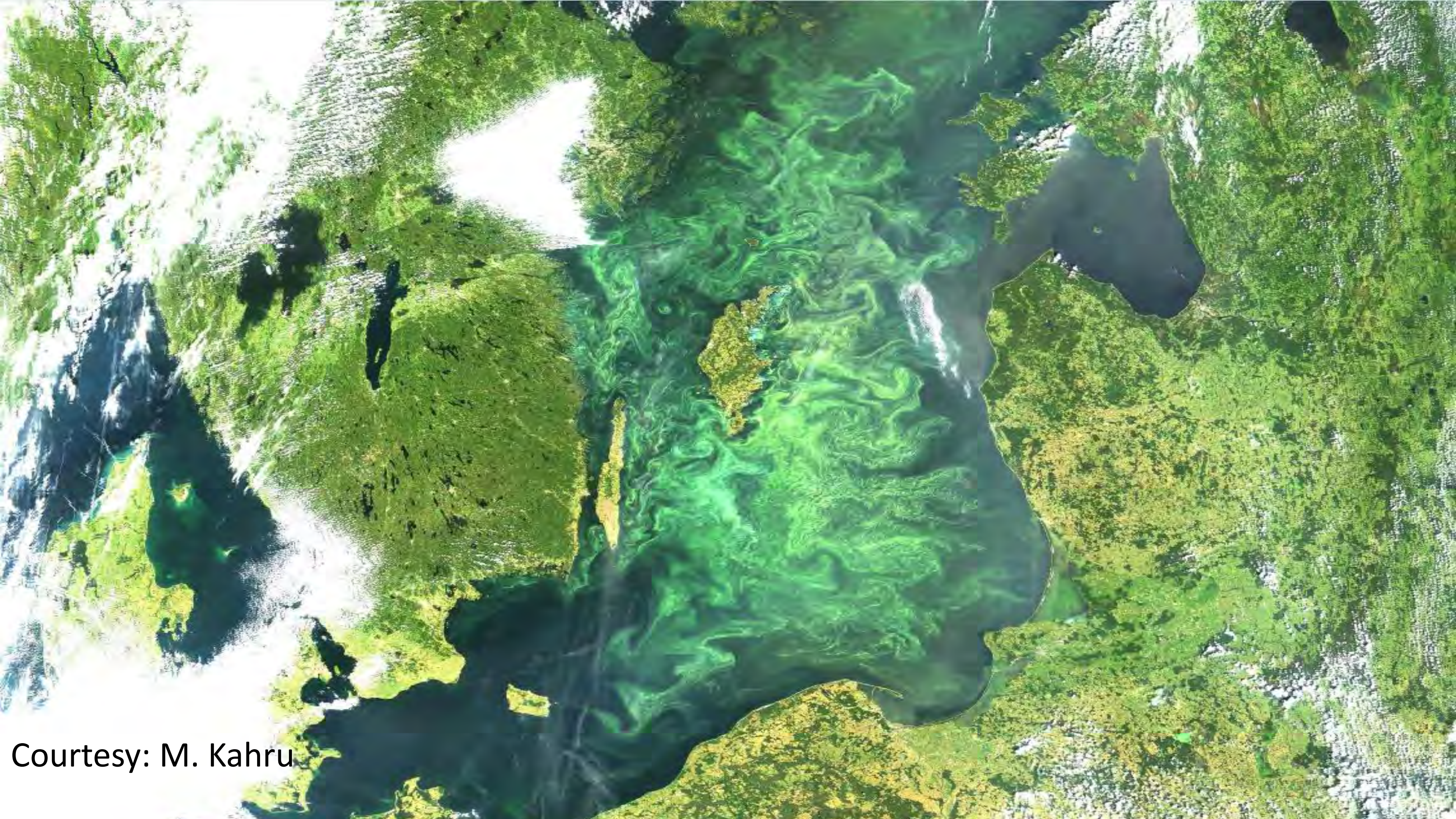
HABs with extreme scattering

(*Nodularia spumigena* dominated blooms in the Baltic Sea)





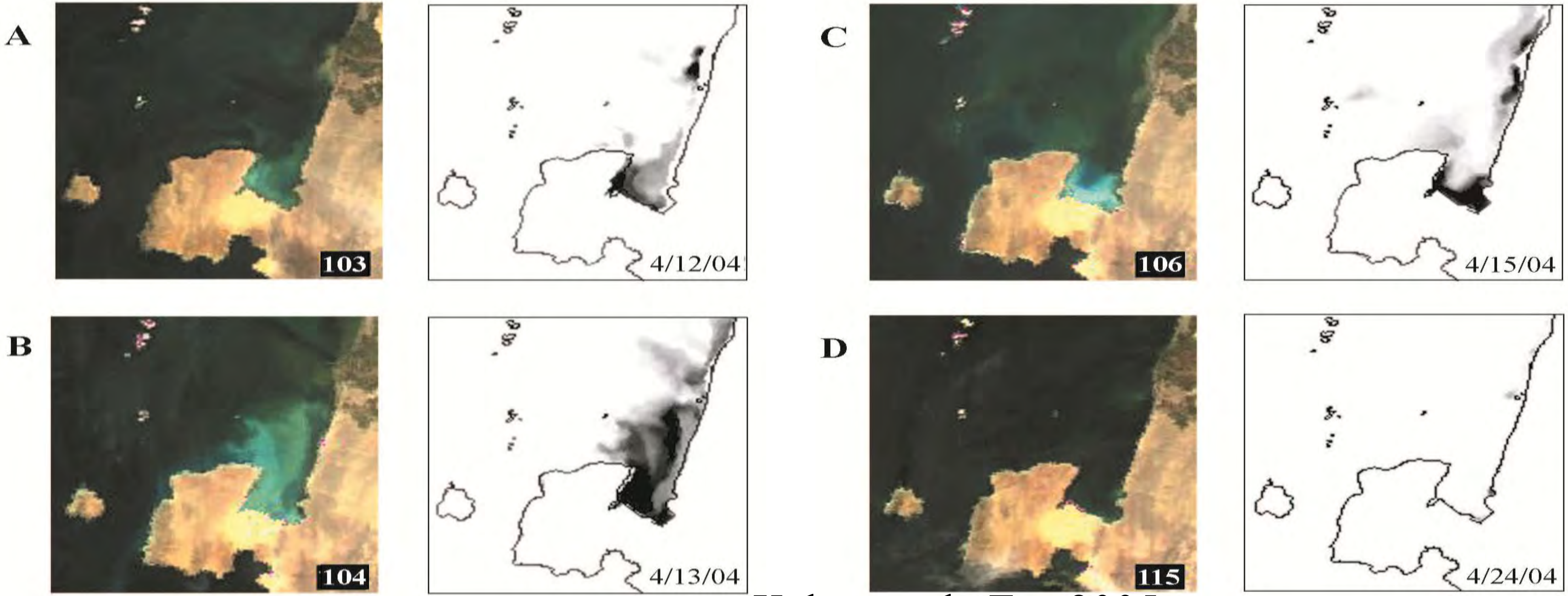
Strong scattering enhanced by the vacuoles in Nodularia cells (M. Kahru)


