Coastal Observing in Your Community

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Coastal Ocean Circulation Influences on Matters of Societal Concern

Robert H. Weisberg

College of Marine Science
University of South Florida
St. Petersburg, FL 33701

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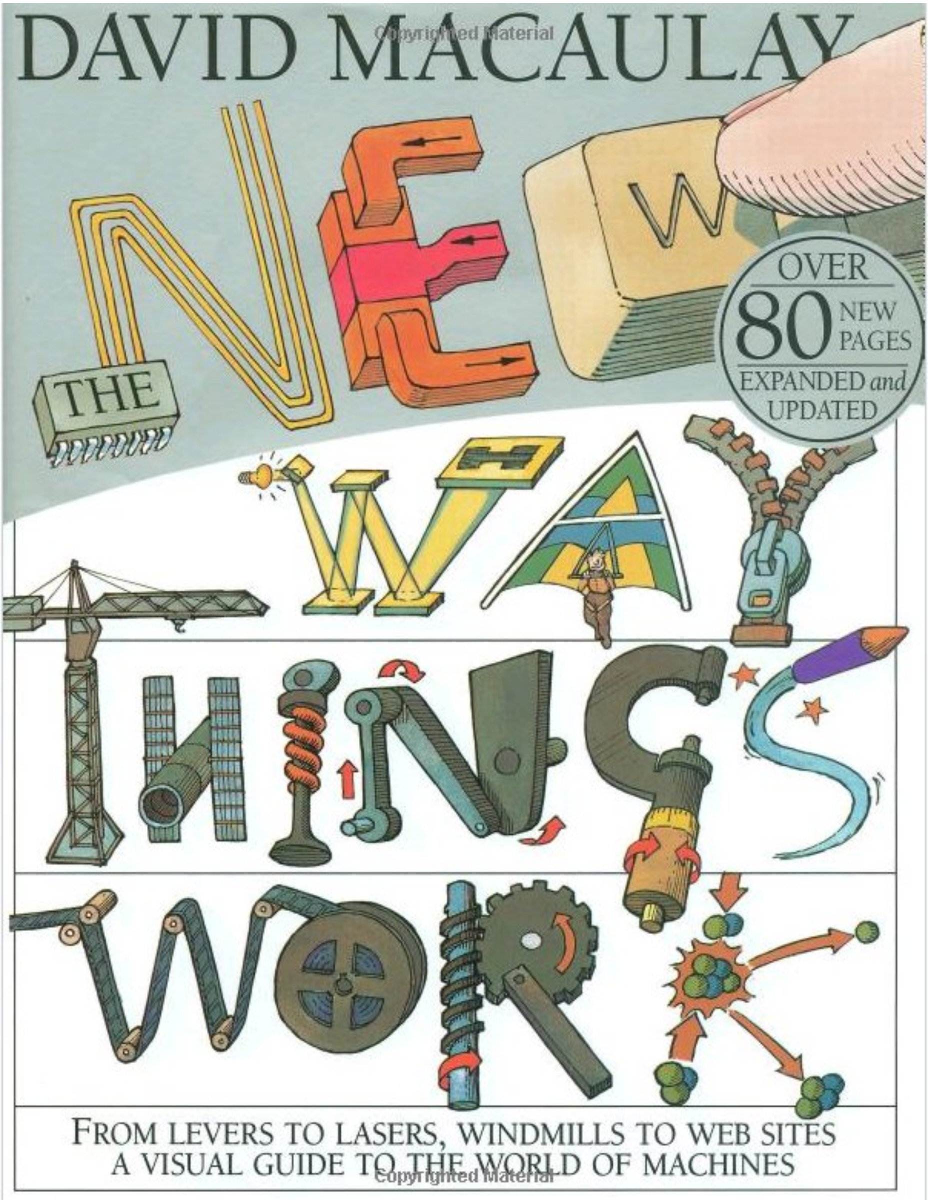
Overview:

The coastal ocean is where society meets the sea, where recreational and fishing activities abound, along with maritime commerce hubs, where harmful algal blooms occur, fossil fuels are tapped and alternative energy sources are considered for exploitation.

Managing these competitive uses requires that we understand how the coastal ocean works.



Coastal Ocean Observing Systems science is about how the coastal ocean works.

We cannot responsibly manage the coastal ocean if we do not know how it works, and workings are all about connections.

Connections begin with the circulation, because this determines the water properties and hence the environment in which organisms make their livings.

Three vignettes will illustrate the importance of the coastal ocean circulation:

A. *Gag grouper* recruitment,

B. How DWH oil arrived on northern Gulf beaches.

C. Red tide

First: What is a Regional Coastal Ocean Observing System (RCOOS)?

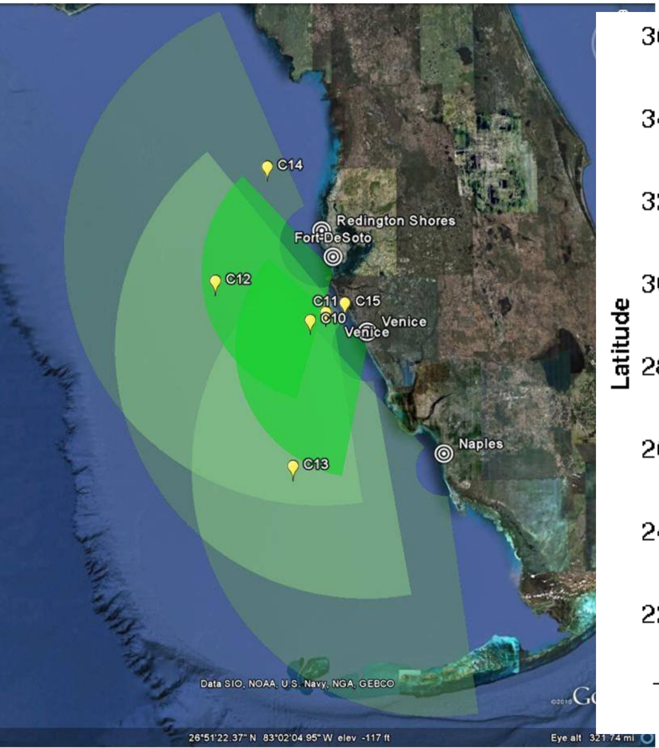
An RCOOS is a coordinated set of observations and models.

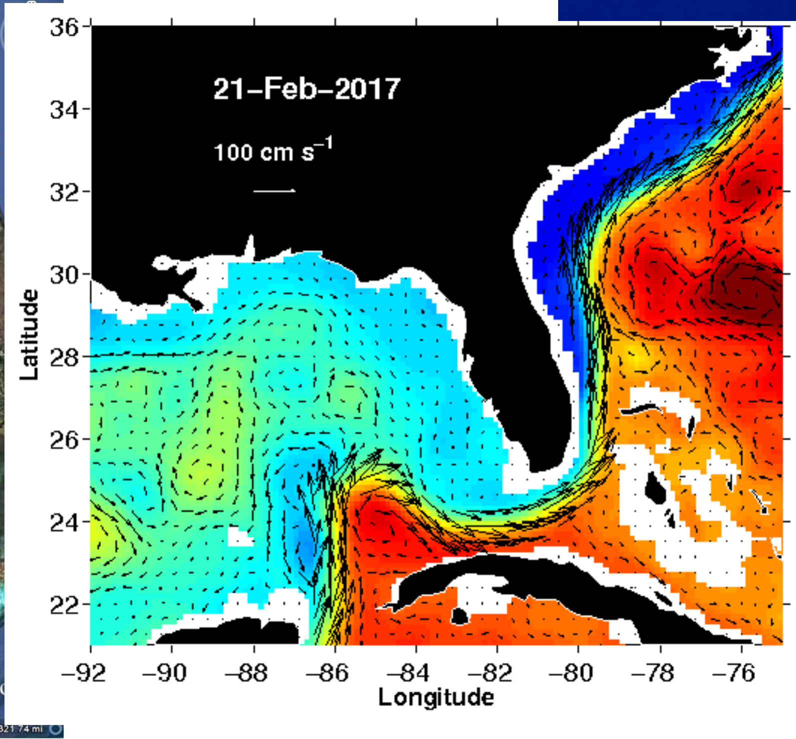
- **The sampling problem is too large for observations alone;**
- **Hence models are needed to fill the gaps;**
- **But model without observations are fraught with errors – We need both!**

