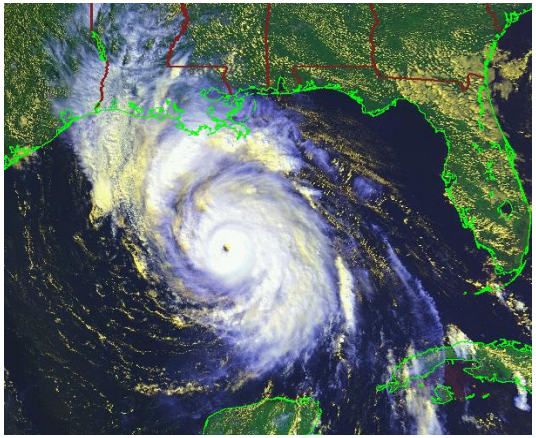
Upper Ocean Observations During Tropical Cyclone Passage

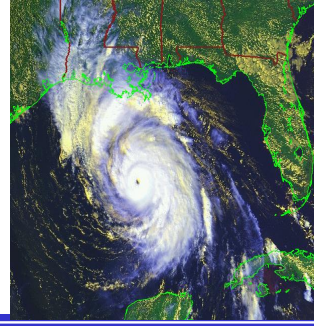


Lynn K. "Nick" Shay

NOAAs' AOML (HRD, PhOD), AOC, NHC/TPC, NCEP, NESDIS, NRL

Halliwell, Uhlhorn, Lumpkin, Lozano, Mainelli, Jacob, Powell, Jaimes, Meyers, Brewster, Zuczek,Teague

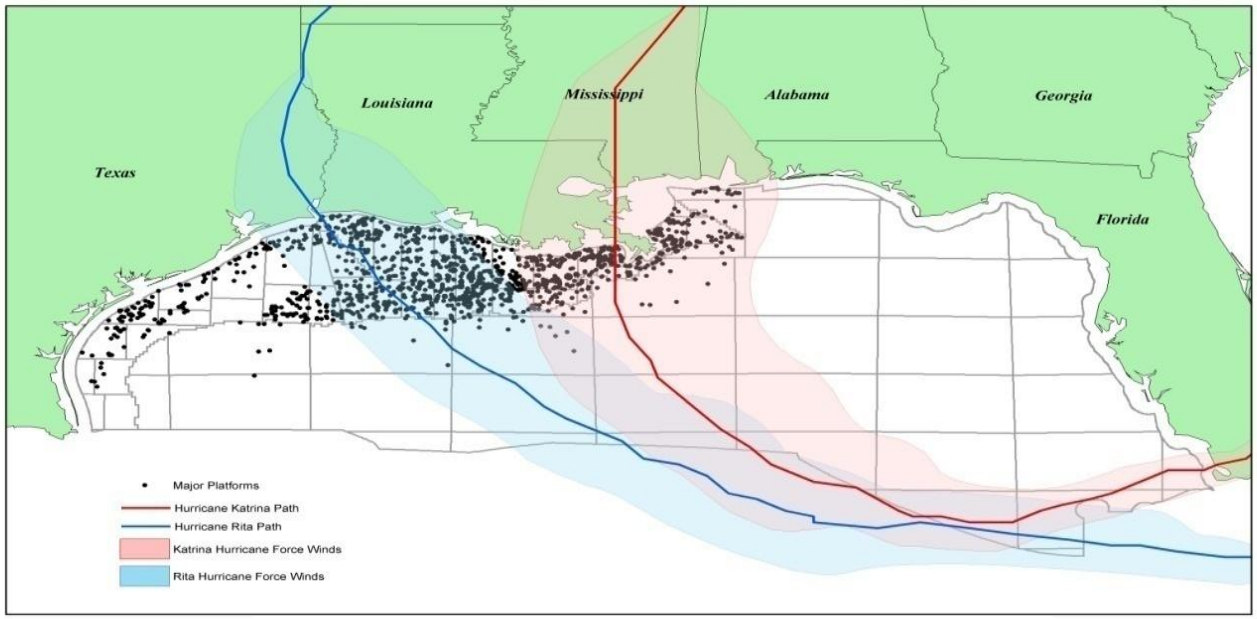
Outline:



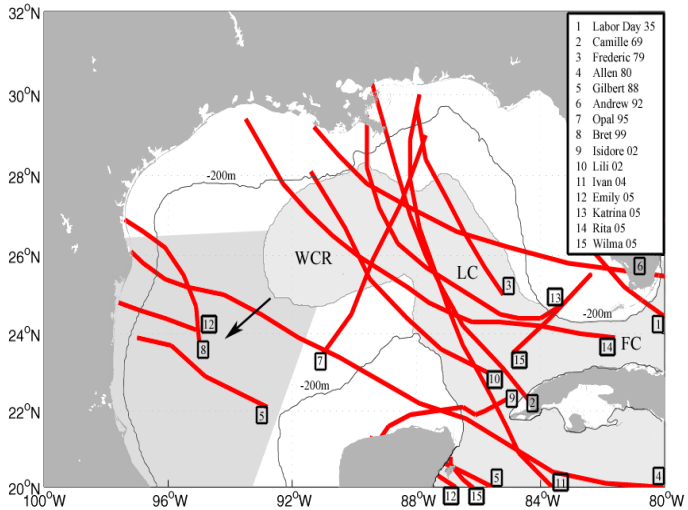
- Motivation
- Oceanic Response Features
- Oceanic Heat Content (OHC)
- Loop Current/Warm Core Eddy Interactions (deep OML)
  1. Isidore and Lili 2002
  2. Katrina and Rita 2005
  3. Gustav and Ike
- Cold Core Eddies (thin OML)-Ivan (2004)
- 2010 HFP with NOAA/MMS/NASA
- Summary

Recurrent Theme:

3-D Upper ocean observations are critical in understanding the response and interactions with atmosphere.

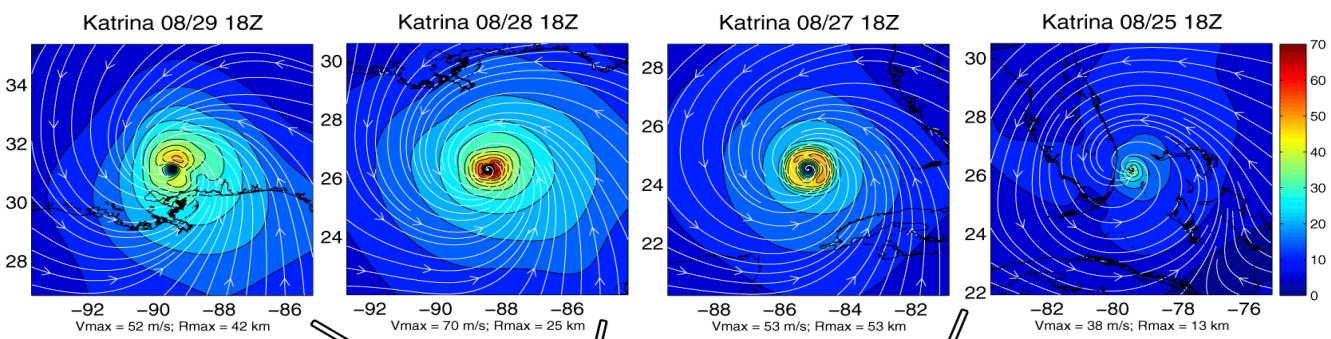


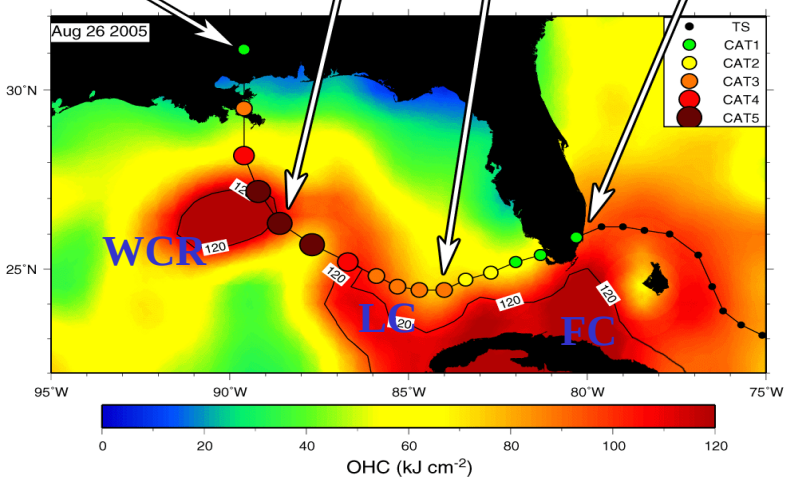
Tracks of Katrina and Rita (2005) in Northern Gulf of Mexico Relative to Oil Rigs.



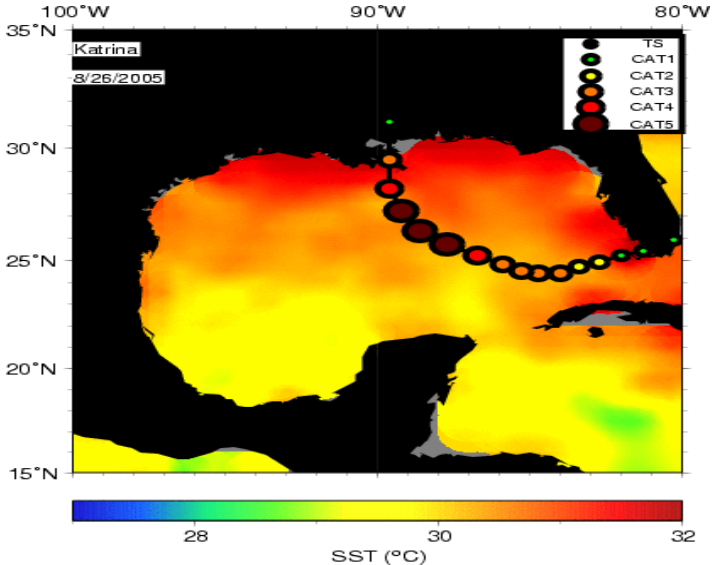
Over 35% of the Rigs were damaged or destroyed in the Gulf.

Pain at the pump!