Courtesy: M. Kahru

Visible anomalies

Anoxic *Gymnodinium sangineum* HAB in Peru, turbidity anomaly

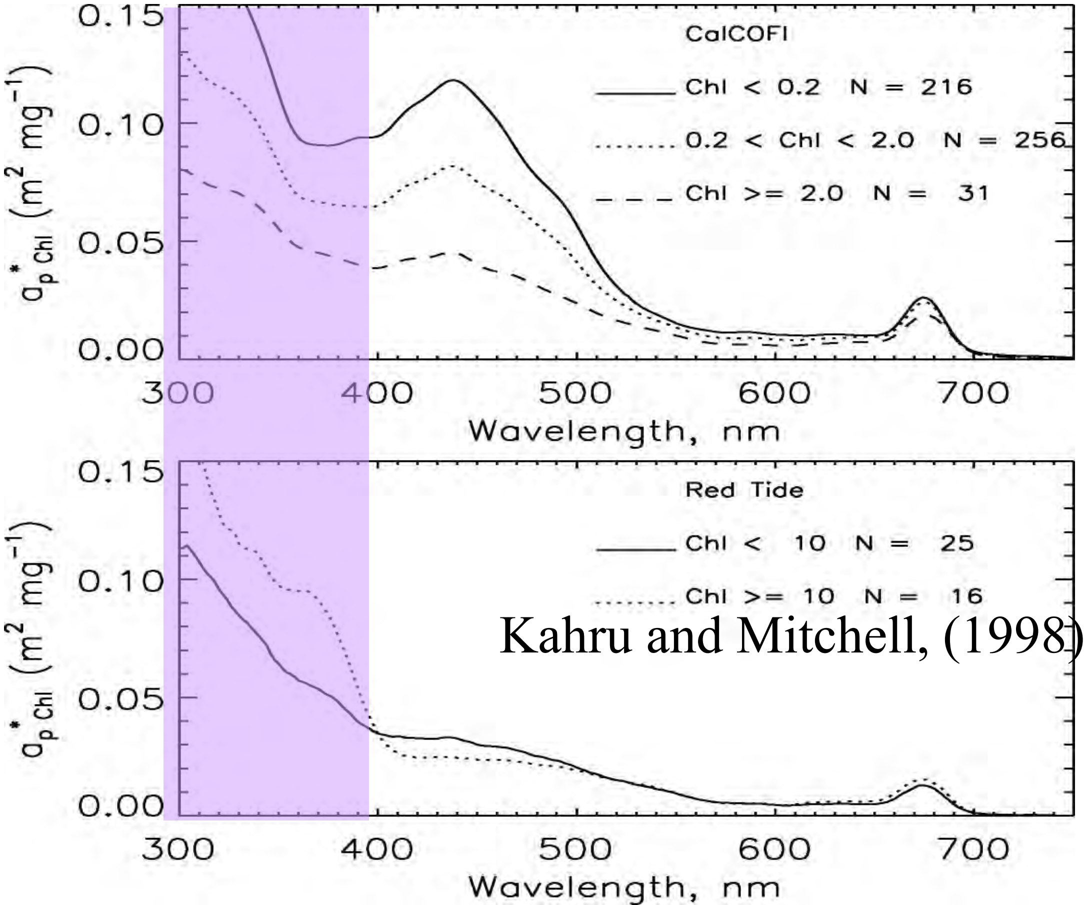
True-color ***"turbidity"***



Kahru et al., Eos 2005

UV spectra, Mycosporine amino acids (MAAs) for dinoflagellates?

- Sunscreen for algae
- More common in dinoflagellates
- Increased UV absorption
- Relevant with future UV sensors
- Issues:
- CDOM areas
- **Not stable, scene by scene classification**



Kahru and Mitchell, (1998)

Common algorithms.

1. Chl-a blue:green
2. Chl-a NIR:red
3. FLH
4. Chlorophyll anomaly
5. MCI (SS-708)
6. CI (SS-681)
7. Bb/a ratio
8. Brightness
9. Multi-band empirical relationship

Exercise. Identify whether potential algal blooms occur. Feb and May images. CI, MCI, & OC4 chl