The Oil Trajectory:
How it behaved in the Gulf of Mexico and why, and where might residual oil be heading?

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Homosassa Springs
August 19, 2010

Now that the spill appears to be stemmed:

How did the CMS-USF Ocean Circulation Group respond?

What are some continuing (environmental) concerns?

What are some Lessons (to be) Learned?

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

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with

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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.

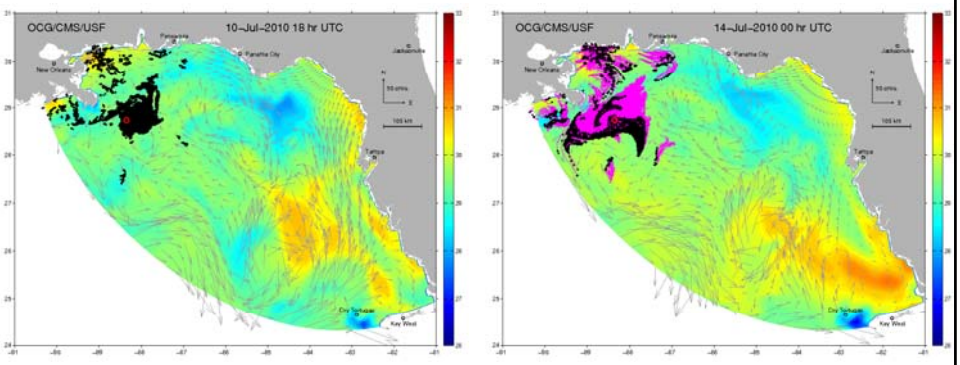
Once oil was in shallow water it progressed more easily along shore, which is why we saw more coastal communities affected. The latest imagery interpretation suggests less oil in general and less in shallow water.

Shown in the following three 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.)

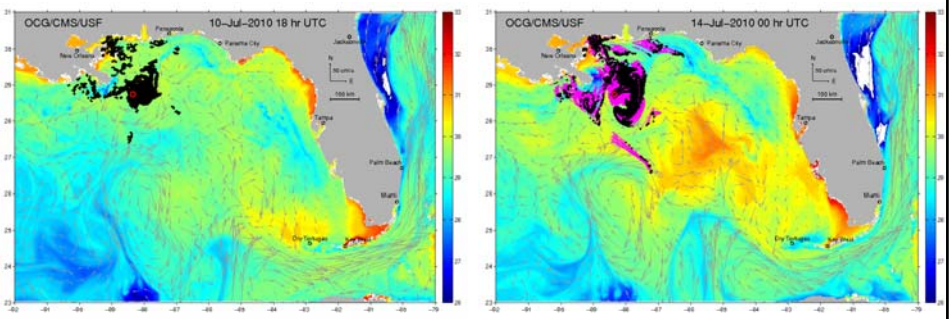
USF WFS Nowcast/Forecast Model Initialized 7/10 with Prediction at 7/14



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

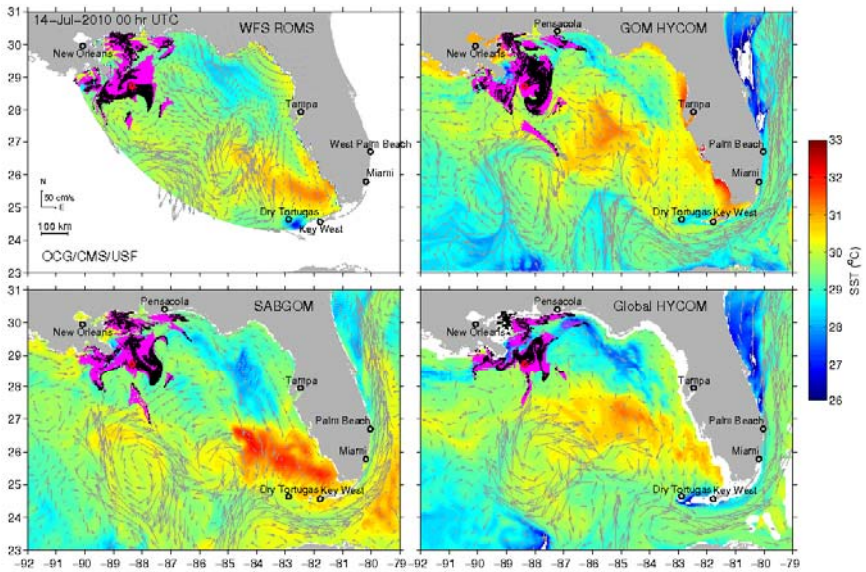
GOM HYCOM Nowcast/Forecast Model Initialized 7/10 with Prediction at 7/14



Using 3-hourly Navy GOM HYCOM 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

Loop Current Update

The next five slides pertain to the Loop Current.

