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

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Harmful Algal Blooms

- 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

Why Do We Care?

- 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)

Goals

- 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

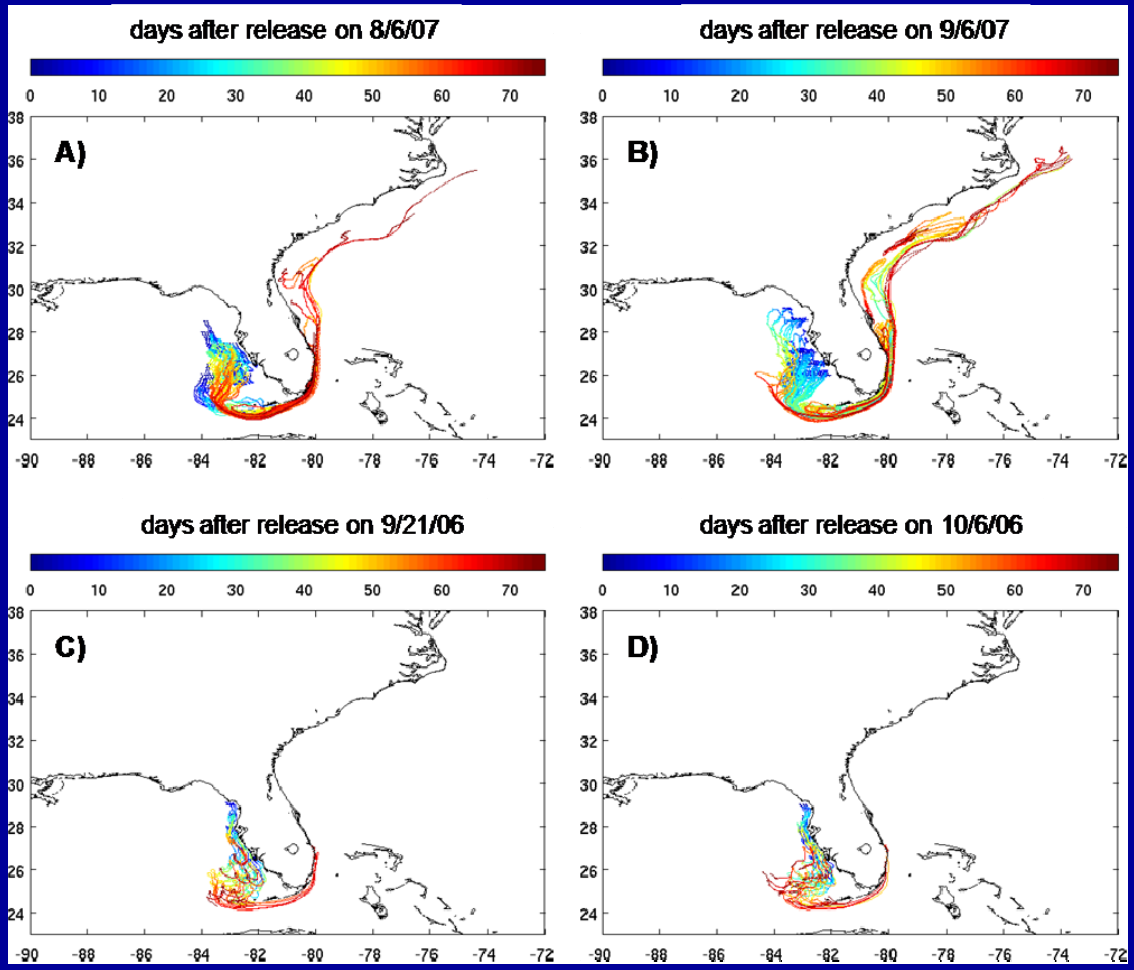
- Physical Models
  - WFS (West Florida Shelf) circulation model (Robert Weisberg – USF)
    - ROMS (Regional Oceanic Modeling System)
    - Nested in the HYCOM (HYbrid Coordinate Ocean Model)
    - Fully 3-d, baroclinic, 2-5 km horizontal resolution
  - FVCOM (Finite Volume Coastal Ocean Model) - (Robert 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)