In 2005: Katrina (896 mb), Rita (892 mb), Wilma (882 mb) Trifecta

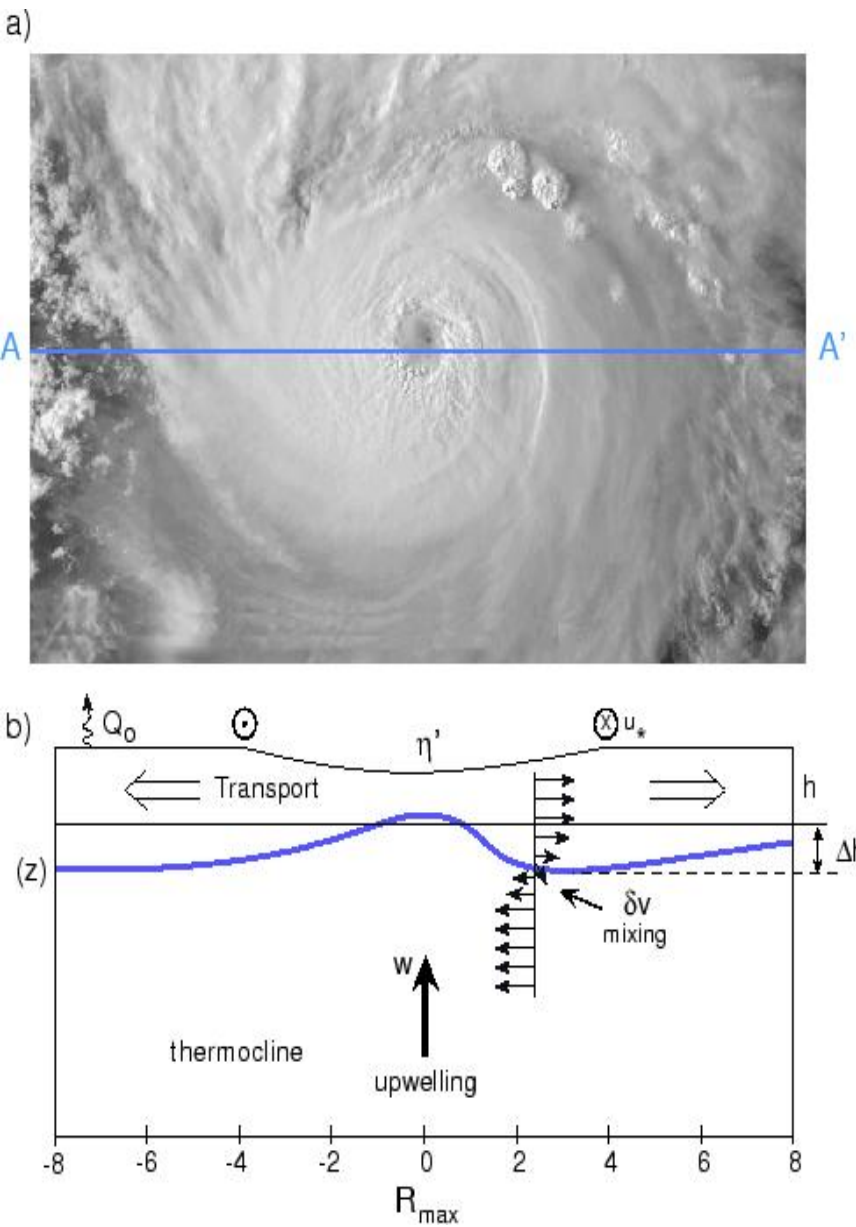


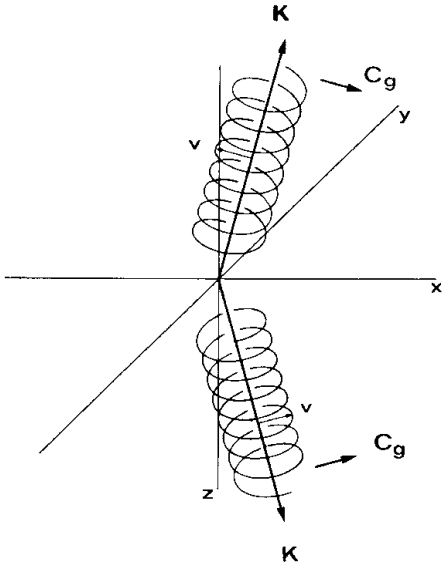
MOTIVATION: Katrina wind field with HRD wind fields (Powell et al). relative to the the LC and WCR based on satellite data in Aug 05.

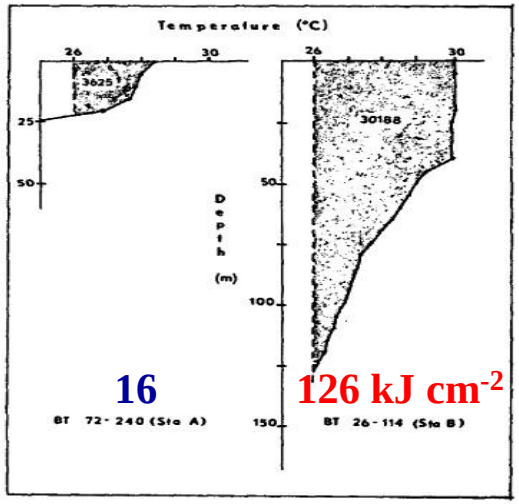
SST Image from TMI (lower panel).

Is SST Enough?

Leaman (1976)







Leipper and Volgenau (JPO, 1972)

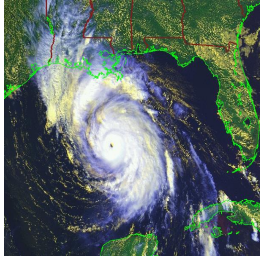
Integrated thermal structure (OHC) and vertical current shear.

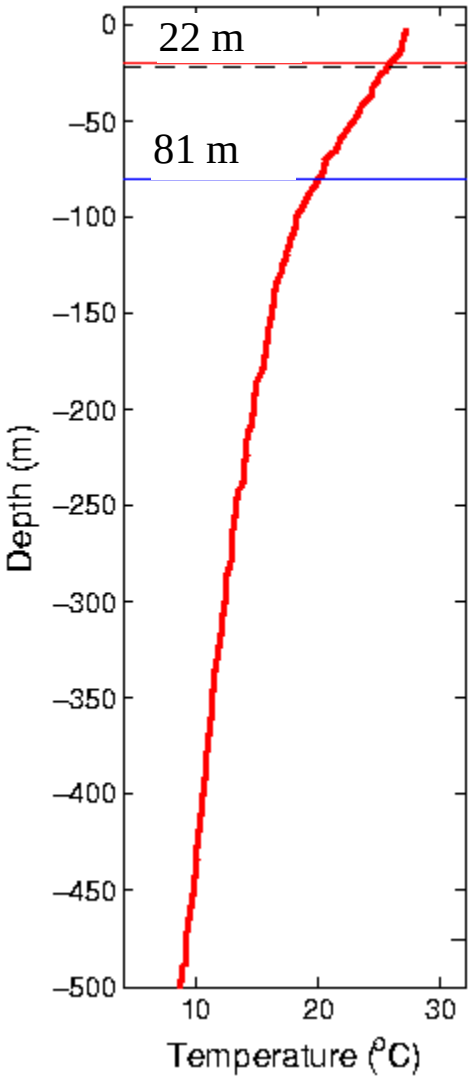
Current and shear central for mixing, cooling and, feedback to the storm.

Due to the depth of warm layers and strong background flows, minimal cooling positive feedback to TC.

Is SST Enough?

From Jaimes and Shay (MWR, 2009)





cyclone

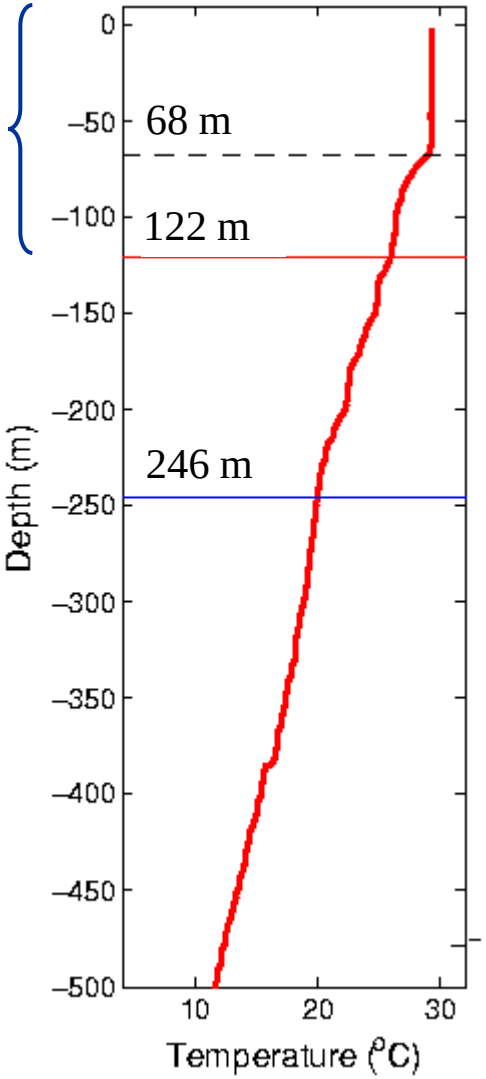
} 6 kJ cm^{-2}

114 kJ cm^{-2}

$$Q = c_p \int_{H26}^{\eta} \rho(z)[T(z) - 26]\, dz$$

Reduced negative feedback in warm core eddies

Hurricanes reach intensities closer to maximum potential intensity.



