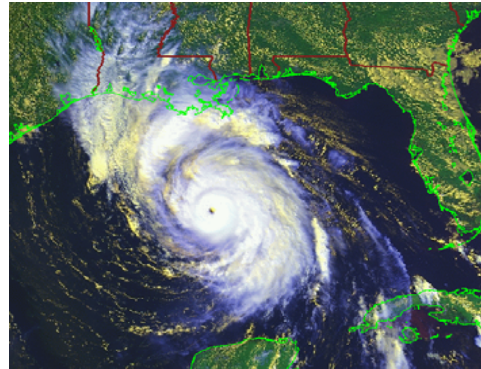


# JHT Project: Evaluation and Improvement of Ocean Model Parameterizations for NCEP Operations



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# Outline:

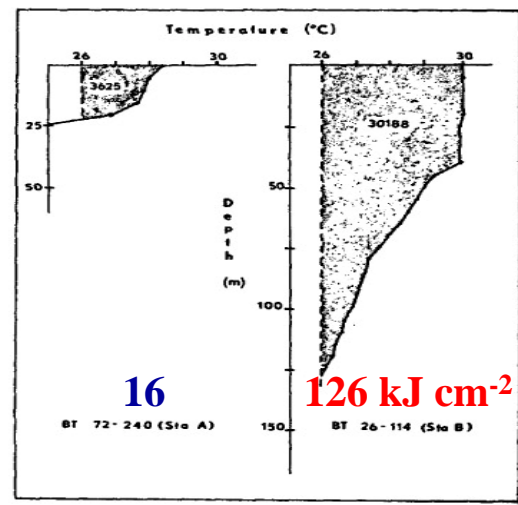
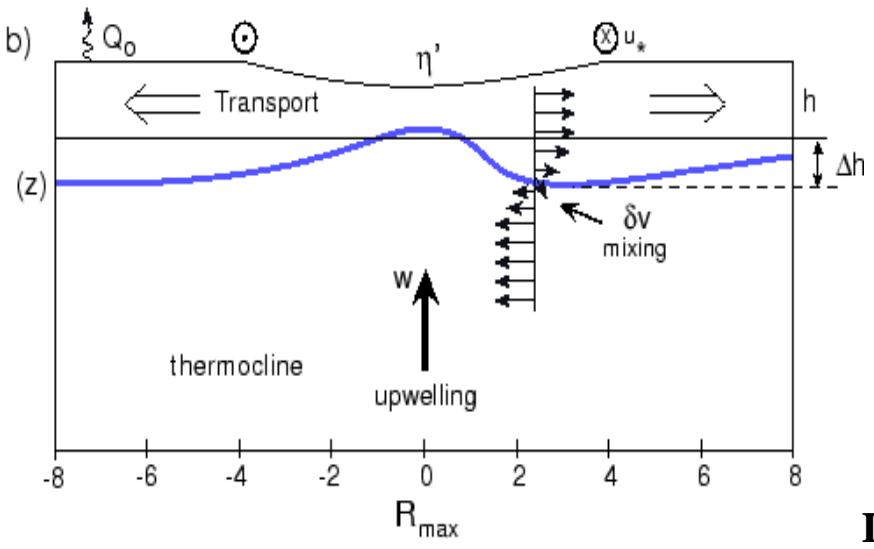
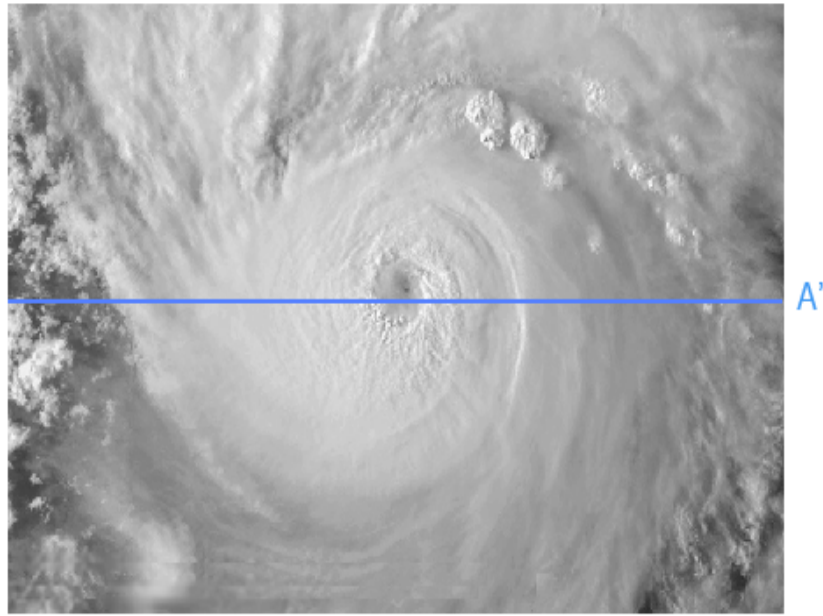


- **Oceanic Response Features**
- **Cold and Warm Core Eddies -Ivan (04)**
- **Loop Current/Warm Core Eddy Interactions (deep OML)**
  1. **Katrina and Rita (05)**
  2. **Gustav and Ike (08)**
- **2010 HFP with NOAA IFEX/MMS/NASA/NSF**
- **Summary**

## *Recurrent Theme:*

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

a)