Model Domains

Nested grids of the circulation models, FVCOM, ROMS, and SABGOM, driving HABSIM over the Gulf of Mexico and downstream South Atlantic Bight

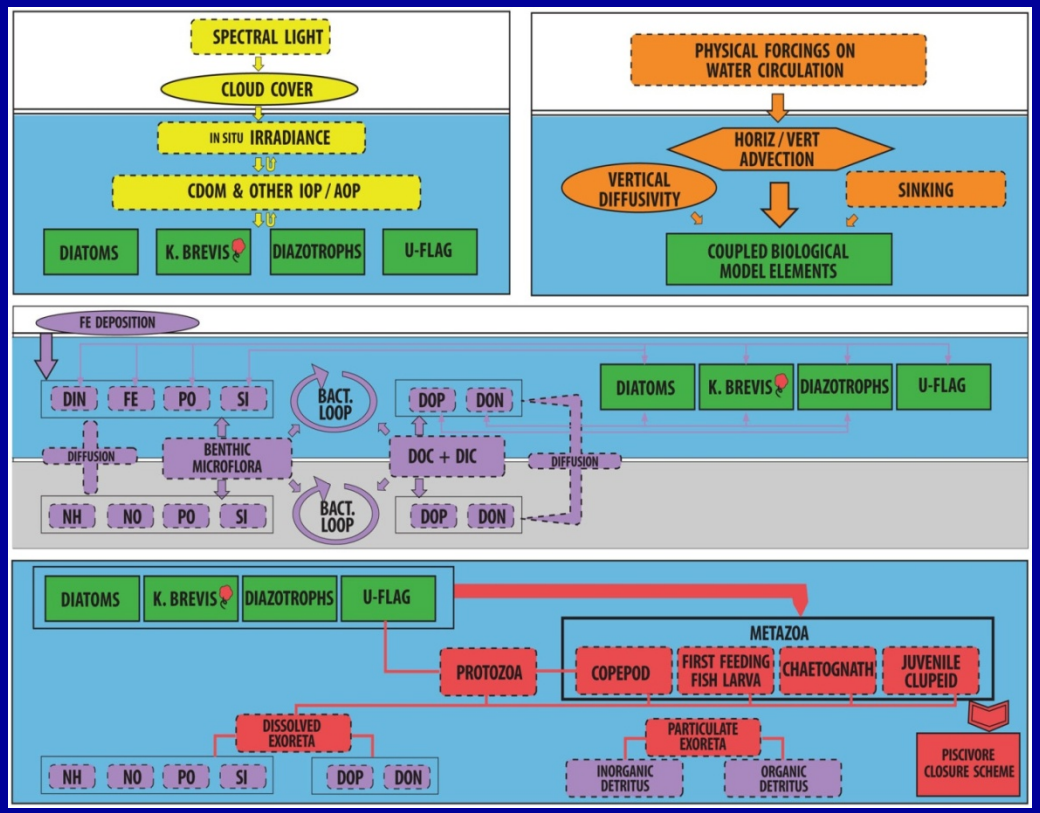
Surface Drifters

- 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



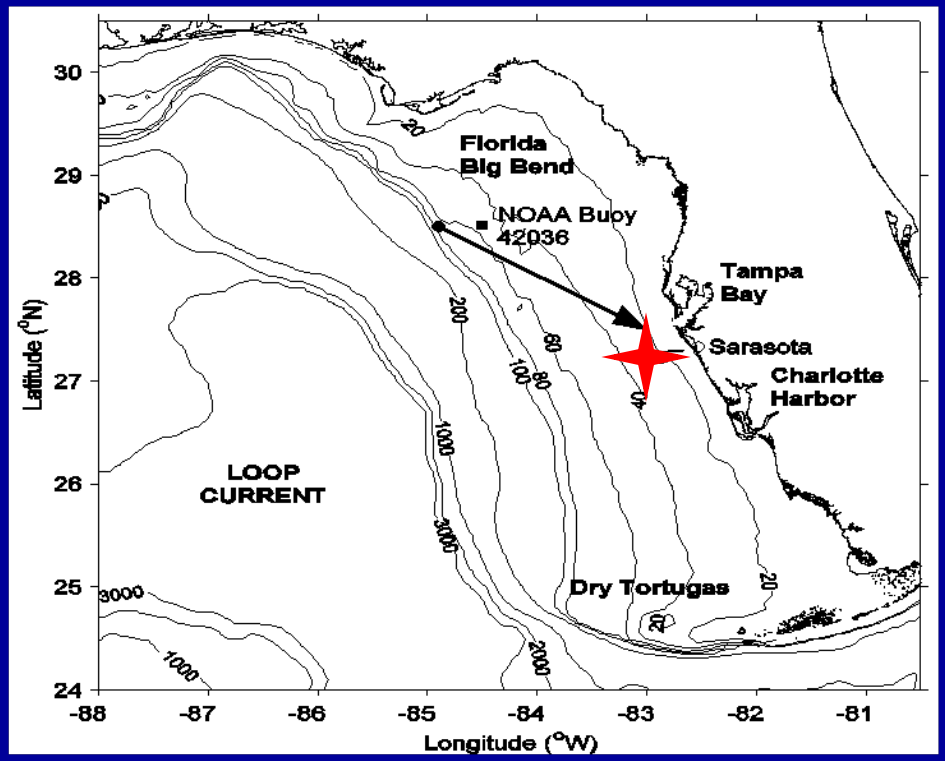
