Response to the Gulf Oil Spill by USF Ocean Circulation Group: A Review

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College of Marine Science
University of South Florida

Deepwater Horizon Oil Spill PI Workshop
NSTC Subcommittee on Ocean Science and Technology
St. Petersburg, FL, October 25-26, 2011

USF UNIVERSITY OF SOUTH FLORIDA

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Ocean Circulation Group University of South Florida · College of Marine Science

COMPS Coastal Ocean Monitoring and Prediction System

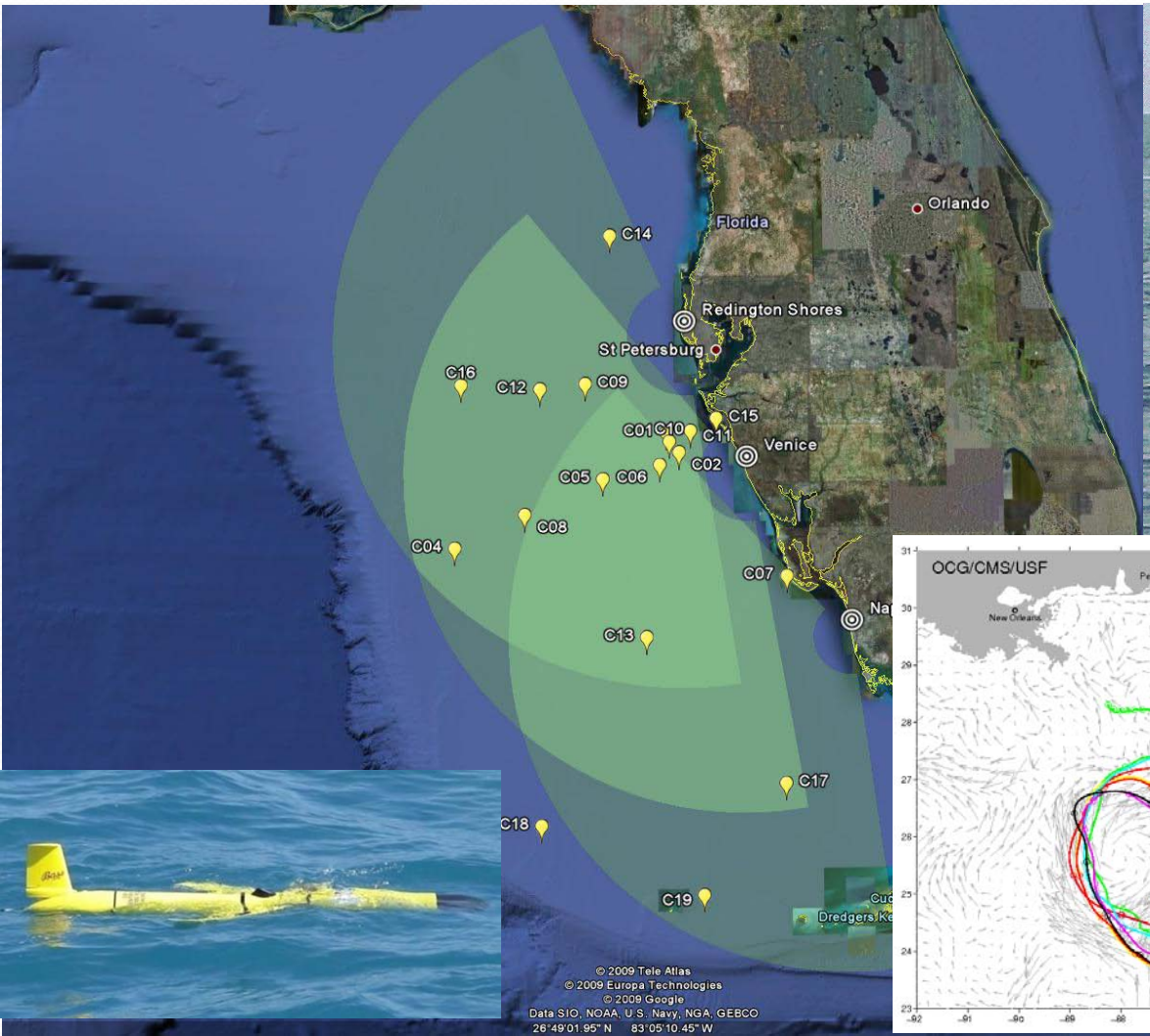
OUTLINE

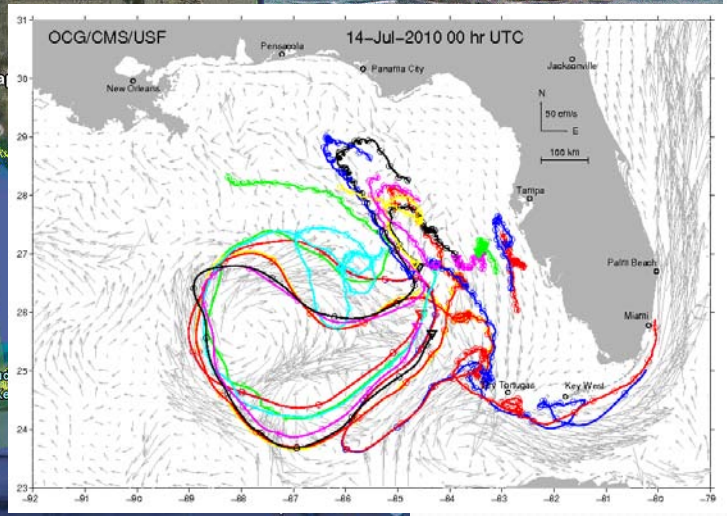
- Integrated Ocean Observation System on the West Florida Shelf
- USF/OCG response to the DWH oil spill
- Recent results on the DWH oil spill research
- Current work
- Summary

Coastal Ocean Observation System on the West Florida Shelf

ADCP moorings: > 10 yrs
HF radars: > 6 yrs
Bottom Stationed Ocean Profilers (BSOP)
Gliders and satellite tracked drifters

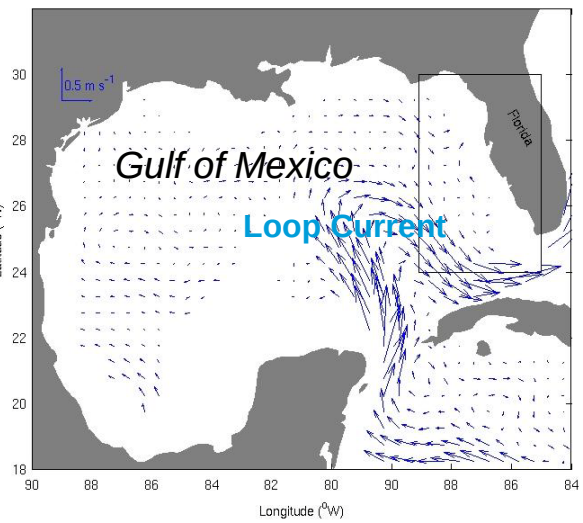
Http://ocgweb.marine.usf.edu/

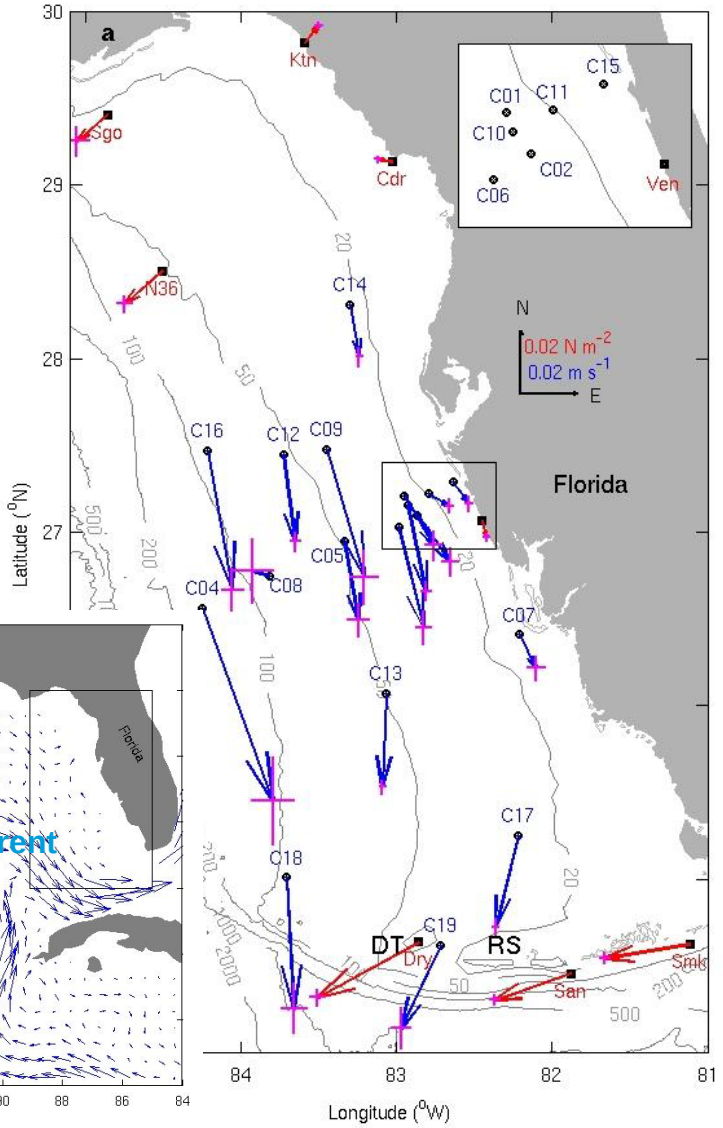


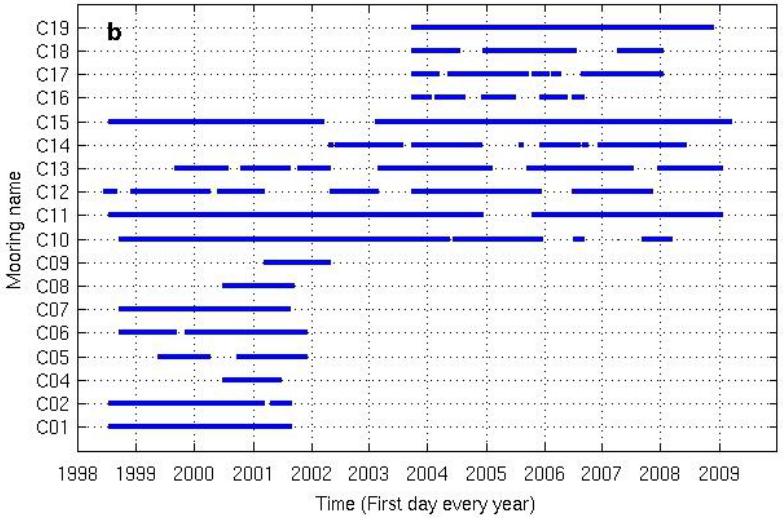


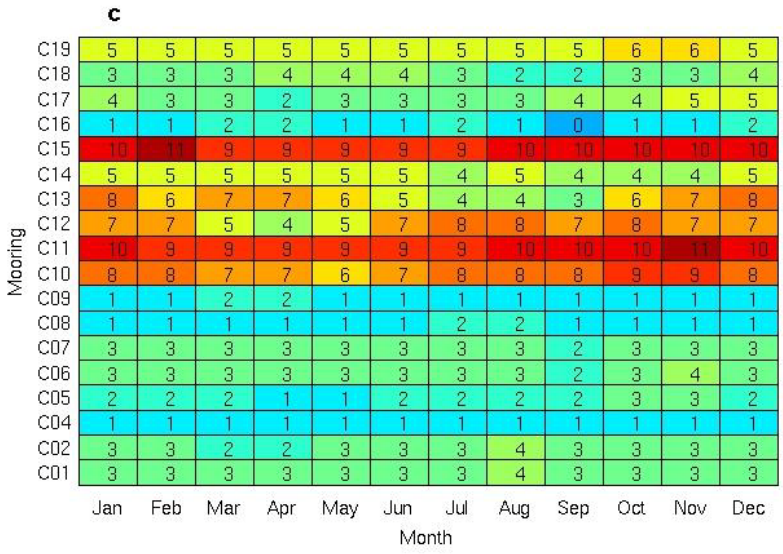
Mean Circulation on the WFS from Long-Term Moorings

Weisberg et al. (2009)
Geophys. Res. Lett.









