Nutrients Controls Contributing to *Karenia Brevis* Blooms in the Gulf Of Mexico

Jason M. Lenes, Brian P. Darrow, Robert H. Weisberg,
John J. Walsh and F. Robert Chen

2/9/2010

Florida HAB Control and Mitigation Workshop

Center for Prediction of Red Tides
College of Marine Science
University of South Florida

USF UNIVERSITY OF SOUTH FLORIDA COLLEGE OF MARINE SCIENCE

CPR Center for Prediction of Red Tides

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 C&M grant, we began testing the hypothesis that alteration of nutrient ratios can potentially suppress the magnitude of *Karenia* blooms, especially silica (Si) ratios.

The Players

Karenia brevis – slow growing dinoflagellate, non-partisan nitrogen (N) user, does not require silicate (Si), toxic, minimally grazed

Diatoms – fast grower, prefers inorganic N (nitrate and ammonium), requires Si (Si:N ~1), non-toxic (locally), the preferred food for higher trophic levels

Trichodesmium – slow growing cyanobacterium, fixes own N from N_2 gas, does not require Si, mildly toxic, minimally grazed

The Nutrient Sources

Multiple sources of nutrients have been implicated to support *Karenia* blooms in the eastern GOM (magnitudes and relative importance will not be addressed here!):

- Nitrogen fixers (cyanophytes) – no Si
- Dead Fish – no Si
- Rivers – Si concentration > N concentration
- Remineralization of diatom blooms – N regenerates faster than Si
- Ground water - Si concentration > N concentration

The Competition

FLORIDA RIVERS & GROUNDWATER

THE WINNER = DIATOMS

Given adequate N and Si sources, the fast growing diatoms will outcompete other species for resources

The Competition

N FIXERS & DEAD FISH

THE WINNER = ????

The Competition

When N fixers and fish die and decay:

- Nutrients are released (C, N, P, but no Si)

Therefore,

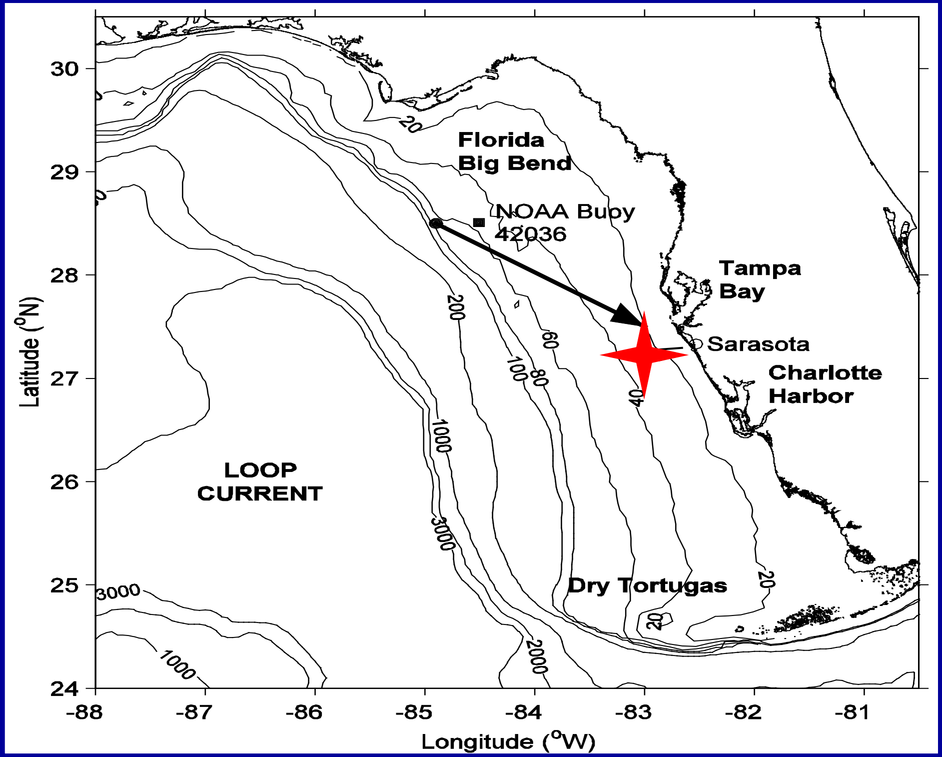
- If there is enough Si, DIATOMS should win since they grow faster
- If Si is depleted, *Karenia brevis* should win because they do not need Si

Hence our hypothesis:

Increasing Si ratios can shift phytoplankton growth from toxic *K. Brevis* to diatoms-based food webs