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

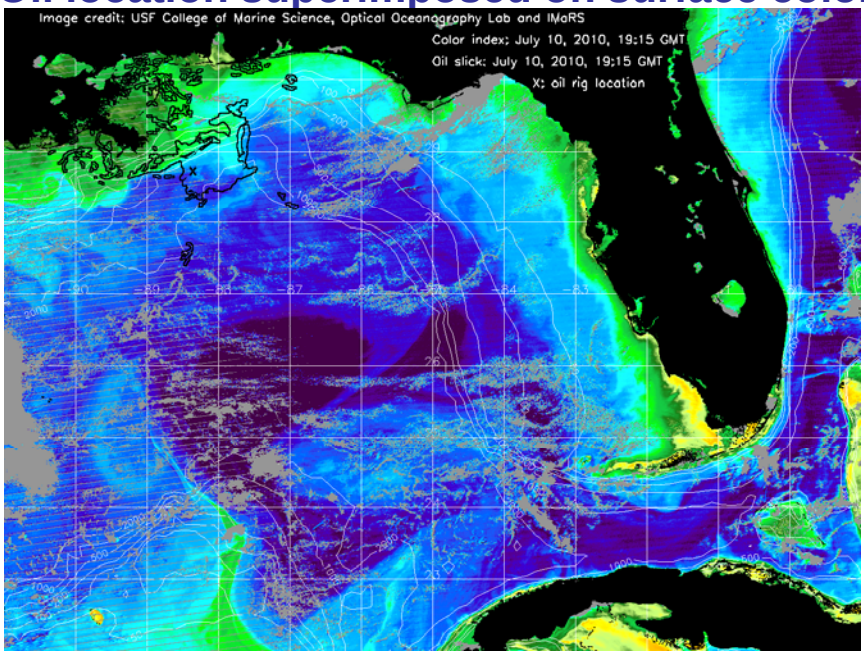
The process of eddy shedding is also evident in analyses of surface currents from satellite altimetry using the geostrophic approximation, and from these satellite altimetry-derived surface currents we can estimate pathlines for virtual particles carried by the currents.

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

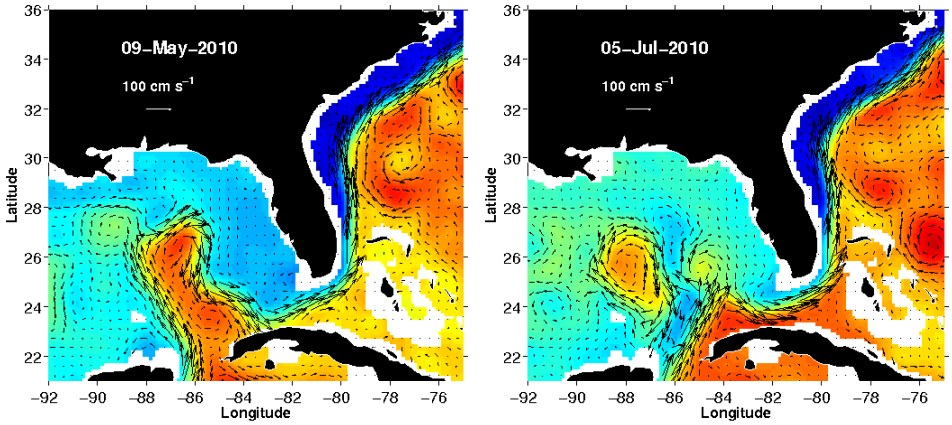
The interactions between the easternmost edges of the LC and its eddy with the shelf slope resulted in flows on the shelf tending to move oil eastward there. This was countered over the past two weeks by strong SE winds. The situation is subject to change owing to winds and LC/eddy interactions with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