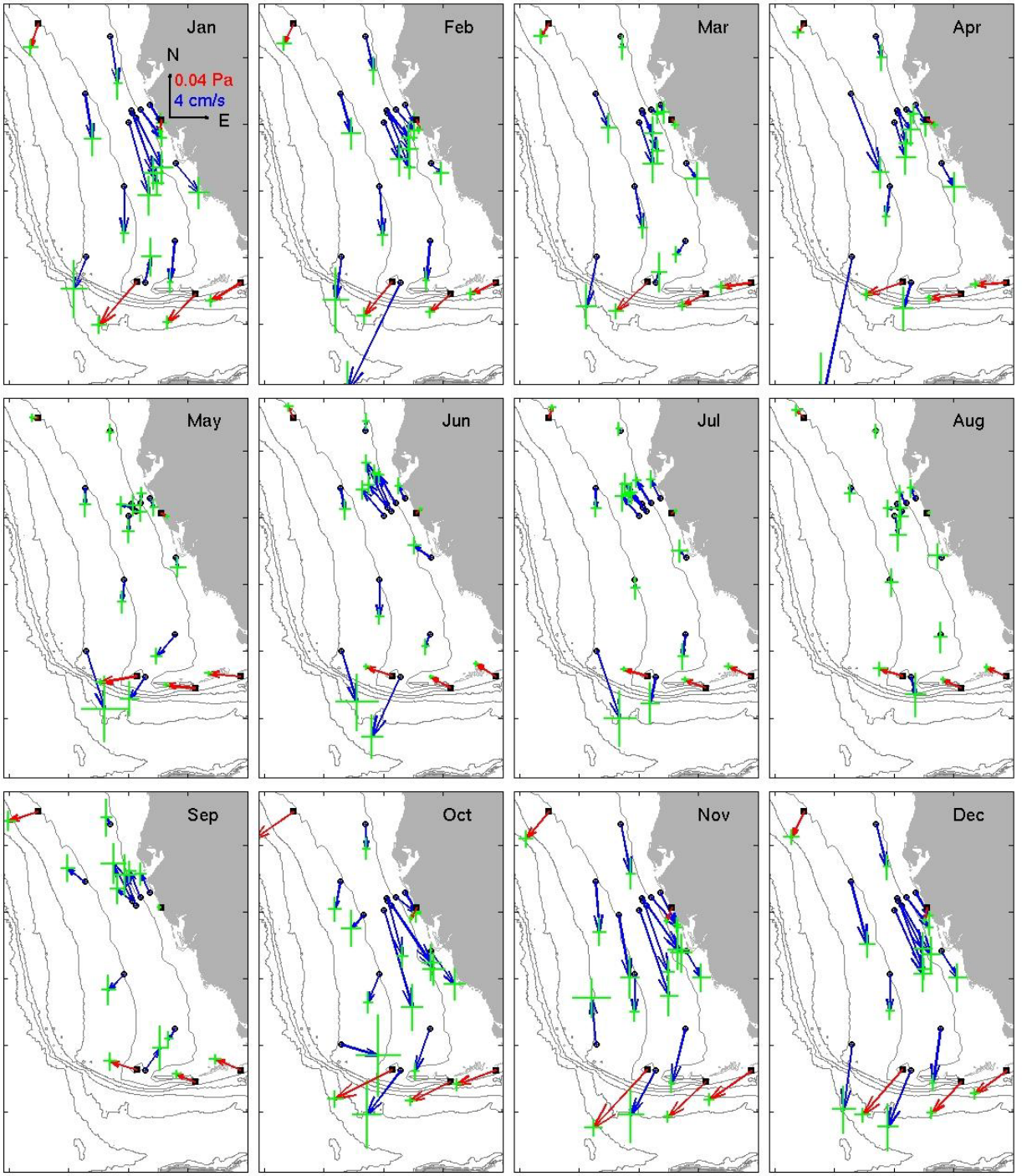
Seasonal Variability

Inner shelf:

seasonal variation,
upwelling Oct – April
downwelling Jun - Sep

Outer shelf:

seasonal variation not obvious



Synoptic Time Scale

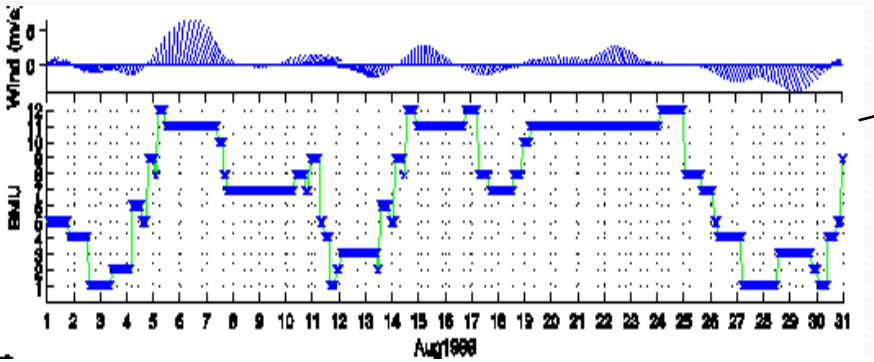
upwelling

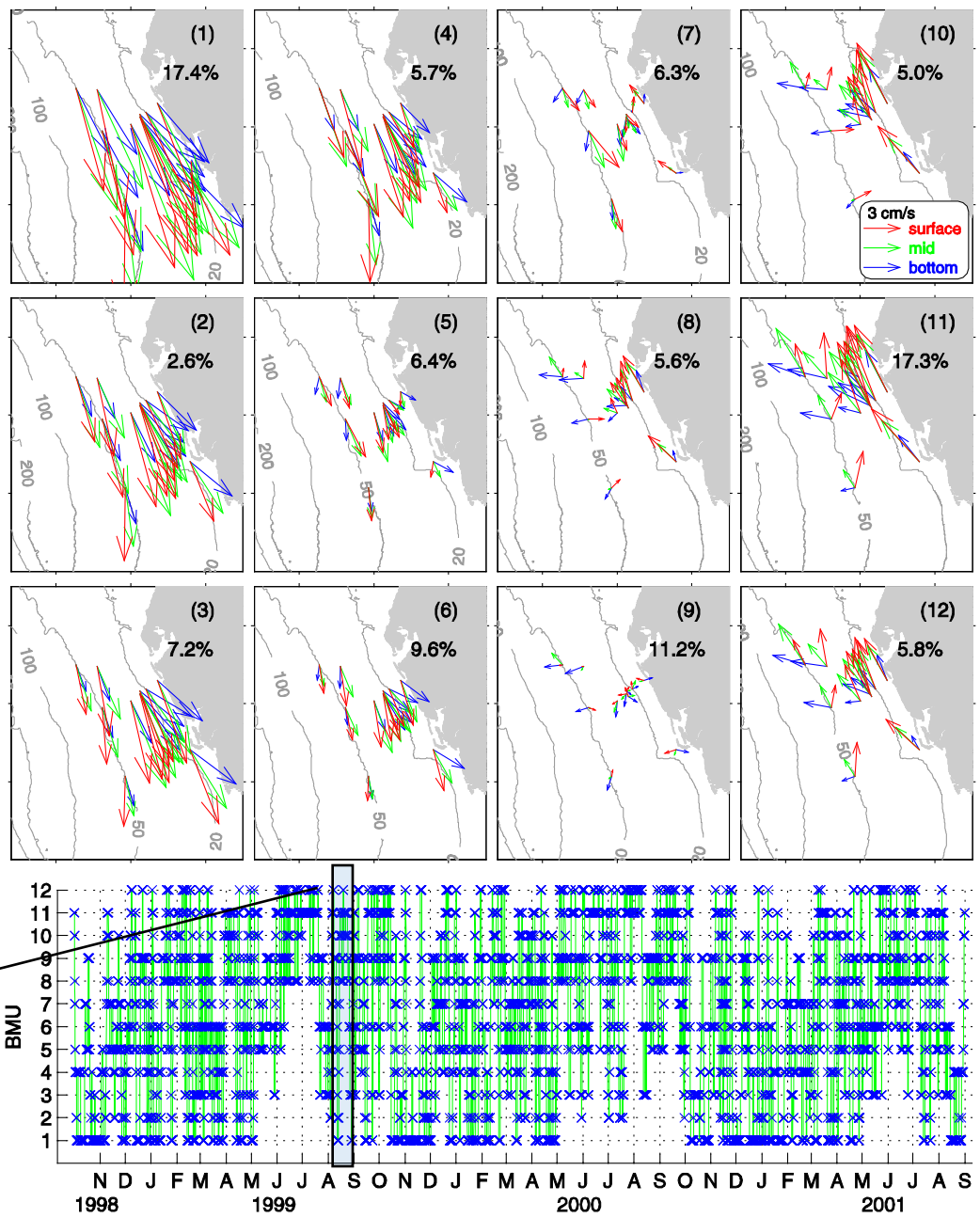
downwelling

Wind-driven shelf circulation

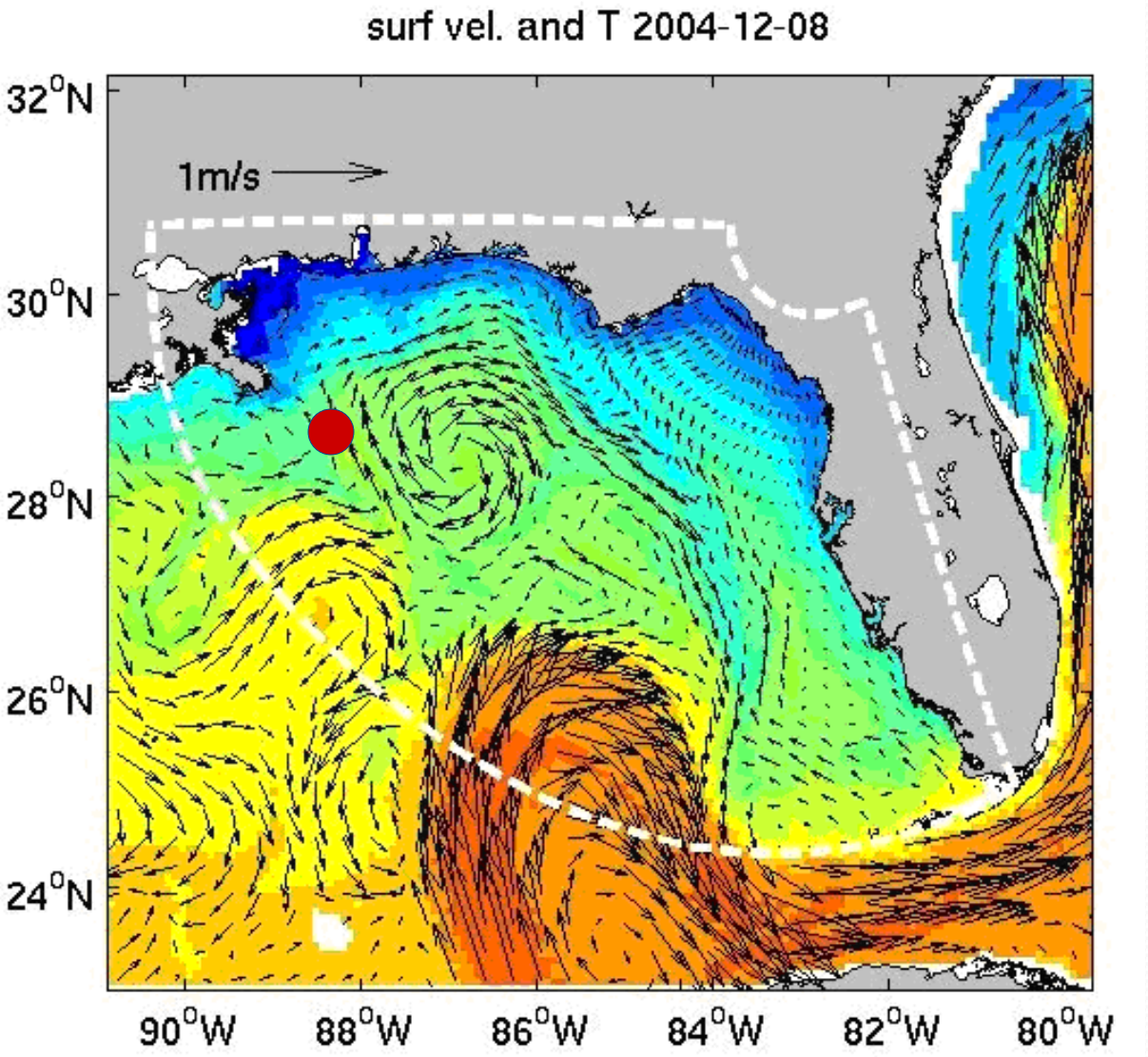
Inner shelf responses are stratification dependent, resulting in asymmetric upwelling and downwelling.

Liu & Weisberg (2005)
Cont. Shelf. Res.





West Florida Shelf Nowcast/Forecast System



- ✓Based on ROMS
- ✓Forced by NCEP forecast winds and heat fluxes, and the past winds blended with observations
- ✓Nested in Global HYCOM
- ✓Operational for 6+ years

Barth et al. (2008)

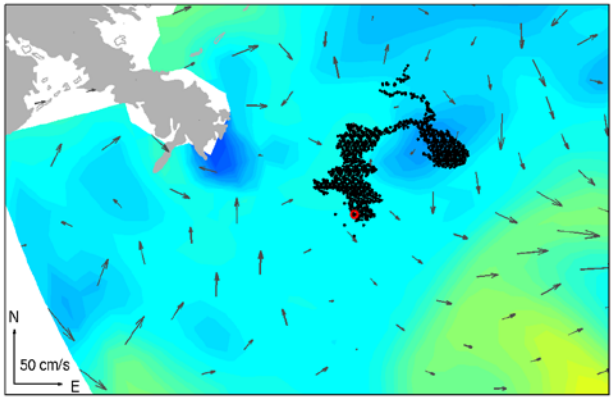
Http://ocgweb.marine.usf.edu/

Surface Oil Trajectory Model Based on WFS ROMS

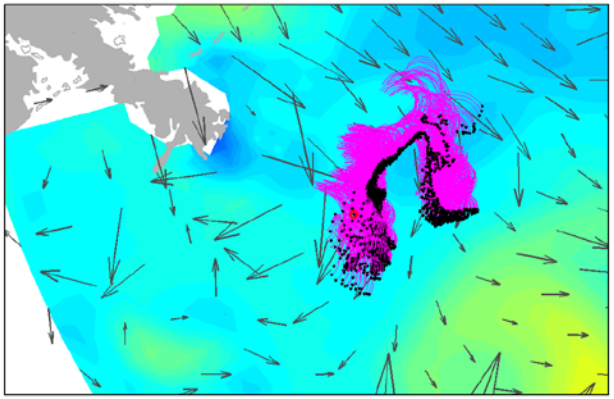
MODIS imagery, 04/25/2010 18:55 UTC

Hu et al. (2009)

Trajectory model initialization



Trajectory model 2-day forecast



Liu et al. (2011) *SPIE Proc.*

Trajectory model features:

- ✓ Re-initialize the locations of the particles from the latest satellite imagery
- ✓ Continually release new particles from the well site

The CMS-USF-OCG Response: Daily updates on the web and regular briefings distributed as ppts (example below)

Oil Spill Tracking in the Eastern Gulf of Mexico

Robert H. Weisberg

with

Drs. L. Zheng and Y. Liu, Prof. C. Hu, & the OCG

College of Marine Science

University of South Florida

and assistance from the HYCOM consortium

July 11, 2010

Oil Spill Tracking in the Eastern Gulf of Mexico

Beginning on 4/22 we applied numerical ocean circulation models for tracking oil spilled from the Deepwater Horizon (Macondo) well. We are now using an ensemble of six different models:

- **USF WFS ROMS nested in HYCOM,**
- **Navy Global HYCOM,**
- **Navy GOM HYCOM**
- **NOAA RTOFS (also HYCOM).**
- **NCSU SABGOM (ROMS nested in HYCOM).**
- **Navy NCOM IAS**

The oil patch location is initialized using satellite imagery, and we simulate the movement of virtual surface particles carried by the models' velocity fields.