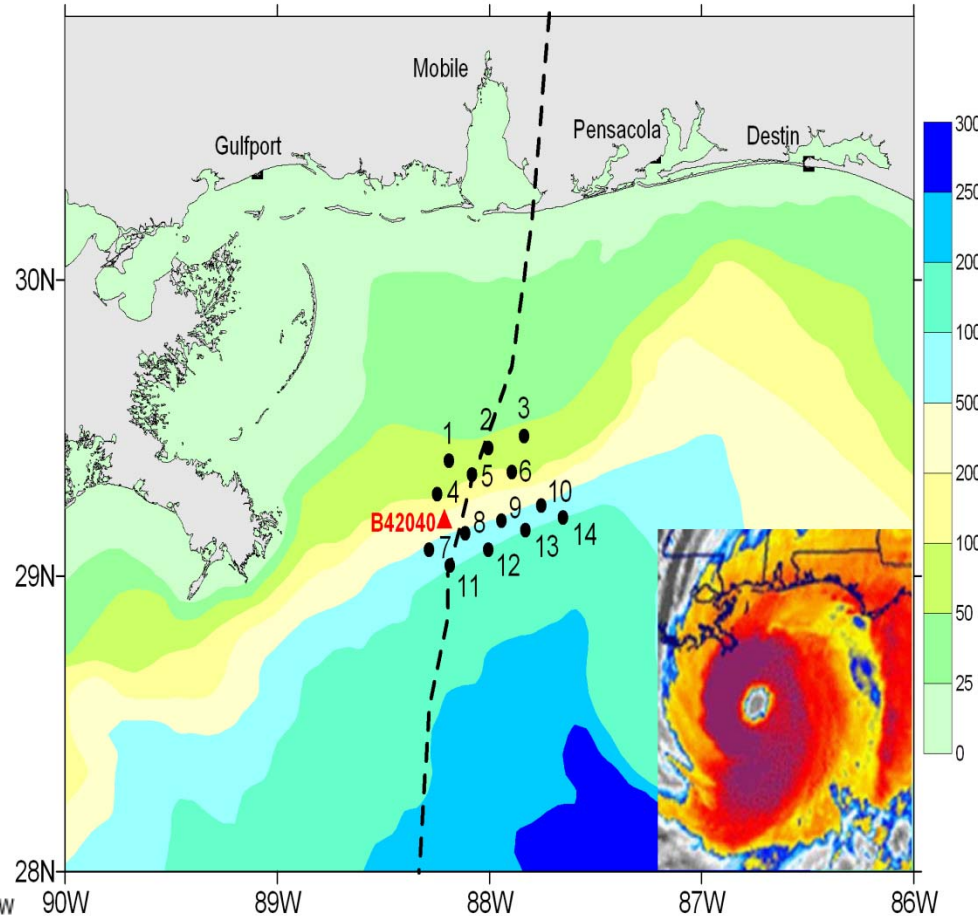
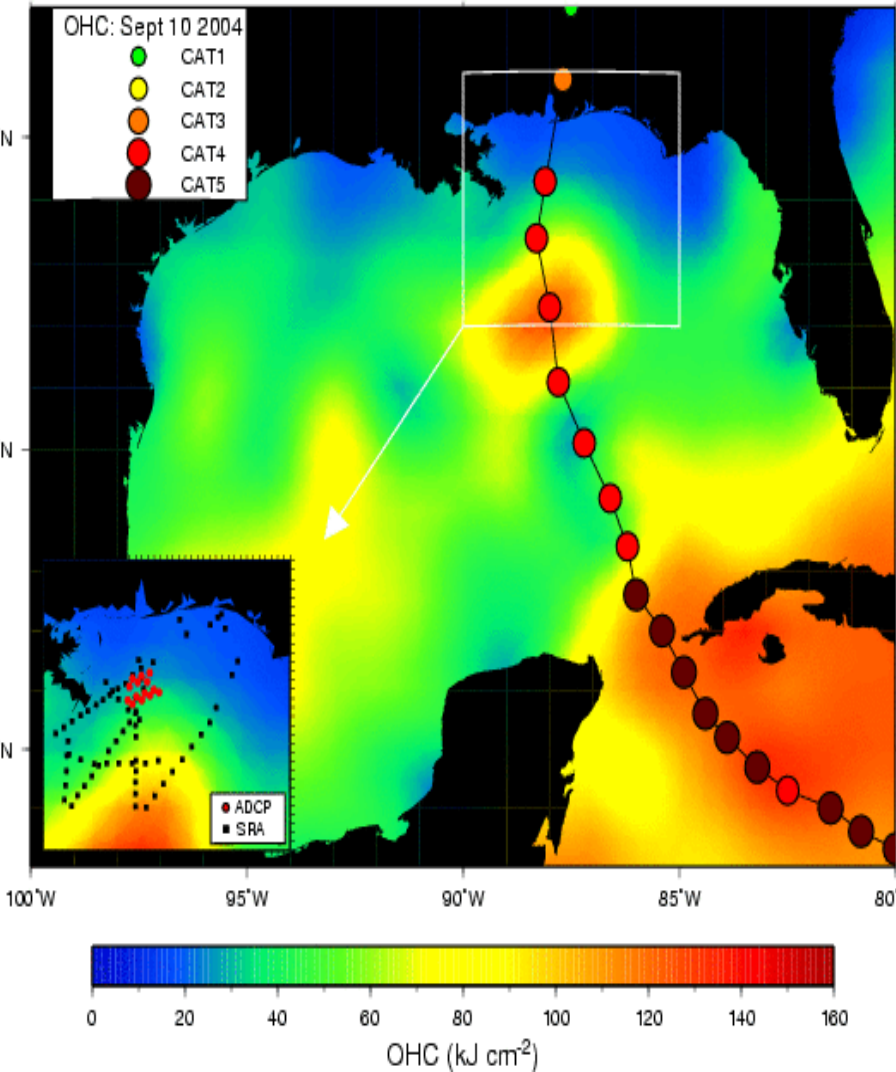
Leipper and Volgenau (JPO, 1972)

Integrated thermal structure (OHC) and vertical current shear.

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

Changing ocean mixed layer depths affect feedback to the TC boundary layer.

# Ivan's Track and Intensity Relative to OHC (left) NRL SEED Mooring Locations in Northern Gulf of Mexico Relative to Bottom Depth (Right) (*Teague et al., JPO, 2007*).

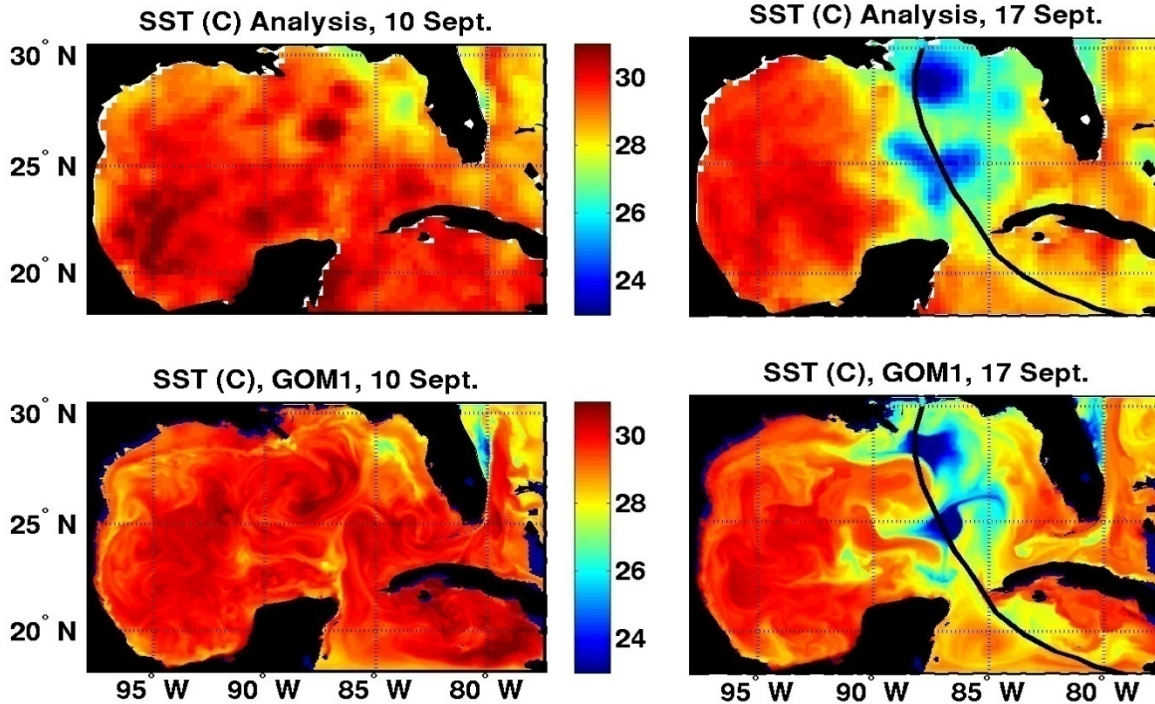
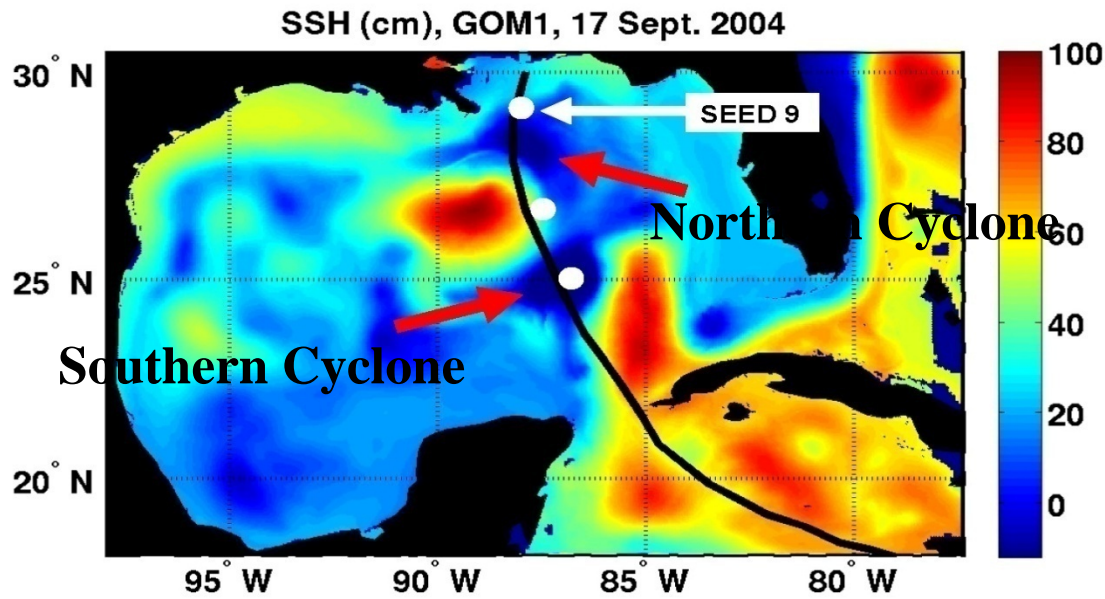