West Florida Shelf RCOOS - part of SECOORA

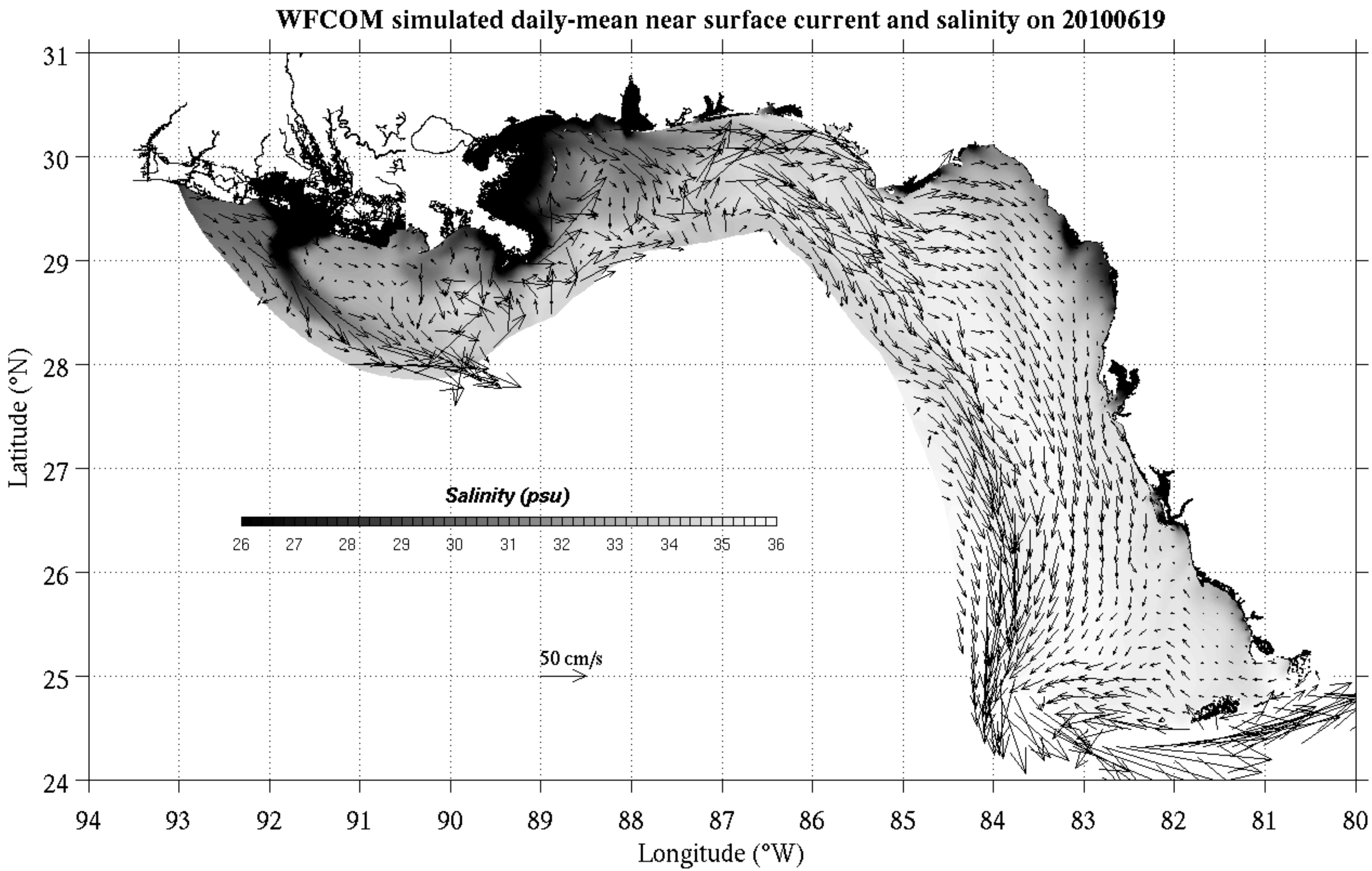
Observations:

- Moored Buoys,
- HF-Radars,
- Robotic Gliders,
- Satellites.

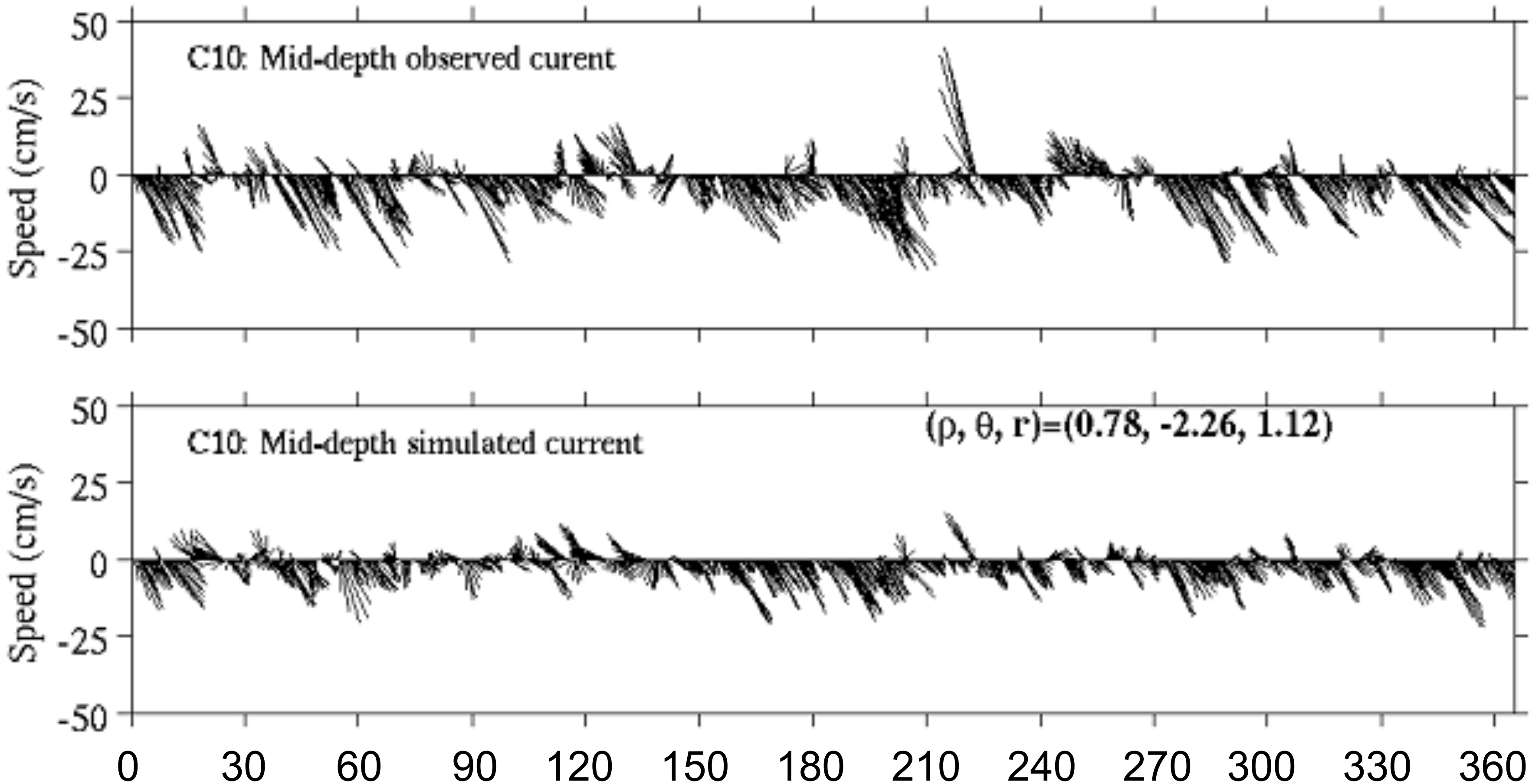




Models: WFCOM (FVCOM nested in GOM HYCOM), with high resolution, 31 layers in the vertical, flooding/drying, and tides, providing daily, automated forecasts.



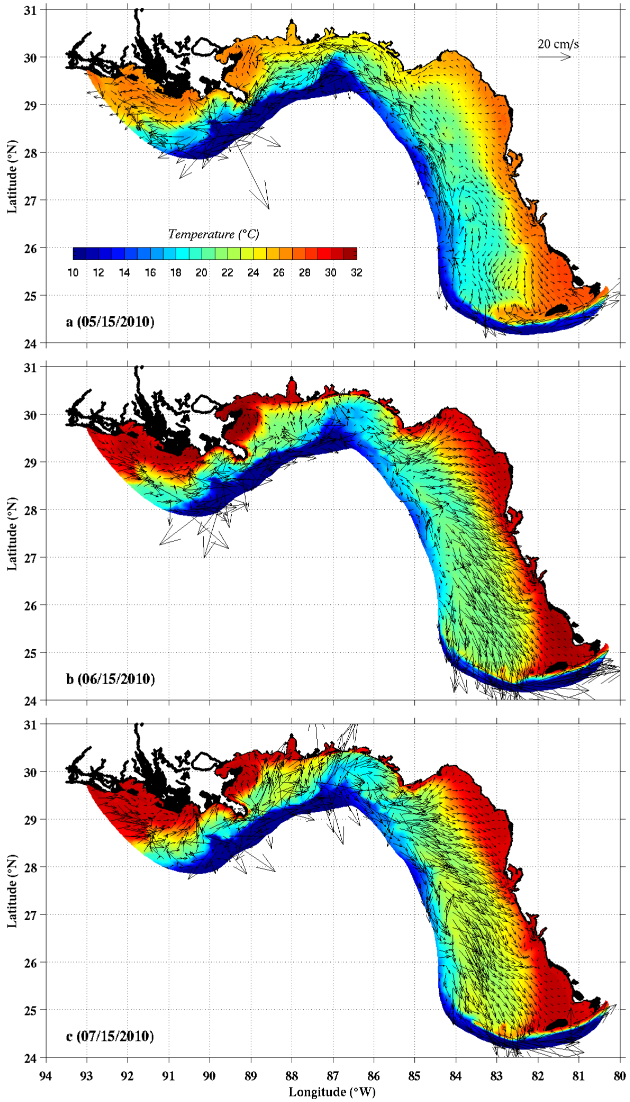
WFCOM simulation comparison with observations: Velocity from moorings.