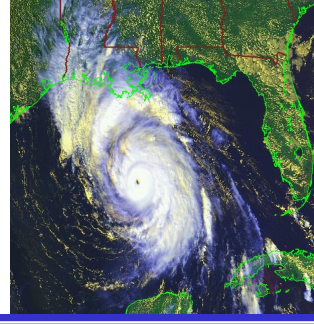
mixed layer depth

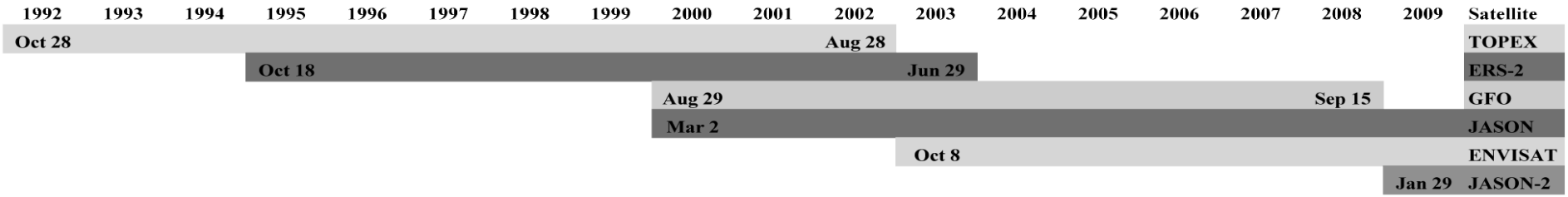
26°C

20°C

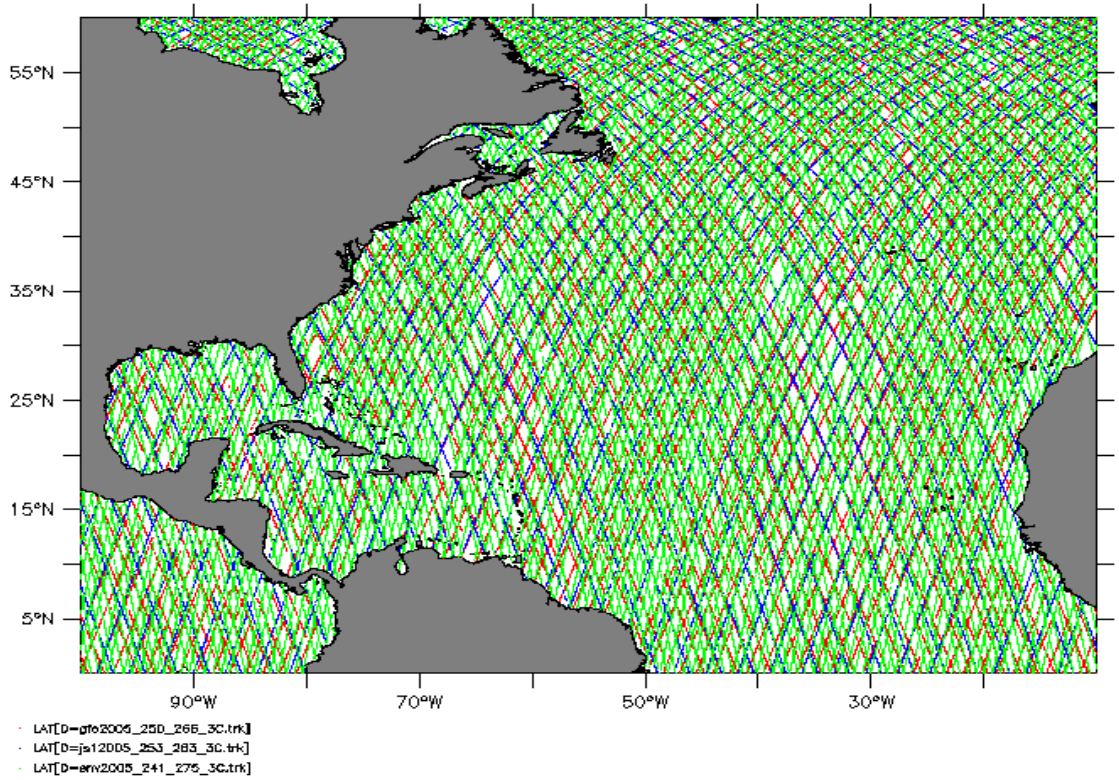
anticyclone

Altimetry Availability Since 1992

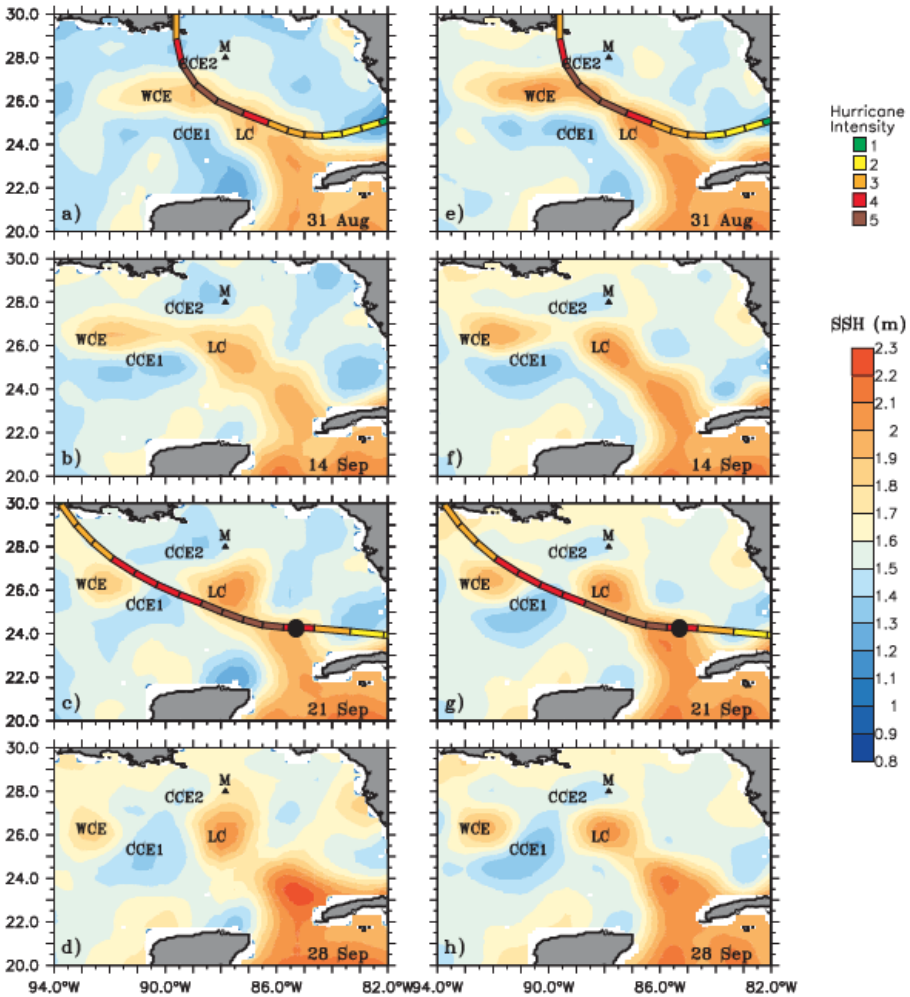




Jason-10 d
GFO- 17 d
Envisat- 35 d

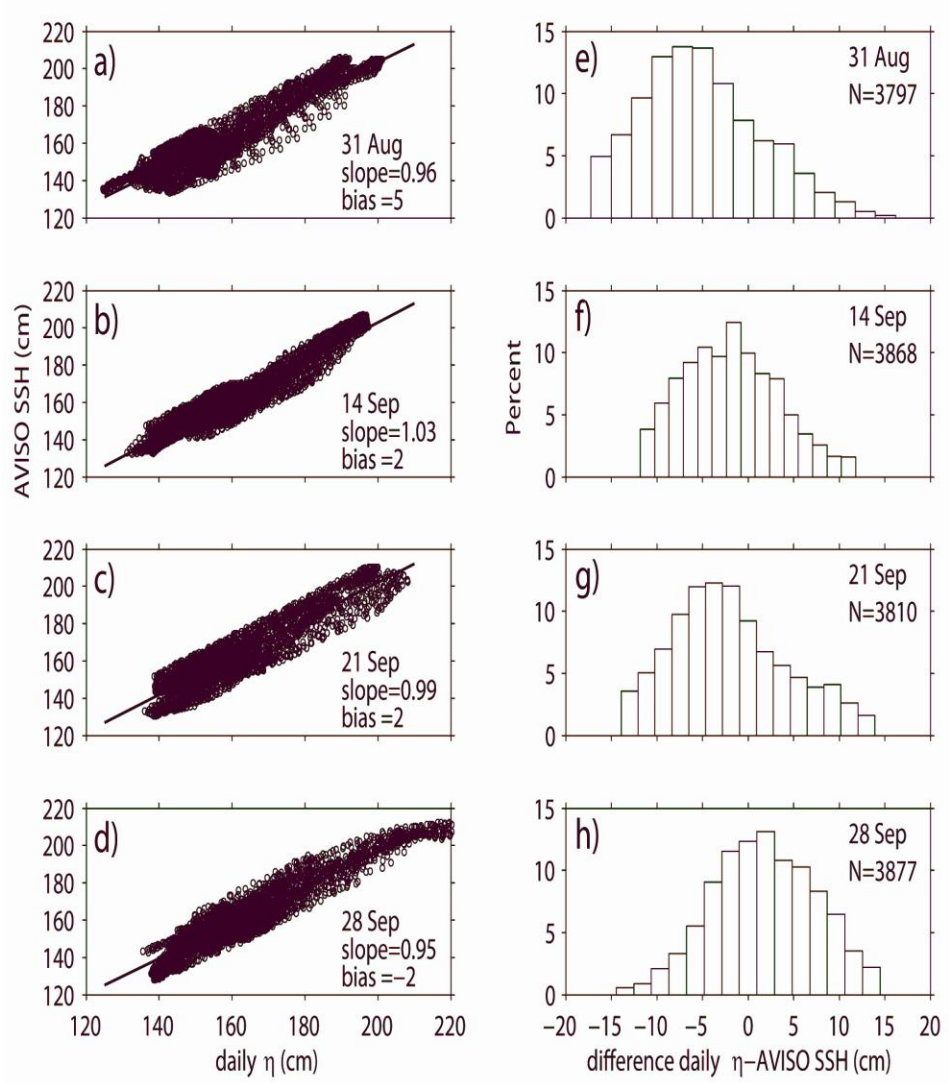


Mesoscale Oceanic Variability from Multiple Altimeters During Katrina and Rita



1-day SSH (RSMAS)

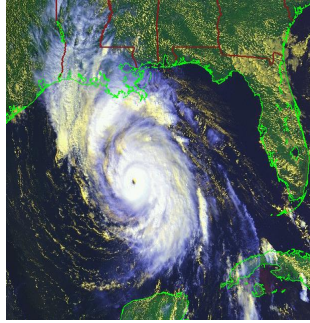
7-day SSH (AVISO)