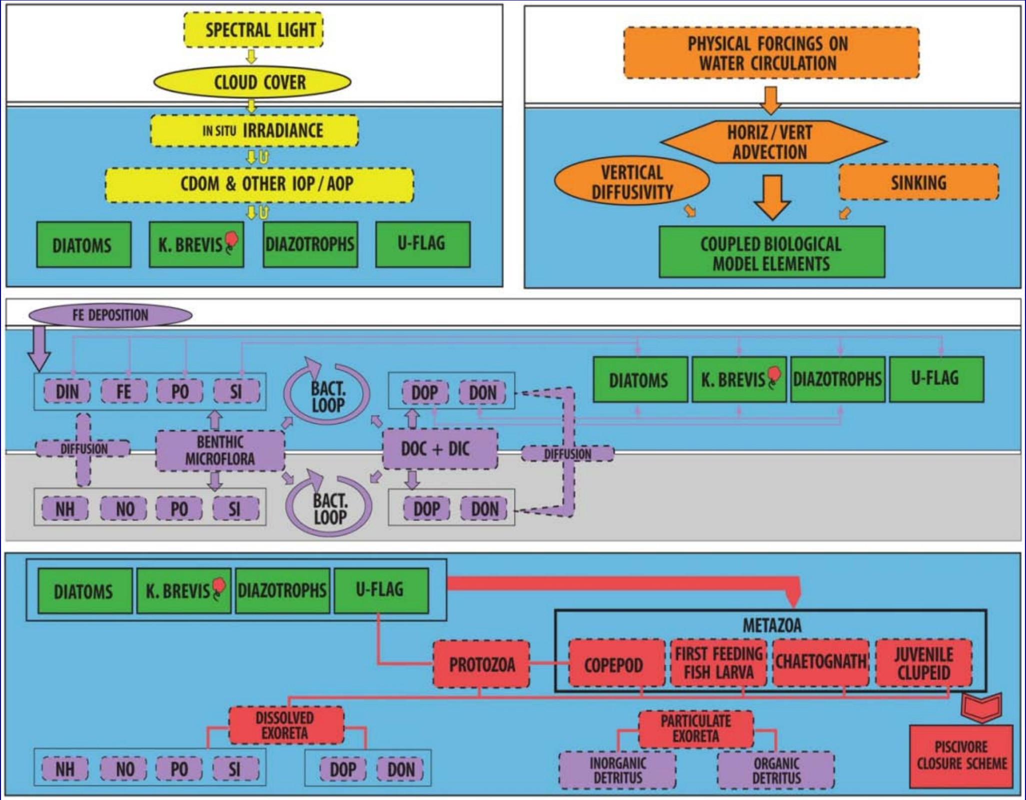
Testing the Hypothesis

- One-dimensional biogeochemical model (HABSIM)
- Ran 2 cases for 2001 HAB
  - Initial Si = 2.0 umol L^{-1}
  - Initial Si = 20.0 umol L^{-1}
- 30-m isobath off Sarasota
- 1-m vertical resolution
- 30-s time step
- Test species succession in relation to potential Si limitation versus no Si limitation