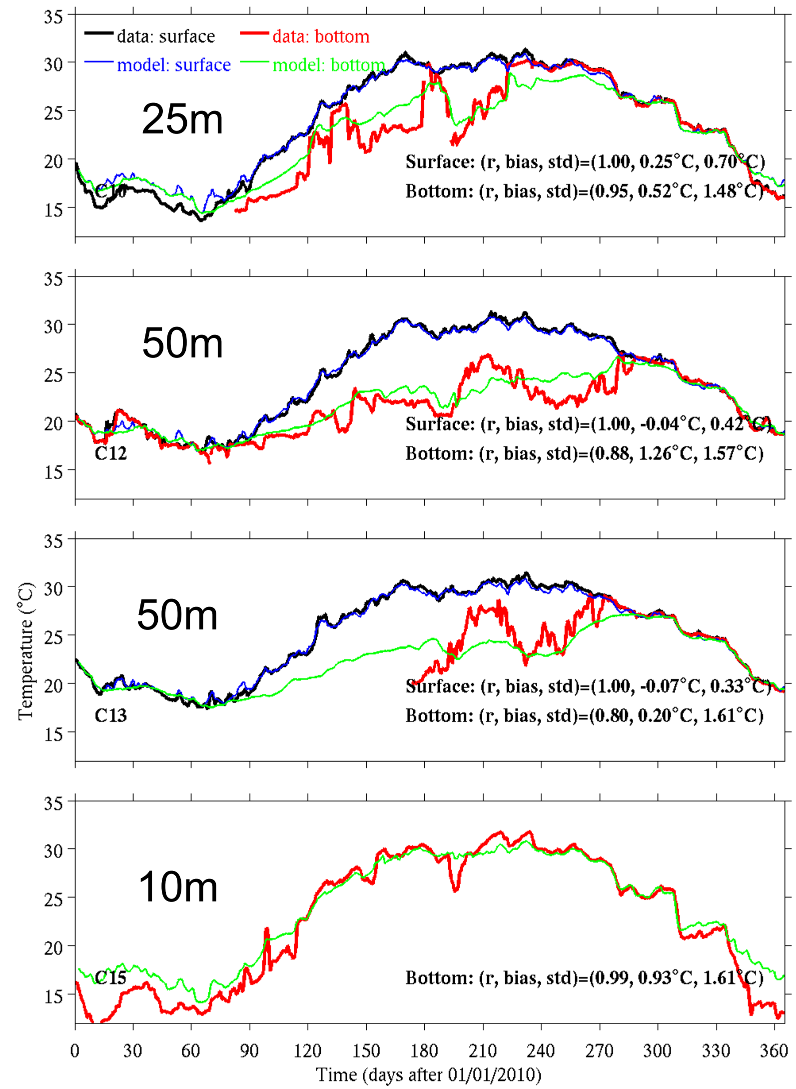


Mid-depth currents observed and modeled for 2010 at mooring C10 on the 25 m isobath off Sarasota FL. Vector correlation, angular deviation and regression coefficient are given. The fidelity is good, although the model underestimates the currents at this location.

WFCOM simulation comparison with observations: Temperature from moorings.

Model/observation fidelity justifies model use in diagnosing how the coastal ocean works.



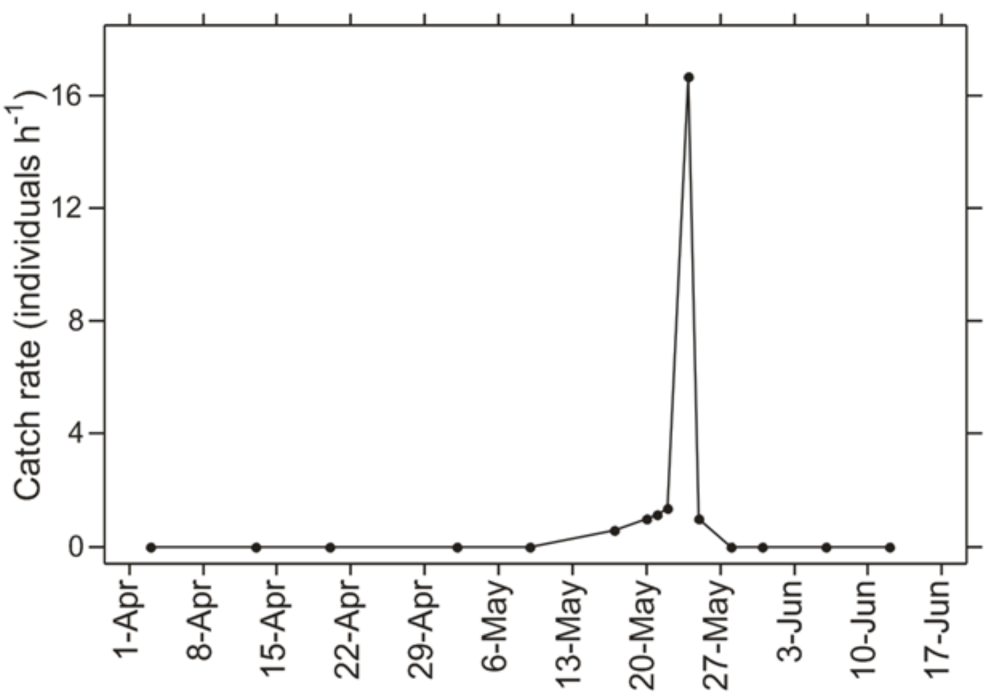


A. *Gag grouper* recruitment.

Weisberg, R.H., L. Zheng and E. Peebles (2014). Gag Grouper Larvae Pathways on the West Florida Shelf. Continental Shelf Research, 88, 11-23, doi.10.1016/j.csr.2014.06.003.

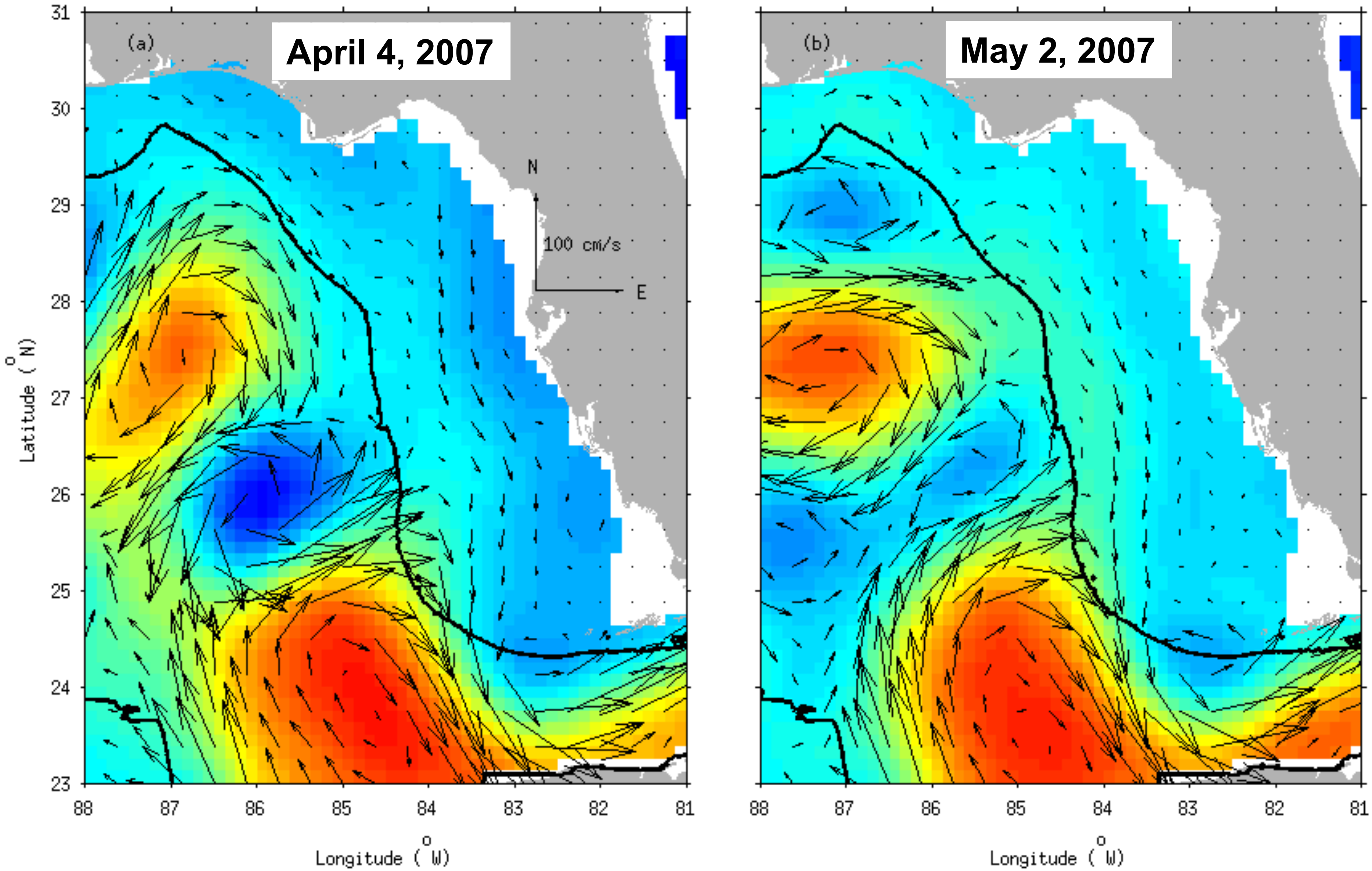
Gag adults spawn offshore from late winter to early spring. Their juveniles settle near shore 40-70 days later.