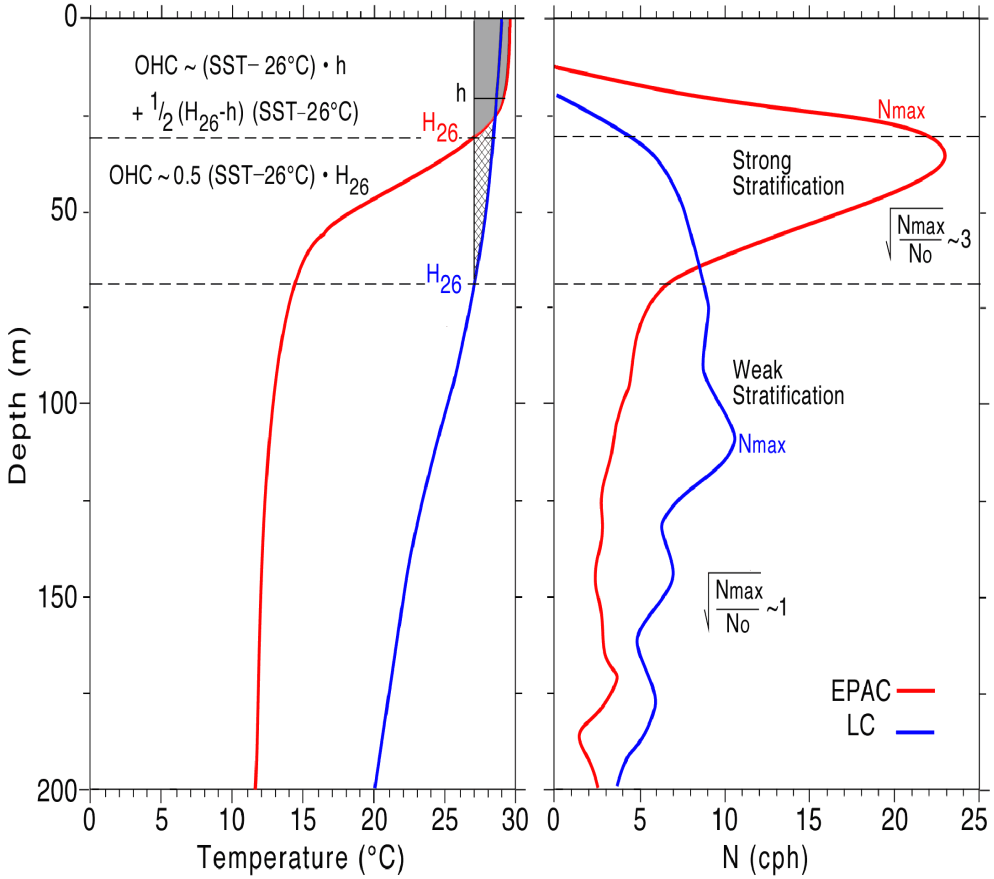
Comparison of 1-day versus 7-day SSH

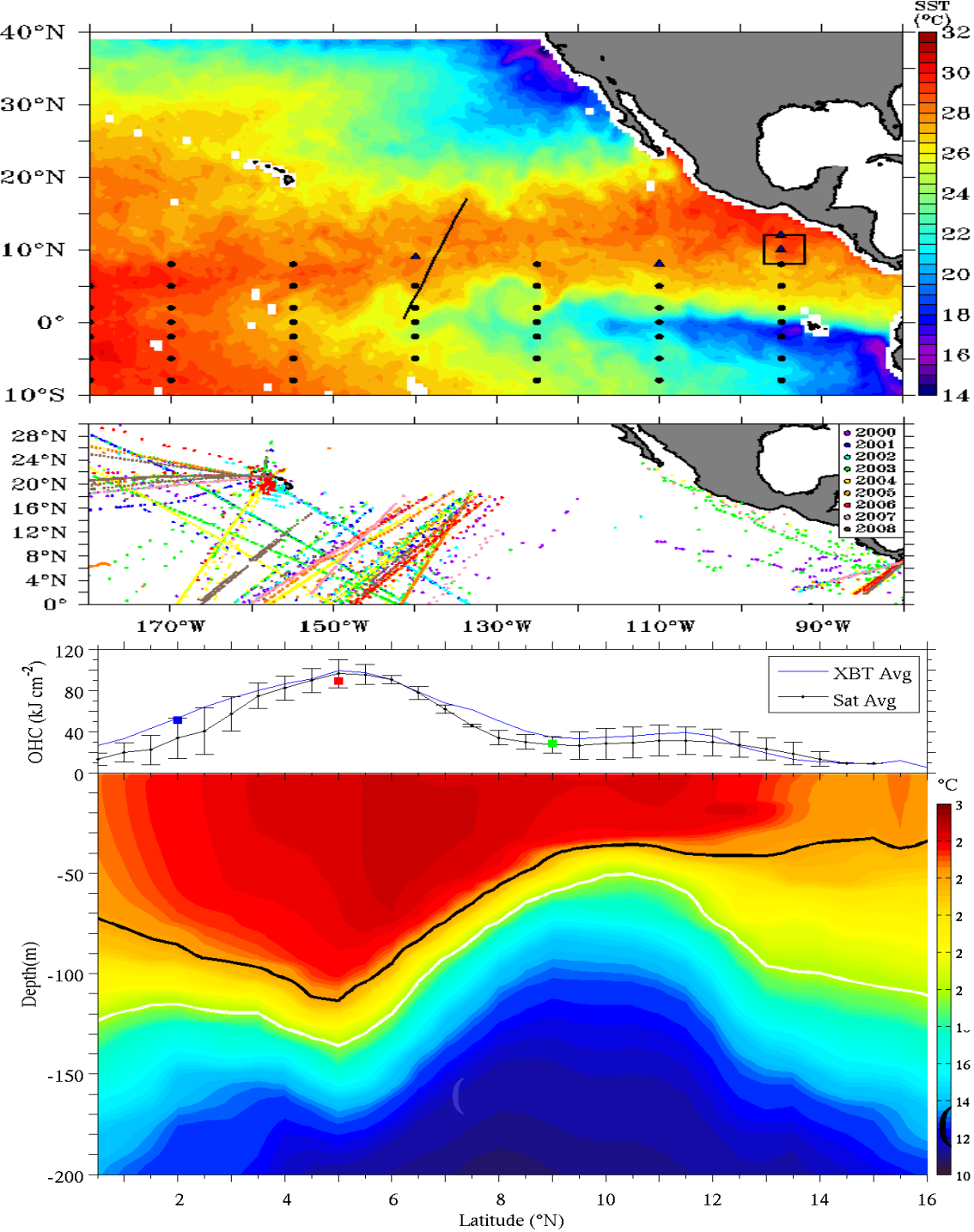
Jaimes and Shay 2009

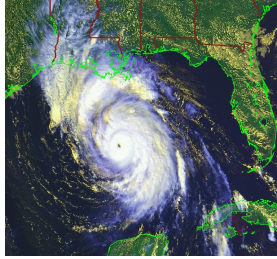
OHC Approach: Empirical Approach (see http://isotherm.rsmas.miami.edu/heat)

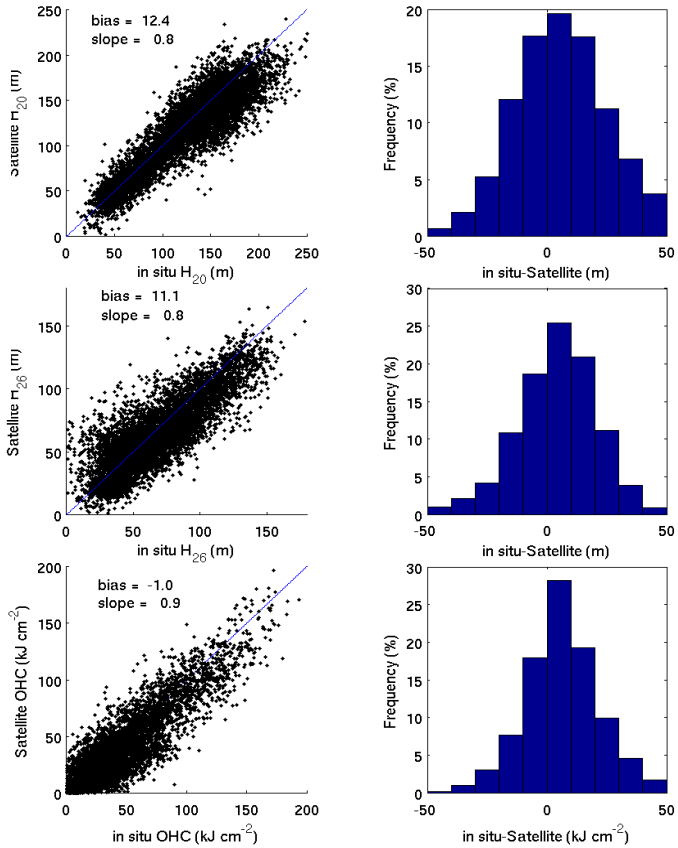


- Reduced gravity (g'), H_{20}, h (ocean mixed layer depth) GDEM **V3.**
- Blend and objectively map SHA from Jason-1, GFO, and Envisat (9.9, 17 and 35-d repeat track).
- Infer H_{20} using mapped SHA and seasonal climatology.
- Estimate H_{26} relative to H_{20} (via ratio).
- Estimate OHC relative to 26°C using H26, h, and SST.

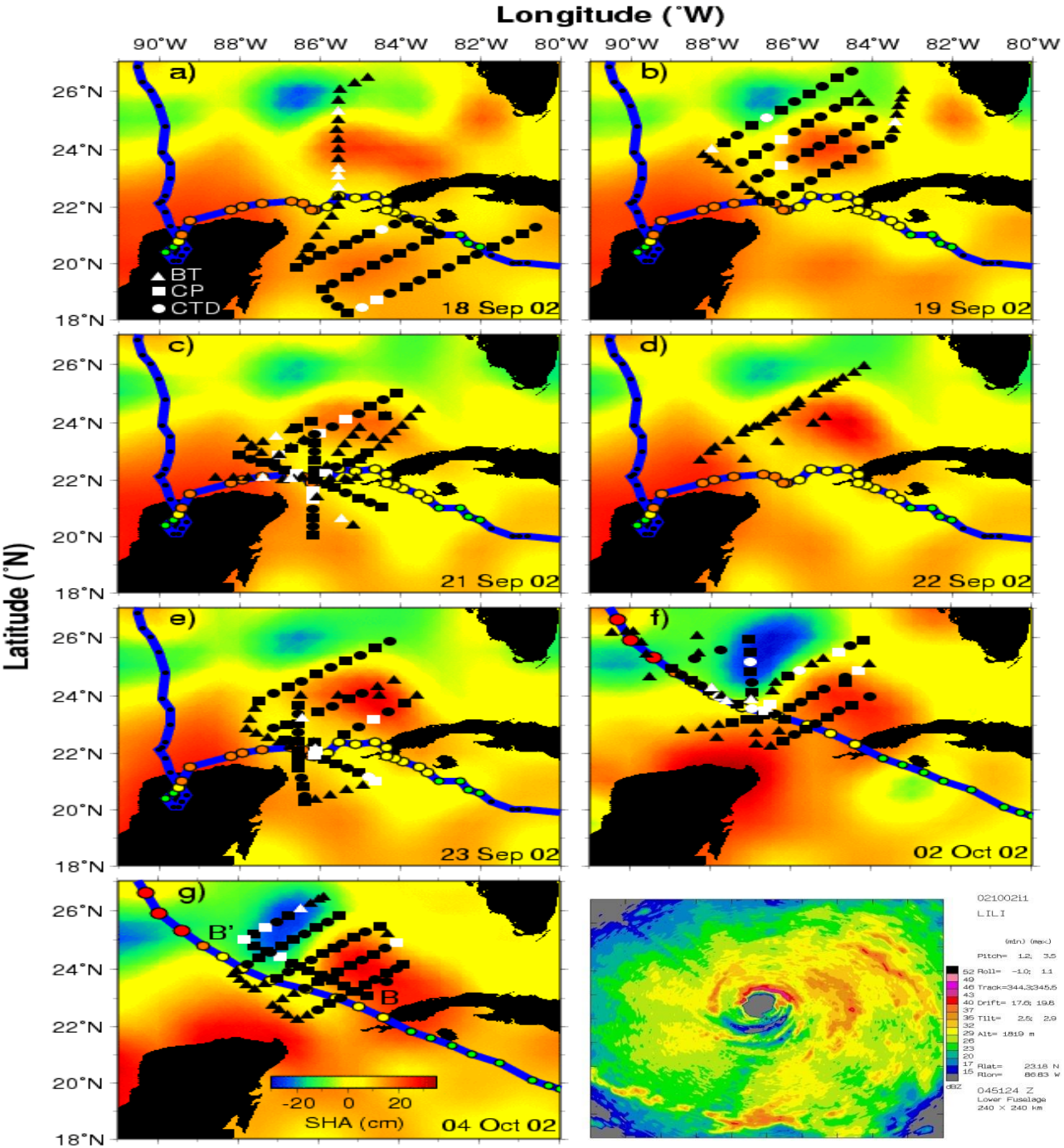








Shay and Brewster, MWR, 2010)



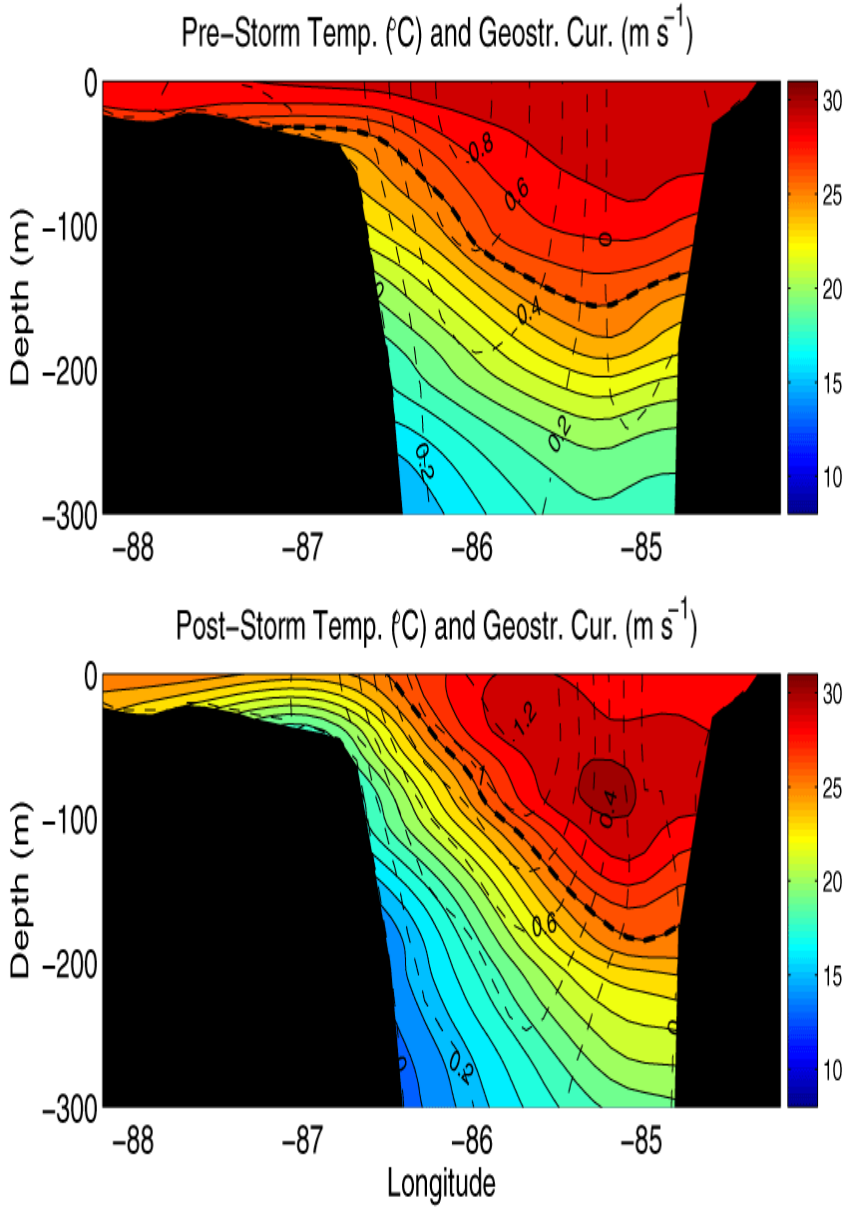
Prototype NSF/NOAA Isidore/Lili (02)