Oil location superimposed on surface color



From C. Hu, CMS-USF in collaboration with OCG

LC-FC-GS system as determined using satellite altimetry



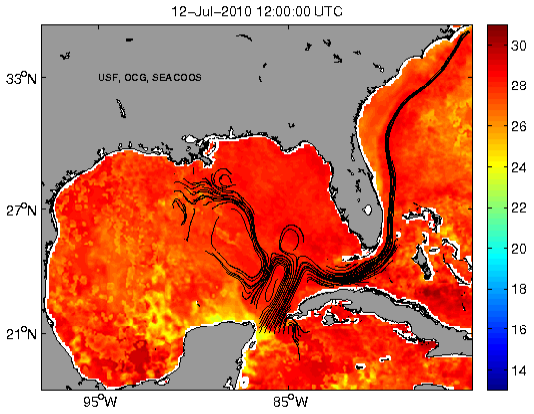
We use sea surface height (SSH) anomalies from AVISO combined with a mean SSH field to estimate absolute SSH. We then estimate surface currents via the geostrophic approximation, which is excellent in deep water. The colors are SSH (red being high, blue low); the arrows are the surface currents. A succession 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.



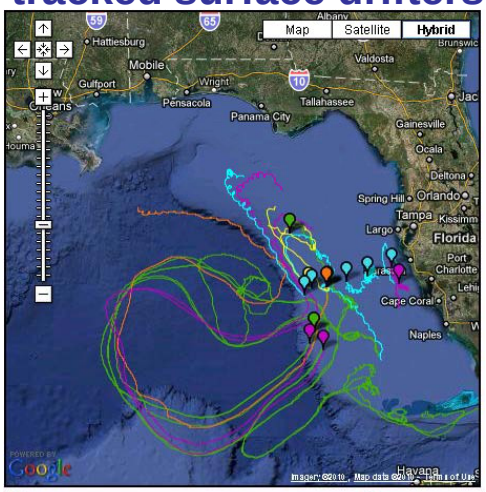
We do a 2-week hindcast/forecast of virtual drifter pathlines, assuming movement with the surface geostrophic currents.
These are publicly available at http://ocgweb.marine.usf.edu
Click on geostrophic drifters.

USF-deployed Satellite-tracked surface drifters

The OCG-CMS-USF deploys surface drifters and coordinates, plots, and serves drifter data in the eastern GofM. Our latest deployment was along a line across the WFS.

The next slide shows these drifters superimposed on modeled surface currents (see movie on the co-evolution of the drifters and modeled currents at http://ocgweb.marine.usf.edu).

Most WFS drifters over the past week continued to move toward the north as oil in the north tended to go westward. These have now reversed and are heading back eastward (in the north) and southward (on the WFS). These flows are not uniform across the WFS. We continue to deploy drifters to monitor the flows on the WFS and in the LC and eddy.



Deployment 1: Drifter ID's; 87795, 87796, 87797, 87798, 87799 CG-38898

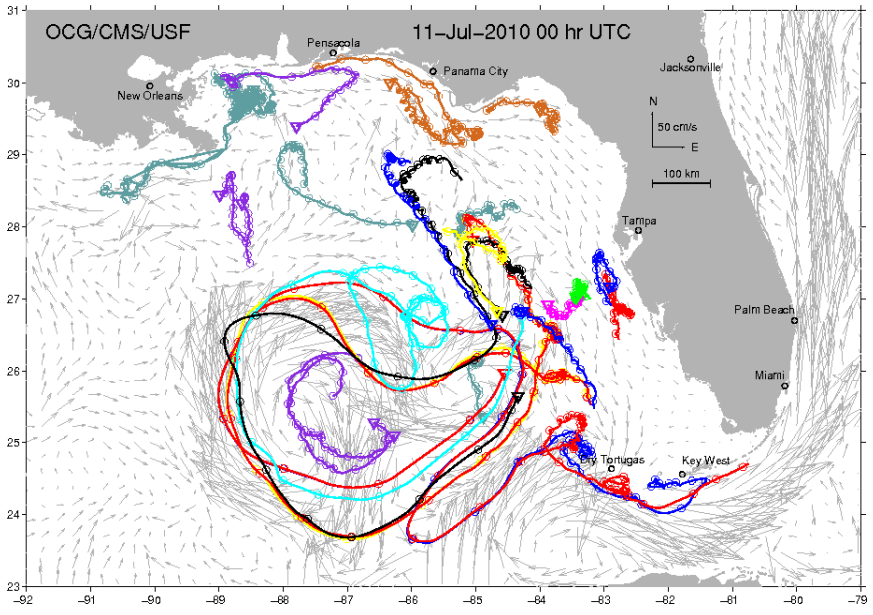
Deployment 2: Drifter ID's; 87803, 87806, 87800