**14 ADCP moorings- Focus here in Array 9.**



## MOTIVATION:

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



## SST Analyses

# HYbrid Coordinate Ocean Model (HYCOM) Hurricane Ivan Simulations 10 Sept-6 Oct 04 (Halliwell et al., 2010)



## Configuration:

- 0.04° Mercator grid, Gulf of Mexico domain
- No data assimilation performed

## Initial and boundary conditions from U.S. Navy HYCOM ocean nowcast-forecast system:

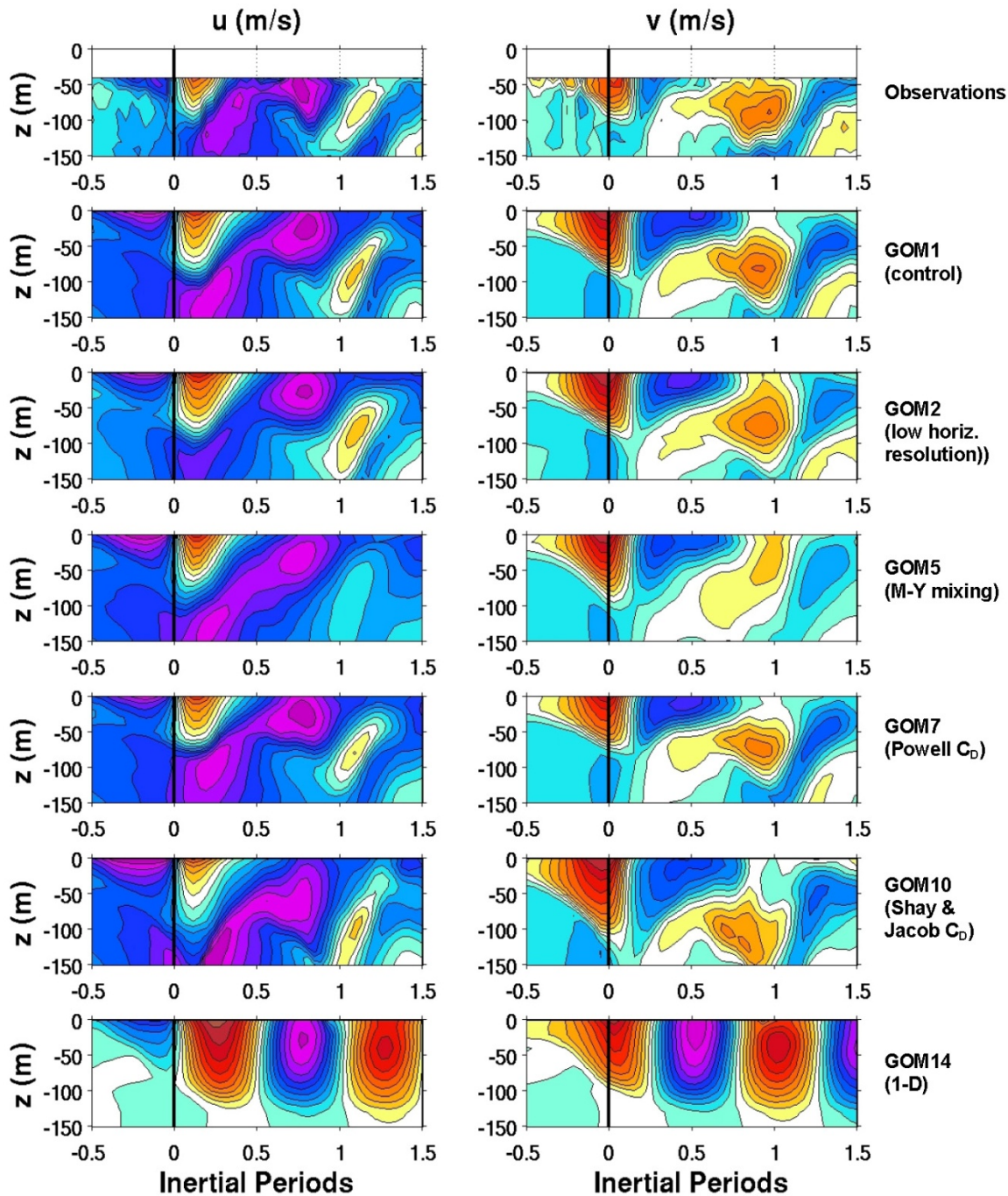
- Data assimilative ocean nowcast
- Navy Coupled Ocean Data Assimilation (NCODA) assimilation

## Atmospheric Forcing:

- Navy 27 km COAMPS atmospheric model
- Vector wind blended with higher resolution fields from HWIND
- Wind stress for HWIND calculated using Donelan cd