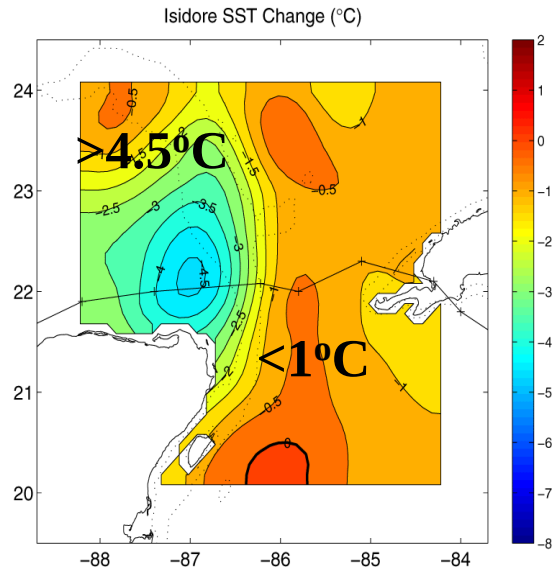
a) Caribbean (Pre)
b) GOM (Pre)
c) Isidore (Dual Aircraft)
d) Wake 1 (Post)
e) Wake 2 (Post)
f) Lili
h) Wake 1 (Post)

SHA field: TOPEX, GFO and ERS-2

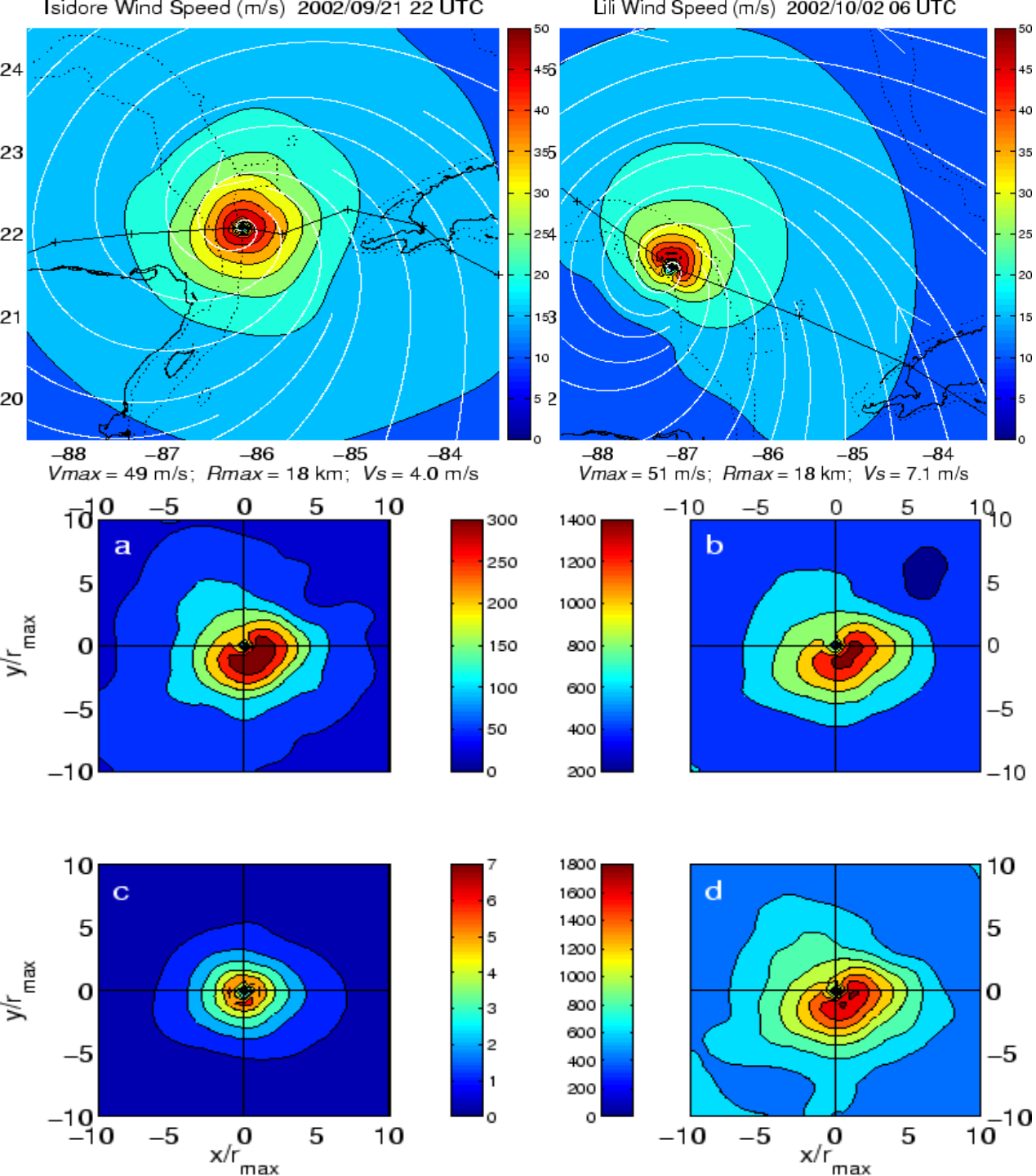
Radar Composites of Lili (f)

From (Shay & Uhlhorn, MWR, 2008):





T(x,z) and V(x,z) Section (left) along 22ºN and ΔSST Change (right) during after Isidore.

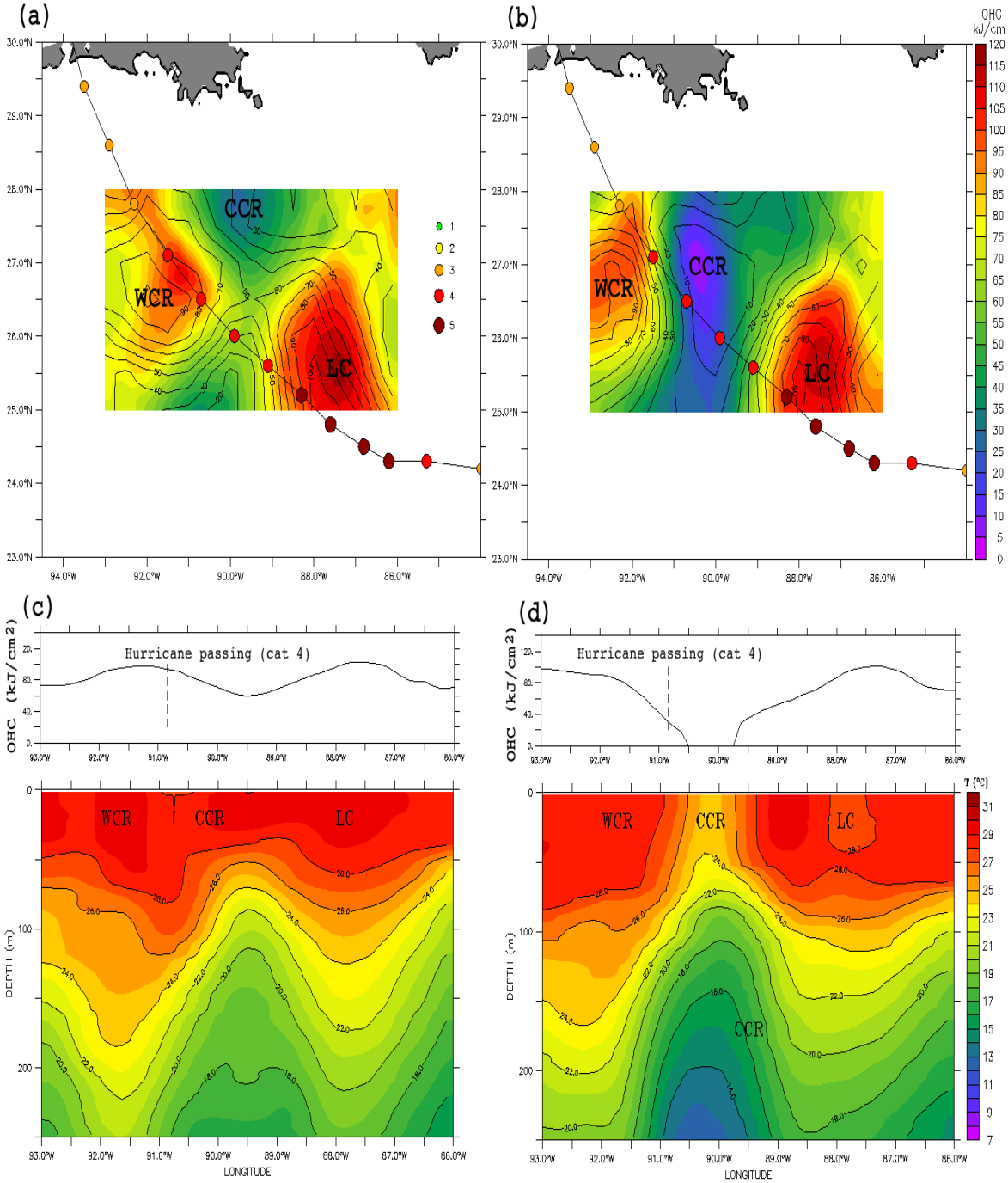


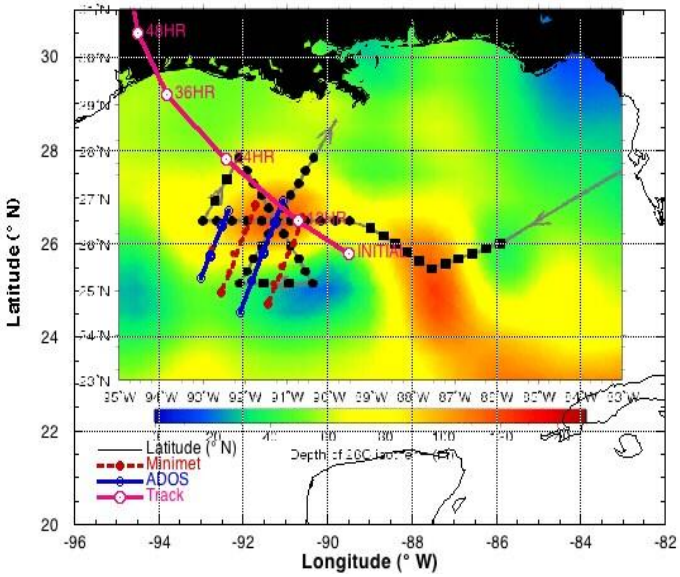
Isidore/Lili SFMR derived wind field:

Isidore Fluxes For:
a) Sensible,
b) Latent,
c) Momentum,
d) Enthalpy.

