**DYNAMIC POSITIONING CONFERENCE**
**September 16-17, 2003**

**Environment Session**

---

# Using Oceanographic Data to Maximize Operational Efficiency in the Gulf of Mexico

Kenneth J. Schaudt
*Marathon Oil Company*

---

## Abstract

Strong currents driven by the Loop Current and its associated eddies first affected deepwater drilling operations in the early 1980's. Since then, mid-water jets believed to have 3 to 4 knot currents have been observed on the slope. Two knot bottom currents have been recorded at the base of the Sigsbee Escarpment. What causes these strong currents? What can be done to promote safe and efficient operations? What new resources are available to aid operations?

## Introduction

With *Bowditch's American Practical Navigator* being in continuous publication since 1802 and the countless handbooks that have been written for the mariner, there are well developed procedures for dealing with marine weather.

Even so, DP operations remain sensitive to metocean conditions and must keep close attention on the situation. Consider one recent DP operation. Even with the successful forecast of hurricane force gusts, (Figure 1); the sudden wind shifts proved interesting. Quoting the logbook:

> *"Extreme conditions, vessel forced off location from 200 m to 544 m in 6 minutes (avg. 2 knots), wind from Starboard. Wind increased from 42 knots to 73 knots in appr. 1 minute. Wind dir. changed from 120 deg. to 225 deg. in 5 minutes. Heavy lightning shower. High force alarm in DP system. Insufficient thrust. All thrusters working maximum output."*

Weather-related problems are minimized by putting in place appropriate observational and forecasting procedures. Although forecasting of ocean circulation has not yet reached the sophistication of weather forecasts, proper procedures can minimize operational downtime.

In the Gulf of Mexico deepwater leases, currents are often fairly mild. However, moderate to strong currents may occur when the Loop Current and its eddies intrude into the leases. Near the fronts separating the waters of the Loop Current and its associated eddies from the resident Gulf waters, currents may change rapidly. In 1989, currents rose from under 1 knot to 3 knots in 24 hours as Nelson Eddy moved into the Ewing Bank leases[1], (Figure 2). According to Forristall[2], the captain of the *Discover Seven Seas* told an interesting story about drilling operations in Mississippi Canyon at that time.

> *"They knew Nelson was approaching. On Tuesday, August 8, he noticed a front line in the water moving slowly toward the ship. There was a noticeable change in wave roughness across the line, and he put two more generators on line in anticipation of needing more power. Nothing happened until the front was 10 feet from the bow, but then he had to rapidly change heading from 290 to 320, and needed the extra power."*

The Loop Current and its eddies are not the only cause of moderate to strong currents. On the slope, submerged jets with currents in excess of 3 knots[3] (Figure 3) have been observed from Viosca Knoll westward through Green Canyon and into East Breaks. The present hypothesis is that these jets are caused by cold-core eddies.

Such currents must be considered for stationkeeping; running of the riser; BOP and ROVs; construction operations; pipelay operations; mooring and riser loads; riser fatigue; and downtime.

## Key Questions

Frequently, several questions are asked when an eddy or the Loop Current moves into the lease areas:

**What the heck is an eddy?** Usually heard shortly after the onset of downtime.

The Loop Current is part of the North Atlantic's western boundary current. The Loop Current is the warm Caribbean waters that enter the Gulf through the Yucatan Channel, head northward before finally turning southward and leave the Gulf through the Florida Strait (Figure 4).

Fronts divide the warm Caribbean waters from the often cooler Gulf waters. Operational analyses[4] show that meanders often migrate along the Loop Current just as atmospheric high pressure and low pressure systems migrate along the jetstream (Figure 5). From time to time, the meanders close off and form eddies. Clockwise rotating eddies are generally called warm-core eddies and are high-pressure systems. Counter-clockwise rotating eddies are generally called cold-core eddies and are low-pressure systems. From time to time, the Loop Current or its eddies intrude into the deepwater lease areas.

**How can it be managed?** Know the synoptic (broad-scale) and local situation and have options.

**Why bother?** As the *Discover Seven Seas* example shows, knowledge of the situation will help ensure that prudent choices are made. Without knowing the situation, a rig might choose to cut and run just as the currents are starting to ease.

**When will it hit?** Conditions change sharply at the front along the edge of the Loop Current and eddies. Along the edge of Nelson Eddy[5], sharp changes in color and waves were noted across the front (Figure 6). Currents can increase from mild to quite strong in a few miles[6] (Figure 7). Meanders can rapidly sweep through the eastern and central Gulf leases. One such meander surged northward and substantially covered Atwater Valley and portions of eastern GC and WR over a period of a few weeks (Figure 5) in 1999. The combined effects of the slow drift of the eddy, rotation and meanders can allow the fronts to close a 20 mile gap in a day. Short-term predictions of the arrival of the fronts and high currents often require repeated surveys of the waters near the rig, as well as operational analysis of satellite images, drifters and nearby rig reports all of which can be available in near real time[4].

During portions of the fall, winter and spring, satellite images[7] (Figure 8) are useful tools for tracking the Loop Current and newly detached eddies. Unfortunately, cloud cover limits use year-round and lack of thermal contrast limits use in summer (Figure 9). Tracking the movement of the front over the period of hours to days requires ship surveys (Figure 7) of the waters between the rig and the nearest fronts. These surveys may be needed every 6 to 48 hours. Ship drift, current measurements, and temperature profiles all have been used to track the front.