HABSIM Submodels

- 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

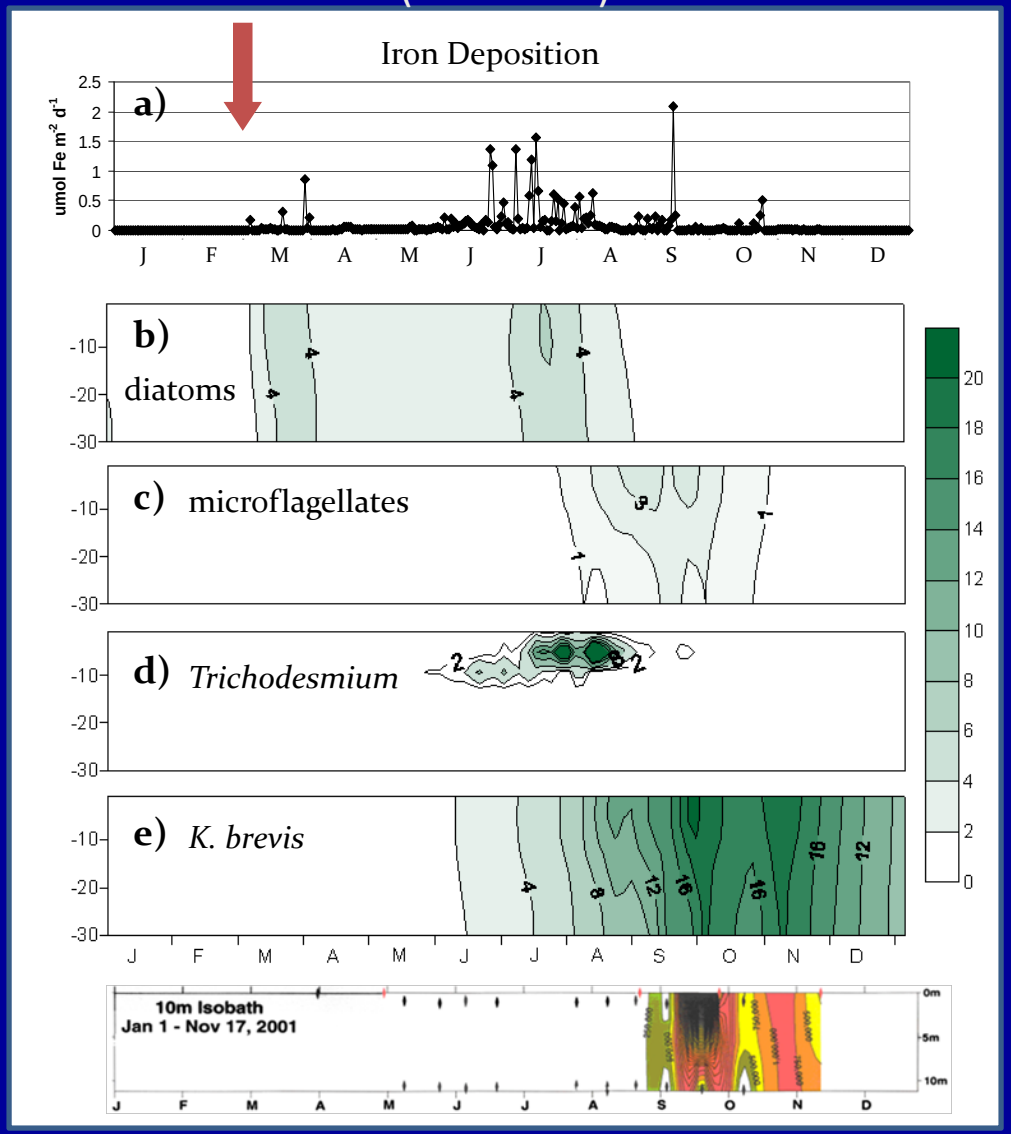
- One-dimensional biochemical simulation
- 30-m isobath off Sarasota
- 1-m vertical resolution
- 30-s time step
- Test species succession
  - Diatoms
  - Microflagellates
  - *Trichodesmium*
  - *Karenia brevis*