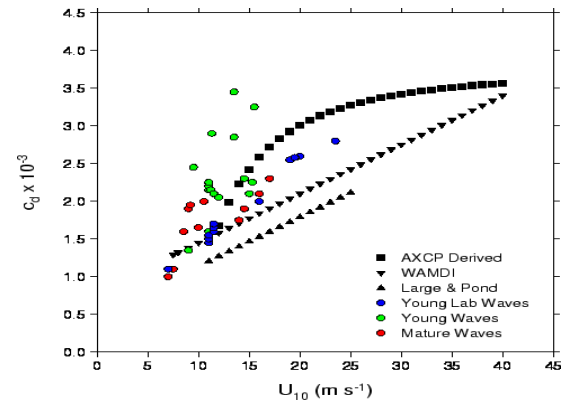
# Hurricane Ivan Modeling Experiment Summary

Model Attribute	Baseline Experiment GOM1	Alternate Experiments
Horizontal resolution	0.04° Mercator	GOM2: 0.08° Mercator
Vertical resolution	26 layers, 4-8m in OML	GOM3: 21 layers, 7.5-15m in OML GOM4: 31 layers, 3-5m in OML
Vertical mixing	KPP	GOM5: MY GOM6: GISS
$C_D$	Donelan	GOM7: Powell GOM8: Large and Pond GOM9: Large and Pond (capped) GOM10: Shay and Jacob
$C_{EL}, C_{ES}$	COARE3.0 algorithm	GOM11: Kara <i>et al.</i>
Atmospheric forcing	27-km COAMPS+H*WIND	GOM12: 27-km COAMPS only
Outer model	NCODA GoM hindcast	GOM13: Free GOM simulation
Ocean Dynamics	3-D Ocean Physics	GOM14: 1-D Column Models



**Observed/Simulated  
Current Response at  
M9 (1.5 Rmax)  
from 7 Experiments  
Halliwell et al., MWR,  
(2009)**

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



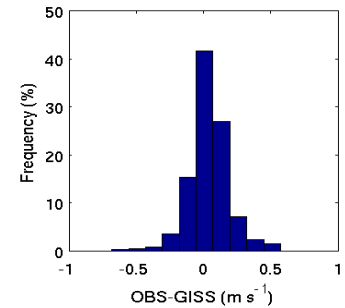
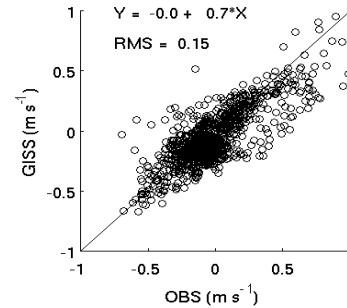
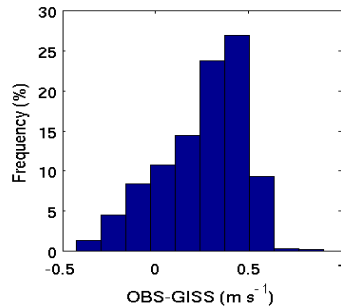
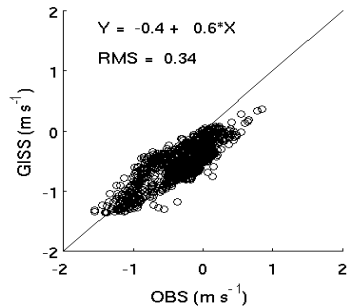
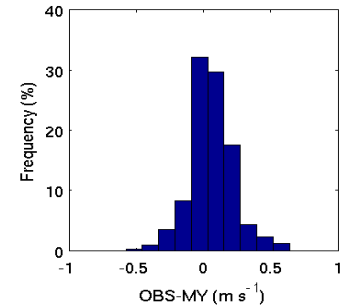
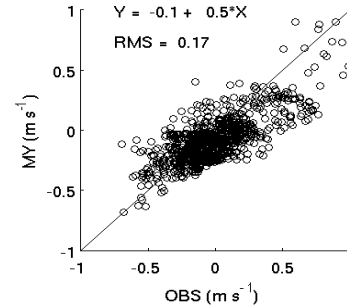
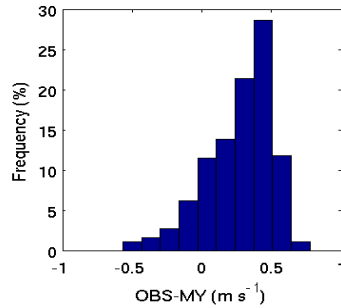
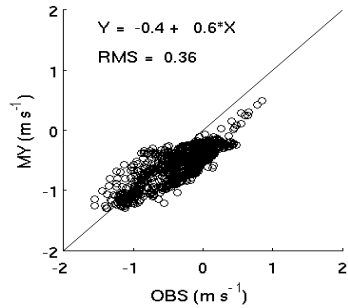
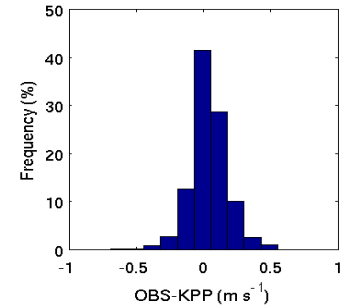
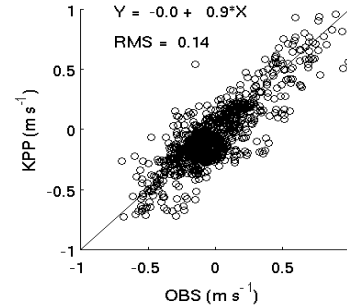
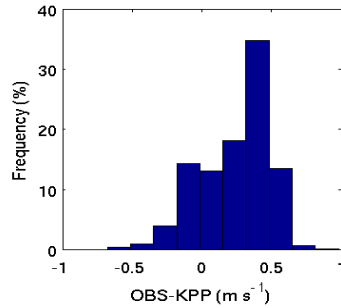
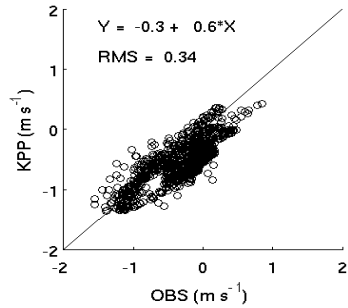
Function =  $3.755 \times 10^{-3} + \tanh(-0.295/U^2)$