Deployment 3: Drifter ID's; 87801, 87802, 87804, 87805, 87812, 87814

WHOI drifters deployed by OCG: Drifter ID's; 327596, 329736

Markers on map indicate deployment start locations. Click on marker for drifter id, start date/time, and initial latitude and longitude. In some cases it is necessary to zoom in to see overlapping markers.

Satellite-tracked surface drifter movie: drifters superimposed on modeled currents



West Florida Shelf Currents

The next two slides pertain to the West Florida Continental Shelf (WFS).

Sustained long-term observations demonstrate that a mean circulation exists from north to south across the WFS.

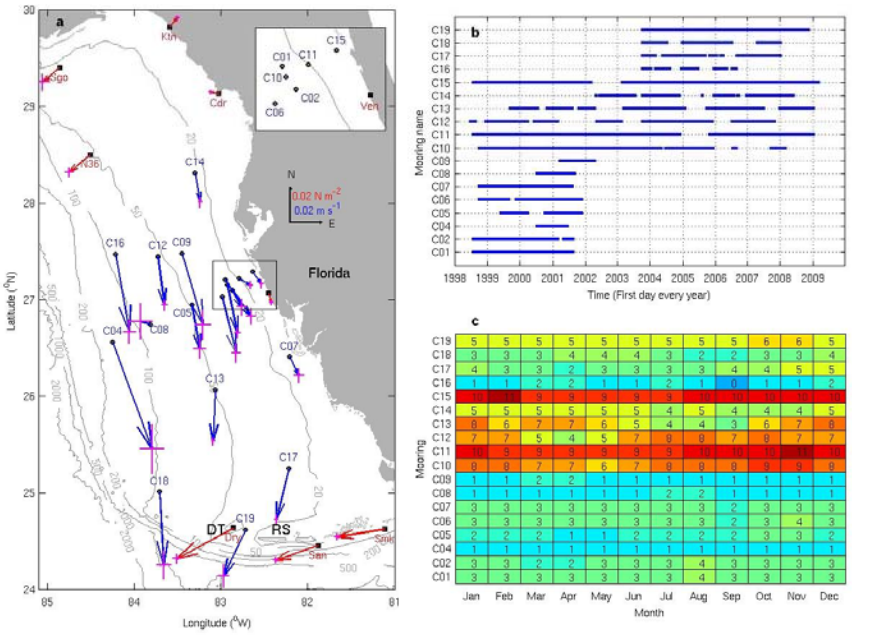
Sustained long-term observations also demonstrate that a seasonal variation exists about the long-term mean. In summertime, the monthly mean currents actually reverse to be from south to north. Daily weather changes, however, can further alter these currents, which is why we must run the forecast models shown previously.

The good news for Florida is that the monthly mean currents in summer will slow the movement of oil to the WFS. The bad news is that if oil is still present in fall then a reversal in the monthly mean currents will hasten the movement of oil to the WFS.

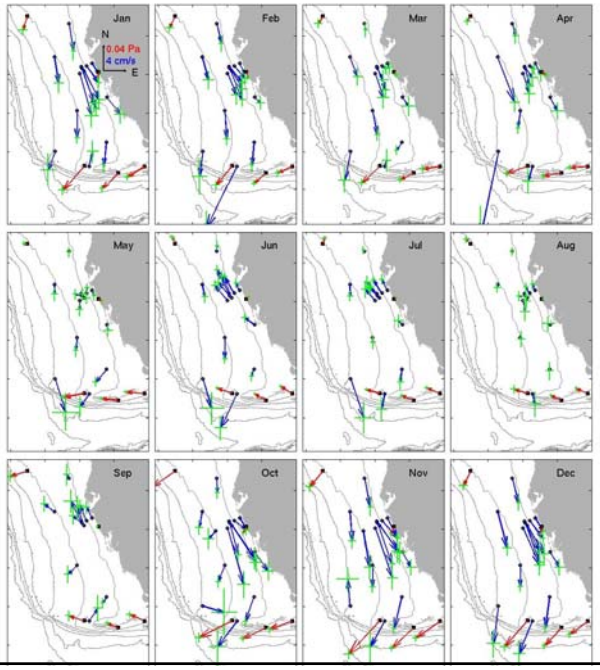
Easterly winds over the past week resulted in oil moving westward along the northern GofM shelf. LC and eddy interactions with the shelf slope also abated somewhat. These two factors provided a reprieve to oil advancing onto the WFS. However, these factors are now reversed, and winds are forecast westerly for the next few days.