**How strong?** Drifting buoys and nearby rig reports provide a general description of the currents. Since conditions change rapidly at the front, surveys may be needed to know if the currents are near the rig's limits. Tracking both the movement of the front and the intensity can extend the operating windows. Drilling operations were conducted in Ewing Bank and eastern Green Canyon with 2.5 to 3 knot operational limits. Since the unexpected approach of stronger currents might have required an emergency disconnect and caused the release of oil-based muds, the drilling plan required the shutdown of drilling operations and purging of the riser at least 1 day before the arrival of strong currents. By measuring the currents at the approaching fronts, the operator knew that currents would remain within the rig's standby limits. No disconnect would be required. Further, by watching the synoptic situation, the operator knew that the currents would sweep through in a few days. Rather than abandoning the site, the operator stood by awaiting the return of lower currents.

## Planning

Knowing the environment, how it acts on the rigs and the operational limits is important. Simply changing the shape or directional variation of the current profile can greatly change drilling and construction operational limits[8].

**Climatology:** The threat of strong currents due to the Loop Current and its eddies varies greatly across the Gulf[9] (Figure 10 and Figure 11) with portions of the leases affected 50% of the time and others rarely. Representative criteria, such as the often mis-used Deepstar[10] criteria, should never be used for design since such criteria may substantially underestimate or overestimate the severity of conditions at specific sites.

**Strategic:** Mariners have well developed procedures for dealing with storms. Consider a rig move from the Gulf of Mexico to West Africa. The rig may be routed through the Florida Strait and proceed north of the Caribbean or through the Yucatan Channel and the Caribbean depending on whether tropical storms are present or if development is expected.

At the strategic level, tracking the Loop Current and its eddies on a broad scale provides the information needed to decide between drilling in the eastern, central or western Gulf at a particular time. If an eddy is likely to affect a site, there may be significant advantages in using a suitable DP rig instead of a moored rig.

**Tactical:** Onroute, mariners adapt their course based on the expected track of storms. While the oceanographer's toolkit is not as sophisticated as that of the hurricane forecaster, an eddy's position and general currents can be determined by analysis of the available buoys, rig reports and images. The broadscale changes in position and intensity can be estimated from recent trends[4] (Figure 12 and Figure 13).

Based on winds and barometric pressures, mariners have well developed rules for recognizing that they are moving into tropical storms[11], for evading them if needed and for minimizing exposure to the heavy winds and seas.

For eddies, currents and subsurface temperatures can be used in the same fashion. The surveys of Fast Eddy[12] (Figure 14 and Figure 15) suggest that the rules would be current to your back, center to your right. Increasing depth of the 15°C or 20°C isotherm means movement towards the center of a warm-core eddy. While mariners wouldn't cross the eyewall just to enter the region of low winds inside, the region inside the high current core of eddies is often broad enough and calm enough to allow many operations to be safely conducted.

## APPLICATIONS

Knowing the general details about conditions from satellite imagery or operational analyses provide a significant starting point.

Several years ago, a rig headed westward at about 4 knots without realizing that it was headed into the core of an eddy with eastward flowing 3 to 4 knot currents. After a day or so without progress, an oceanographer was consulted. The rig was redirected 5 to 10 miles northward, out of the eddy, and proceeded westward without further problems. More recently, a rig detoured 50 miles east so to follow the Loop Current. The normal rig transit speed is 2.5 to 3.2 knots. In the Loop Current, the rig speed was consistently over 5 knots with a peak speed of 6.1 knots. Average speed over the transit averaged 4.8 knots which saved about 30 hrs of time. Near the fronts, more detailed information may be needed since the rig is dancing with eddies.

When dancing, one must know your partner's position and where your partner will move next. Dancing with eddies requires knowing the rig's position relative to the high current core. Is the rig in the lower currents outside the high-speed core, or in similar currents just inside the core? Is the rig in the low currents outside the eddy or in the low current in the eye? Is the rig in low currents near a meandering front? Is the eddy moving away or moving towards the site?

Broadscale movements can be tracked from the operational charts. Smaller scale changes near meandering fronts can be tracked by repeated surveys and the movement used to forecast windows. If in the eye, surveys may be needed to track the eventual return of high currents when the eddy moves away from the rig.

In early 2001, a dynamically-positioned rig encountered the western wall of the Loop Current upon arrival at location (Figure 16). The area was surveyed (Figure 17), the rig moved into quieter waters upcurrent from the wellsite. As the riser was run, the rig eased into the current, drifting downstream towards the site at 2 - 2.2 knots. With sufficient riser in the water, the latching operations were completed once the rig arrived at the site.

Near a hurricane, a mariner locates the ships position relative to the storm by tracking the pressure, wind speed, direction magnitude and change. Near an eddy or the Loop Current,

Return to Session Directory



currents and temperatures can be used in the same fashion. Figure 18 shows the currents during the passage of a small eddy from west to east. As the leading edge approached on day 5, currents turned clockwise (veered) to a northerly set and speed increased sharply. Towards the center, currents became variable. As the trailing edge approached, current directions turned counterclockwise (backed) to a southerly set and speeds again increased.

The large meanders (Figure 5), sweep moderate to strong currents into major sections of the Gulf's deepwater leases. Smaller meanders, such as the sequence shown in Figures 19 and 20, will open and close operational windows. Finding these windows most often requires vessel surveys since satellite imagery is often obscured by clouds.

As with tropical storms, knowing pressure (depth of isotherm) adds considerable value to the observation of current speed and direction. During the passage of a Loop Current meander, current speeds increased drastically (Figure 21 and Figure 22) from 0.7 to 1.8 knots. After June 22nd, current speeds started to fall off quickly. Has the Loop Current moved away from the site? No. A quick check of the depth of the 15°C isotherm shows that the isotherm depth has increased from 152m to 290m. Outside the Loop Current, the 15°C isotherm would be shallower than 200m. With only information that could be measured onsite, it is clear that the currents have eased since rig is inside the core of the Loop Current. Alternately, it might have been possible to recognize this from the operational charts if there were clear skies, good buoy observations and good thermal contrast.