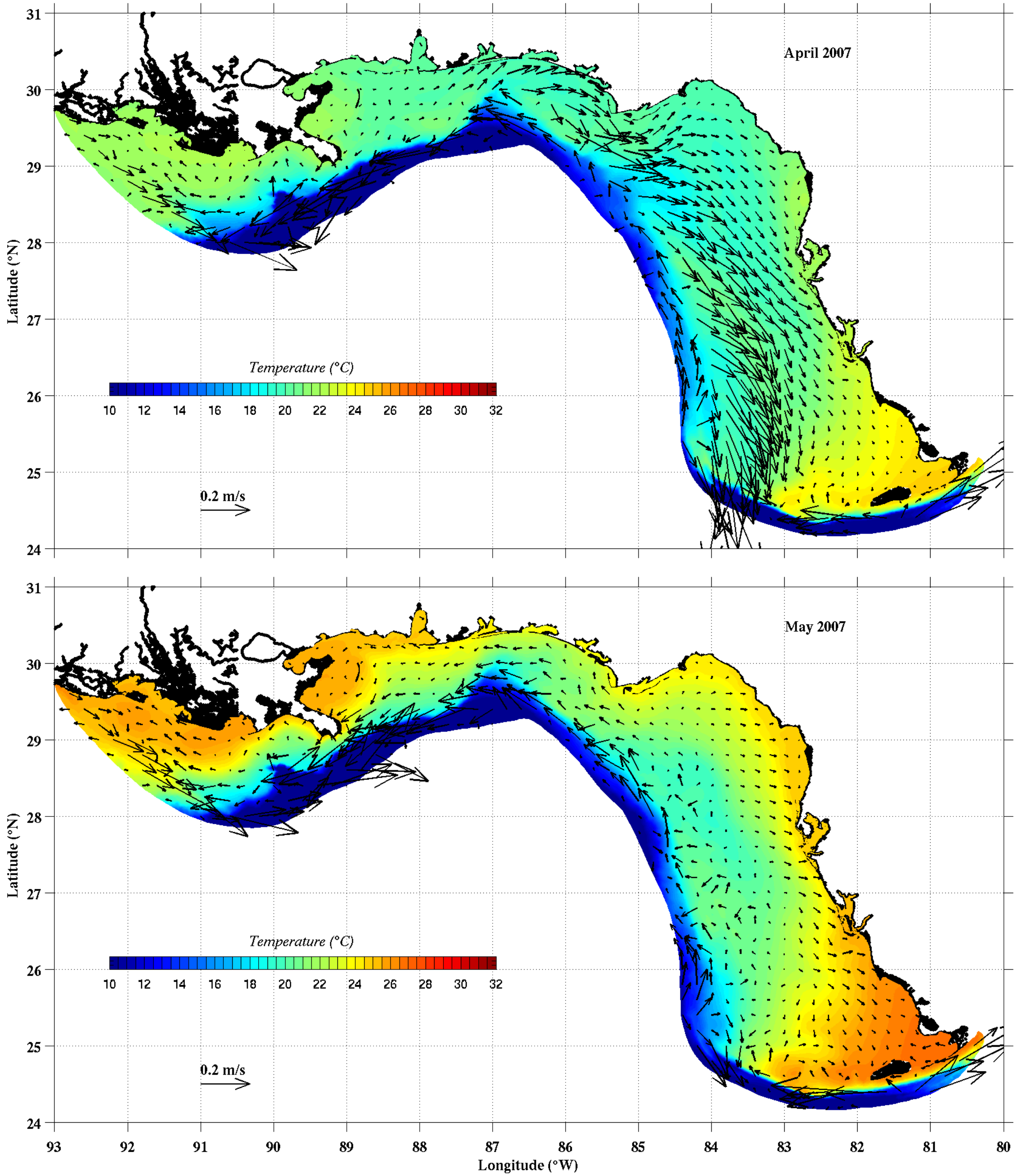
How larvae get from spawning to settlement was a mystery.



We solved this mystery via circulation model simulations for spring 2007 when gag juveniles were caught on Mullet Key (entrance to Tampa Bay).

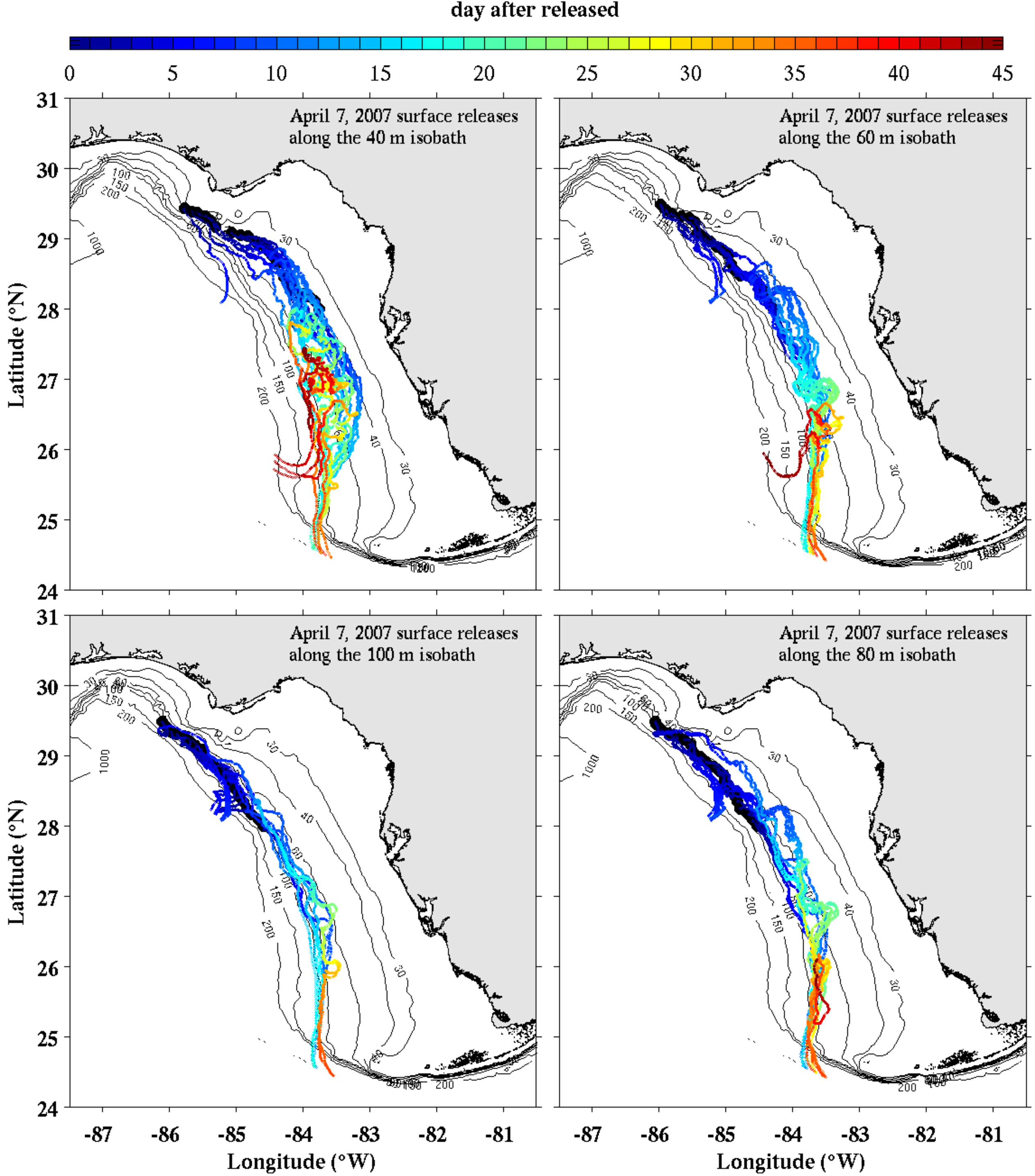
Deep-ocean forcing is important.
SSH and Surface Geostrophic V





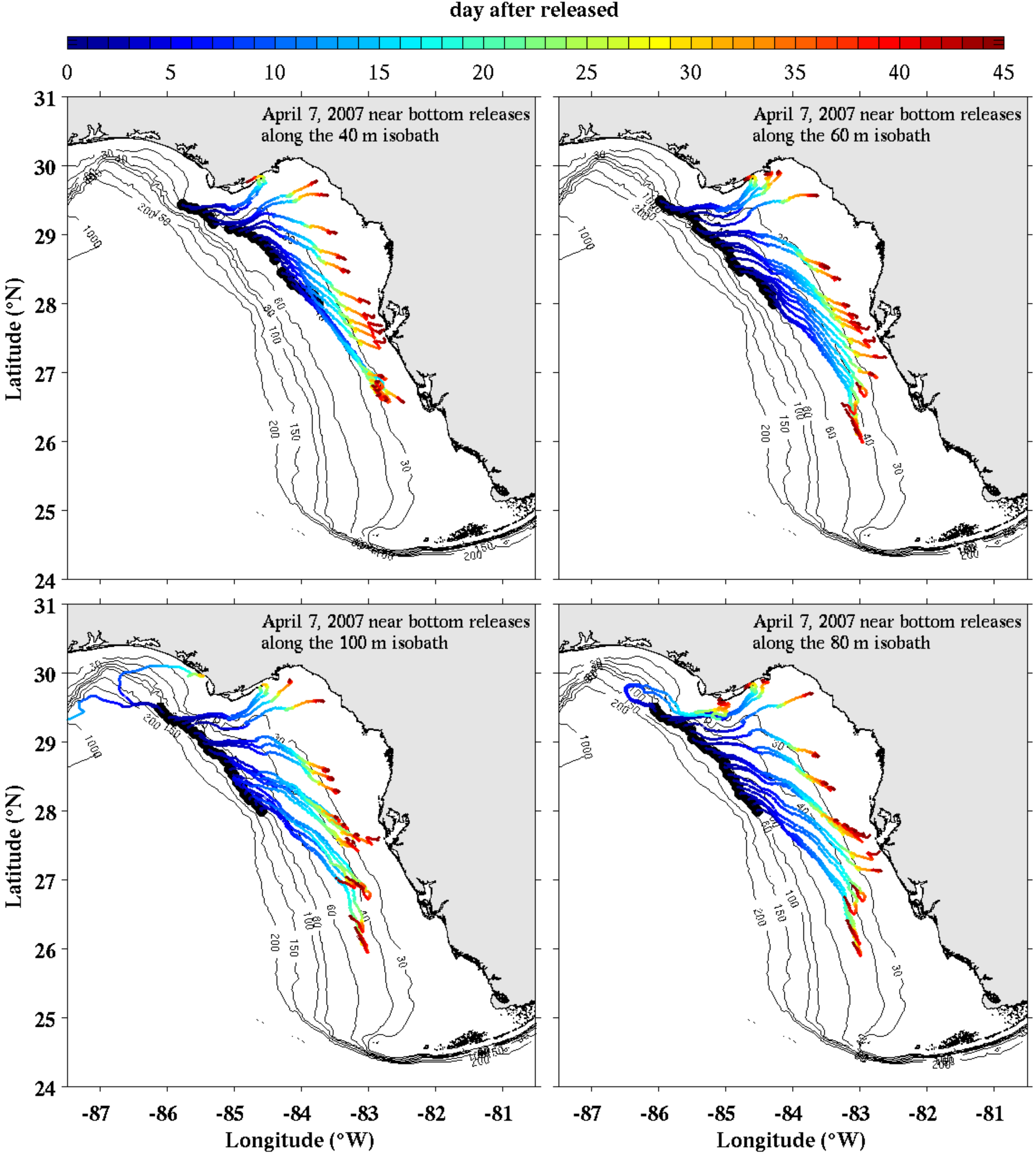
WFCOM simulated near bottom velocity and temperature averaged over the months of April (top) and May (bottom), 2007.