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})

Nutrient Pulse (March 1st)

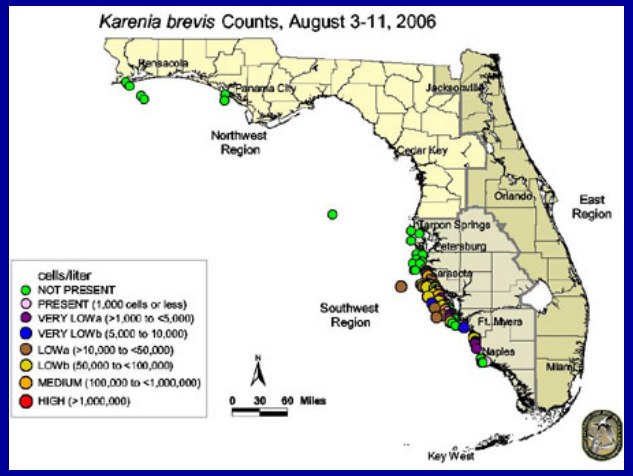


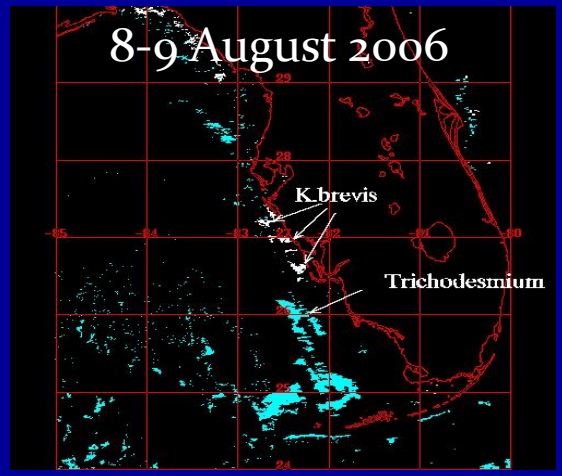
Next Steps

- 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

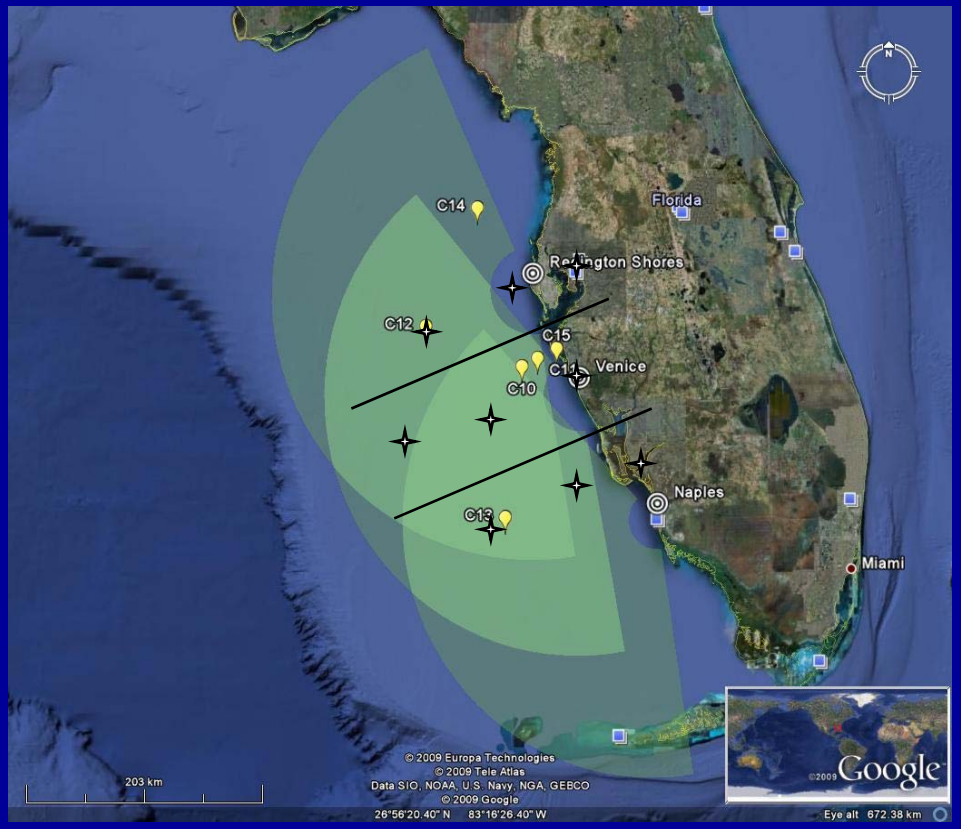




