

# **A Gulf-Wide Historical Perspective on Ocean Features in the Gulf of Mexico**

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# Introduction

- ▶ **The Loop Current (LC) and its associated eddies (LCEs) are the most energetic component of the upper ocean circulation in the deepwater of the GOM.**
- ▶ **A gulf-wide historical perspective of these ocean features is required to better understand the context of the MMS-funded deepwater programs along the northern GOM continental slope from April 2003 through January 2006.**
- ▶ **Continuous sampling of SSH over the GOM since 1993 by satellite altimeters provides this perspective.**



# MMS Deepwater Studies

## Exploratory Study

- ▶ March 2003 through April 2004
- ▶ 26 PIES and 19 Moorings

## Northwest Gulf Study

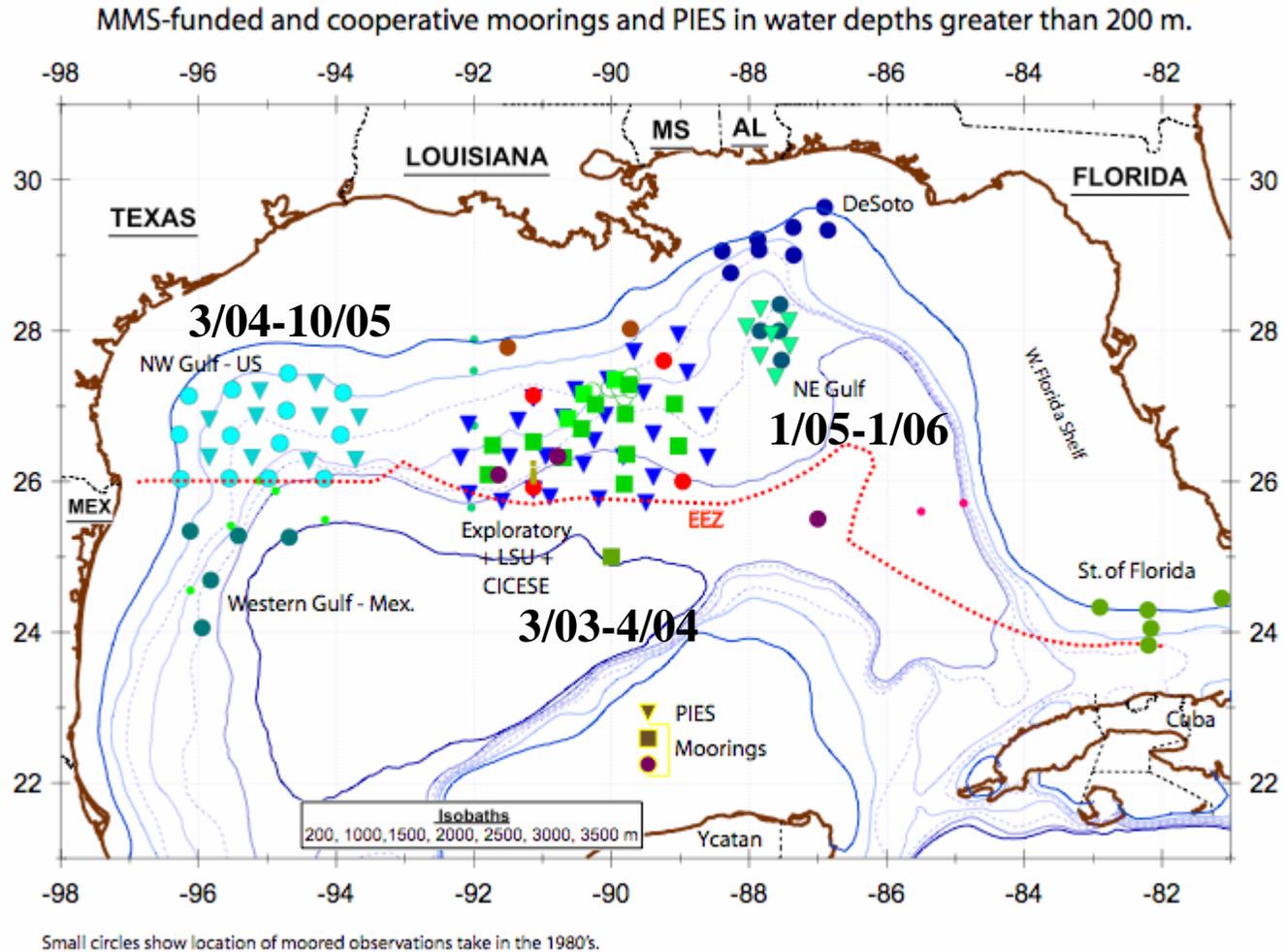
- ▶ March 2004 through October 2005
- ▶ 10 PIES and 18 Moorings

## Northeast Gulf Study

- ▶ January 2005 through January 2006
- ▶ 7 PIES and 4 Moorings



# MMS Funded and Cooperative Mooring/PIES in Deepwater



# Historical Perspective

The full altimetric record 1993 to present is used to place into context the Loop Current and Loop Current eddies' influences on the study regions during the measurement time periods.

We used:

- ▶ Loop Current Metrics
- ▶ Loop Current Eddy Tracking
- ▶ Energetics

Altimetry plays a significant role in the quantitative monitoring of the far-field flow conditions surrounding the study area.



# Loop Current Metrics

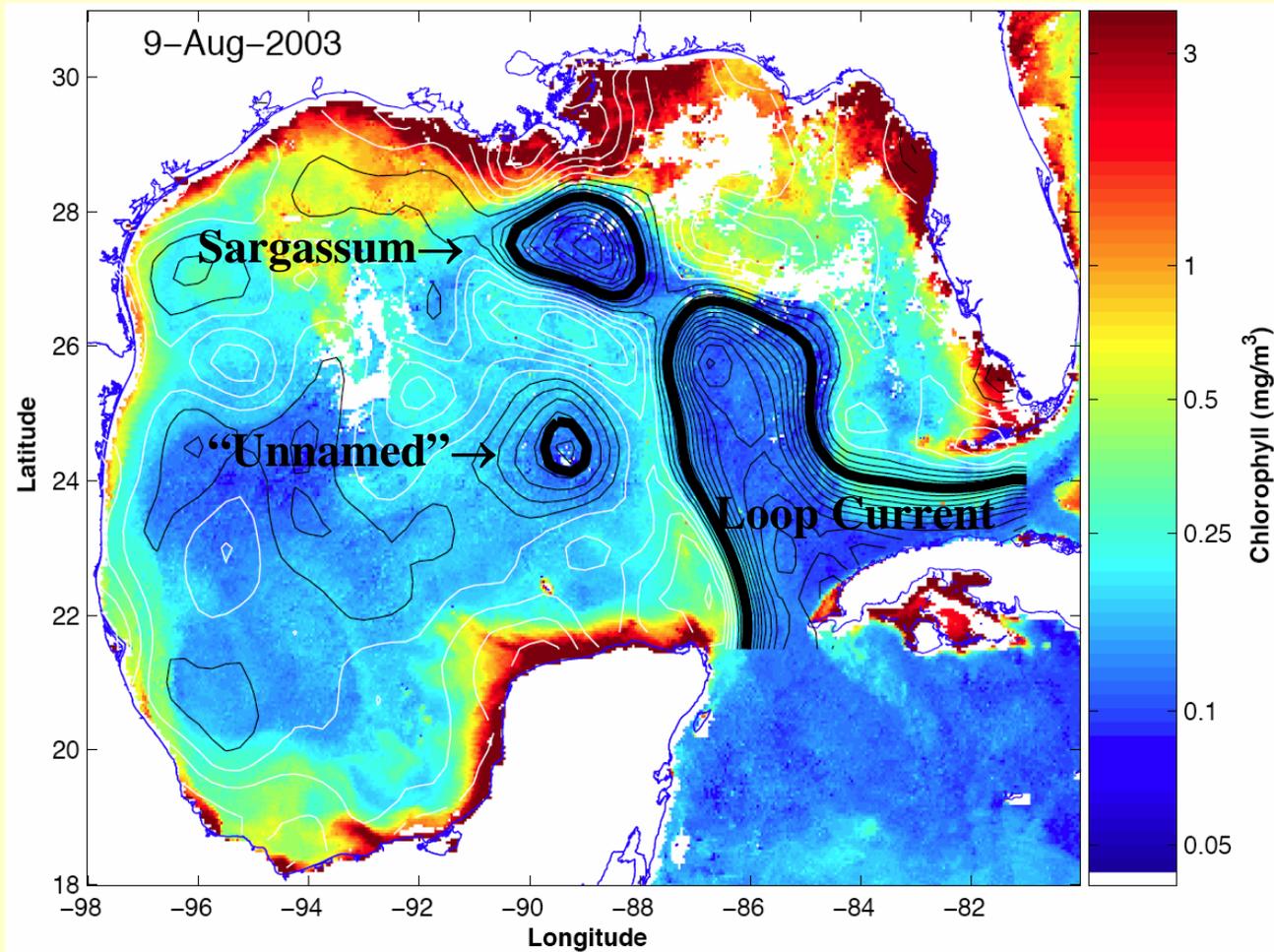
**Loop Current (LC) metrics are computed using the 17-cm sea surface height contour as a proxy for the high velocity core of the LC in the eastern Gulf of Mexico.**

**This proxy allows objective computation of LC metrics such as:**

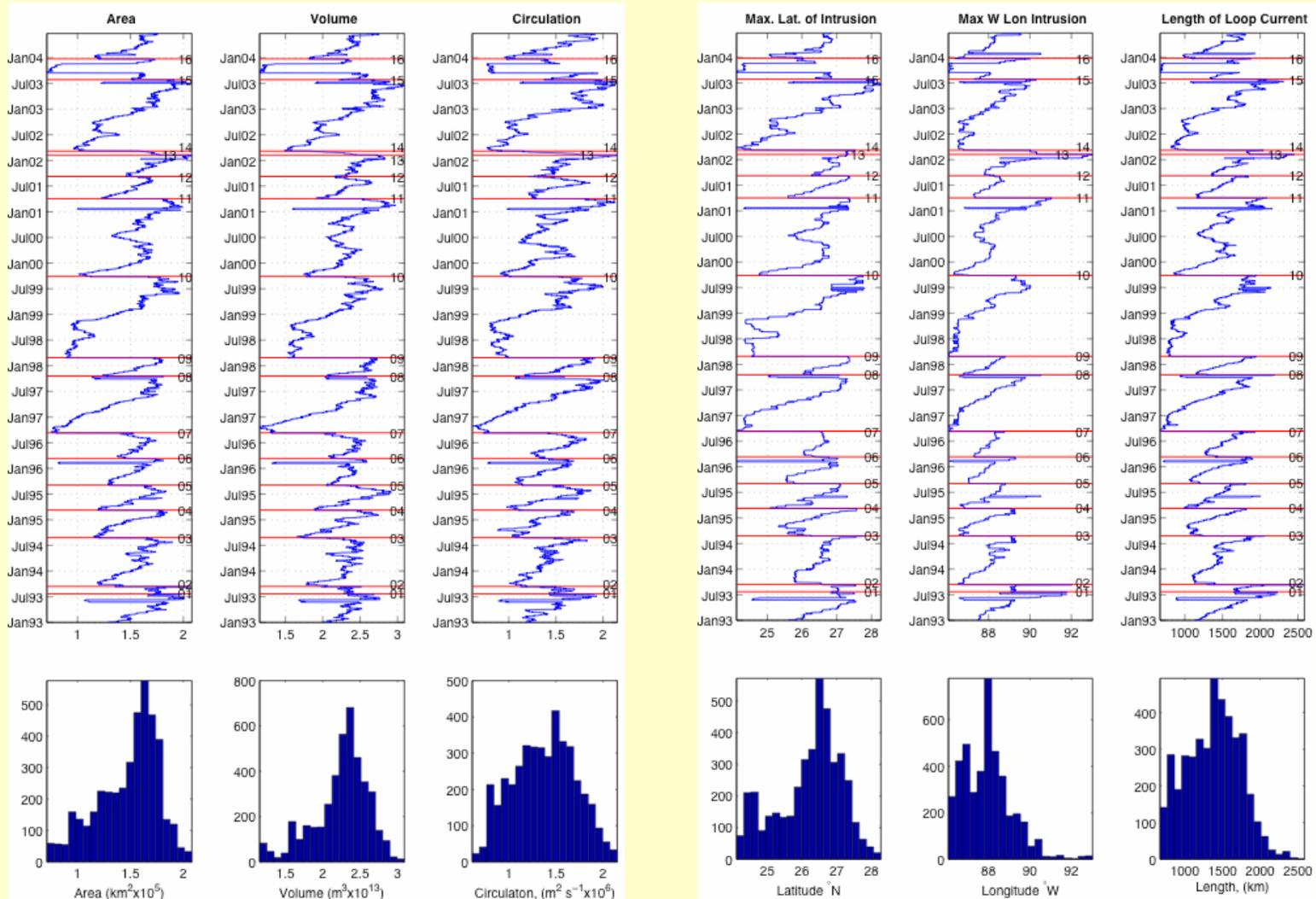
- ▶ **Maximum northward and westward extent of LC penetration**
- ▶ **Length**
- ▶ **Area**
- ▶ **Circulation**
- ▶ **Volume**



# Eddy Sargassum



# 1993–2004 LC Statistics



# Loop Current Eddy Metrics

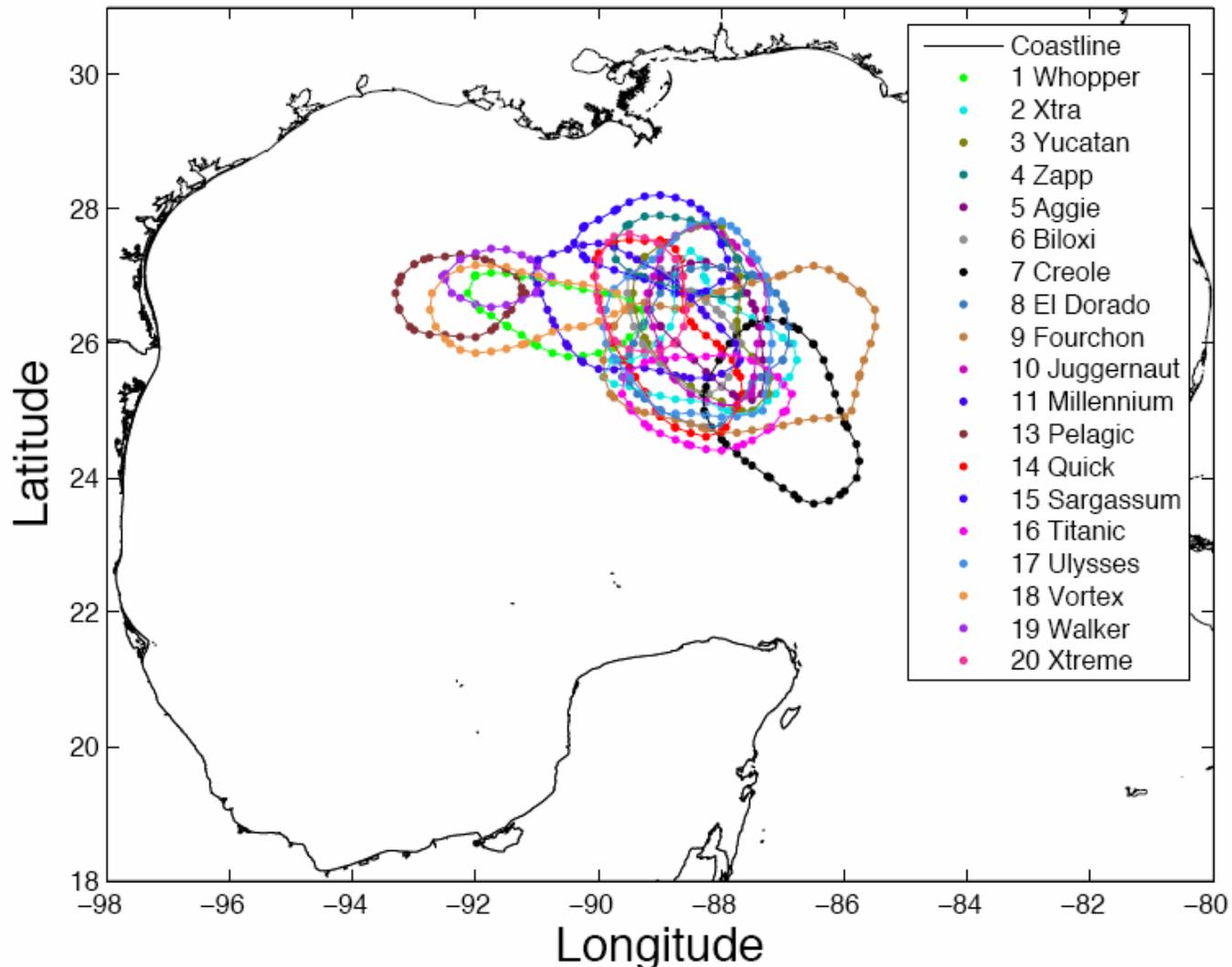
**Loop Current Eddies (LCEs) are objectively defined as anticyclonic eddies that separate from the LC breaking the 17-cm LC contour.**

**This proxy allows objective computation of LCE metrics such as:**

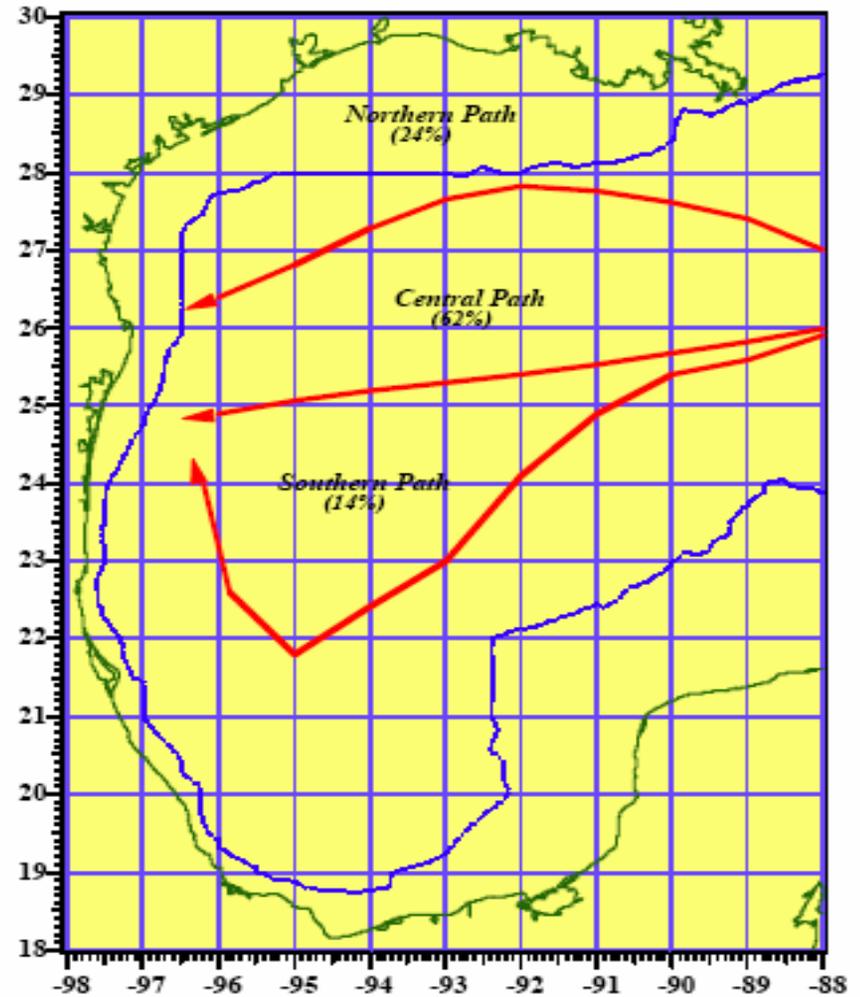
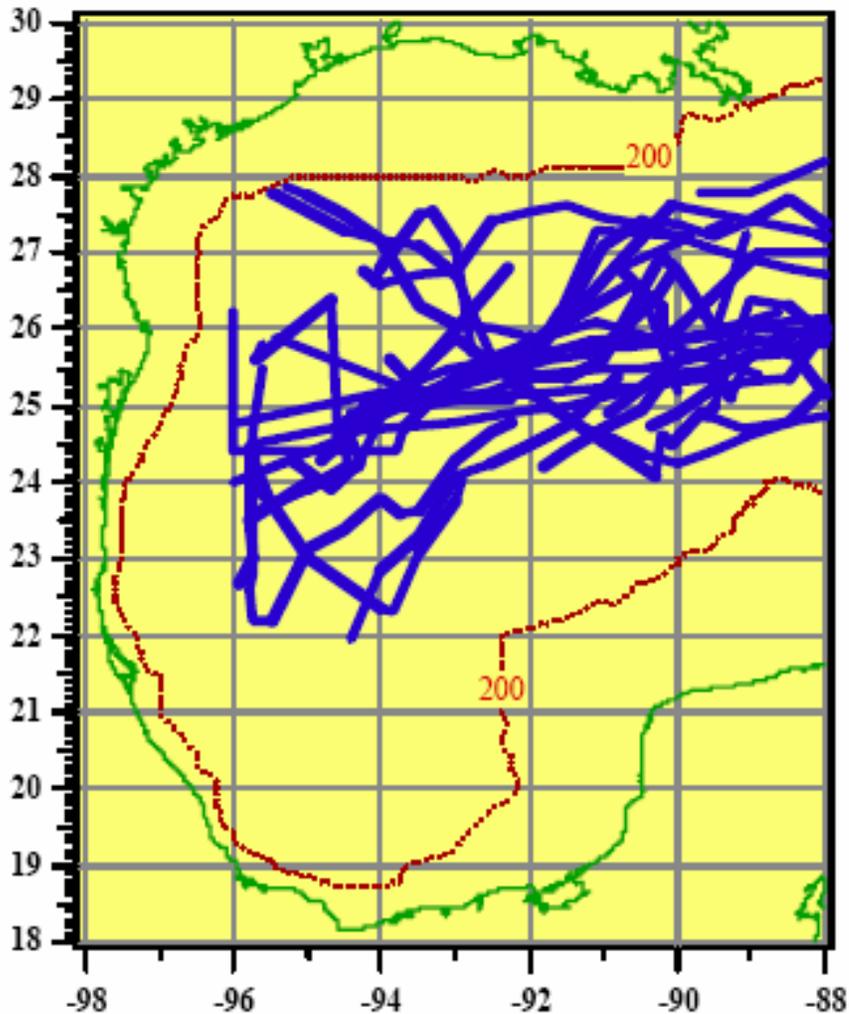
- ▶ **Path**
- ▶ **Max SSH**
- ▶ **Area**
- ▶ **Circulation**
- ▶ **Volume**



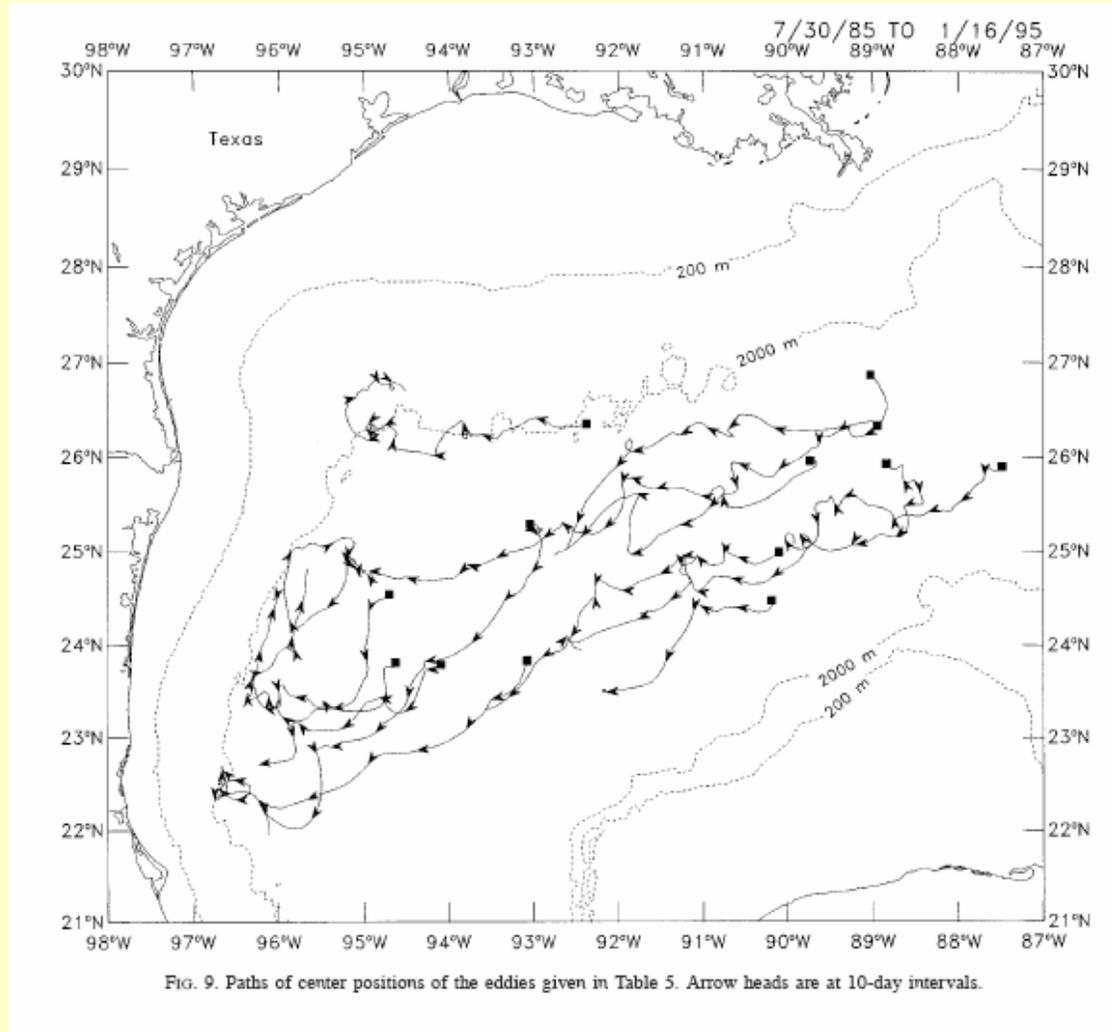
# LCEs at Separation: 1993–2005



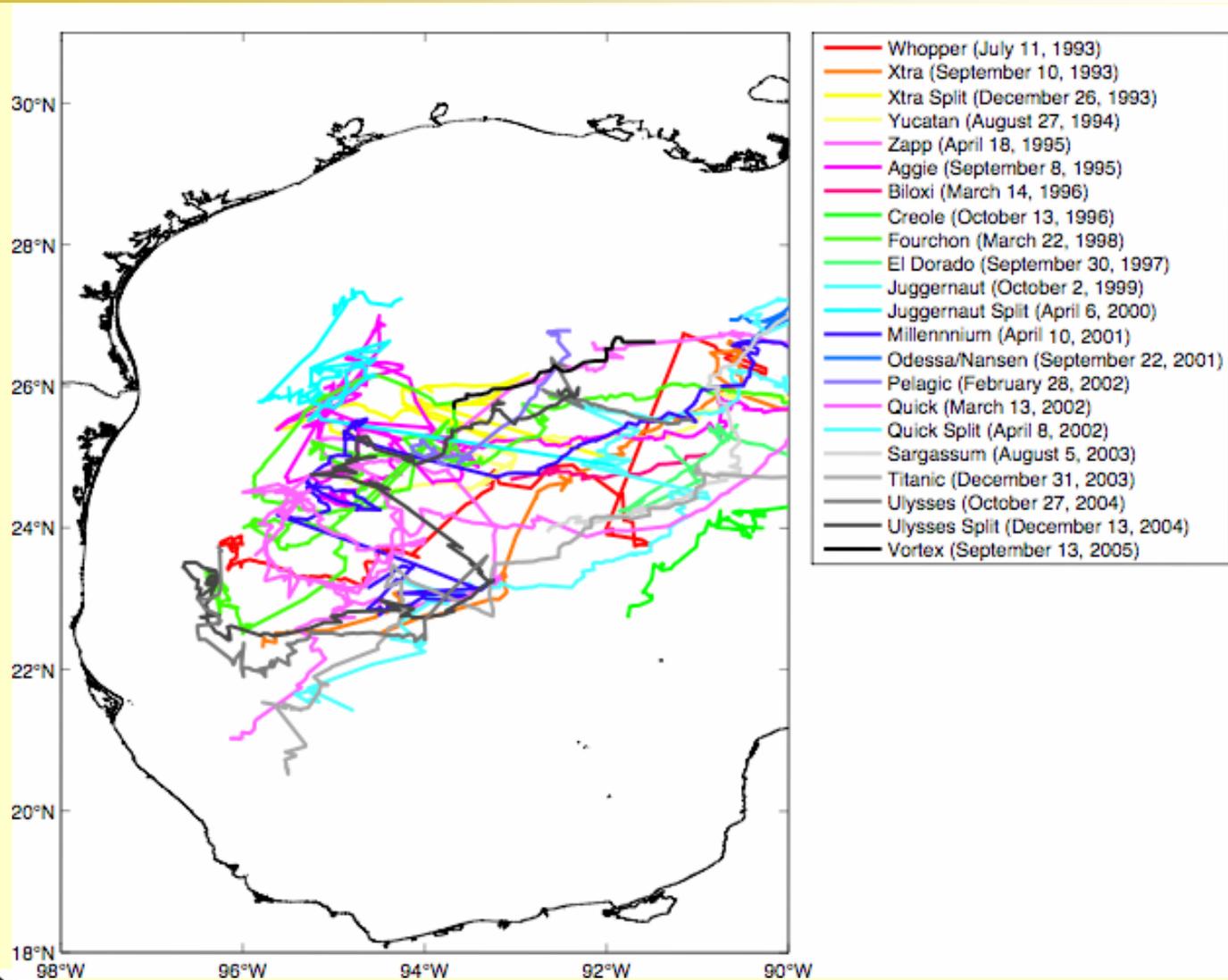
# LCE Paths (Vukovich 2005)