Simulations, updated daily, include periods of both hindcast and 3.5 day forecasts (using forecast winds).

Predictions are compared with observations when satellite imagery is available, and the predictions are being used by NOAA in their forecasts.

Subsurface trajectories from the well site are also updated daily.

Real time velocity observations from moorings and HF-radar are also used.

All information is publicly available at http://ocgweb.marine.usf.edu and ppt briefings are provided to agencies and others.

7/11 Forecast Update

The ocean circulation determines where oil may go.

Deep ocean currents (the Loop current and its eddies) tend to stay in deep water; shallow water currents tend to stay in shallow water, and this explains why the Mississippi River delta and the region of Pensacola FL where the first land areas oiled. There the continental shelf is narrow and deep water is in proximity to land.

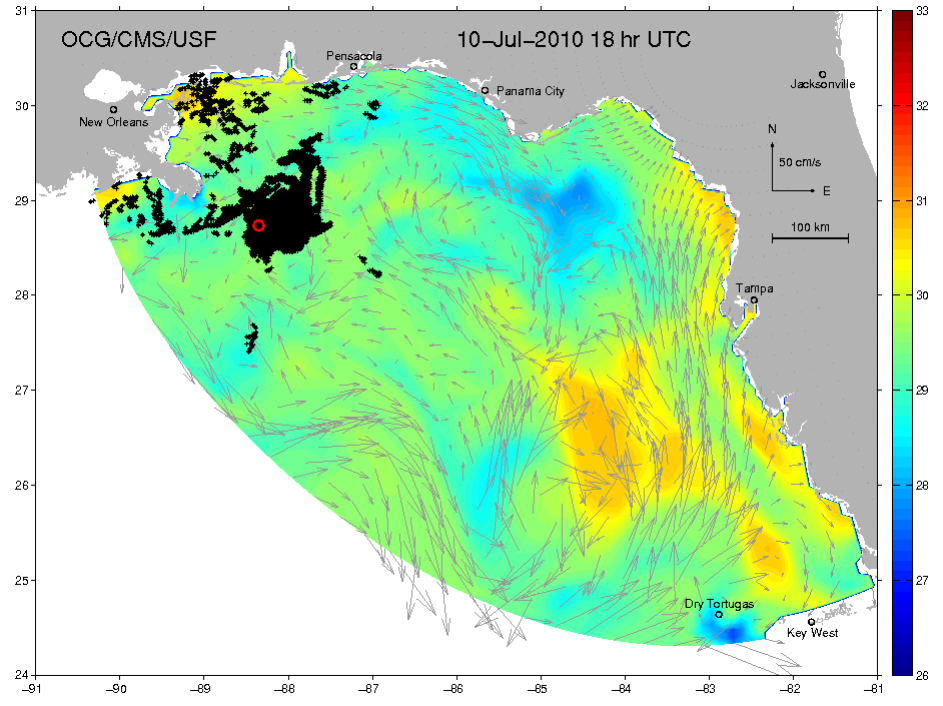
Once oil was in shallow water it progressed more easily along shore, which is why we saw more coastal communities affected. The latest imagery interpretation suggests less oil in general and less in shallow water.

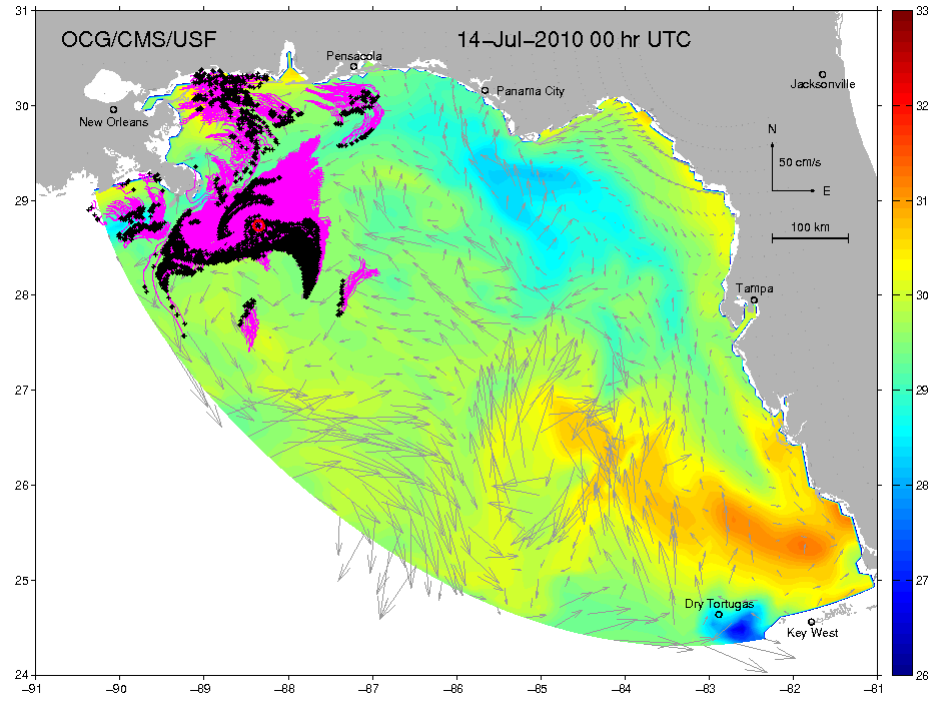
Shown in the following two slides are surface trajectory forecasts with the USF eastern G of M model (ROMS nested in HYCOM), the Navy GOM HYCOM, and an ensemble of four models (the previous two, plus the Navy Global HYCOM and the NCSU SABGOM), all driven by forecast winds (NOAA/NCEP or Navy/NOGAPS).

Movement along the coast is in response to winds and LC/eddy interactions with the shelf slope. Over the past two weeks easterly winds and a relaxation in eddy/slope interaction shifted near shore oil back west, which was good news for Florida. However, the winds for the next few days are forecast to be westerly, and the WFS circulation is now upwelling. Oil will move eastward near-term.

The Loop current, which shed an eddy around 5/20, is undergoing a torturous path. It now appears to be detached from the eddy. How this will evolve cannot be predicted. It remains possible for the Loop Current in the future to extend northward to the well site (e.g., see movie loop at http://ocgweb.marine.usf.edu.)

USF WFS Nowcast/Forecast Model Initialized 7/10 with Prediction at 7/14

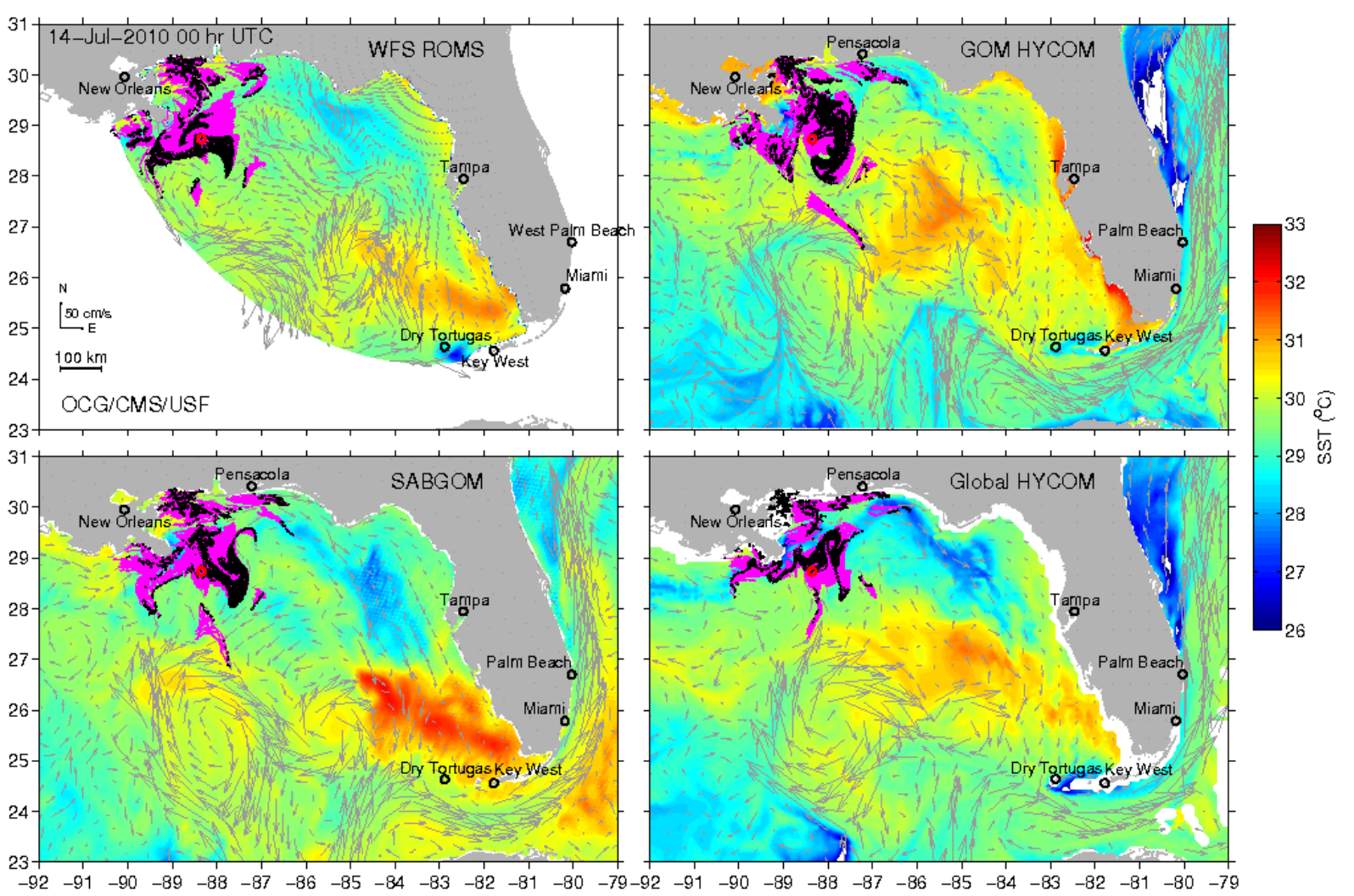




Using 3-hourly USF WFS model results we estimate trajectories emanating from the well site by releasing new particles every 3 hours starting from a 07/10 spill initialization using satellite imagery.

http://ocgweb.marine.usf.edu

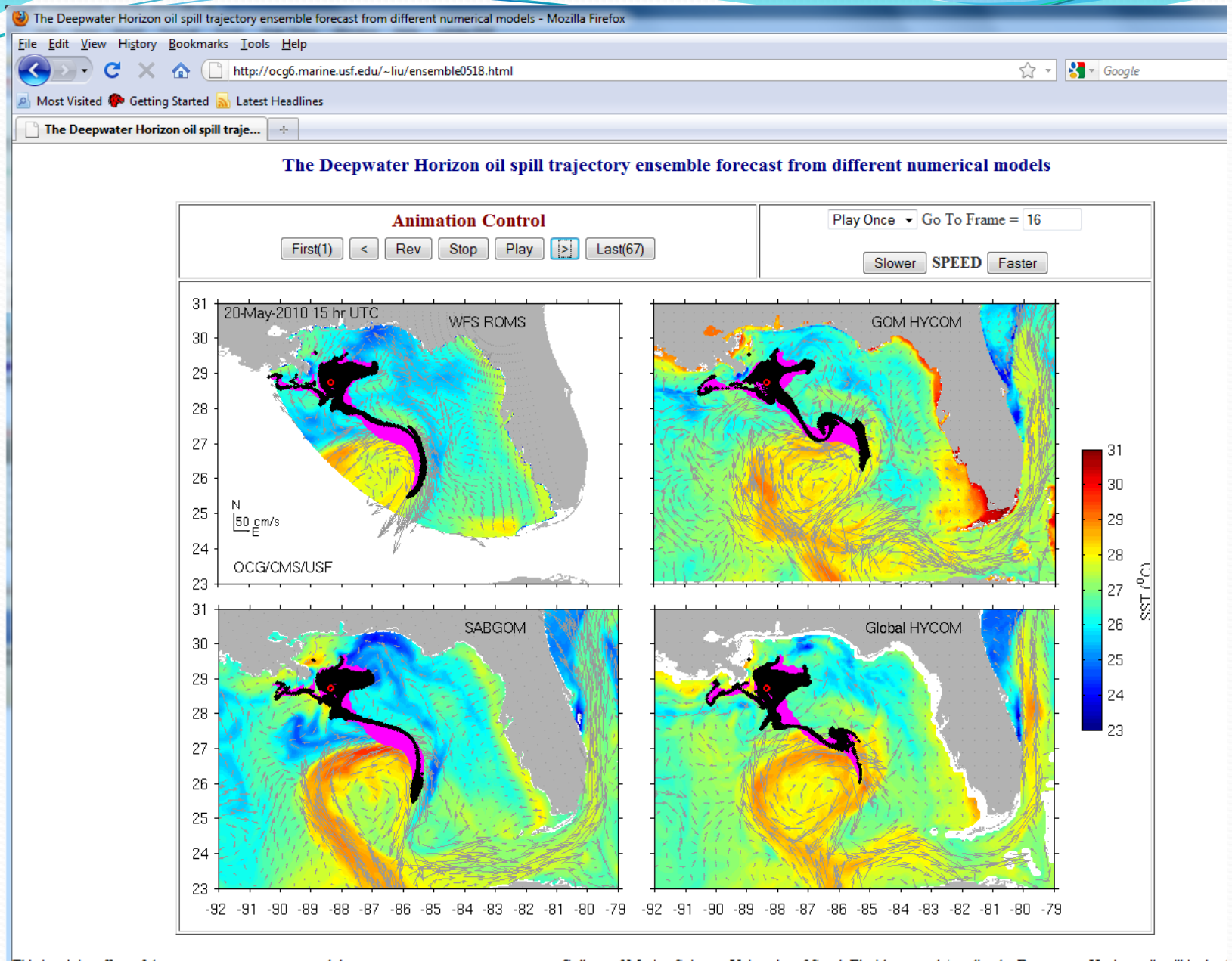
Ensemble Forecast (4 of 6 Models) Initialized 7/10 with Prediction at 7/14



