The Physical Oceanographic Environment Impacting Northern Gulf of Mexico Deepwater Coral Communities

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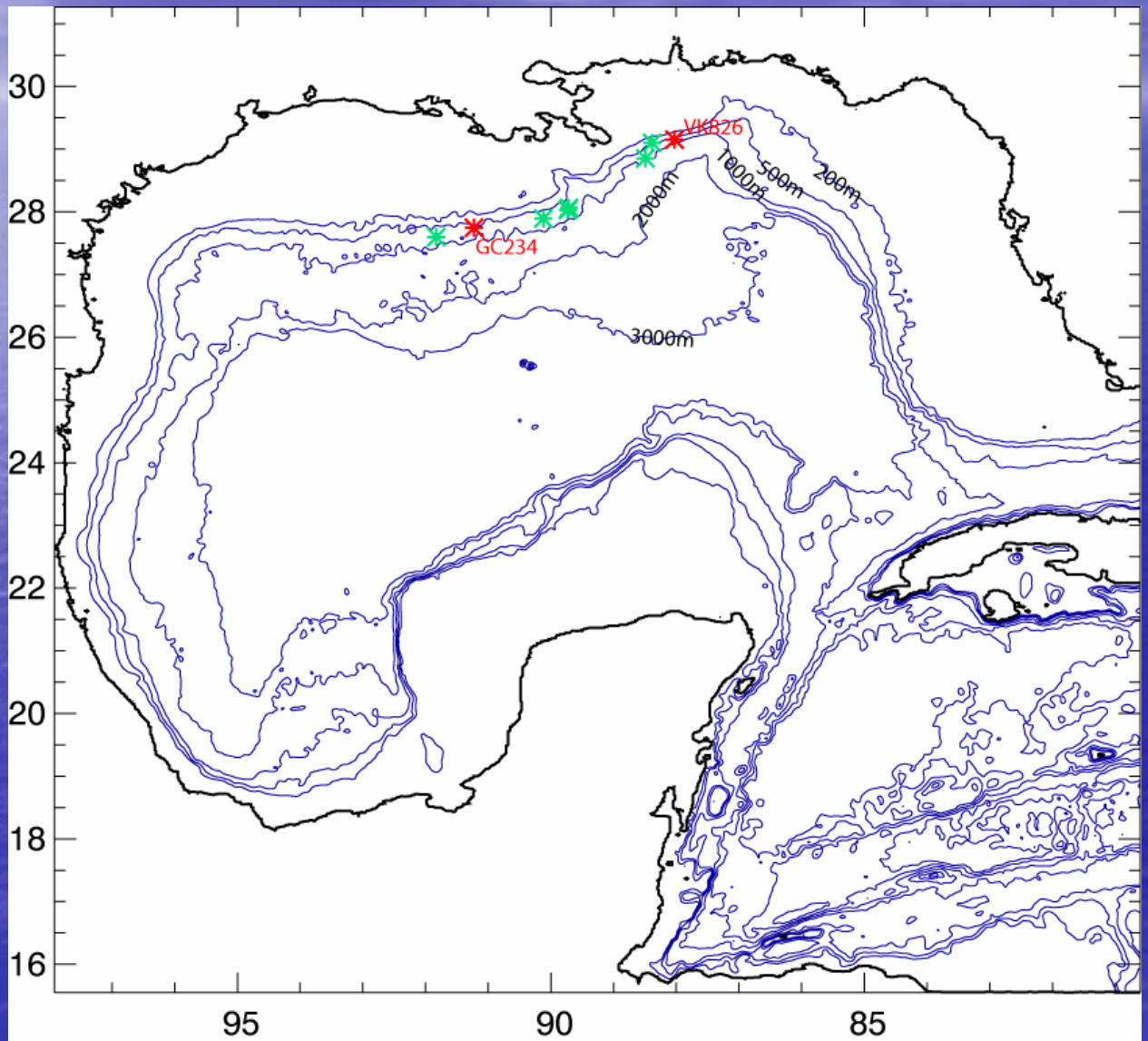
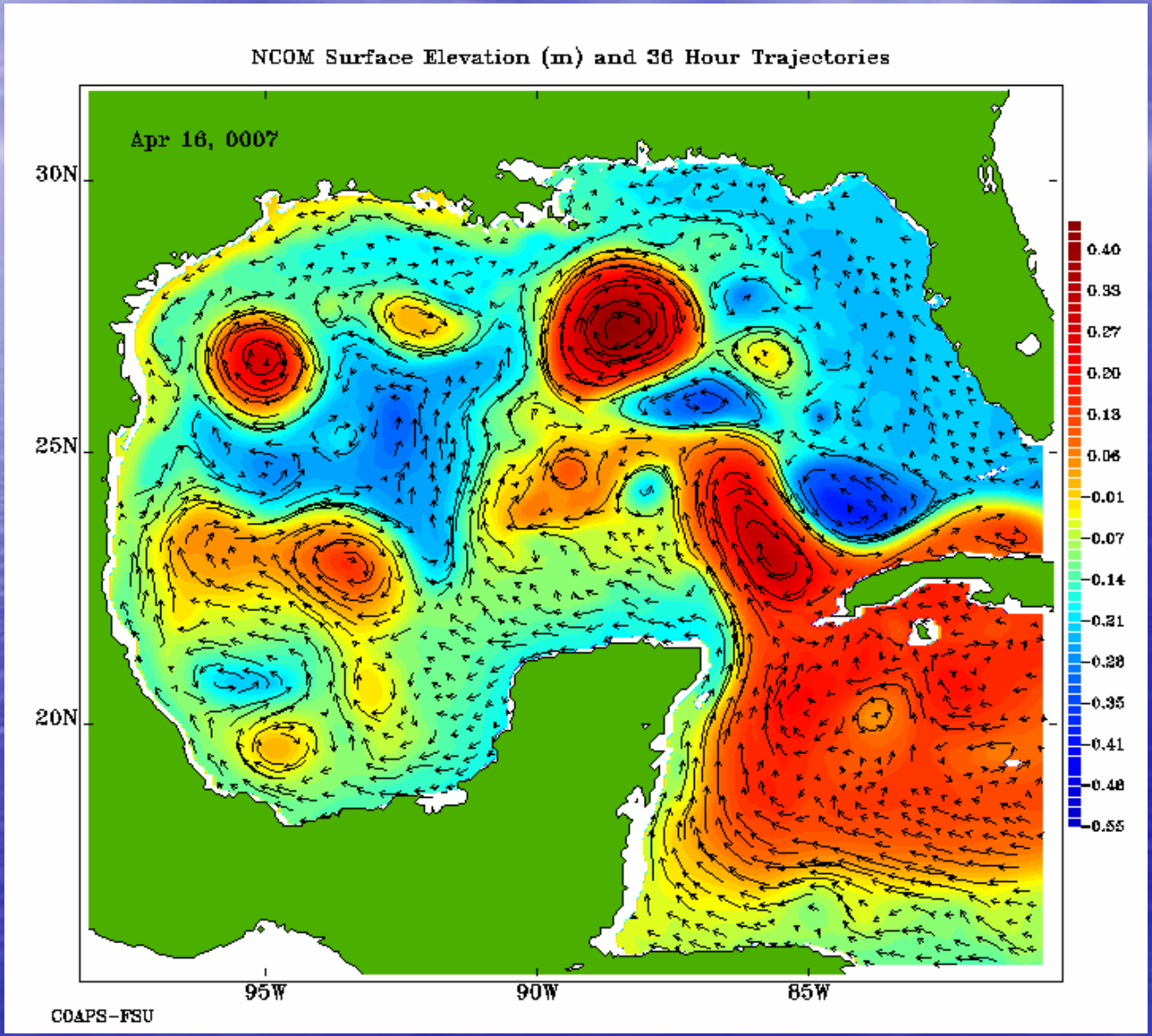
Goals

- Understand the variability of currents and water properties near the deepwater coral habitats.
- Determine likely patterns for dispersal of larvae.
- Explore physical mechanisms for supplying organic material to the benthic food webs.
- Determine the variability of the bottom boundary layer and shear stresses that can impact the fragile branched coral and can remove sediments from the hard substrate so organisms might attach.

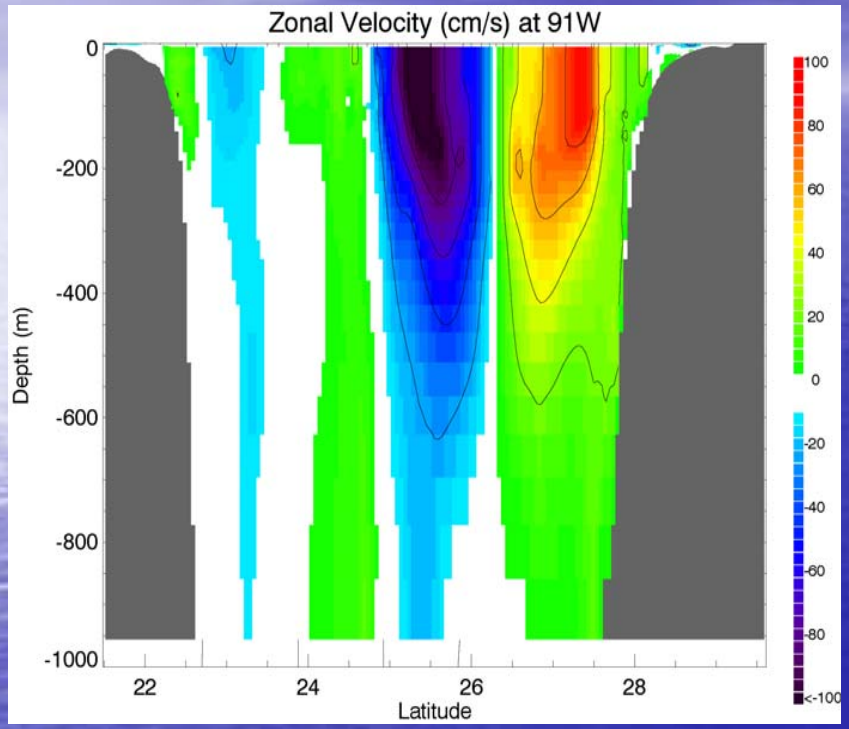
Deepwater hard-bottom communities in the Northern Gulf of Mexico are distributed within a depth range that covers the steep slope offshore of the continental shelf.