We continue to observe the currents with a set of moored buoys, each containing instrumentation for measuring the water velocity. Also used are high frequency radars and surface drifters. All now show an upwelling circulation on the WFS.

West Florida Shelf Mean circulation



West Florida Shelf Seasonal Variability



West Florida Shelf COMPS Data

The next three slides pertain to the West Florida Shelf (WFS) Coastal Ocean Observing System.

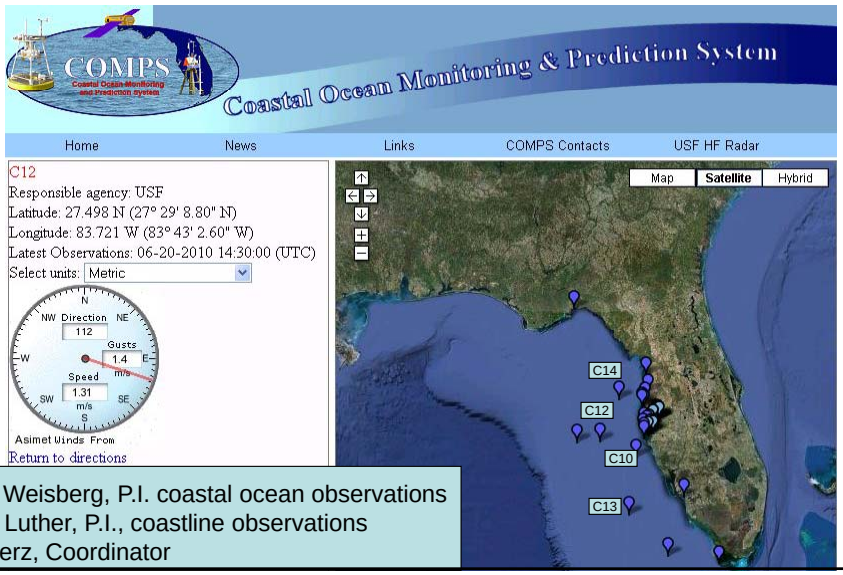
We presently maintain four surface moorings with real time telemetry for surface meteorology, water column currents, and temperature and salinity. Two additional moorings had to be retrieved last year for lack of funding. The remaining systems also remain in jeopardy.

The next slide shows the location of the four moorings, and the second slide shows the real time currents for the past few days (E-W component of velocity on the left; N-S component on the right). The WFS was in a strongly upwelling state of motion as oil moved eastward in the north. This abated over the past 1-2 weeks, but the situation just reversed. The interactions of the LC and eddy are important factors, along with the winds (now westerly).

We also maintain HF-radars on the WFS for monitoring surface currents. These work well when the winds and hence waves are well developed. Summertime generally shows spotty coverage because of weak winds and hence at times no waves. An upwelling circulation (southward currents) is now observed.

Along with the moored buoys and HF-radar are a limited number of satellite-tracked surfaced drifters. These are all essential parts of a Coastal Ocean Observing System because no single sensor or sensor delivery system is adequate, and the same can be said of models, as previously shown.

WFS COMPS Real Time Moorings: Ocean Circulation Group, CMS-USF
http://ocgweb.marine.usf.edu and http://comps.marine.usf.edu
Moorings C10, C12, C14 are active; C13 to be repaired; others (C16 and C17) are no longer deployed due to lack of funding.