Inside the core, currents are weak and variable near the center. Moderate to strong currents extend from 85% of the way out from the center to the edge of the eddy. As the edge again crosses the site, an increase in currents would be expected. In this example, current speeds and temperatures are derived from nowcasts[13]. Loop Current fronts were taken from operational charts [4].

## Summary

While knowing the operational limits as well as the local and broad scale situation won't reduce the current speed, it will at least allow a more timely return to normal operations and may prevent the untimely release of a rig just as currents are preparing to return to normal.

## Acknowledgments

This talk is substantially based the published presentation given in September 2002 at the Society for Underwater Technology's Gulf of Mexico Currents for Deepwater Operations Workshop. Thanks are again gratefully extended to Horizon Marine, the Climatology and Simulation of Eddies Project, George Forristall and John Vermersch for providing information used in both of these presentations. Thanks are given to Charlie Theriot, Gale Baxter and Carol Schaudt for reviewing the drafts of this paper. Many thanks to Marathon Oil Company for enabling this presentation.

## References

[1] Chevron Texaco, Ewing Bank Block 966 Current Measurements, 3 July to 16 August, 1989. 1989
[2] G. Z. Forristall. "Nelson Eddy News"." E-mail to the author. 13 August 1989.
[3] M. Vogel, "Brutus Field Current Measurements", Shell International EP, April 2001.
[4] Horizon Marine. Eddywatch and Eddynet operational analysis. <www.horizonmarine.com>
[5] J. A Vermersch, 1989.
[6] Texas A&M University Geochemical and Environmental Research Group. NOPP Ocean Monitoring System. September 2002. <tabs.gerg.tamu.edu/gomoms/adcp.html>.
[7] Johns Hopkins University Applied Physics Laboratory, Ocean Remote Sensing, Group, Gulf of Mexico AVHRR Imagery. September 2001. <fermi.jhuapl.edu/avhrr/gm>.
[8] T. Farrant and K. Javed, Minimizing the effect of deepwater currents on drilling riser operations. Deepwater Drilling Technologies Conference, Aberdeen, Aberdeen 2001. September 2002. <www.2hoffshore.com/papers/papers_2001.htm>.

[9] Minerals Management Service Physical Oceanography of the Gulf of Mexico, Visual No. 7.
[10] Deepstar Joint Industry Project. <http://www.deepstar.org>.
[11] Holweg, E.J., Mariner's Guide for Hurricane Awareness in the North Atlantic Basin, August 2000. <www.nhc.noaa.gov/marinersguide.pdf>.
[12] G.Z. Forristall, K.J. Schaudt, and C.K. Cooper "Evolution and kinematics of a Loop Current eddy in the Gulf of Mexico during 1985", J. Geophys. Res., **97**, (1992) 2173-2184
[13] K.J. Schaudt, G.Z. Forristall, L.H. Kantha, R. Leben, J.K. Choi, P. Black, E. Uhlhorn, N.L. Guinasso, Jr., J.N. Walpert, F.J. Kelly, S.F. DiMarco, O. Wang, S. Anderson, and P. Coholan, "A Look at Currents in the Gulf of Mexico in 1999 – OTC 12996. May 2000.

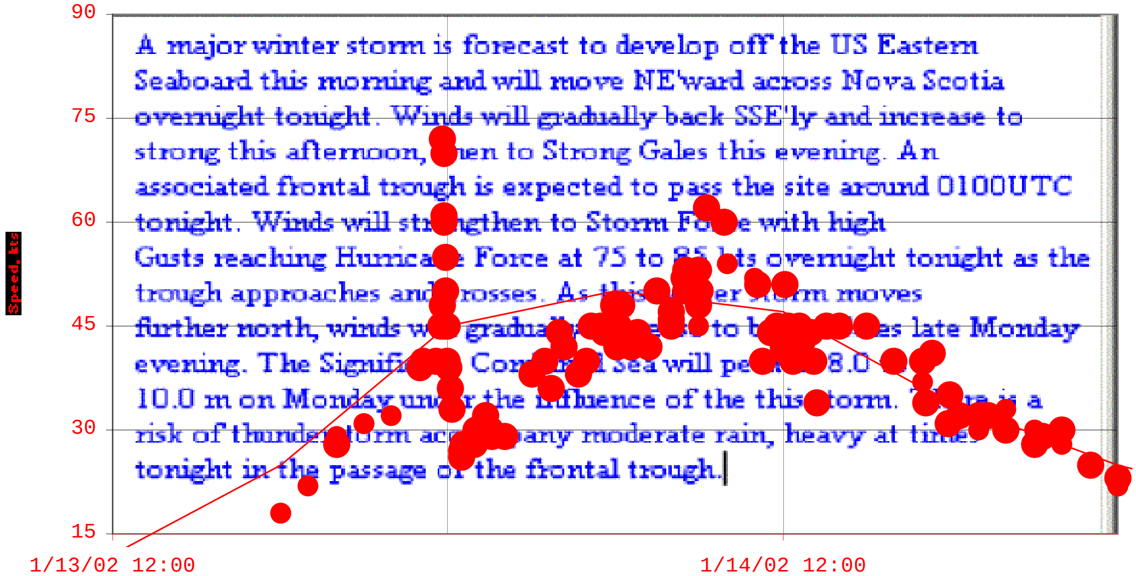


Figure 1. Wind forecast and observations.