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

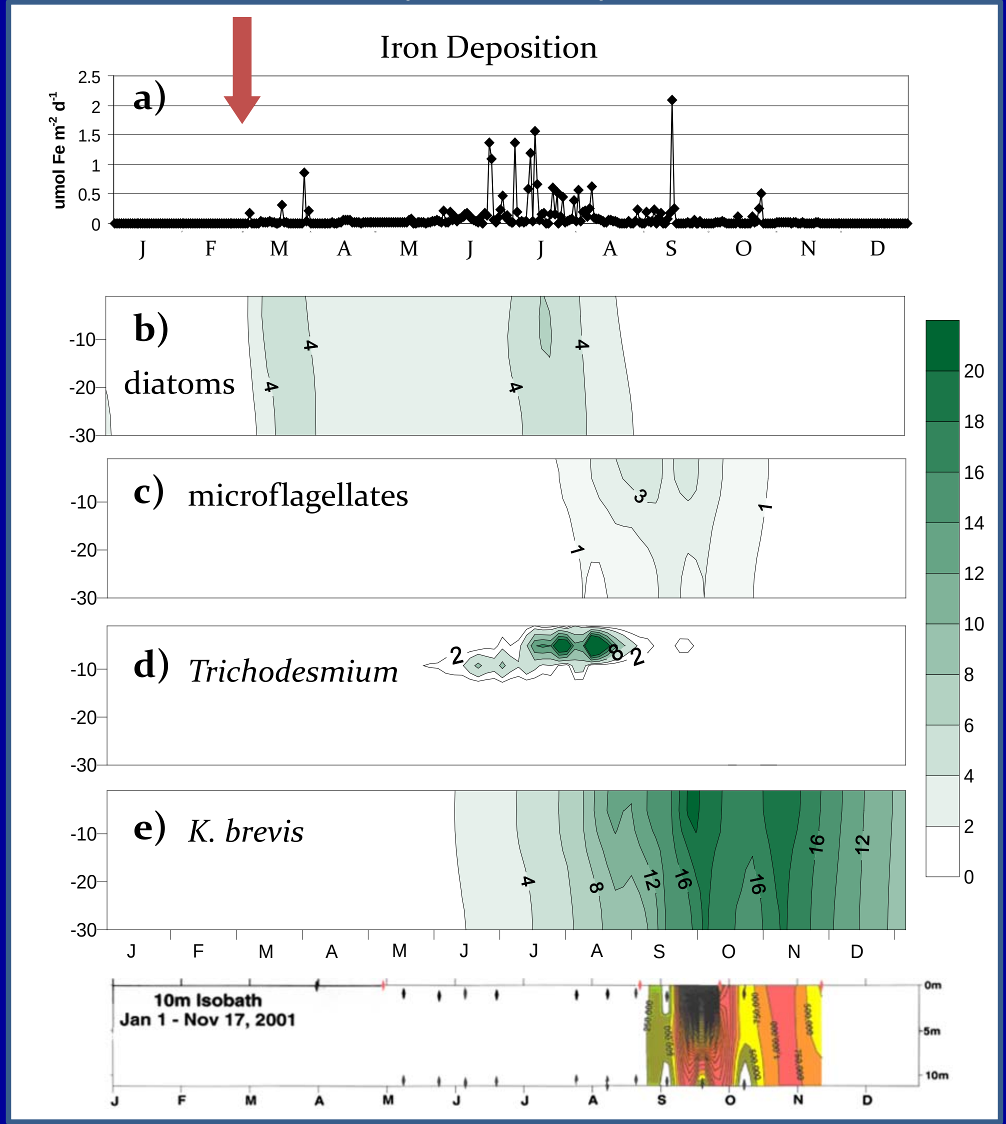
Both Cases

- 4 species of phytoplankton (umol C l^{-1} or mmol C m^{-3})
- Spring nutrient pulse on March 1st to simulate northern Gulf rivers
- Summer input of iron (Fe) via wet and dry deposition of Aeolian dust
- *Karenia brevis* toxic (fish kill) concentration - 4.5 umol C l^{-1} (~$2x10^5$ cells l^{-1})

2001 Case Study – Normal Si

- 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 controlled by Si-limitation and microflagellates controlled by grazing
- *K. brevis* reaches toxic levels (fish kill) by late July
- *K. brevis* utilizes fish nutrients to reach observed concentrations in late September (>20 umol C l^{-1} or >8 ug chl l^{-1})

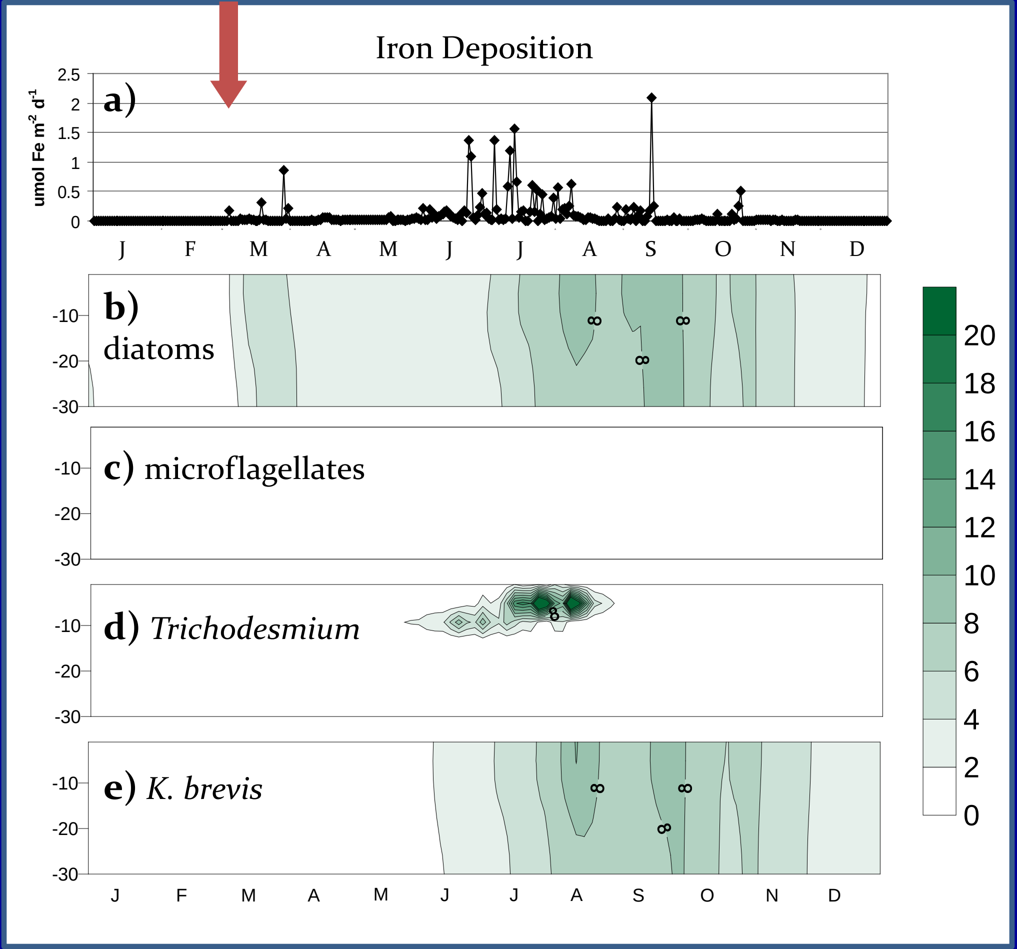
Nutrient Pulse (March 1st)