# Current Time Series Comparisons @ 1.5 R<sub>max</sub>

## U (east-west)

## V (north-south)



# Vertical Mixing

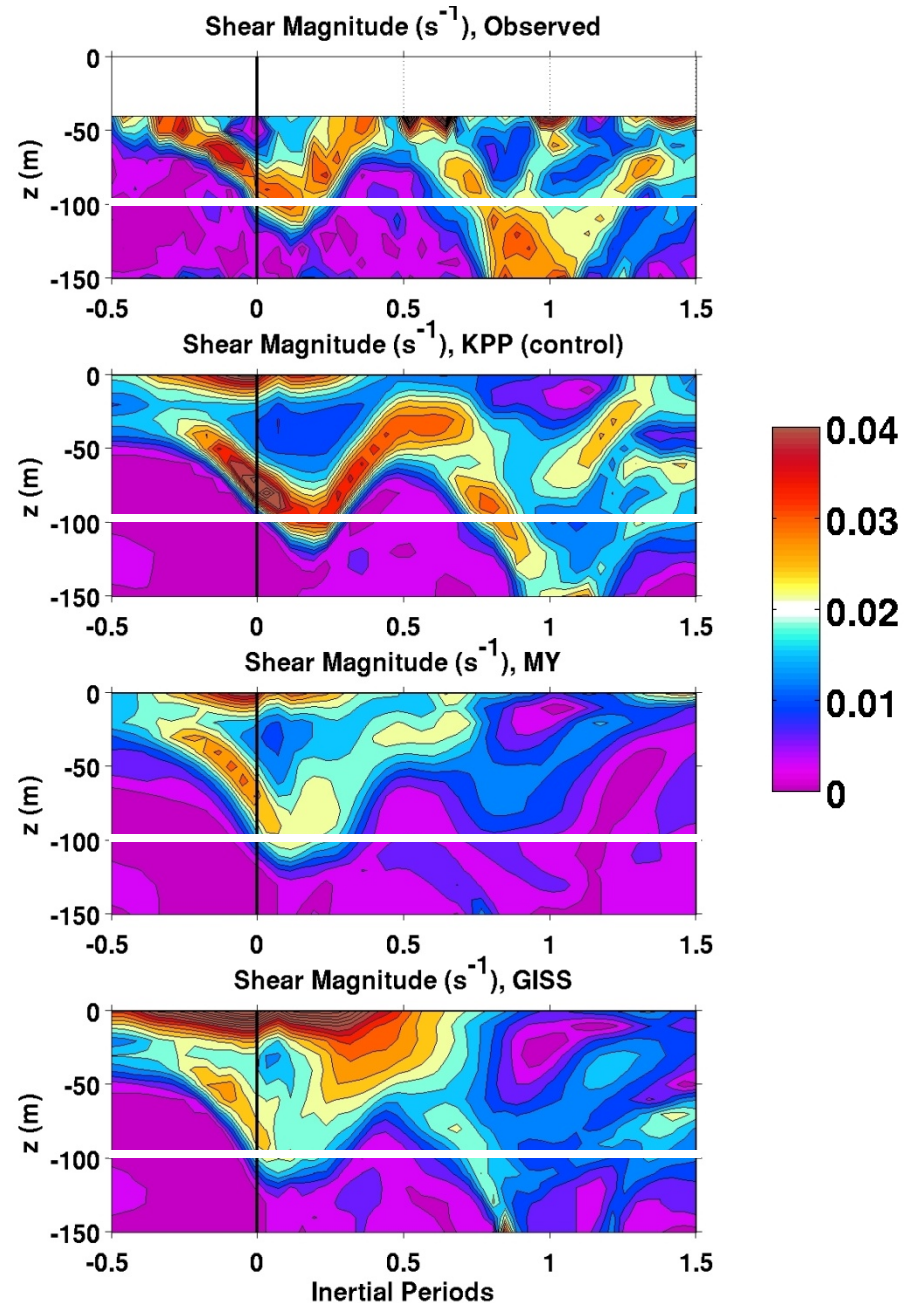
**Observed**

**Conclusion: KPP mixing produces the most realistic shear response. Other two choices underestimate entrainment, which reduces mixed layer deepening and SST cooling.**