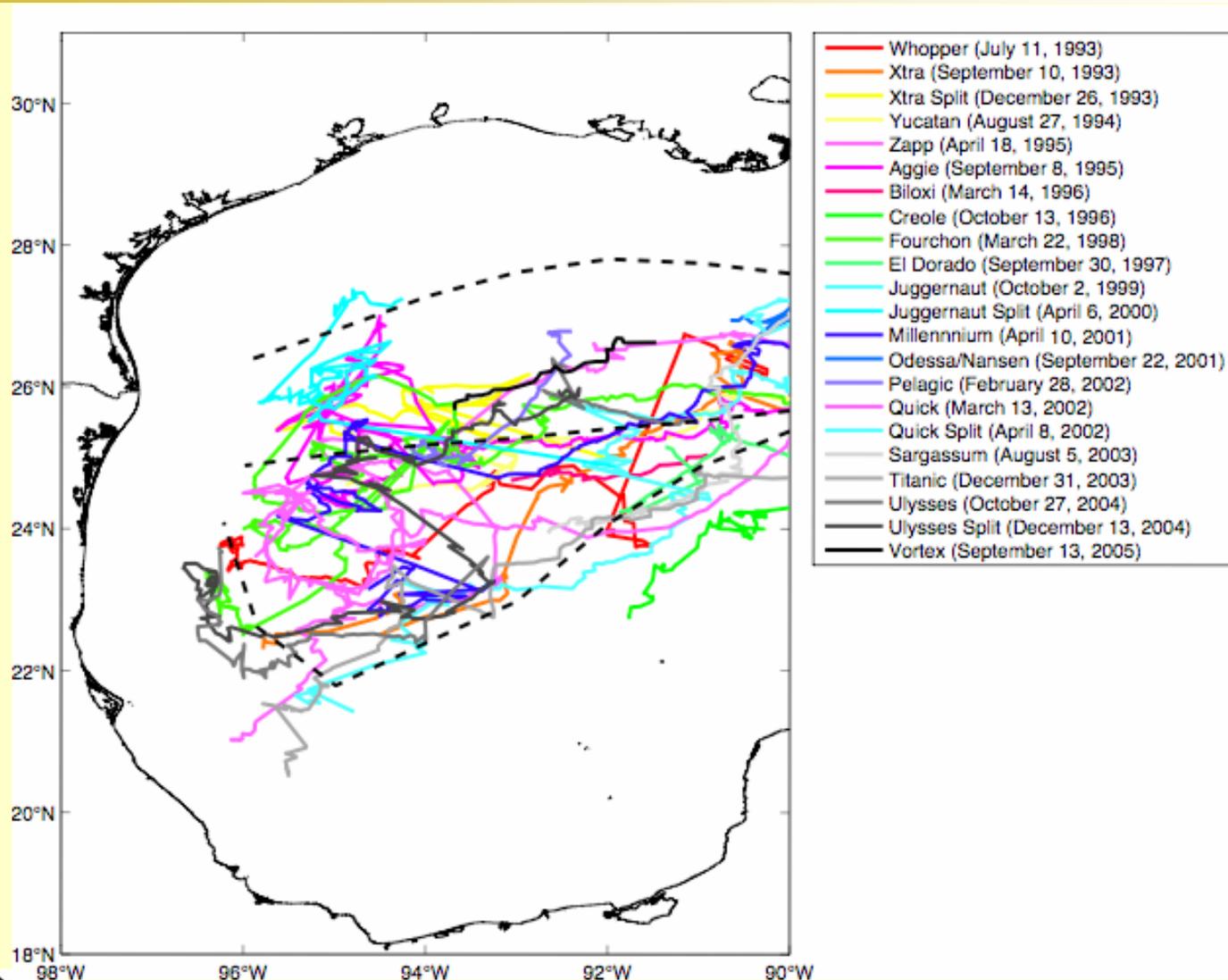
# LCE Paths (Hamilton et al. 1999)



# LCE Paths: 1993–2005



# Eddy Paths?



# Exploratory Study



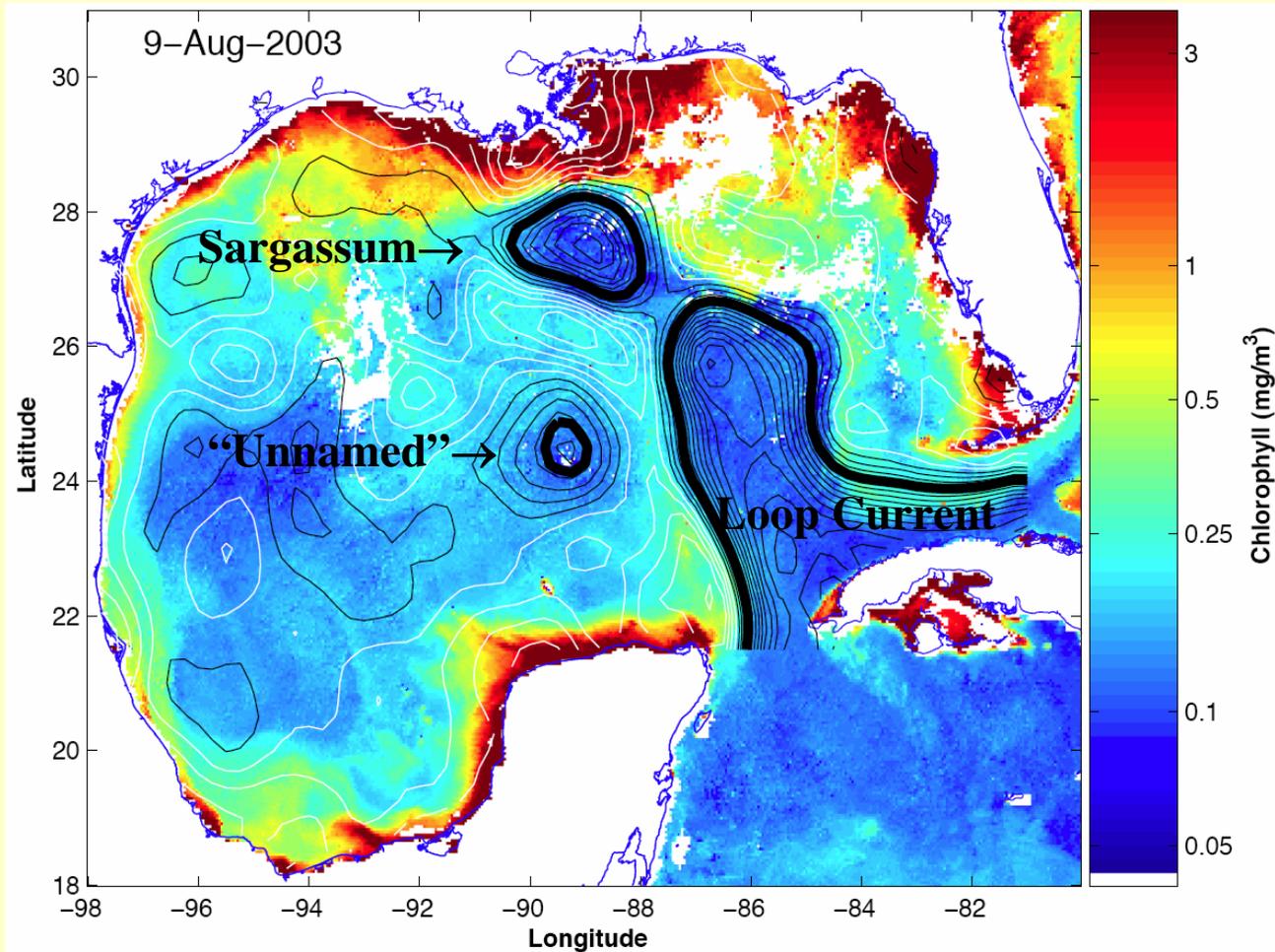
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# LCEs During Exploratory Program

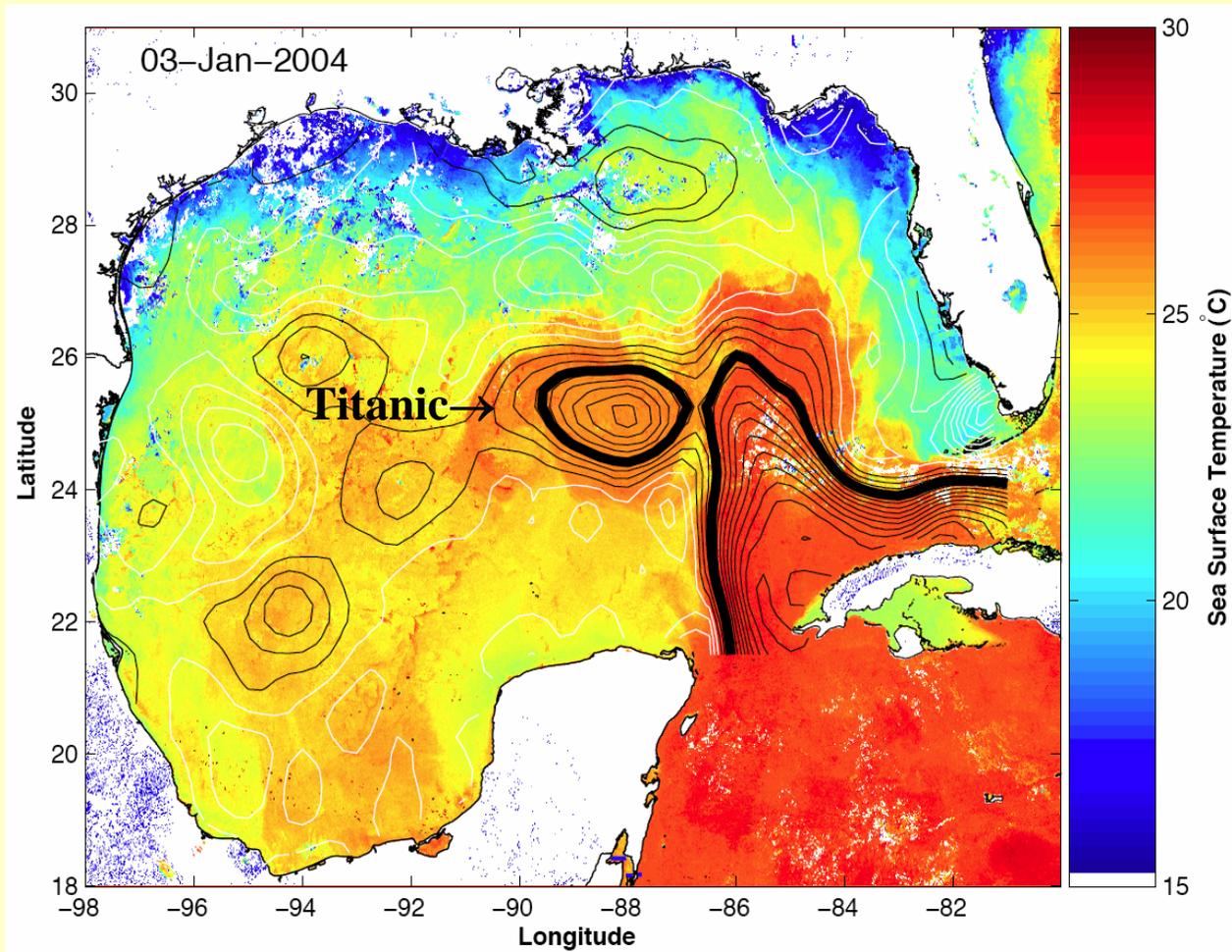
<b>Eddy Number</b>	<b>Date</b>	<b>Separation Period (months)</b>	<b>Industry Eddy Name</b>
<b>#15</b>	<b>5 August 2003</b>	<b>17</b>	<b>Sargassum</b>
<b>#16</b>	<b>31 December 2003</b>	<b>5</b>	<b>Titanic</b>



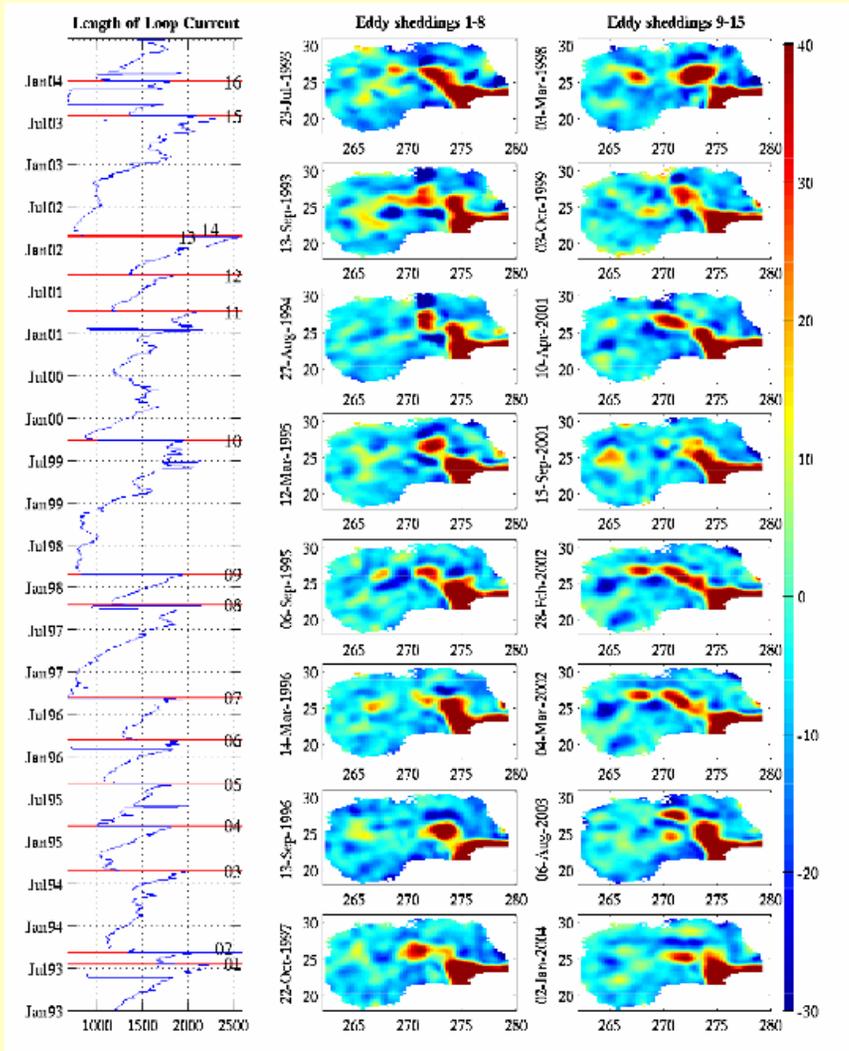
# Eddy Sargassum



# Eddy Titanic



# Exploratory Study: Altimetric Record of Loop Current Shedding Events



- ▶ A total of 16 LC eddies separated from the Loop Current during the time period from 1993 through 2003.

- ▶ Eddies 15 and 16 shed during the MMS Exploratory Program.

- ▶ These eddies were named Sargassum and Titanic by the offshore industry.

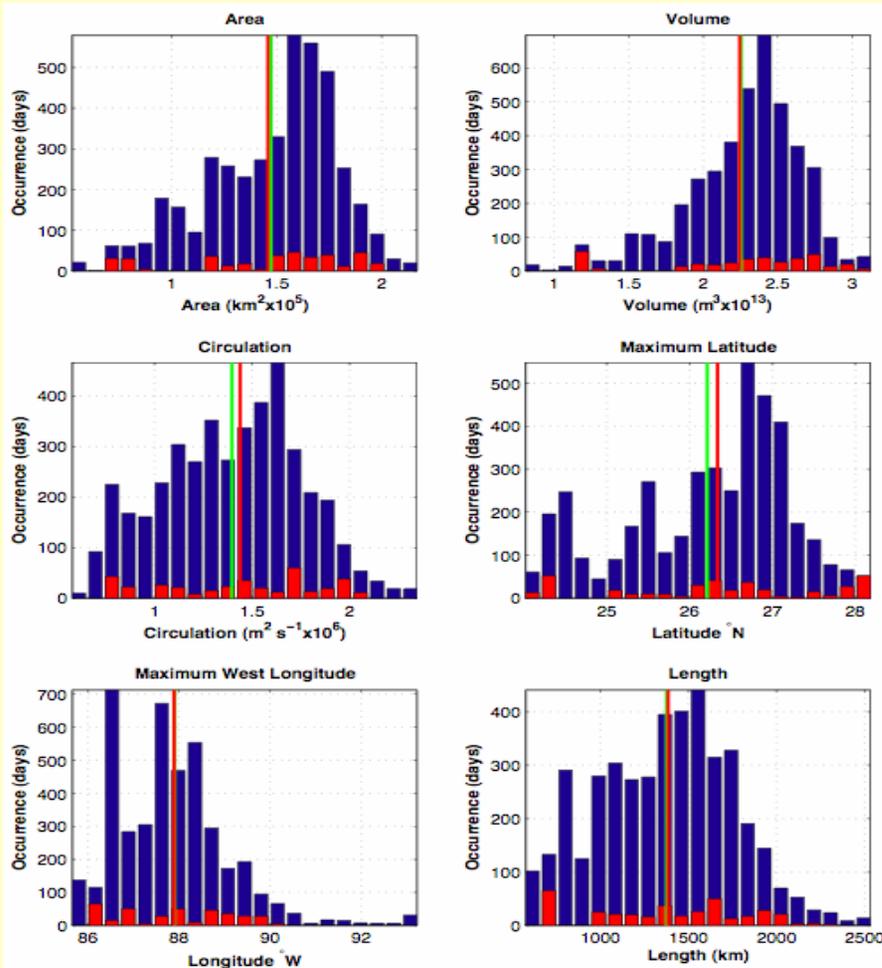
These eddies were notable in the altimetric record for:

- ▶ most northern shedding (Sargassum)

- ▶ longest detachment/reattachment before separation (Titanic)



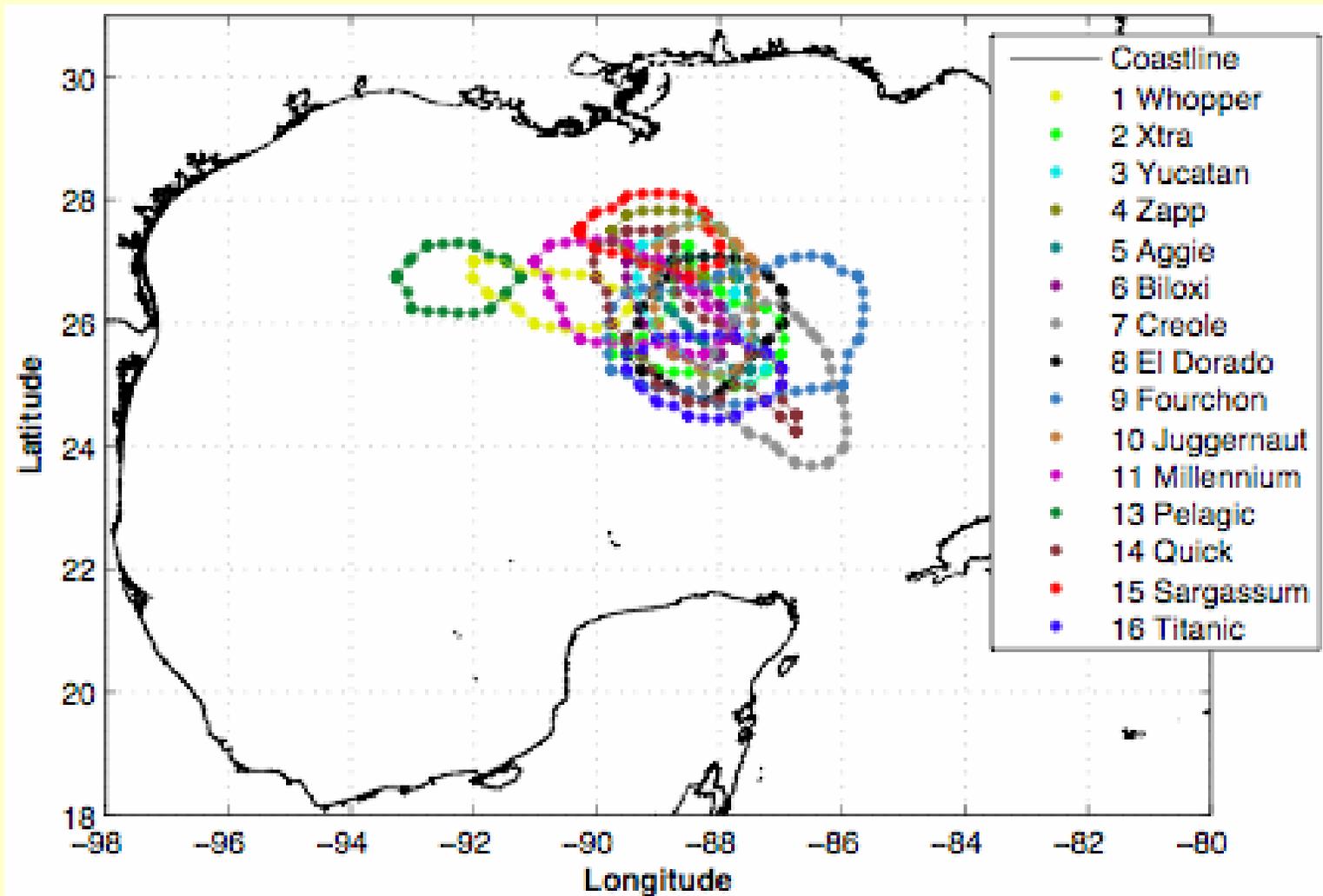
# Comparisons of LC Metrics' Distributions Program (red) vs. Historical Record (blue)



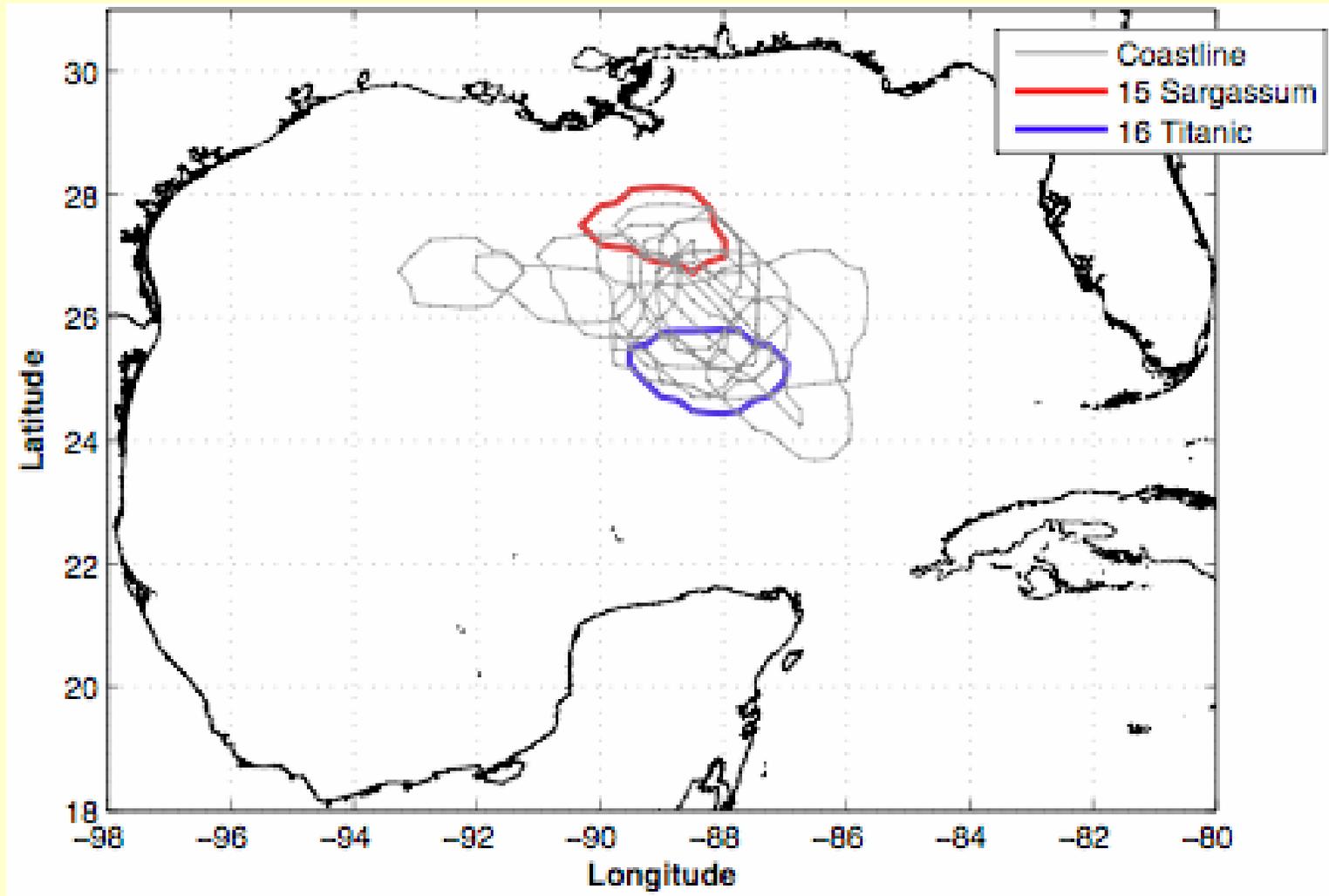
- ▶ Histograms from the program record (1 year) are overlaid on histograms from the historical record (11.5 years) to allow direct comparison of the distribution of the LC metrics during the program to the historical time period (1/1993–6/2004).
- ▶ The distributions are quite different, which is expected given the relatively short time period of the observational program and the energetic LC events that occurred therein.
- ▶ Still the mean LC metric values are very similar for the two disparate time periods.