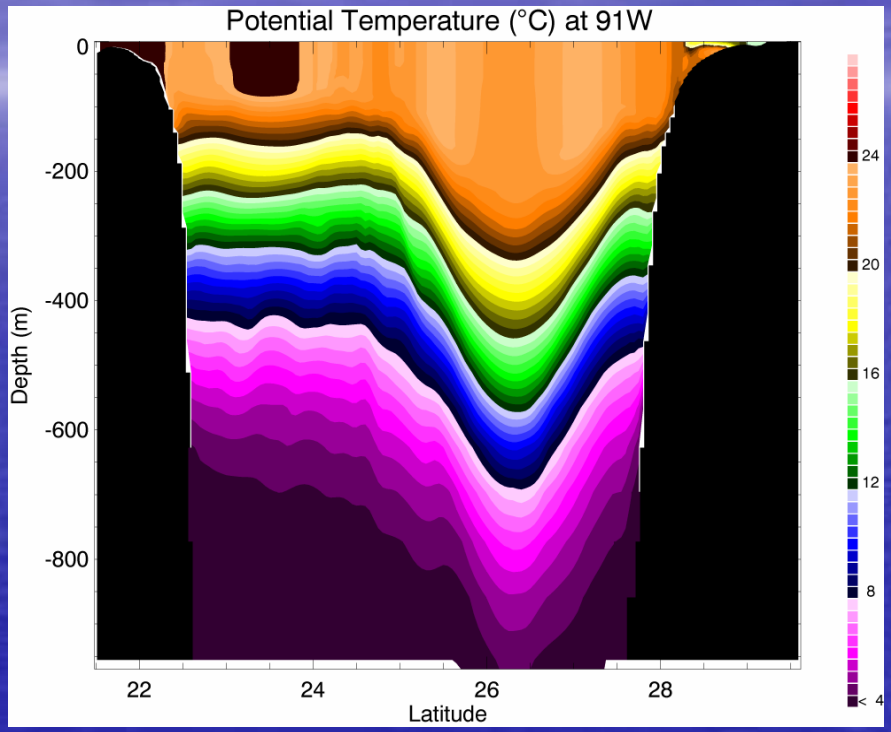


Gulf of Mexico Circulation

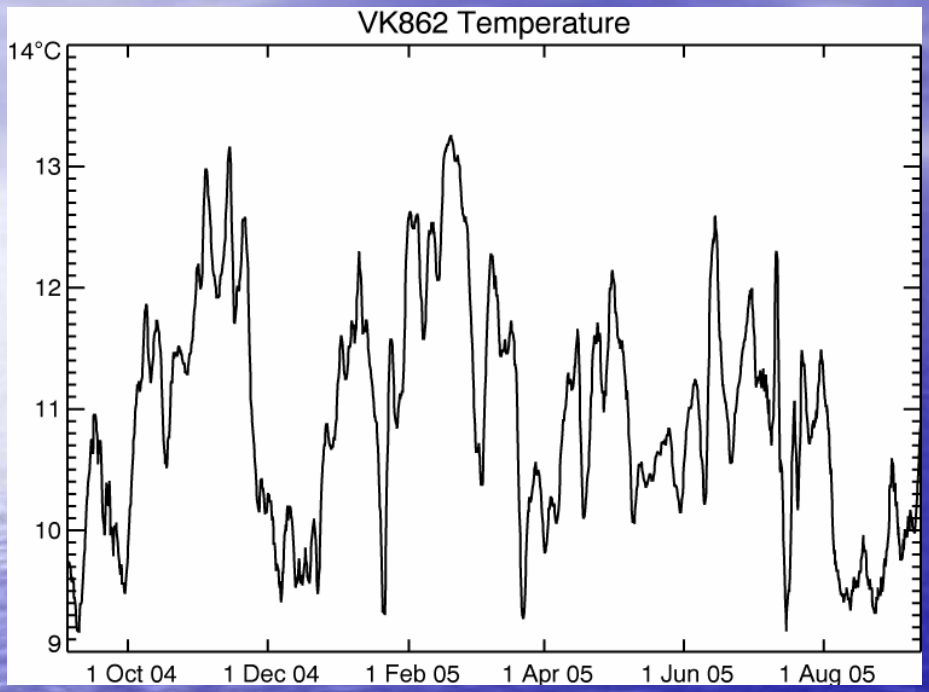


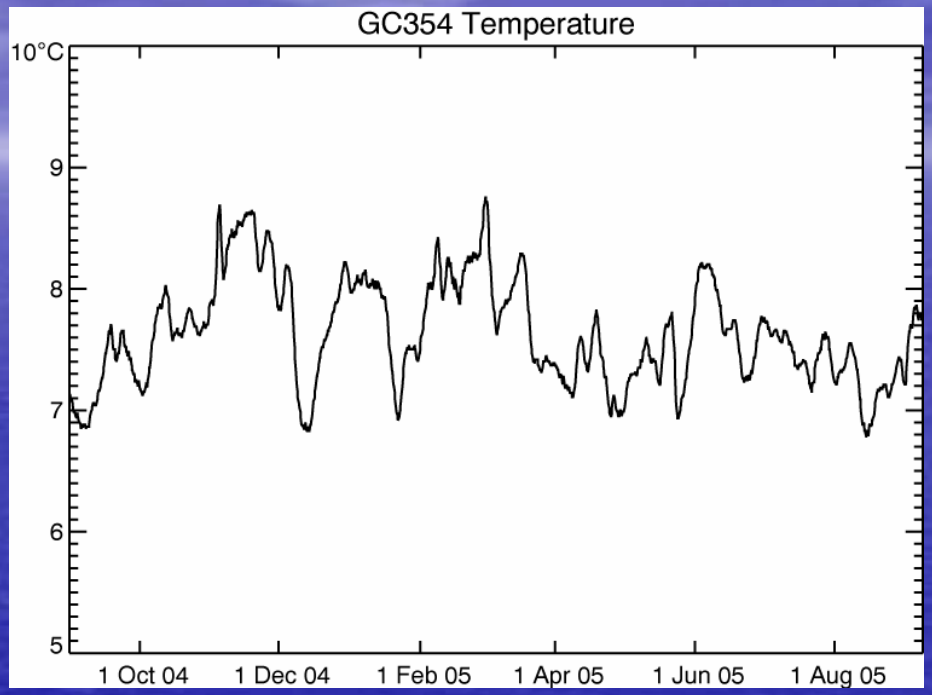
Loop Current Eddy Profile





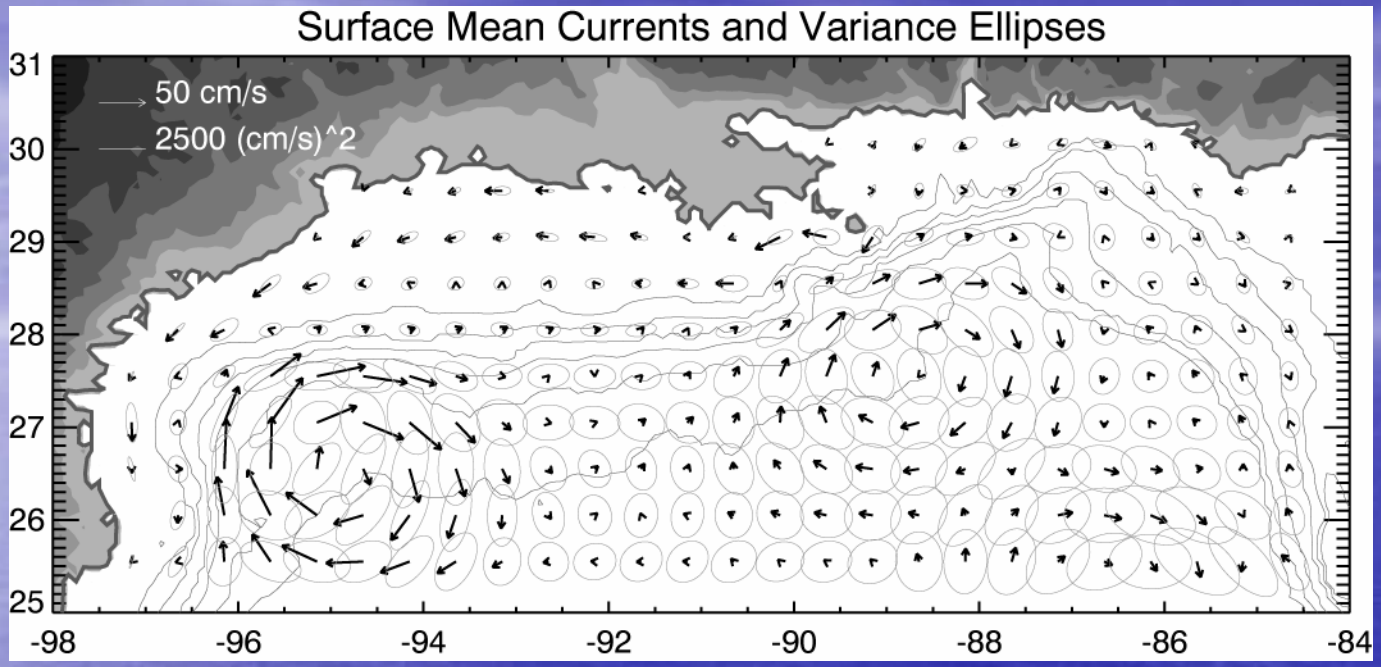
Temperature Variability

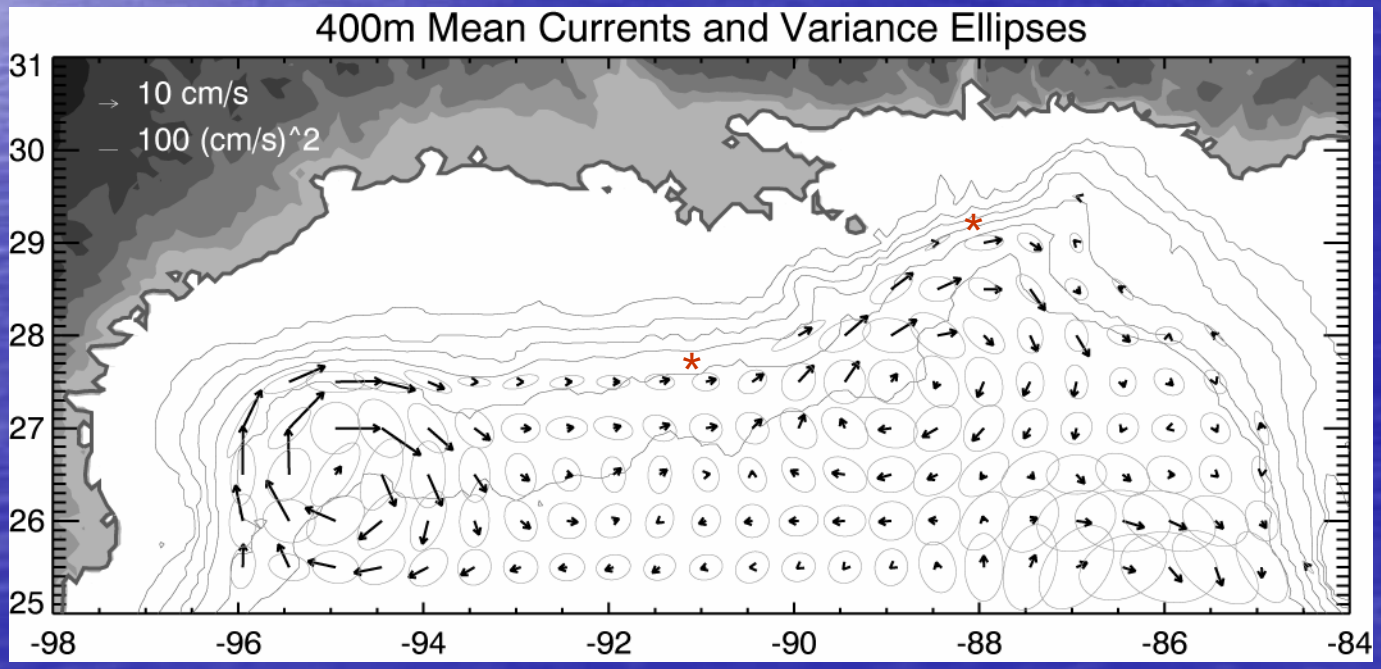




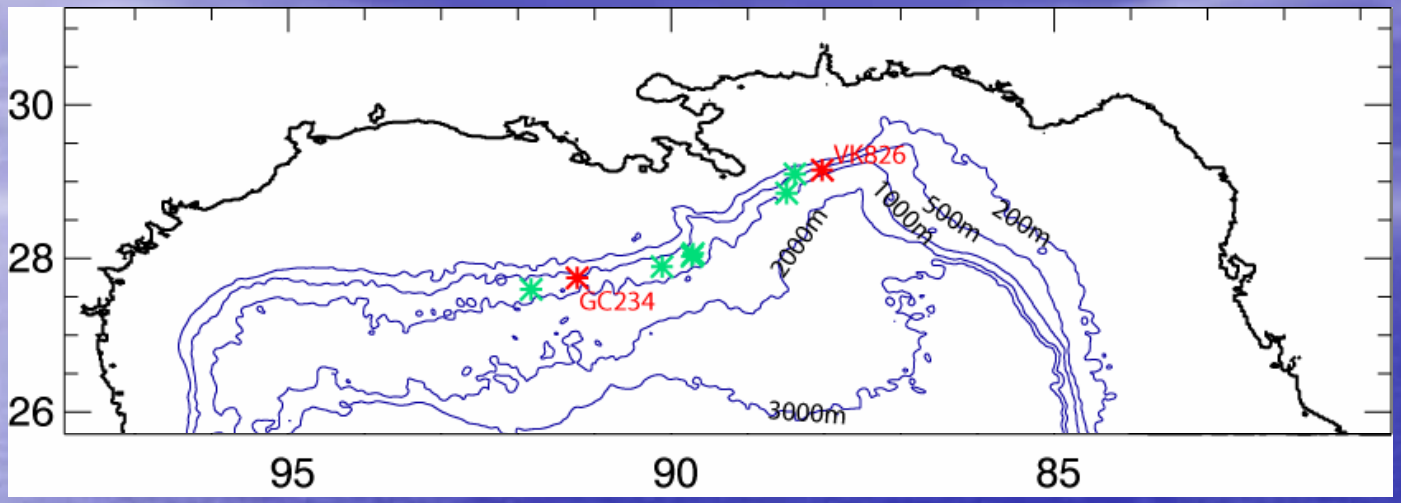
Temperature time series collected at VK862 (316m) and GC354 (538m)

Variability is due to thermocline fluctuations—greater variability at the shallower site.