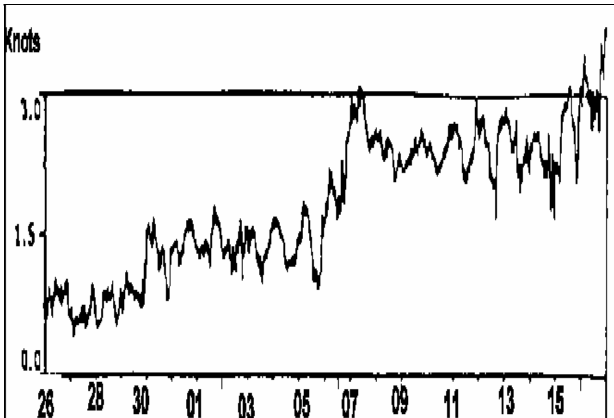


Figure 2. Surface currents during approach of Nelson Eddy at Ewing Bank

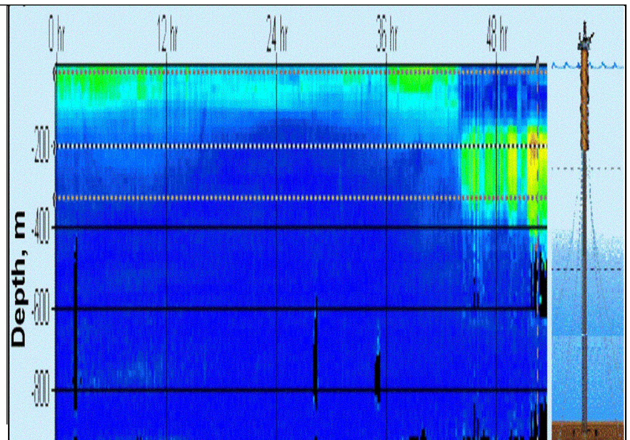


Figure 3. Submerged jet. Currents > 2 knots in green, yellow or red.

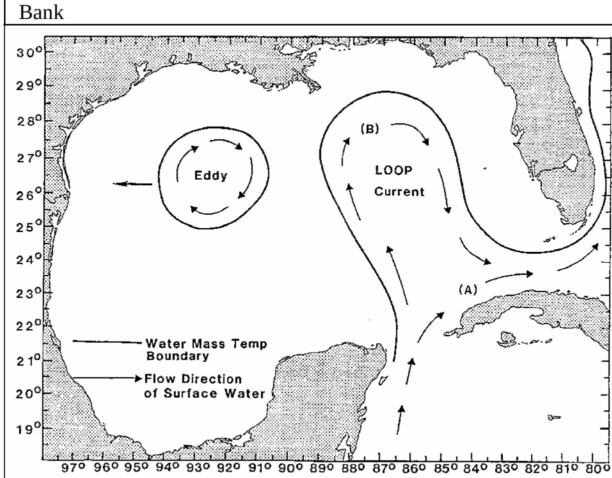


Figure 4. Schematic of the Gulf of Mexico Loop Current System.

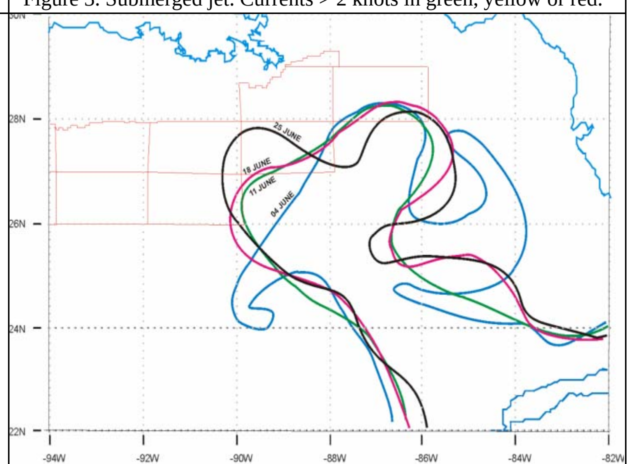


Figure 5. June 1999 frontal movements.

Figure 6. Frontal boundary along Nelson Eddy.

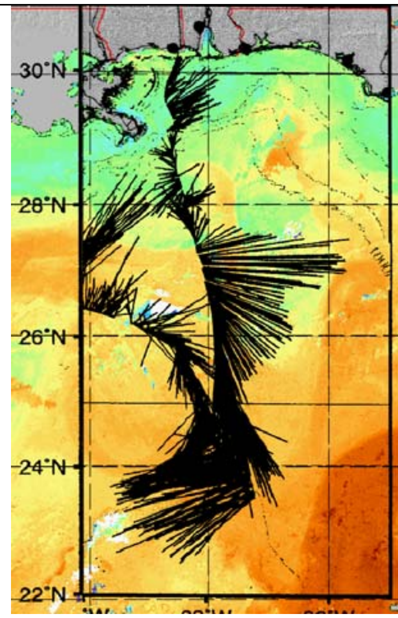


Figure 7. Thermal image (red:hot, blue:cool) and surface currents.

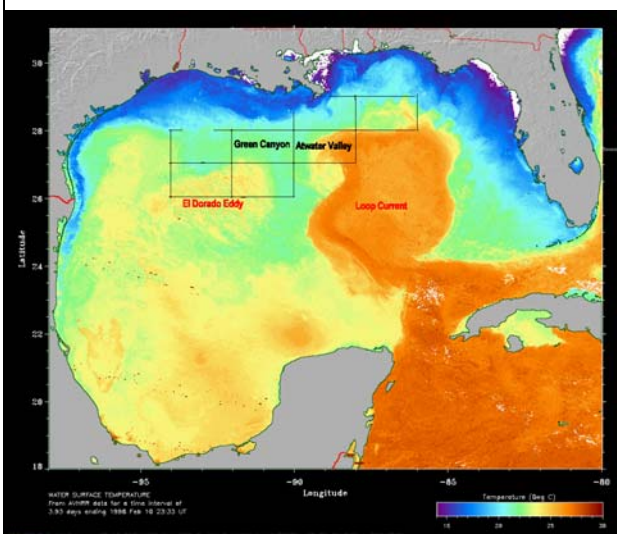


Figure 8. February 1998 thermal image.

