Remote Sensing and Forecasting
*Karenia brevis* and Cyanobacteria

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Dunns Creek, FL, credit Robert Burks
Florida Blooms. “Red tides” and “blue-green”

Both are amenable to satellite or other remote sensing

• *Karenia brevis* typically dominates biomass on west Florida shelf in the fall (Vargo et al.).
• *Cyanobacteria* produce high biomass blooms in lakes.

Satellite data can provide key data for various modeling efforts.
Coastal Zone Color Scanner, Nov 14, 1978, one month after launch

Field documented (by coincidence) “Red Tide” HAB of *Karenia brevis* (then *Gymnodinium breve*)

Demonstrated the potential value of ocean color (Used by Steidinger and Haddad, 1981)

But chlorophyll concentration is insufficient.
Sensitivity (ID blooms, true positives)
Specificity (ID other blooms, true negatives)

1. Chlorophyll, not specific to either
2. Color is not particularly useful
   1. Karenia is not “red”, diatoms and other dinos will be brown, similar pigments
   2. cyanos are not always bright green. Raphidopsis (formerly Cyli) is golden brown
      1. But color might help separation some cyanos, depends on CDOM interference
3. Algorithm issues
   1. Some algorithms are sensitive to other phenomenon
   2. Interference from sediment, CDOM, bottom (optically shallow)
4. Method/presentation need to explicitly identify algorithm issues
5. Quality requires routine review and evaluation.
“New Bloom” Anomaly
“oldest” (from 2000) routine *Karenia* detection method

- Brings “ecology” into consideration, removes signal from bottom, reduces CDOM
Anomaly intended for short-lived blooms. Newer method is chla fluorescence

- MODIS and Sentinel-3 products
  - Doesn’t work with VIIRS NOAA-20
    - (or SeaWIFS 1997-2010)
  - Does not detect bottom (mostly) or CDOM
  - Some Fluor algorithms respond to sediment
  - Some Fluor algorithms fail in densest bloom
Fluorescence not specific to *Karenia*
Other algae fluoresce, how do we apply this?

• Easy during unique mono-specific *Karenia* blooms in the fall.
• **Need “ecology”**
  • However, images are treated as pixels, not as features
    • Pixels, good for concentration, not good for ID
  • Application, classification, prior knowledge matters
    • *was/wasn’t Karenia* last week, probably *is/isn’t* this week
      If we were *right/wrong* last week, *right/wrong* this week
• We need a data base to aid in bloom identification
• *Karenia* may scatter less than diatoms, but need accurate chl-a and scatter for that
• More work on bloom feature, ID, and tracking
~680 nm band is now critical for both blooms: chla absorption peak AND chla fluorescence peak

**Fluorescence: Karenia (PS-II, photosynthetic eukaryotic algae and plants)**
- chl-a fluoresces about 680 nm, overwhelms chl-a absorption.
- peak in reflectance around 680 nm.
  - Eliminates CDOM, bottom mostly, sediment (depending on algorithm)

**Absorption: Cyanobacteria (PS-I, negligible chl-a fluorescence at 680 nm)**
- Chl-a absorption peak about 680 (dip in reflectance)
Also, Phycocyanin (PC) found in cyanos, not in most freshwater algae
  - PC absorbs about 620 nm
Cyanos, easier, chla absorption at 680 nm
Phycocyanin presence

• Cyanos have PS-I so their chl-a doesn’t fluoresce.
• True algae, PS-II, chl-a typically fluoresces.
• Look for chl-a absorption peak at 680 nm
• PC presence, absorbs more around 620 nm.
• Sentinel-3 has bands useful for this.

• Monitoring Lake Erie for a decade.
• U.S. monitoring with CyAN project. Evaluations continuing
understand inter-annual variability and build seasonal forecasts

Satellite data either used for model building, or for evaluation

Multiple models to determine phosphorus target
Models used for forecasts
Satellite data validates.


Requires good environmental data
decade+ daily nutrient loads were available
Frequency of observed cyanobacterial (cyanophycean) algal bloom occurrence above WHO high threshold in Florida from 2008 through 2011. Clark et al., 2017
Cyano problems

• Toxicity cannot be measured from satellite.
  • Work on model approach in Lake Erie.

• Picocyanoplankton. Can have PC, does it matter?

• Satellite sensitivity is greater than eyeball sensitivity
  • Cyanos can be detected at concentrations that pose a risk and are not visible.

• Spatial resolution.
  • Sentinel-3 is 300 pixels, so water body width > 600-900 m
  • Cyanos have strong spatial gradients nearshore.
  • Sentinel-2 can find scum at 10 m, but only every 5 days (at best in summer).
Sentinel-2 MSI 20 m every five days, potential cyano product ("MCI")

- Glint for the several months around solstice
- 07/28 image, Caloosahatchee
- MCI or similar only identifies high biomass. Not specific.
Questions in satellite + modeling

• We can find Karenia, but it will be confused with other eukaroytes.
  • Big intense Karenia blooms are easy.
  • **We need a data site for bloom species information for ID and validation.**
  • This information may need to be incorporated into monitoring.
  • If Karenia doesn’t fluoresce, we won’t see it. How often does this occur?

• Freshwater Cyanos, much better discrimination
  • If it isn’t toxic does it matter?
  • If it is picoplankton, does it matter?
  • How do we collect valid field data during potential errors?

• **Cyanos can be used for evaluation of different lakes, model building etc.**
  • Is there enough environmental data for a water body to develop seasonal forecasts?

• Karenia imagery may best support monitoring and input into other models.

• Resolution. Unmanned vehicles. We are now developing a system that may allow routine monitoring near the beach.

• Respiratory forecasts are another topic
Satellite issues

• Can’t see *Karenia* when not at the surface. We don’t know how much of a problem this is. Do blooms form at bottom or at the surface?

• Scum forming Cyanos strongly affected by wind. We have a model for this for Lake Erie. Will it work in other lakes?

• Wind could be used to distinguish scum-formers and non-scum (*Microcystis* in Lake Erie, from and *Planktothrix* in Sandusky Bay).
Experimental respiratory forecast
https://habscope.gcoos.org/
Oct 26 11 am nowcast, Oct 25 image, satellite may help, but only on clear days.
Finally, a reality check

1. Hindcast validation ≠ Forecast validation.

2. “All models are wrong, ... how wrong do they have to be to not be useful?” (George E.P. Box, 1987)