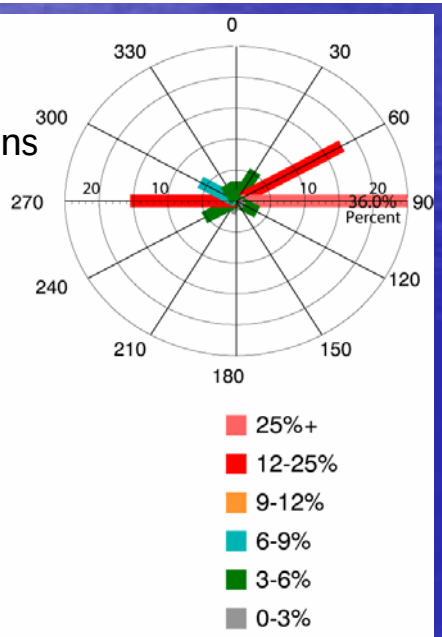

Surface Mean Currents and Variance Ellipses
50 cm/s
2500 (cm/s)^2
31
30
29
28
27
26
25
-98
-96
-94
-92
-90
-88
-86
-84


400m Mean Currents and Variance Ellipses
10 cm/s
100 (cm/s)^2
31
30
29
28
27
26
25
-98
-96
-94
-92
-90
-88
-86
-84

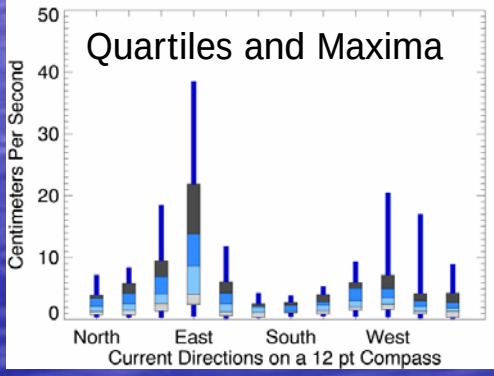
Variability of Modeled Currents



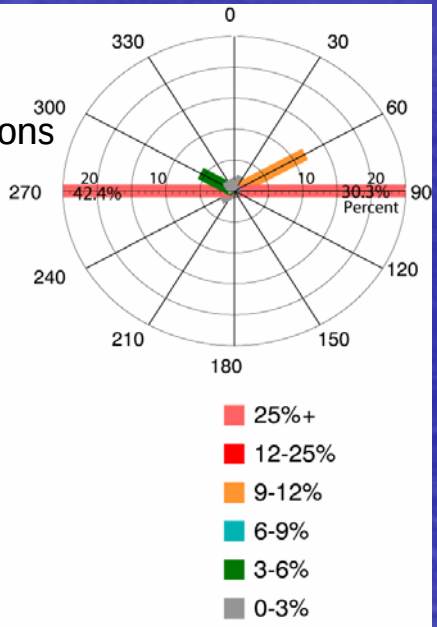
GC234 Simulated currents
Speed and direction distributions



