Hurricane Currents & Waves

L.-Y. Oey & D.-P. Wang
Princeton University & Stony Brook University

Goal:

Provide "best" estimates of currents & waves produced by Katrina & Rita; and to understand dynamics; (focus: outer continental shelves & deeper waters)

Tasks:

1. **"Best-estimate" of initial states: positions & strengths of LC & rings;**
2. **Currents, simulation without data assimilation, i.e. "forecast";**
3. **Accurate wind fields;**
4. **Wave modeling;**

   Skill assessments & physics …

Work based on (note co-authors):

Oey, L.-Y., **T. Ezer**, D.-P. Wang, **X.-Q.Yin**, and **S.-J. Fan**. 2007. Hurricane-induced motions and interaction with ocean currents. Cont. Shelf Res. 27:1249–1263.

Oey, L.-Y, **T. Ezer**, D.-P. Wang, **S.-J. Fan**, and **X.-Q. Yin**. 2006. Loop Current warming by Hurricane Wilma. Geophys. Res. Lett. 33.

Wang, D.-P. and L.-Y. Oey. 2007. Hurricane Katrina: Waves and currents. Submitted.

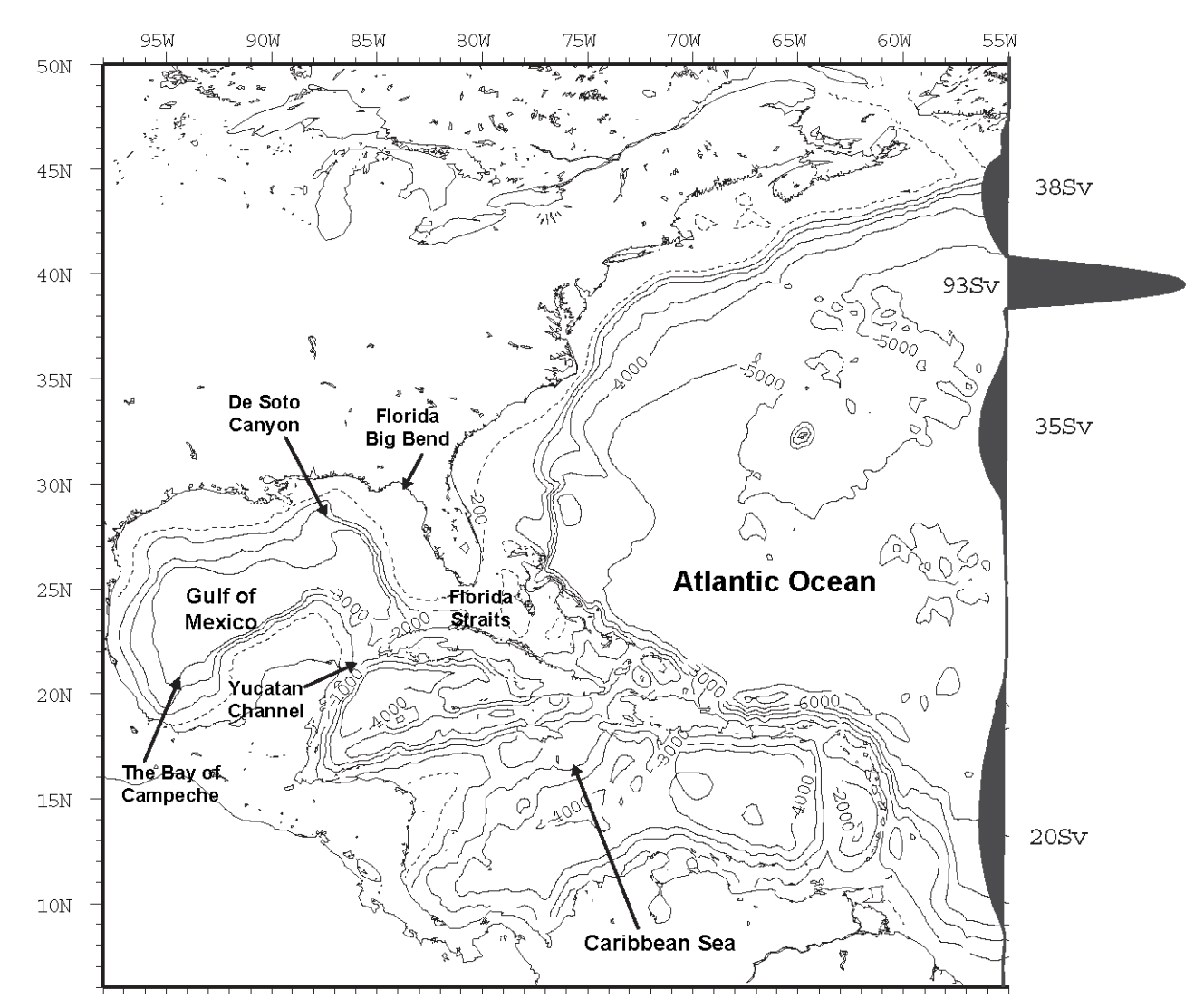
Yin, X.-Q. and L.-Y. Oey. 2006. Bred-ensemble ocean forecast of Loop Current and rings. Submitted.