http://ocgweb.marine.usf.edu

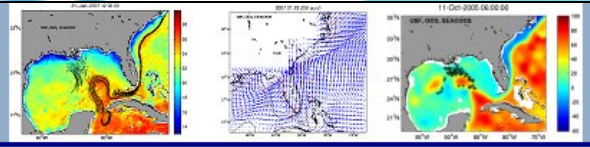
Liu et al. (2011) *Eos Trans. AGU*

Web-based Animations with Interactive Functions



Surface Oil Trajectory Nowcast/Forecast System

Ocean Circulation Group
University of South Florida - College of Marine Science



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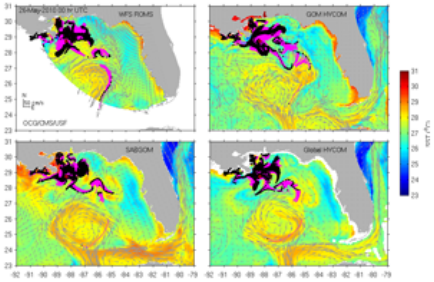
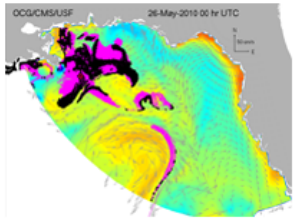
Tracking And Predicting The Deepwater Horizon Oil Spill In The Gulf Of Mexico

In a joint effort of the **Ocean Circulation Group** and the **Optical Oceanography Laboratory** at College of Marine Science, University of South Florida to track and predict the Deepwater Horizon (Macondo Well) oil spill spreading, surface drifter trajectories are simulated based on the surface ocean currents output from five numerical models, the **West Florida Shelf ROMS Hindcast/Forecast System**, the **Global HYCOM + NCODA Analysis**, the **Navy Gulf of Mexico HYCOM Nowcast/Forecast System**, the **SABGOM Nowcast/Forecast System**, and the **RTOFS (Atlantic) hindcast/forecast system**. The latest **satellite imageries** of oil slick are also used to initialize the drifter locations so that the simulation is as getting close to the real situation as possible. A series of experiments have been implemented and the results are listed as follows (with the most recent results listed on top).It must be recognized that all forecast models have errors that grow with time for a variety of reasons. So, it is important to consider ensemble analyses from several different models.

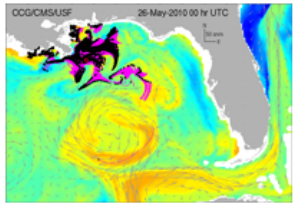


Four-panel view of four oil spill trajectory models (the latest ensemble forecast) *NEW!*

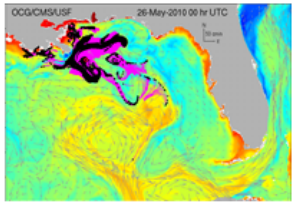
Individual surface oil spill trajectory models:



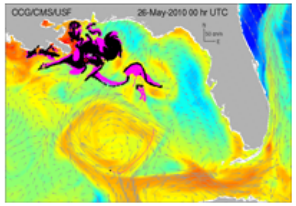
WFS ROMS based surface oil trajectory initialized from the latest satellite imagery *New!*



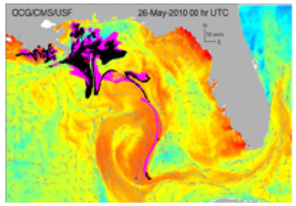
Global HYCOM based surface oil trajectory initialized from the latest satellite imagery *New!*



Navy GOM HYCOM based surface oil trajectory initialized from the latest satellite imagery *New!*



SABGOM based surface oil trajectory initialized from the lastest satellite imagery *New!*



RTOFS based surface oil trajectory initialized from the latest satellite imagery *New!*

http://ocgweb.marine.usf.edu/~liu/oil.html

Loop Current Update

Ocean surface color imagery was spotty last week due to clouds. The LC and eddy pathways remain torturous, and what may happen is unknown.

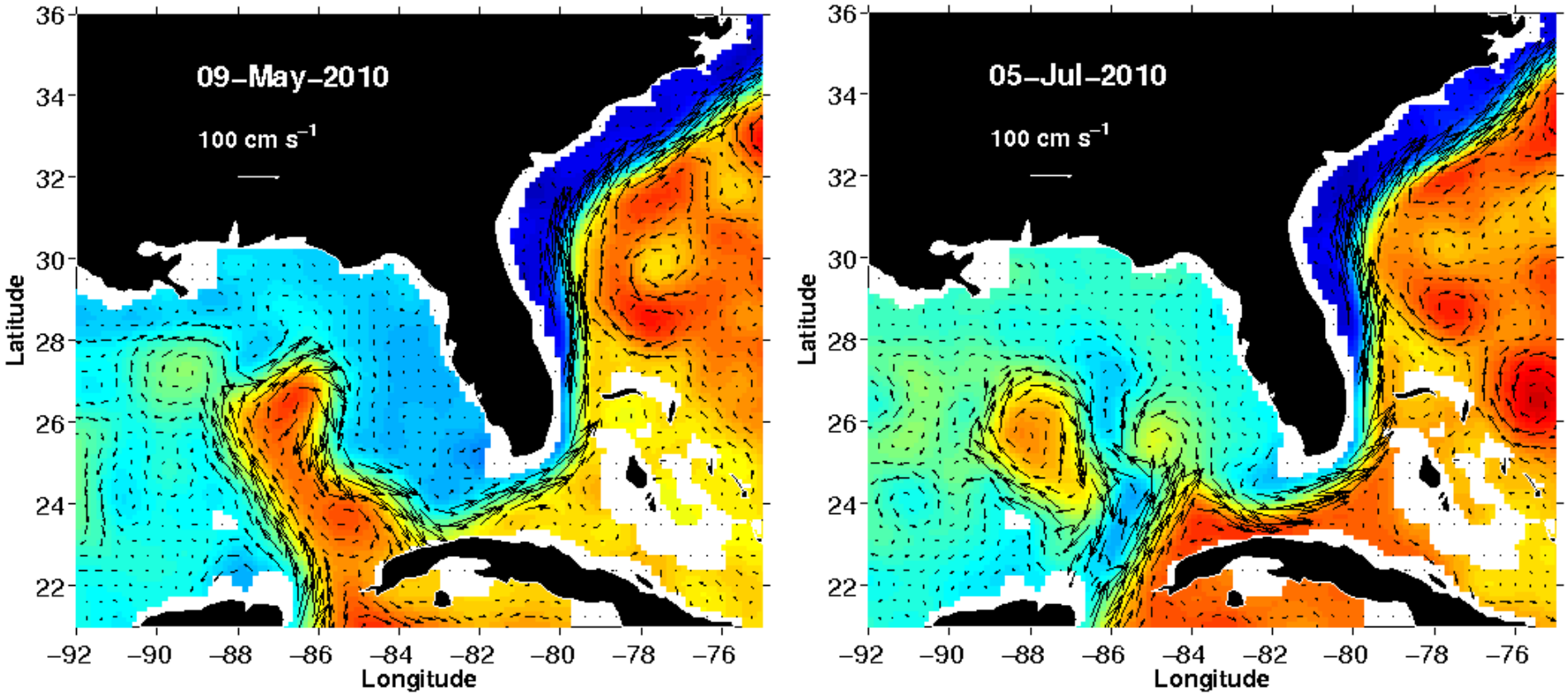
The process of eddy shedding is also evident in analyses of surface currents from satellite altimetry using the geostrophic approximation, and from these satellite altimetry-derived surface currents we can estimate pathlines for virtual particles carried by the currents.

By deploying actual satellite tracked drifters, and overlaying these on modeled currents, we can further appreciate the movement by the currents.

While we cannot predict what the near-term evolution of the Loop Current may be, historical observations show that eddy reattachment is common and that the Loop Current can extend right up to the well site, which is situated on the continental slope. As examples please see the movie loop at http://ocgweb.marine.usf.edu under products, second line down. It remains possible that large amounts of oil can flow to the Florida Straits and east coast. For now, however, the eddy appears to be separating to the west

The interactions between the easternmost edges of the LC and its eddy with the shelf slope resulted in flows on the shelf tending to move oil eastward there. This was countered over the past two weeks by strong SE winds. The situation is subject to change owing to winds and LC/eddy interactions with the shelf slope. The winds and LC/eddy interactions will continue to be variable.

LC-FC-GS System as Determined Using Satellite Altimetry



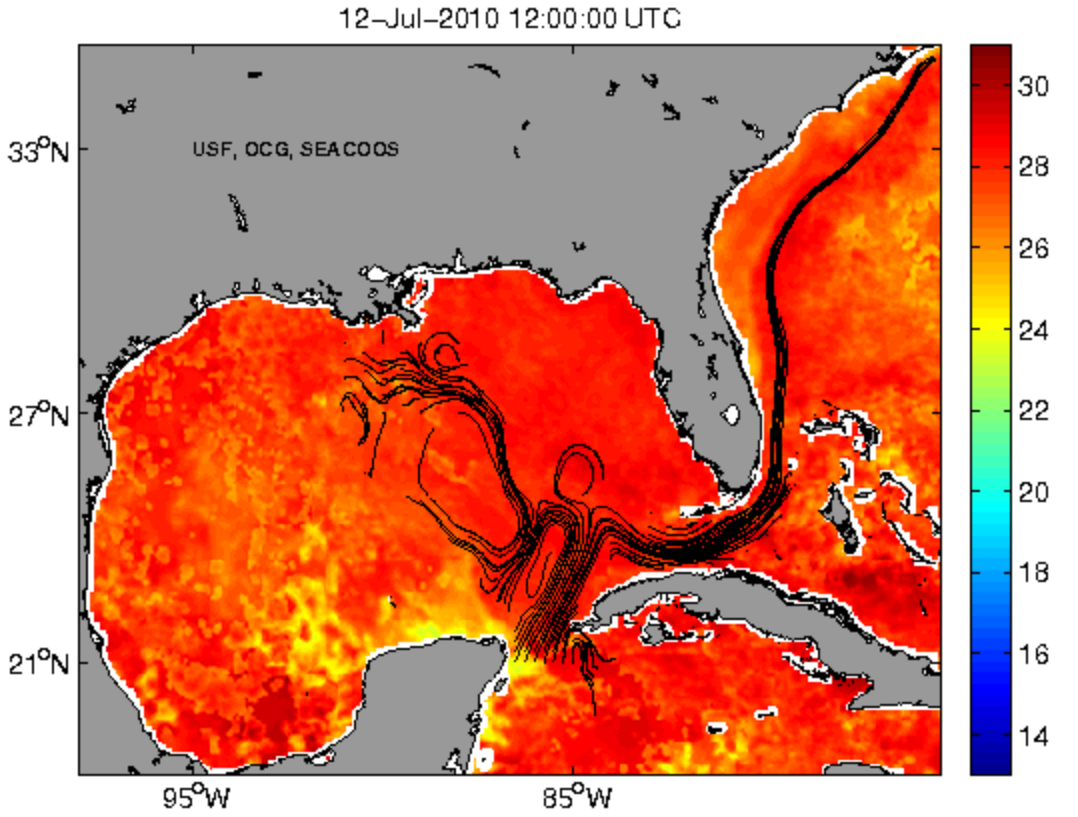
We use sea surface height (SSH) anomalies from AVISO combined with a mean SSH field to estimate absolute SSH. We then estimate surface currents via the geostrophic approximation, which is excellent in deep water. The colors are SSH (red being high, blue low); the arrows are the surface currents. A succession of estimates shows the eddy evolution. The eddy separated from the LC around 5/20 and again on 7/2.

LC-FC-GS System as Determined Using Satellite Altimetry, Plus Virtual Surface Drifters to Trace the Pathways

Travel times (mean and SD from an 8 year analysis):

YS to FS: 20 9 days
FS to CH: 15 2 days

NOTE: Cloud-free SST is product (background color) is now flawed by too much cloud cover for too many days.