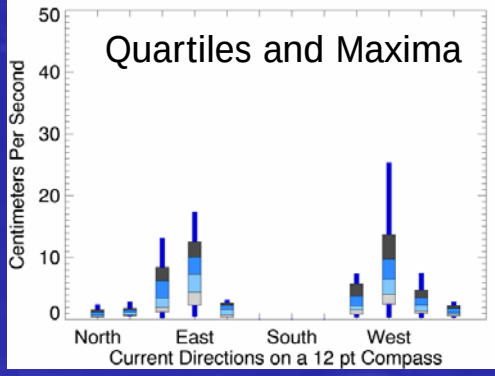
Quartiles and Maxima



VK826 Simulated currents
Speed and direction distributions



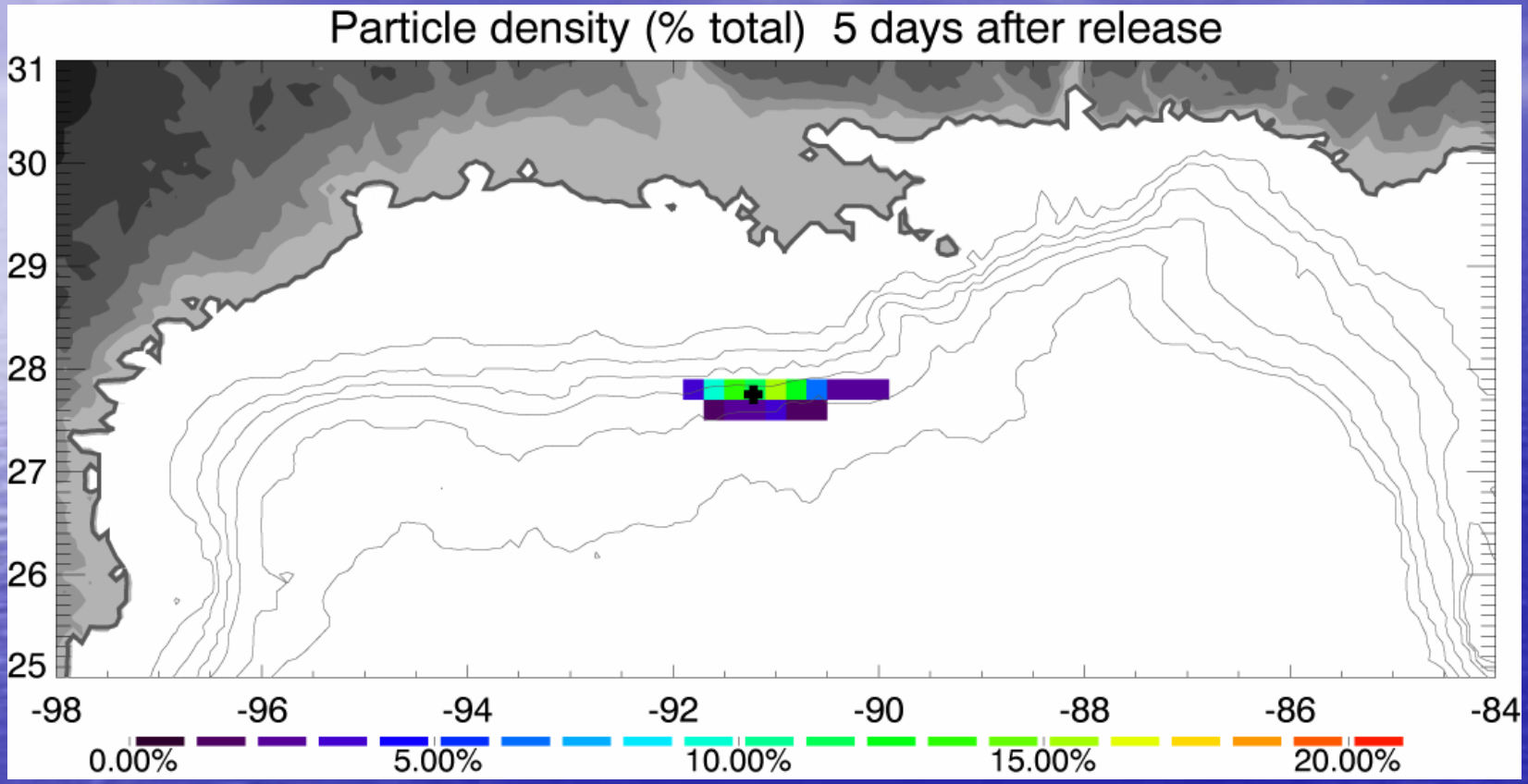
Quartiles and Maxima

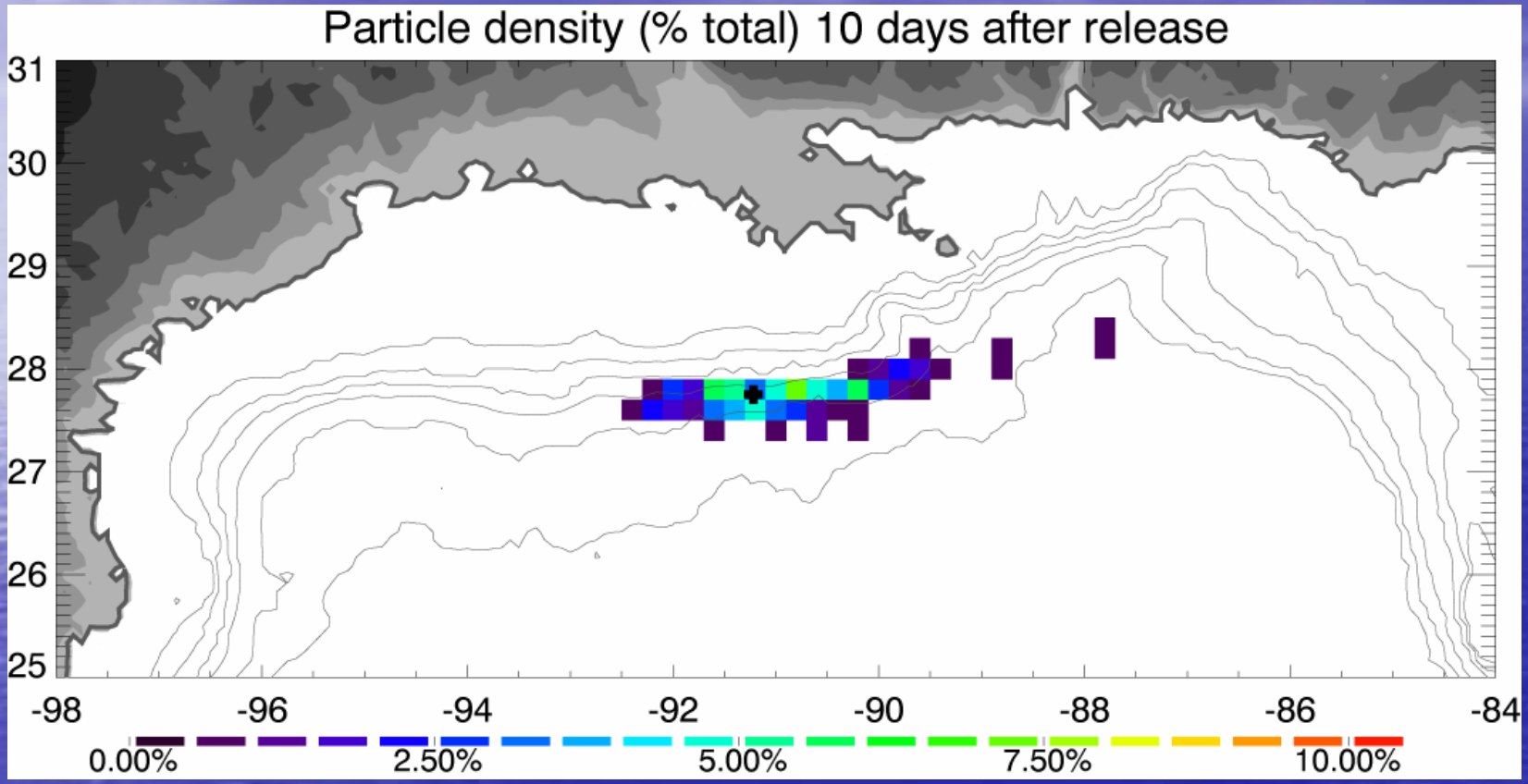


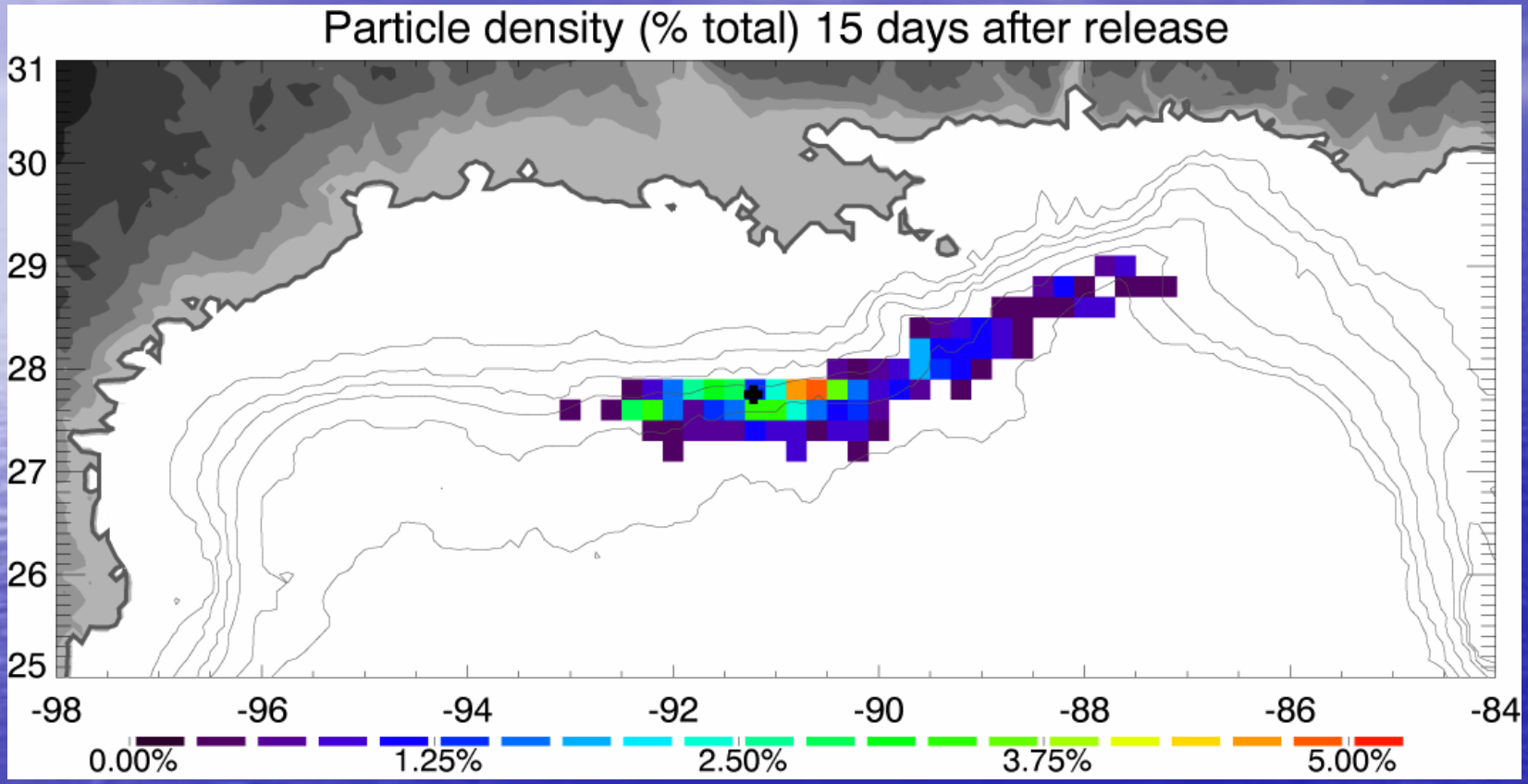
Simulated Advection of Larvae

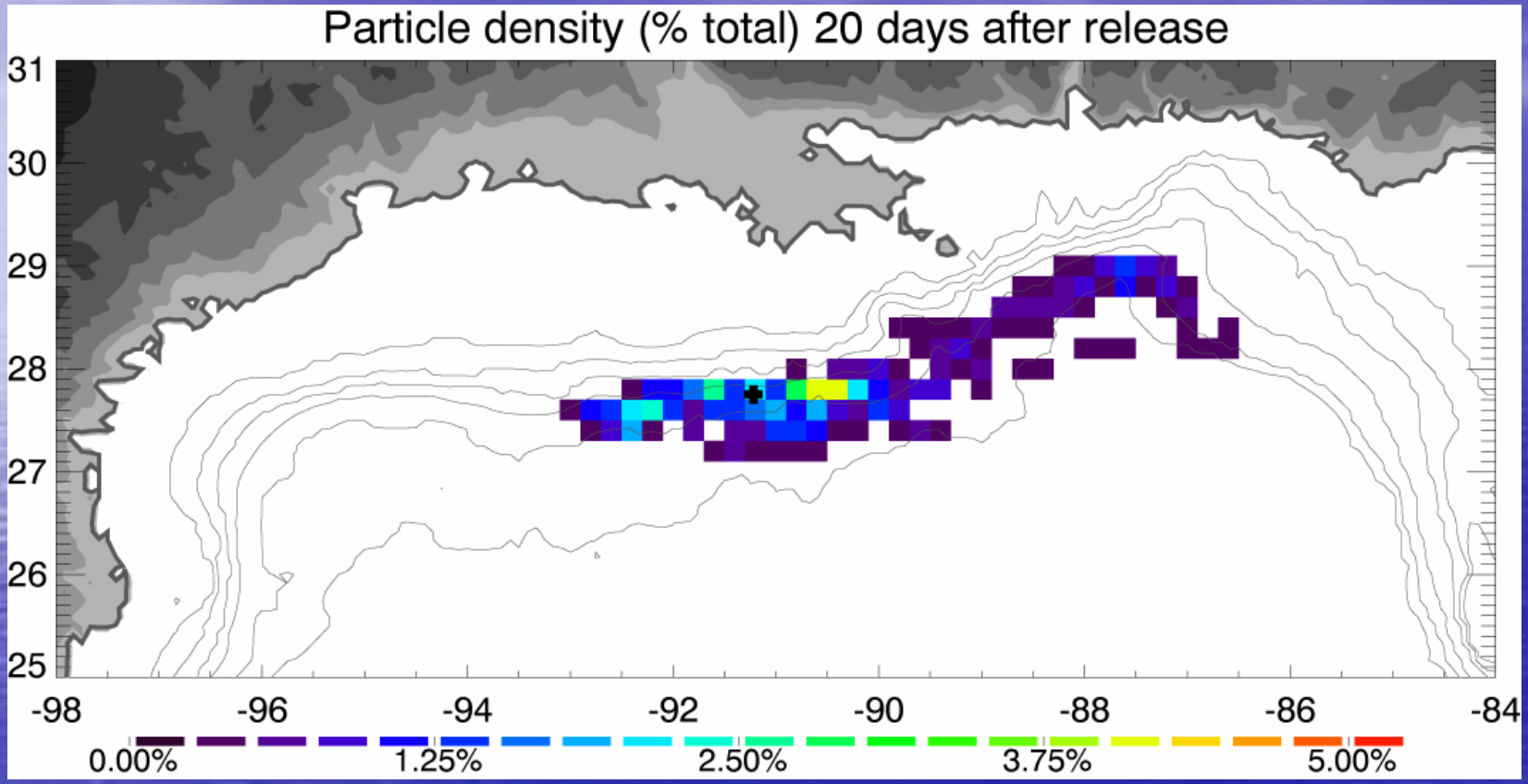
- Particles are passively advected in the model horizontal velocity field for 25 days.
- 100 particles are released every 6 hours for 3 days -> 1200 particles per experiment.
- Experiment is repeated each month for 8 years of model data -> 115,200 particles total.
- Results:
  - Dispersion primarily along the shelf slope (along-isobath)
  - Dispersion patterns are biased eastward
  - No obvious seasonal patterns
  - Interannual variability due to presence of Loop Current Eddies

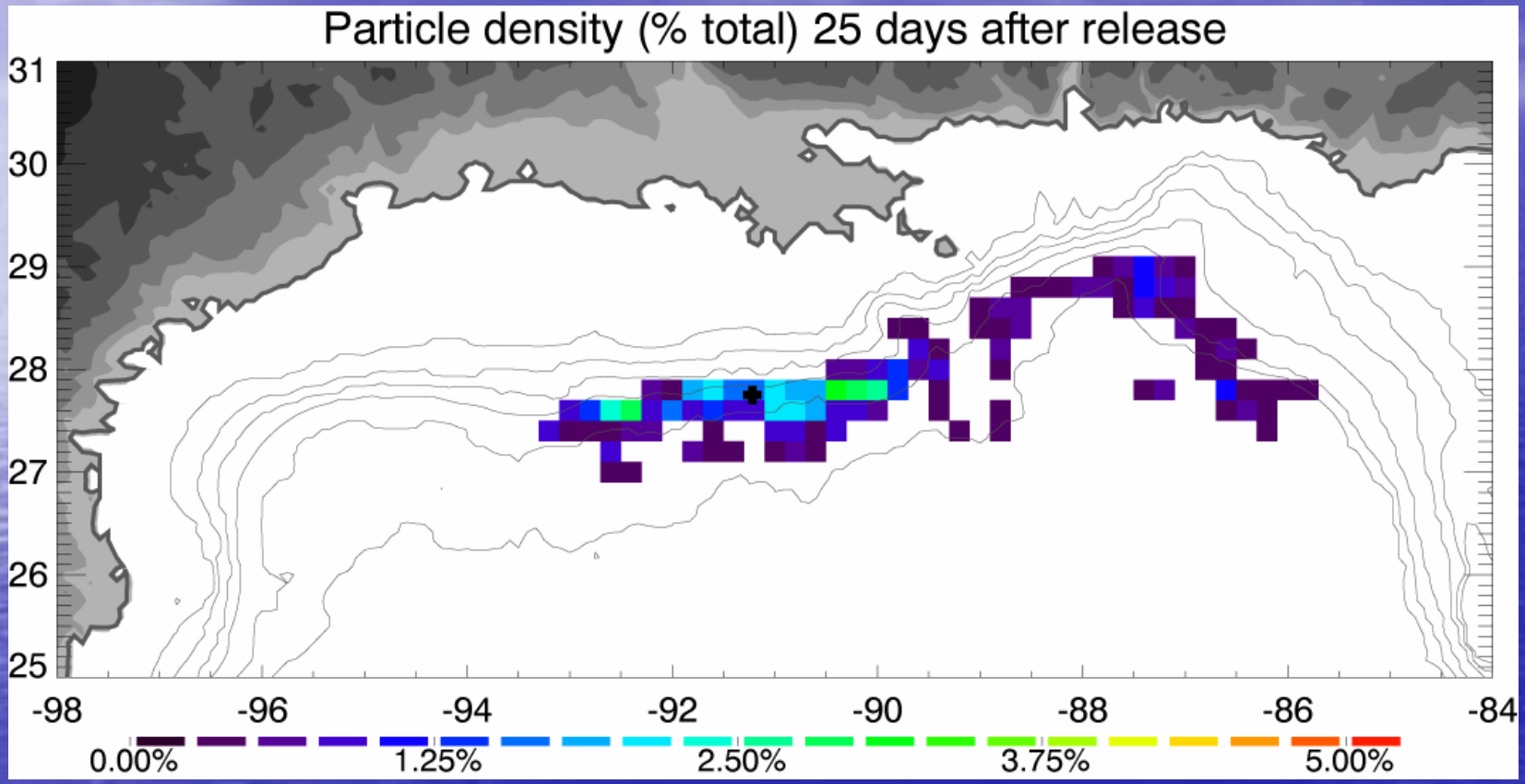
Percentage of 115,200 particles in each 0.5°x0.5° bin following release from GC234 location




Particle density (% total) 10 days after release
31
30
29
28
27
26
25
-98
-96
-94
-92
-90
-88
-86
-84
0.00%
2.50%
5.00%
7.50%
10.00%


Particle density (% total) 15 days after release
31
30
29
28
27
26
25
-98
-96
-94
-92
-90
-88
-86
-84
0.00%
1.25%
2.50%
3.75%
5.00%


Particle density (% total) 20 days after release
31
30
29
28
27
26
25
-98
-96
-94
-92
-90
-88
-86
-84
0.00%
1.25%
2.50%
3.75%
5.00%