R.H. Weisberg, P.I. coastal ocean observations
M.E. Luther, P.I., coastline observations
C. Merz, Coordinator

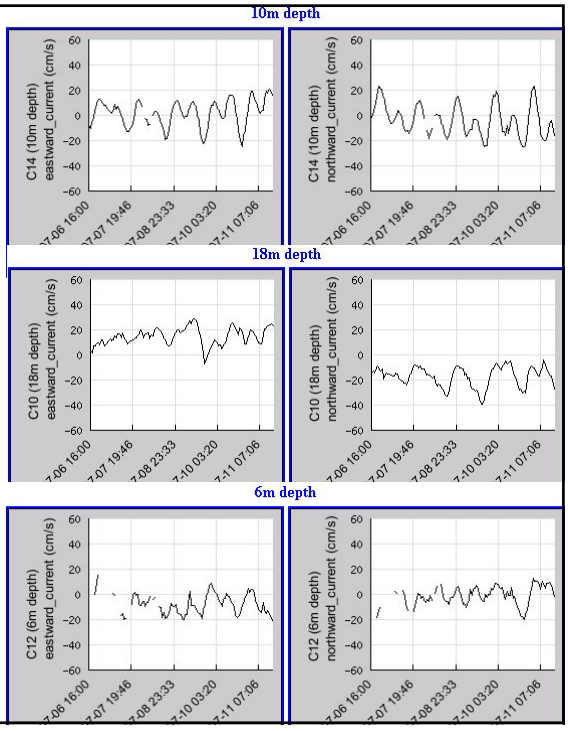
WFS COMPS Real Time Data

Using moored acoustic Doppler current profilers, we monitor currents on the WFS and serve these on the internet.

Upwelling is again observed in C14 and C10 on the 20m and 25m isobath, respectively. The flow at C12 on the 50m isobath remains neutral. As a gauge 20cm/s is ~20km/day.

These data, collected by the Ocean Circulation Group, CMS-USF, are now of increasing importance as more oil moves into shallower, near shore waters.

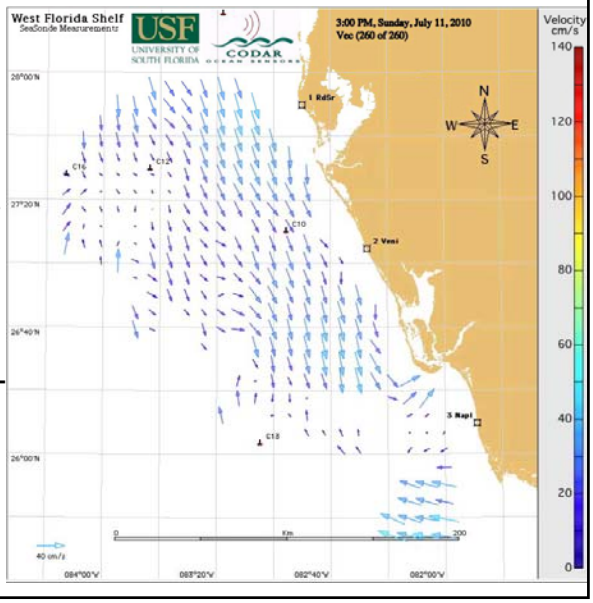
C10 Temp. also shows bottom water getting colder as offshore water advances to the coast.



HF-radar

The OCG-CMS-USF operates an HF-radar array for surface currents with CODAR units at Redington Beach, Venice (joint with Mote), and Naples. Two new WERA systems were recently deployed at Ft. DeSoto Park and Venice.

HF-radar works well when there are sufficient waves offshore. This is often problematic in summertime when weak winds result in flat seas. Intermittencies are therefore expected in summertime for HF-radar on the WFS.



Subsurface Currents

The next three slides pertain to the currents below the surface.

Along with trajectory tracking at the surface we track virtual particles carried by the currents below the surface. Not knowing the depth of subsurface hydrocarbons we track particles continually released at nine different depths (between 1400m and 50m) using the USF eastern G of M model (ROMS nested in HYCOM).