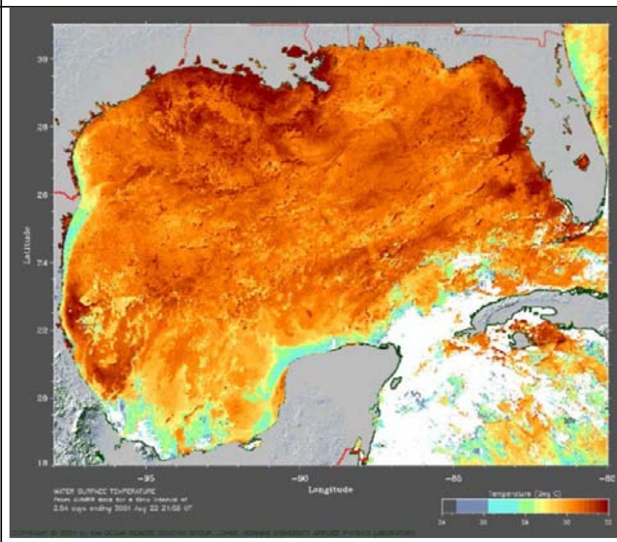


Figure 9. August 2001 thermal image.

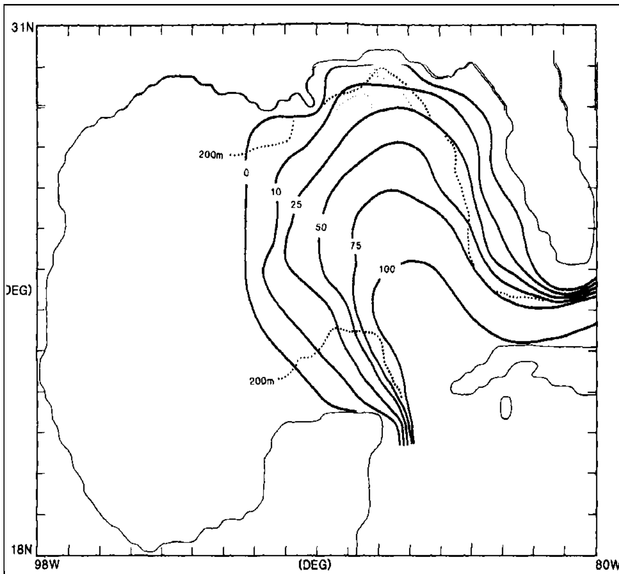


Figure 10. Chance of Loop Current water

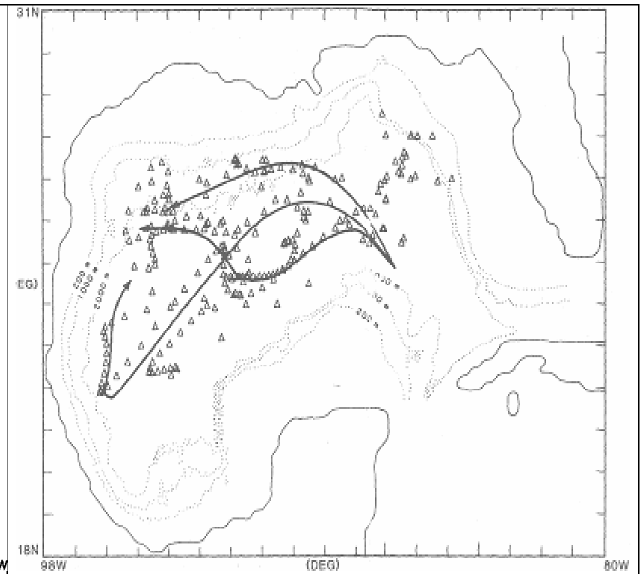


Figure 11. Observed eddy locations and preferred paths.

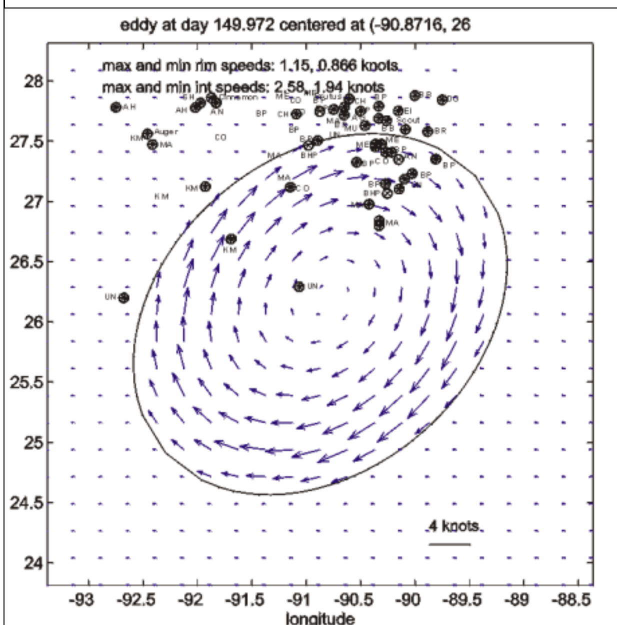


Figure 12. Operational analysis for day 149.