We do a 2-week hindcast/forecast of virtual drifter pathlines, assuming movement with the surface geostrophic currents.
These are publicly available at http://ocgweb.marine.usf.edu
Click on geostrophic drifters.

Refereed Publications by USF/OCG

1. Liu, Y., A. MacFadyen, Z.-G. Ji, and R.H. Weisberg (editors), 2011: *Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise, Geophys. Monogr. Ser.*, AGU, Washington D.C. (in production).
2. Liu, Y., R.H. Weisberg, C. Hu, and L. Zheng, 2011: Trajectory forecast as a rapid response to the Deepwater Horizon oil spill, in *Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise, Geophys. Monogr. Ser.*, AGU, Washington D.C. (in press).
3. Liu, Y., R.H. Weisberg, C. Hu, C. Kovach, and R. Riethmüller, 2011: Evolution of the Loop Current system during the Deepwater Horizon oil spill event as observed with drifters and satellites, in *Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise, Geophys. Monogr. Ser.*, AGU, Washington D.C. (in press).
4. Weisberg, R.H., L. Zheng, and Y. Liu, 2011: Tracking subsurface oil in the aftermath of the Deepwater Horizon well blowout, in *Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise, Geophysical Monograph Series*, AGU, Washington D.C. (in press).
5. Liu, Y., and R.H. Weisberg, 2011: Evaluation of trajectory modeling in different dynamic regions using normalized cumulative Lagrangian separation, *J. Geophys. Res., 116,* C09013, doi:10.1029/2010JC006837.
6. Hu, C., R.H. Weisberg, Y. Liu, L. Zheng, K.L. Daly, D.C. English, J. Zhao, and G.A. Vargo, 2011: Did the northeastern Gulf of Mexico become greener after the Deepwater Horizon oil spill? *Geophys. Res. Lett.,* 38, L09601, doi:10.1029/2011GL047184.
7. Weisberg, R.H. 2011: Coastal ocean pollution, water quality and ecology: A commentary, *MTS Journal*, 45(2), 35-42.
8. Liu, Y., R.H. Weisberg, C. Hu, and L. Zheng, 2011: Tracking the Deepwater Horizon oil spill: A modeling perspective, *Eos Trans. AGU,* 92(6), 45-46, doi: 10.1029/2011EO060001.

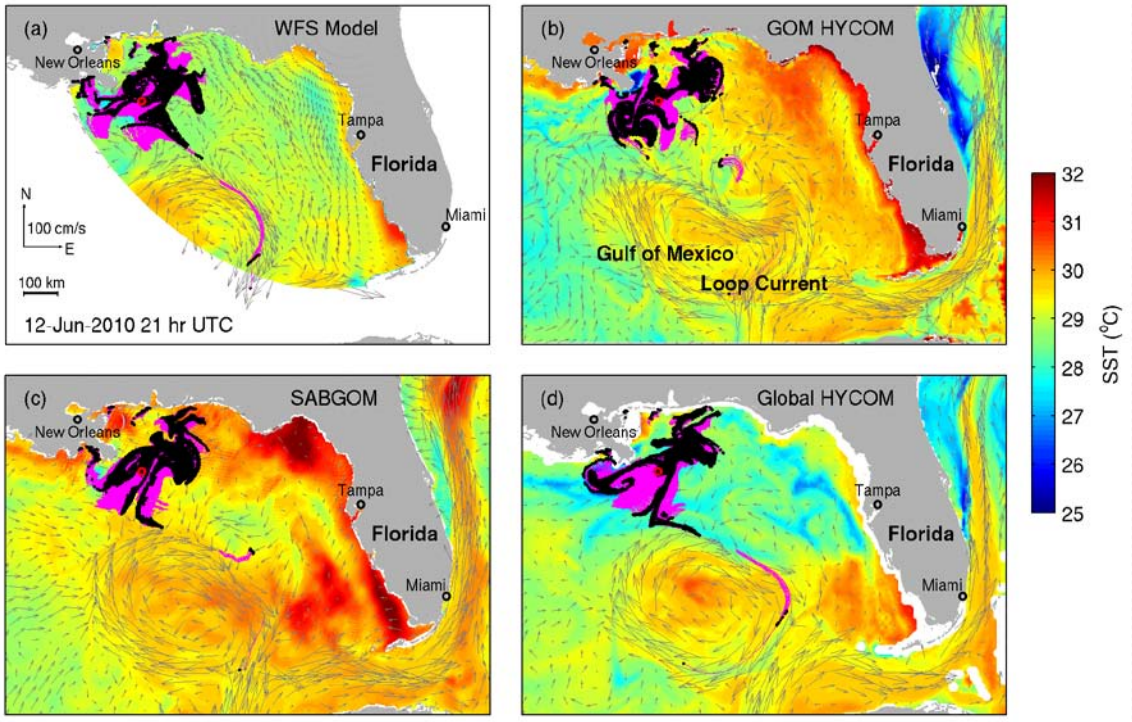
Non-Refereed Publications by USF/OCG

1. Liu, Y., A. MacFadyen, Z.-G. Ji, and R.H. Weisberg, 2011: Preface, in *Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise, Geophys. Monogr. Ser.*, AGU, Washington D.C. (in press).
2. Liu, Y., A. MacFadyen, Z.-G. Ji, and R.H. Weisberg, 2011: Introduction to Monitoring and Modeling the Deepwater Horizon Oil Spill, in *Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise, Geophys. Monogr. Ser.*, AGU, Washington D.C. (in press).
3. Liu, Y., R.H. Weisberg, C. Hu, and L. Zheng, 2011: Combining numerical ocean circulation models with satellite observations in a trajectory forecast system: a rapid response to the Deepwater Horizon oil spill, *Proc. SPIE 8030*, 80300K. doi:10.1117/12.887983.
4. Liu, Y., R.H. Weisberg, C. Hu, and L. Zheng, 2011: Satellites, models combine to track Deepwater Horizon oil spill, *SPIE Newsroom*, doi:10.1117/2.1201104.003575.

Research Highlights

Liu, Y., R. H. Weisberg, C. Hu, and L. Zheng (2011), **Tracking the Deepwater Horizon oil spill: A modeling perspective**, *Eos Trans. AGU*, 92(6), 45-46, doi:10.1029/2011EO060001.

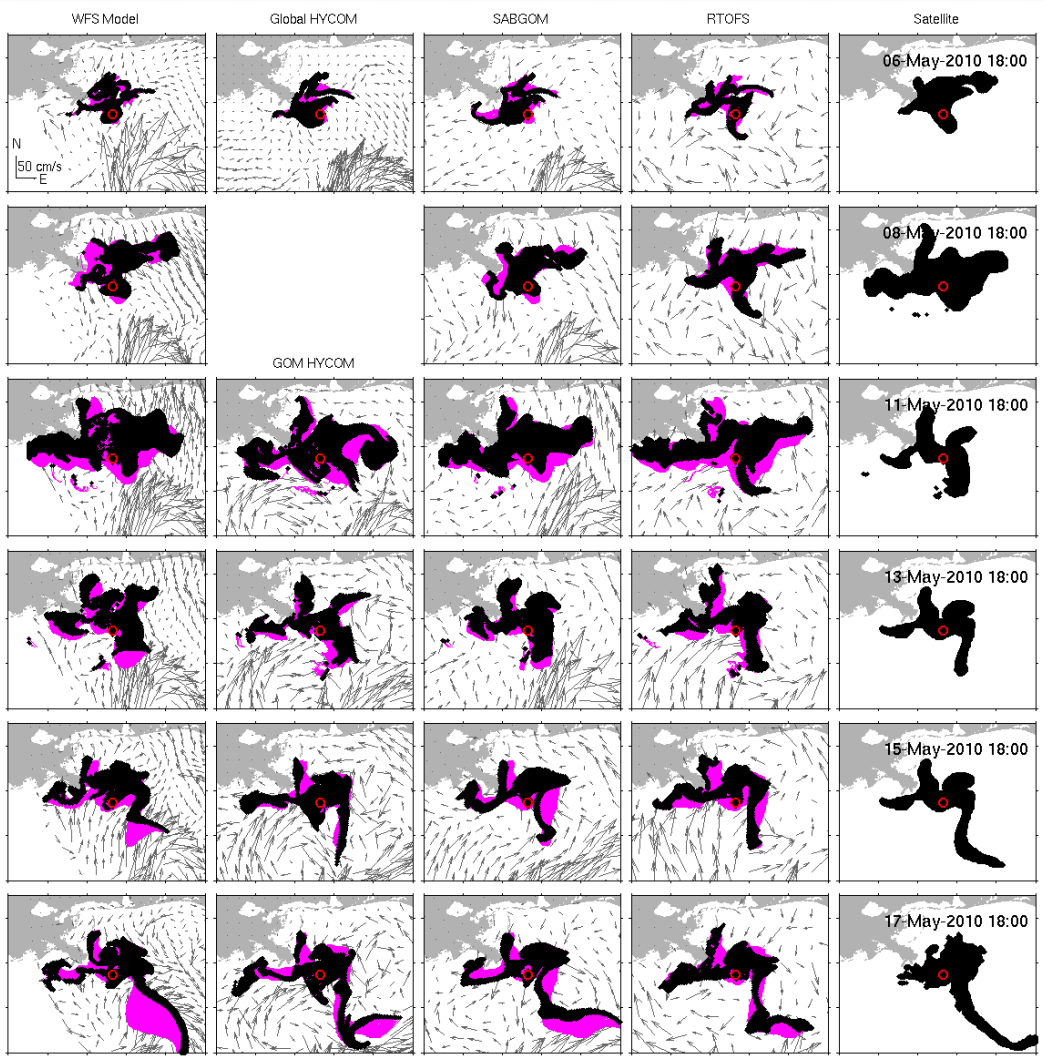
(Eos feature article)



An Integrated Ocean Observing System as a partnership between the academics, the agencies, and the private sector can be of great benefit to the nation.

Research Highlights

Liu, Y., R.H. Weisberg, C. Hu, and L. Zheng, 2011: **Trajectory forecast as a rapid response to the Deepwater Horizon oil spill**, in *Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise, Geophys. Monogr. Ser.*, AGU, Washington D.C. (in press).



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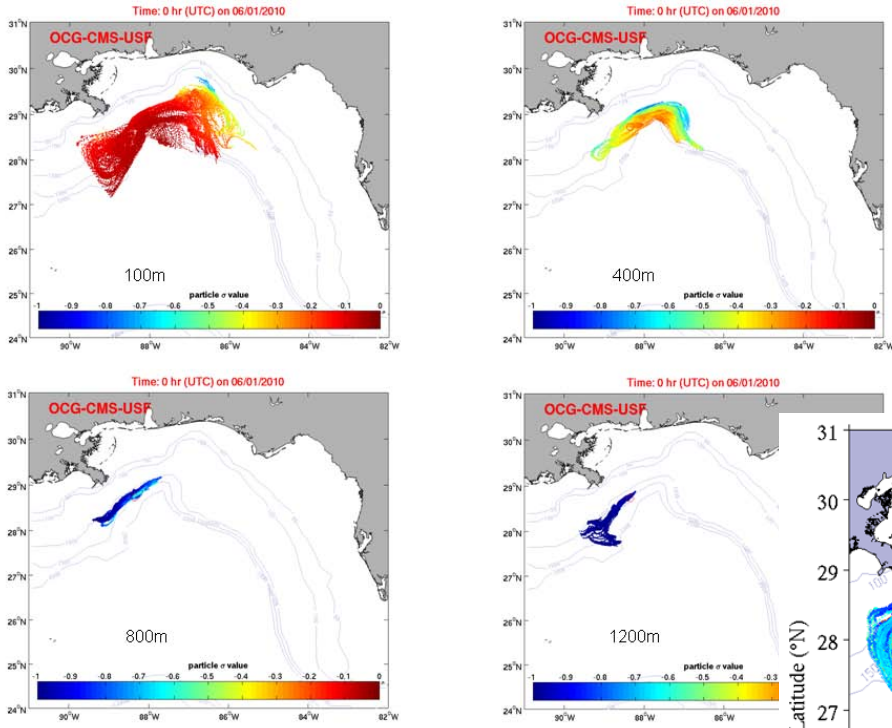
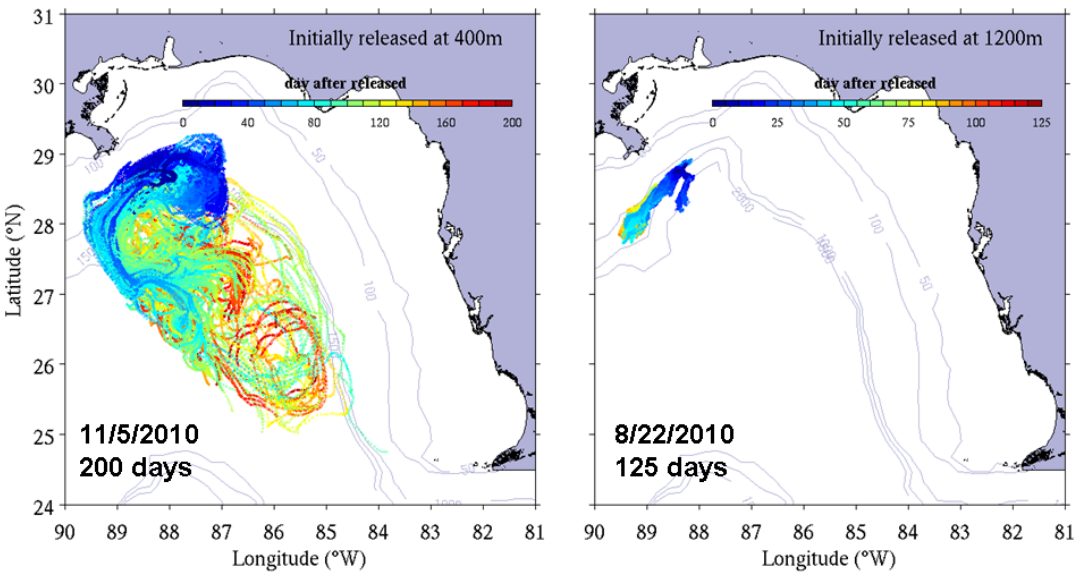