2001 Case Study – Elevated Si

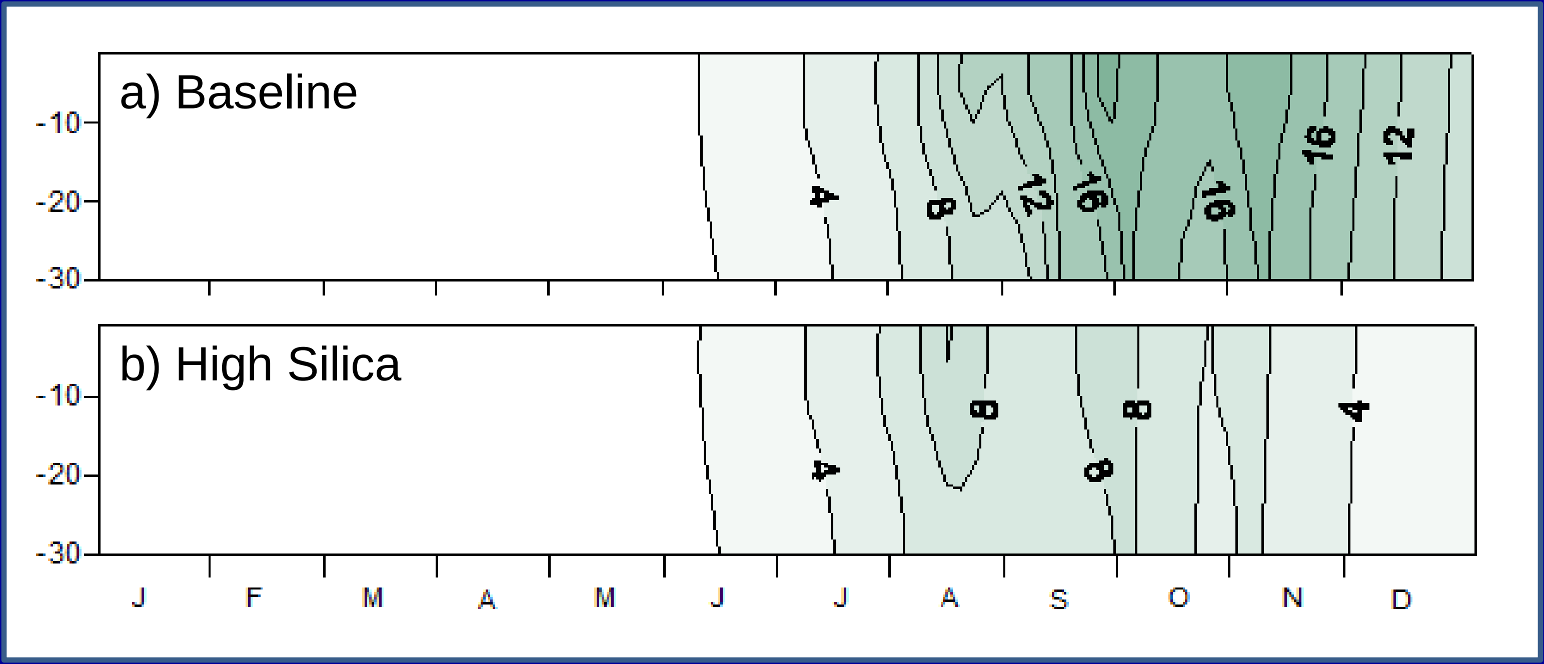
- Still have large spring pulse diatoms stripping the water column of inorganic N
- *Trichodesmium* stimulates other phytoplankton during release of fixed-N
- Diatoms outcompete microflagellates now that Si is not limiting
- *K. brevis still* reaches toxic levels (fish kill) in July
- Diatoms compete with *K. brevis* for fish and *Trichodesmium* nutrients, both reaching max. concentrations of ~10 umol C l^{-1}

Nutrient Pulse (March 1st)