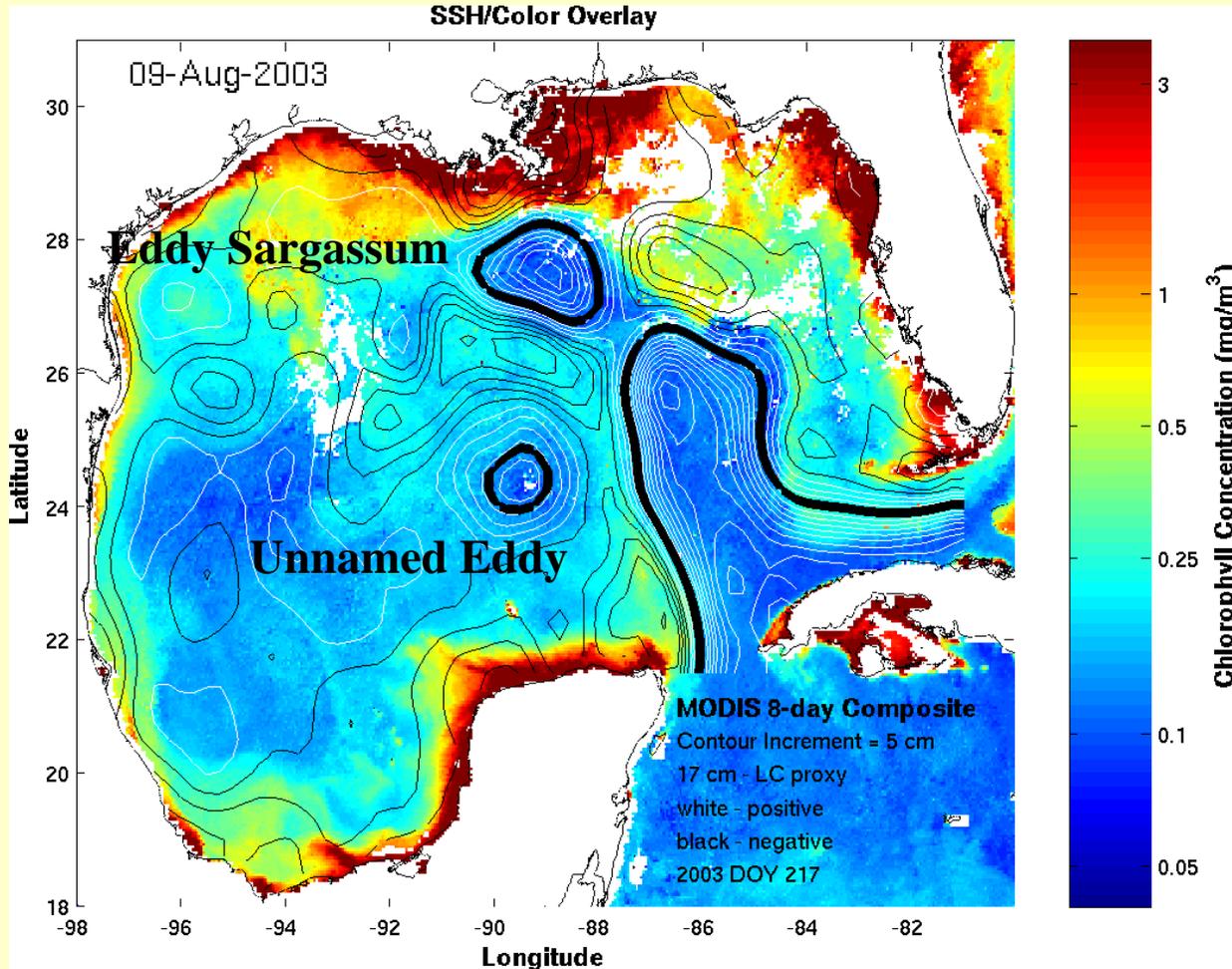
# LCEs at Separation: 1993–2003



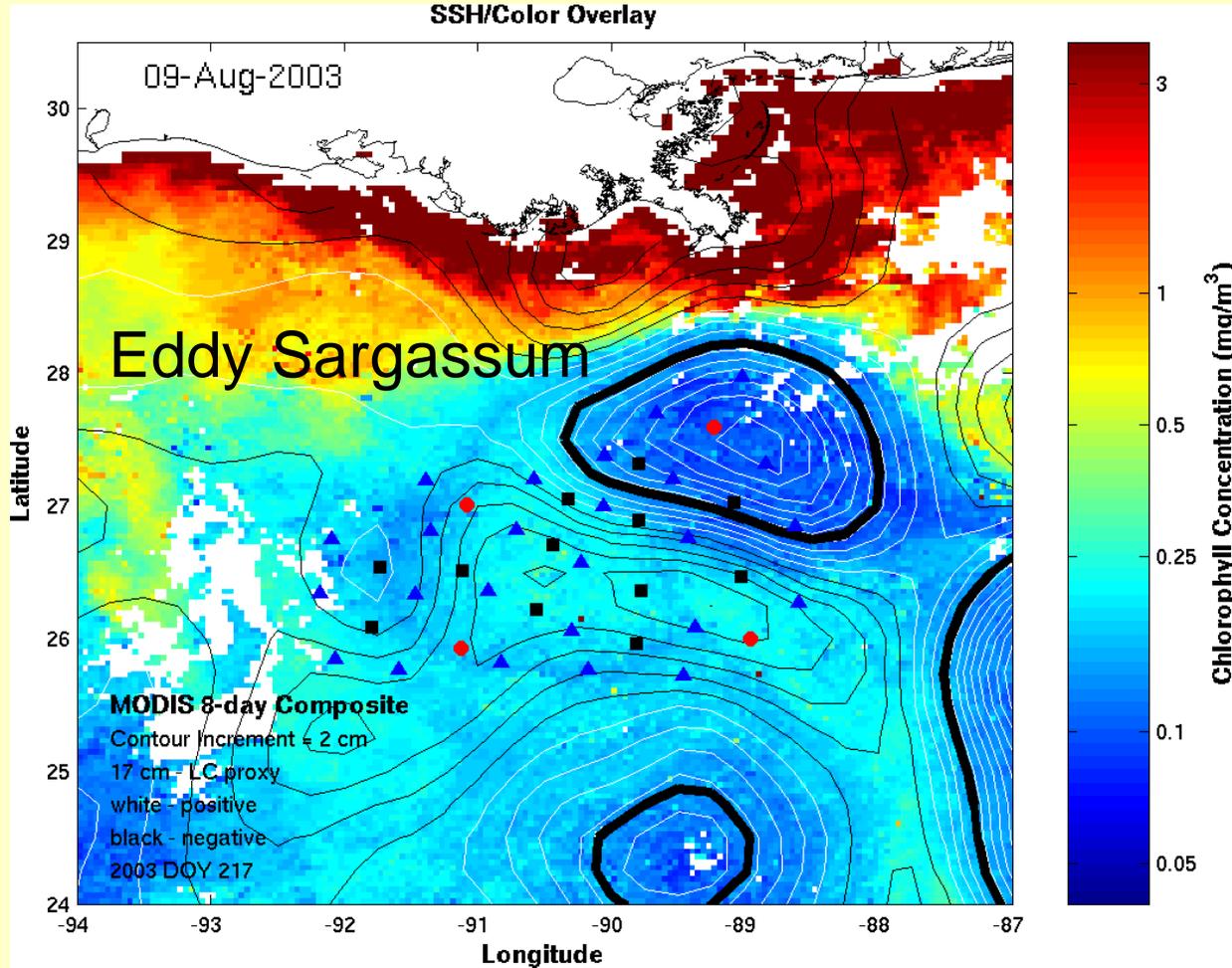
# LCEs Sargassum and Titanic



# Eddy Sargassum



# Study Region Zoom

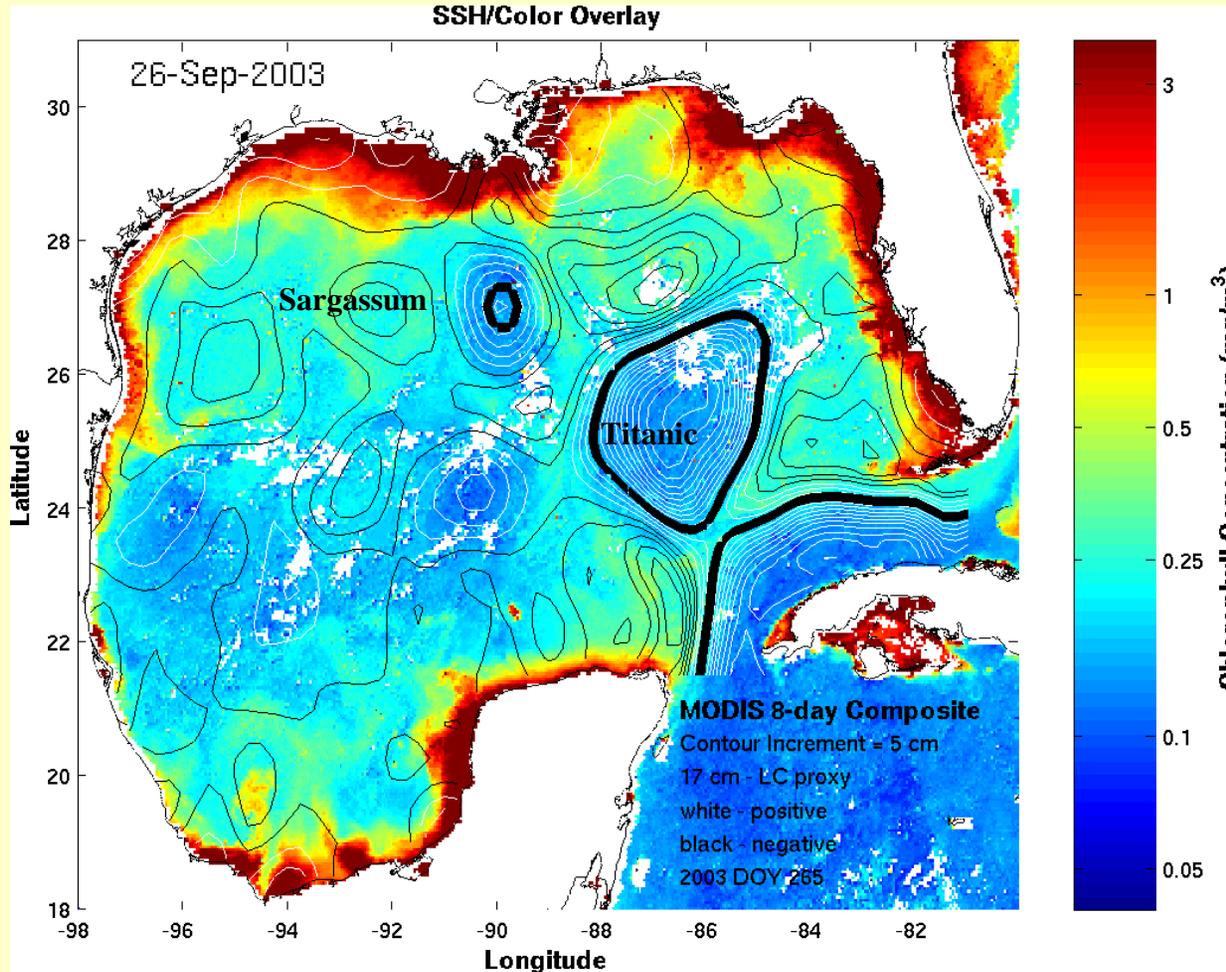


# Eddy Sargassum Summary

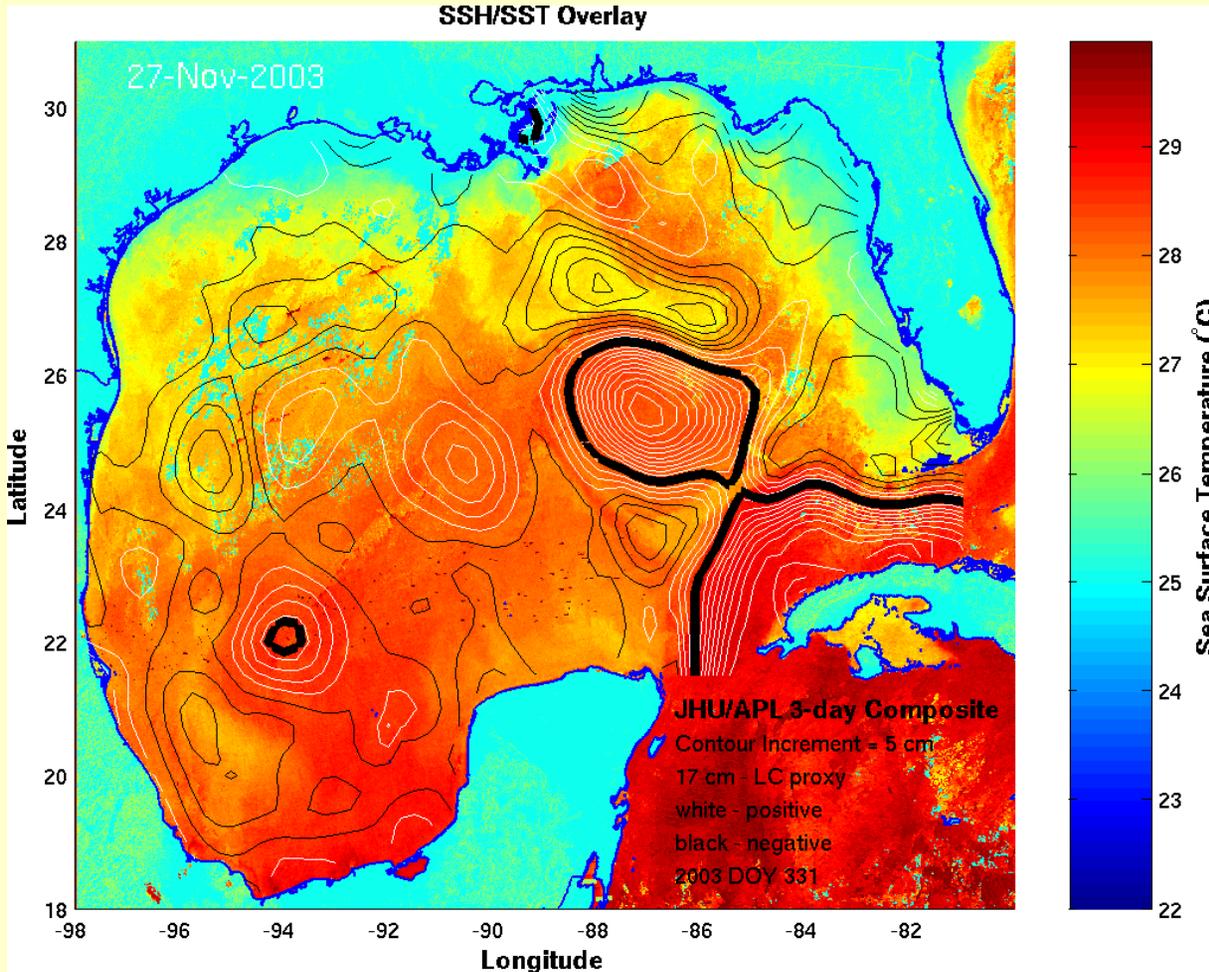
- ▶ **Strong northern intrusion of Loop Current into study region during late spring and summer 2003**
- ▶ **Very energetic and dynamic separation in summer 2003**
- ▶ **Detached and reattached in mid-July 2003**
- ▶ **Vortex splitting event ejected small unnamed eddy to the south of the study area**
- ▶ **Eddy separated in August 2003**
- ▶ **Sargassum was the strongest LC eddy in the altimetric record observed in the study region**
- ▶ **The eddy ranked 10th out of 16 eddies in areal extent and 4th out of 16 in eddy maximum SSH of the LCEs observed in the 1993 through 2003 altimeter record**



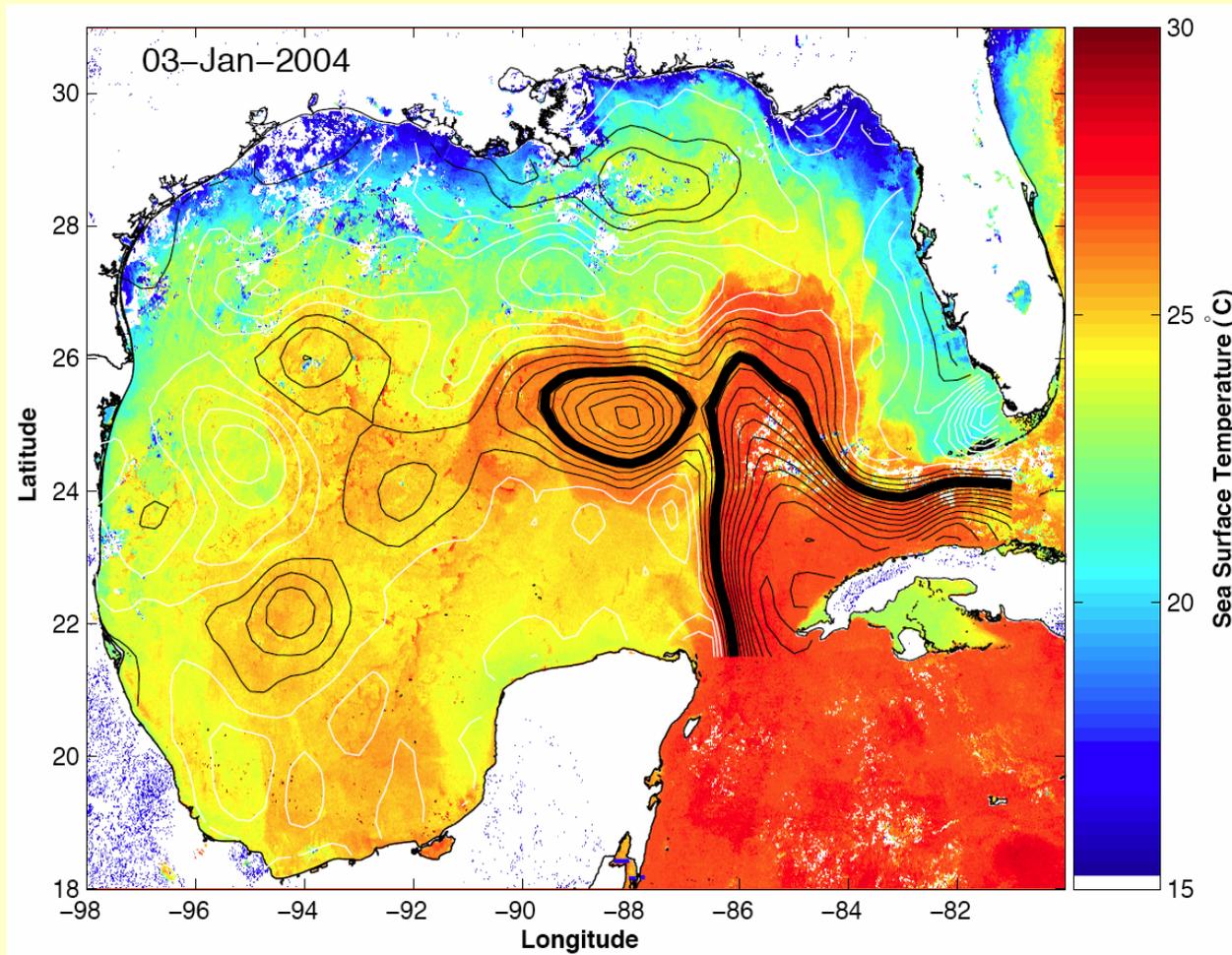
# Titanic Eddy



# Reattached after Over Two Months



# Separation of Eddy Titanic



# Titanic Eddy Summary

- ▶ **Large energetic LC Eddy detached from Loop Current in September 2003 and reattached two months later in November.**
- ▶ **There was strong cyclonic circulation north of the detached eddy.**
- ▶ **Eddy separated on 31 December 2003 and propagated westward just south of the exploratory array.**
- ▶ **This eddy ranked 9th in areal extent and 6th in maximum SSH out of the 16 eddies observed in the 1993–2003.**



# Northwest Gulf Study



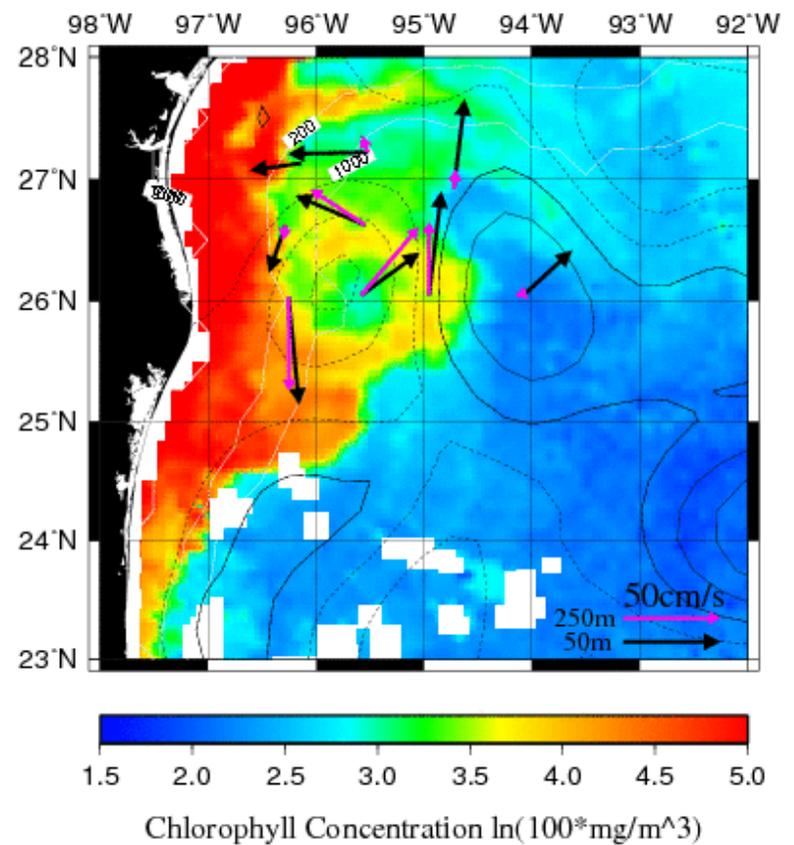
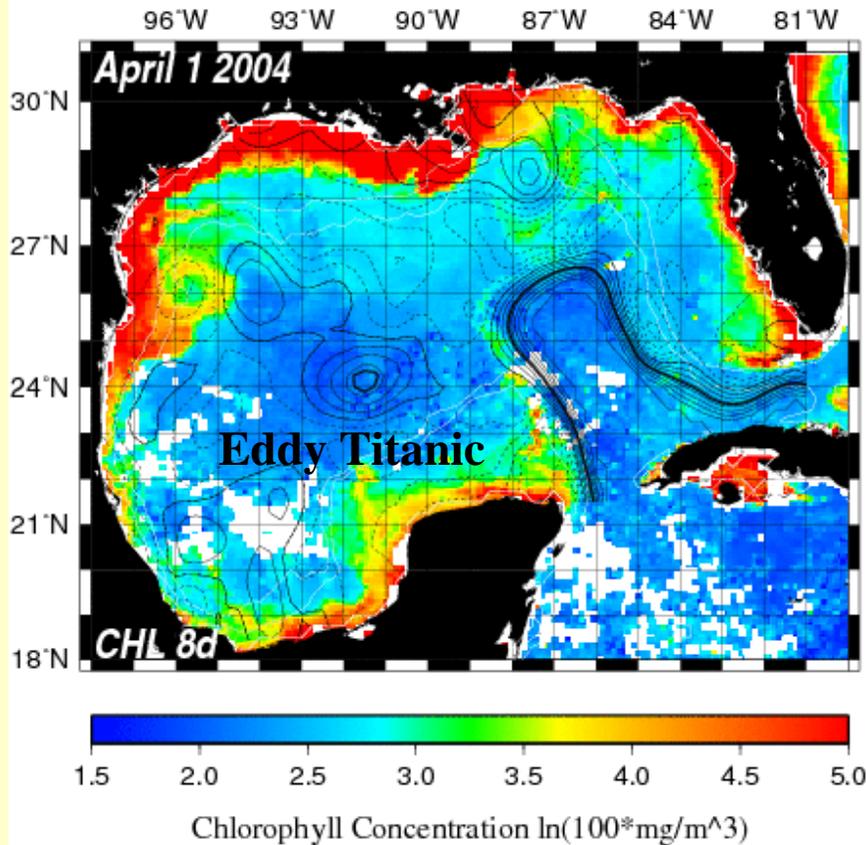
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# LCEs During NW Gulf Program

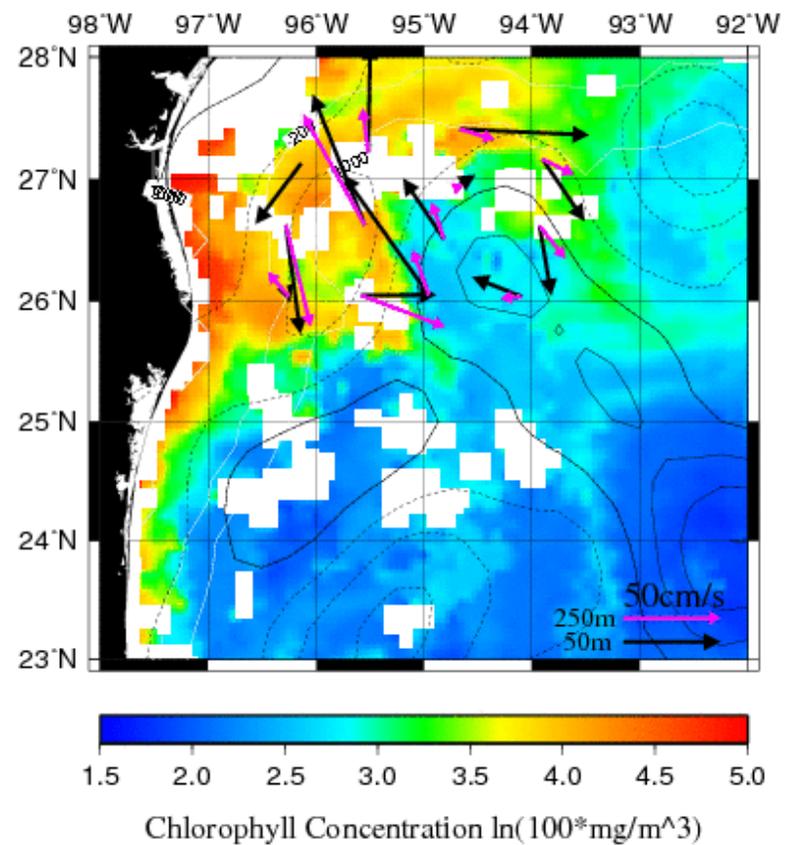
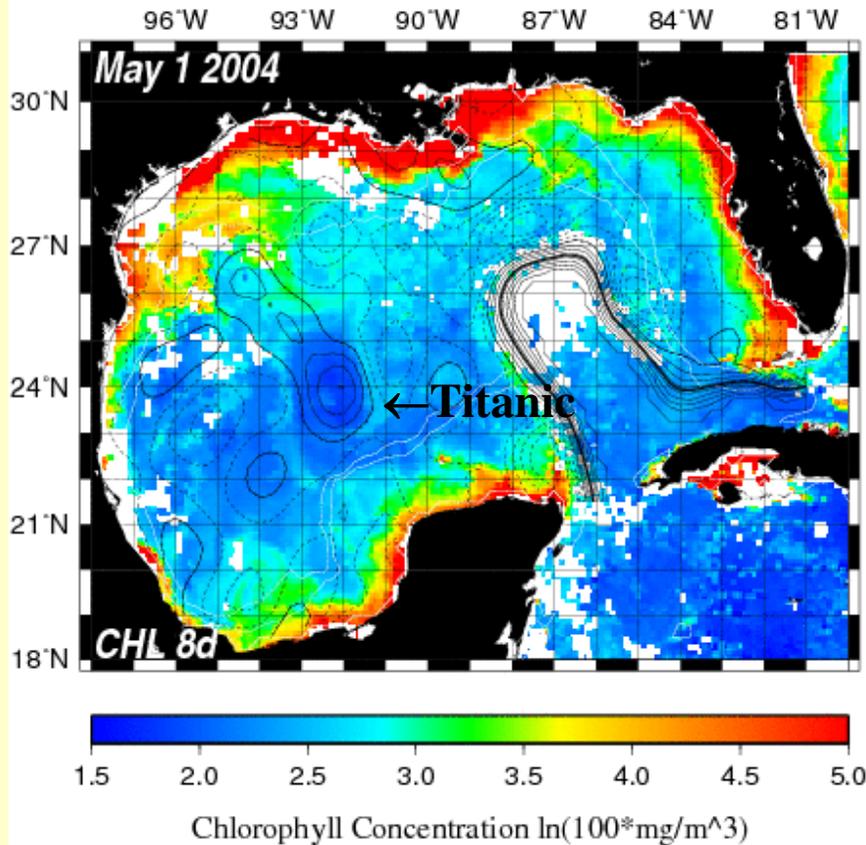
<b>Eddy Number</b>	<b>Date</b>	<b>Separation Period (months)</b>	<b>Industry Eddy Name</b>
<b>#16</b>	<b>31 December 2003</b>	<b>5</b>	<b>Titanic</b>
<b>#17</b>	<b>23 August 2004</b>	<b>8</b>	<b>Ulysses</b>
<b>#18</b>	<b>13 September 2005</b>	<b>12.5</b>	<b>Vortex</b>



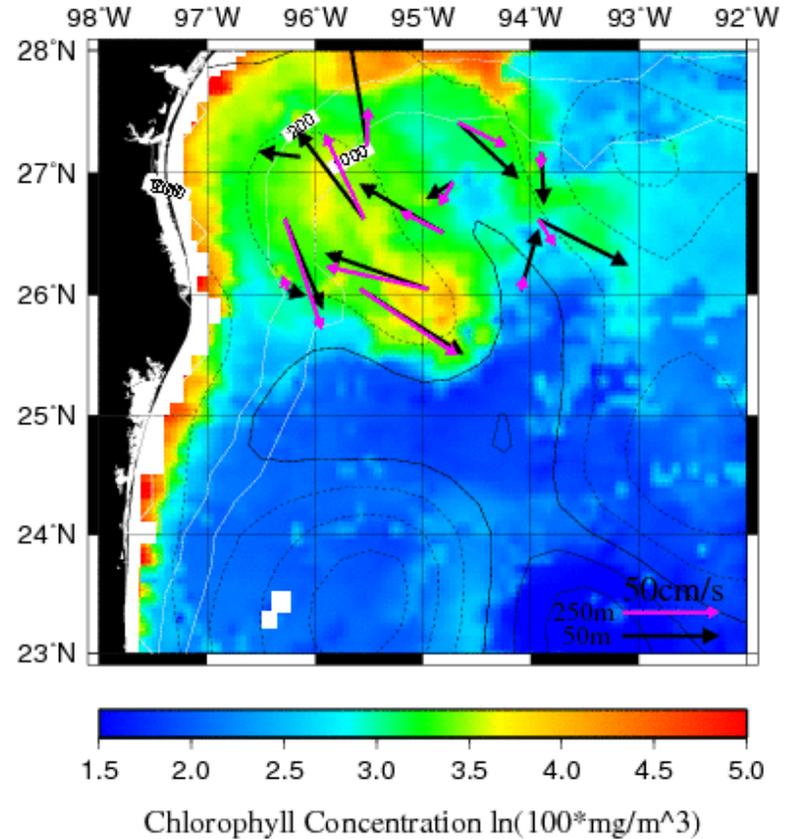
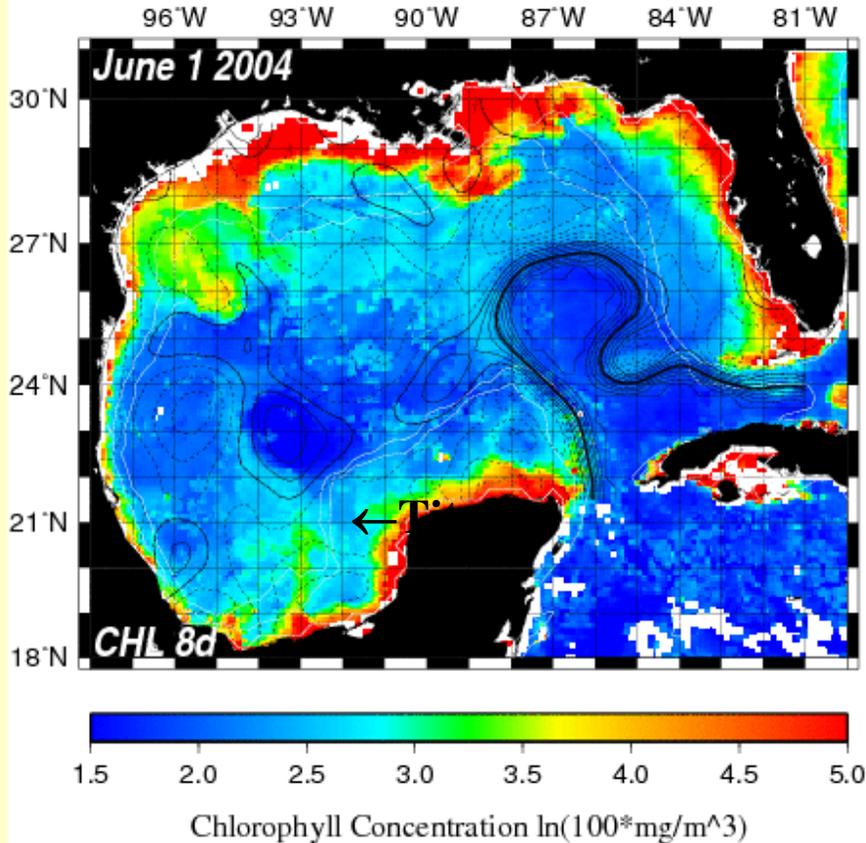
# Eddy Titanic