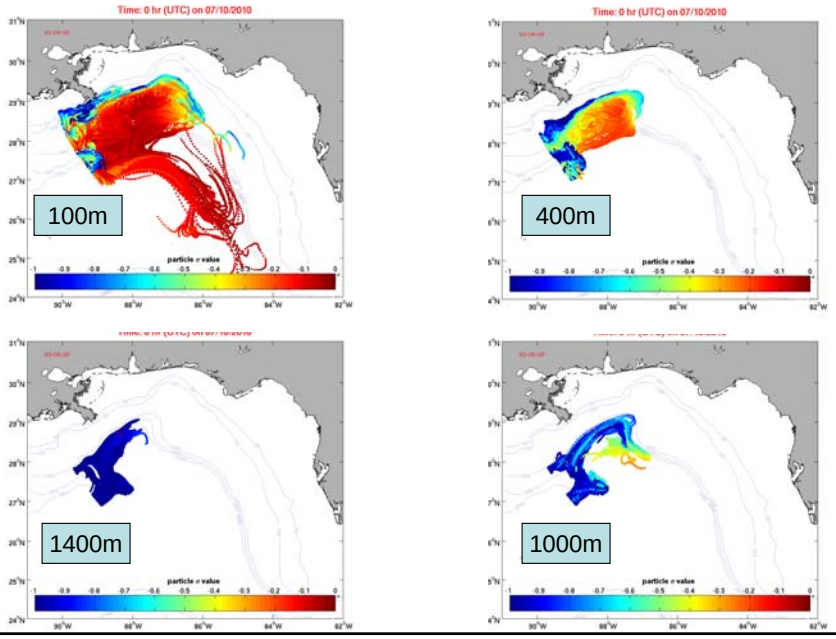
Being that the WFS is generally an upwelling favorable environment, it is not uncommon for cold water to appear along the coast line. Such cold water originates seaward of the shelf break in the northeastern G of M. So if subsurface hydrocarbons upwell across the shelf break then an added threat to the benthos and the coast line may exist as these waters move landward within the bottom Ekman layer. The threat, of course, will depend upon concentrations and decay of toxic materials.

Upwelling of cold water from the deep ocean ha been quite evident on the WFS. It abated last week but it now appears to be increasing again. We see this in model simulations shown below and also in observations. All of these tools are necessary to monitor the complex currents both in deep water and on the continental shelf.

Errors in modeled trajectories grow with time. Reinitialization data exist at the surface but not at depth. Being that a potential hydrocarbon threat exists at depth, it is important that systematic surveys of subsurface hydrocarbons be conducted on a regular basis, either directly of with calibrated proxies.

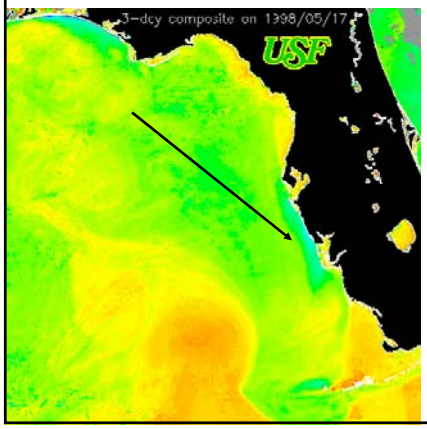
Subsurface Trajectories (4/20-7/11)