Subsurface trajectory model

Virtual particle age



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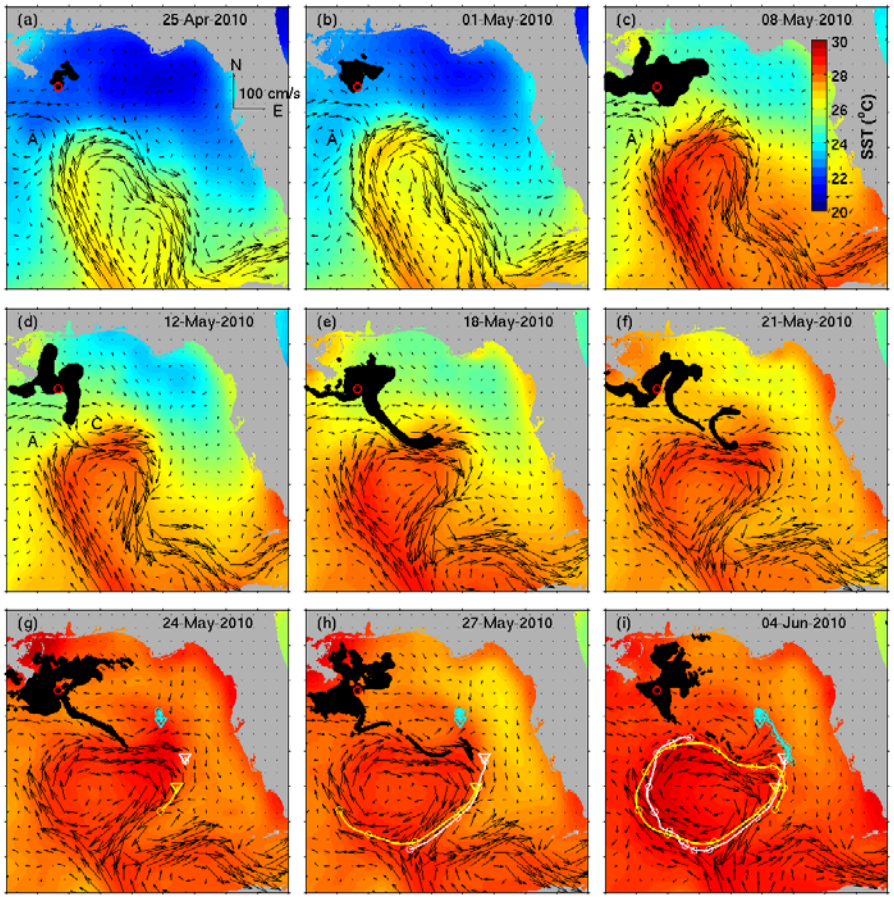

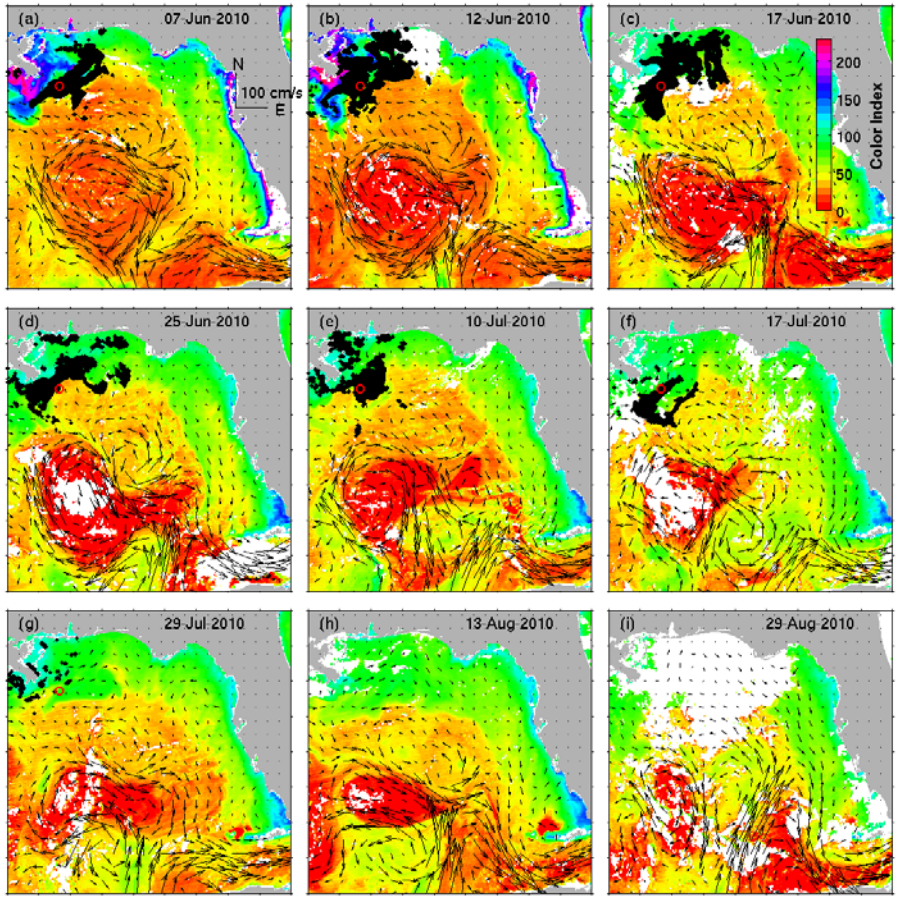

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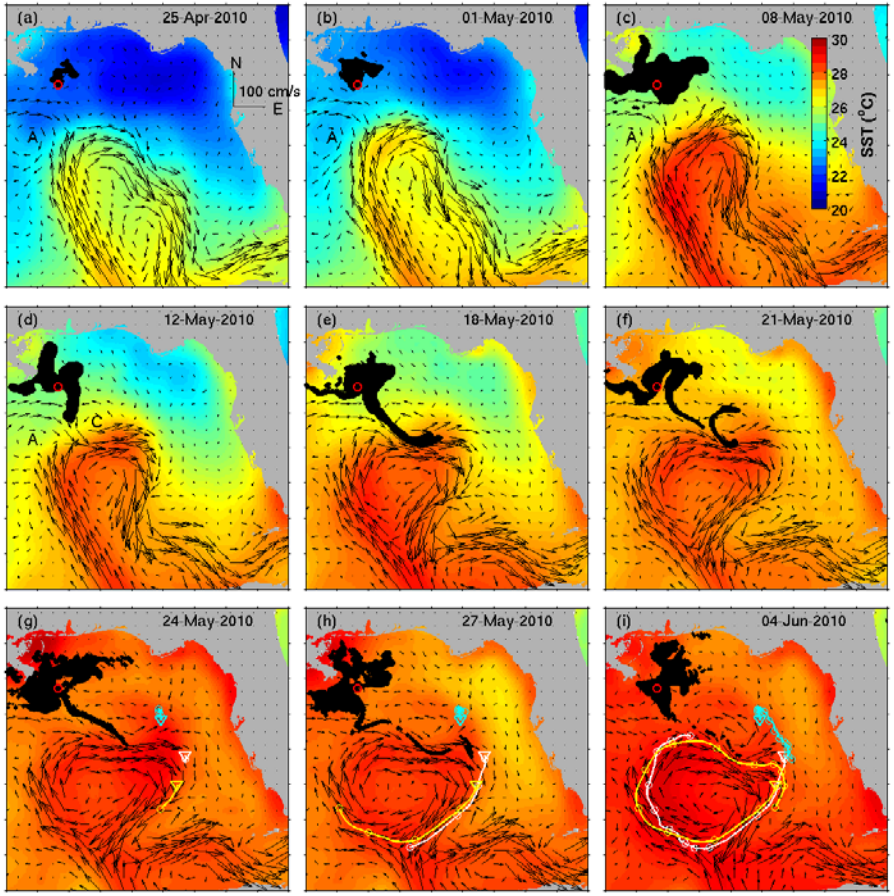
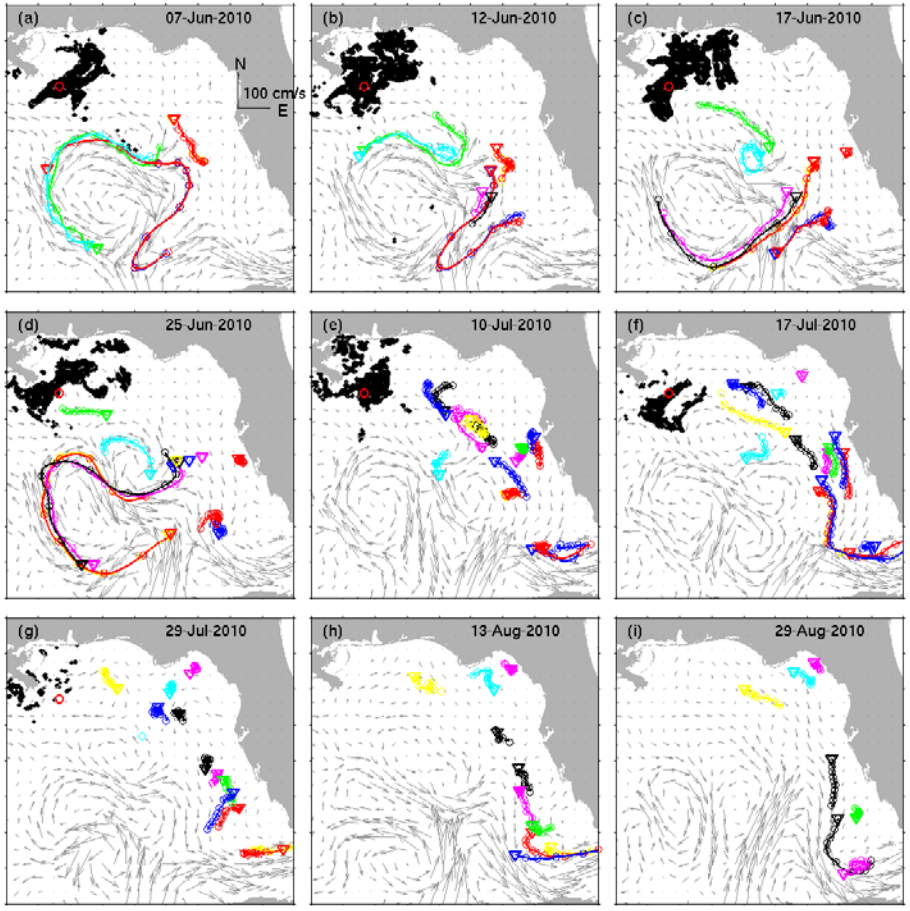
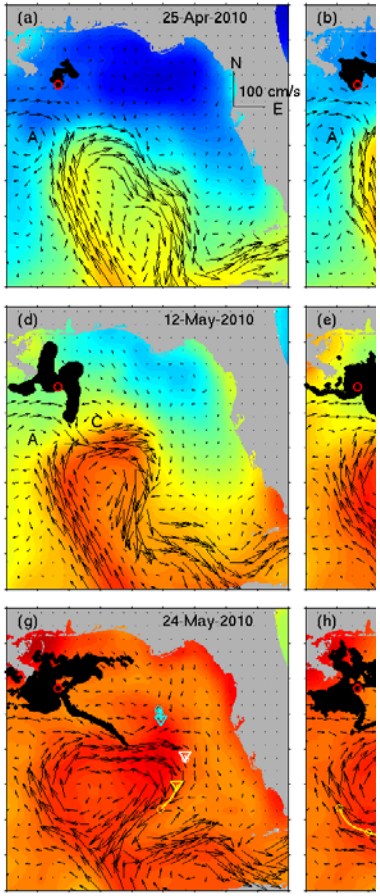
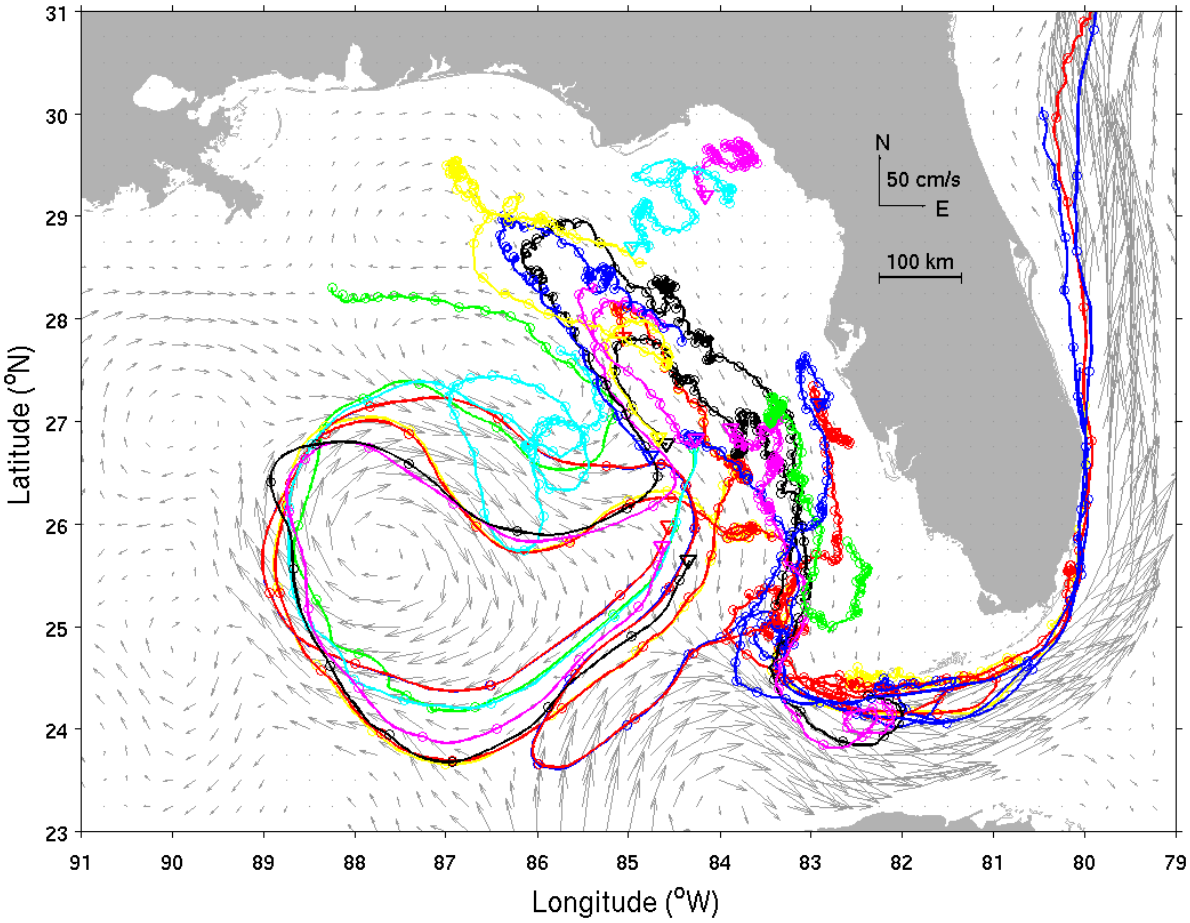