Uses GPS, AX.., and SFMR fields.

(Shay and Uhlhorn, MWR, 2008)





Sampling Pattern: AXCTDs and Drifters relative to OHC and Rita's track.

Pre (15 Sep) and Post Rita (26 Sep) WCR/CCR/ LC OHC and 26°C isotherm depth.

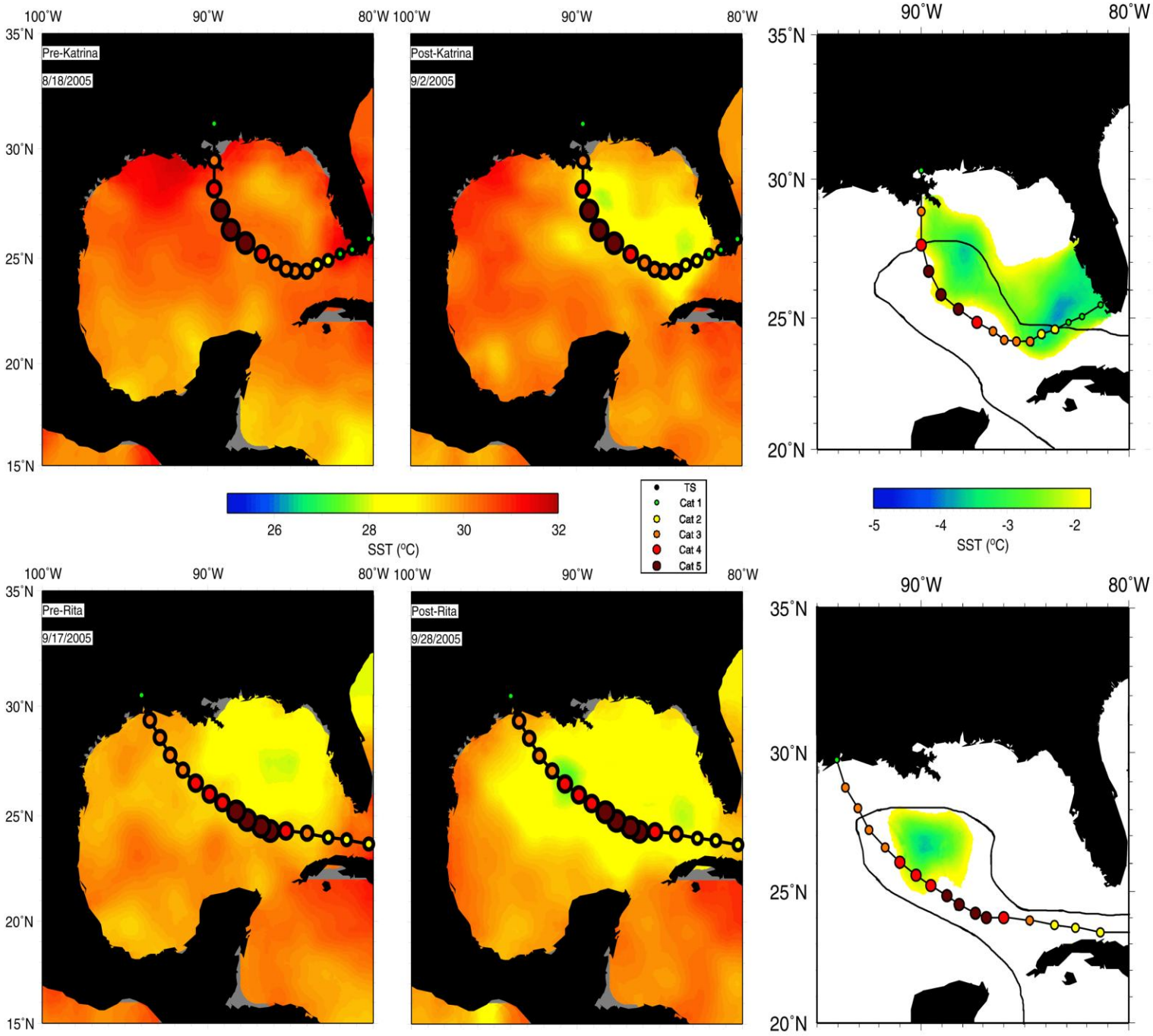
Vertical structure from AXCTDs

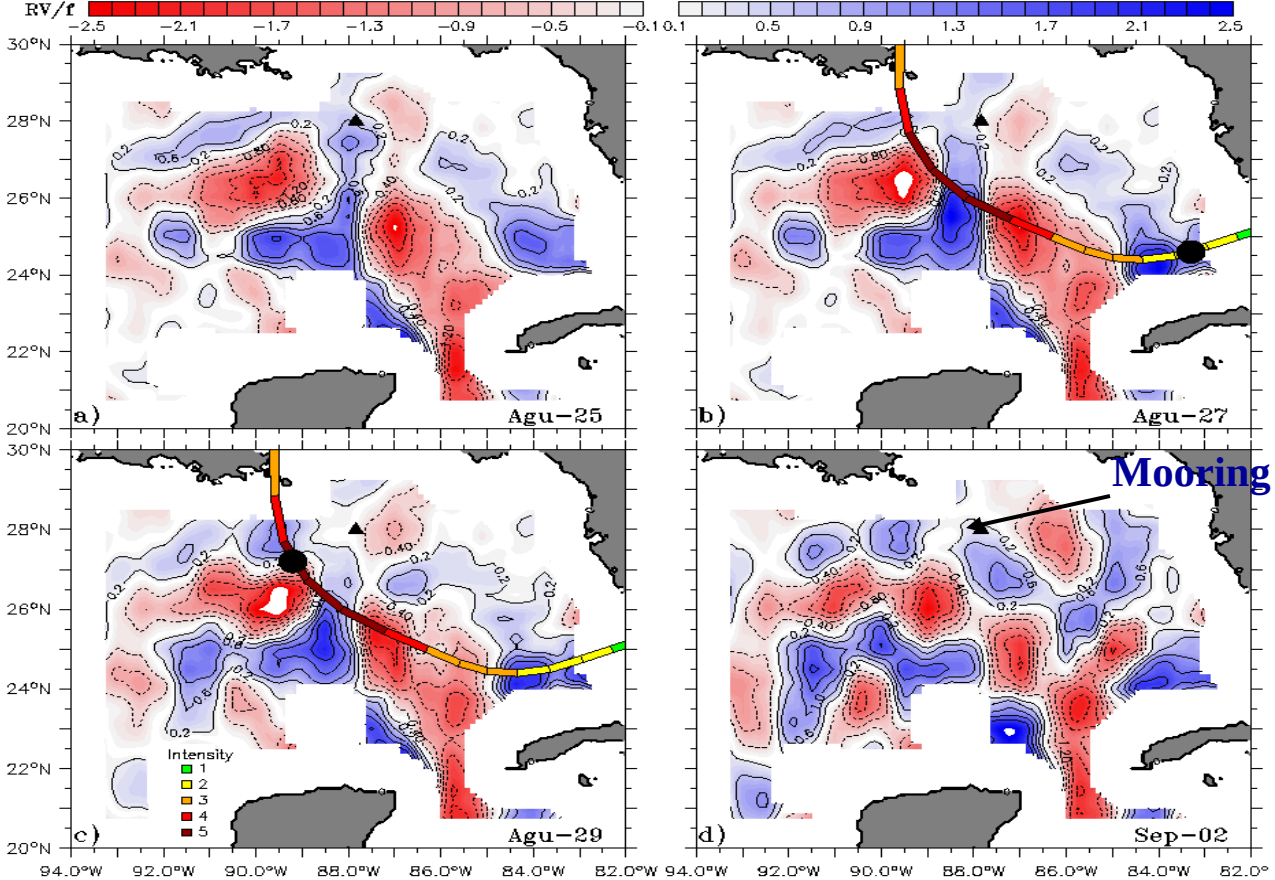
(Jaimes and Shay, MWR, 2009)

TMI Pre and Post Katrina SSTs and cooling (top);

Pre and Post Rita SSTs and cooling (bottom).

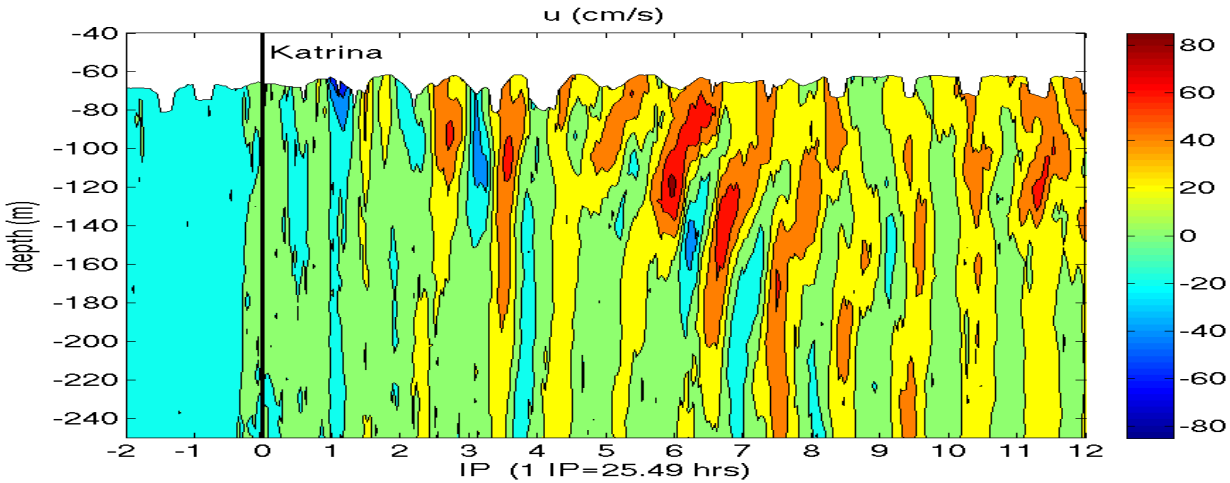
TMI Data courtesy of C. Gentemann.