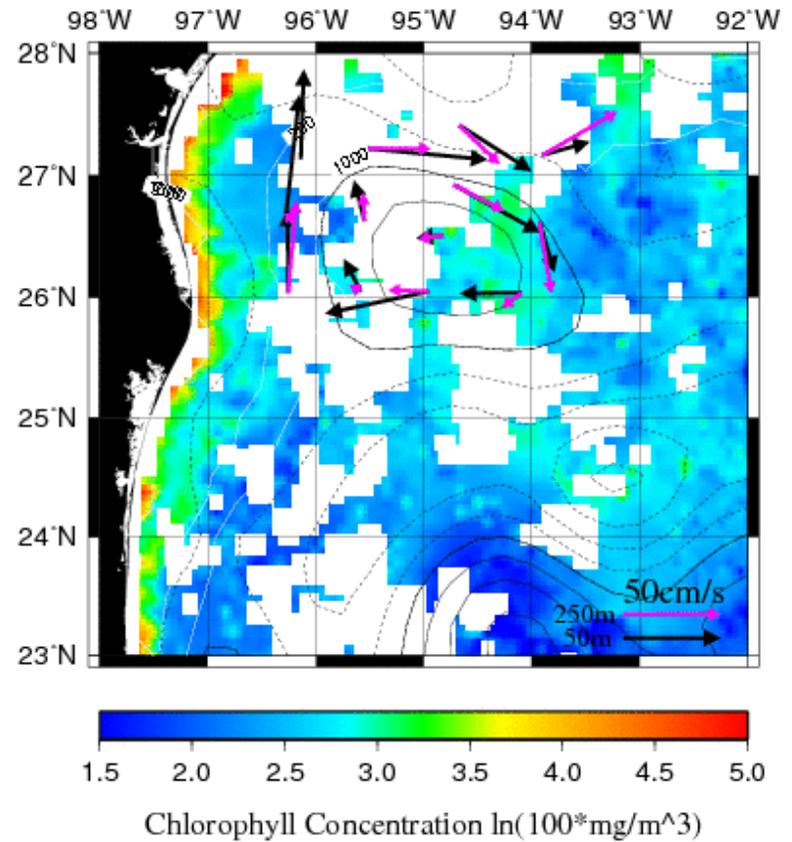
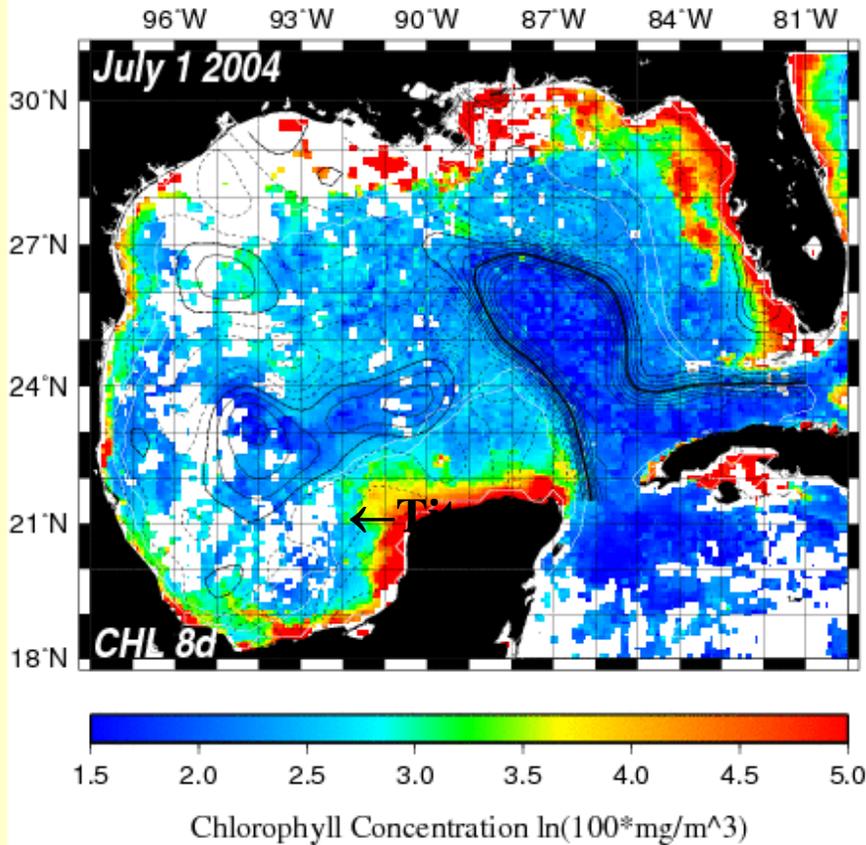
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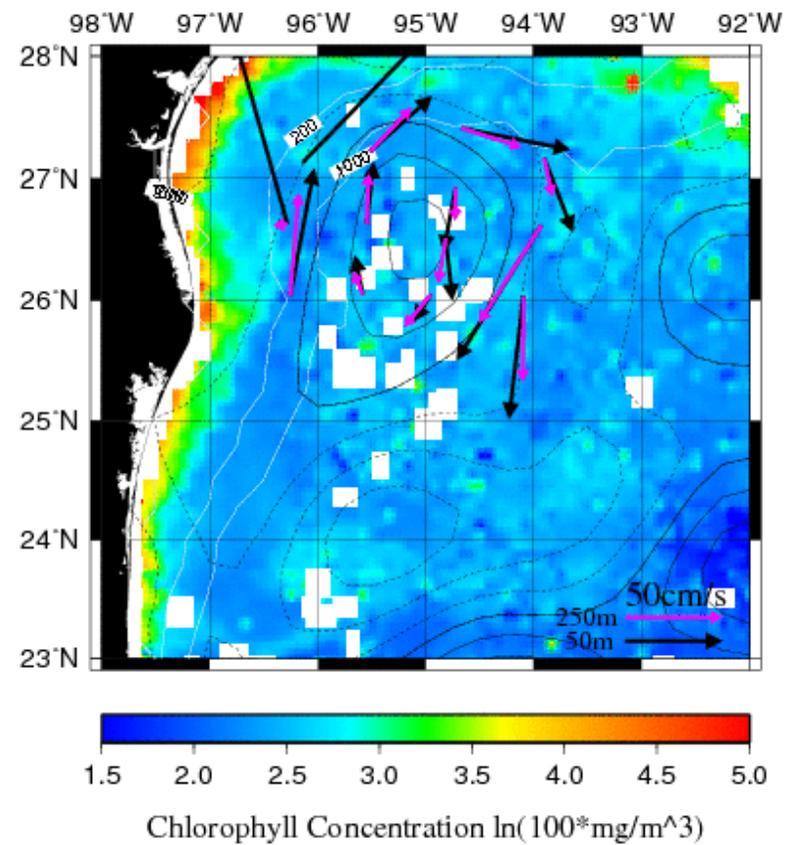
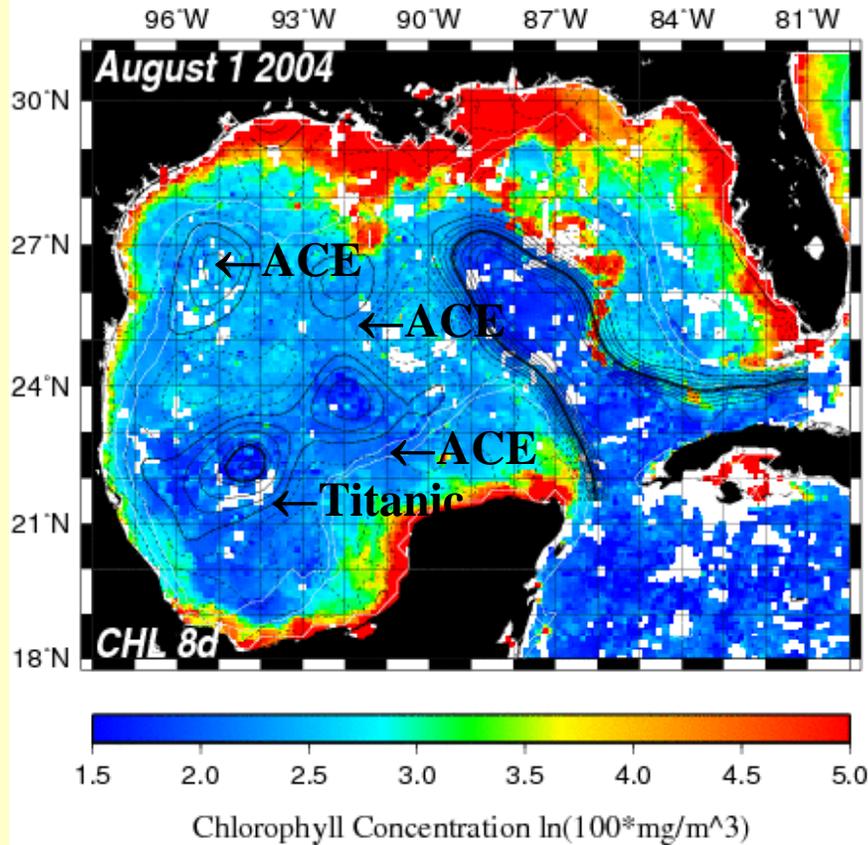
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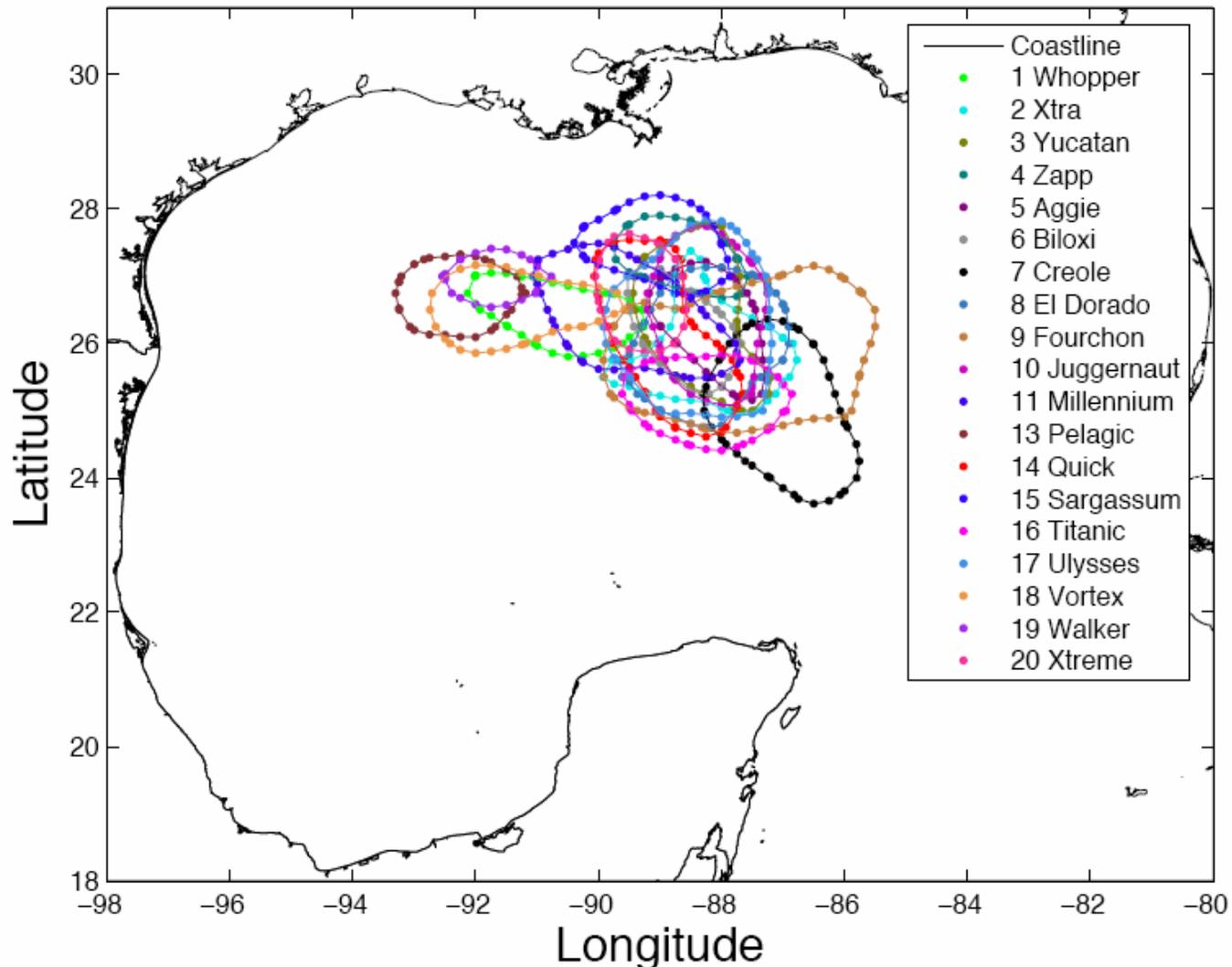
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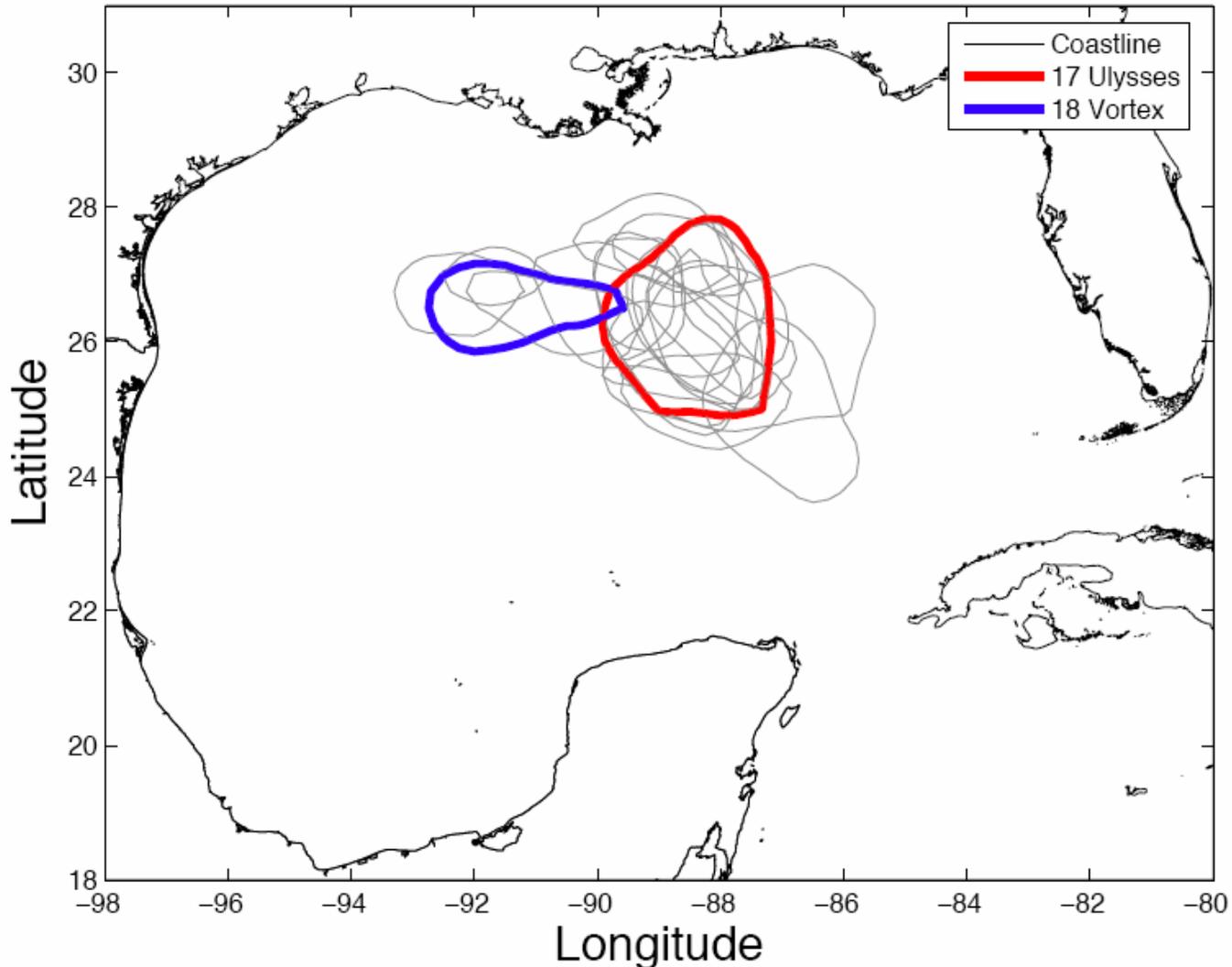
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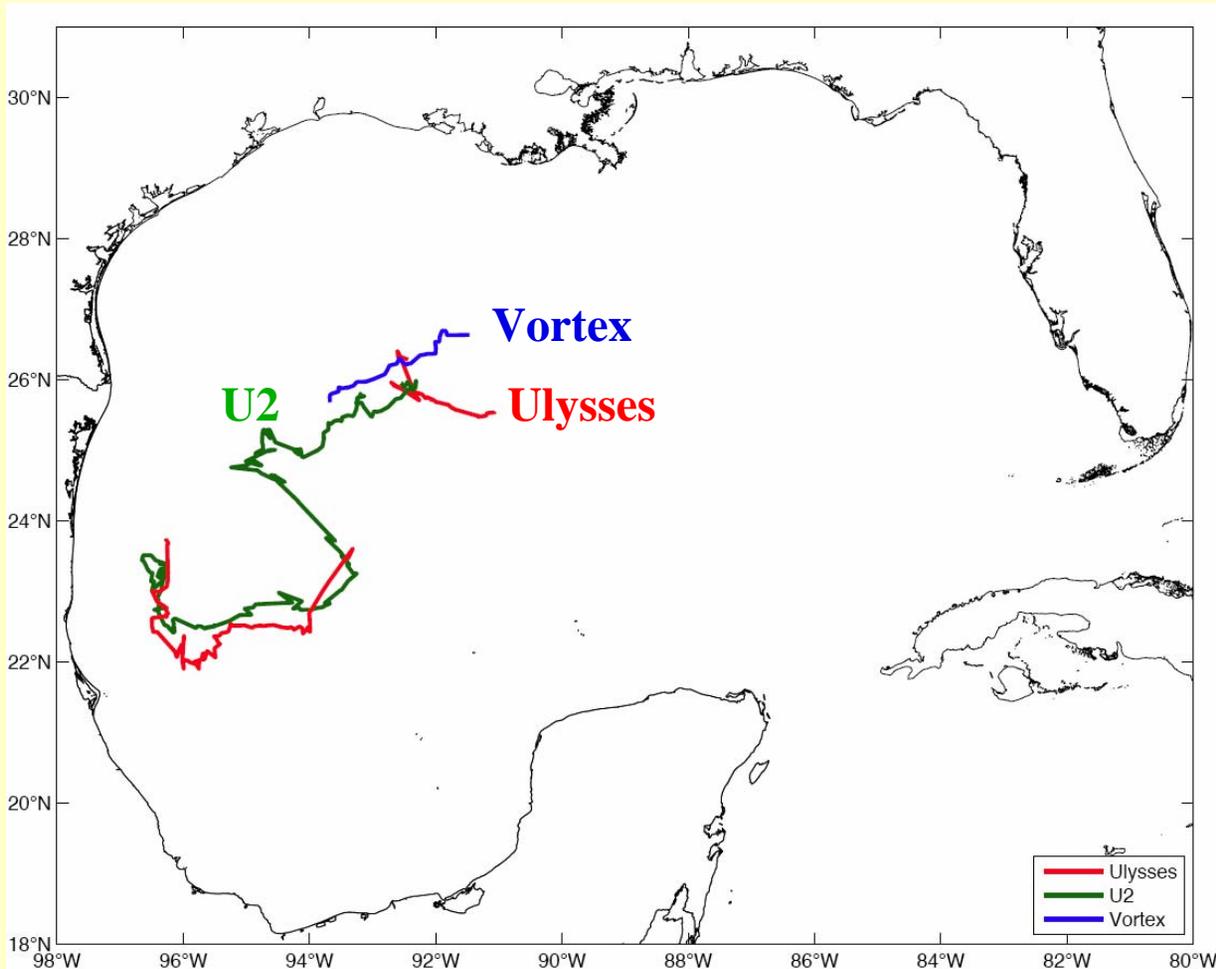
# LCEs at Separation: 1993–2005



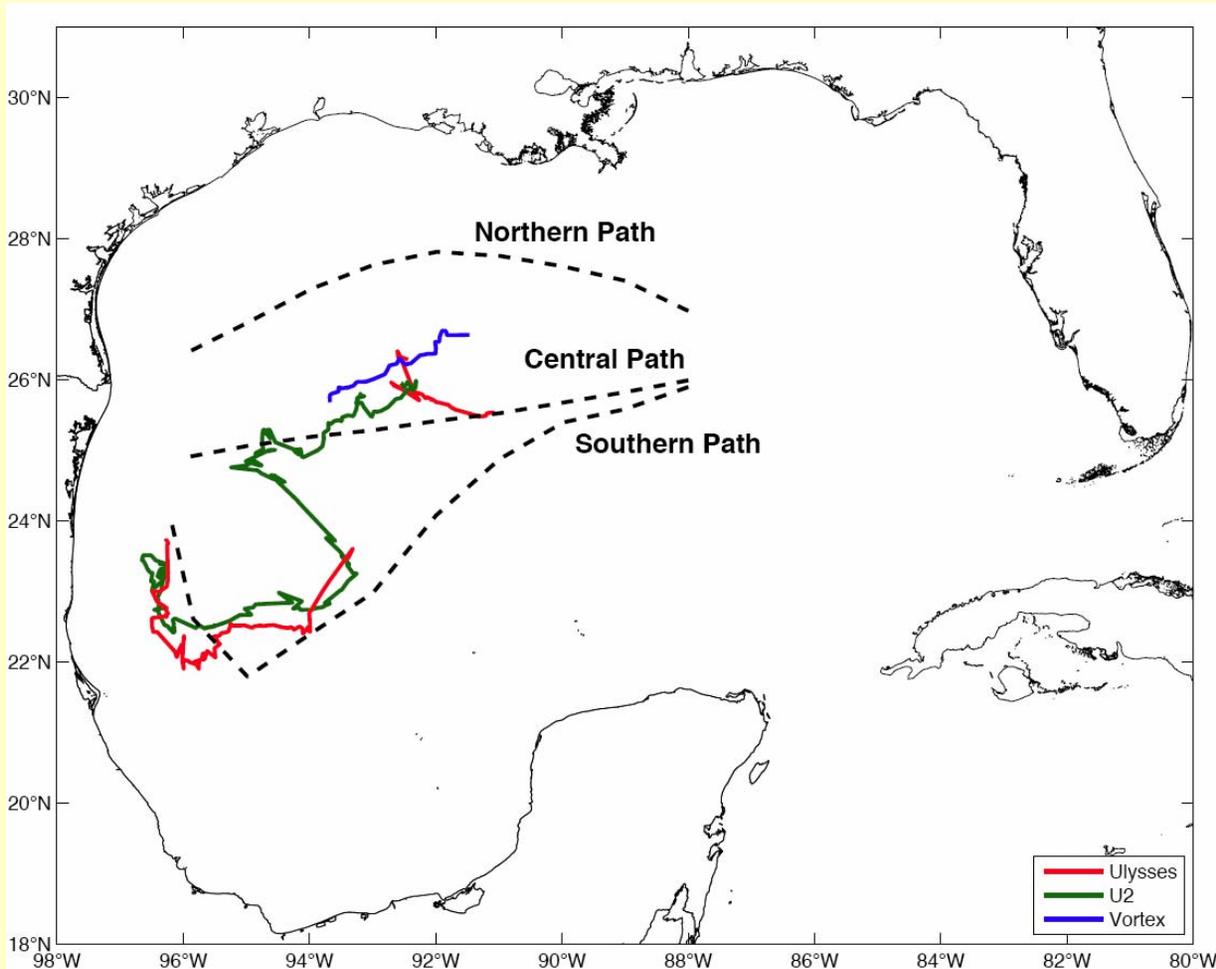
# LCEs Ulysses and Vortex



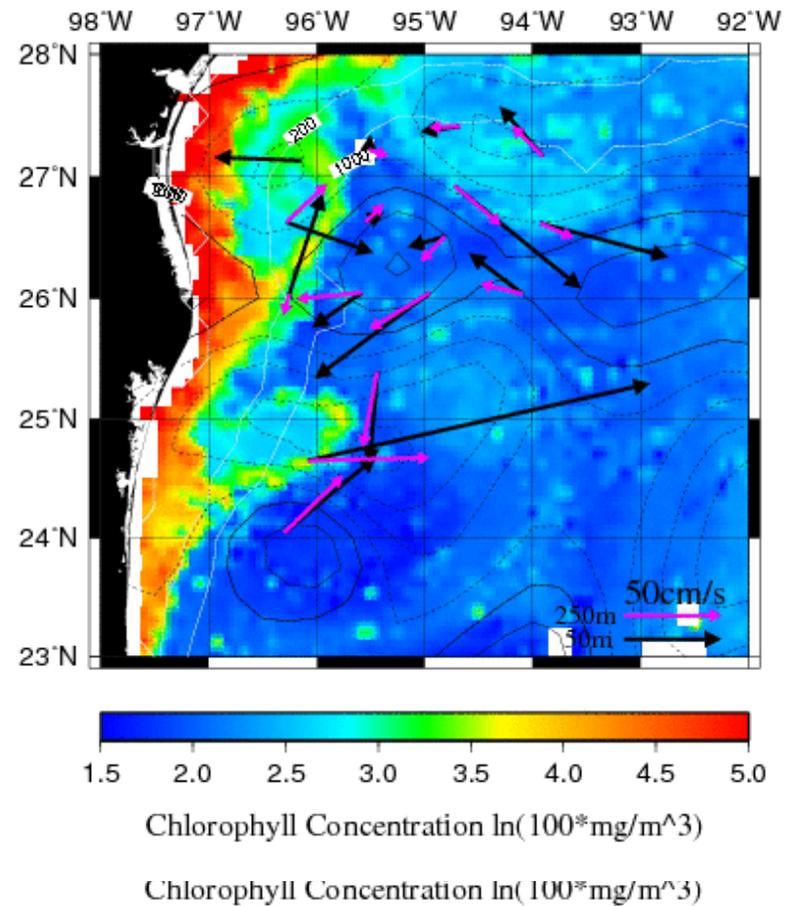
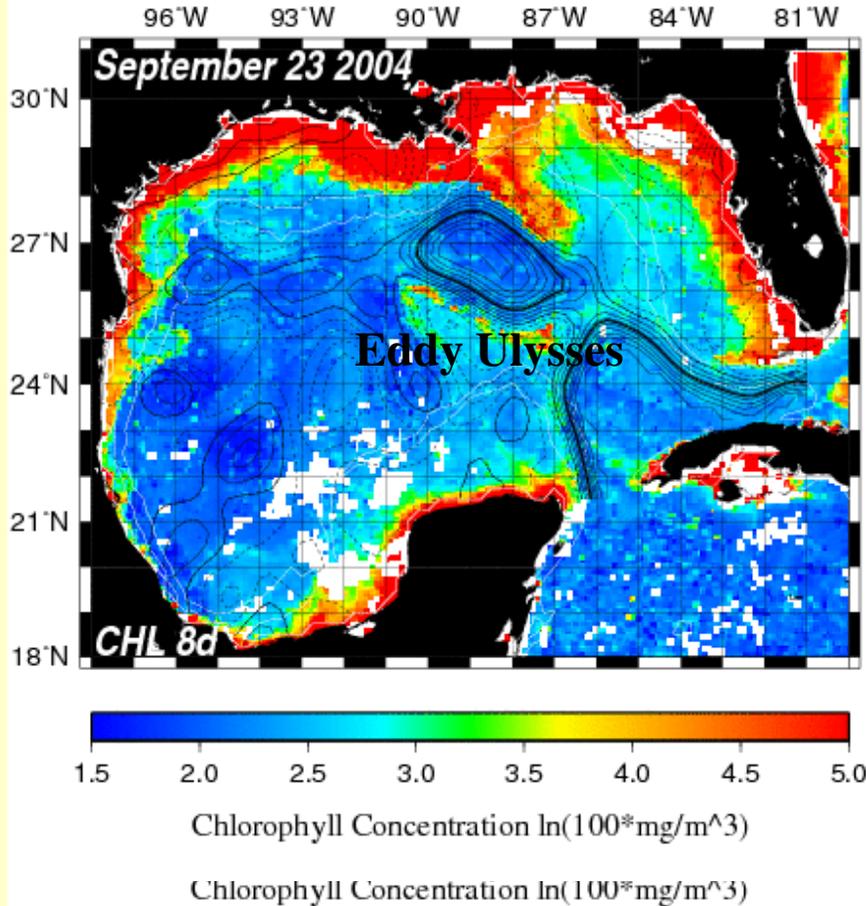
# LCEs Paths During NW Gulf Program



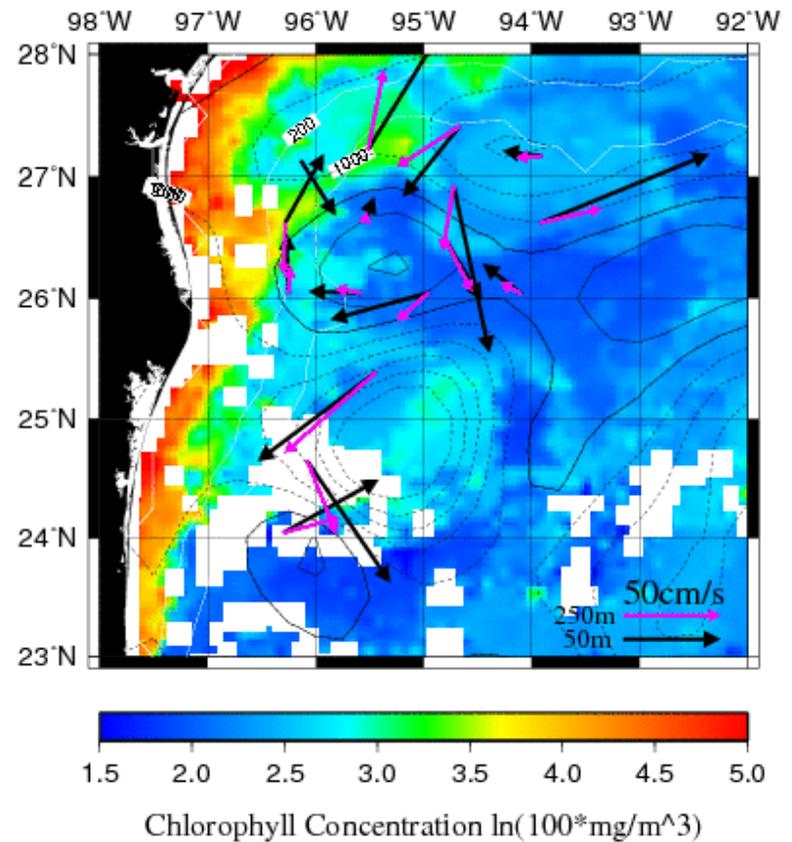
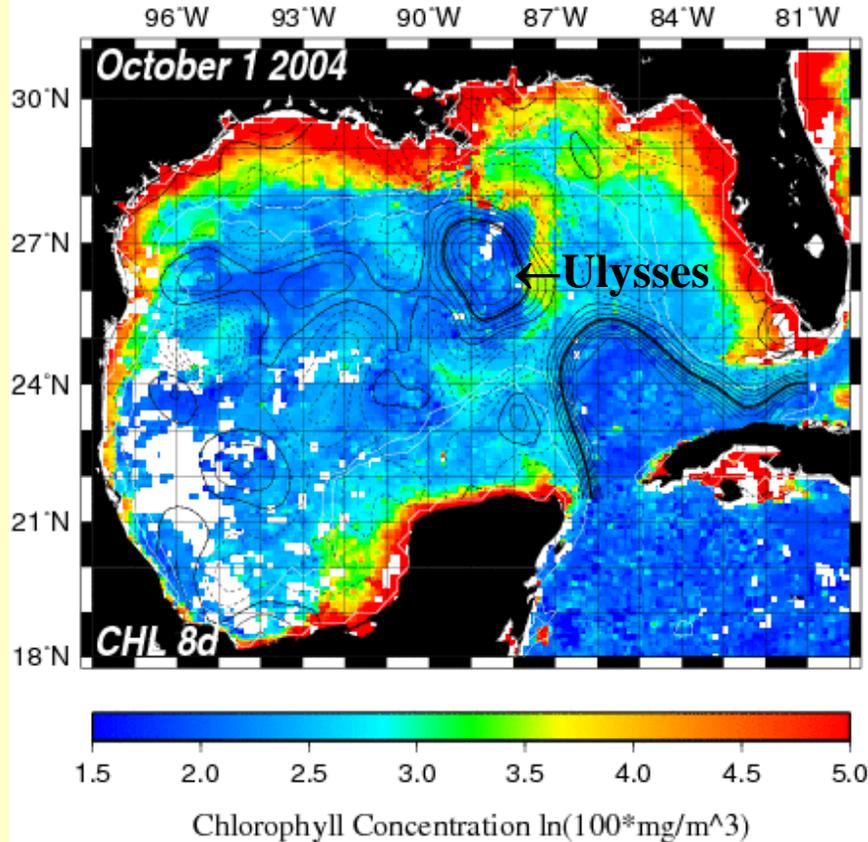
# LCEs Paths During NW Gulf Program