Note the upwelling circulation forced by the deep-ocean.



45 day surface trajectories for particles initialized on April 7 at the 40m, 60m, 80m and 100 m isobaths.

None of these surface particles gained proximity to the near shore.



45 day near-bottom trajectories for particles initialized on April 7 at the 40m, 60m, 80m and 100m isobaths.

Many of these near-bottom particles gained proximity to the near shore, especially Mullet Key.

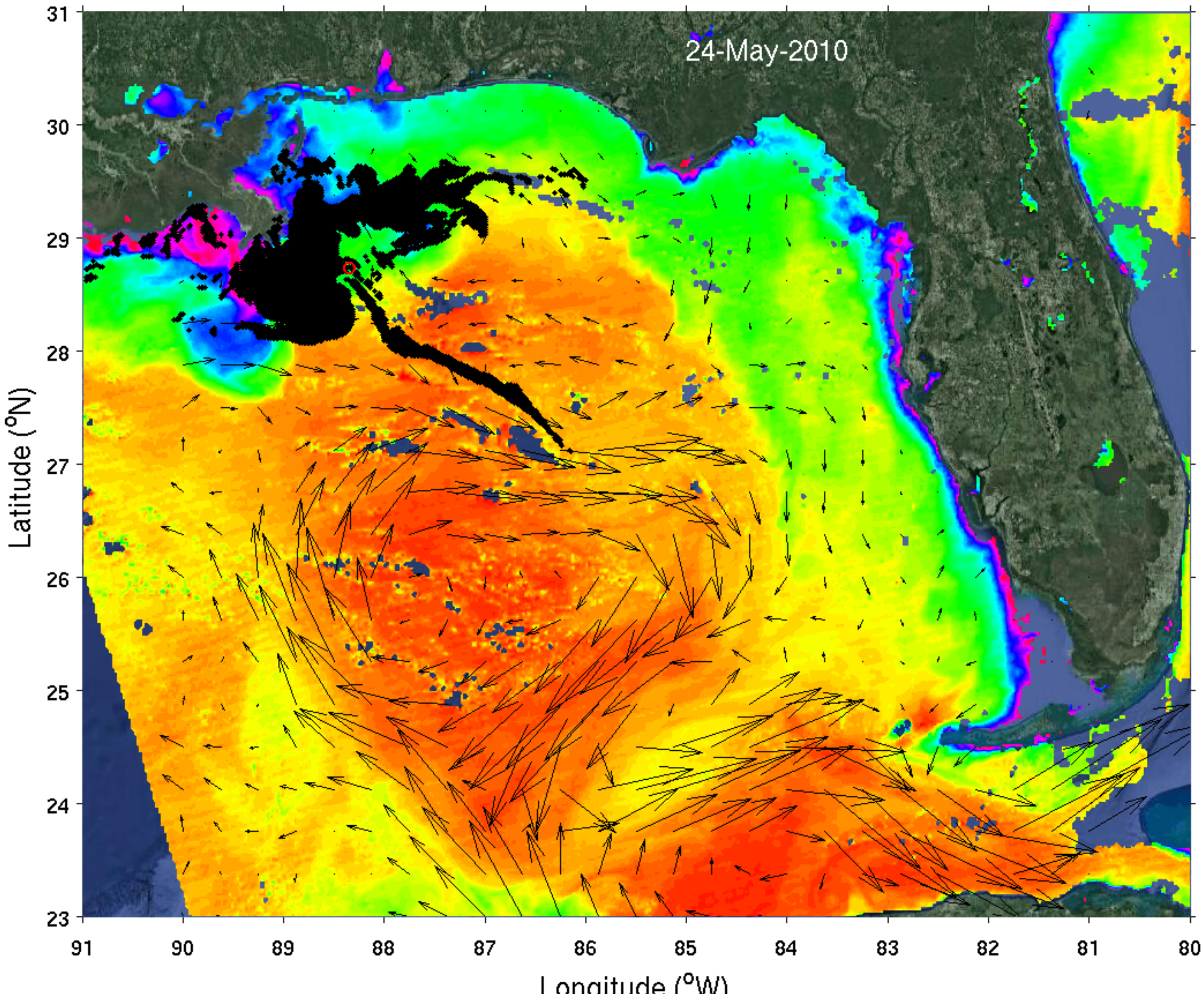
Findings from A:

- ***Gag grouper*** **larvae and juveniles are transported from spawning to settlement along the bottom under upwelling circulation conditions. This finding is supported by the co-location of *Gag* juveniles with macro-algae of offshore, hard bottom origin.**
- **Gag year class success requires upwelling to occur in phase with spawning and to last long enough. Such protracted upwelling is due to Loop Current interactions with the shelf slope near the Dry Tortugas.**
- **We now have a means for forecasting successful *gag* recruitment years.**

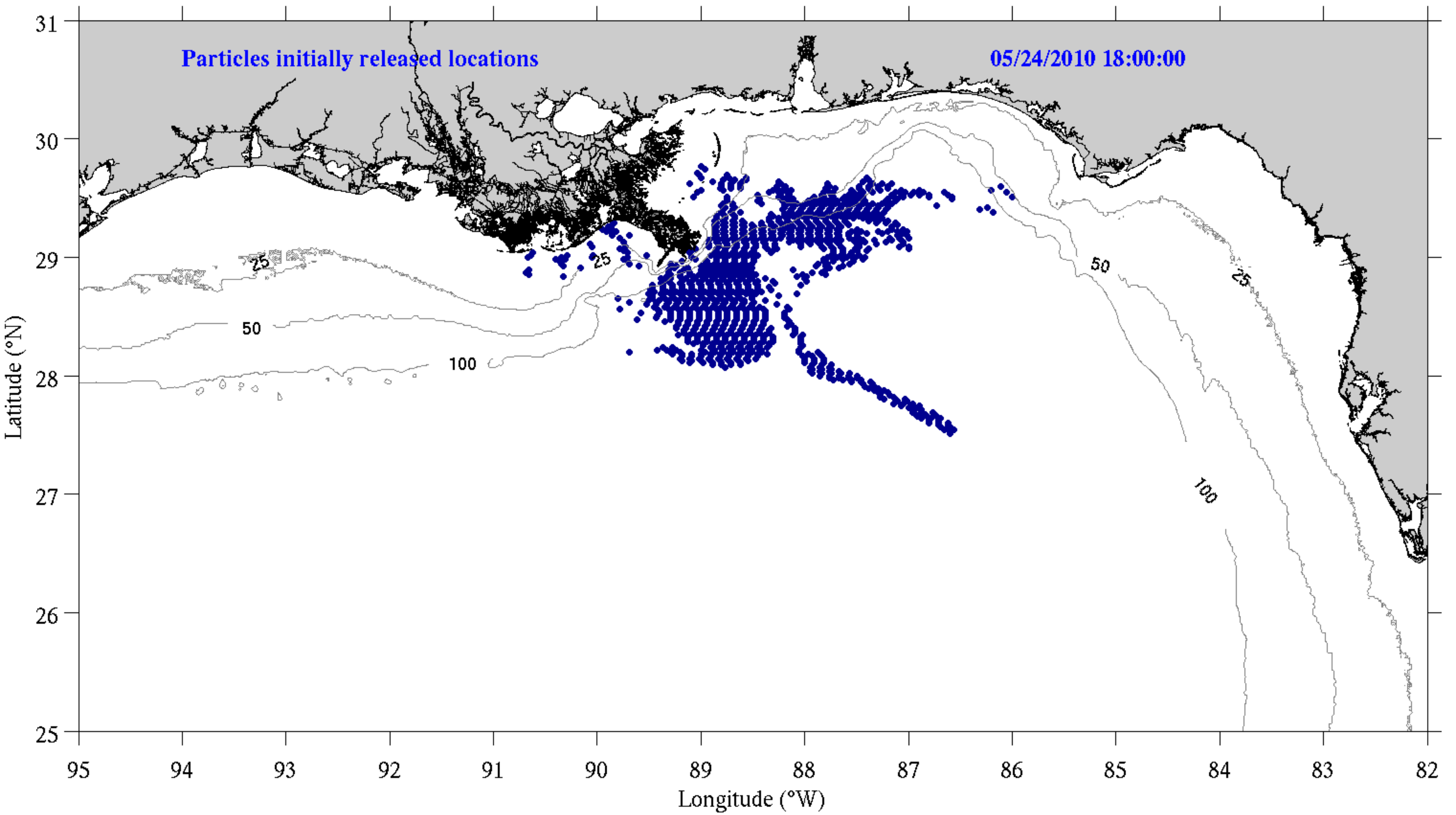
B. How DWH oil arrived on northern Gulf beaches.