2001 Case Study

This is a 50% reduction in *K. brevis* biomass

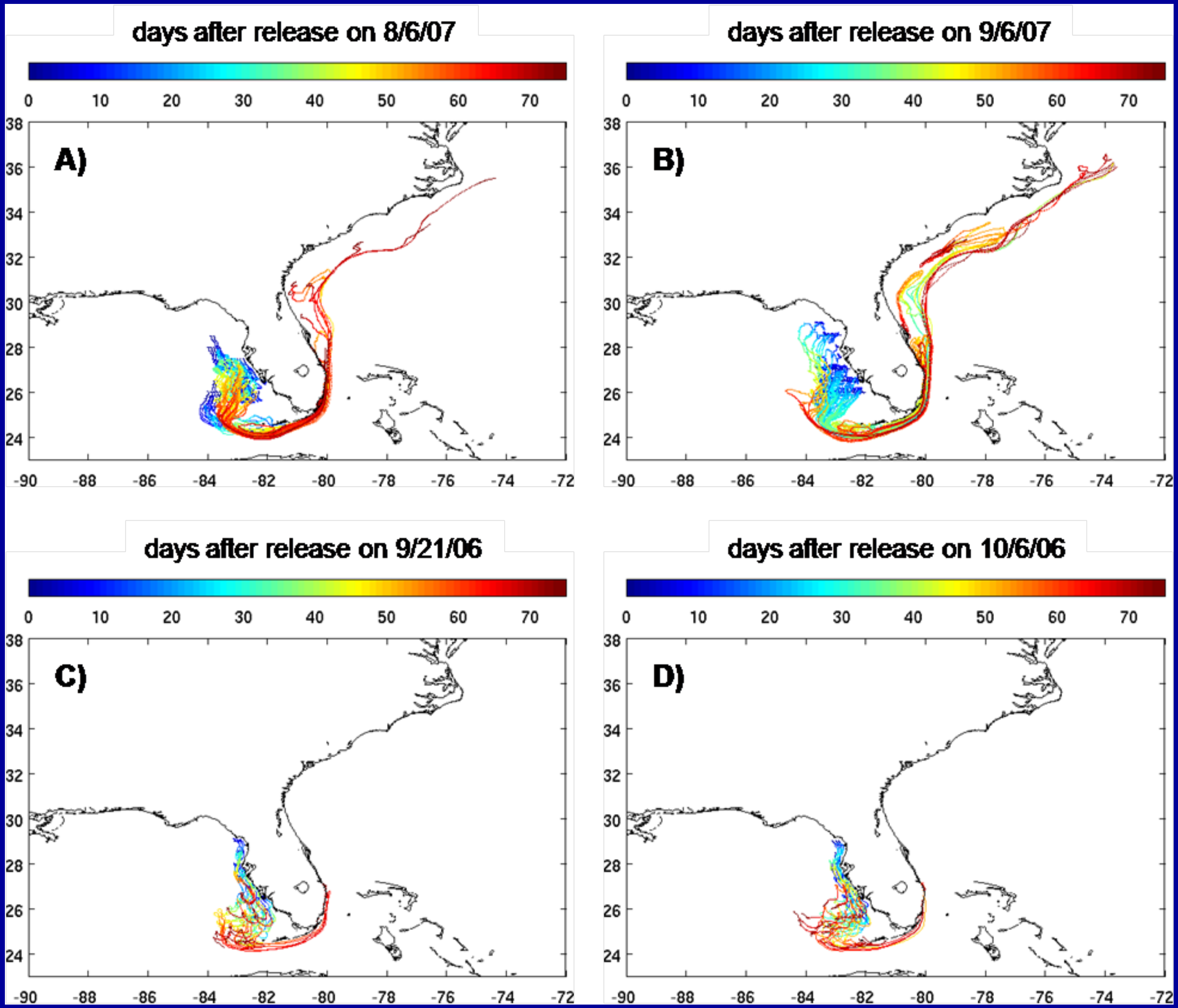


Physics

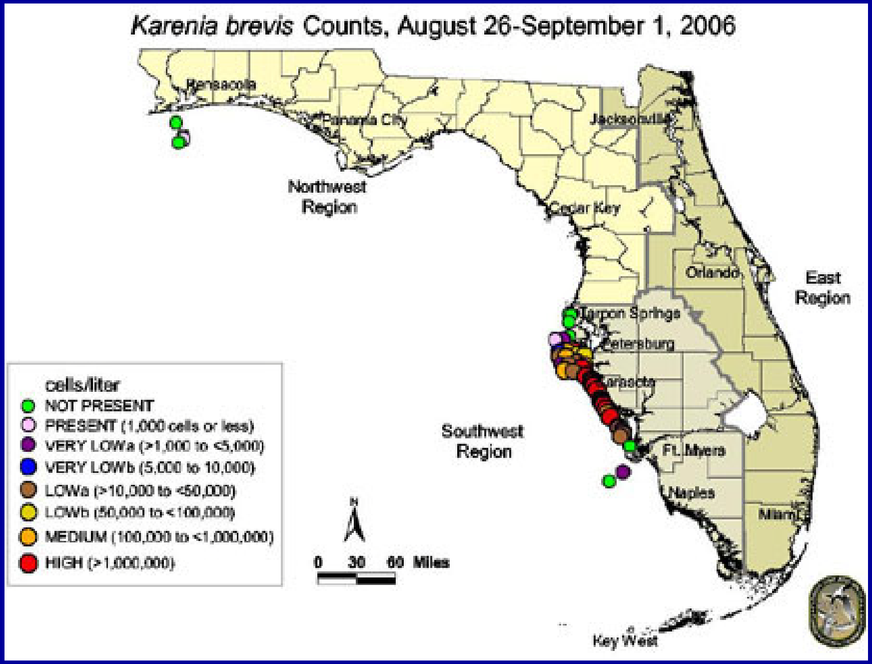
- Unfortunately, biogeochemistry is only half the battle
- A fully 3-dimensional circulation model is required to accurately reproduce or predict the blooms dynamics
    - Cell aggregation along fronts
    - Coastal trapping of blooms
    - Export or decantation of blooms