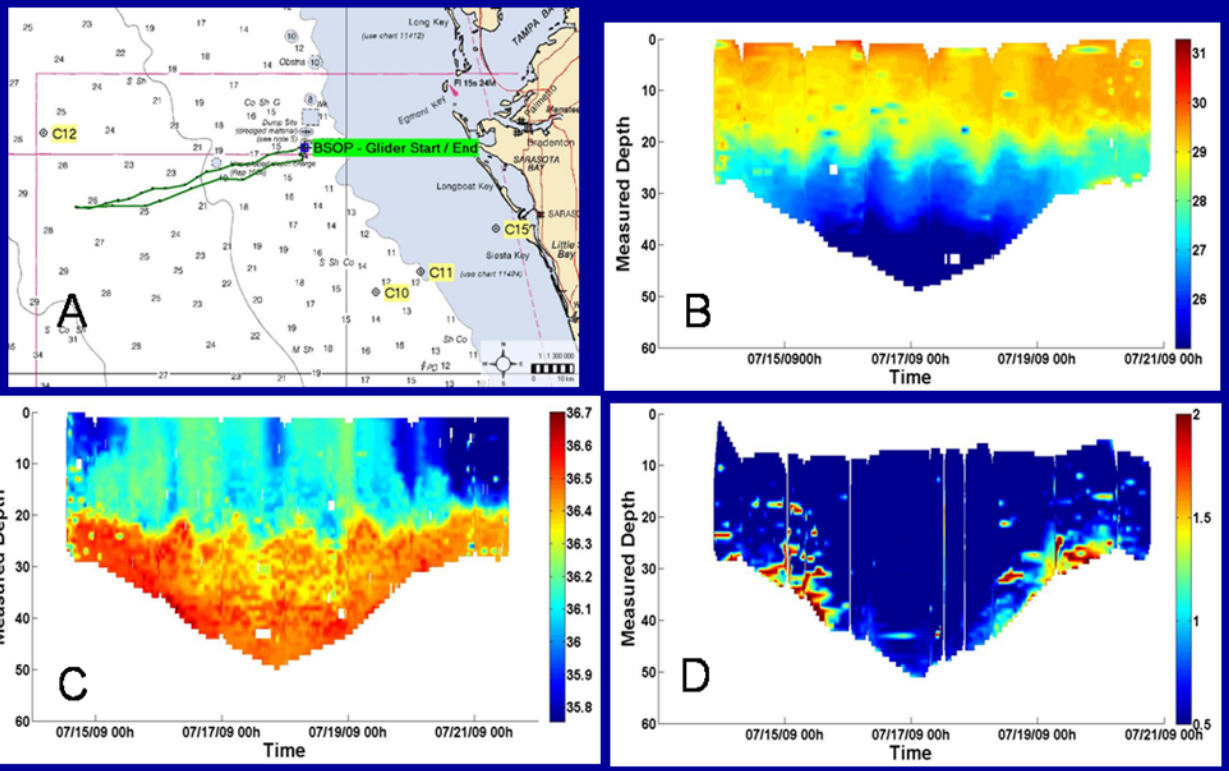
K. brevis flags (Carder et al., 2007; Cannizaro et al., 2008) will be overlaid with the MODIS chl a and the FWRI *in situ* cell counts to calculate a data field to assimilate into the *K. brevis* state variable