Particle density (% total) 25 days after release
31
30
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28
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26
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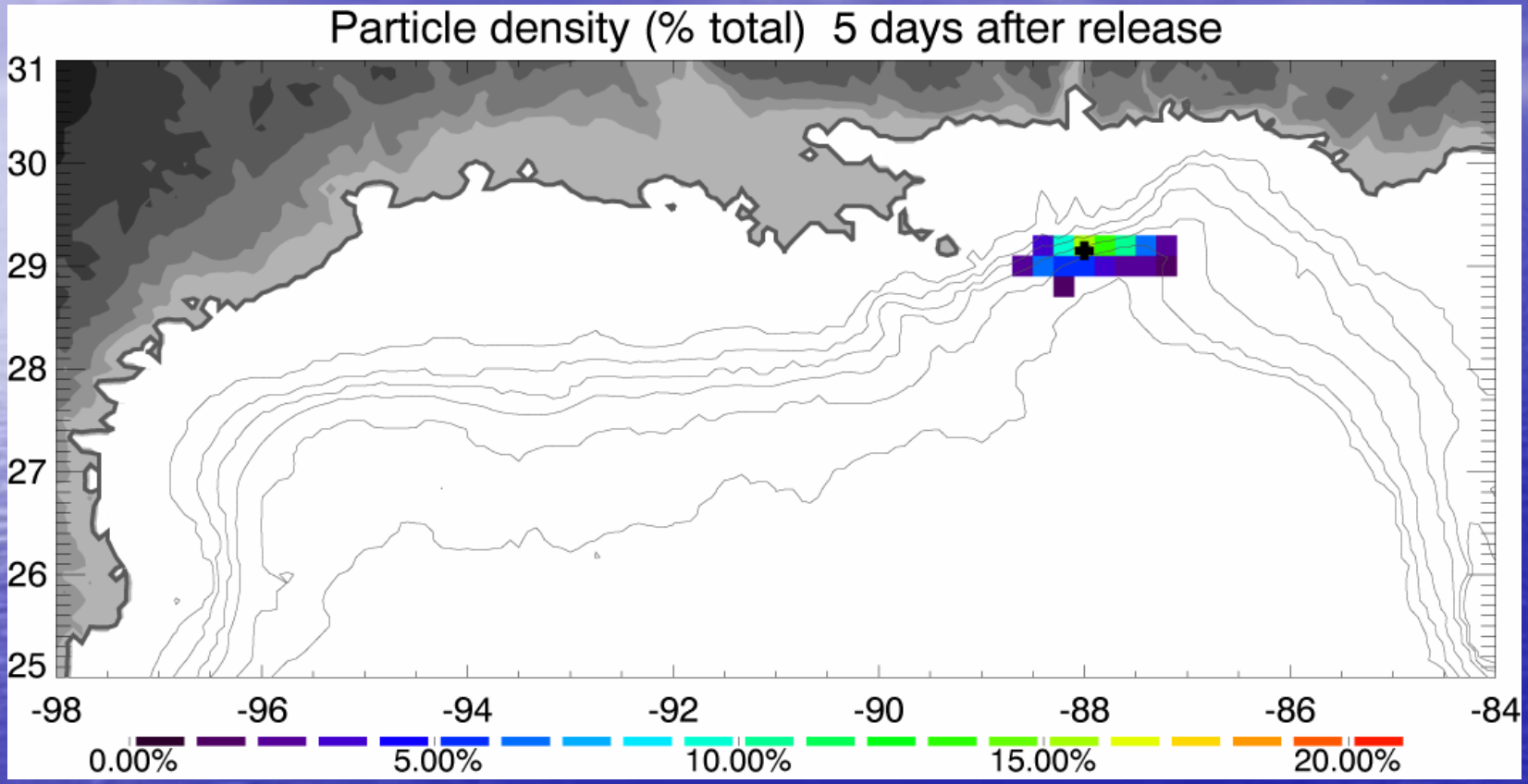
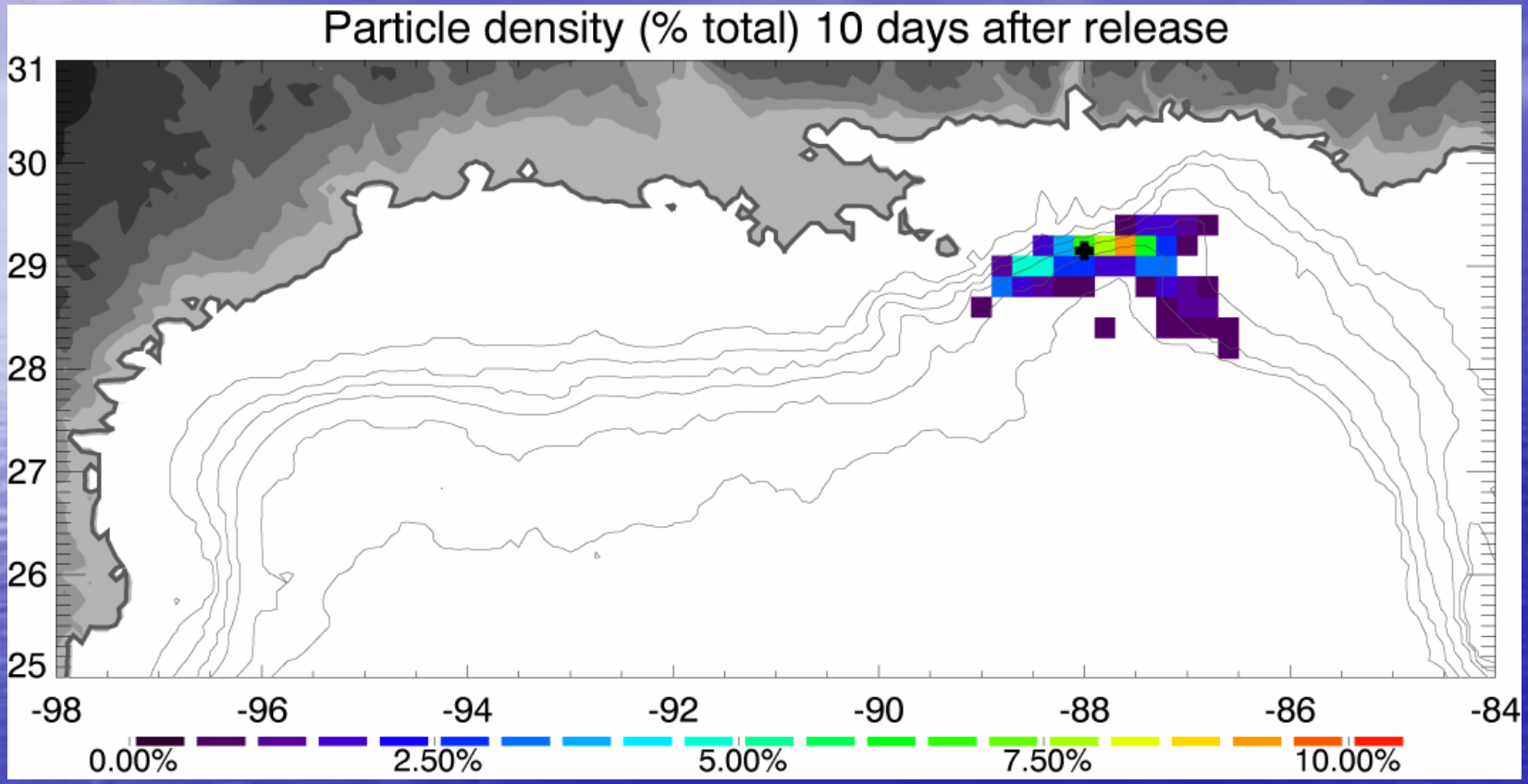
-98
-96
-94
-92
-90
-88
-86
-84
0.00%
1.25%
2.50%
3.75%
5.00%

Percentage of 115,200 particles in each 0.5°x0.5° bin following release from VK826 location




Particle density (% total) 10 days after release
31
30
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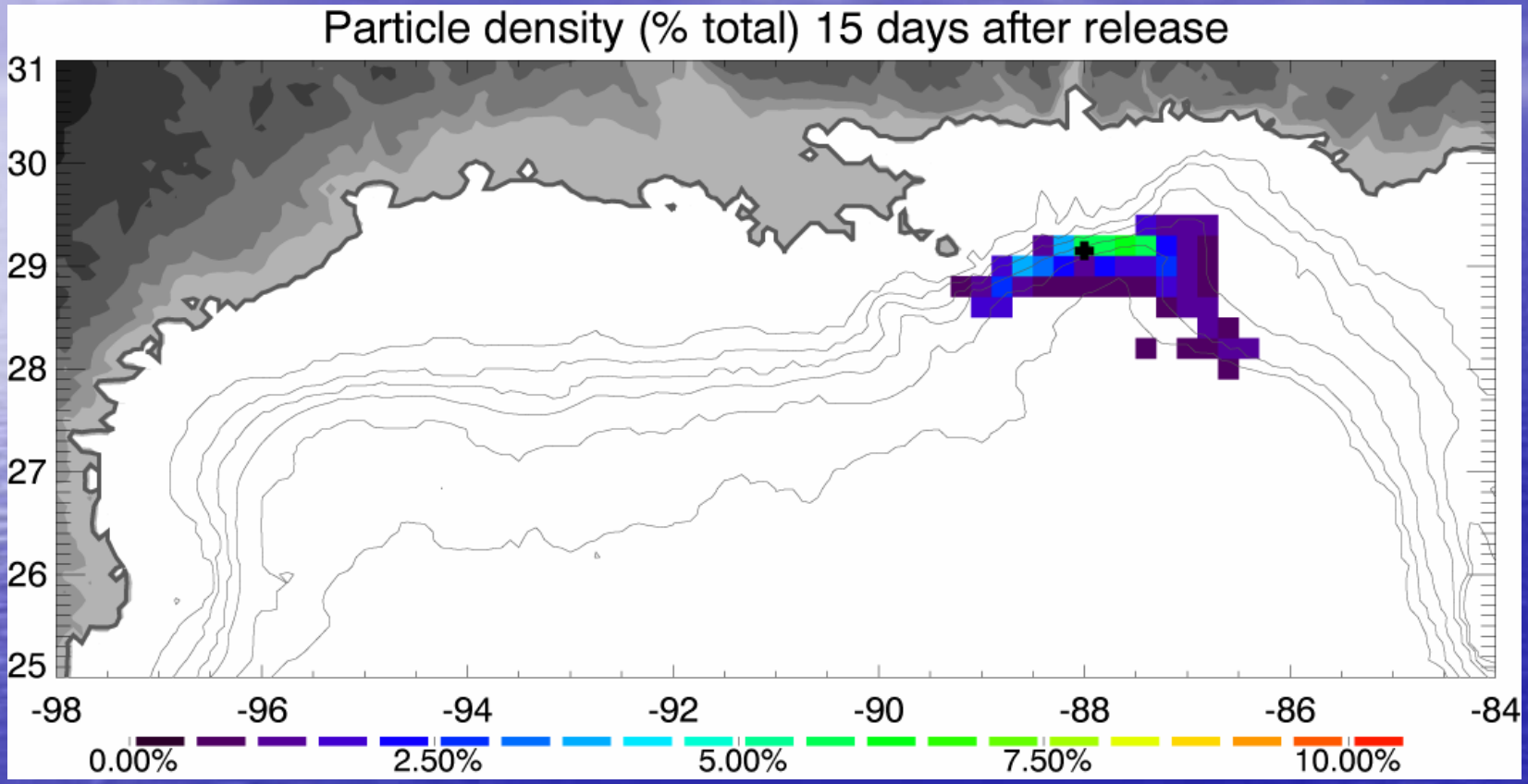
-90
-88
-86
-84
0.00%
2.50%
5.00%
7.50%
10.00%


Particle density (% total) 15 days after release
31
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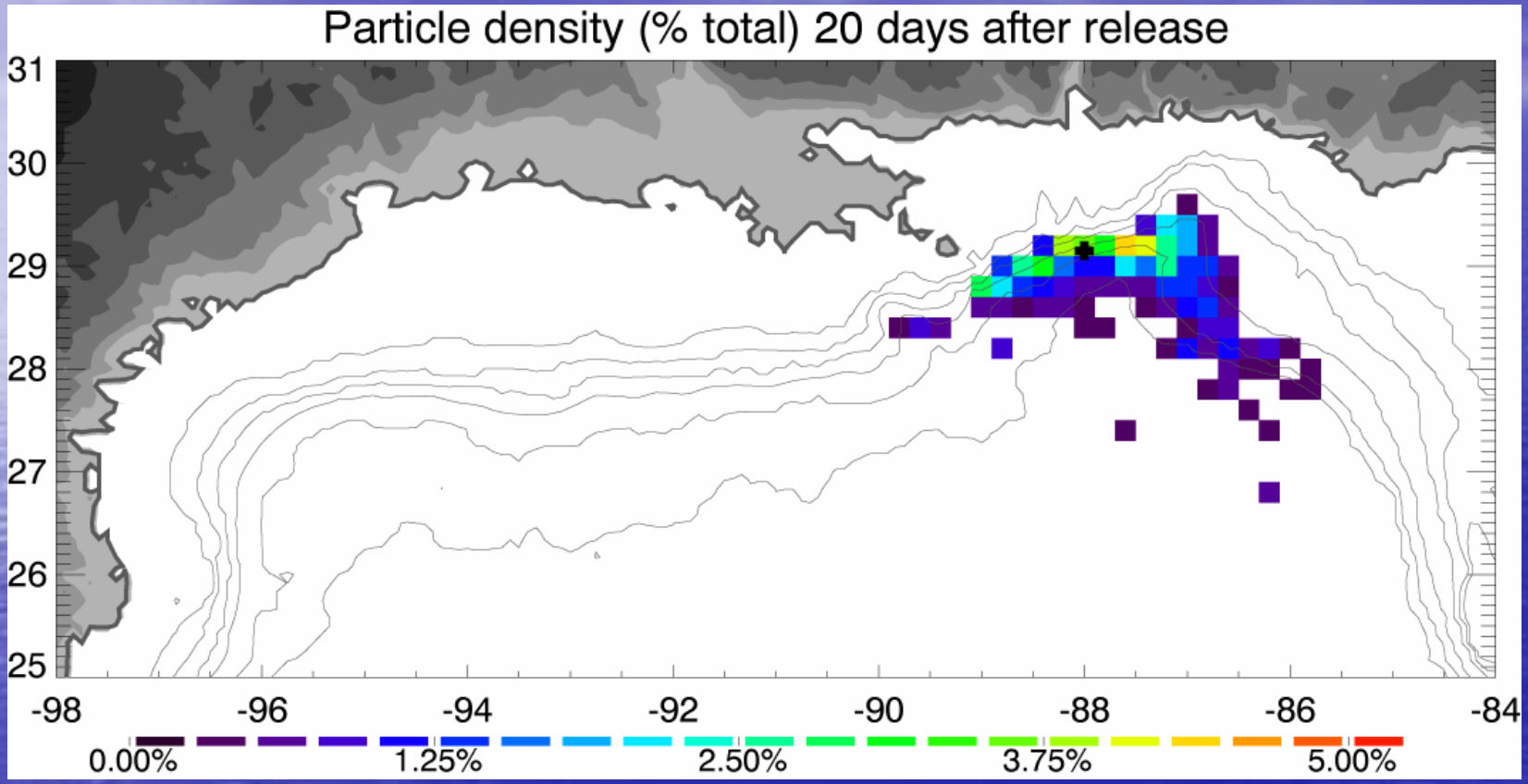
-90
-88
-86
-84
0.00%
2.50%
5.00%
7.50%
10.00%


