Use of Remote Sensing in Operational HAB Monitoring and Forecasting

Microcystis, Lake Erie, Landsat
MODIS Est. Chlorophyll Sep 25, 2008

Rick Stumpf, NOAA National Ocean Service

Mid-Atlantic, April 28, 2008
What is “Harmful”?  

- Are they **Toxic**, **Noxious**, or **Nuisance/Hypoxia**?  
  - **Toxic**: Phycotoxins (direct and indirect effects) many species (e.g. Florida and New England “red tide”)  
    - Most critical, public health, aquaculture  
  - Mechanical (irritation) *Chaetoceros*  
    - Fisheries  
  - **Noxious**:  
    - Starvation of Scallops, etc. (*Aureococcus* “brown tide”)  
    - Physical (secretions interfering with fish) *Chatonella*  
      - Aquaculture  
      - NH$_4$ toxicity (*Noctiluca*)  
  - **Nuisance**:  
    - Macroalgae, drift algae  
    - Anoxia (Many species, depends on concentration and mixing)  

- Concentrate here on toxin-producing blooms:  
- Examples: **Cyanobacteria** (recreation, drinkable water)  
  - *Karenia brevis* (shellfish, respiratory, tourism impacts)  

*Karenia brevis*, Florida > 500,000 cells L$^{-1}$
What is a “Bloom”? 

- An increase in concentration of the organism 
- If harmful, a persistent high concentration 
- A species does not have to achieve high biomass, or high population densities to be in a bloom state (Smayda, 1997) 
- Only a few thousand cells/L (negligible chlorophyll) can cause toxicity in shellfish (e.g. Alexandrium spp) 

Many HABs cannot be detected with remote sensing. Many optical blooms are not HABs.

Karenia brevis; Paul Schmidt, Sun-Herald

Mid-Atlantic, April 28, 2008
The start of satellite remote sensing of HABs. 

**The important image:** Coastal Zone Color Scanner, Nov 14, 1978

• “Red Tide” HAB of *Karenia brevis*
• (then *Gymnodinium breve*)
• Demonstrated the potential value of ocean color (Used by Steidinger and Haddad, 1981)
• (a year earlier Jim Mueller flew CZCS simulator over Florida “red tide”)
• 1974 Wrigley overflew a cyanobacteria bloom

*Red tide in image identified by anomalous chlorophyll*
Harmful Algal Blooms
Integrated Observing Strategy

- NOAA has identified 7 regions where Harmful Algal Blooms (HABs) are a critical problem to Federal, State, and Local managers. The 7 operational HAB coverage areas, prioritized according to maturity of science and technology, are:
  - Florida and eastern Gulf of Mexico – Operational in Fall 2004
  - Western Gulf of Mexico – Demo now; Operational FY09
  - Lake Erie – FY10
  - Gulf of Maine – FY11
  - Washington and Oregon Coast – FY13
  - California Coast – TBD
  - Chesapeake Bay – TBD
NOAA Operational Forecast System
Gulf of Mexico, Demonstration since Sep 1999;
Operational since Sep 2004:
An Operational **forecast** of impact: 0-3 days
and a **prediction** of likelihood of a bloom for mgmt

Harmful Algal Bloom Forecasting System

Conditions Report

Monday, July 11, 2005

A harmful algal bloom has been identified from northern Pinellas to northern Lee County. Patchy very low to high impacts possible in Pinellas and northern Sarasota Counties every afternoon through Thursday. Patchy very low to moderate impacts are possible in southern Florida.

Conditions forecast for public. Over 100 bulletins per year

http://www.csc.noaa.gov/crs/habf

Mid-Atlantic, April 28, 2008
Harmful Algal Blooms
Integrated Observing Strategy

Observing systems for HAB detection fall into three categories:

- **Satellites** – ocean color and sea surface temperature (SST)
- **Fixed Sampling Systems** – Buoys, Platforms
  - To measure currents, wind speed, SST, salinity, HAB presence
- **Mobile Sampling Systems** – People, AUVs, Ships
  - To measure currents, SST, salinity, HAB presence, and HAB concentration

Observing system sensors support three requirements for HAB monitoring and prediction

- Ocean color (except Gulf of Maine), SST
- Ocean circulation (currents, wind speed)
- Phytoplankton cell counts from field sampling
Harmful Algal Blooms
Integrated Observing Strategy

• **Satellites**
  - **Pro:** Geographic and temporal coverage. Provide broad area coverage not available from other means (up to 10K sample locations per day for SW Florida)
  - **Con:** Ambiguous, not effective for “non-correlative” blooms. Need verifying in situ sampling for HAB presence and concentration; can’t yet measure currents or salinity effectively; impacted by cloudiness. Satellite should not be used alone.