In Situ Sensors

- 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

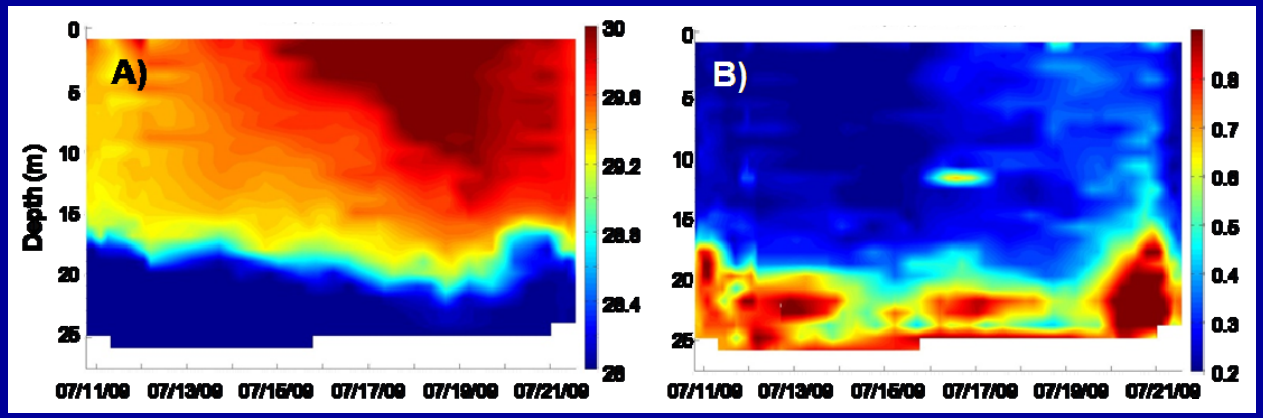


Gliders



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.