Particle density (% total) 20 days after release
31
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29
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26
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-96
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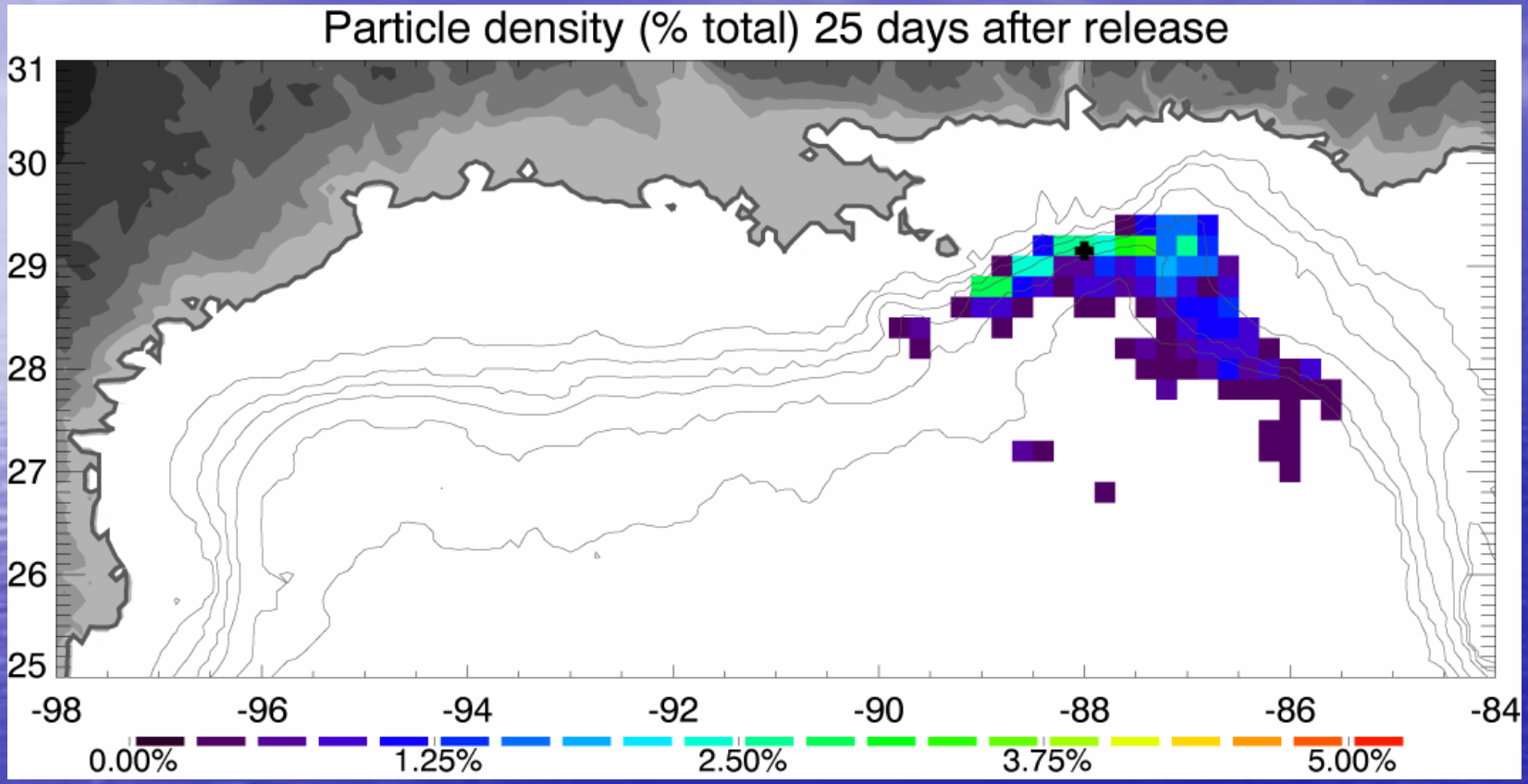
-92
-90
-88
-86
-84
0.00%
1.25%
2.50%
3.75%
5.00%


Particle density (% total) 25 days after release
31
30
29
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-98
-96
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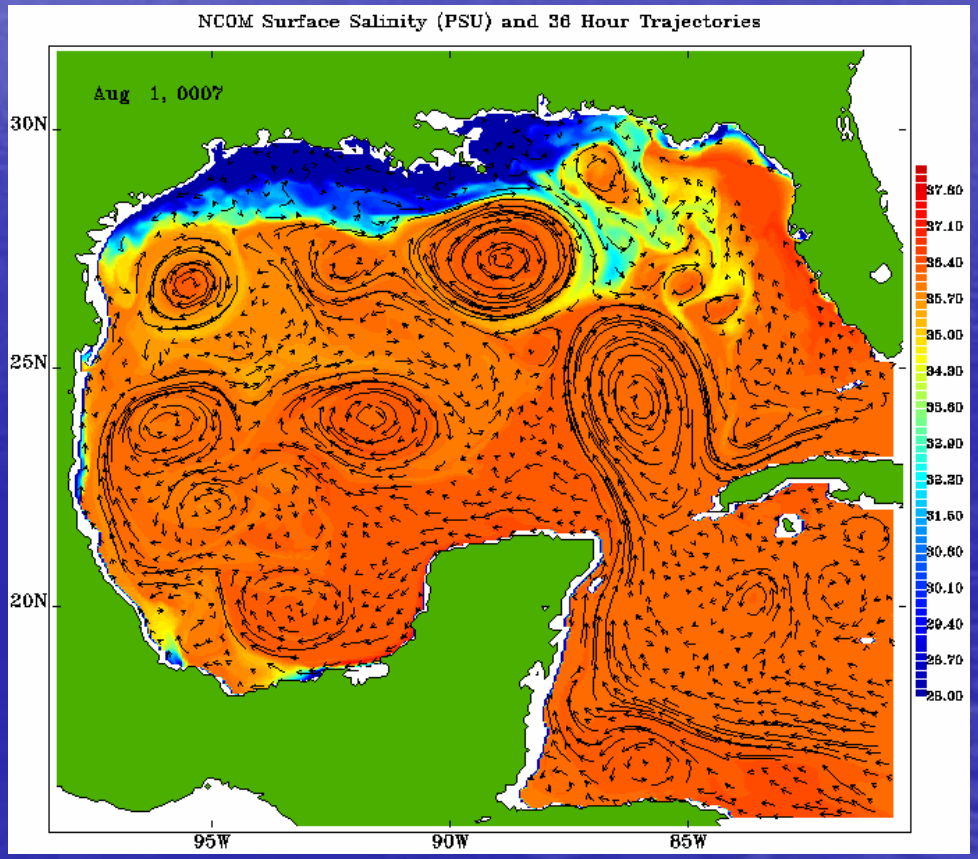
-92
-90
-88
-86
-84
0.00%
1.25%
2.50%
3.75%
5.00%

Seasonal Variability of Near-Surface Biological Properties

Previous studies (Morey et al. 2003a, Morey et al. 2003b) have shown that transport pathways for Mississippi River water have a distinct seasonal signal.

In fall and winter, Mississippi discharged water is transported westward in a coastally trapped current.

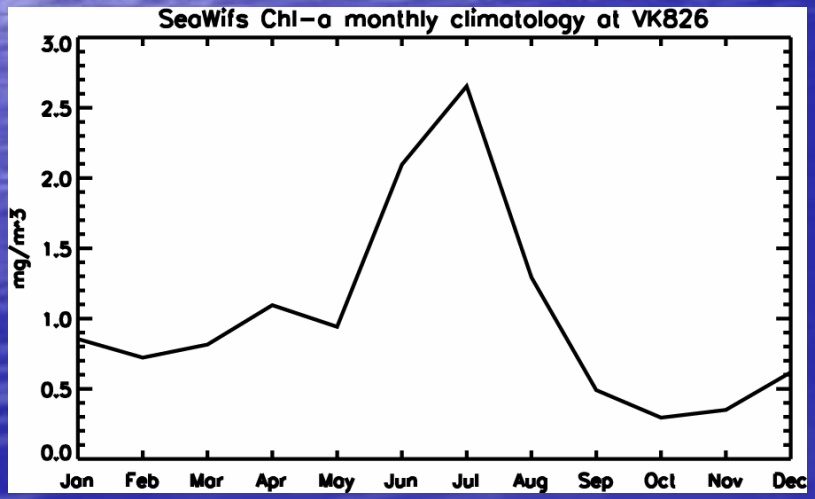
In summer, it can be entrained in Loop Current and Eddy circulations in the eastern Gulf of Mexico.

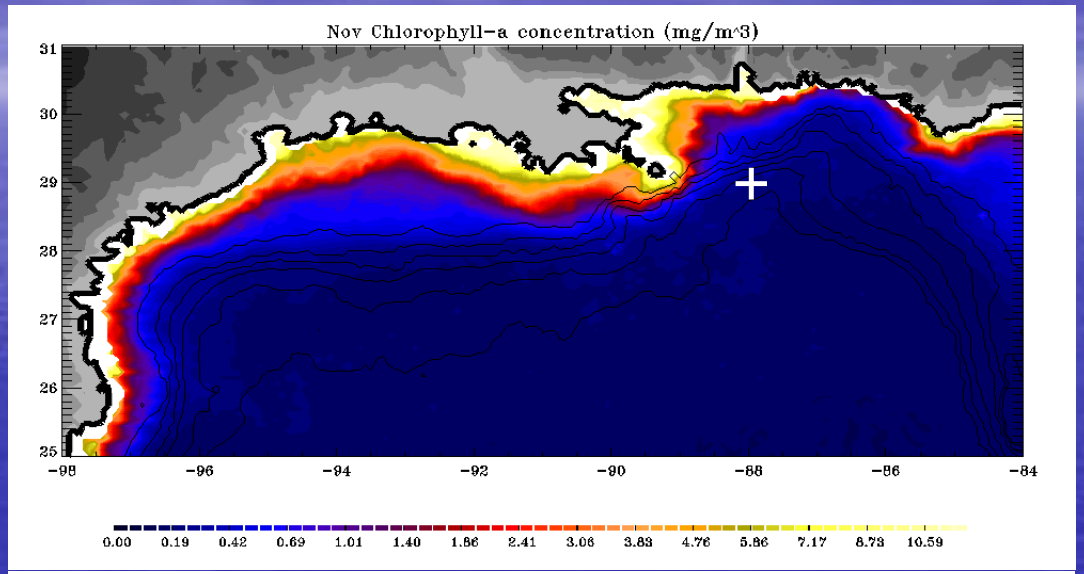


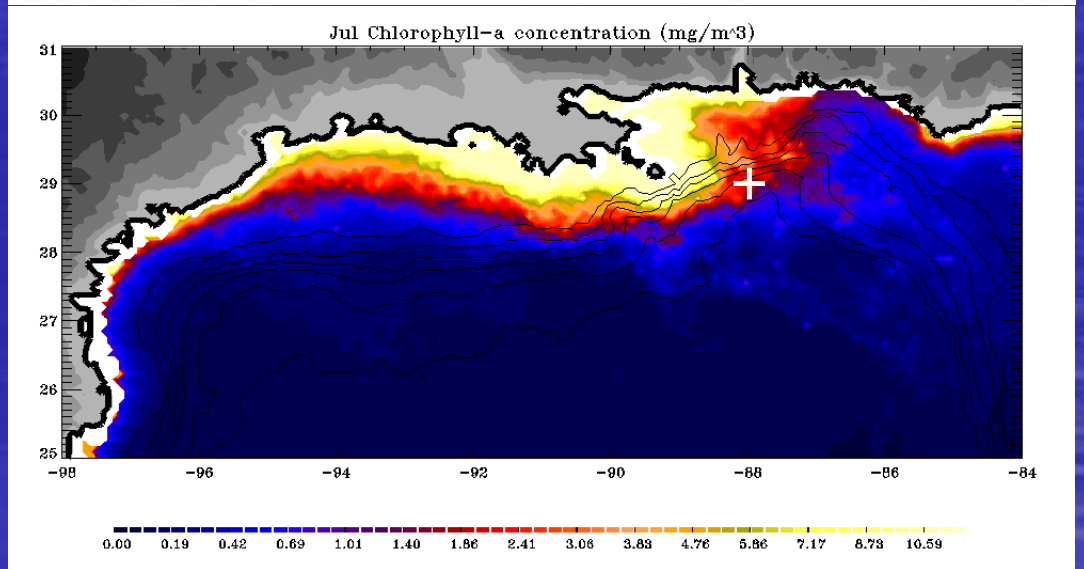
Seasonal Variability of Near-Surface Biological Properties

Riverine-influenced water will have enhanced nutrient concentrations leading to enhanced productivity.