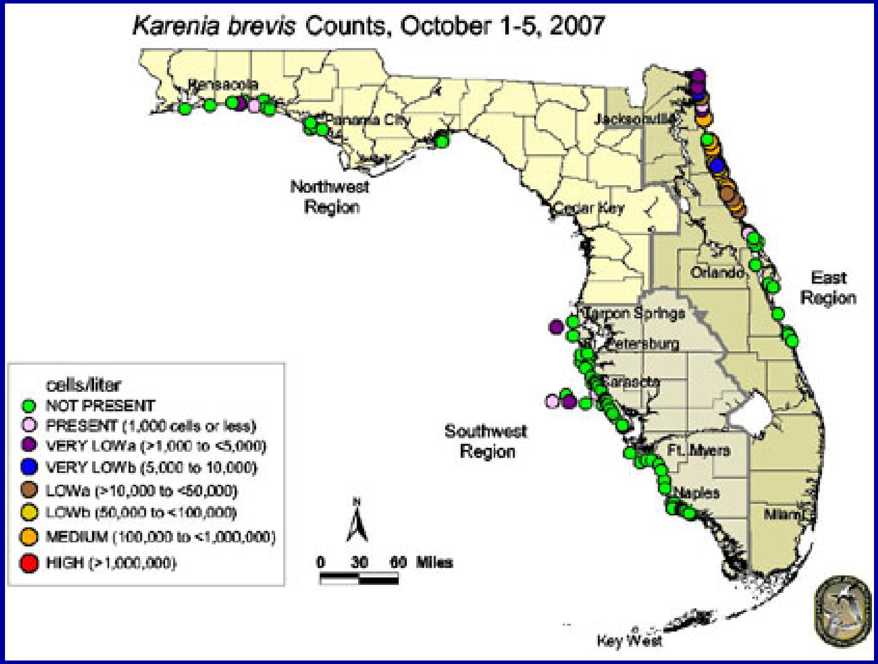
Simulated Surface Drifters

- 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



Red Tides – 2006/07





Large red tide on WFS

Small red tide on WFS

In 2007, exported *K. brevis* populations were observed along the East Florida coast

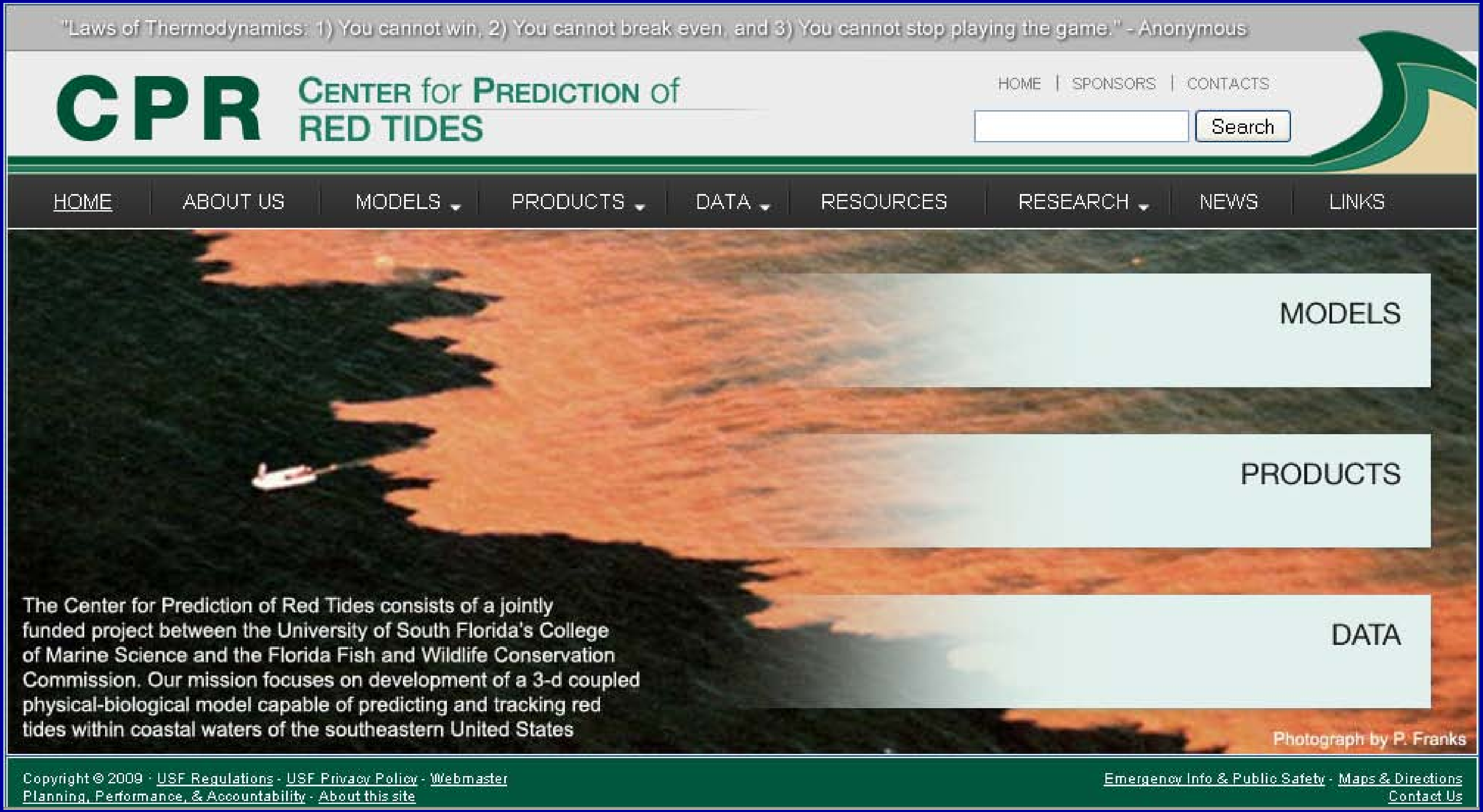
Models

- 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 (Jason Lenes and John Walsh – USF)