• **Fixed Sampling Systems**
  - **Pro:** Can provide data in all weather conditions, day and night
  - **Con:** Detection only at site. Potential miss for mixed blooms

• **Mobile Sampling Systems**
  - **Pro:** Accuracy. Can be moved to where the HAB event is taking place; Quantify severity of HAB at targeted location. Provide sub-surface measurements (gliders)
  - **Con:** Limited offshore. Logistical difficulty (<10 to 100 (with glider) sample locations per day)

Mid-Atlantic, April 28, 2008
### Harmful Algal Blooms

**Satellites** (Ocean Color -- chlorophyll absorption, turbidity, reflectance, fluorescence)

<table>
<thead>
<tr>
<th>Year</th>
<th>Satellite</th>
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<tbody>
<tr>
<td>2007</td>
<td>SeaWiFS / SeaStar</td>
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<td>2008</td>
<td>VIIRS/NPP ?</td>
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<td>2009</td>
<td>VIIRS / NPOESS - C1</td>
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<td>2010</td>
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<td>2012</td>
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<td>OLC / Sentinel - 3</td>
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<td>2014</td>
<td>OCM / OCEANSAT-2</td>
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<td>2015</td>
<td>FY-3A, B, C, D, E, F, G (VIRR/MODI)</td>
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<td>2016</td>
<td>SGLI / GCOM C-1, C-2, C-3</td>
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**Legend:**
- Operational or In Orbit
- Approved
- Planned/Pending Approval
- Mid-Atlantic, April 28, 2008
- Primary
- Secondary
Satellite detection involves ecological factors: blooms in Florida after fall upwelling are more likely to be *K. brevis*. Red is bloom identified as HAB.

Offshore winds intensify blooms; monitored from satellite.
HAB Field to input to model. Uninterpreted satellite image lacks information and accuracy

- Problems with satellite imagery
- And with water sampling (in the best of programs)

A typical week of sampling in FL

Various data sources are used with satellite to produce HAB field

Mid-Atlantic, April 28, 2008
Harmful Algal Blooms
Integrated Observing Strategy

Fixed Sampling Systems (Currents, salinity, SST, wind speed, and HAB presence)

- **NOAA NWLON, Naples, FL**
  - SST, wind, HAB presence
  - 1 each, Requirement is 6 buoys

- **NOAA CMAN/Buoy, Venice, FL**
  - SST, wind, HAB presence
  - 1 each

- **Mote Marine Lab Buoys**
  - HAB presence
  - Sarasota Bay and Charlotte Harbor
  - 1 each

- **Univ. S. FL Research / COMPS**
  - Currents (some), HABs (some), salinity, SST, wind
  - Several
  - COMPS = Coastal Ocean Monitoring and Prediction System

- **CODAR Radar Stations**
  - Currents, wind
  - None available
  - 2 needed; 30 to 60 km apart

Mid-Atlantic, April 28, 2008
Harmful Algal Blooms
Integrated Observing Strategy

Mobile Sampling Systems (Cell counts, HAB presence (including concentration), currents, salinity, and SST) – mostly event-driven

<table>
<thead>
<tr>
<th>Year</th>
<th>Florida State Monitoring Network</th>
<th>Lifeguard Network (not operational)</th>
<th>AUVs -- 2 deployed in season; research</th>
<th>Research Cruises (Universities, States, Labs)</th>
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<tbody>
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People
1 Run by Florida Fish and Wildlife Research Inst. (FWRI) and Mote, event driven

Lifeguard Network (not operational) (Lifeguards, volunteer networks) 8 locations, 100 required

AUVs
AUVs -- 2 deployed in season; research (Currents, salinity, temperature, and HAB presence) Requirement = 3 operational

Slocum Glider

Ships
Research Cruises (Universities, States, Labs) (HAB Concentration) (Universities, state labs)

Mid-Atlantic, April 28, 2008
A harmful algal bloom has been identified in patches from southern Lee to central Collier County. Patchy very low impacts are possible from southern Lee County to central Collier County today through Thursday. No other impacts are expected.

Monday, April 26, 2003

Gulf of Mexico Harmful Algal Bloom Bulletin

http://www.csc.noaa.gov/crs/habf

Conditions Report (public)

HAB Bulletin (managers)

http://www.csc.noaa.gov/crs/habf

NOAA HAB Forecast System:
Operational in Florida since 2004,
Demonstration Texas 2006
Planned Demonstration Lake Erie 2008

Observations
(MODIS and SeaWiFS satellite imagery, buoys, field samples, respiratory irritation)

Model output
(heuristic, empirical)

Synthesis and Analysis
Operational HAB Forecasts

- **Problem:**
  - Advance warning of HABs for shellfisheries, public health, economic impacts

- **Objective:**
  - National System of Regional Forecasts
  - Initial: Phased with operational capability to provide some advance warning in each regions
  - Ultimate: Operational advance warning of at least several days in all critical areas.

- **A Solution:**
  - Partnership of Fed/State/Regional/Research to achieve operational capability
  - Planning with partners for Lake Erie, Gulf of Maine, California, Pacific NW is ongoing; mid-Atlantic is pending

Mid-Atlantic, April 28, 2008
Final Points for HAB monitoring and assessment

• Understand the conditions of the bloom
  – Deal with the common
  – A system should allow for response to the uncommon
• Remote sensing from satellite is available
  – Requires additional data, context, and interpretation
  – May provide ecological context, even if not the blooms
• Satellite should not be used for HABs without interpretation
• Multiple data types (and models) are necessary and must be integrated
• Routine problems warrant a routine solution (such as an operational capability)