Weisberg, R.H., L. Zheng, and Y. Liu (2017), On the Movement of Deepwater Horizon Oil to Northern Gulf Beaches, Ocean Modelling, 111, 81-97, doi:10.1016/j.ocemod.2017.02.002..

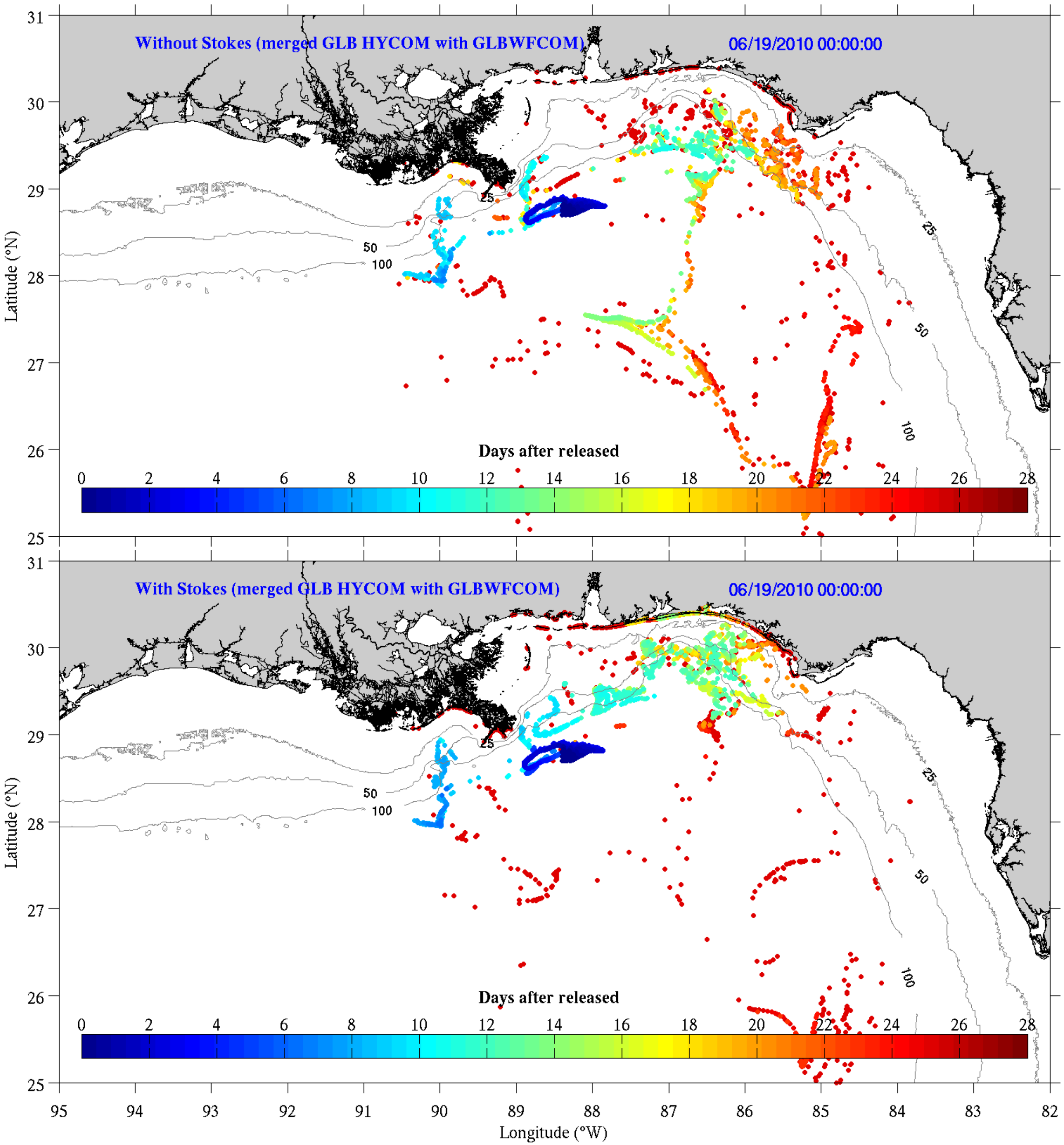
DWH surface oil location on 5/24/10, along with surface currents and temperature.



WFCOM particle initialization on 5/24/10 to simulate oil movement. Nine particles were added hourly at the well-head to simulate the continual oil flow.



WFCOM particle distribution on 6/19/10.

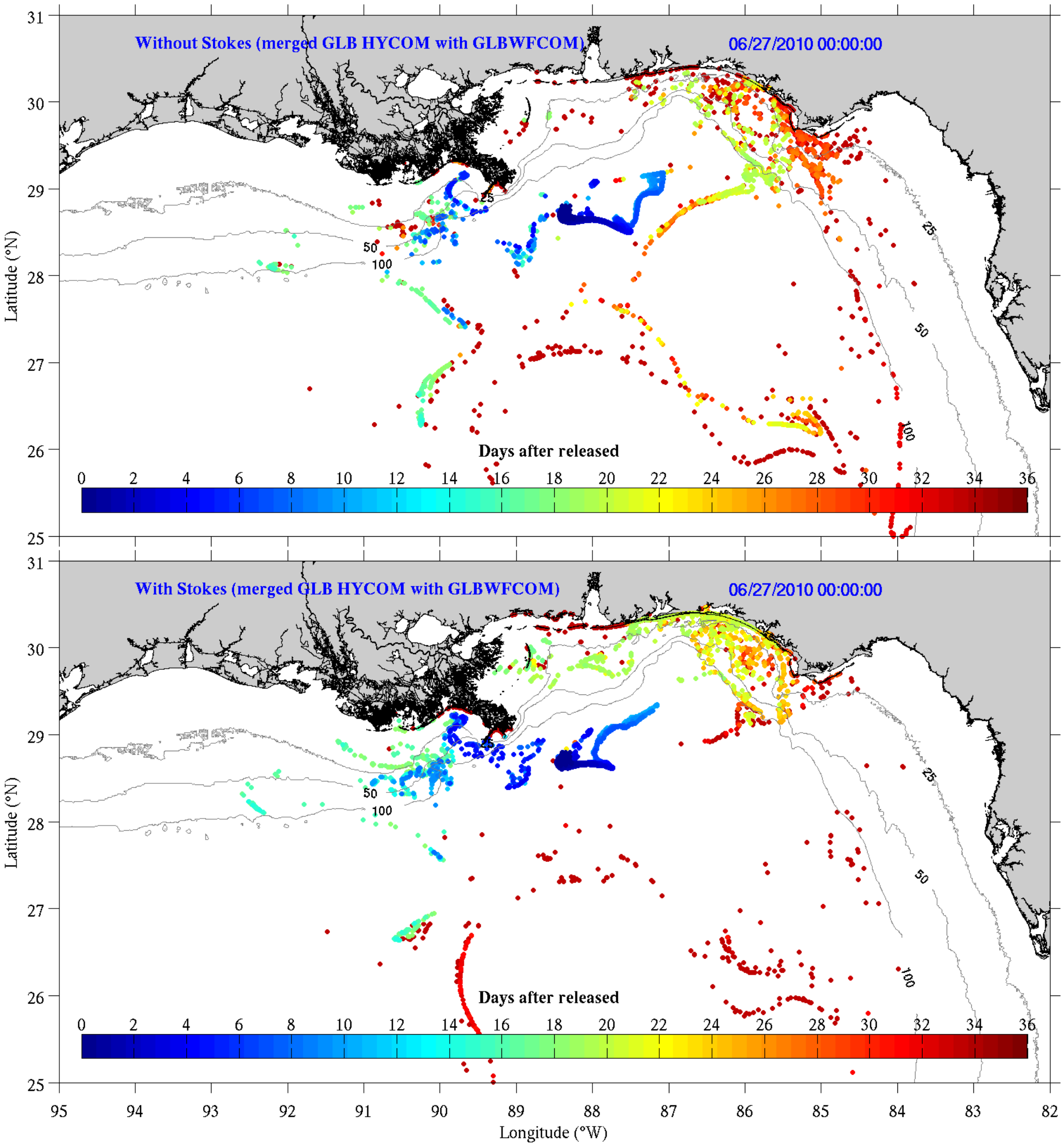


Particle color is its age

Without Stokes drift

With Stokes drift

WFCOM particle distribution on 6/27/10.