Model Domains

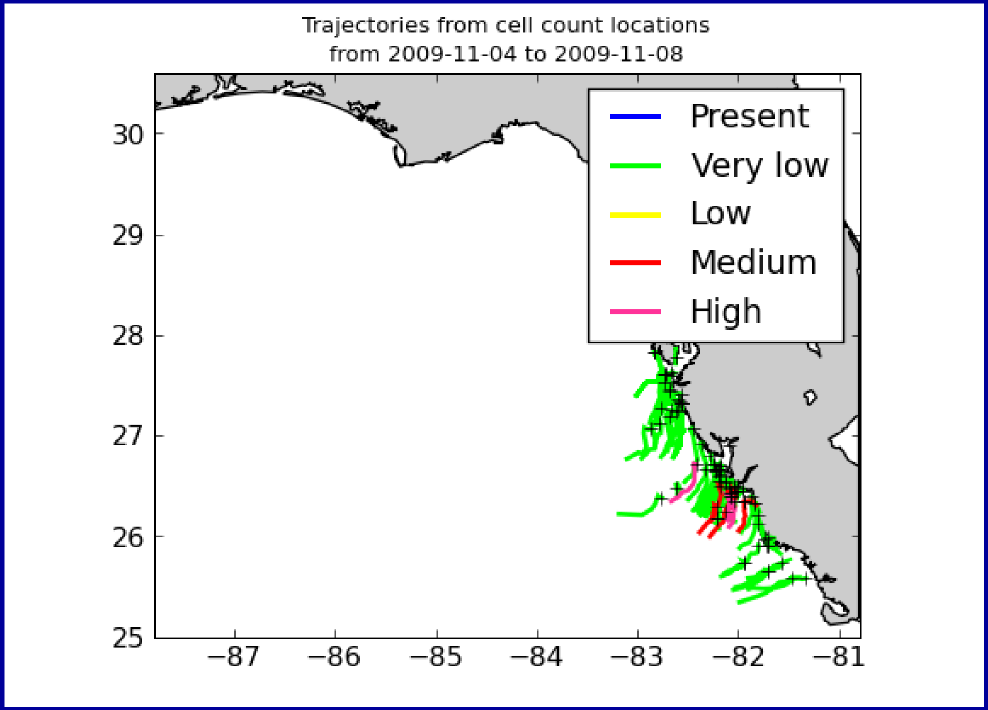
Nested grids of the circulation models, FVCOM, ROMS, and SABGOM, driving HABSIM over the Gulf of Mexico and downstream South Atlantic Bight