BSOPs

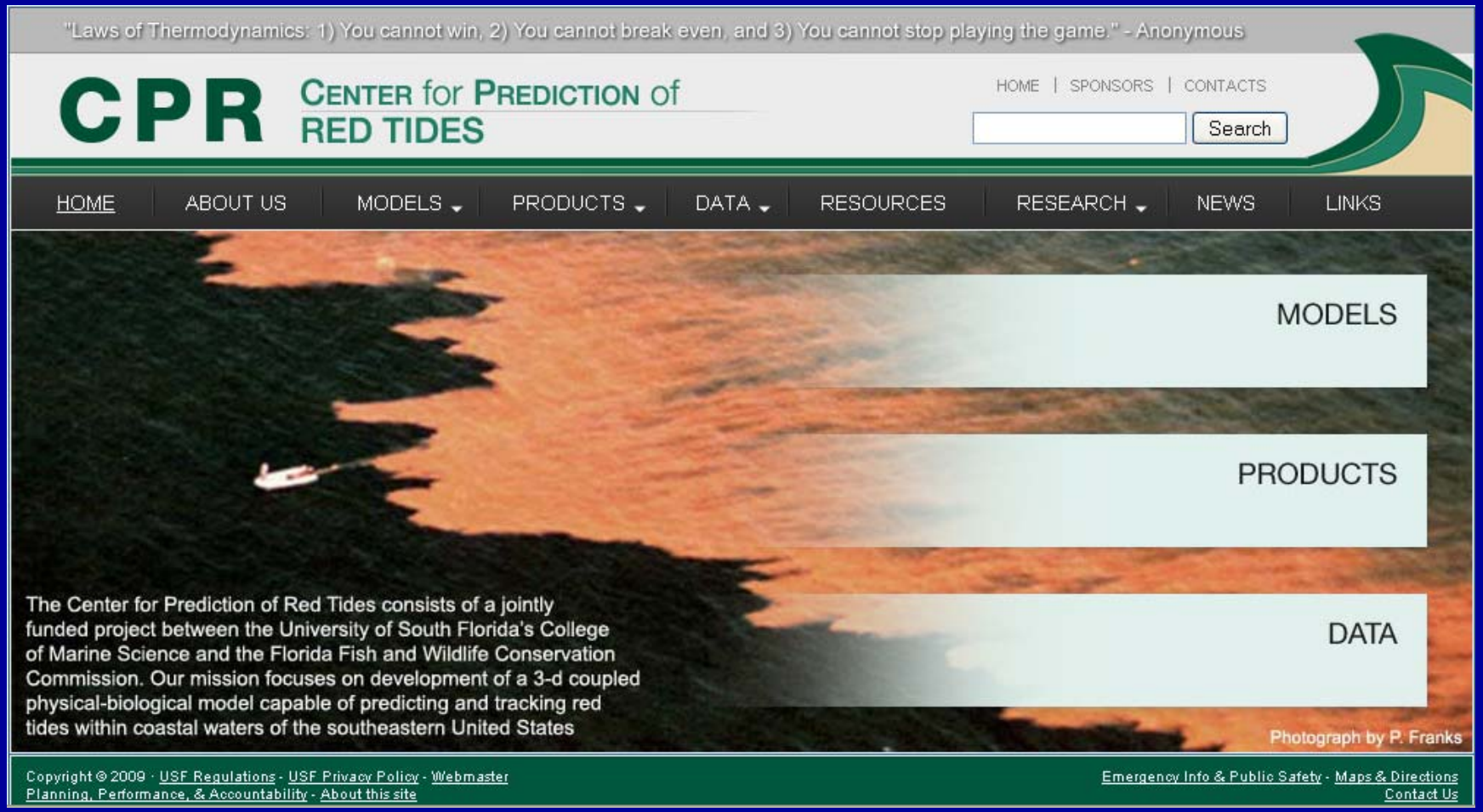


Daily vertical structures of A) temperature and B) chlorophyll fluorescence at 09:00 hours on the 25-m isobath, derived from the USF-CMS-COT/CPR Bottom Station Ocean Profiler (BSOP), at a standard WFS mooring during 11-21 July 2009

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)

http://cprweb.marine.usf.edu

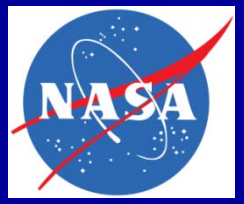


End-Users

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

Acknowledgements

- National Aeronautics and Space Administration



- National Oceanic and Atmospheric Administration

- University of South Florida – College of Marine Science

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- Florida Fish and Wildlife Conservation Commission