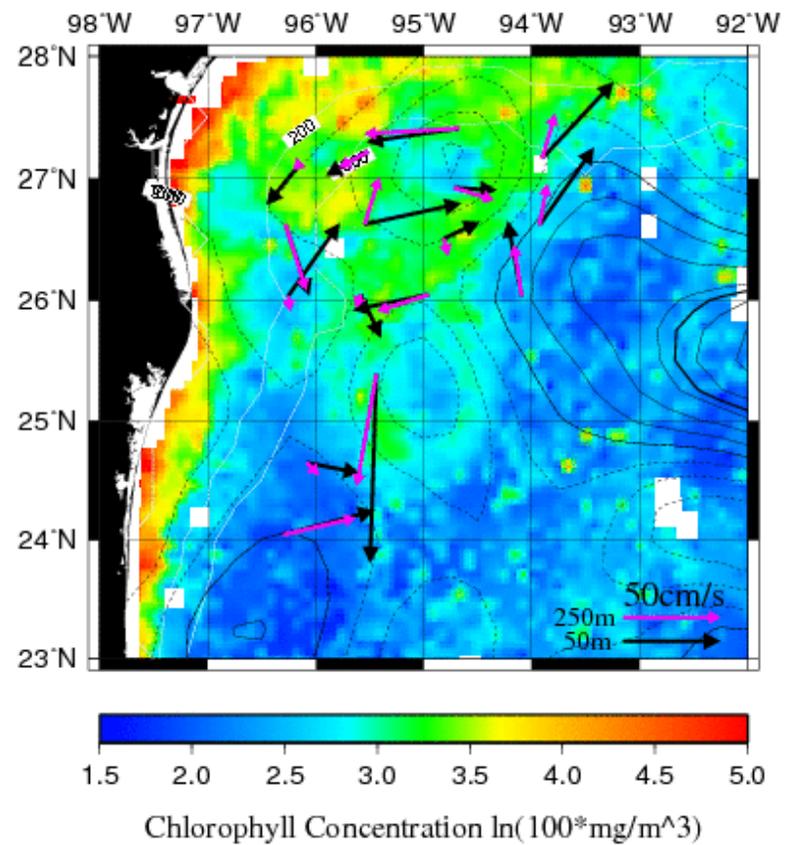
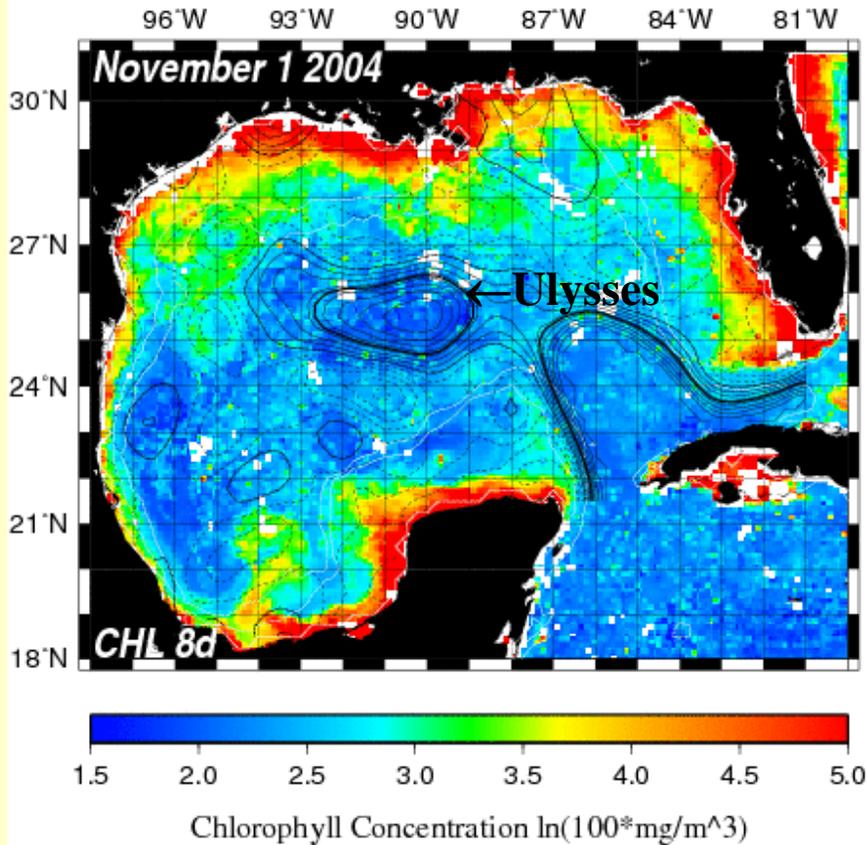
# Eddy Ulysses



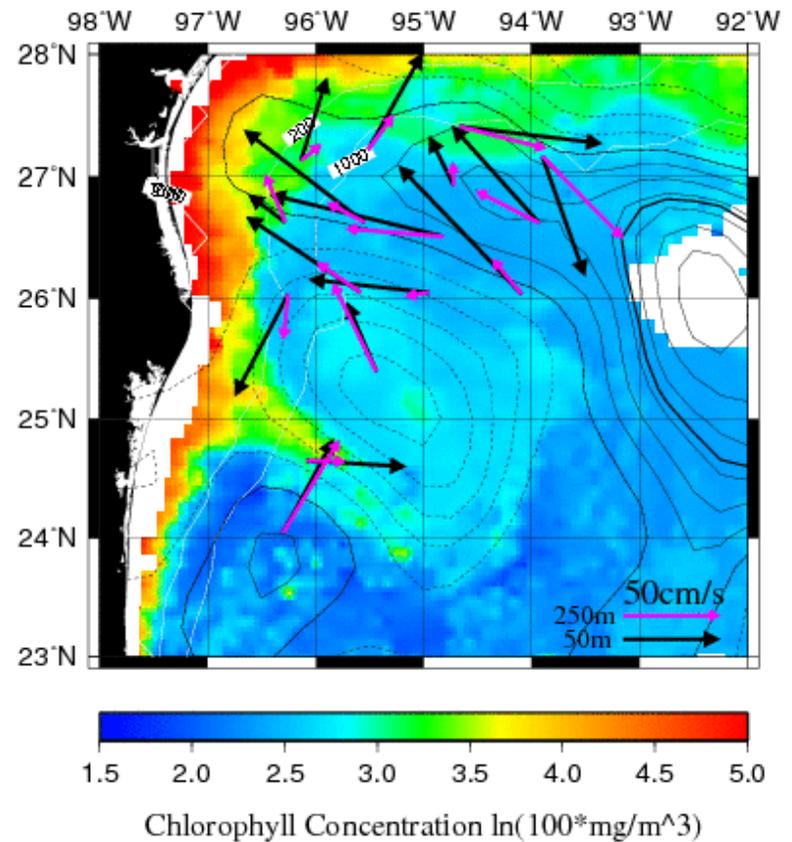
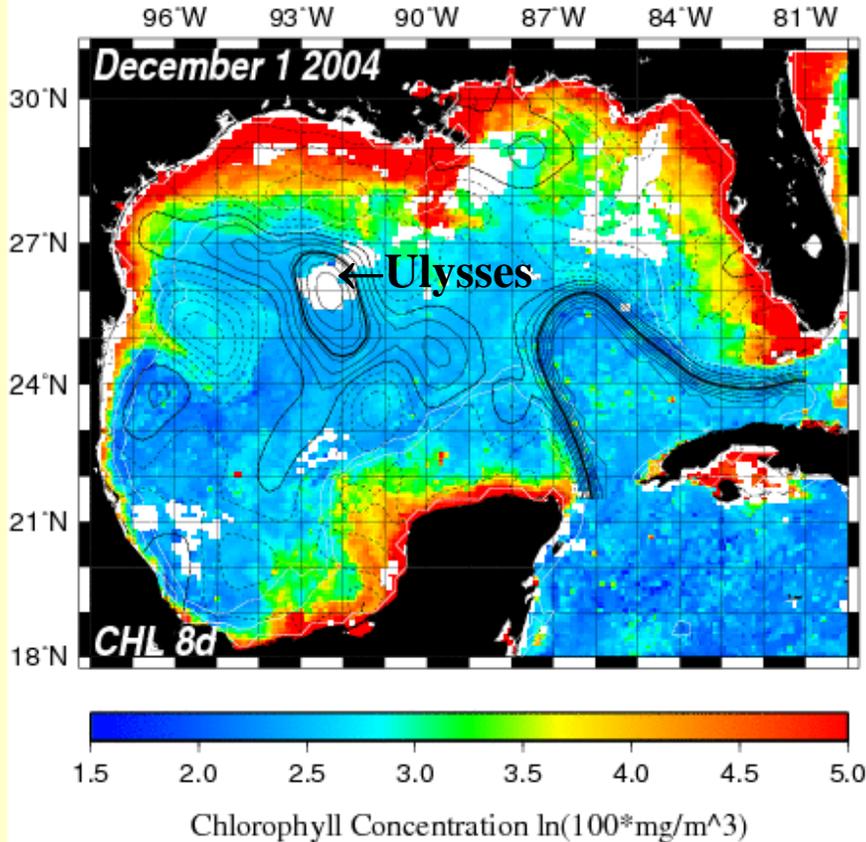
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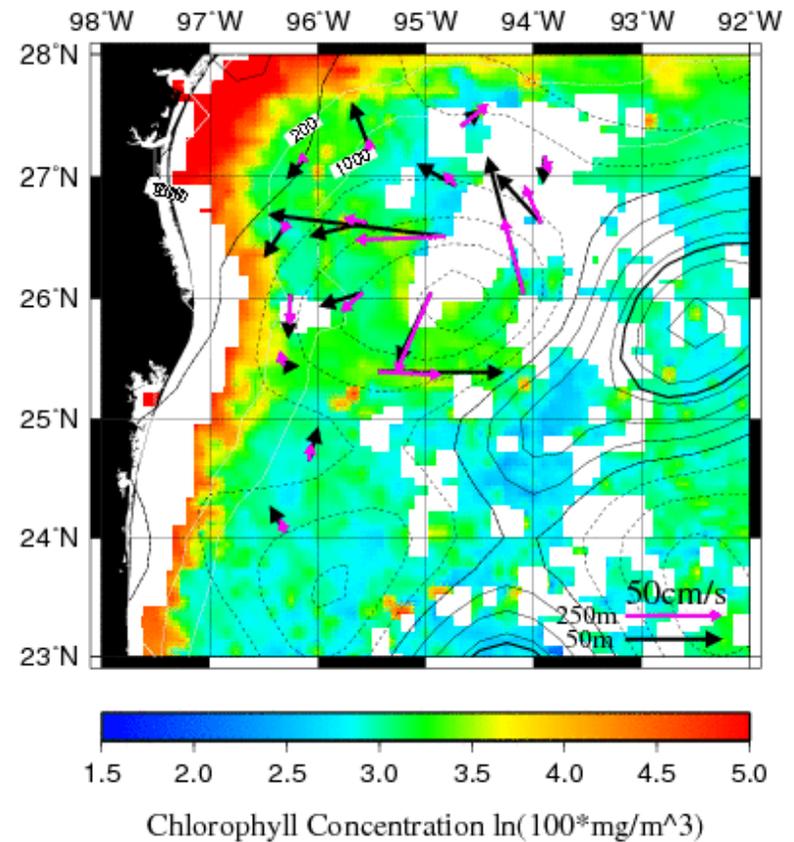
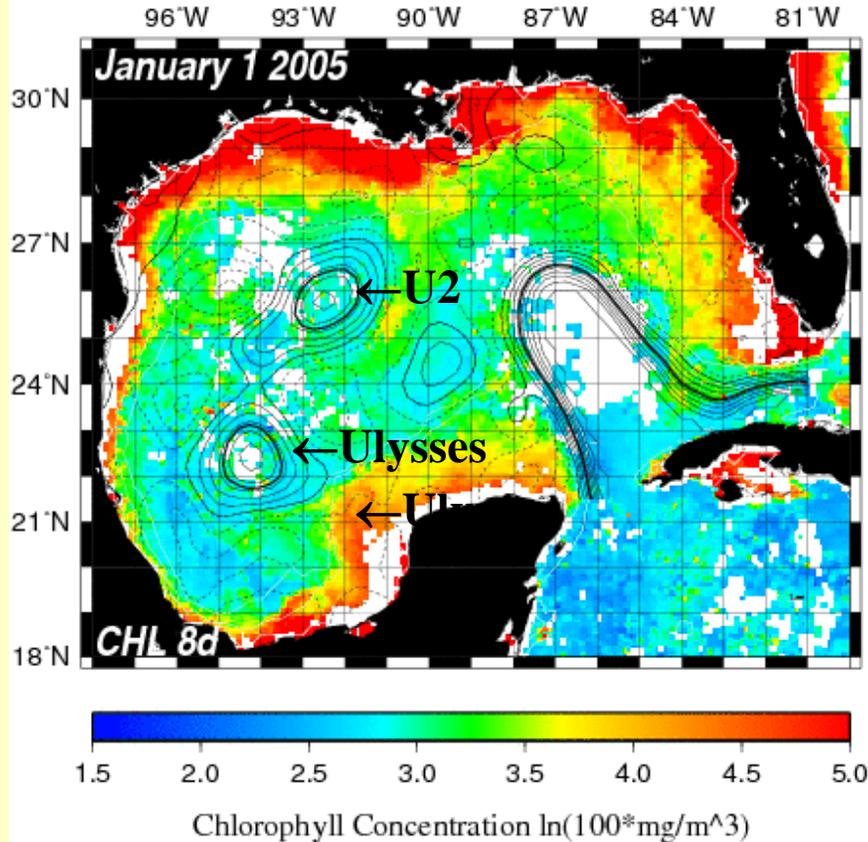
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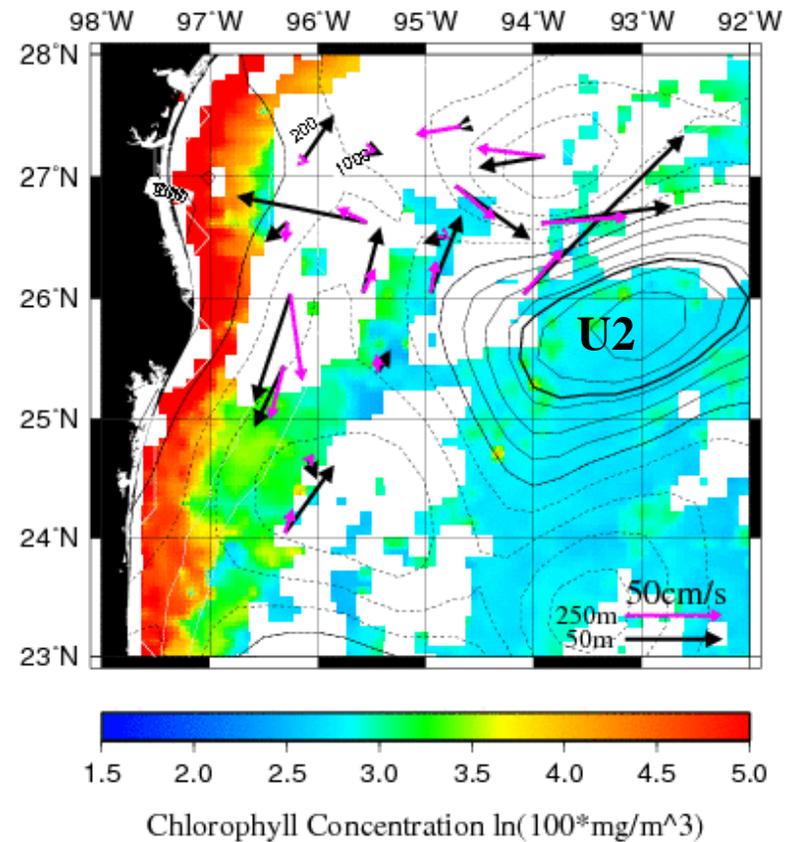
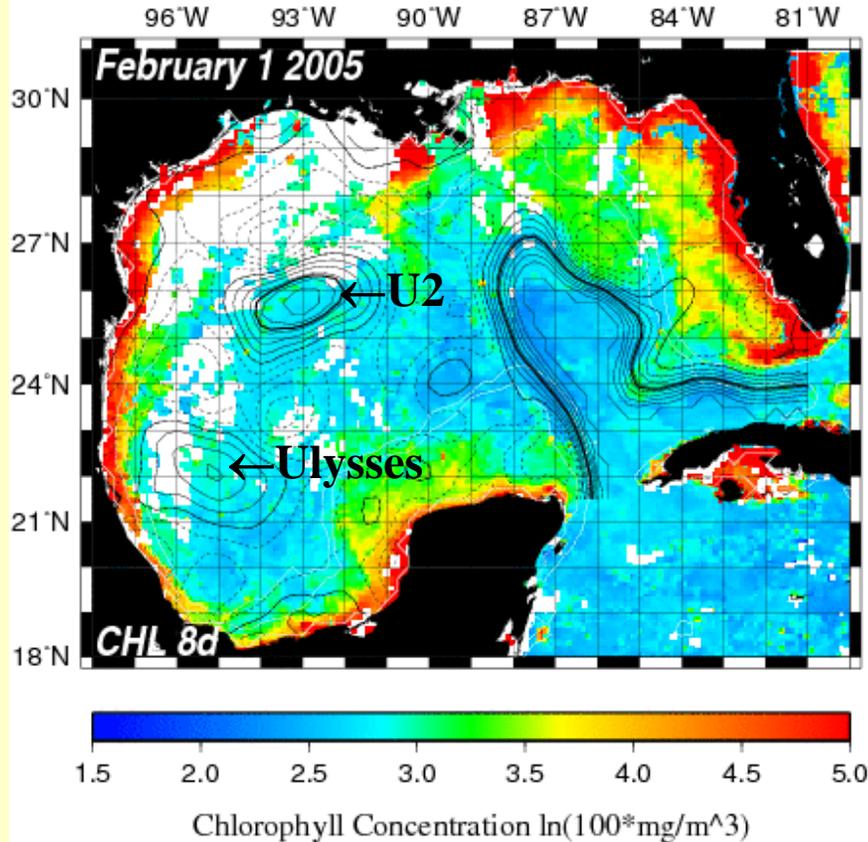
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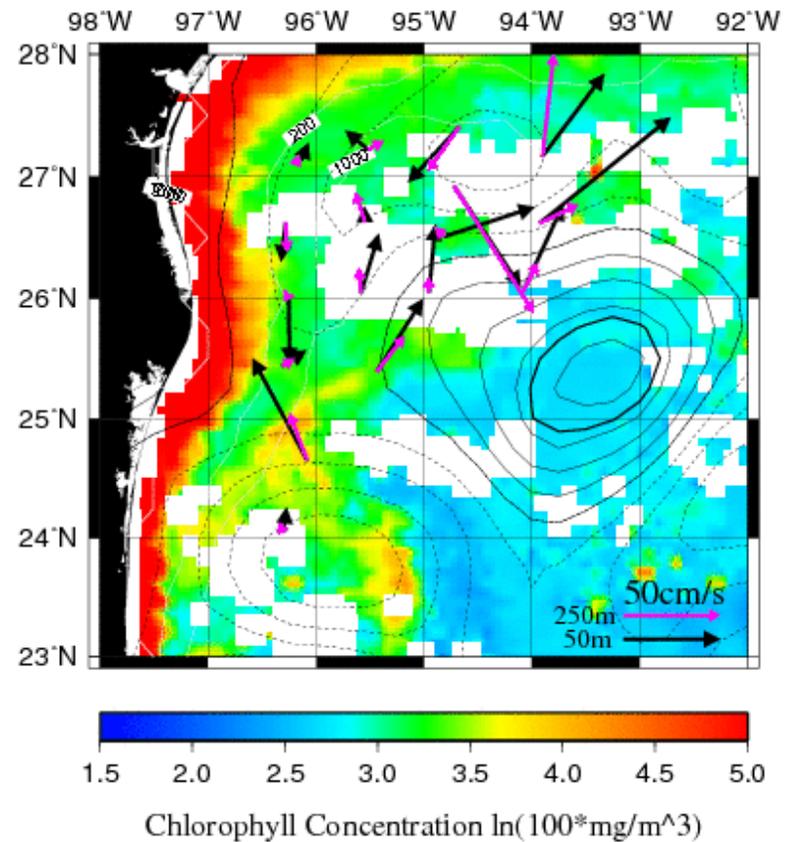
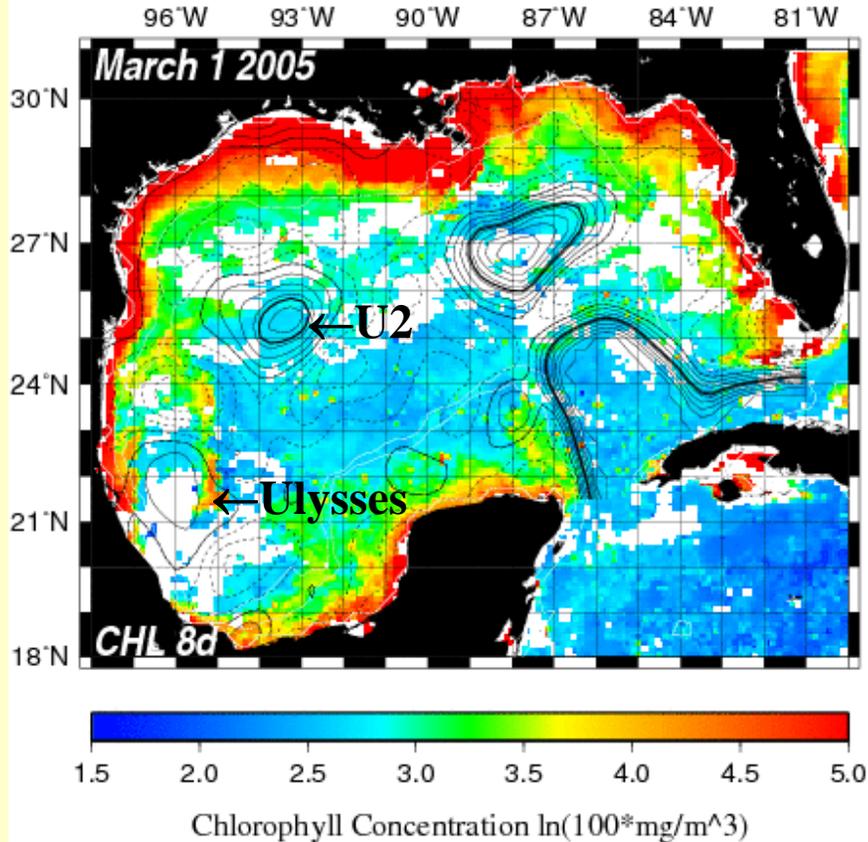
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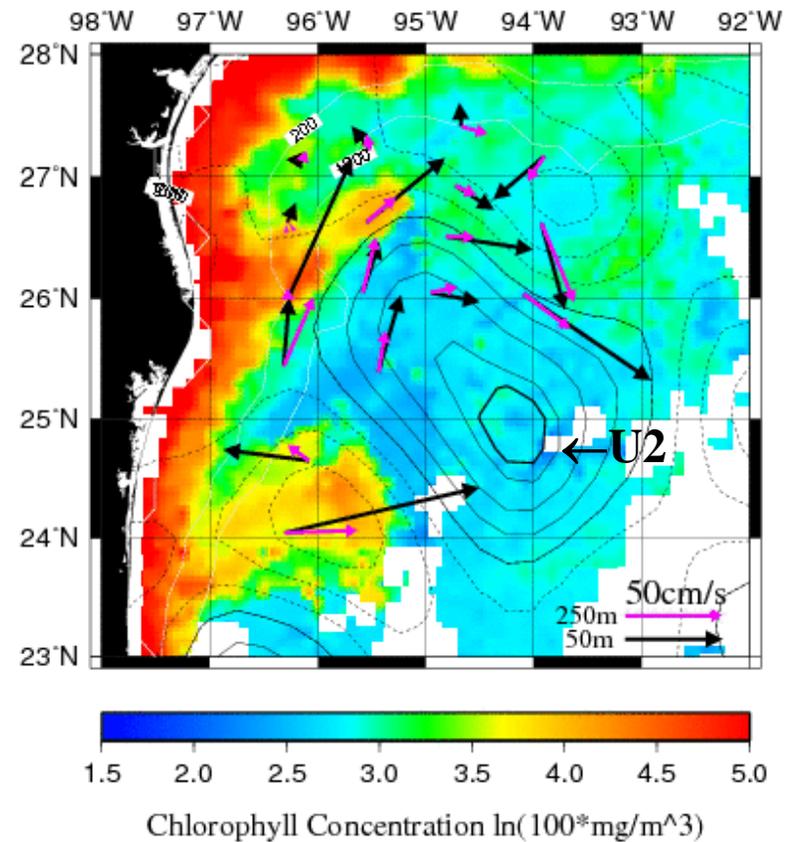
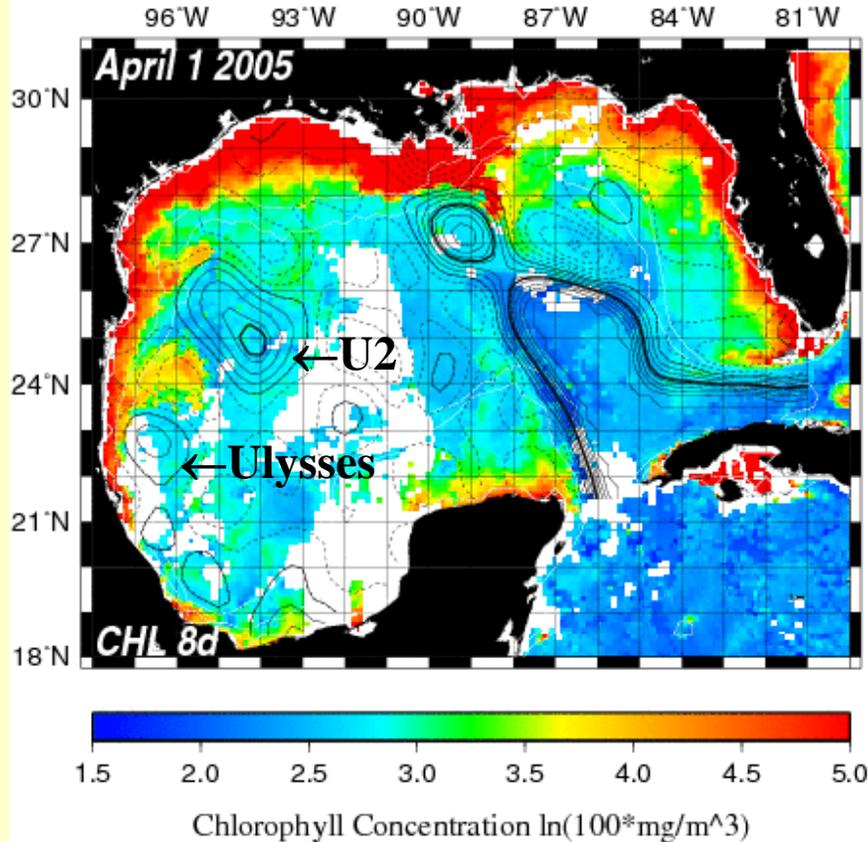
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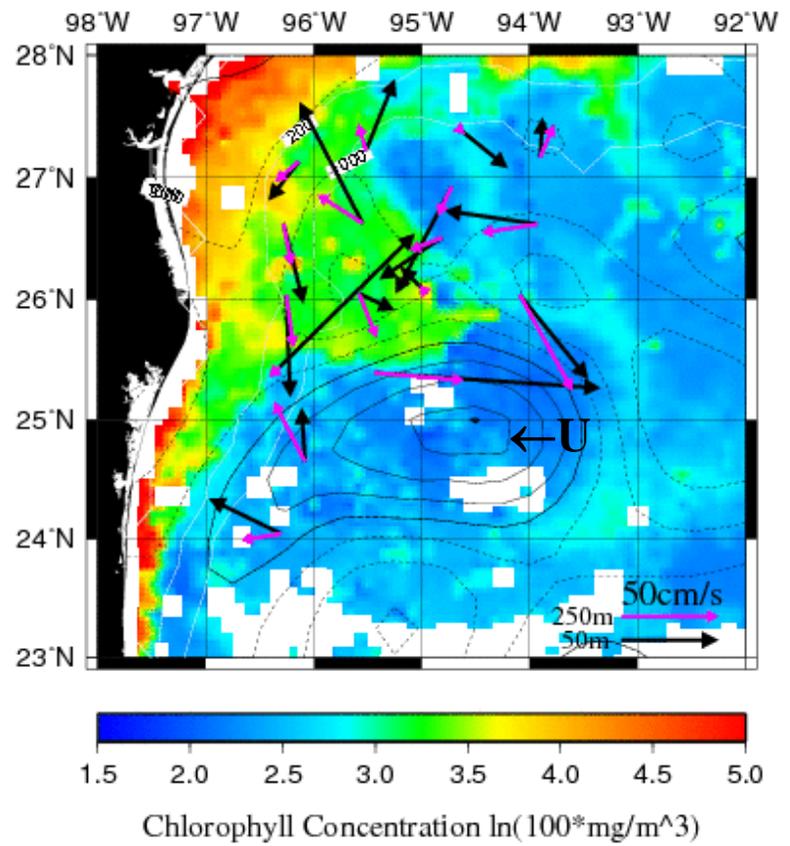
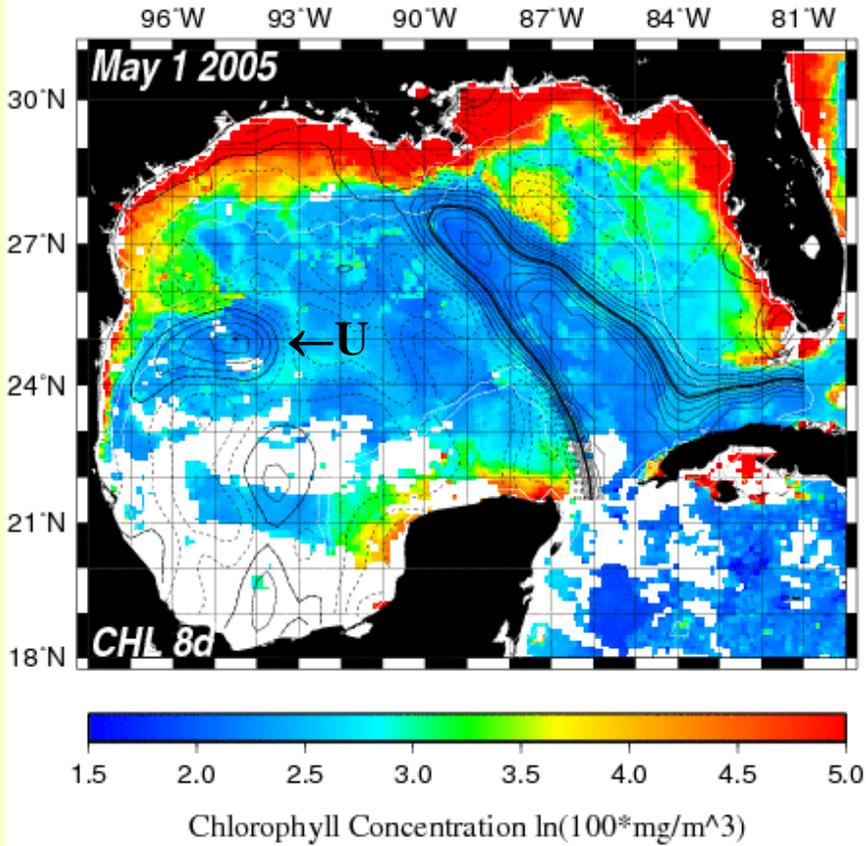
# 1 March 2005