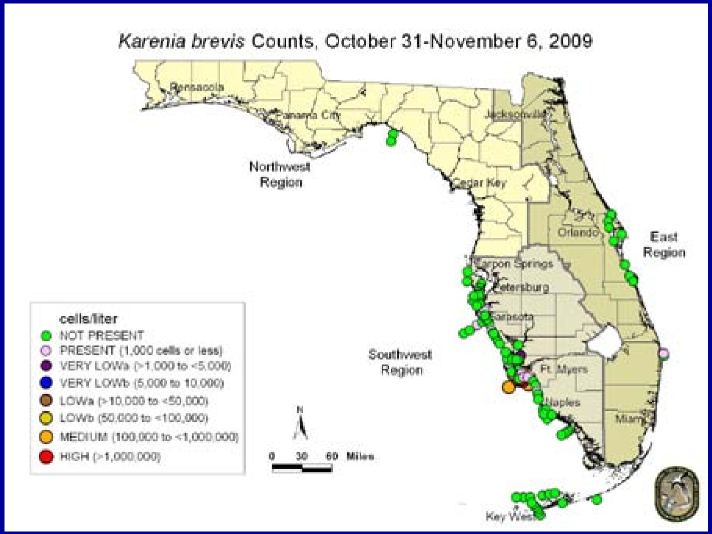
http://cprweb.marine.usf.edu

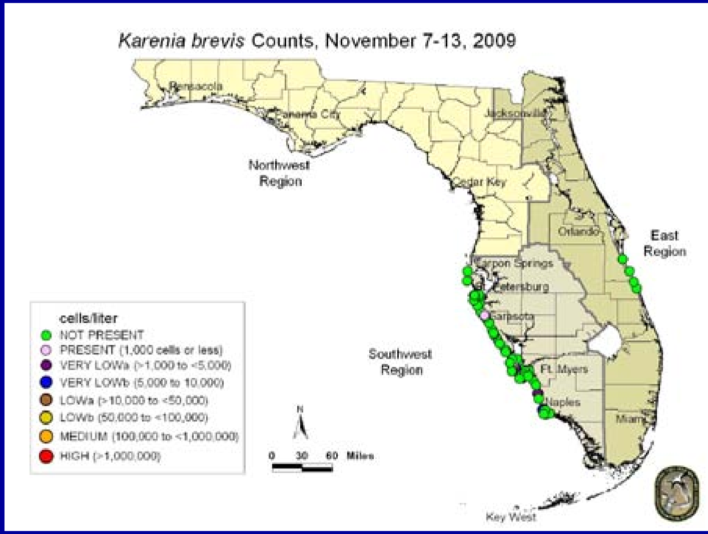


Decision Support Tools

- HAB tracking tool
  - Short term (1-3 day) trajectories

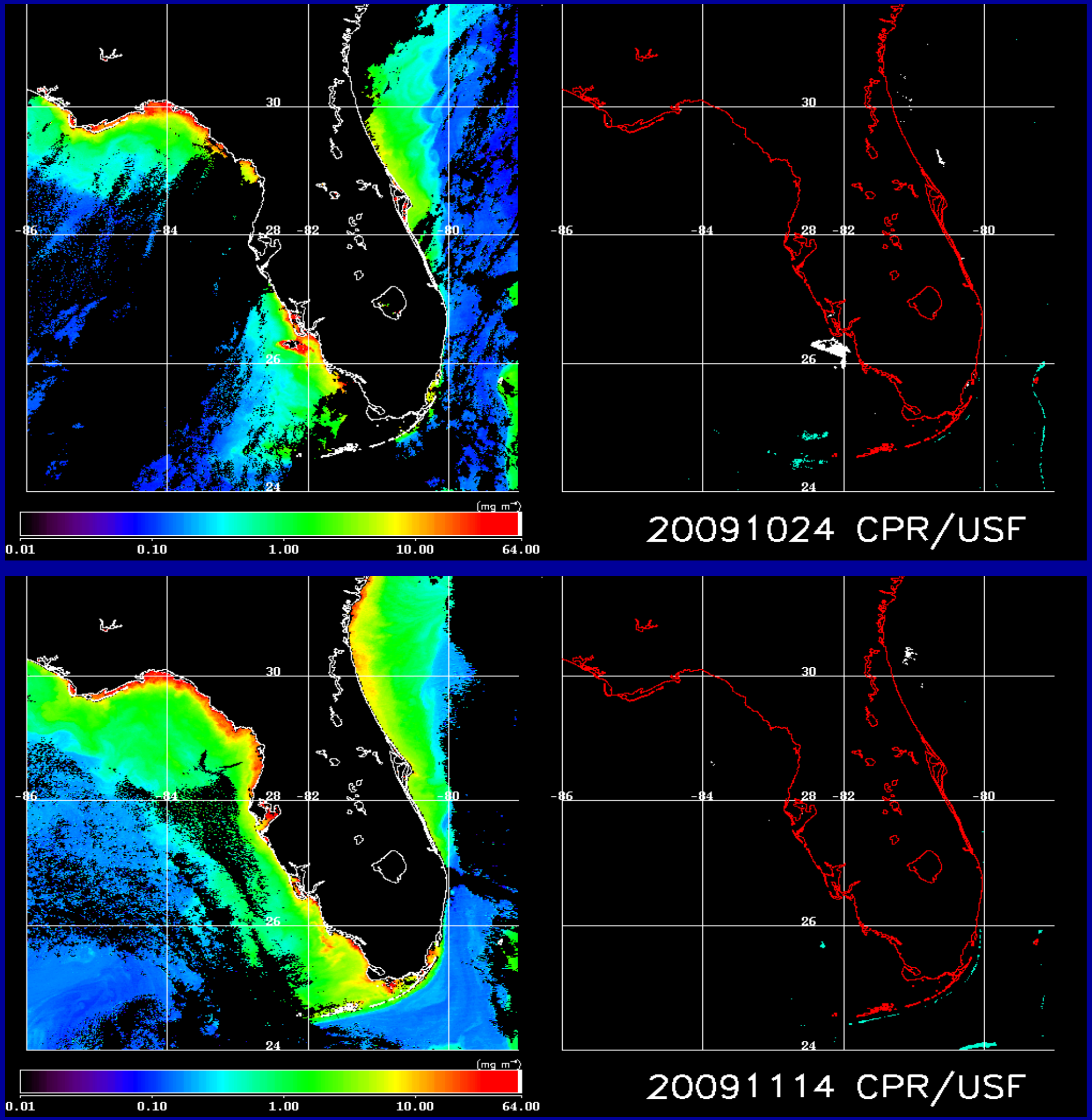






Decision Support Tools

- *Karenia* satellite flags
  - Maps of *Karenia* surface bloom locations
  - Updated daily with the most recent two weeks password protected (password available for resource managers)



Conclusions

- Silica can potentially help mitigate the magnitude of *Karenia brevis* blooms from non-siliceous nutrient sources such as cyanophytes, decaying dead fish, and remineralization of diatom blooms
- Physical transport plays a crucial role in the aggregation and decantation of red tide blooms on the WFS

Acknowledgements

- National Aeronautics and Space Administration
- National Oceanic and Atmospheric Administration
- University of South Florida – College of Marine Science
- Center for Prediction of Red Tides
- Florida Fish and Wildlife Conservation Commission