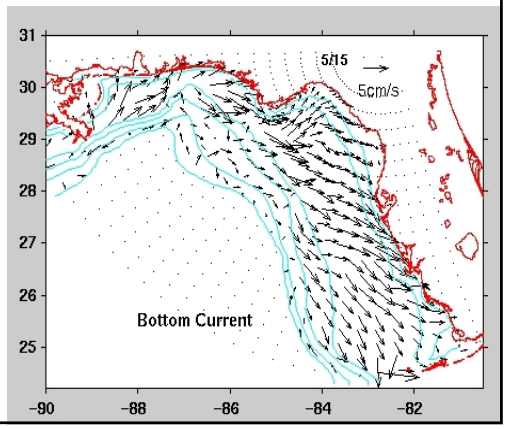
http://ocgweb.marine.usf.edu



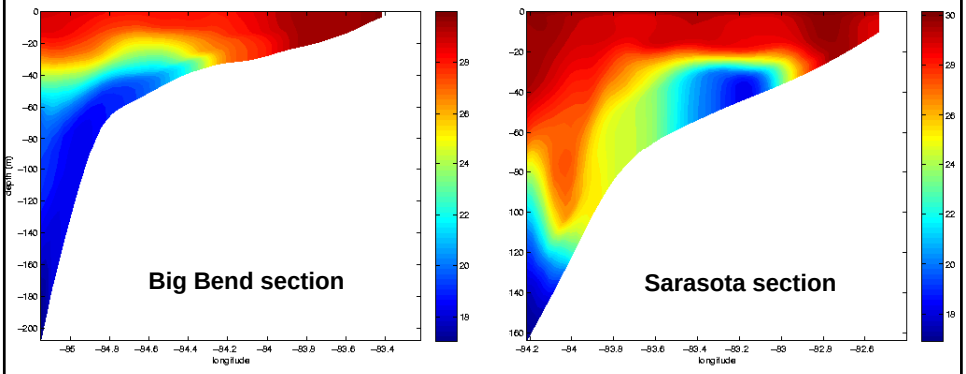
Subsurface Oil can Approach the Beach via the Bottom Ekman Layer

May 1998 provides an example in which a prolonged upwelling event provided connectivity from the Florida Big Bend shelf break to the Sanibel coast ~300 km away.





Model-Simulated Upwelling on the WFS



The upwelling implied by some of the drifter and mooring data is also seen in cross-sections of temperature simulated by the WFS N/F model. Observations by gliders deployed both by the CMS-USF and by Mote/Rutgers confirm this. The continuation of all of these observations, along with the modeling, are of critical importance toward monitoring the potential effects of oil on WFS waters and beaches. Note that the upwelling increased over the past week, consistent with the observed flows on the WFS. It is the coordination between observations and models that allow us to understand the behaviors on the WFS.

Needs

- **Observations:**
  - **Where is the oil, both at the surface and below the surface? Cloudiness highlights the need for an oil location product that combines all forms of data (sat., ships, aircraft etc.).**
  - **Data on the three-dimensional ocean currents and internal density field for model initializations, assimilation into the models for improved forecasts, and for gauging model veracity.**
- **Models:**
  - **An ensemble of models run by different groups is necessary because each has errors.**
  - **Improved wind predictions are necessary because these determine model performance even for a perfect model.**
  - **Also required are models tailored to resolve the estuaries and inland waterways.**
- **Sustained funding for personnel and equipment is required for coordinated observing and modeling. IOOS/COOS was designed for this, but IOOS/COOS remains grossly under-funded. Moreover, the role of the academic community in IOOS is essential. The environmental stewardship of the nation's coastal ocean requires partnerships between the agencies, the academic institutions and the private sector. Each has an important role to play.**

What are some continuing environmental concerns?

- **What is the spatial (both horizontal and vertical) extent of the subsurface oil?**
  This information is needed to reinitialize ocean circulation models for the purpose of tracking where these hydrocarbons and related dispersants will head.
- **What are the concentrations of the hydrocarbons and dispersants?**
  We know that these concentrations are low, simply on the basis of how much oil was leaked relative to the volume over which it has spread. Nevertheless, there are concentrations for which these materials may be harmful.
- **What concentrations are toxic to marine life, and how quickly might toxic levels bio-accumulate up the food chain?**
- **What are the rates of chemical decomposition or biological consumption, i.e., how quickly will the subsurface hydrocarbons/dispersants diminish to levels at which they will pose no ecological threat?**
- **Florida was very lucky!**
  We must recognize that just because a larger natural disaster did not occur for Florida, such risk should not be underestimated going forward.

What are some Lessons (to be) Learned?

- **Better coordination is needed between all parties: the agencies (federal, state, local), the private sector and the academics; each has an important role to play.**
- **Was the use of dispersants a good, or a bad, idea?**
- **With regard to ocean observing and modeling capabilities we were caught short. This requires remedy? A pathway forward is the implementation of an integrated ocean observing system (IOOS) as conceived a decade ago, but without adequate coordination or funding.**
- **The ocean is a complex system, and the behavior of oil spilled into the ocean certainly bears this out. If we are to understand our ocean ecology and thereby engage in concepts like *Ecologically-Based –Management* or *Marine Spatial Planning* then we must approach the ocean in a systematic, comprehensive, multidisciplinary way. Otherwise we will fail at environmental stewardship.**
- **Florida's economy is in every way touched by the ocean. We were lucky, and the BP spill gives us pause to re-evaluate how we all interact to better understanding the workings of our precious ocean resources.**