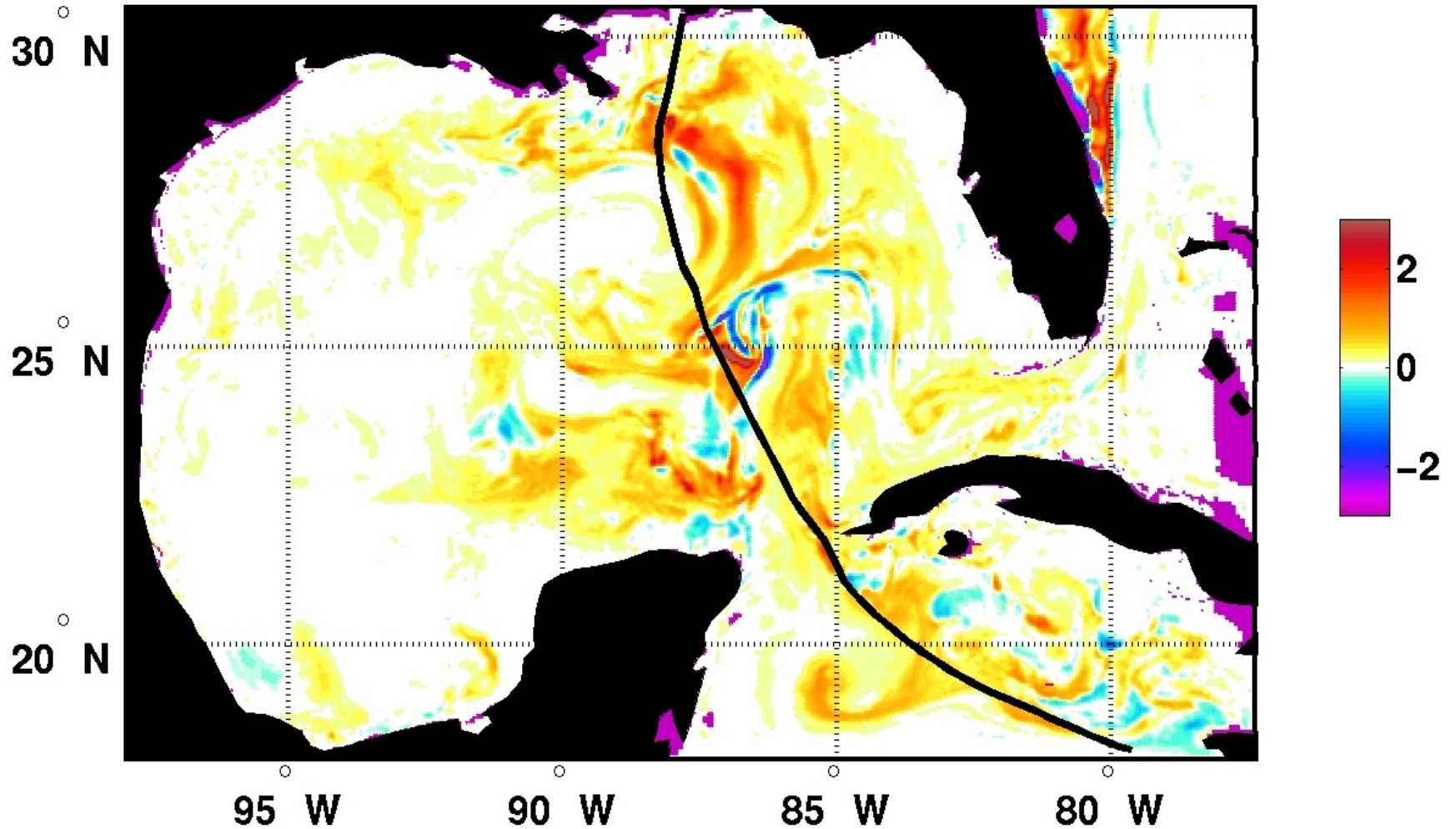
**KPP (control)**

**Mellor-Yamada**

**GISS**



# Difference in SST cooling GISS minus KPP mixing



# Drag Coeff. Parameterization

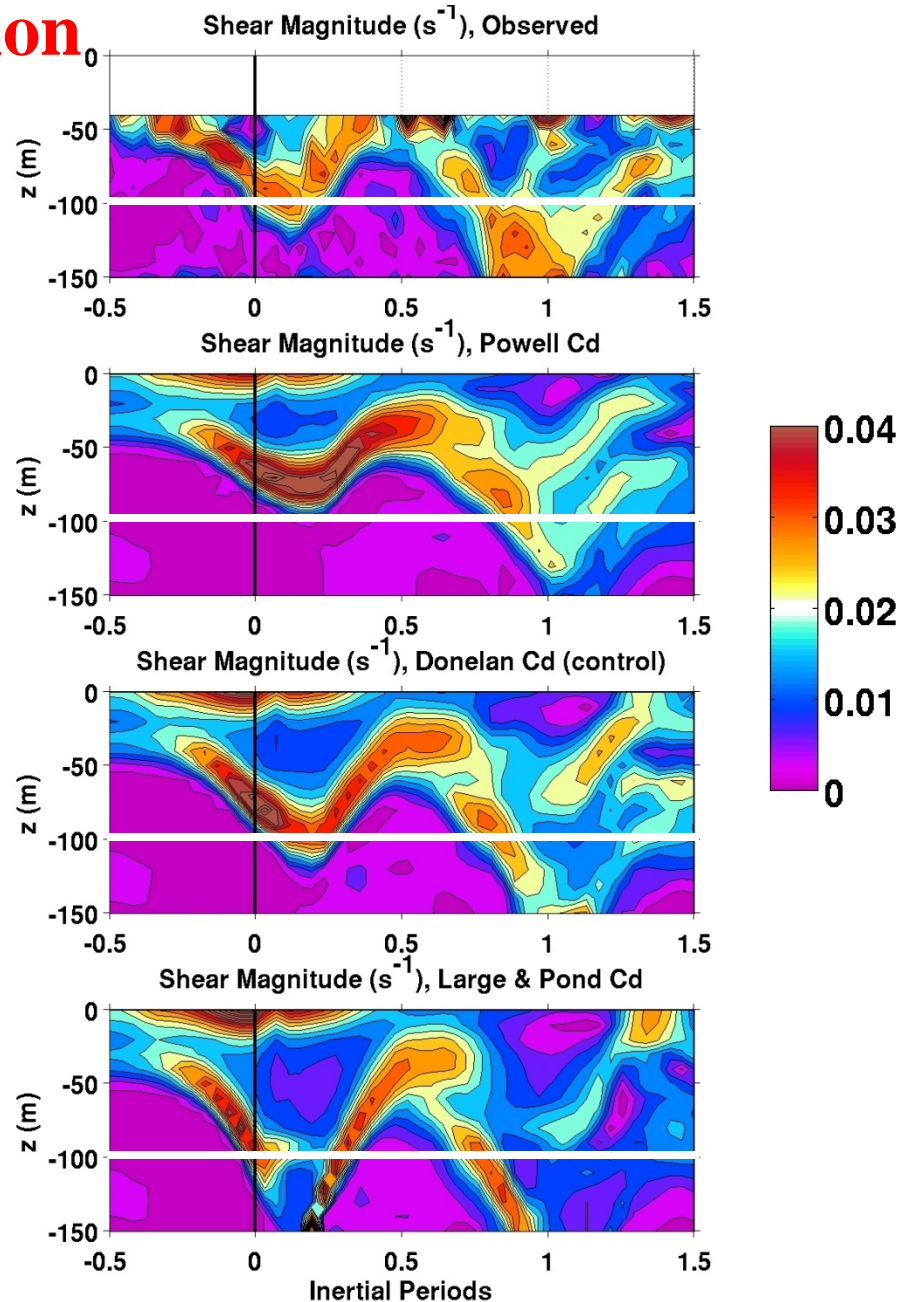
**Conclusion:** parameterizations that yield coefficients between  $2 \times 10^{-3}$  and  $2.5 \times 10^{-3}$  at high wind speeds produce the most realistic shear response. Larger (smaller) coefficient values increase (decrease) mixed layer deepening and SST cooling