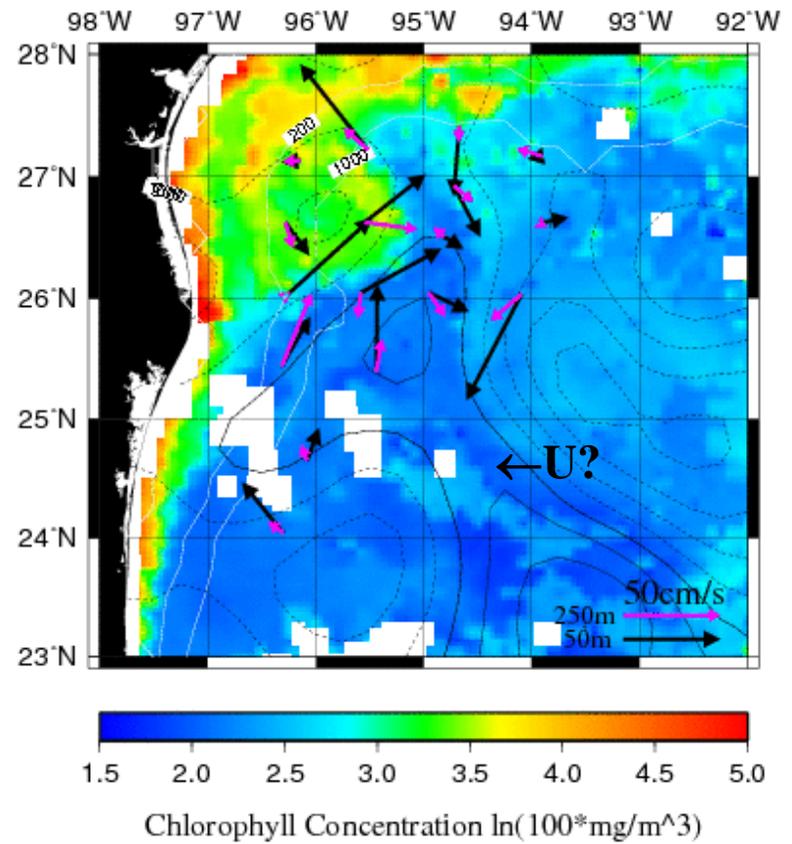
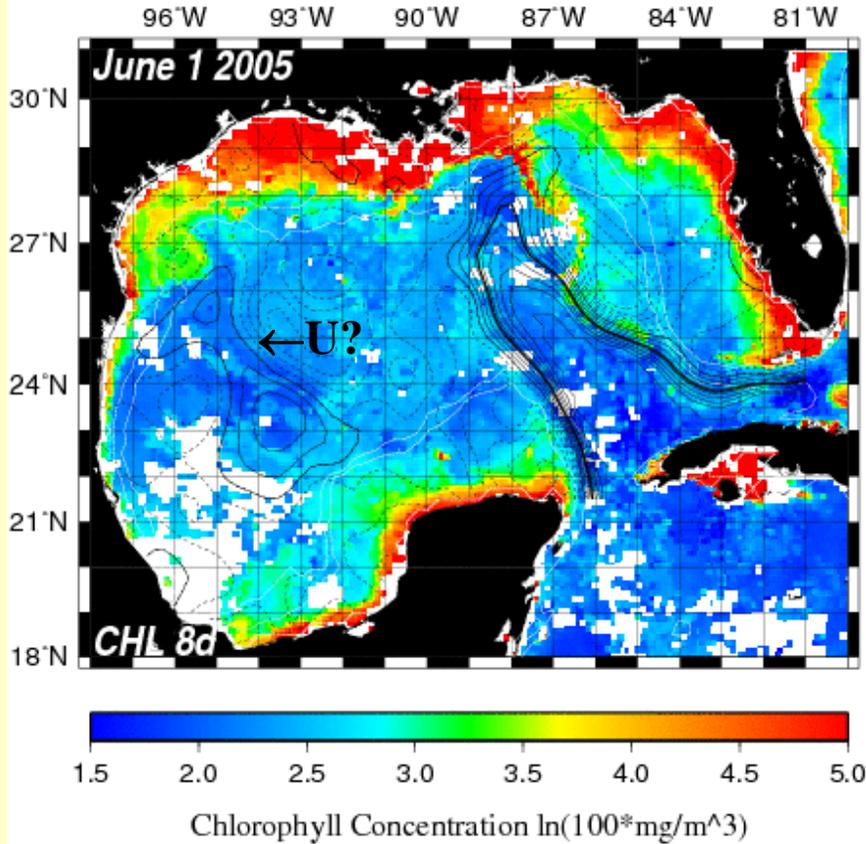
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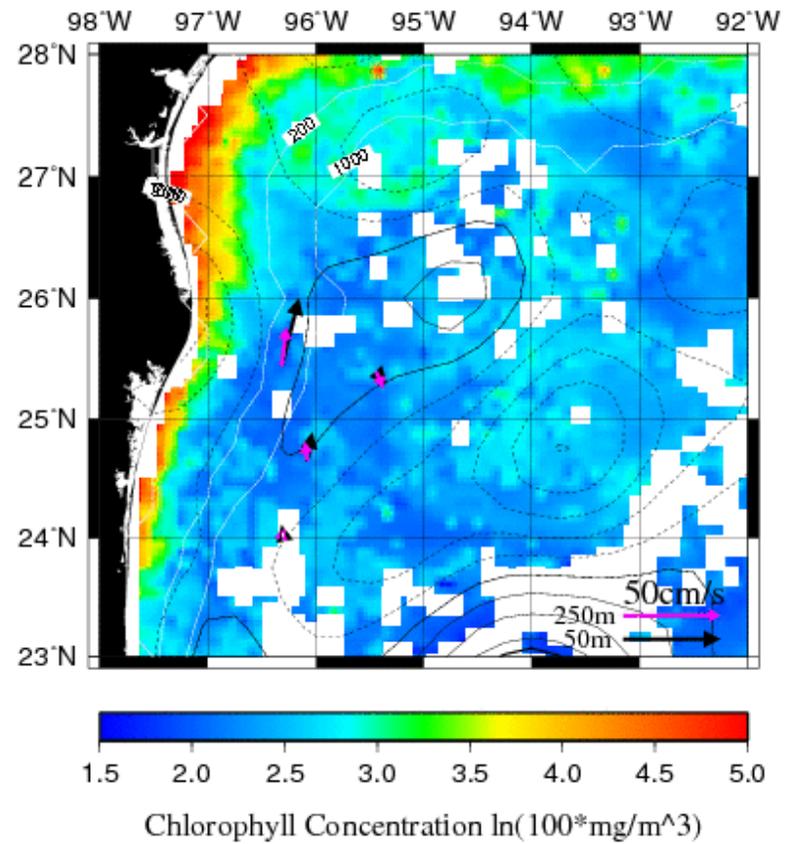
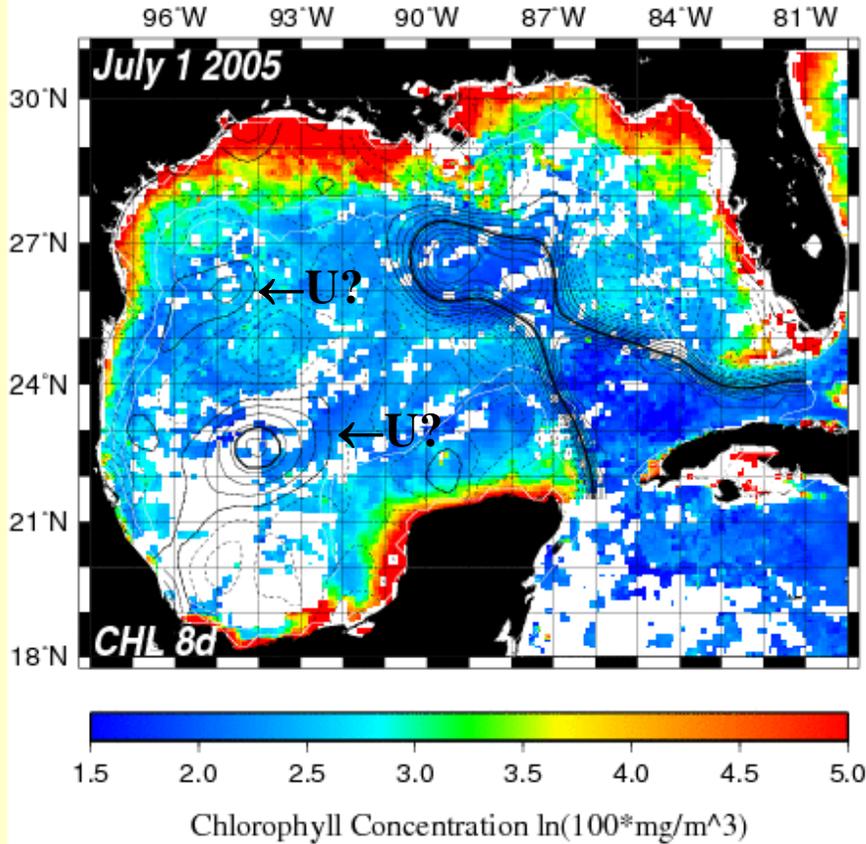
# 1 May 2005



# 1 June 2005



# 1 July 2005



# Eddy Ulysses Summary

- ▶ **Large energetic LC Eddy detached from Loop Current in September 2004.**
- ▶ **This eddy ranked 2nd in areal extent and 6th in maximum SSH out of the 20 eddies observed in the 1993–2005 record based.**
- ▶ **Eddy split in western Gulf and both pieces impacted circulation in the study array.**



# Northeast Gulf Study



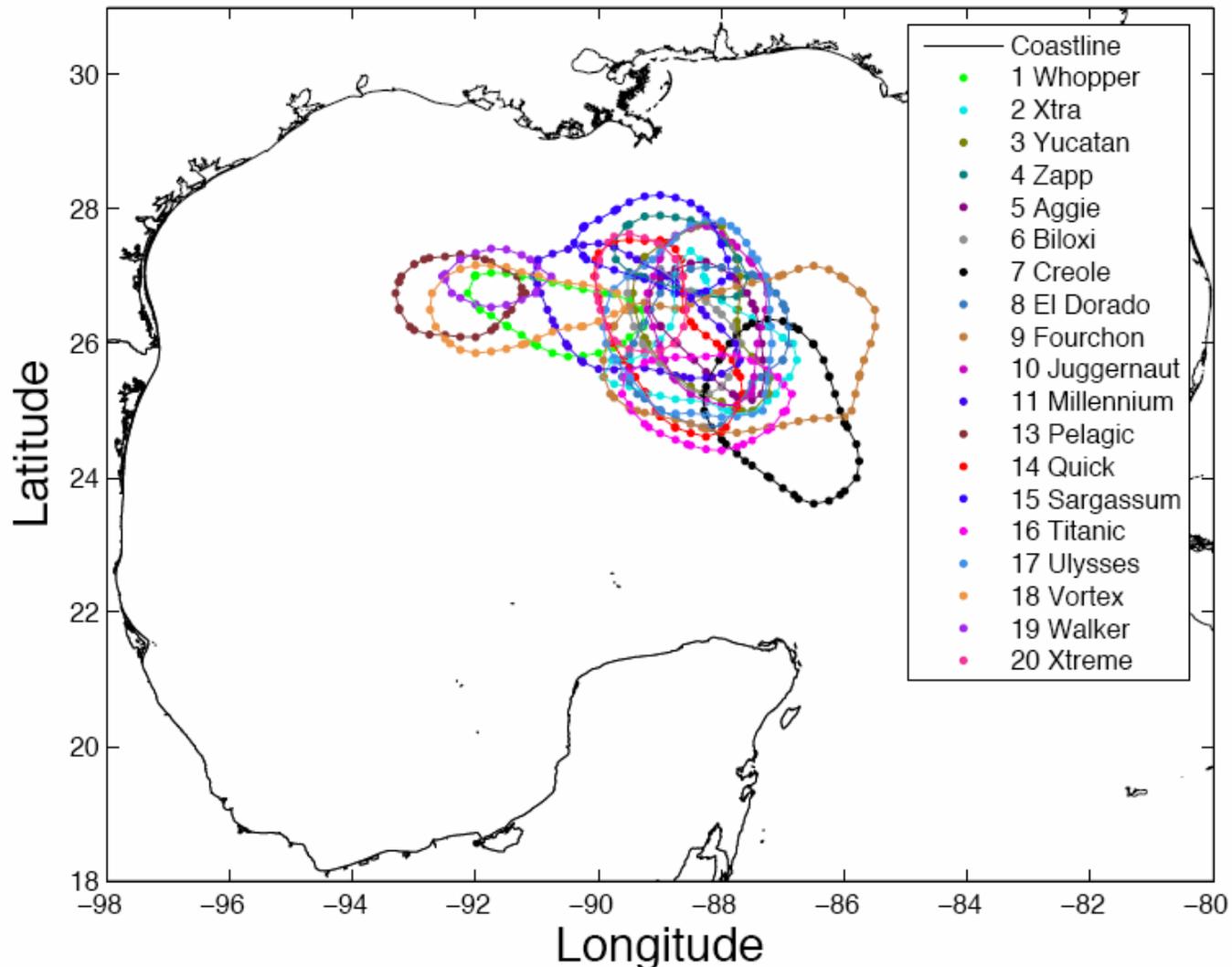
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# LCEs During NE Gulf Program

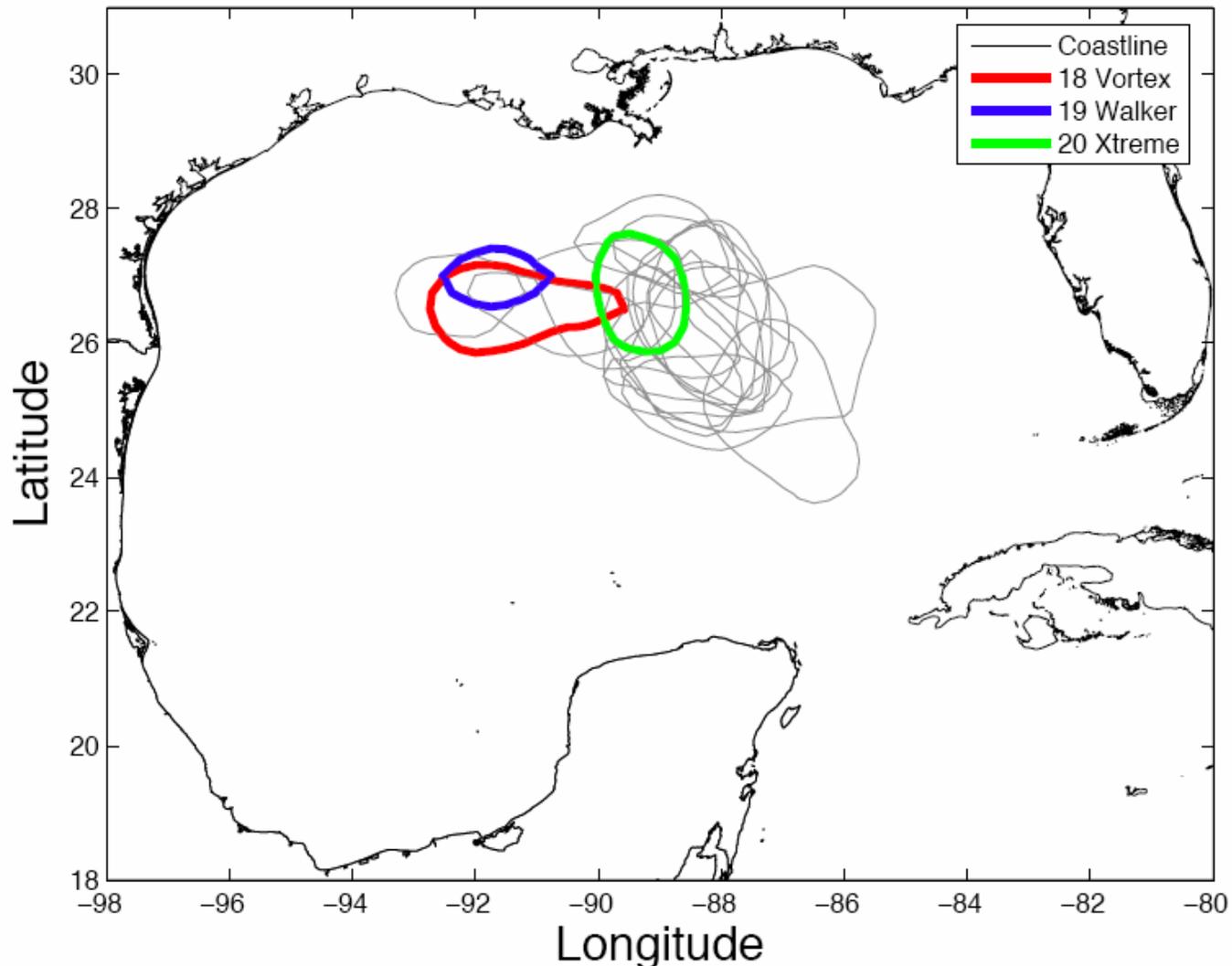
<b>Eddy Number</b>	<b>Date</b>	<b>Separation Period (months)</b>	<b>Industry Eddy Name</b>
<b>#18</b>	<b>13 September 2005</b>	<b>12.5</b>	<b>Vortex</b>
<b>#19</b>	<b>6 February 2006</b>	<b>5</b>	<b>Walker</b>
<b>#20</b>	<b>7 March 2006</b>	<b>1</b>	<b>Xtreme</b>



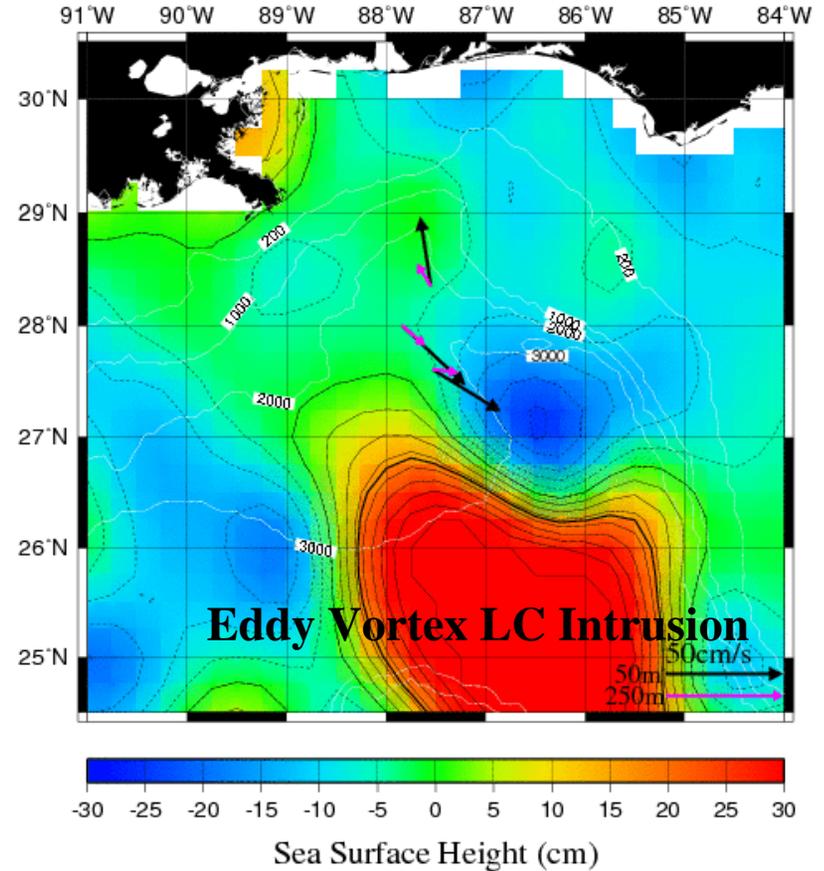
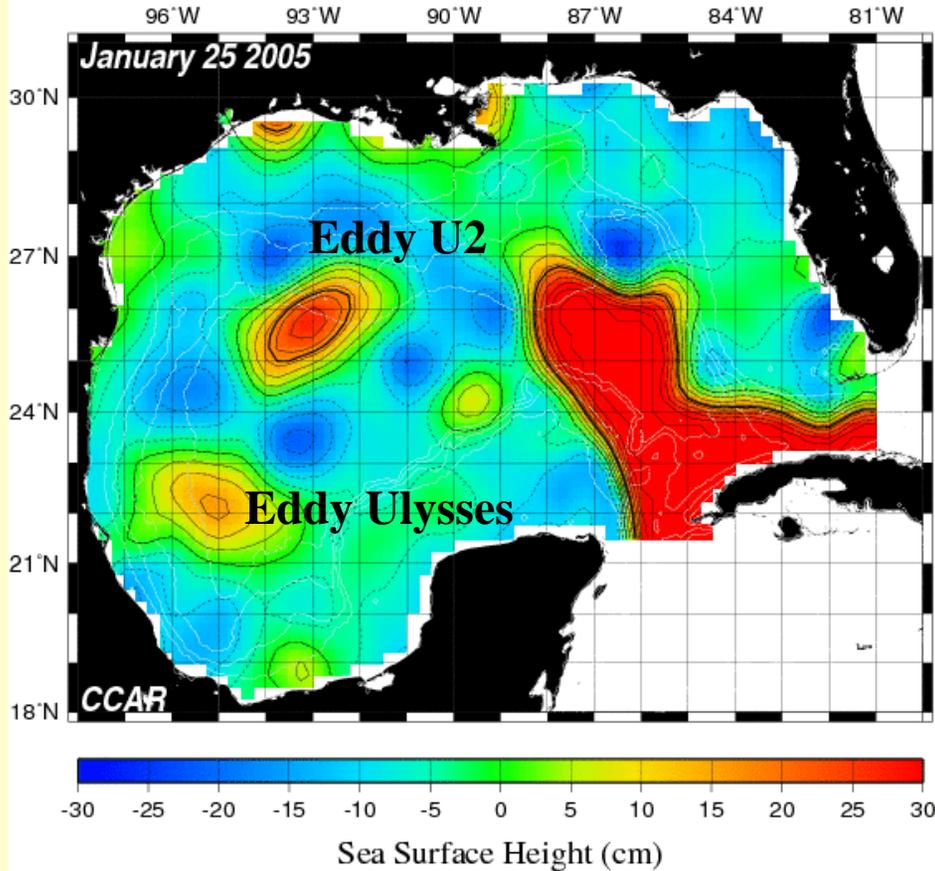
# LCEs at Separation:1993–2005



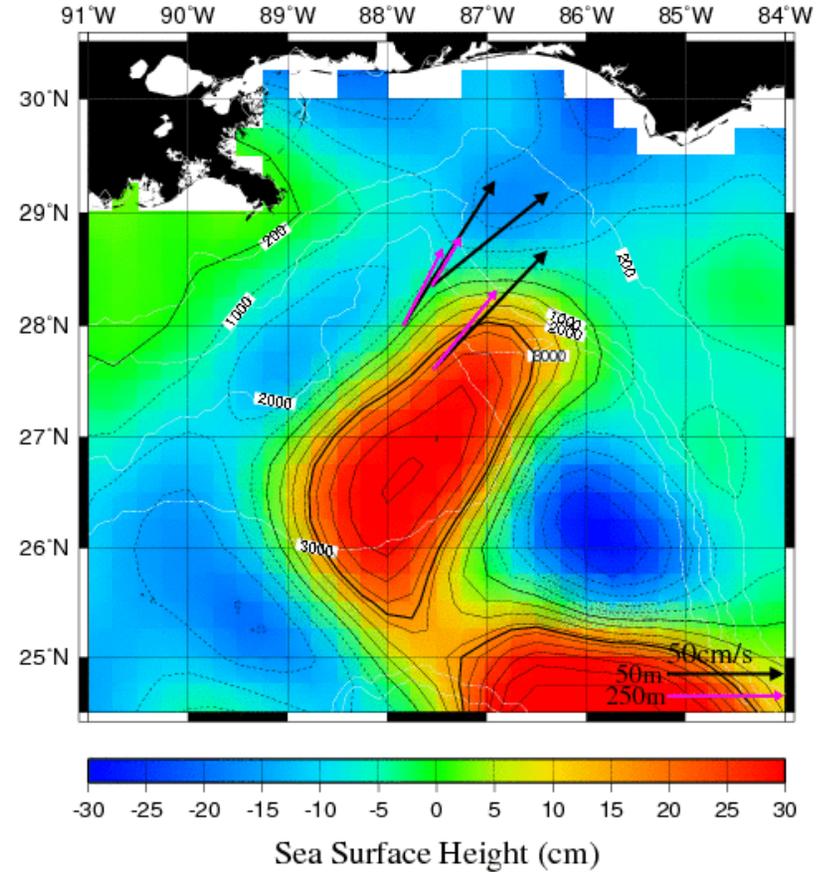
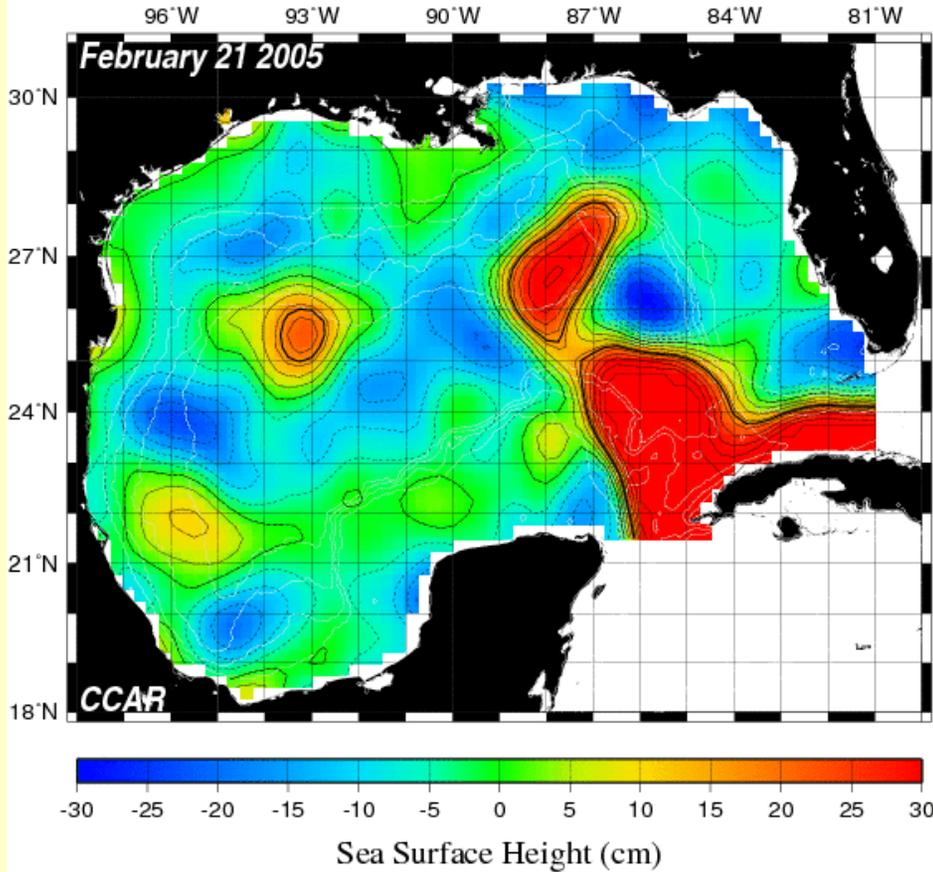
# LCEs Vortex, Walker, and Xtreme