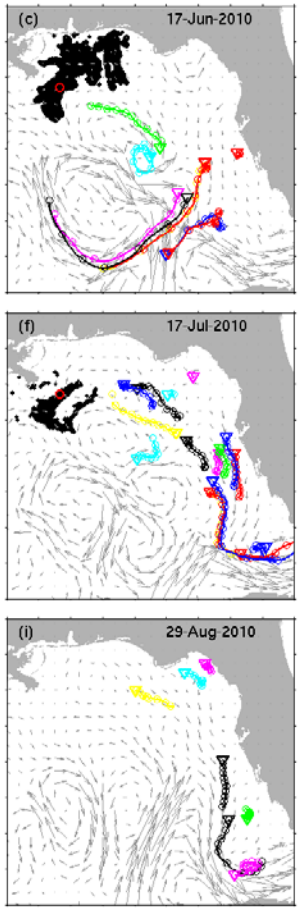


Research Highlights

Liu, Y., R.H. Weisberg, C. Hu, C. Kovach, and R. Riethmüller, 2011: **Evolution of the Loop Current system during the Deepwater Horizon oil spill event as observed with drifters and satellites**, in *Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise, Geophys. Monogr. Ser.*, AGU, Washington D.C. (in press).

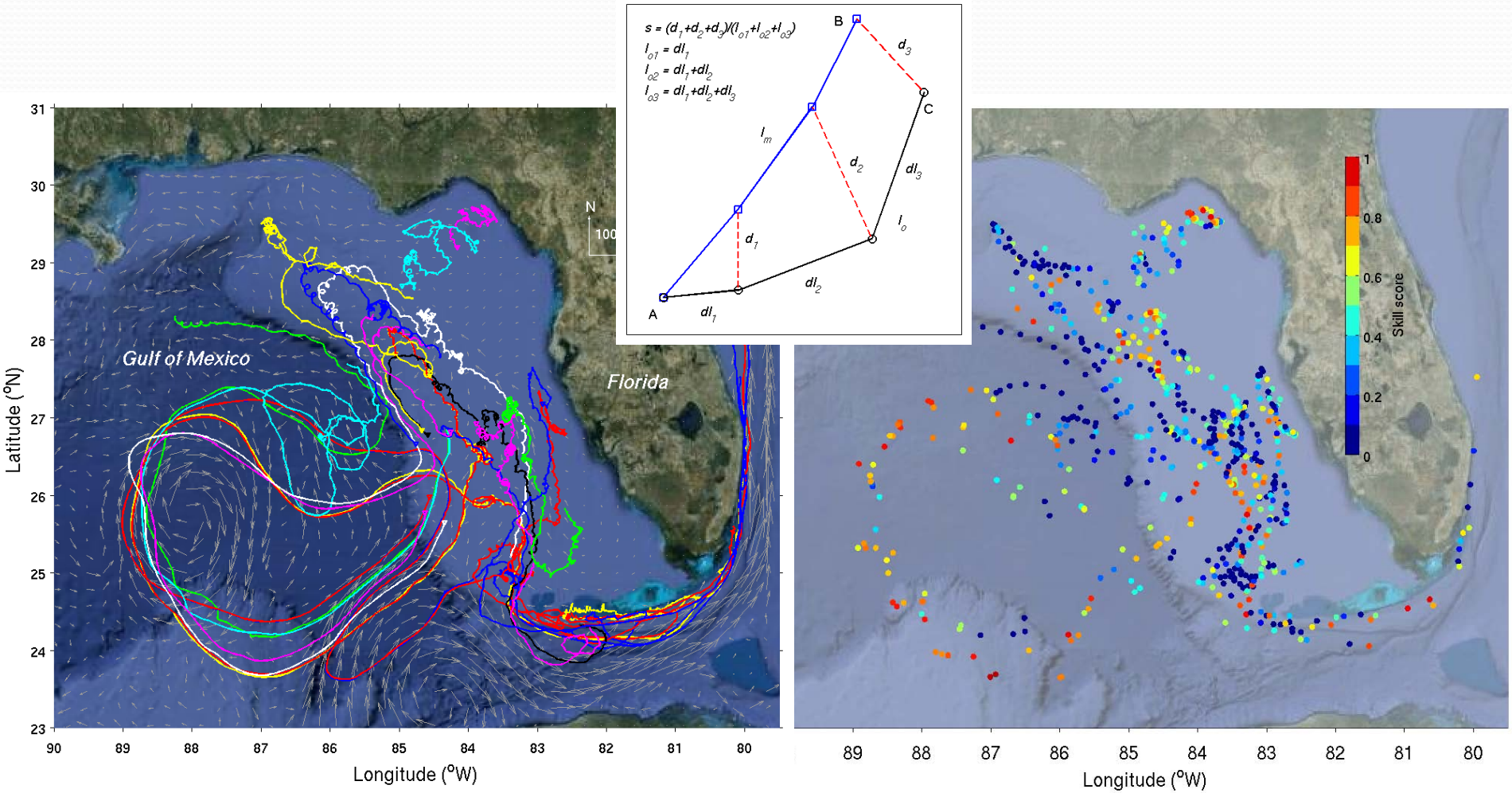






Research Highlights

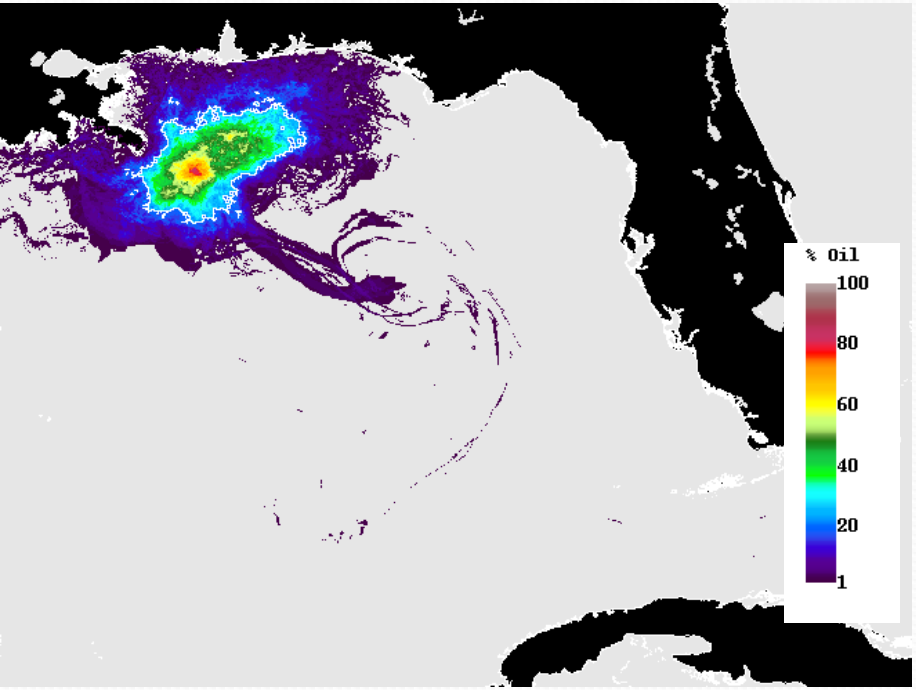
Liu, Y., and R.H. Weisberg, 2011: **Evaluation of trajectory modeling in different dynamic regions using normalized cumulative Lagrangian separation**, *J. Geophys. Res., 116,* C09013, doi:10.1029/2010JC006837.



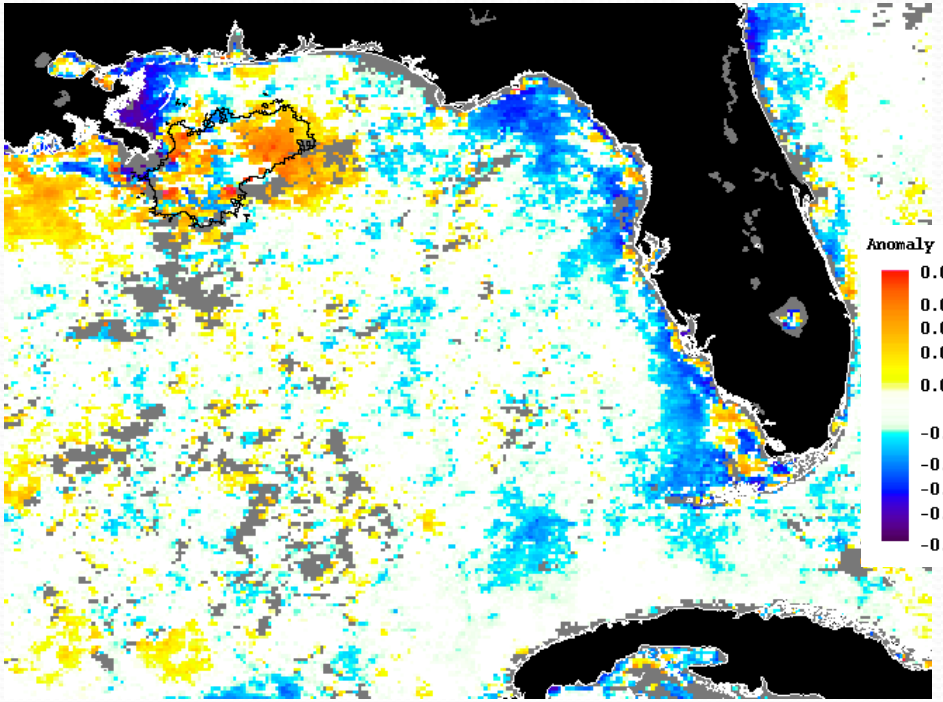
Research Highlights

Hu, C., R.H. Weisberg, Y. Liu, L. Zheng, K.L. Daly, D.C. English, J. Zhao, and G.A. Vargo, 2011: **Did the northeastern Gulf of Mexico become greener after the Deepwater Horizon oil spill?** *Geophys. Res. Lett.,* 38, L09601, doi:10.1029/2011GL047184.