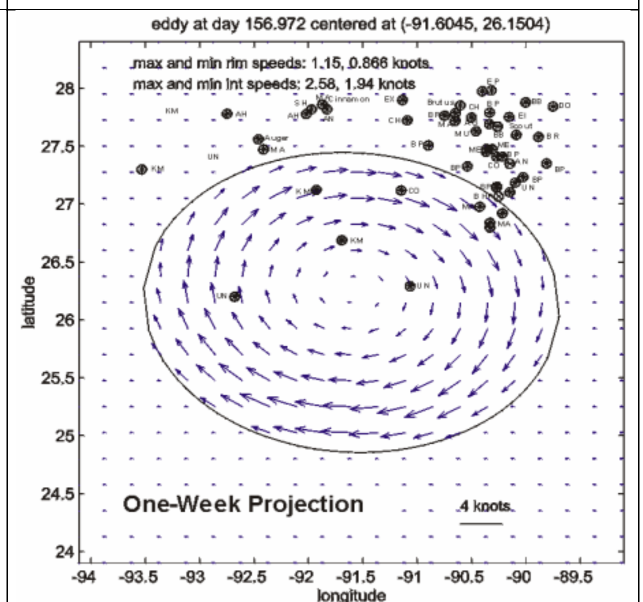


Figure 13. One week projection for day 156.

Return to Session Directory



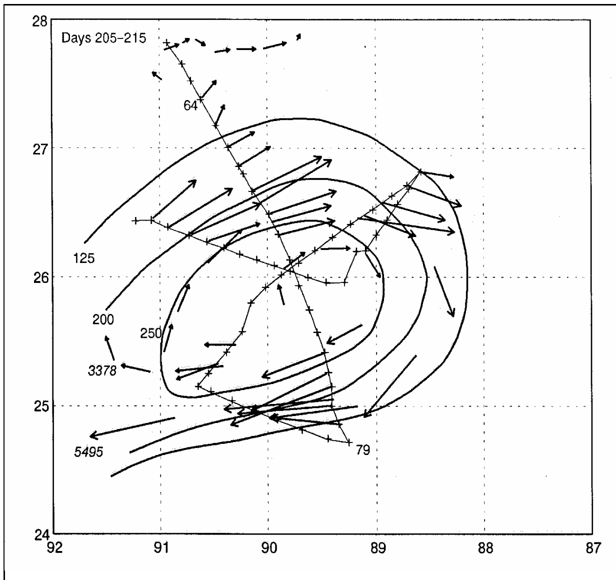


Figure 14. XBT lines, depth (m) of 20°C isotherm and current vectors

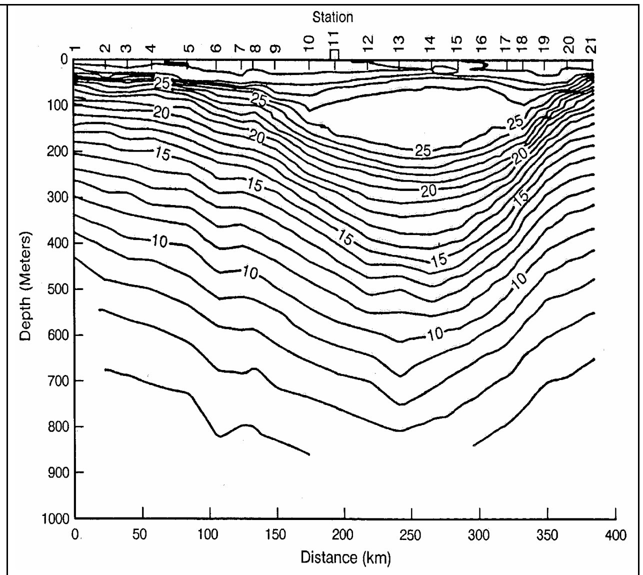


Figure 15. Temperature section for along NW to SE line in previous figure.

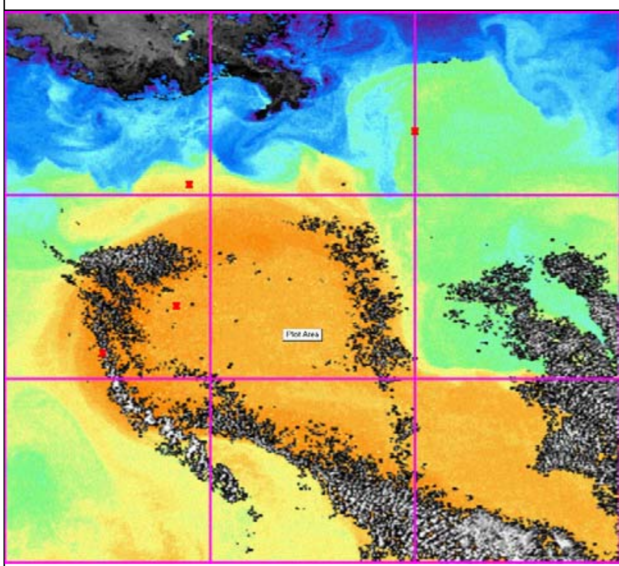

Figure 16. Situation upon rig arrival.

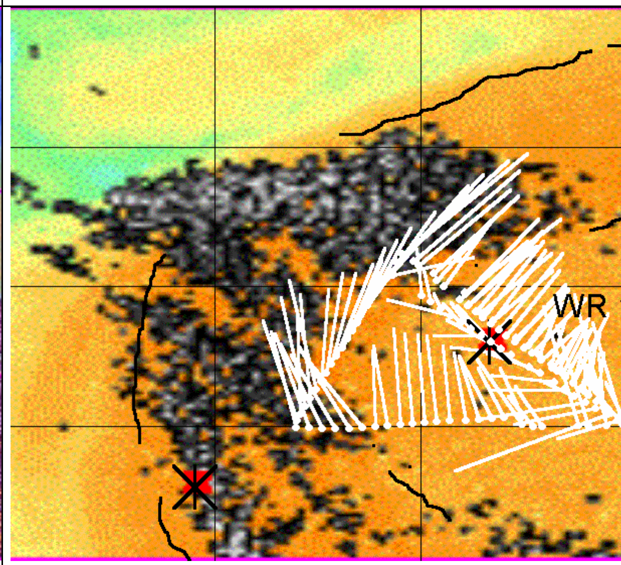


Figure 17. Detailed survey results.

