Multi-Model Simulations with Data Assimilation for Harmful Algal Blooms in the Eastern Gulf Of Mexico

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A harmful algal bloom (HAB) is the proliferation of a toxic or nuisance algal species that negatively affects natural resources or humans.

There are several main groups that form HABs: flagellates (includes dinoflagellates), diatoms, and blue-green algae.

Each group has unique characteristics, life cycles, nutrient requirements, motility, and toxins.

Approximately 85 HAB species currently documented.
It’s estimated that losses due to HABS equal ~$50 million per year, with >50% from Florida red tides, predominantly the toxic dinoflagellate *Karenia brevis* (Anderson et al., 2000).

Brevetoxin, the neurotoxin produced by *K. brevis*, frequently causes respiratory irritation in humans, as well as mass mortalities to fish, marine mammals, and sea birds (Landsberg, 2002; Flewelling et al., 2005).
Our major goal is to develop a predictive model to forecast HABs in the eastern Gulf of Mexico (GOM).

In order to forecast HABs, we require a multi-disciplinary approach (physical, biochemical, atmospheric, and fisheries science).

In relation to this NASA grant, we will utilize data assimilation tools to improve the model fidelity by incorporating satellite and in situ measurements.
Models

• Physical Models
  • WFS (West Florida Shelf) circulation model (Robert Weisberg – USF)
    • ROMS (Regional Oceanic Modeling System)
    • Nested in the HYCOM (HYbrid Coordinate Ocean Model)
    • Fully 3-d, baroclinic, 2-5 km horizontal resolution
  • FVCOM (Finite Volume Coastal Ocean Model) - (Robert Weisberg – USF)
    • Links the WFS with the estuaries
  • SABGOM (South Atlantic Bight and Gulf of Mexico) Circulation Model
    • ROMS nested in HYCOM (Ruoying He – NCSU)

• Biochemical Model
  • HABSIM (John Walsh and Jason Lenes – USF)
Nested grids of the circulation models, FVCOM, ROMS, and SABGOM, driving HABSIM over the Gulf of Mexico and downstream South Atlantic Bight
It is crucial to accurately calculate the circulation in order to forecast HABs.

The 75-day surface drifter trajectories simulated by the circulation model in 2006-07.

Released along the 10-20 m isobaths within 30 km of the West Florida coastline.

In 2006, a large red tide versus a small/moderate red tide in 2007.

This was due to export in 2007, where *K. brevis* populations were observed along the East Florida coast.
Biological – phytoplankton, zooplankton, bacteria, fish
(Walsh et al., 2003; 2006; 2009; Lenes et al., 2005; 2008; Milroy et al., 2008)

Chemical – macro and micro nutrients (C, N, P, Si, Fe)
(Walsh et al., 2003; 2009; Jolliff et al., 2003; Darrow et al; 2005; Lenes et al., 2008)

Atmospheric – Saharan dust (Fe) as wet and dry deposition
(Lenes et al., 2005; 2008)

Benthic – benthic diatoms, regeneration of nutrients
(Darrow et al., 2005; Darrow, 2008)
2001 Case Study

- One-dimensional biochemical simulation
- 30-m isobath off Sarasota
- 1-m vertical resolution
- 30-s time step
- Test species succession
  - Diatoms
  - Microflagellates
  - *Trichodesmium*
  - *Karenia brevis*
2001 Case Study

- Phytoplankton (umol C l\(^{-1}\))
- Large spring pulse of fast growing diatoms
- Strips water column of inorganic N
- *Trichodesmium* responds to atmospheric Fe inputs
- Stimulates other phytoplankton during release of fixed-N
- Diatoms and microflagellates controlled by grazing
- *K. brevis* reaches toxic levels (fish kill) by late July - 4.5 umol C l\(^{-1}\) (~2x10\(^5\) cells l\(^{-1}\))
- *K. brevis* utilizes fish nutrients to reach observed concentrations in late September (>20 umol C l\(^{-1}\) or >8 ug chl l\(^{-1}\))
Next Steps

- Assimilation of satellite data into the 1-d model
- Utilize HABSIM to hindcast the 2001 case in 3-d
- Assimilation of satellite data into the 3-d model
- Test multi-model simulations with data assimilation in nowcast mode
- Run predictive simulations
Data Assimilation

- Data assimilation is a process for optimally combining observations with models for the purpose of reducing errors in state variable estimation (Kalney, 2004)

- HABSIM will assimilate a combination of:
  - chlorophyll a concentration (Chl a) from MODIS
  - *K. brevis* satellite flags

*K. brevis* flags (Carder et al., 2007; Cannizaro et al., 2008) will be overlaid with the MODIS chl a and the FWRI *in situ* cell counts to calculate a data field to assimilate into the *K. brevis* state variable
In addition, we currently utilize data streams from NOAA NCEP winds, moored arrays, and HF-radar stations.

Additional physical and optical data is expected from USF’s Center for Ocean Technology (COT), which manage an integrated program of Webb gliders and Bottom Stationed Ocean Profilers (BSOP).

Current WFS moorings (yellow) and HF-radar footprints (green), along with projected glider (—) and BSOP (stars) locations.
A vertical cross-section between the 25-m and 50-m isobaths off Tampa Bay, Florida obtained by A) the USF-COT/CPR glider during 11-21 July 2009 of B) temperature, C) salinity, and D) chlorophyll fluorescence.
Daily vertical structures of A) temperature and B) chlorophyll fluorescence at 09:00 hours on the 25-m isobath, derived from the USF-CMS-COT/CPR Bottom Station Ocean Profiler (BSOP), at a standard WFS mooring during 11-21 July 2009
Decision Support Tools

- **HAB tracking tool**
  - Short term (1-3 day) trajectories
  - Simplified version available on website (http://cprweb.marine.usf.edu)

- **Nowcast/forecast model**
  - Generate midrange (~1 week) forecast maps
  - Full coupled biophysical model simulations w/ data assimilation

- **Karenia satellite flags**
  - Maps of *Karenia* surface bloom locations
  - Currently available on website (http://cprweb.marine.usf.edu)
  - Updated daily with the most recent two weeks password protected (password available for resource managers)
The Center for Prediction of Red Tides consists of a jointly funded project between the University of South Florida’s College of Marine Science and the Florida Fish and Wildlife Conservation Commission. Our mission focuses on development of a 3-d coupled physical-biological model capable of predicting and tracking red tides within coastal waters of the southeastern United States.
End-Users

- Florida Fish and Wildlife Conservation Commission
- NOAA HAB bulletin
- Fisheries managers
- Local beach communities
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