A distinct seasonal cycle can be seen at the VK826 location from SeaWiFS satellite ocean color data.







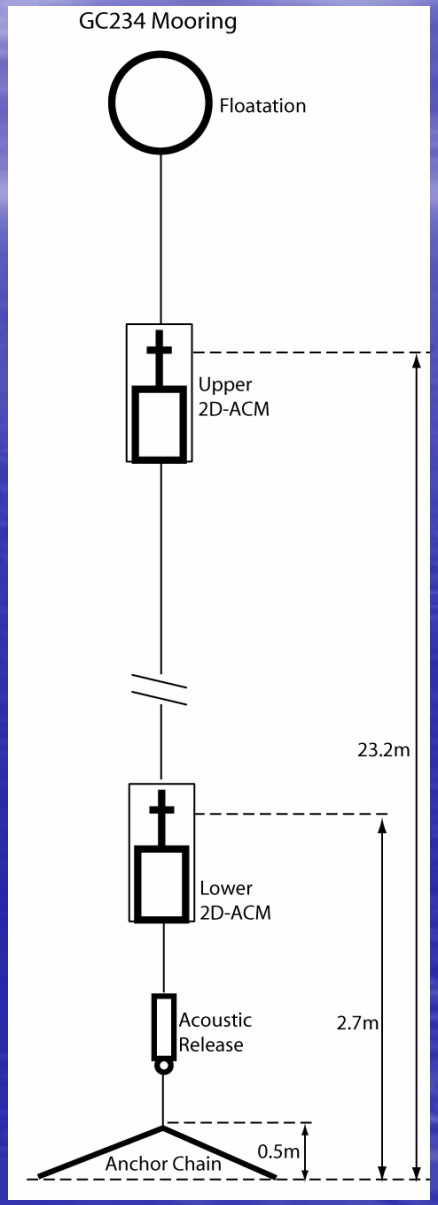
Current Meter Moorings

Current meters moorings were deployed at VK826 and GC234 during the July 2004 SJII cruise.

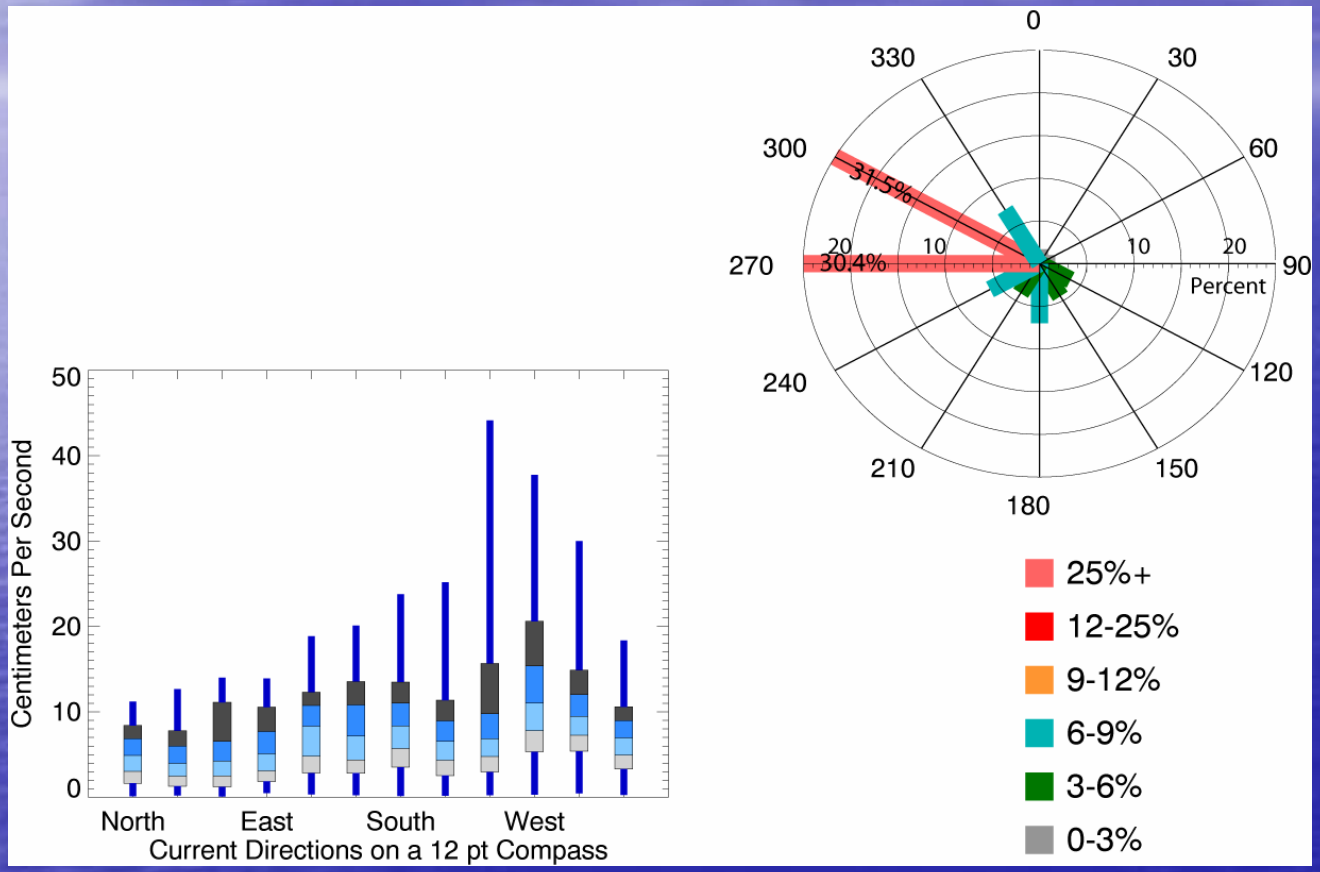
(Limited data from VK826 due to instrument failure)

The instrument 2.7m above the sea floor at GC234 returned approximately nine months of velocity measurements (20-minute sampling frequency). The Upper (23.2m) current meter recorded 45 days of data.

FSI 2D-ACM in housing

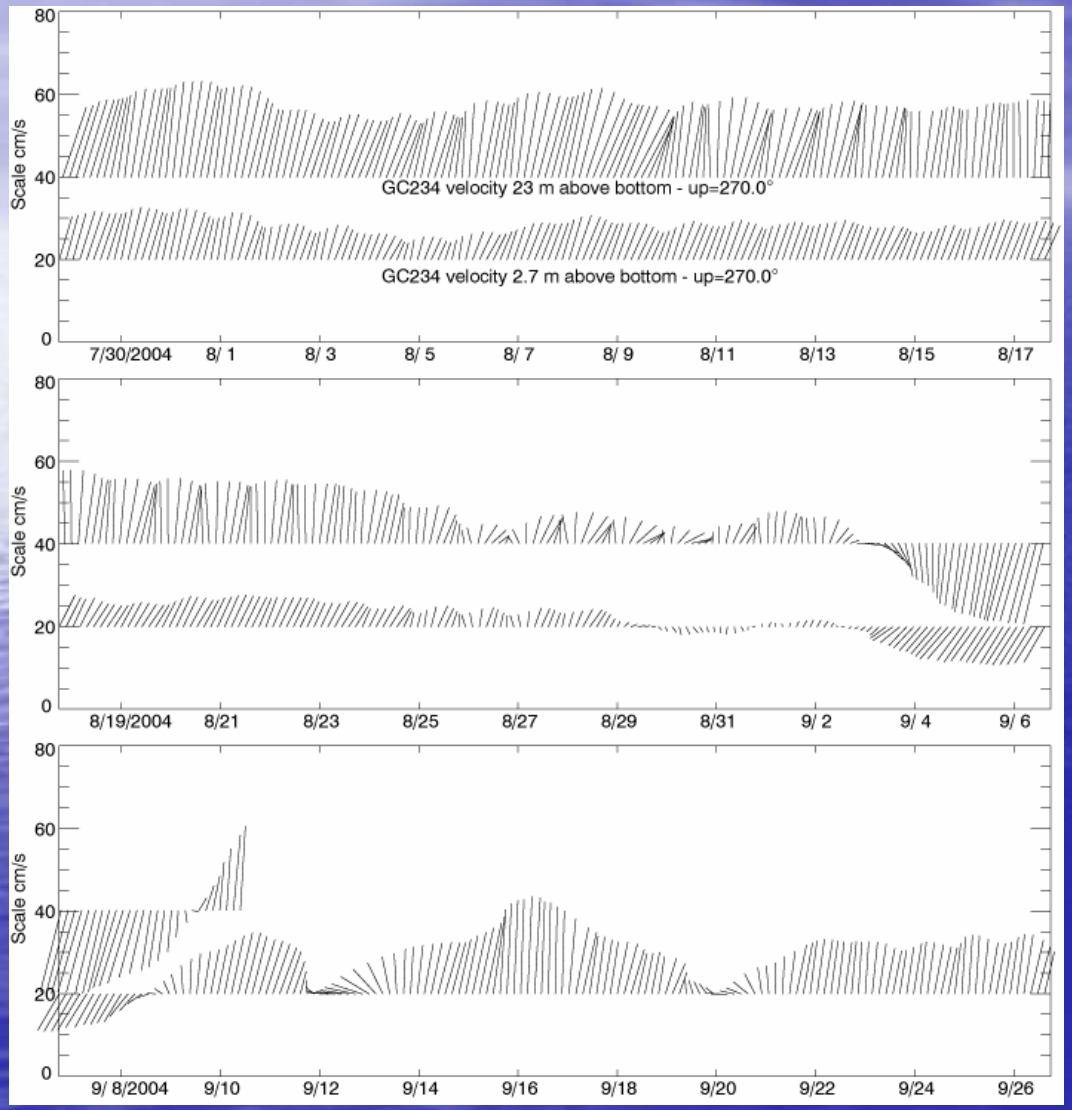


GC234 Moored Current Meter (2.7m above bottom)



Max speed: 44 cm/s
Mean vector velocity: 6.7cm/s at 276° (westward)
Expected value of current speed: 9.6 cm/s