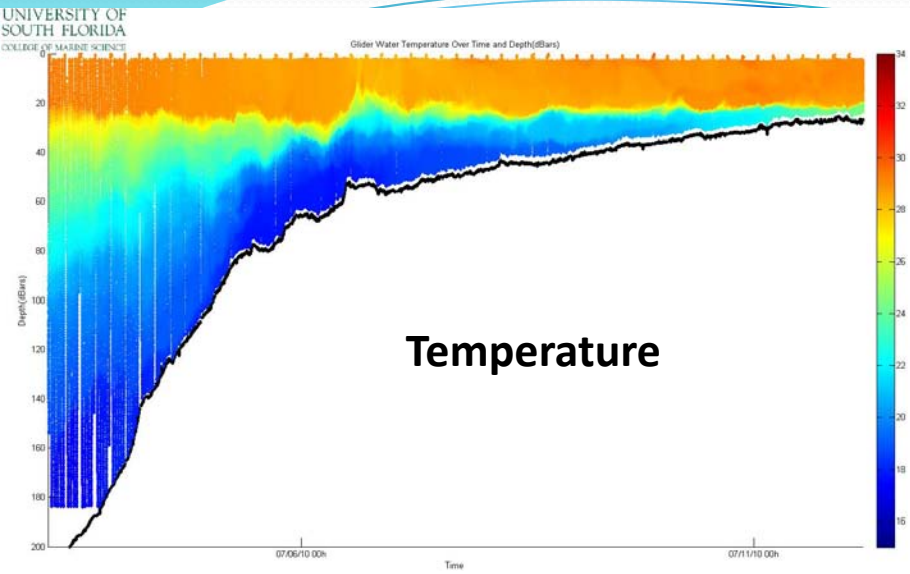
Surface oil percentage occurrence
(4/21 – 7/31/2010)

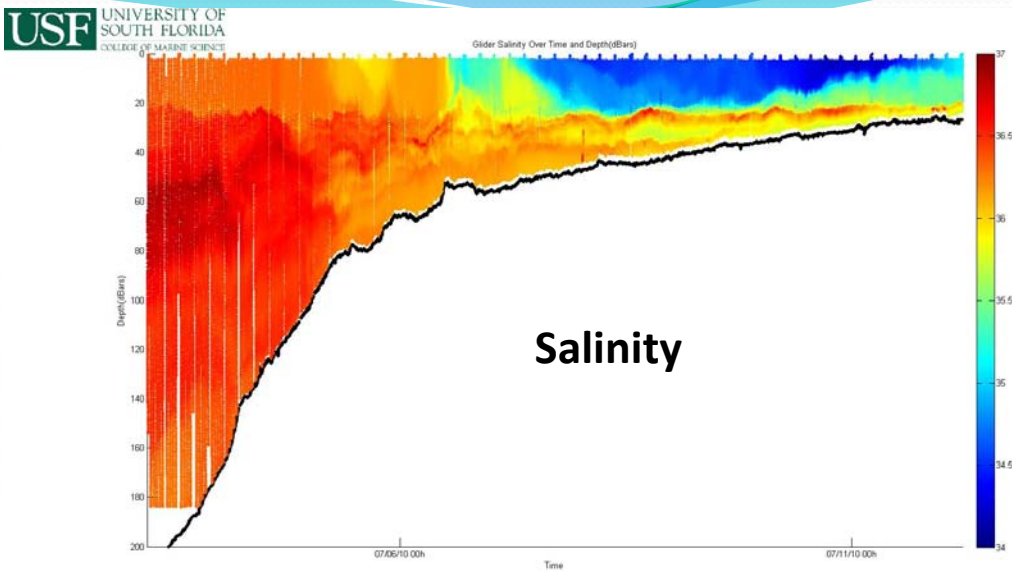


MODIS FLH anomaly, Aug 2010

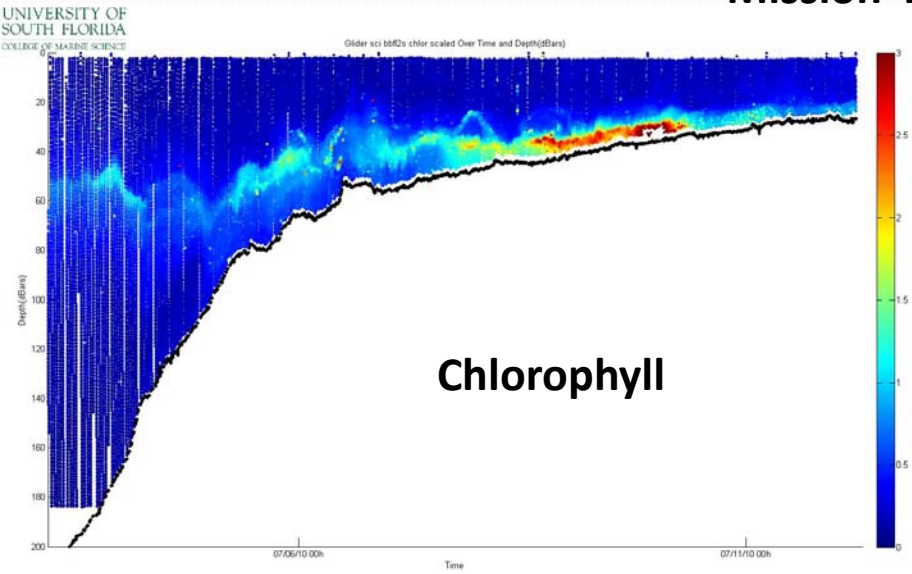


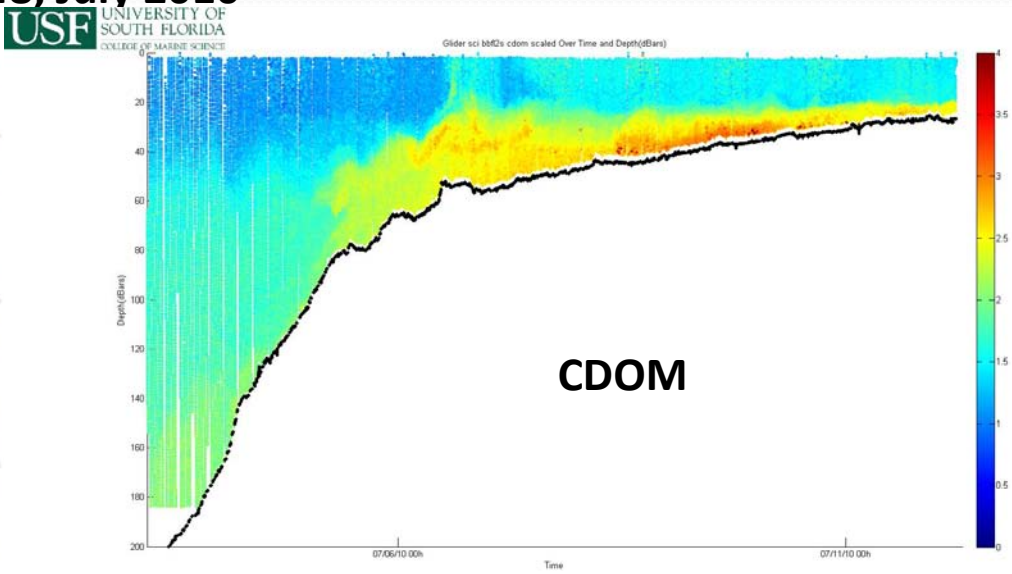
Was there upwelling in summer 2010 – There sure was!





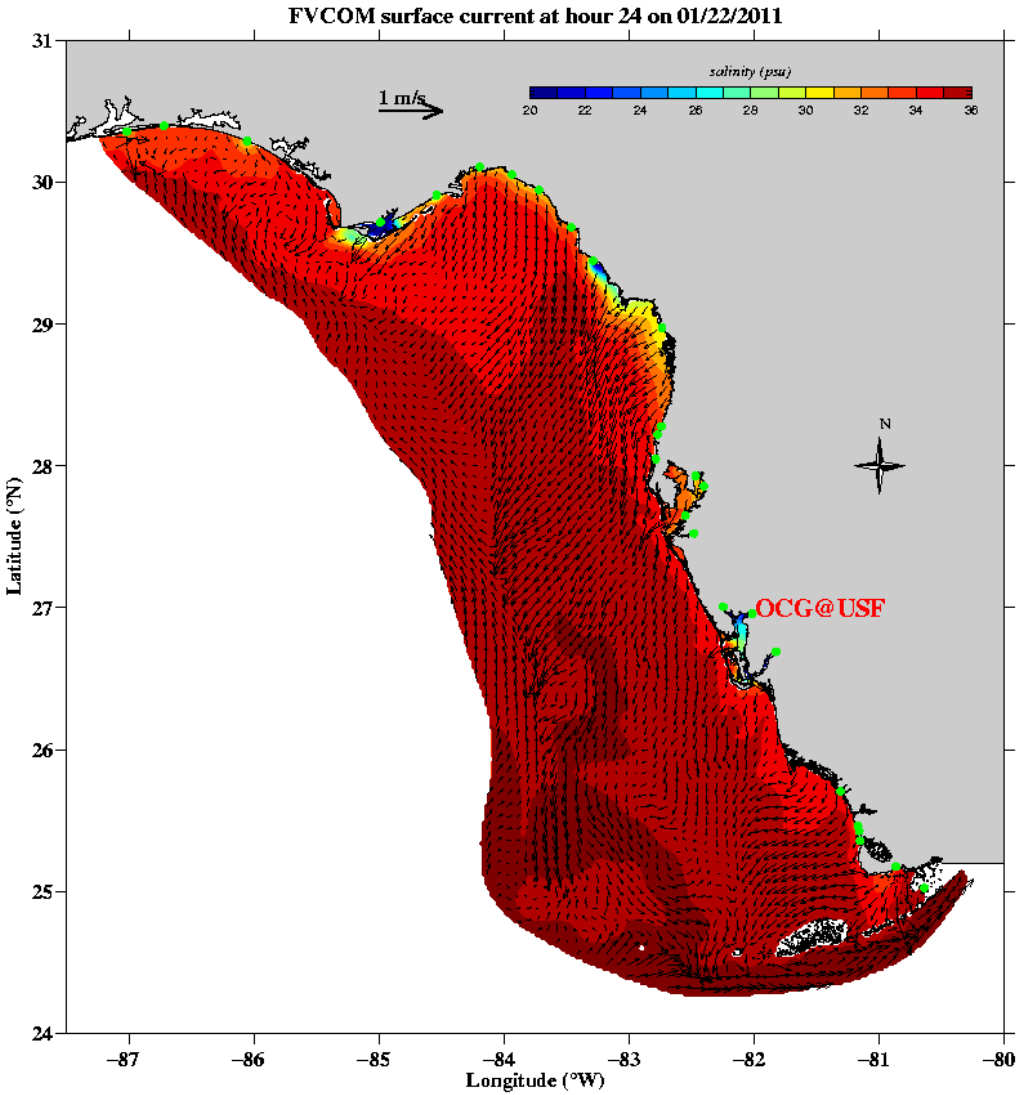
Mission 48, July 2010

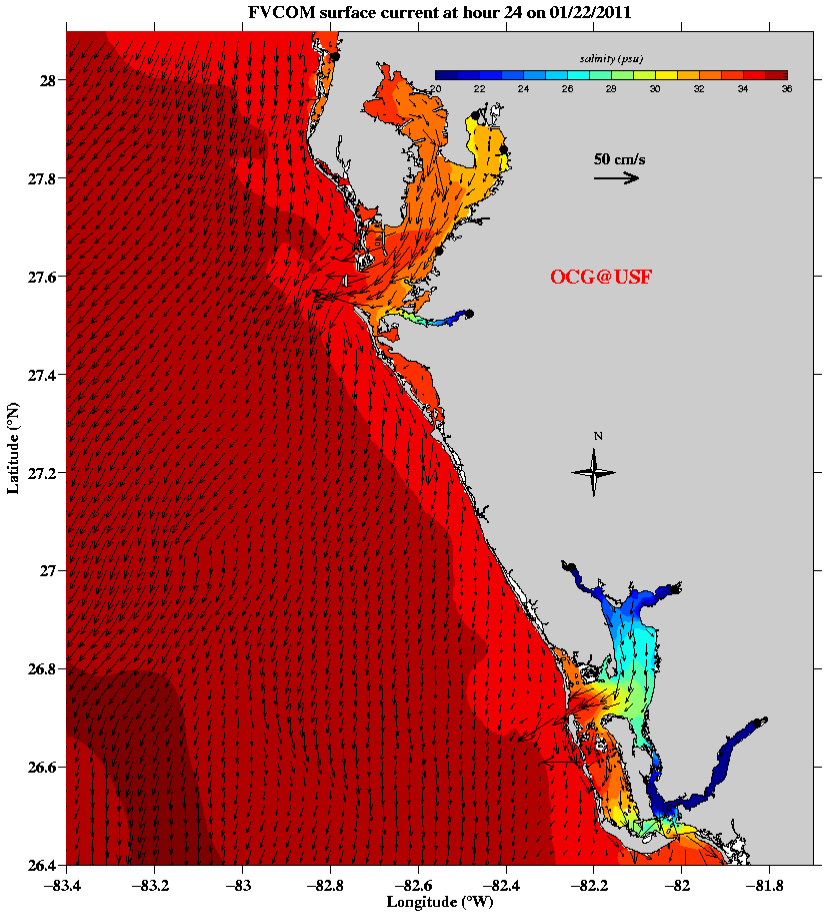


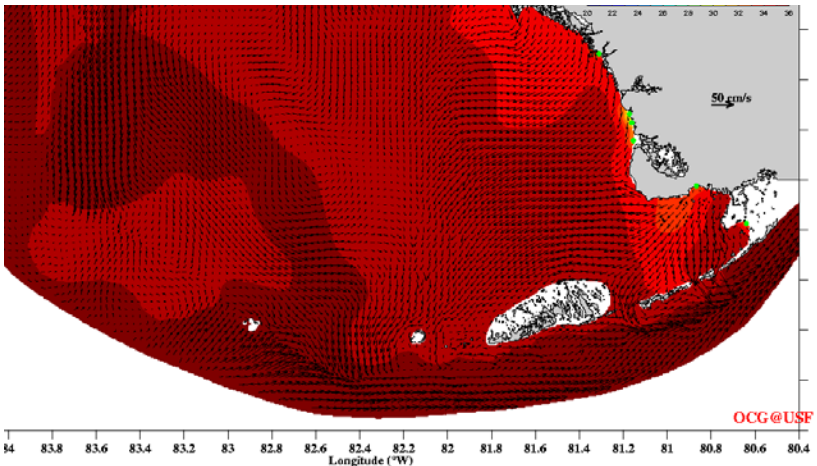


Glider data courtesy of CMS-USF BSOP-Glider Team

Fruits of our BP-sponsored work through the FIO. We are now prepared to forecast connections from the deep ocean to the coastal ocean to the estuaries.







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Editors: *Yonggang Liu, Amy MacFadyen, Zhen-Gang Ji, and Robert H. Weisberg*

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Models:

WFS ROMS – A. Barth
Global HYCOM – E. Chassignet, HYCOM Consortium
GOM HYCOM – O.M. Smedstad, P. Hogan, NRL
SABGOM – R. He, NCSU
RTOFS – C. Lozano, NOAA/NCEP
NCOM – NRL, F. Bub, NAVO.

Oil spill trajectory modeling & analysis collaborators:
C. Hu, L. Zheng, C. Kovach