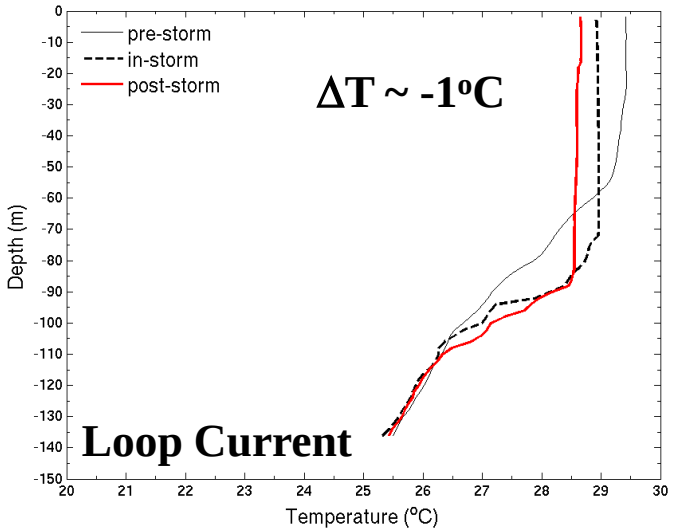
Evolution of the normalized relative vorticity by *f* relative to Katrina Track and Intensity from 25 Aug-2 Sept. 2005

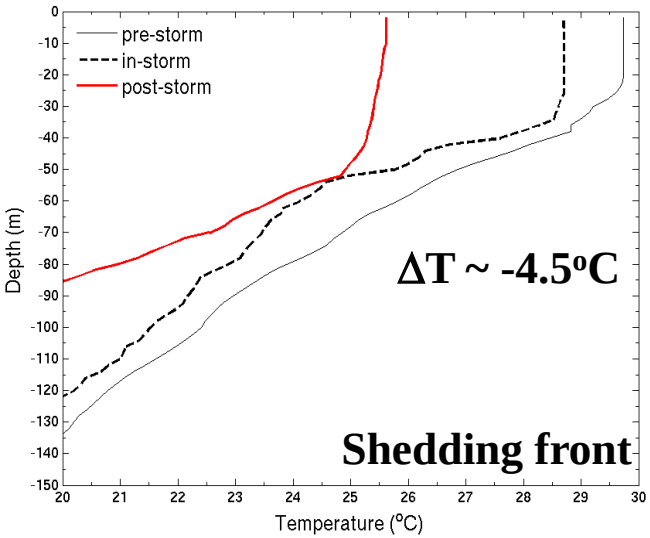
From Jaimes and Shay (JPO, 2010)

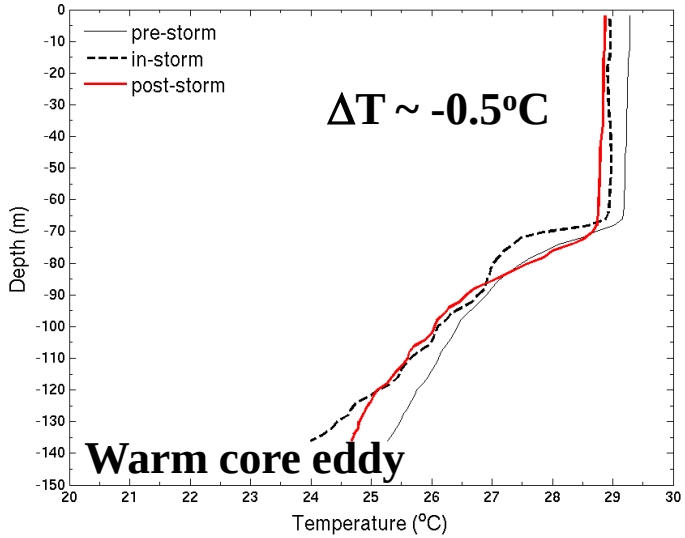


Observed cross-track velocity Structure at Mooring as cold cyclone moved over it.

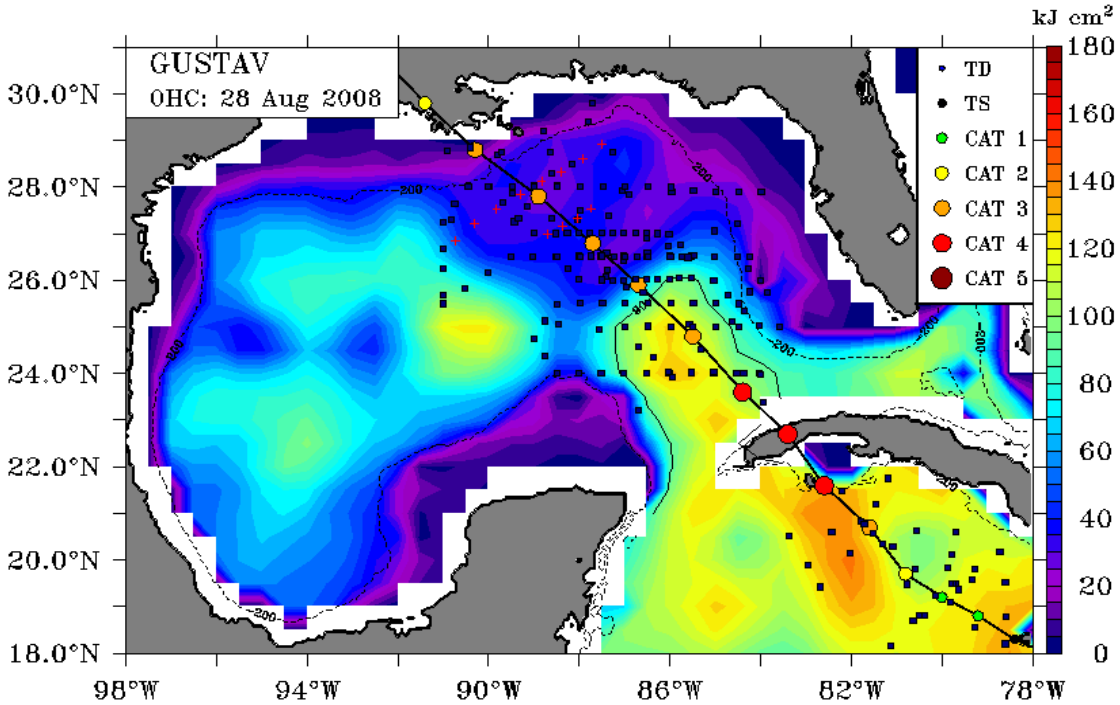
Differentiated cooling in the LC system (Jaimes and Shay, MWR, 2009)

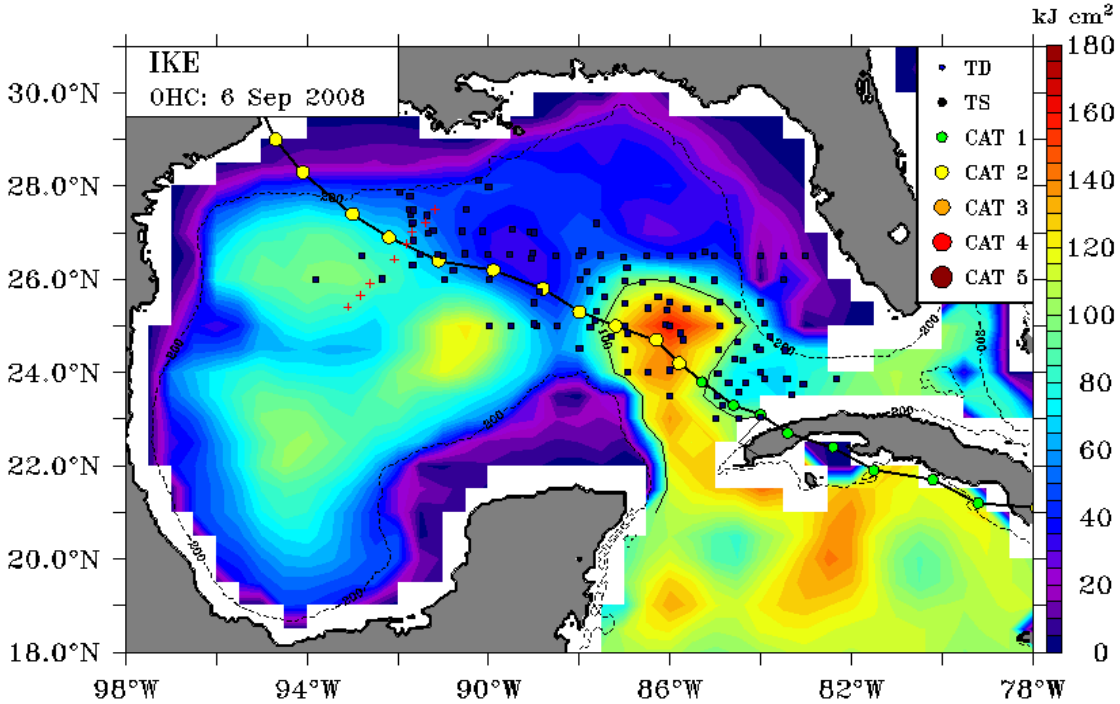






Cluster-averaged temperature profiles



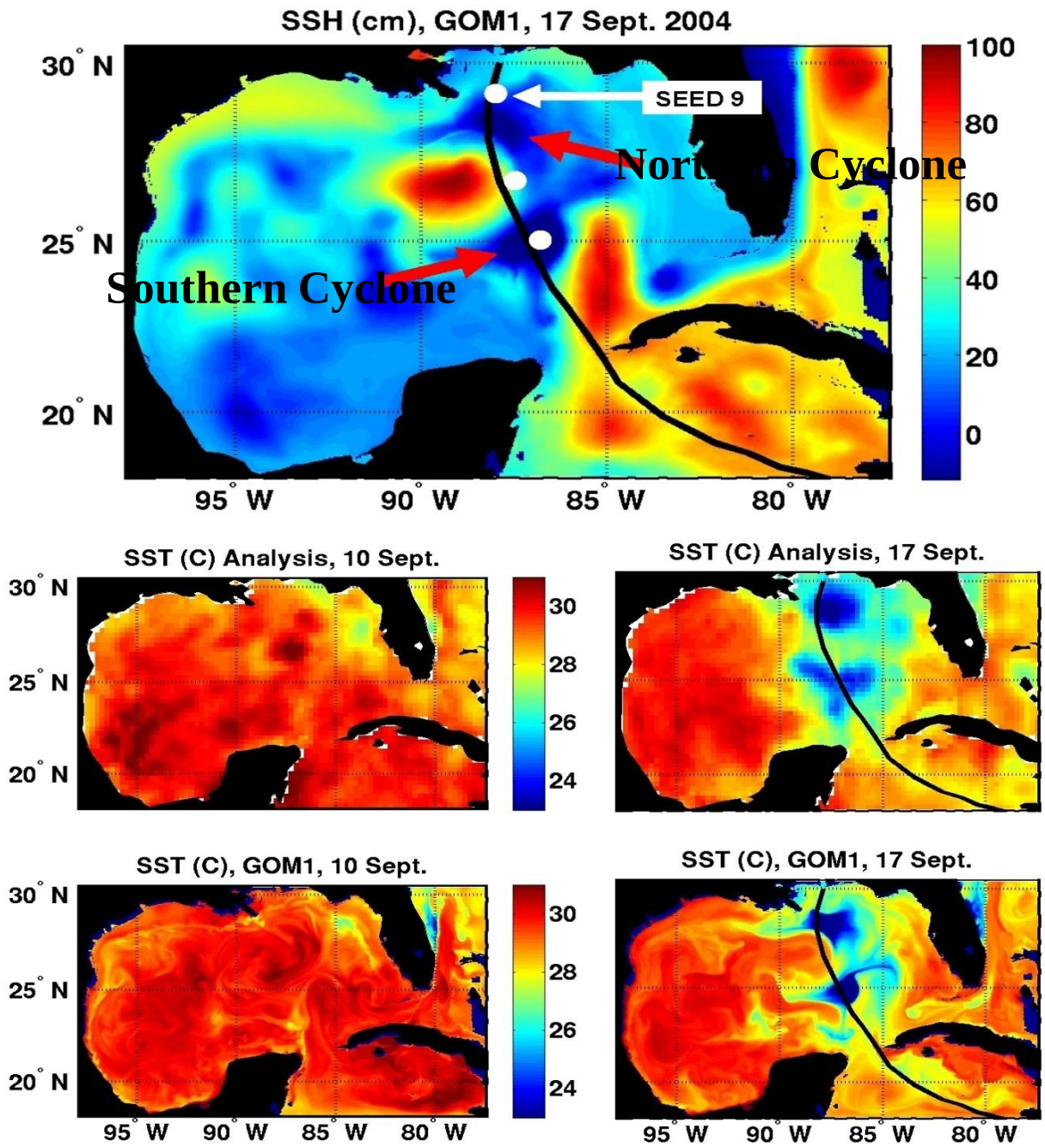


Track and Intensity of TC's Gustav and Ike Versus AXBTs relative to OHC and 26°C Isotherm Depth.