# Beginning of Program: Altimetry



# Eddy Vortex Detachment #1

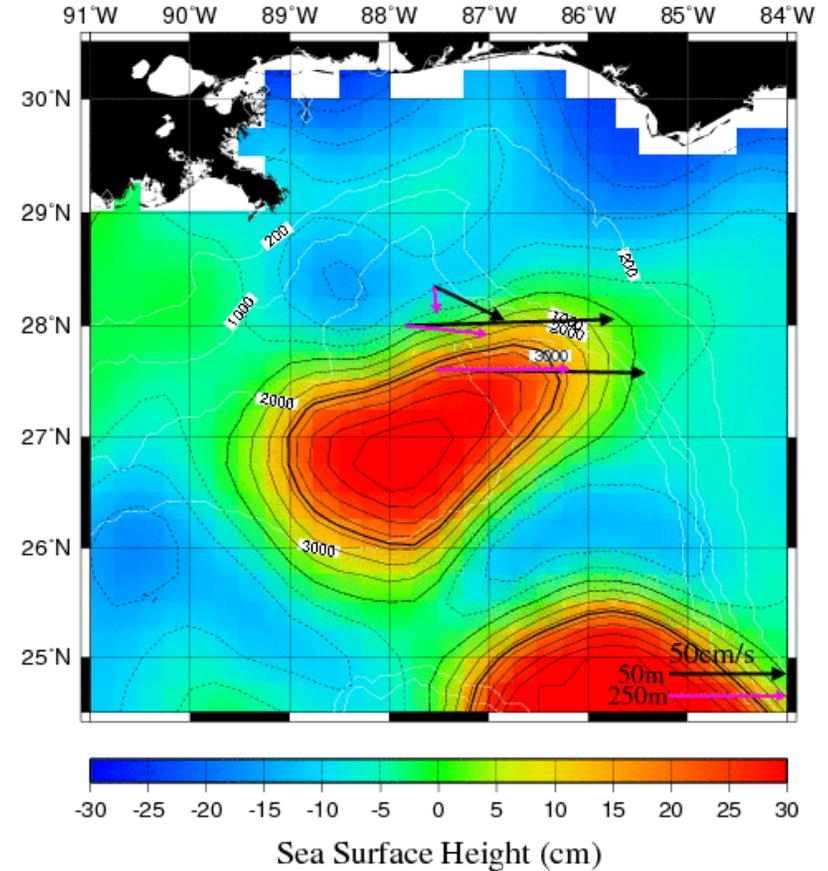
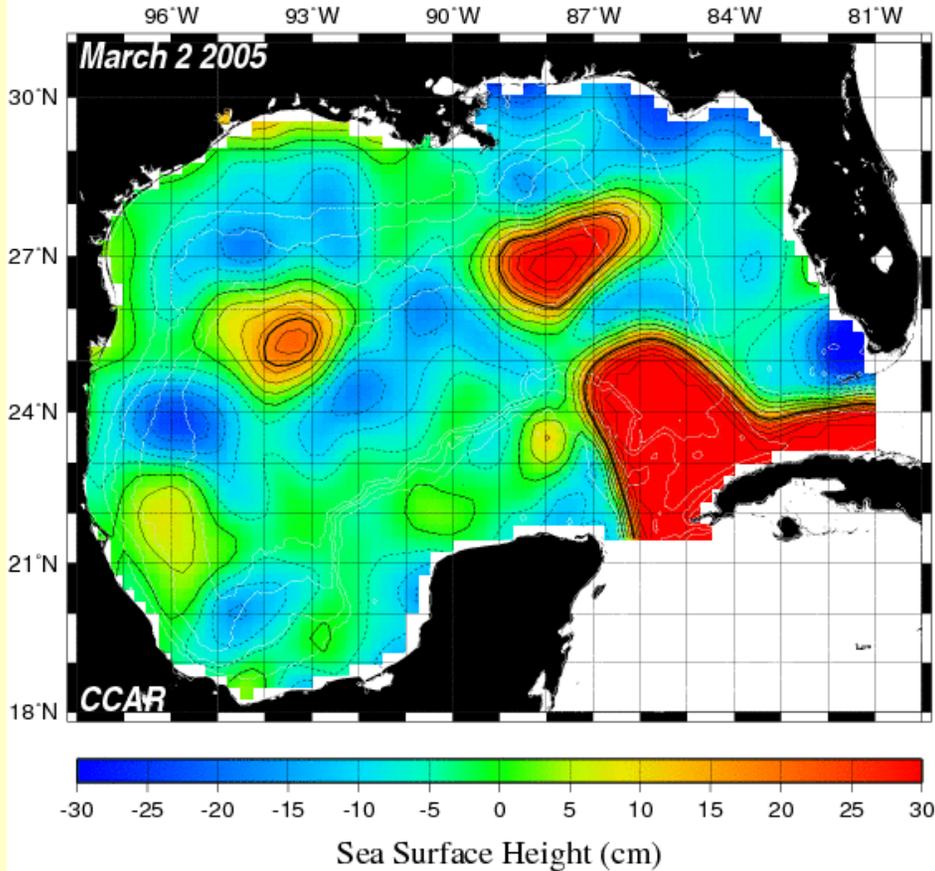


# Eddy Vortex Detachment, Reattachment and Separation Events

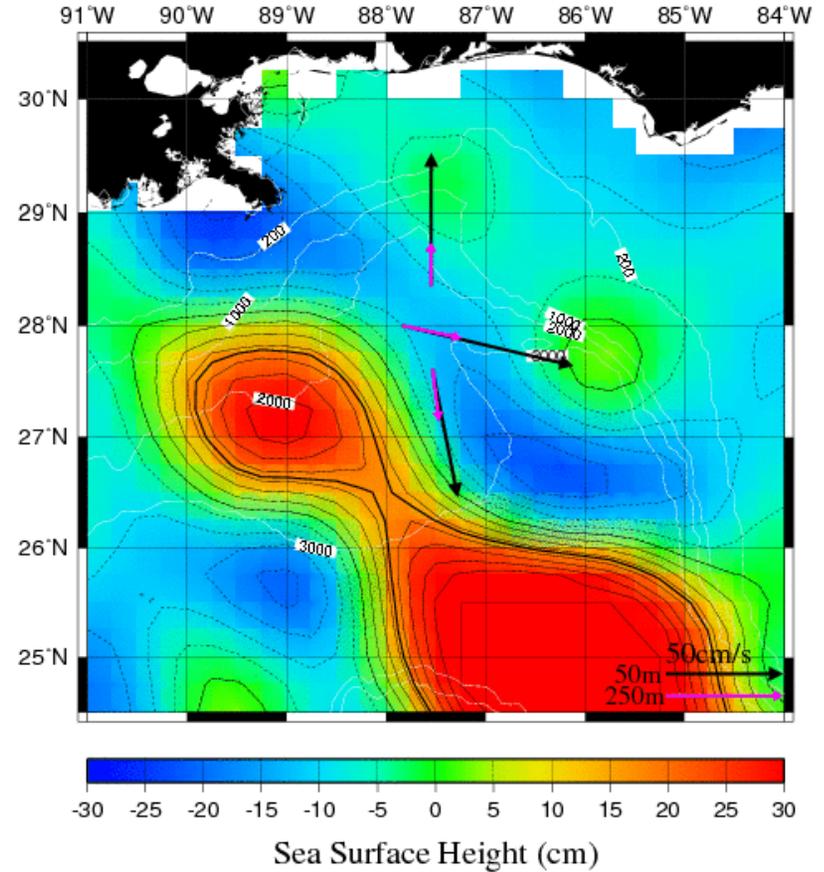
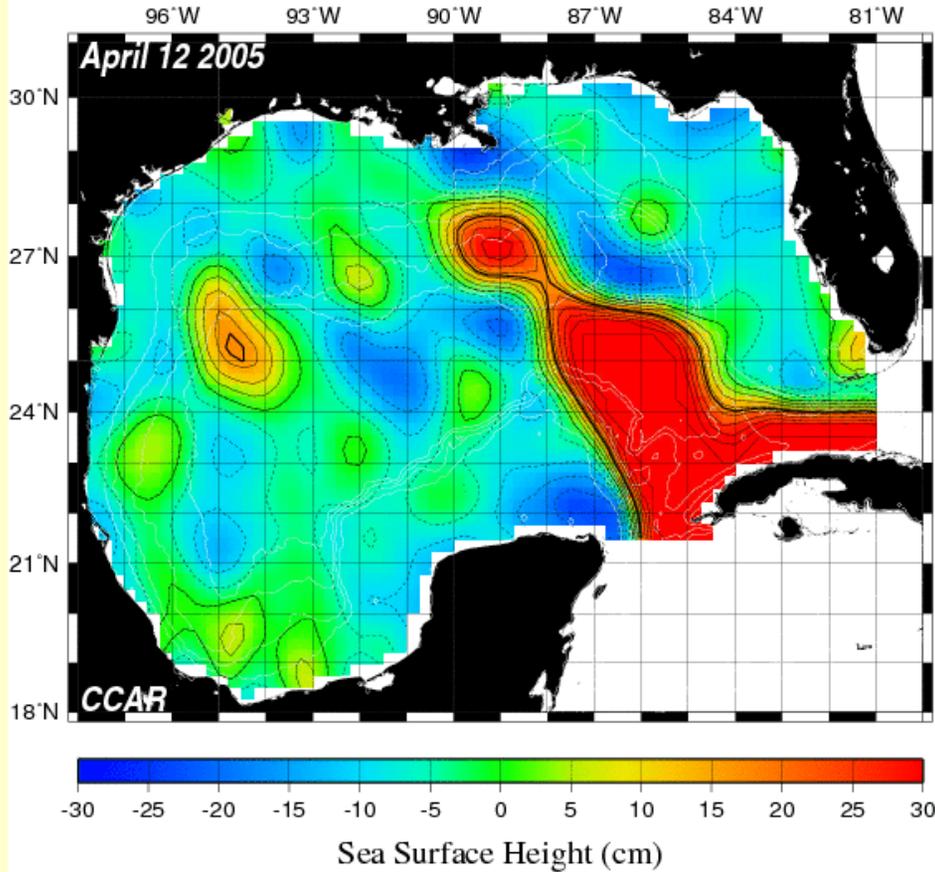
Detachment #1	21 February 2005
Reattachment #1	12 April 2005
Detachment #2	14 May 2005
Reattachment #2	21 May 2005
Detachment #3	16 June 2005
Reattachment #3	30 June 2005
Detachment #4	3 August 2005
Reattachment #4	21 August 2005
Separation	13 September 2005



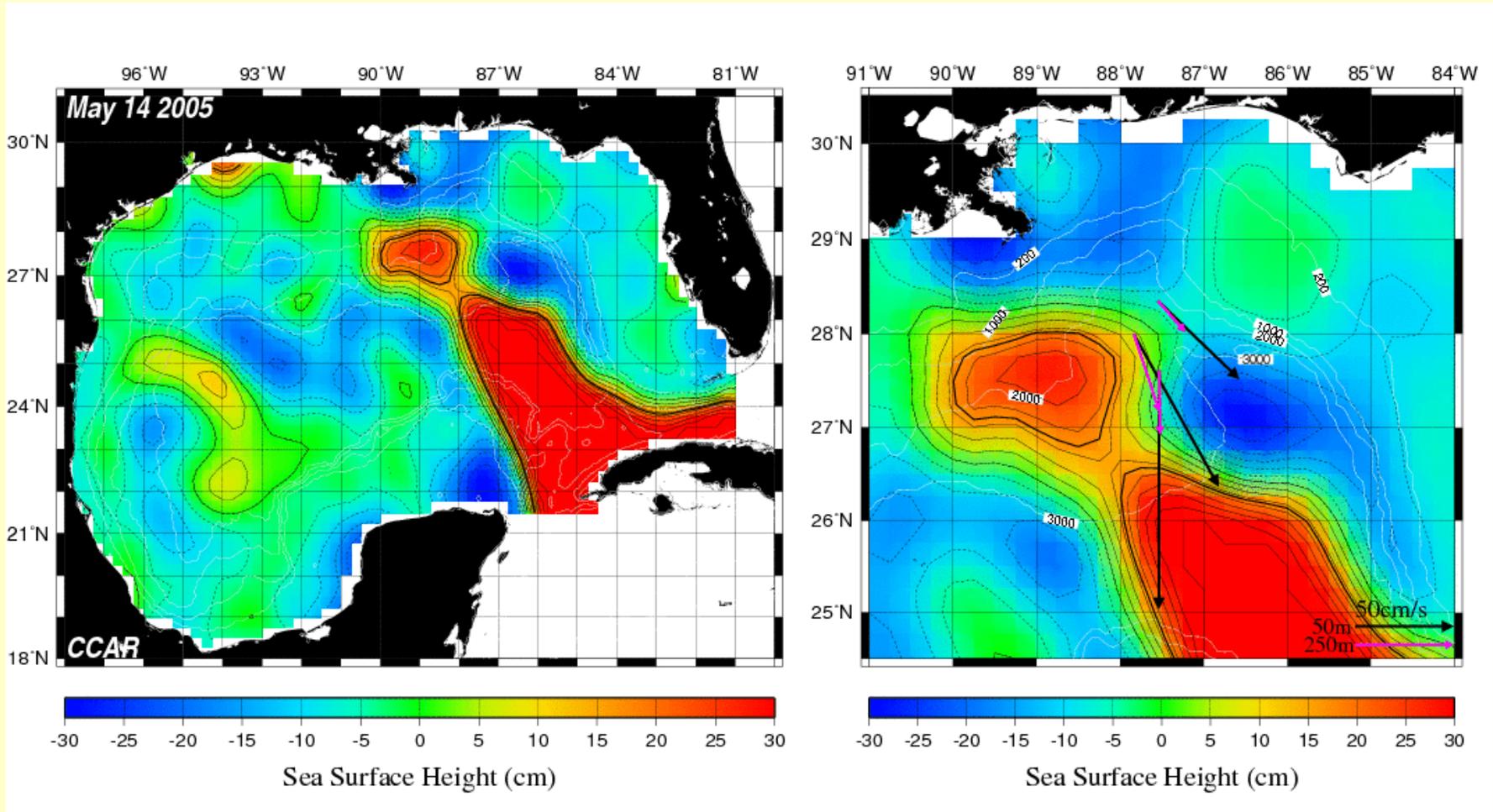
# Detached Eddy Vortex



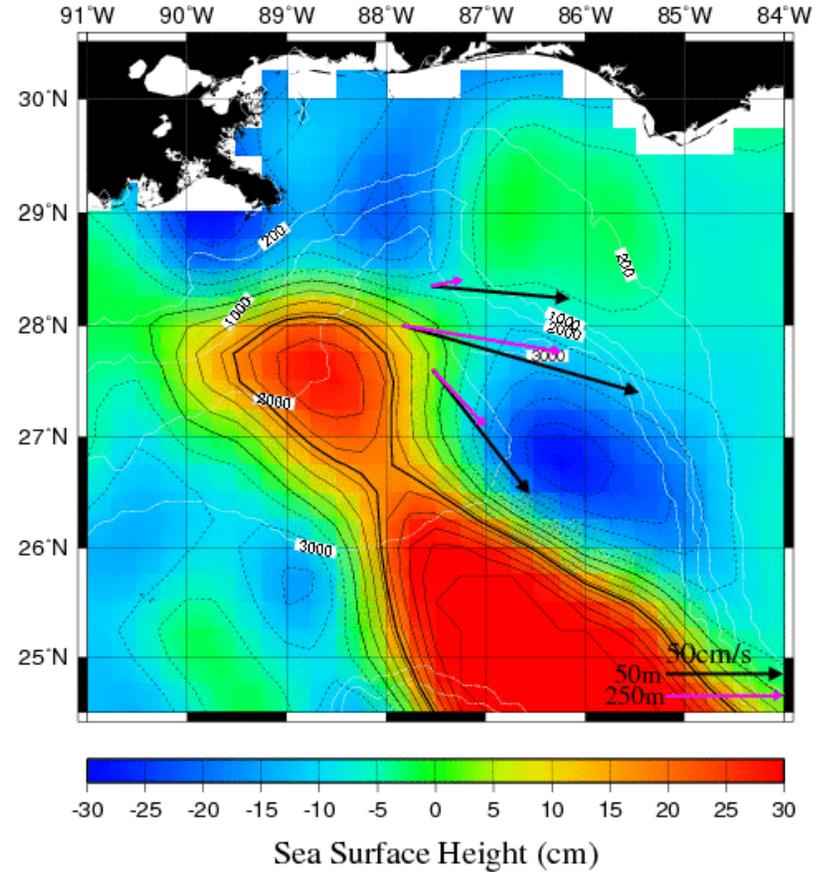
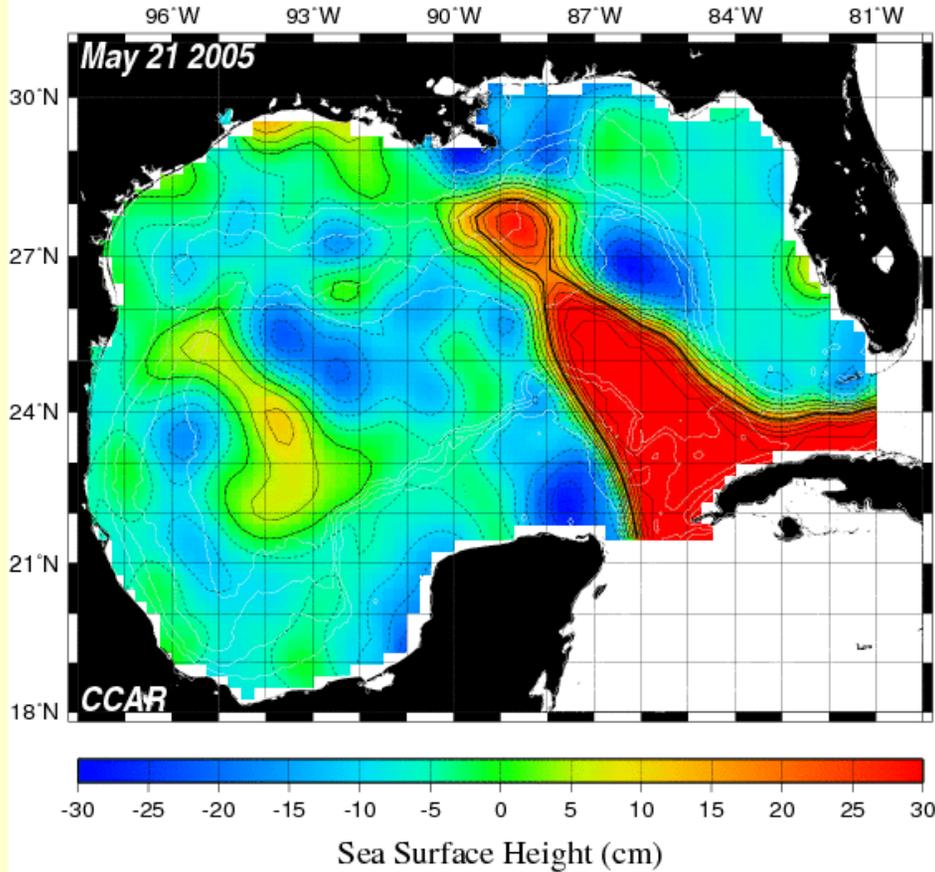
# Eddy Vortex Reattachment #1



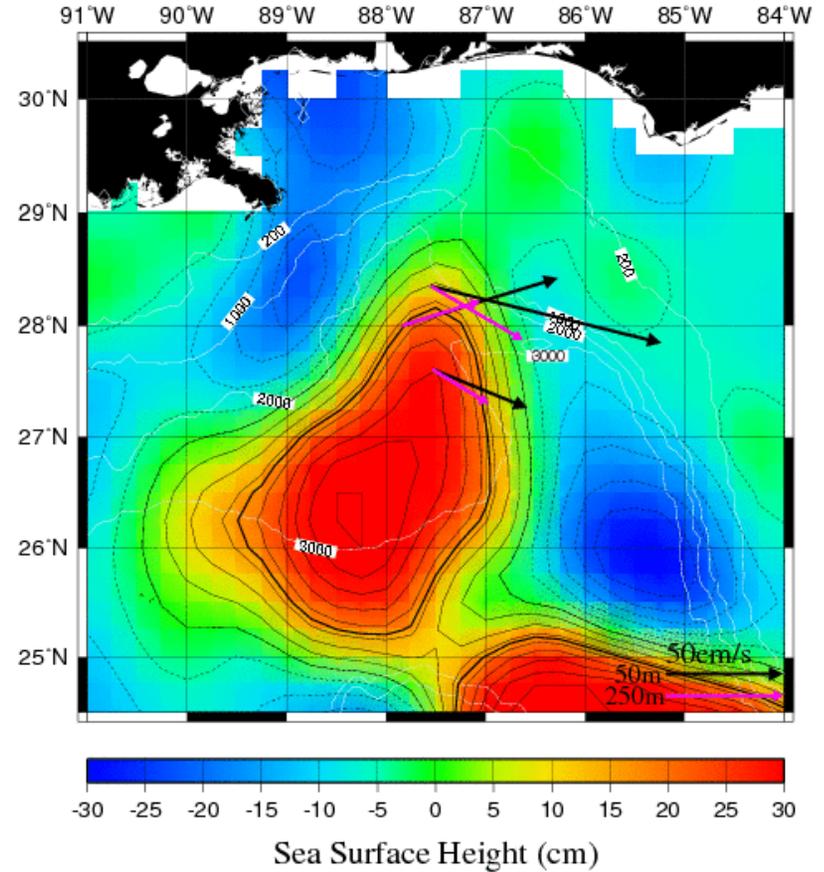
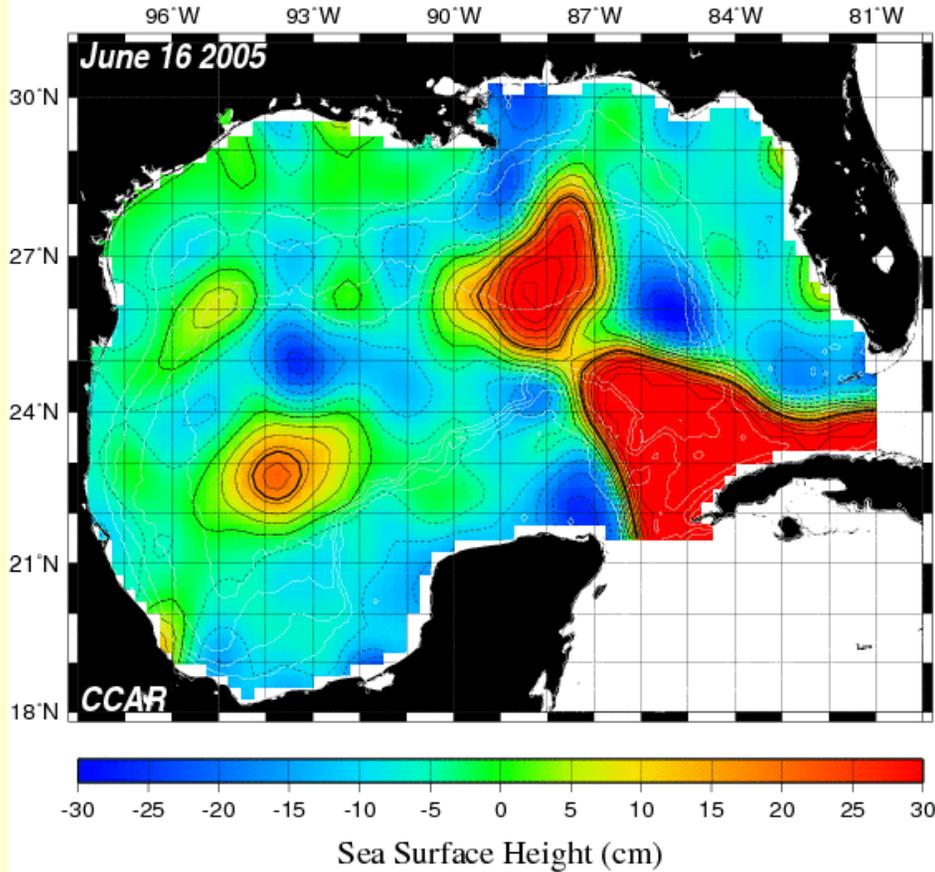
# Eddy Vortex Detachment #2



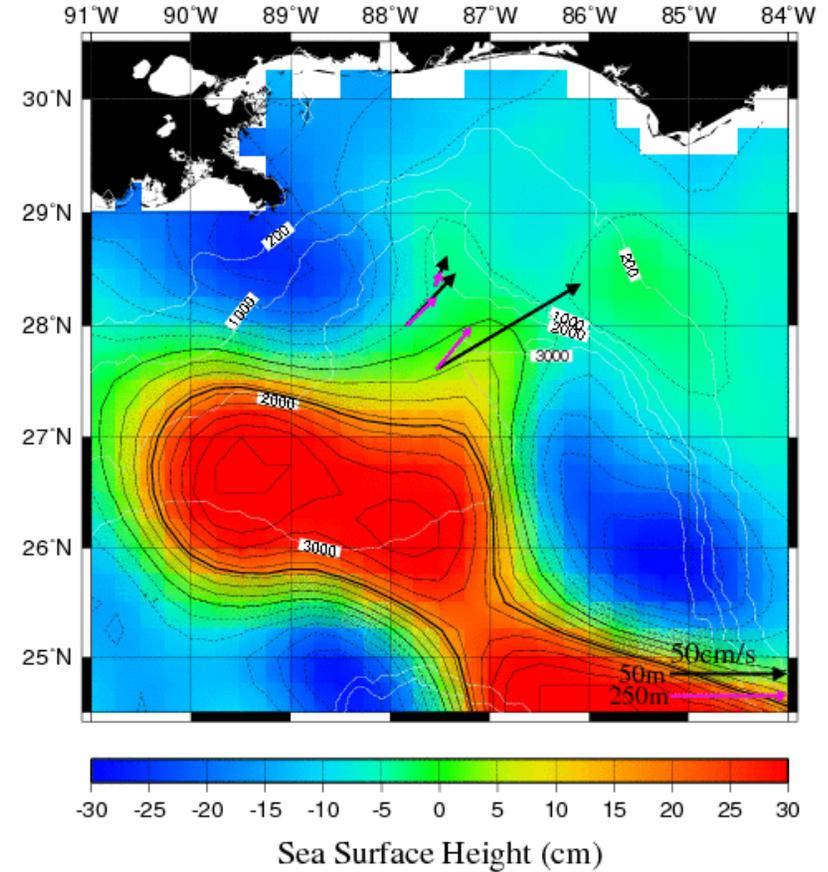
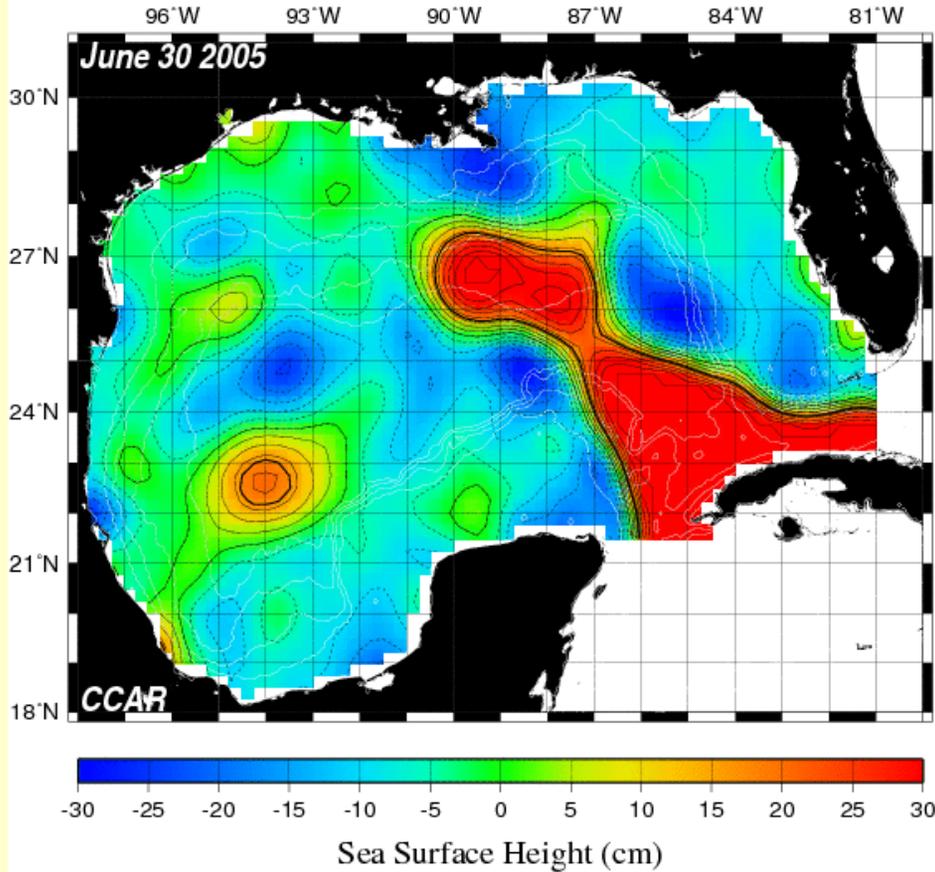
# Eddy Vortex Reattachment #2