**Observed**

**Powell *et al.***

**Donelan *et al.***  
**(control)**

**Large and Pond**

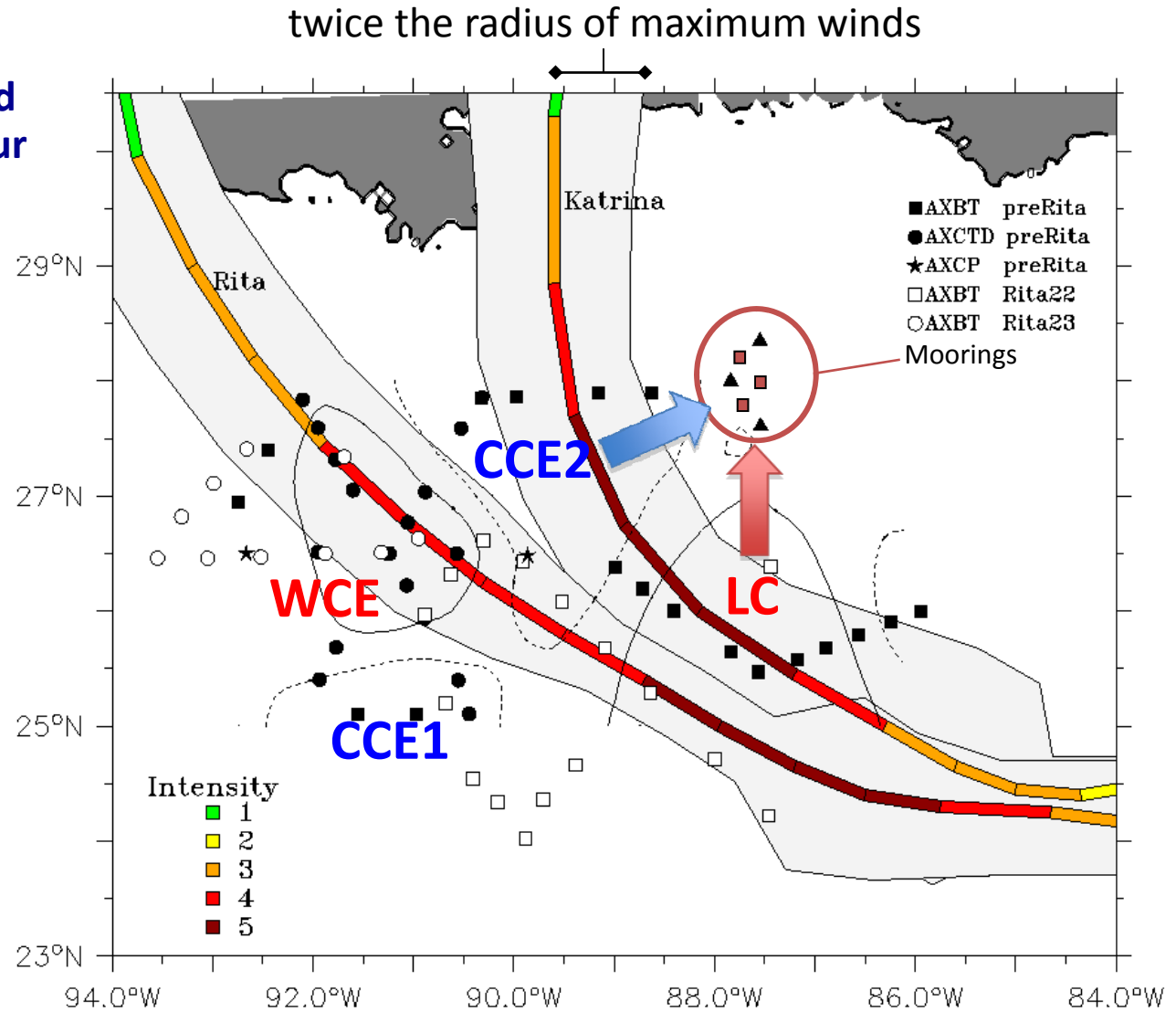




# The 2005 Loop Current System experiment

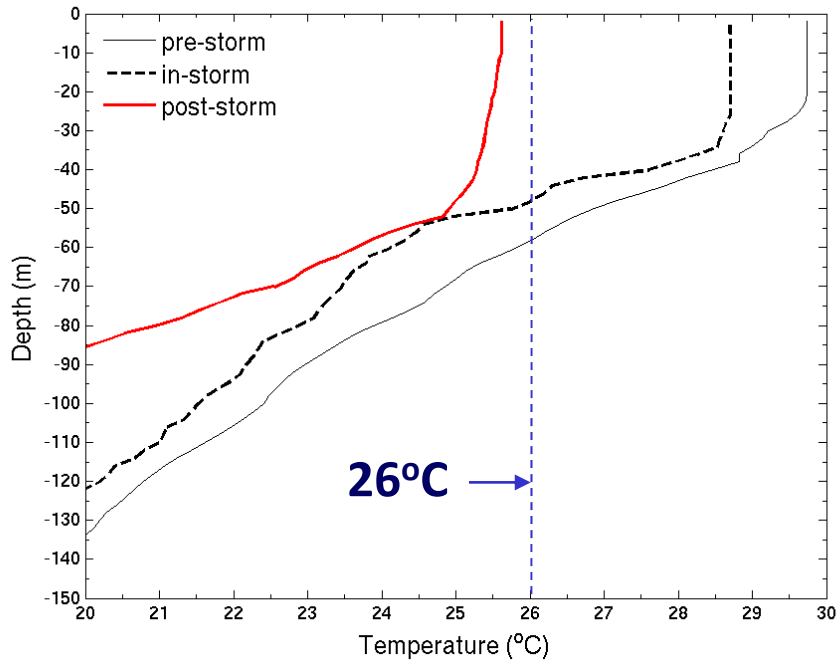
- Seawater temperature and conductivity data from four airborne surveys.
- Mooring data: velocity, temperature, and conductivity at ~10 m intervals.

For the first time, the ocean response to major hurricanes was simultaneously measured inside cyclonic and anticyclonic geostrophic features.

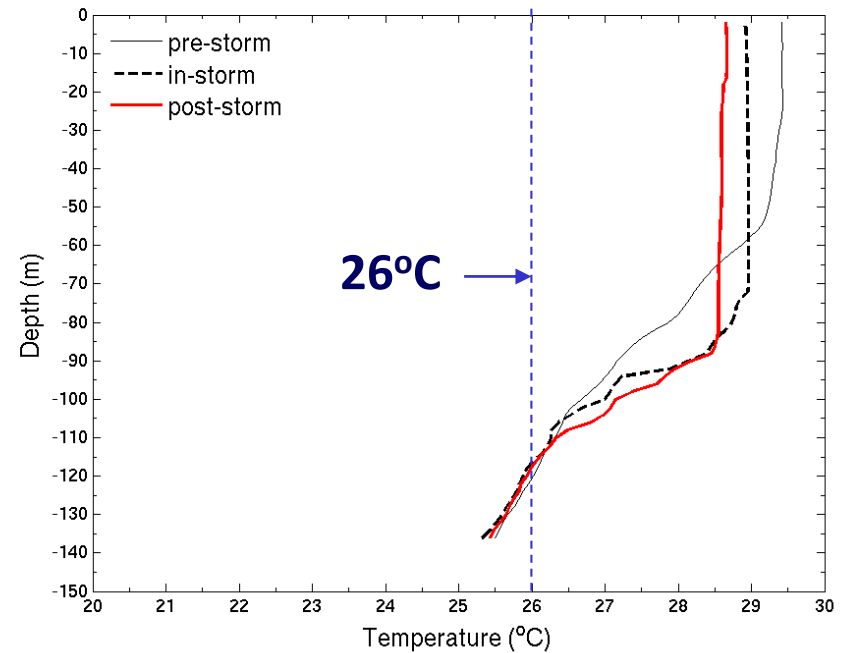


# TC-induced cooling in geostrophic eddies (airborne data)

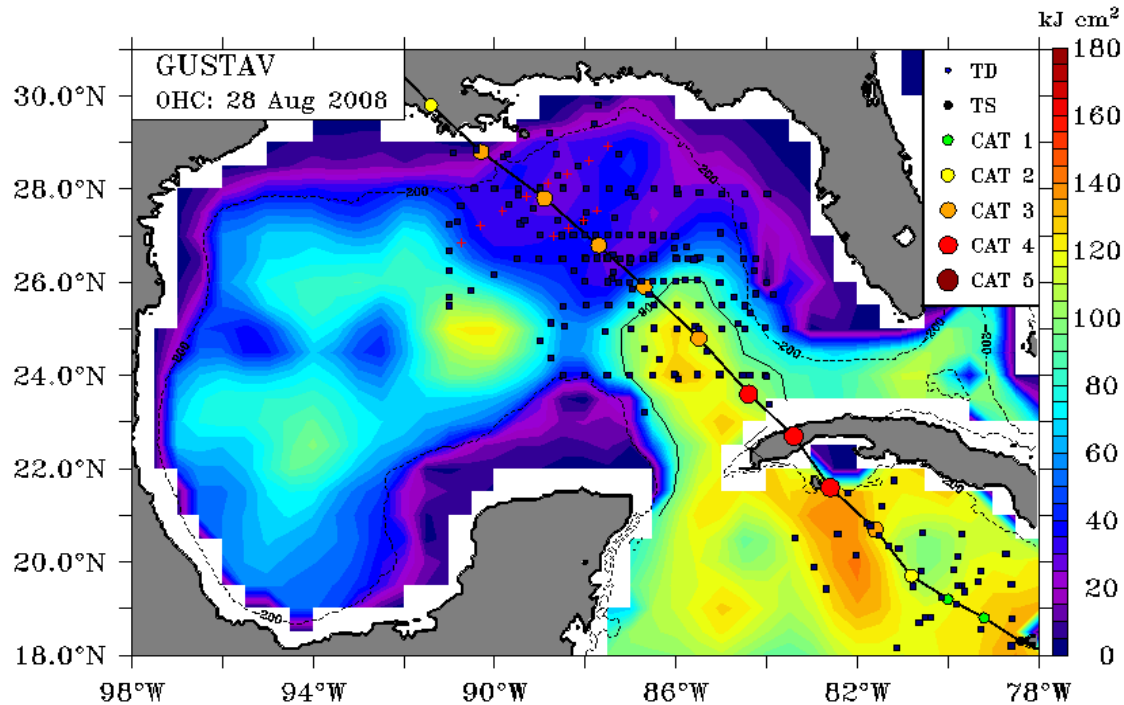
CCE:  $\Delta T \sim -4.5^\circ\text{C}$