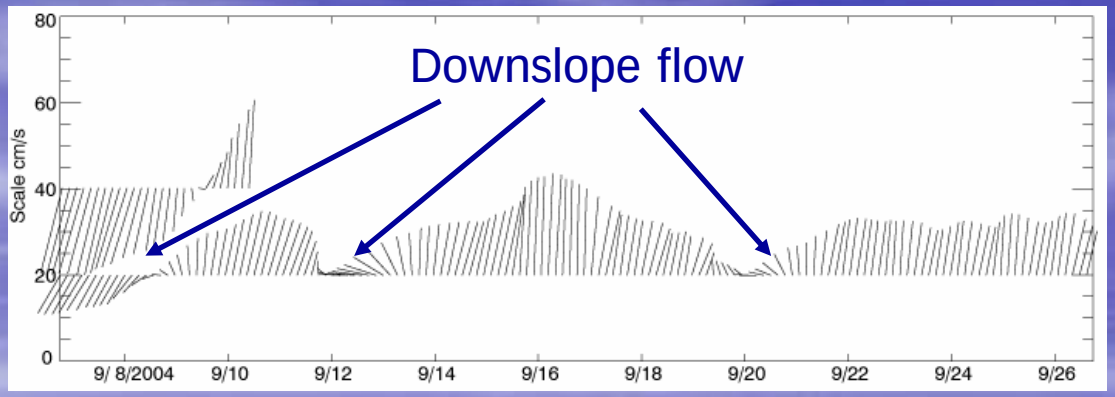
GC234 Currents

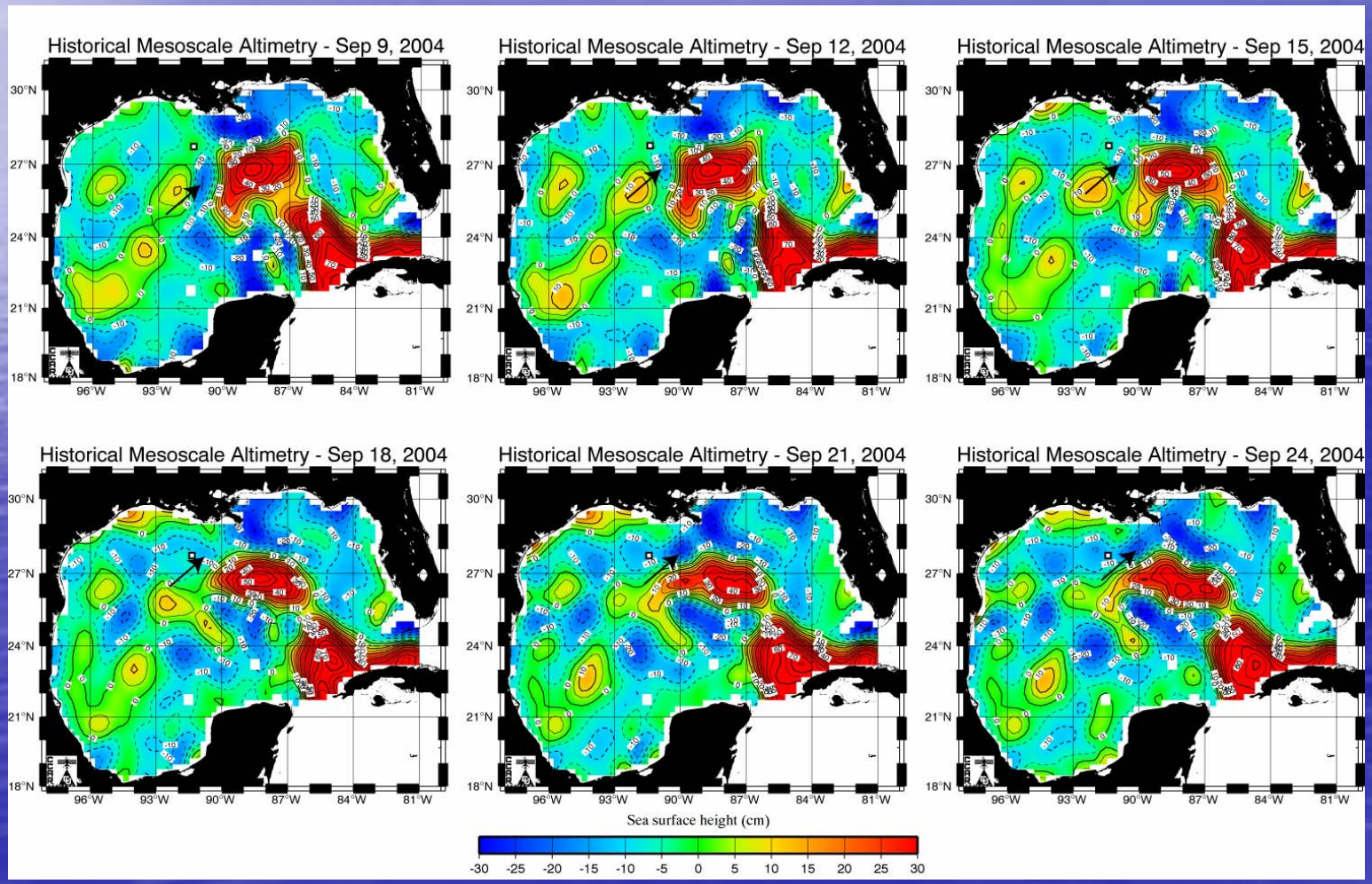


Increase in speed and anticlockwise turning of the velocity vectors with height above bottom.

Current fluctuations dominantly along-isobath and westward – cross isobath flow evident during passage of cyclonic frontal eddies at edge of a large Loop Current Eddy (September 2004).

Weak tidal signals: 1-3 cm/s and dominantly diurnal (K1)


Downslope flow
Scale cm/s
80
60
40
20
0
9/ 8/2004
9/10
9/12
9/14
9/16
9/18
9/20
9/22
9/24
9/26


Historical Mesoscale Altimetry - Sep 9, 2004
Historical Mesoscale Altimetry - Sep 12, 2004
Historical Mesoscale Altimetry - Sep 15, 2004
Historical Mesoscale Altimetry - Sep 18, 2004
Historical Mesoscale Altimetry - Sep 21, 2004
Historical Mesoscale Altimetry - Sep 24, 2004
30°N
27°N
24°N
21°N
18°N
96°W
93°W
90°W
87°W
84°W
81°W
Sea surface height (cm)
-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

Bottom-Boundary Layer Profile

The velocity profile in the boundary layer has a logarithmic structure that vanishes at some roughness height z_0

$$u(z) = u_* \kappa^{-1} \ln z / z_0$$

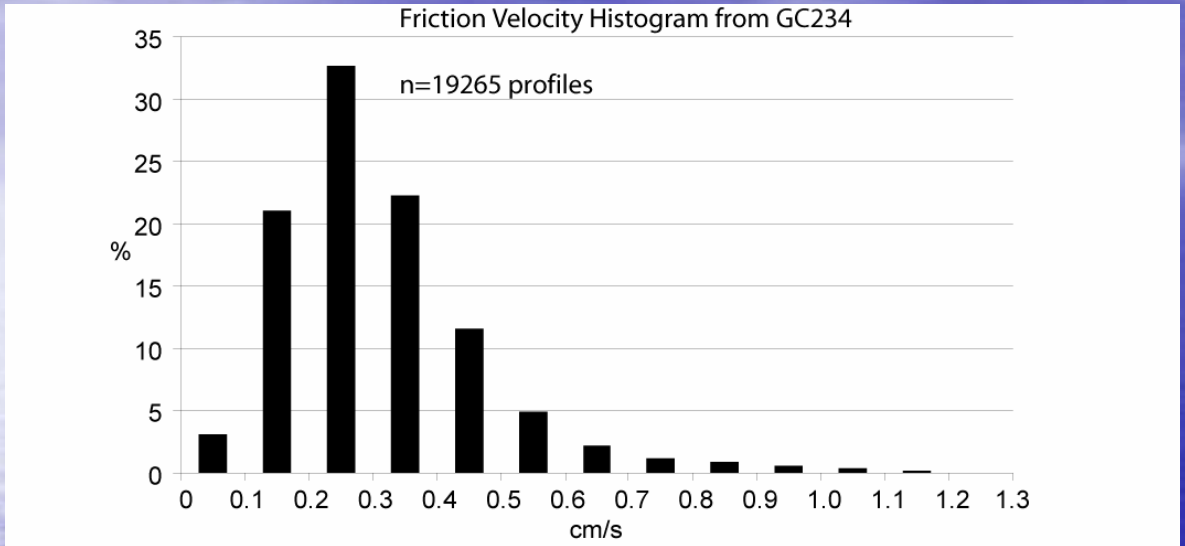
(κ is a constant) where

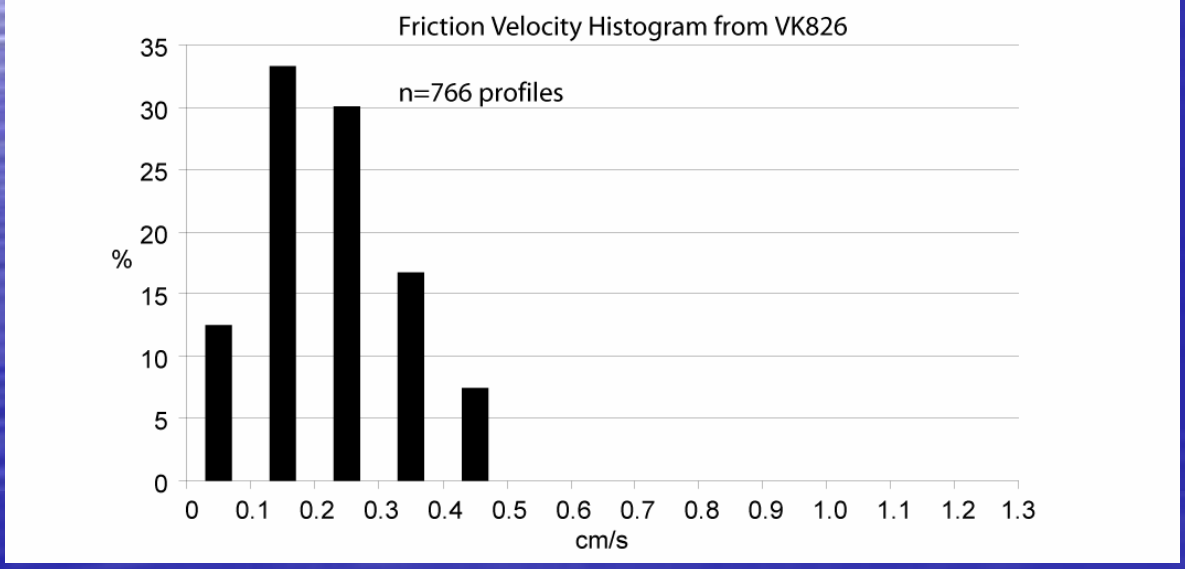
$$\tau = \rho \; u_*^{\;2}$$

If we know z_0 and the velocity at some height z, then we can solve for the friction velocity u_*.

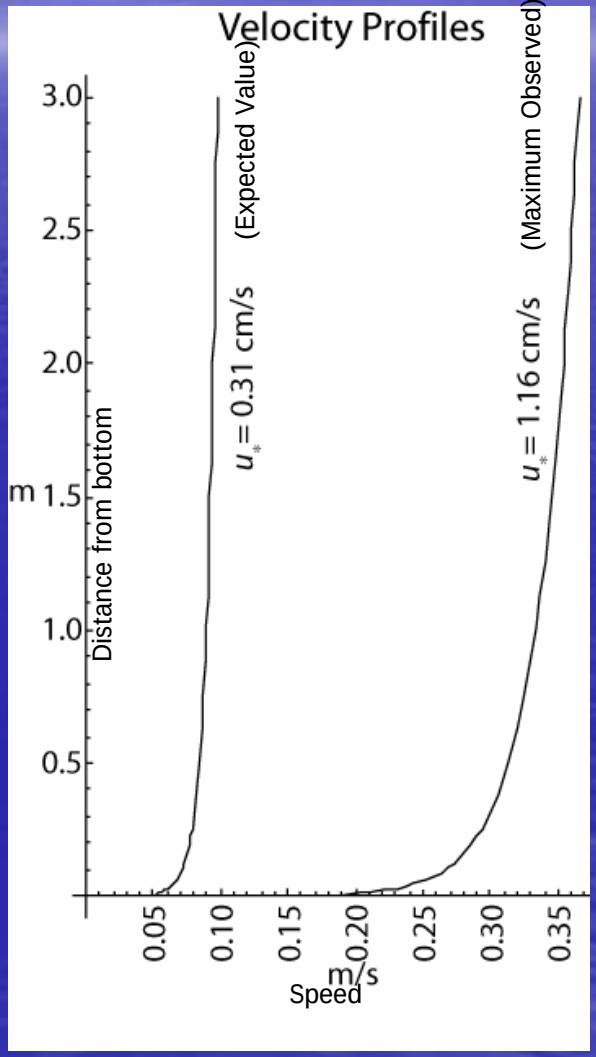
Through analysis of the characteristics of the seafloor and computing spectral estimates of the friction velocity using high-frequency current measurements, a scale roughness height of $z_0 = 10^{-5}$m was estimated.

Friction Velocity Distributions and Velocity Profiles





GC234



Summary

- Current and temperature variability along the northern Gulf of Mexico continental shelf slope is dominated by the passage of oceanic mesoscale features.
- Currents at the study sites fluctuate dominantly in the along-isobath direction, and it is anticipated that larvae will be dispersed accordingly.
- The main source of any seasonal variability impacting the deepwater ecosystems is likely linked to the seasonality of upper ocean production over the areas.
- The largest velocity measured 2.7m above the seafloor at GC234 (511m) was 44 cm/s over an 11-month period.

Suggested Future Studies

- Further knowledge of the larvae behavior and life cycle can be used to refine estimations of larvae dispersal patterns.
- The suggested linkage between surface productivity and the benthic food webs should be explored further.
- Additional velocity measurements (longer time series) are needed to better estimate the mean and variability of the deep currents and to determine the likelihood of extreme currents.
- Need to know the characteristics of the sediment to determine likelihood of sediment resuspension and exposing of the underlying hard substrate.

References

Morey, S.L., P.J. Martin, J.J. O'Brien, A.A. Wallcraft, and J. Zavala-Hidalgo. 2003a. Export pathways for river discharged fresh water in the northern Gulf of Mexico. J. Geophys. Res. 108(C10):3303, doi:10.1029/2002JC001674.

Morey, S.L., W.W. Schroeder, J.J. O'Brien, and J. Zavala-Hidalgo. 2003b. The annual cycle of riverine influence in the eastern Gulf of Mexico basin. Geophys. Res. Let. 30(16):1867, doi: 10.1029/2003GL017348.