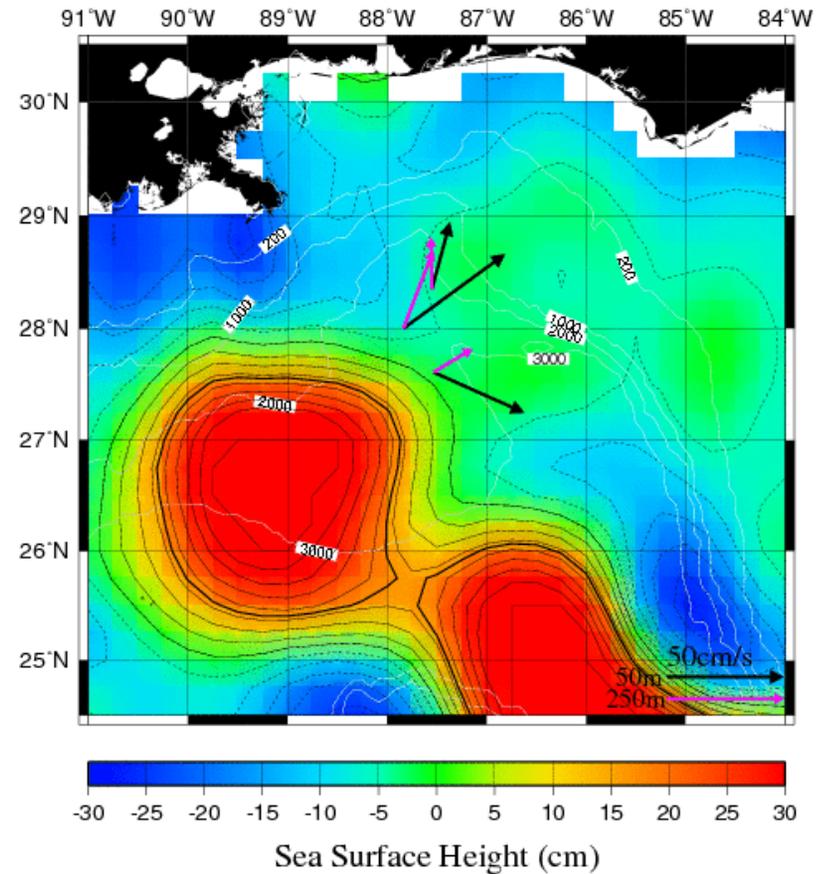
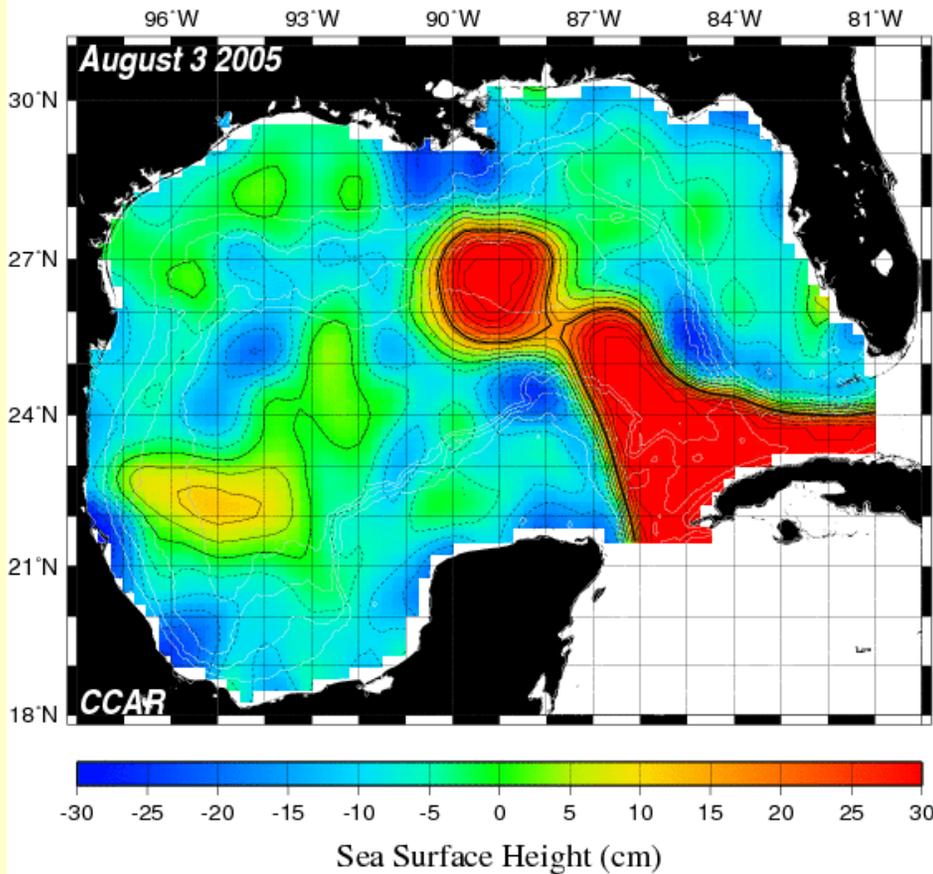
# Eddy Vortex Detachment #3



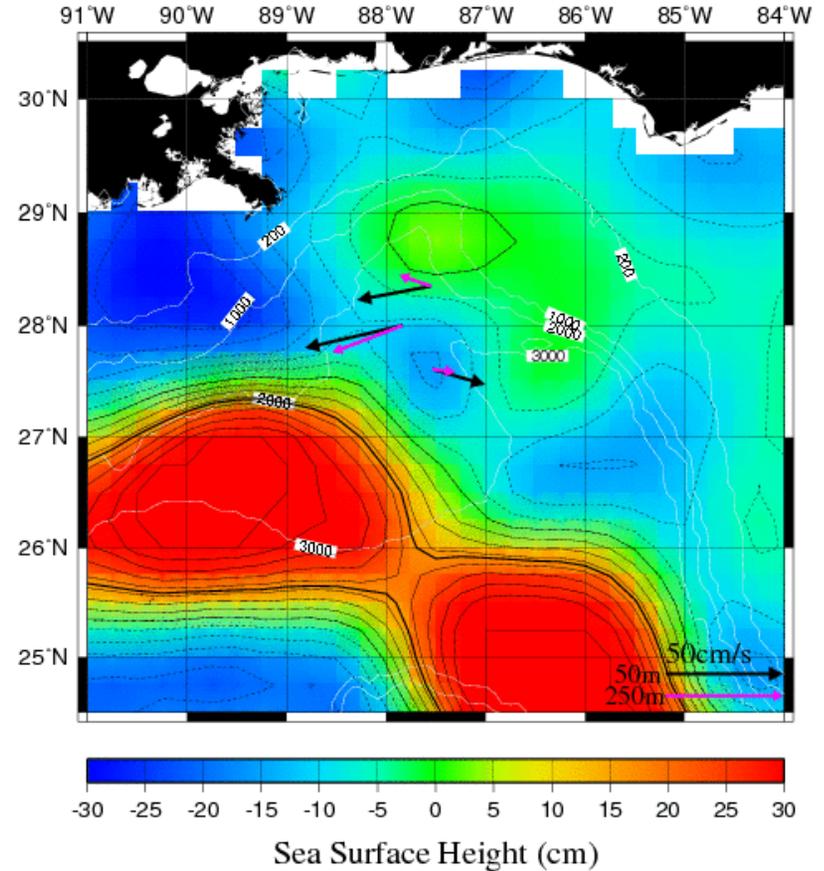
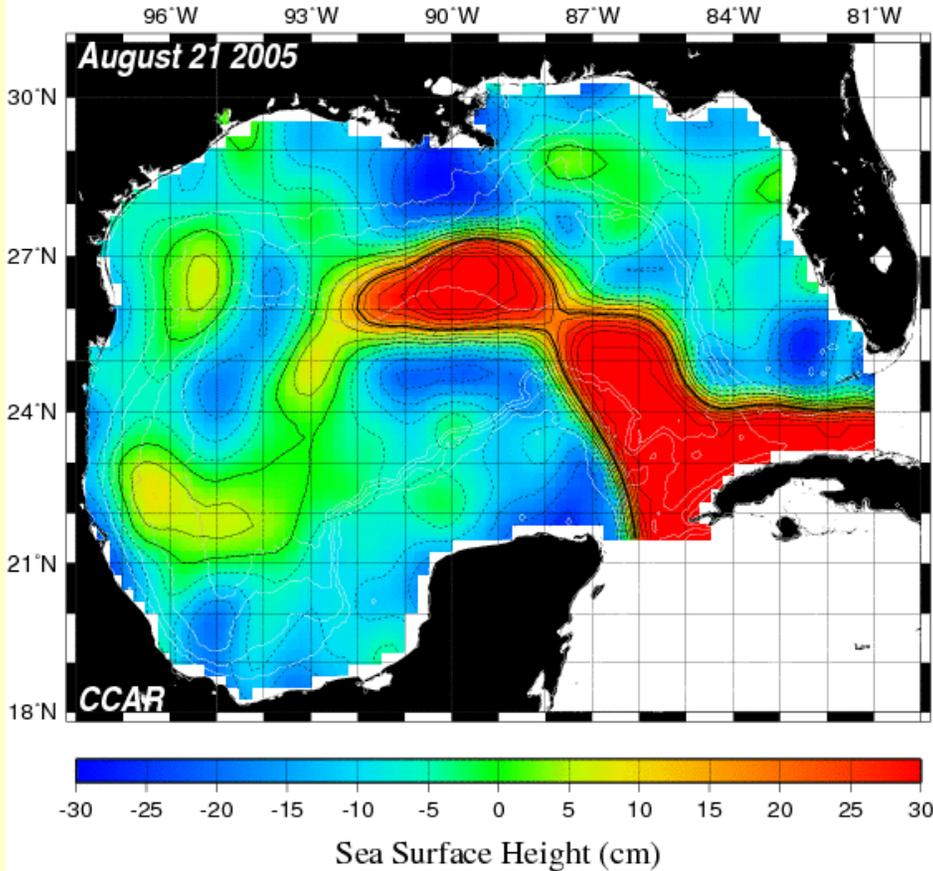
# Eddy Vortex Reattachment #3



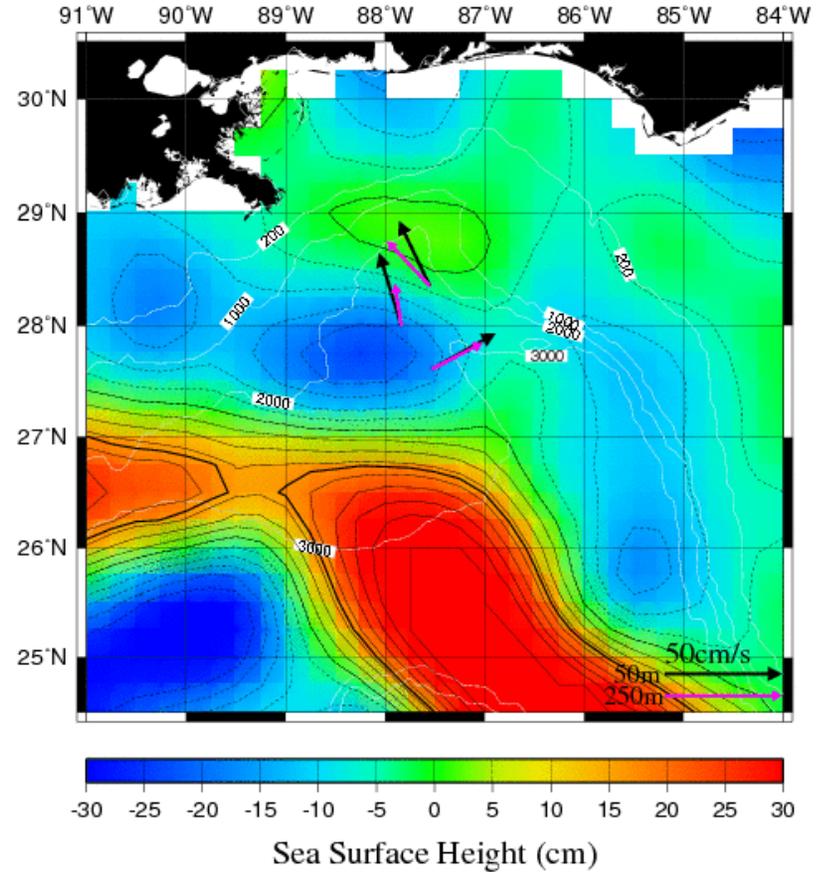
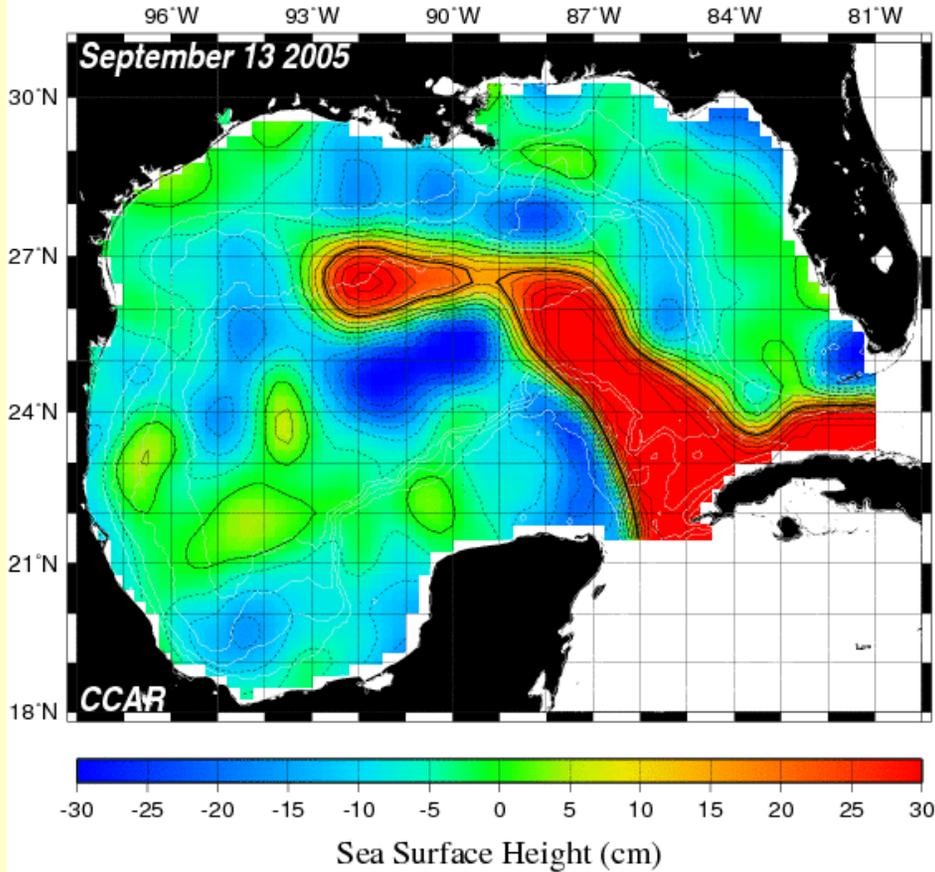
# Eddy Vortex Detachment #4



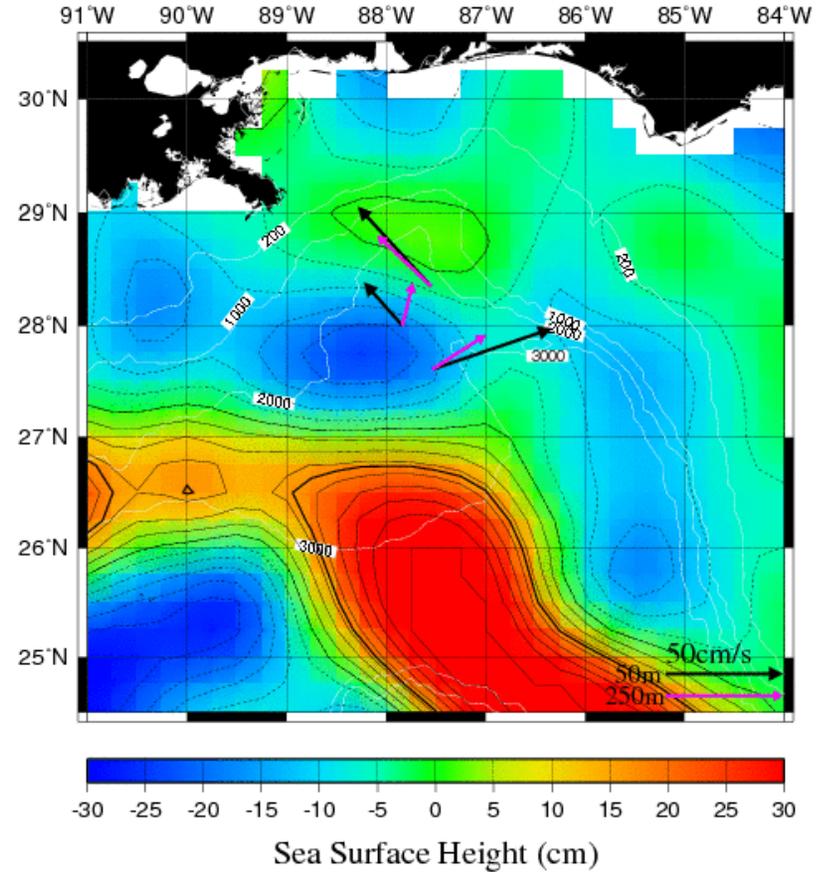
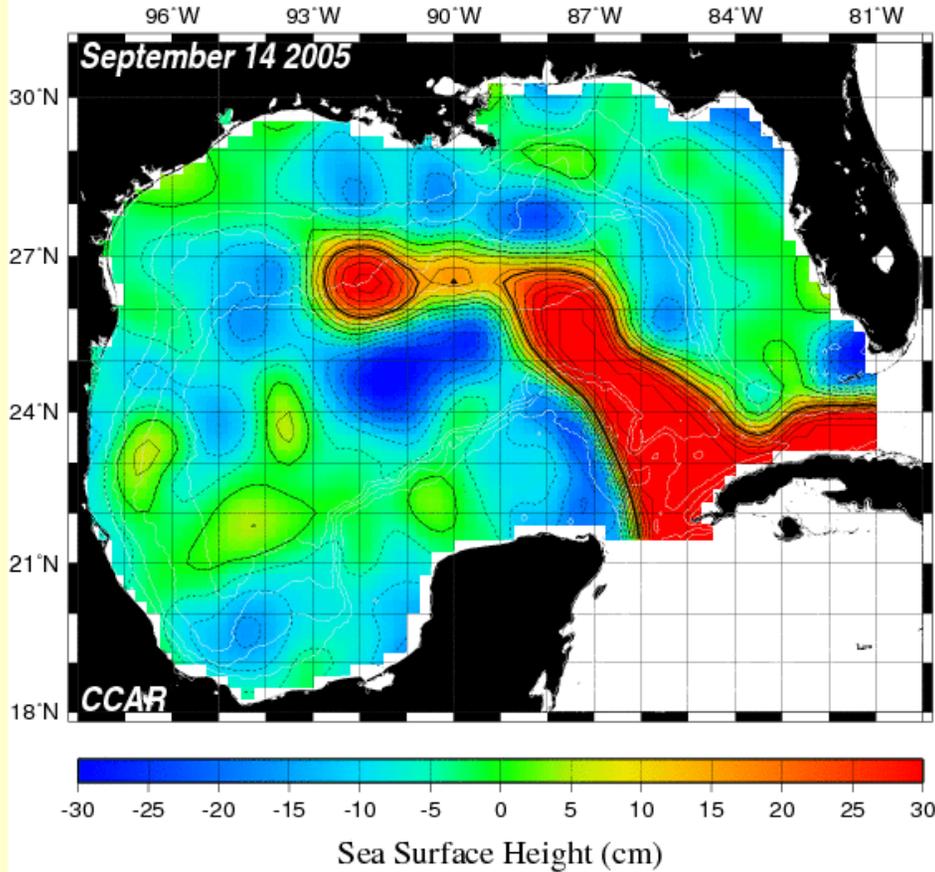
# Eddy Vortex Reattachment #4



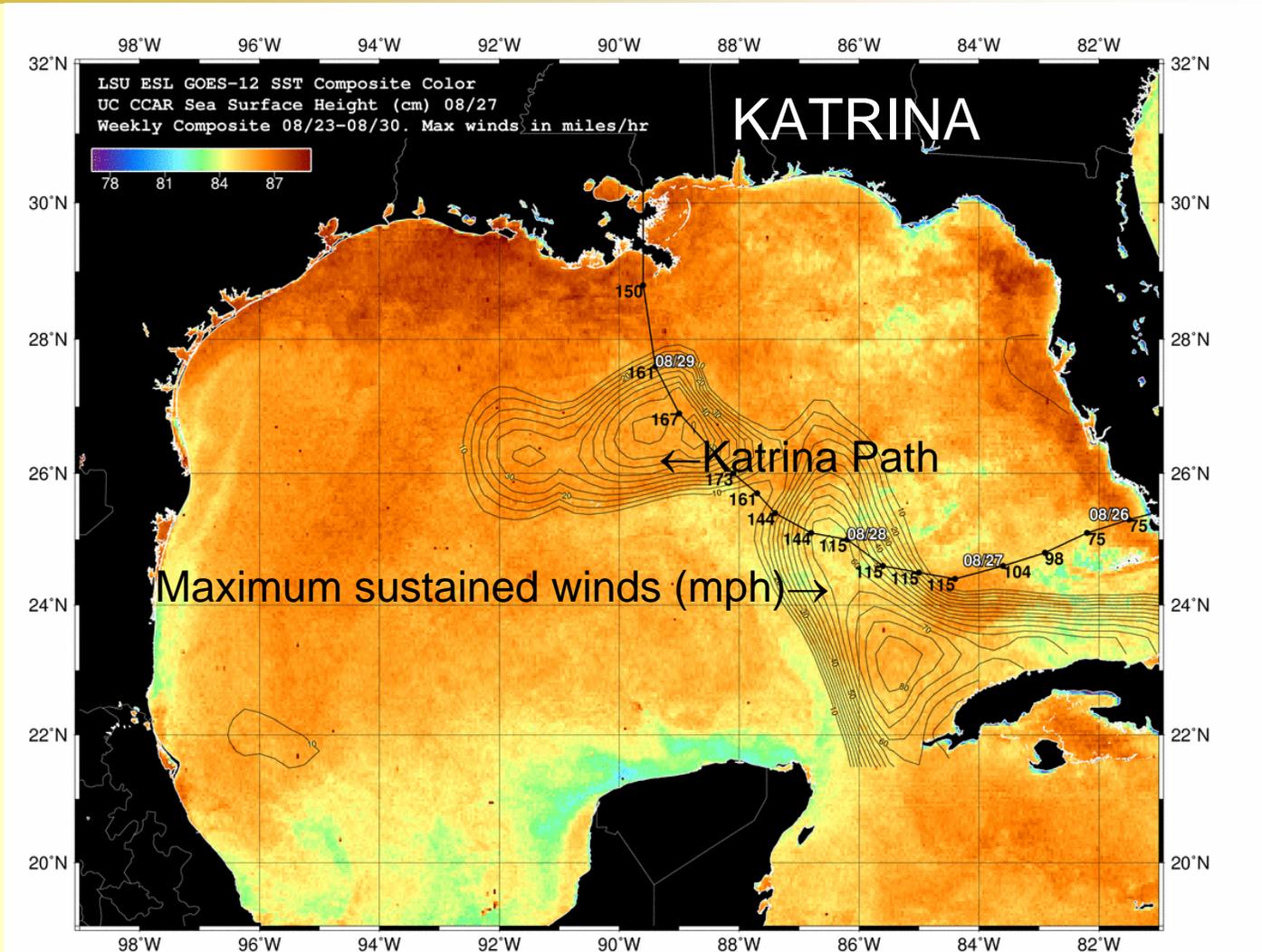
# Eddy Vortex Separation



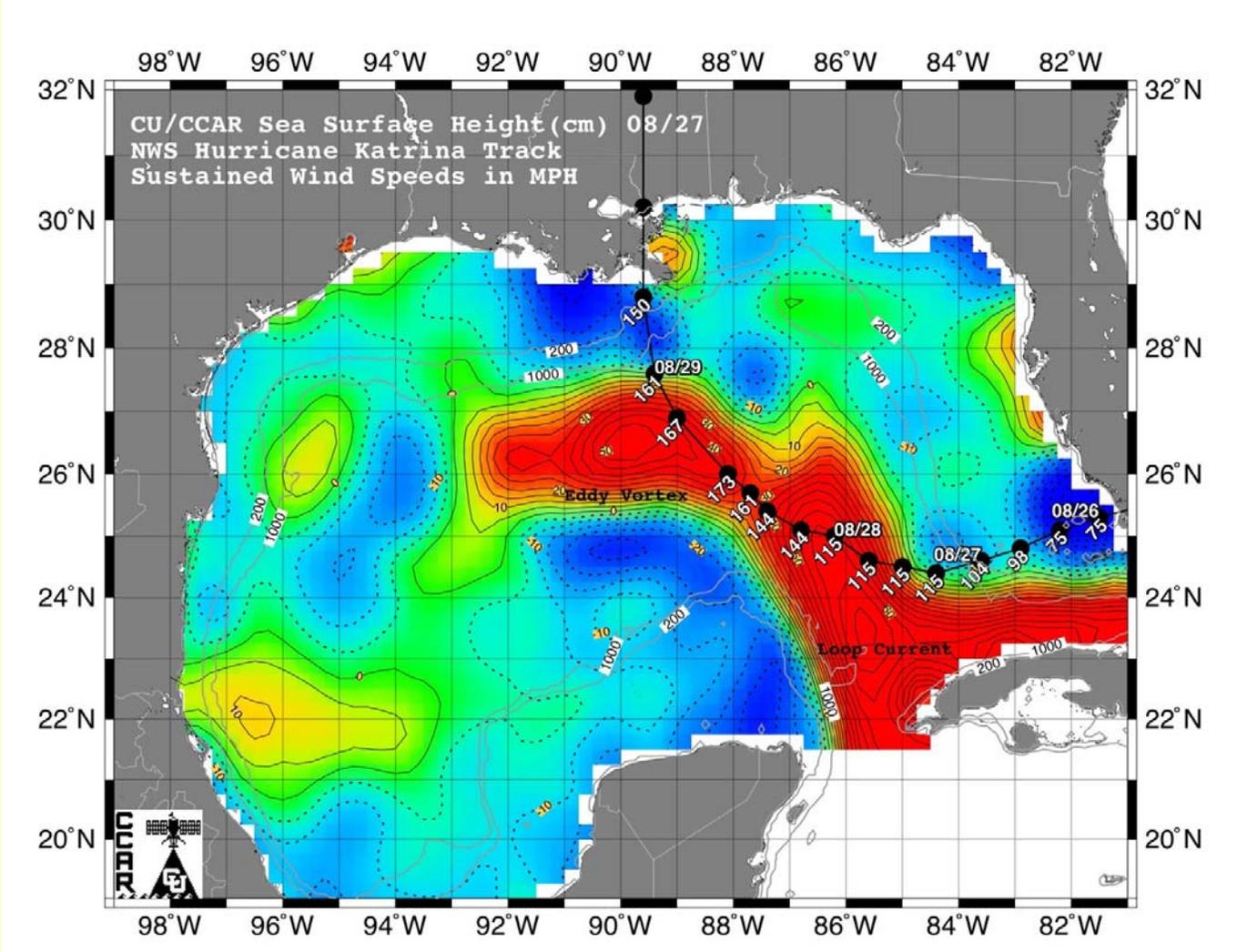
# Eddy Vortex Separation



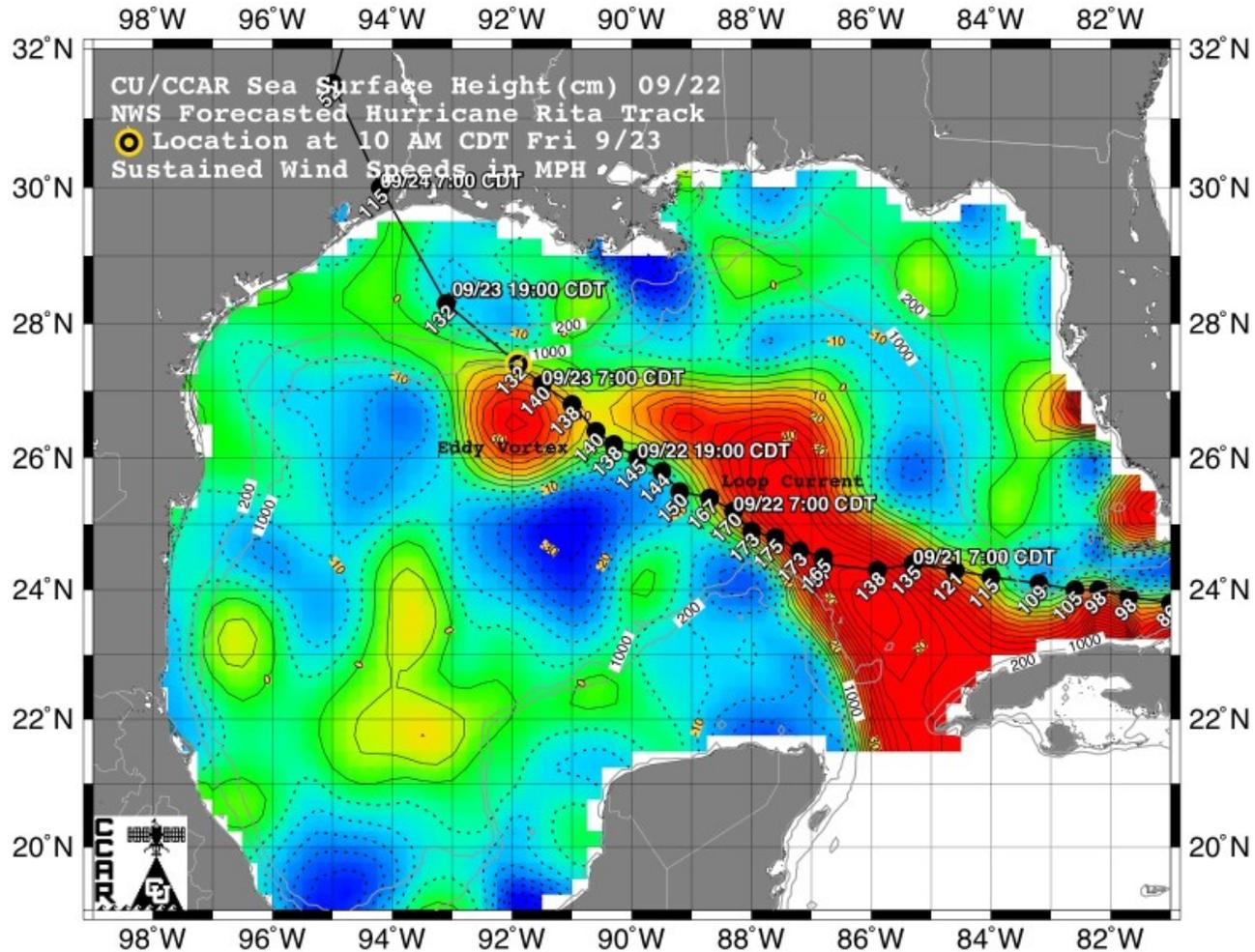
# GOES-12 SST Composite with SSH Overlaid



# CCAR SSH Map Overlaid with Katrina Path/Sustained Winds



# Eddy Vortex



Colorado Center for Astrodynamics Research  
University of Colorado at Boulder

# Eddy Vortex Summary

- ▶ **Large energetic LC intrusion**
- ▶ **First LC intrusion into array in February 2005 and after repeated (3 or 4) detachment/reattachment events, Eddy Vortex separated from the LC in September 2005.**
- ▶ **Eddy Vortex was the 2nd most western separation event out of the 20 eddies observed in the 1993–2005 record.**
- ▶ **Interacted with both Katrina and Rita.**



# Summary

**It is simplistic to characterize the gulf-wide conditions during the MMS deepwater programs as unique. Nevertheless:**

- ▶ LC and LCEs in and around the arrays were very energetic and were some of the most westerly and northerly intrusions observed.**
- ▶ In each case, the yearlong studies encountered conditions that would not typically be observed in one-year time intervals.**
- ▶ The conditions, however, were not so atypical that statistics computed over each of the year-long study time periods would be remarkably different from the long-term average.**
- ▶ Still, care must be taken when interpreting the measurements collected given some of the extreme events sampled.**



# References

**Hamilton, P., G. S. Fargion, and D. C. Biggs. 1999. Loop Current eddy paths in the western Gulf of Mexico. J. Phys. Oceanogr. 29:1180–1207.**

**Vukovich, F.M. 2005. Climatology of ocean features in the Gulf of Mexico: Final report. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2005-031. 58 pp.**