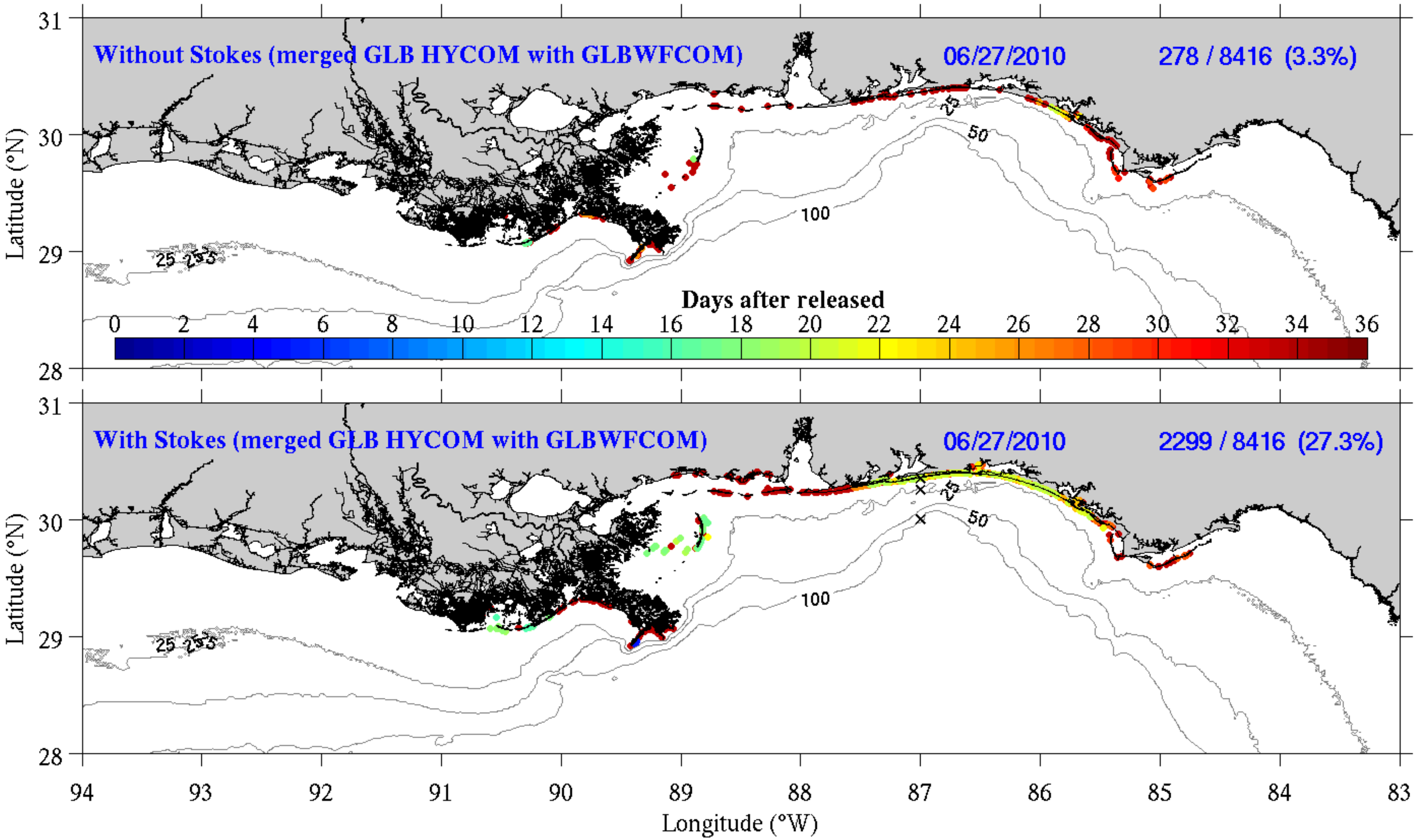


Particle color is its age

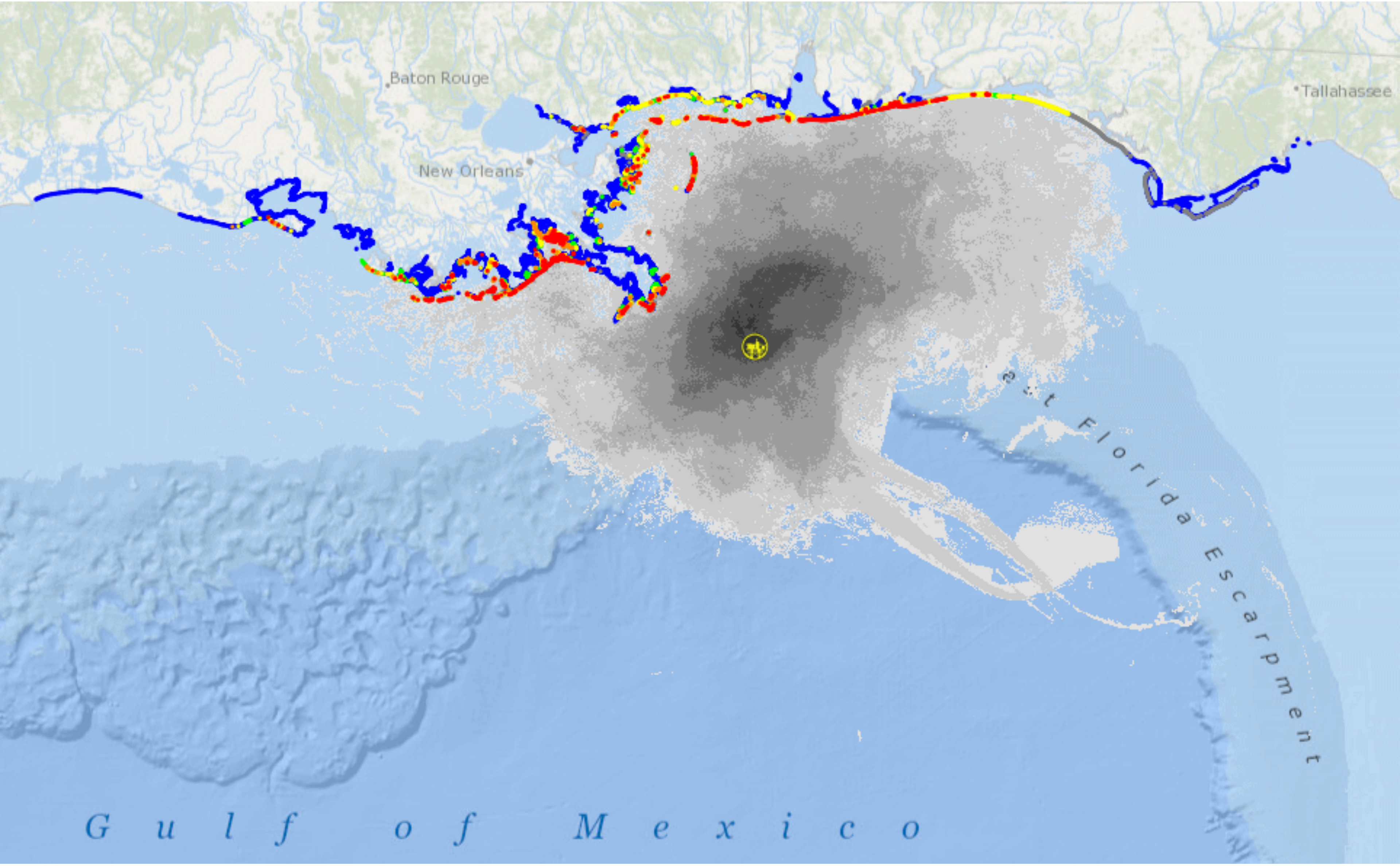
Without Stokes drift

With Stokes drift

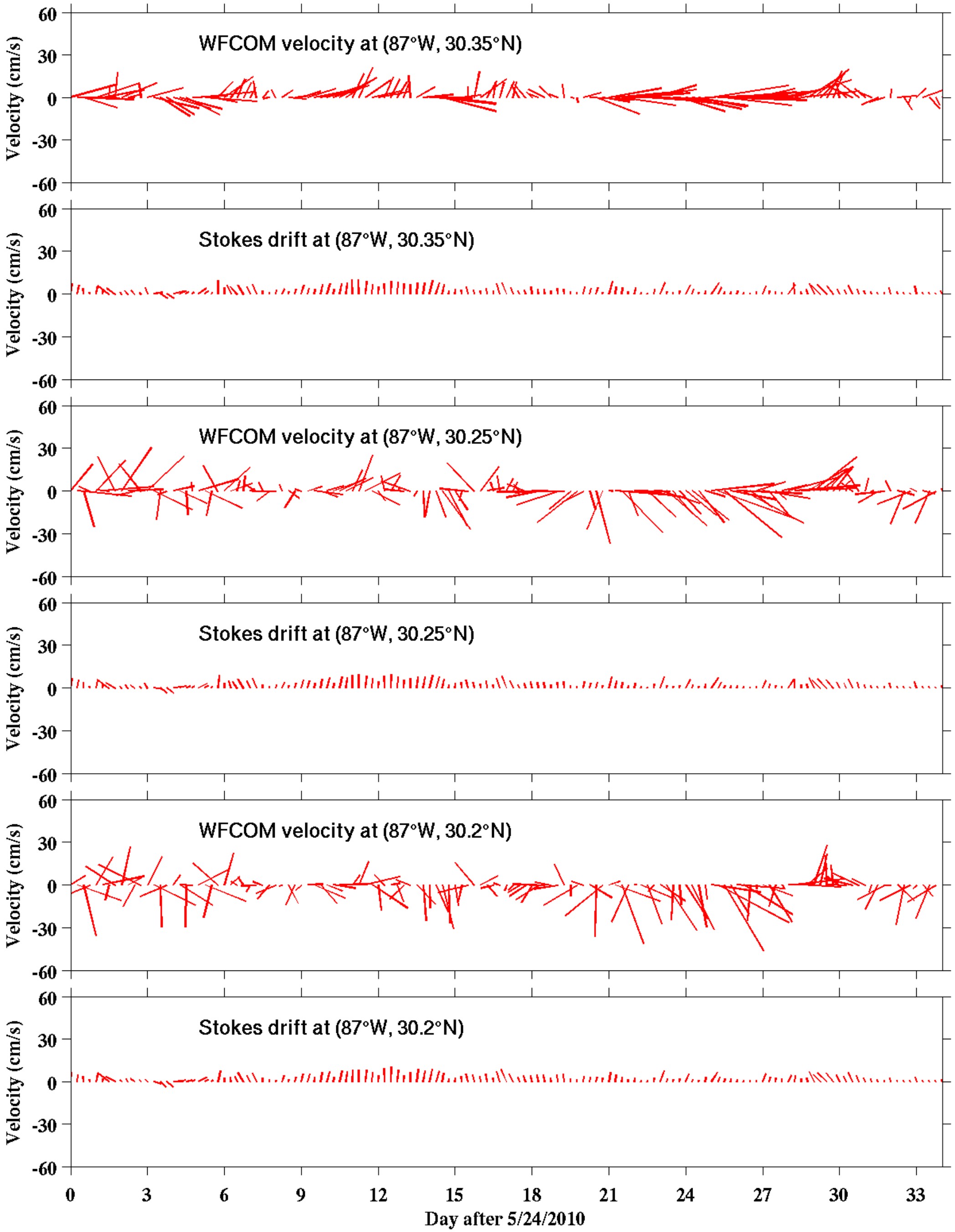
WFCOM beached particle distribution on 6/27/10.