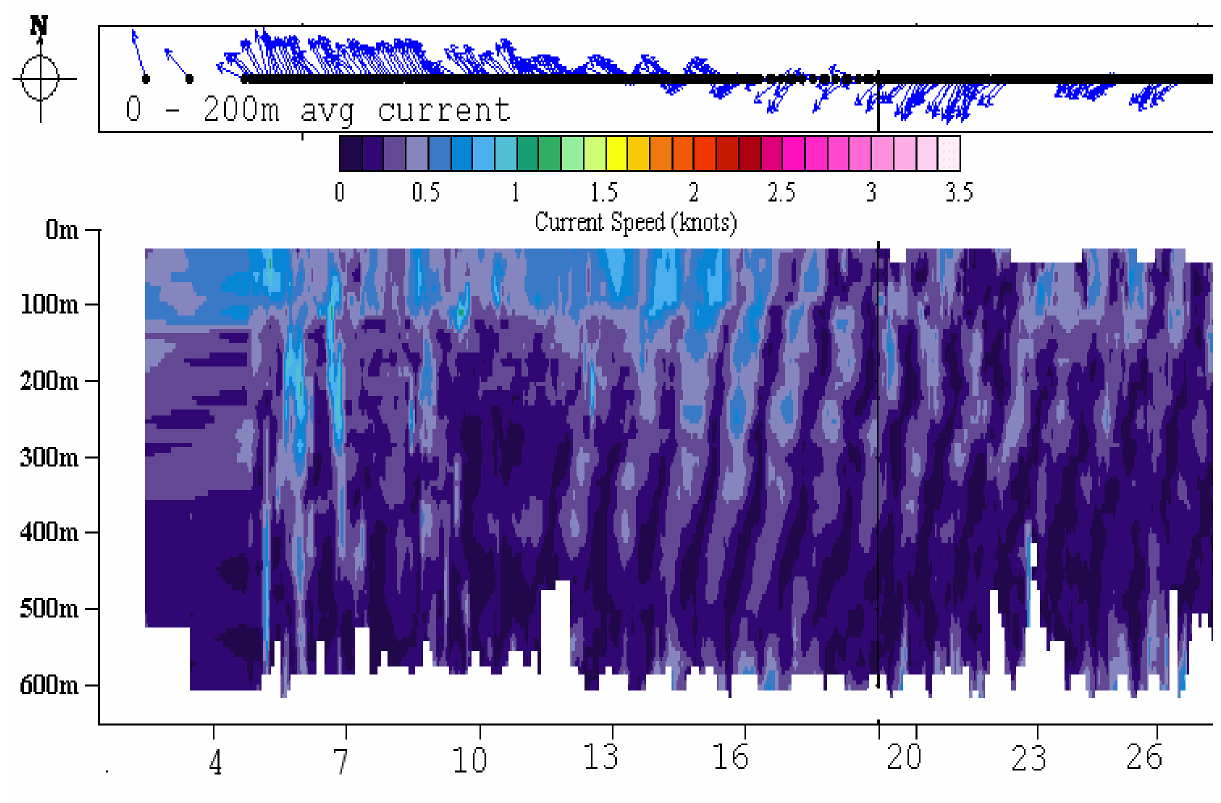


Figure 18. Currents by day during passage of a small eddy.

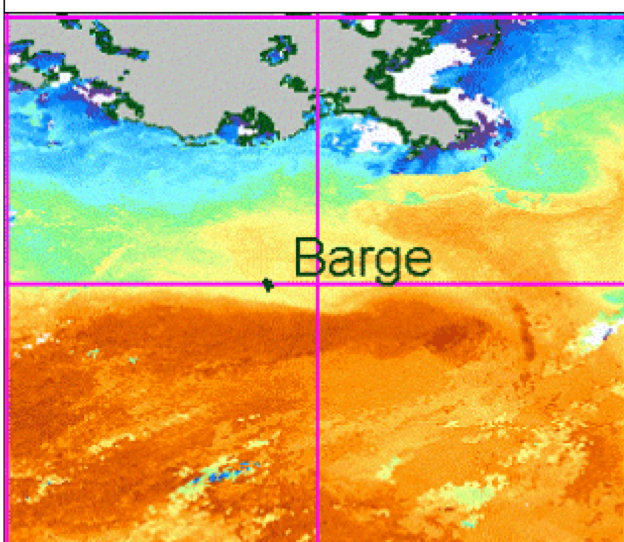


Figure 19. Situation on day 1, Spring 2001.