Loop Current bulge:  $\Delta T \sim -1^\circ\text{C}$

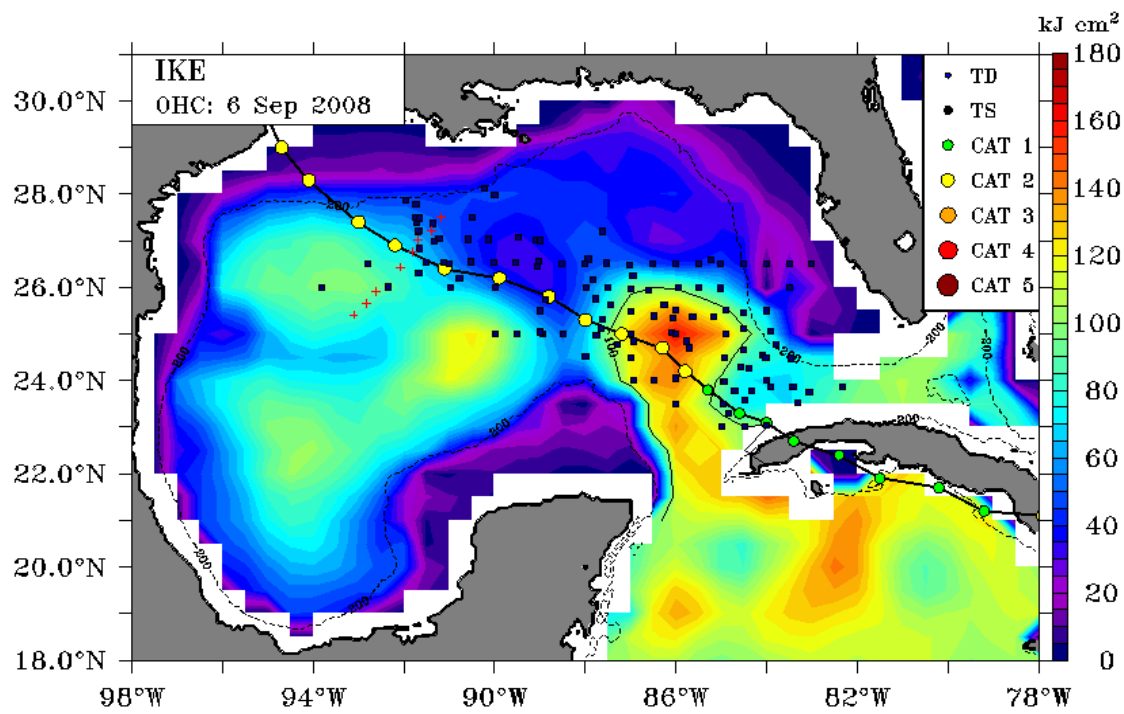


cluster-averaged temperature profiles  
(Hurricane Rita)



# 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

**SMFR, SRA measurements.**

# Progress Summary and Blueprint For Future



*Ivan* a clear example of **negative feedback** (wake cooling/mixing induced by strong winds and Cold Core Ring) as opposed to **positive feedback** over the Loop Current and Warm Core Rings.

*Relative to the moored ocean measurements:*

- Simulated shear response is a stringent test of model performance
  - KPP mixing outperforms Mellor-Yamada and GISS
  - Drag coefficient parameterizations that yield values between  $2.0 \times 10^{-3}$  and  $2.6 \times 10^{-3}$  (e.g. Donelan *et al.*) outperform those that yield larger or smaller values
  - No need to use vertical resolution of  $< 10$  m with KPP mixing
  - Same conclusions realized at other SEED moorings (not shown)
- Model evaluation must be extended to other storms and to differing ocean regions (Katrina and Rita (05); Frances (04); Gustav and Ike (08))
- **High quality ocean observations are critically important for model evaluations (e.g., NOAA IFEX, MMS, NASA GRIP this summer)**



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

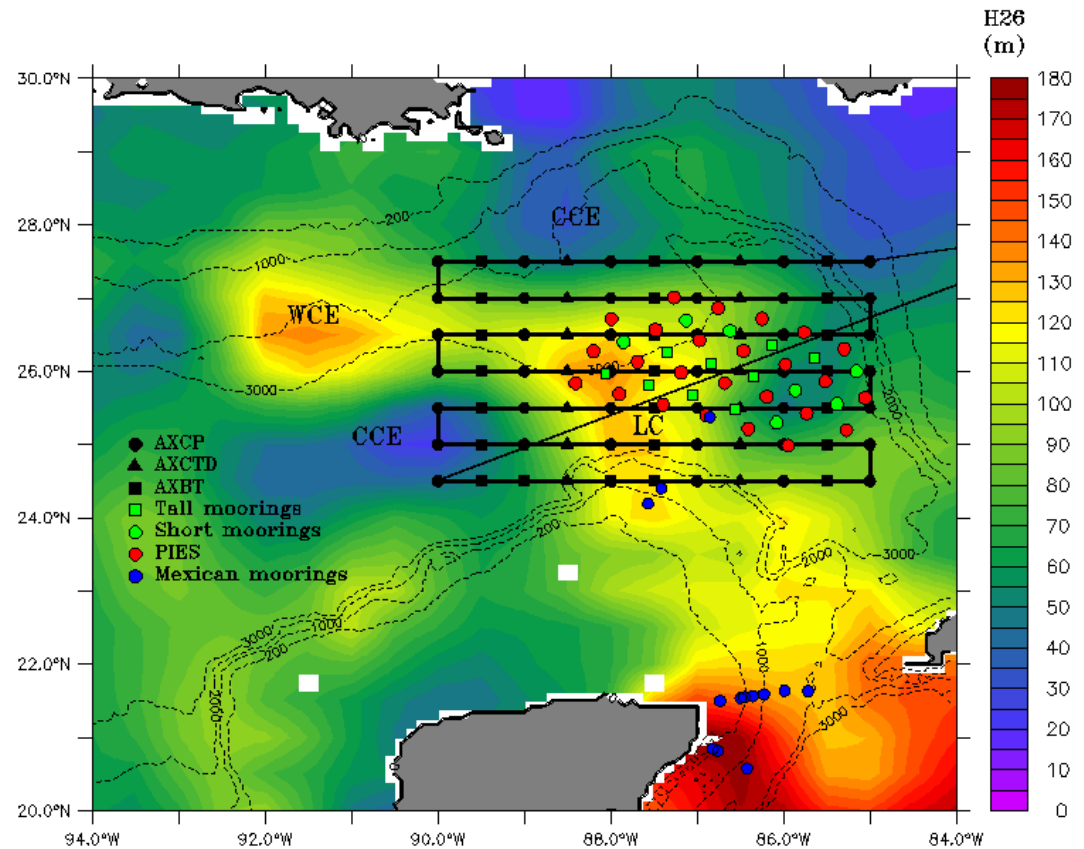


**Deliverables include:**

**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).**