Gustav : 191 AXBTs
111 GPS Drifters
Floats

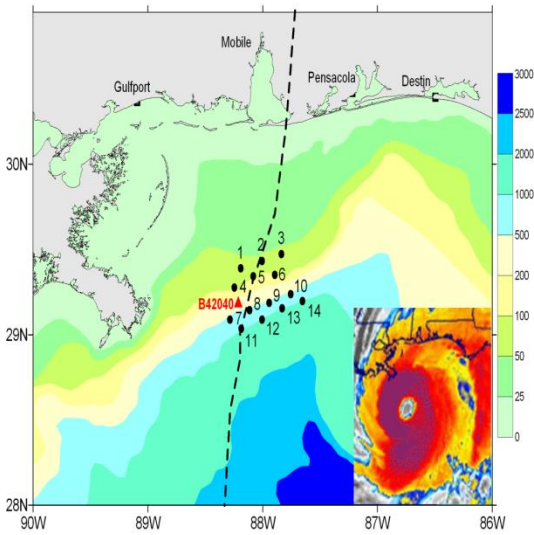
Ike : 216 AXBTs
111 GPS Drifters
Floats

(Zuczek et al. 2010)

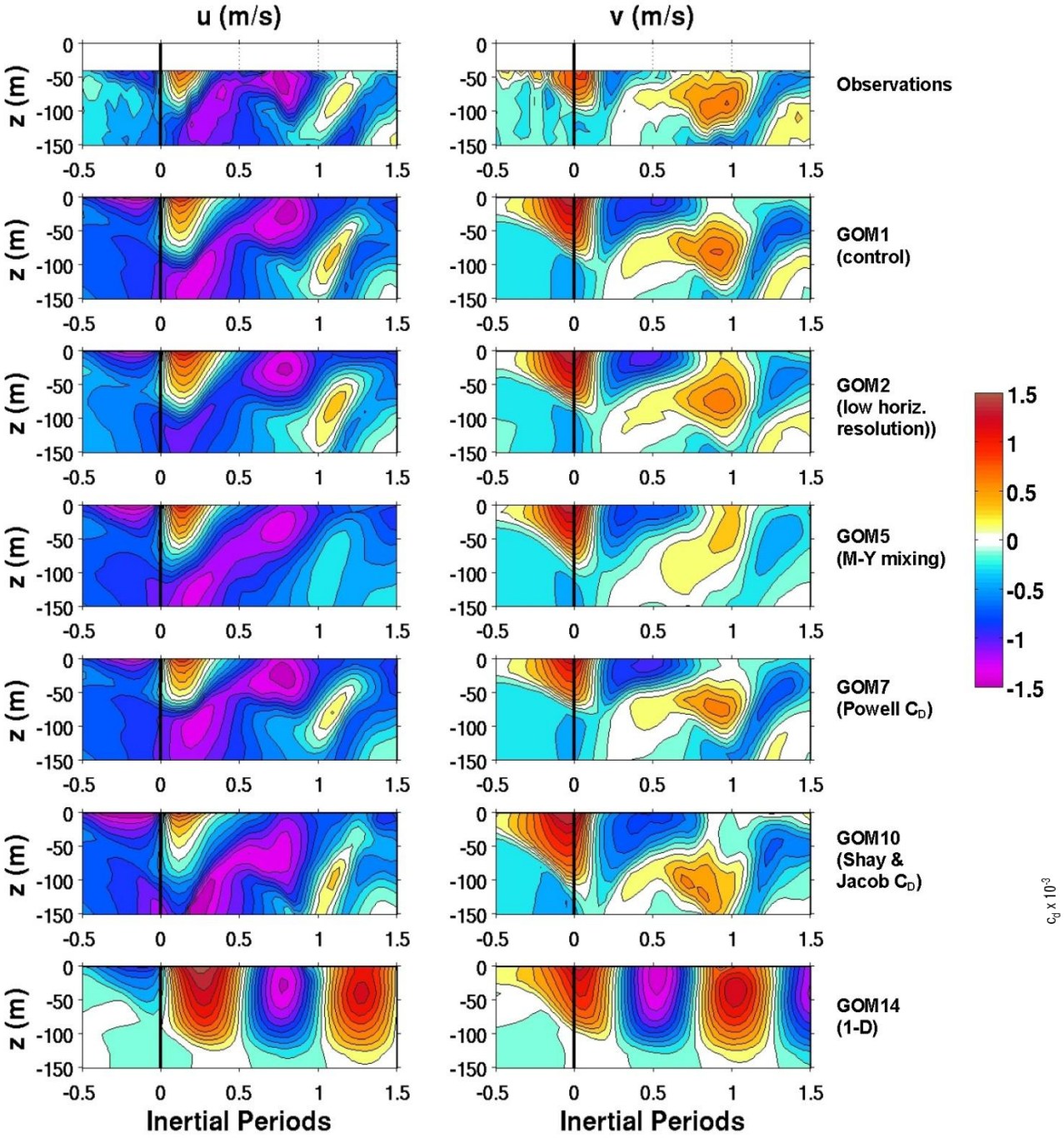


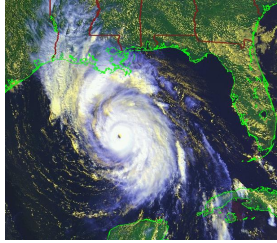
Ivan (2004) over the GOM SSH (cm) from HYCOM (from Halliwell et al., MWR, 2008).

WCR disrupts the the cold wake in data and the model.



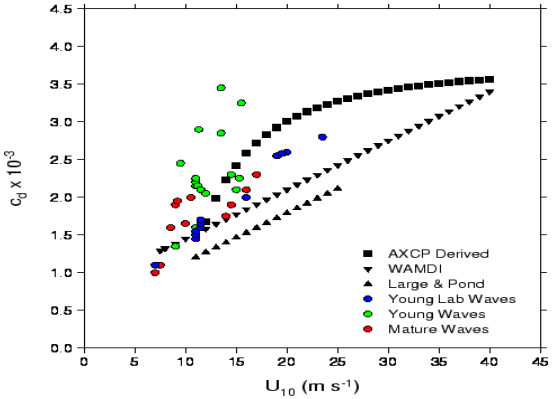
14 ADCP SEED Moorings
Teague et al., JPO (2007)





Observed/Simulated Current Response at M9 (1.5 Rmax) from 7 Experiments Halliwell et al., MWR, (2010)

Below cd using ocean response as a tracer in Shay and Jacob (2006)



Function = $3.755 \times 10^{-3} + \tanh(-0.295/U^2)$

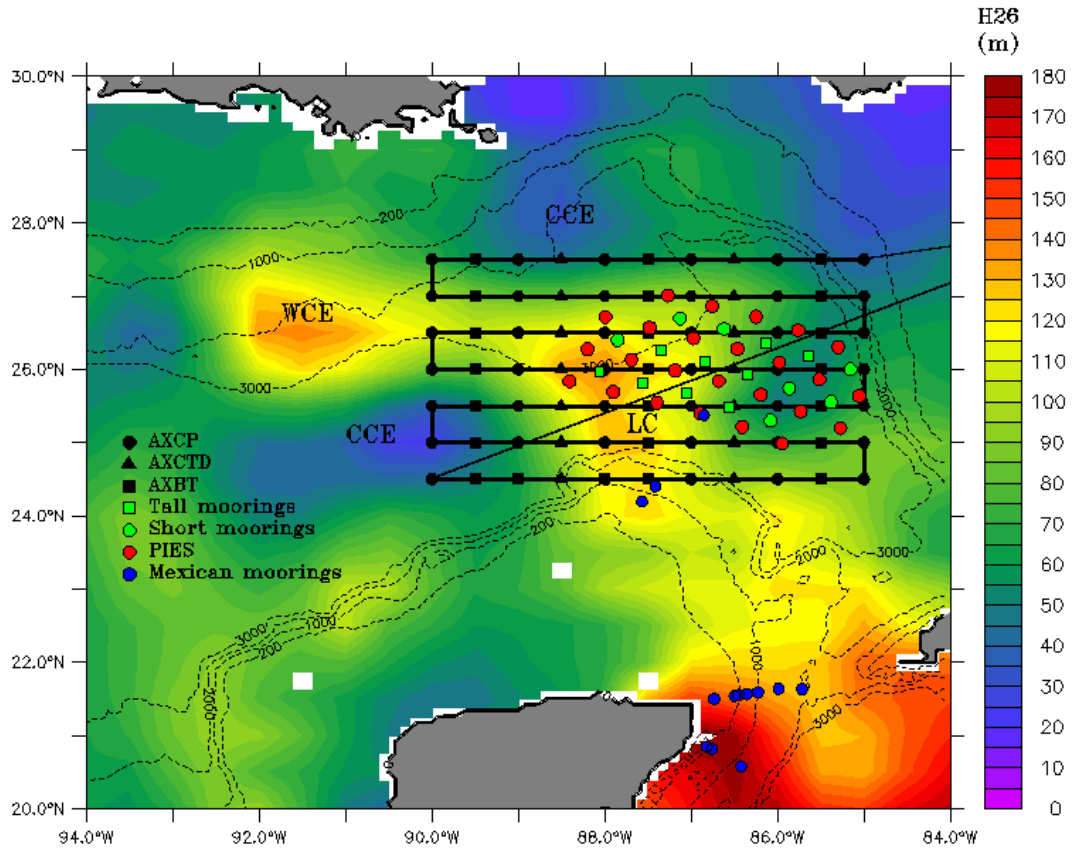
NOAA WP-3D profiling over MMS Moorings (IFEX, NASA GRIP)

Deliverables include:

V, T, S profiles to 1000 m @ 2-m resolution.

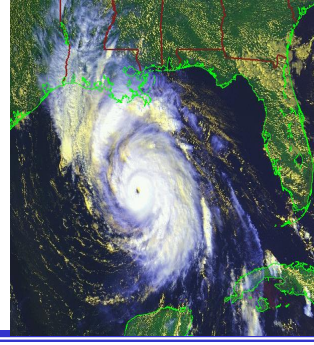
Surface winds (SFMR, GPS) provided by HRD.

Atmospheric profiles of V, T and RH @ 5-m resolution.



Expendables deployed from P-3 and proposed moorings relative to the LC, WCE and CCE superposed on late Sept 05 altimetry derived 26°C isotherm Depth (After Rita).

Summary



Combine adaptive *aircraft surveys* with *moored, drifter and ship based measurements* as part of the MMS/SAIC Dynamics of the Loop Current Study embedded within the NOAA IFEX (AOML, NCEP) and NASA GRIP Experiments.

Negative feedback (upwelling and mixing induced by strong winds and CCR) as opposed to **less negative feedback** **over the LC/ WCR.**

SST modulated by warm and cold ocean features that have to be properly initialized in ocean models and mixing processes impact fluxes.

Targeted obs (storm-coordinate system) of temperatures and currents needed to assess mixing schemes and evaluate initialization schemes. Expendables (AXCP, AXCTD) drifters and floats needed for satellite and oceanic and coupled model evaluations.