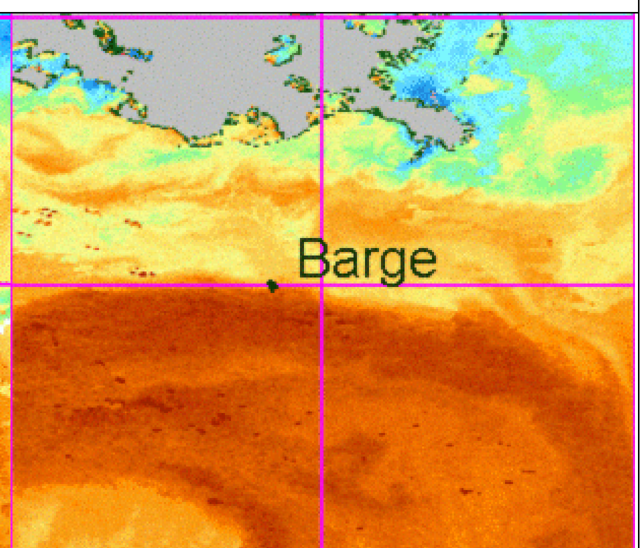


Figure 20. Situation on Day 3

Return to Session Directory



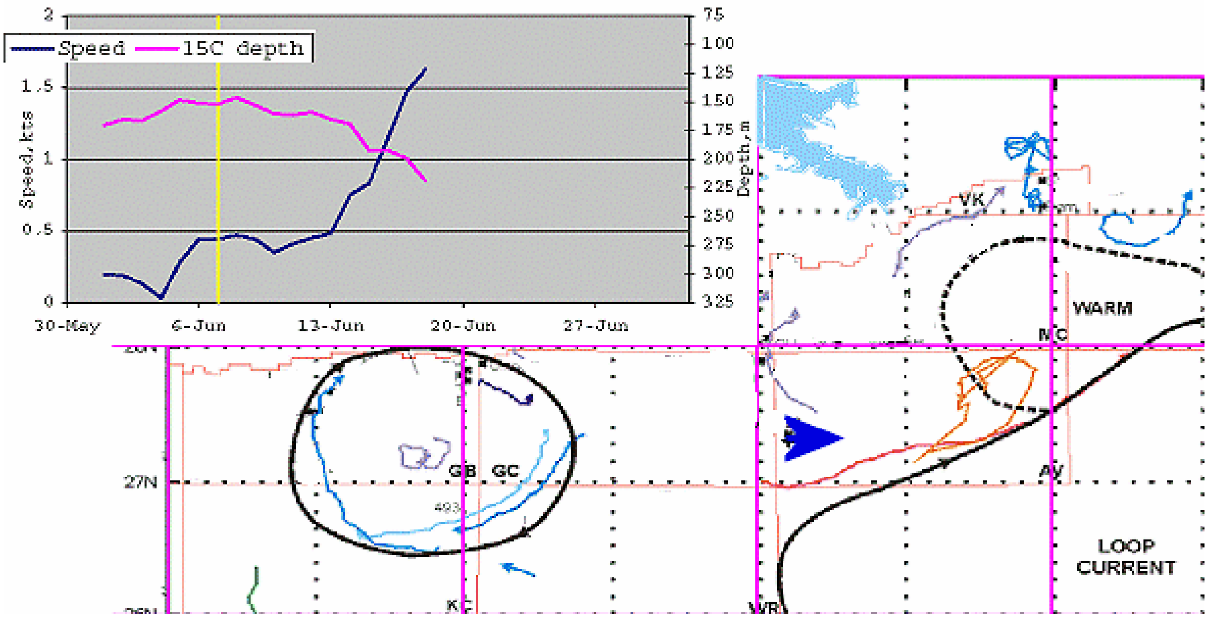


Figure 21. Oceanographic situation on June 7th. Current 0.4 kt bearing 75 degrees. Depth of 15°C isotherm: 152m. Plot shows depth of 15°C isotherm and speed from CU hindcast.

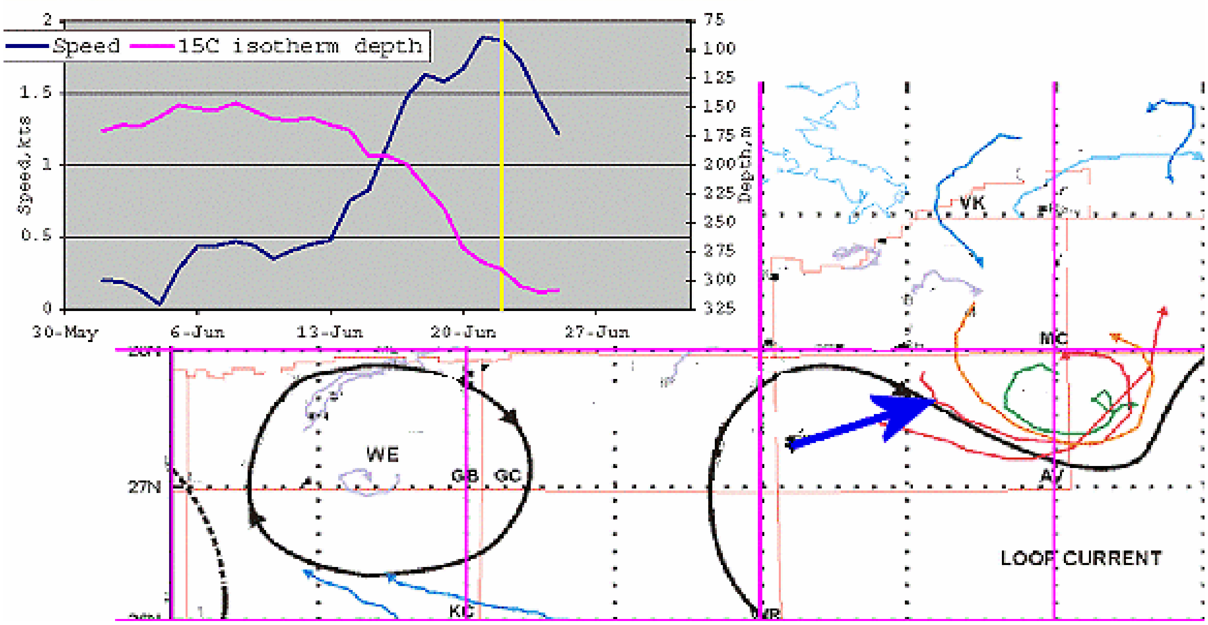


Figure 22. Oceanographic situation on June 22. Currents: 1.8 kts. Bearing 71 degrees. Depth of 15°C isotherm: 290m. Plot shows depth of 15°C isotherm and speed from CU hindcast.