Observed beached oil distribution.



Velocity vectors by ocean circulation and by Stokes drift.



- Ocean circulation >> Stokes drift
- Ocean circulation tends parallel to the shoreline upon approaching the coast.
- Stokes drift remains perpendicular to the shoreline.

Findings from B:

- The ocean circulation is responsible for getting oil to the vicinity of the shoreline.
- The wave effects via Stokes drift are responsible for depositing the oil on the beach.
- These findings are physically intuitive because in shallow water the circulation tends to align with the shoreline, whereas the Stokes drift tends to be perpendicular to the shoreline.
- Required for oil tracking are:
    - A high resolution coastal ocean model downscaling from the deep-ocean, across the shelf and into the estuaries (WFCOM).
    - A wave model for calculating Stokes drift.
    - A sufficiently accurate deep-ocean model supported by adequate observations for data assimilation.
- The same tools are required for anything of an ecological nature in the coastal ocean.

C. Circulation control of *K. brevis*, red tide blooms on the WFS.

Weisberg, R.H., A. Barth, A. Alvera-Azcárate, and L. Zheng (2009). A coordinated coastal ocean observing and modeling system for the West Florida Shelf, *Harmful Algae*., 8, 585-598.

Weisberg, R.H., L. Zheng, Y. Liu, C. Lembke, J.M. Lenes and J.J. Walsh (2014), Why no red tide was observed on the West Florida Continental Shelf in 2010. *Harmful Algae*, 38, 119-126, doi.org/10.1016/j.hal.2014.04.010.

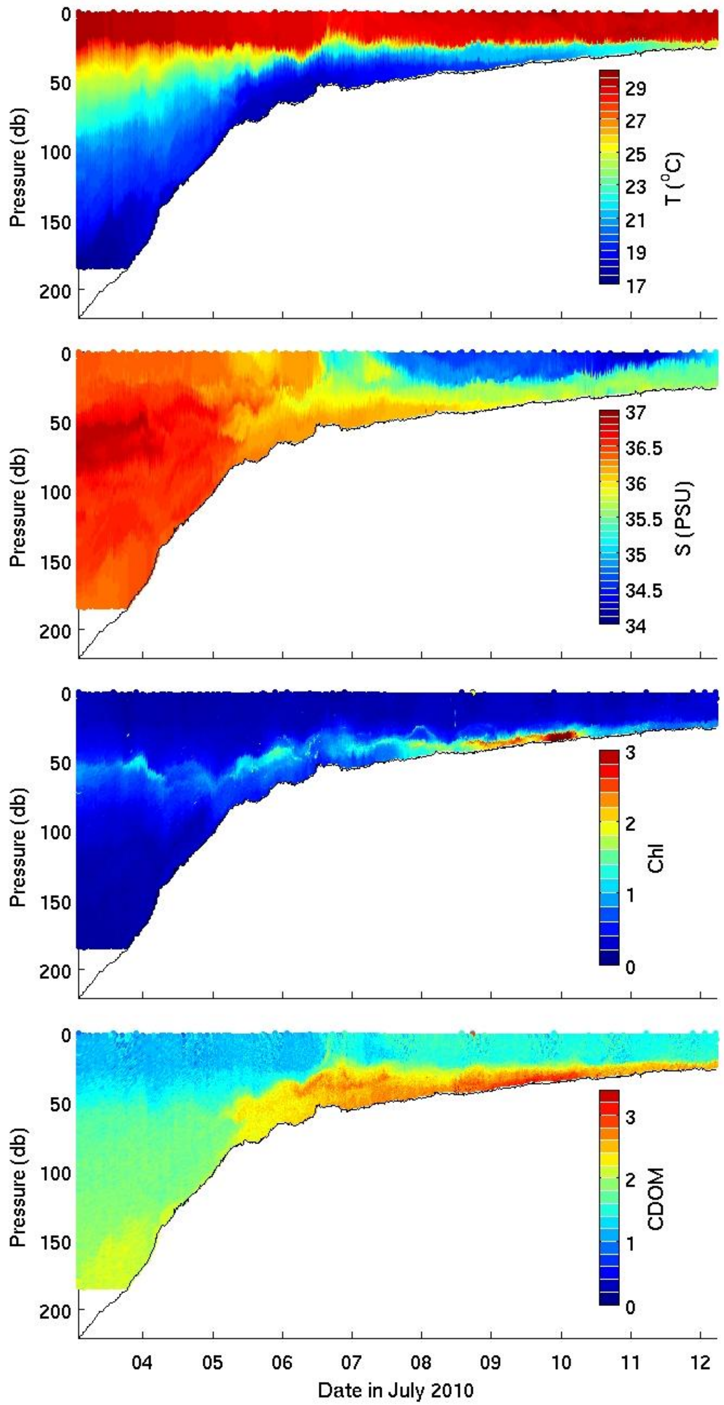
Weisberg, R.H., L. Zheng, Y. Liu, A.A. Corcoran, C. Lembke, C. Hu, J.M. Lenes and J.J. Walsh (2016). *Karenia brevis* blooms on the West Florida Shelf: A comparative study of the robust 2012 bloom and the nearly null 2013 event, *Cont. Shelf Res*., 120, 106-121, doi.org/10.1016/j.csr.2016.03.011

Liu, Y., R.H. Weisberg, J.M. Lenes, L. Zheng, K. Hubbard, and J.J Walsh (2016), Offshore forcing on the "pressure point" of the West Florida Shelf: Anomalous upwelling and its influence on harmful algal blooms, *Jour. Geophys. Res.-Oceans*, http://dx.doi.org/10.1002/2016JC011938, in press.

***K. brevis*, a slow growing dinoflagellate, requires nutrient deplete conditions to out-compete faster growing diatoms. This generally occurs at mid-shelf in spring. Red tide blooms then occur along the shore in late summer/fall if cells are transported to the shore.**

Anomalous upwelling caused by the Loop Current can bring deeper-ocean nutrients onto the shelf, favoring diatoms and suppressing *K. brevis* red tide, as occurred, for example, in 2010.

The upwelling was observed by glider transects.



T, S, Chlorophyll and CDOM sampled along an across-shelf glider path just to the north of Tampa Bay (from *Weisberg et al*., 2014). **Note the effects of upwelling on the WFS water properties.**

We defined a LC forcing index and compared this with major *K. brevis* bloom occurrence.

Year	Persistent offshore forcing during spring and early summer (√)	Major blooms (×)	No major blooms in fall (√) or occurred in early of the year but the intensity is reduced in fall (√*)
1993	√		√
1994		×	
1995		×	
1996		×	
1997			√*
1998	√		√*
1999		×	
2000		×	
2001		×	
2002	√		√
2003	√		√
2004			√
2005		×	
2006		×	
2007		×	
2008			√
2009			√
2010	√		√
2011		×	
2012		×	
2013	√		√*
2014		×	
2015		×	

19 out of 23 years appear to have followed the major bloom criteria defined.

Following explanations of why there was no bloom in 2010, why the 2012 bloom was robust, whereas the 2013 bloom was not, we successfully predicted the 2014 and 2015 blooms.

We then got confident, and in mid-June of this year we opined that there would not be a major bloom in late summer/fall of 2016.

We were wrong!
Demonstrating that the only real constant in science is surprise, and also why more observations (RCOOS's) are needed.

We think we understand why. The mechanism is correct; but, there was a resurgence of the 2015 bloom as late as April 2016 and with those cells still in play there was enough nutrients to keep all of the phytoplankton happy.

"It is tough to make predictions, especially about the future."
Yogi Berra

Findings from C:

- ***K. brevis***, **a slow growing dinoflagellate, is generally outcompeted by diatoms. The injection of new, inorganic nutrients via upwelling across the shelf break favors diatoms over *K. brevis,* supressing red tide blooms.**
- **Both the ocean circulation physics and the organism biology are necessary conditions for a *K. brevis* bloom, but neither alone are sufficient conditions.**

Conclusions

- Coastal ocean stewardship requires a multidisciplinary approach, including coordinated observations and models (i.e., RCOOS's)
- Why: Ecology is not just biology. Ecology is the sum of all processes responsible for an organism to make a living.
- By determining the water properties in which organisms reside, the coastal ocean circulation is of fundamental ecological importance.
- Adapting our science strategy to accommodate these facts will facilitate understandings on how the coastal ocean system works and enable better environmental stewardship of this region where society meets the sea.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