Financial supports from MMS/DOI and computing supports from GFDL/NOAA are gratefully acknowledged.

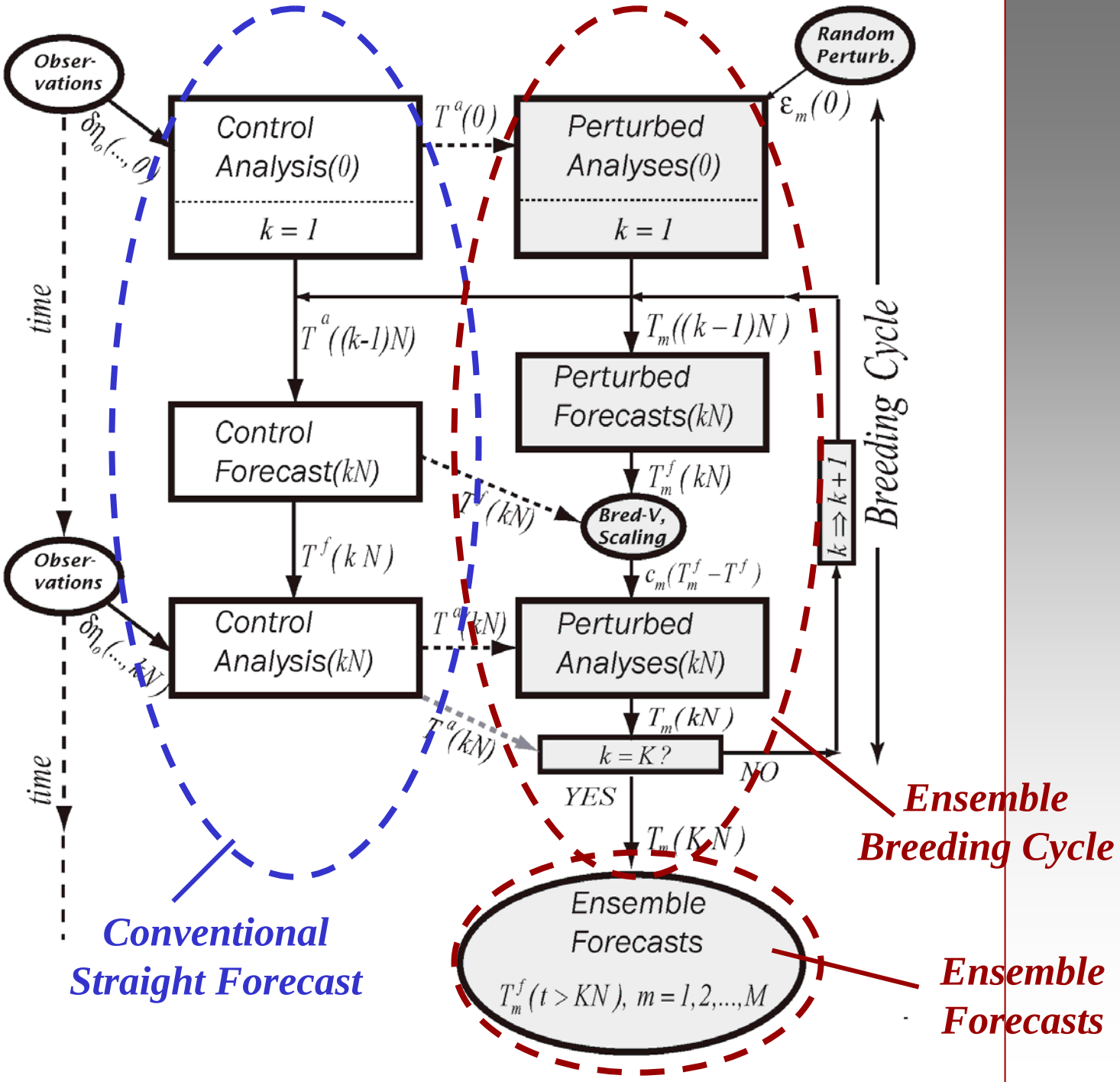
Princeton Regional Ocean Forecast System (PROFS)

Princeton Ocean Model (POM)

http://www.aos.princeton.edu/WWWPUBLIC/PROFS/

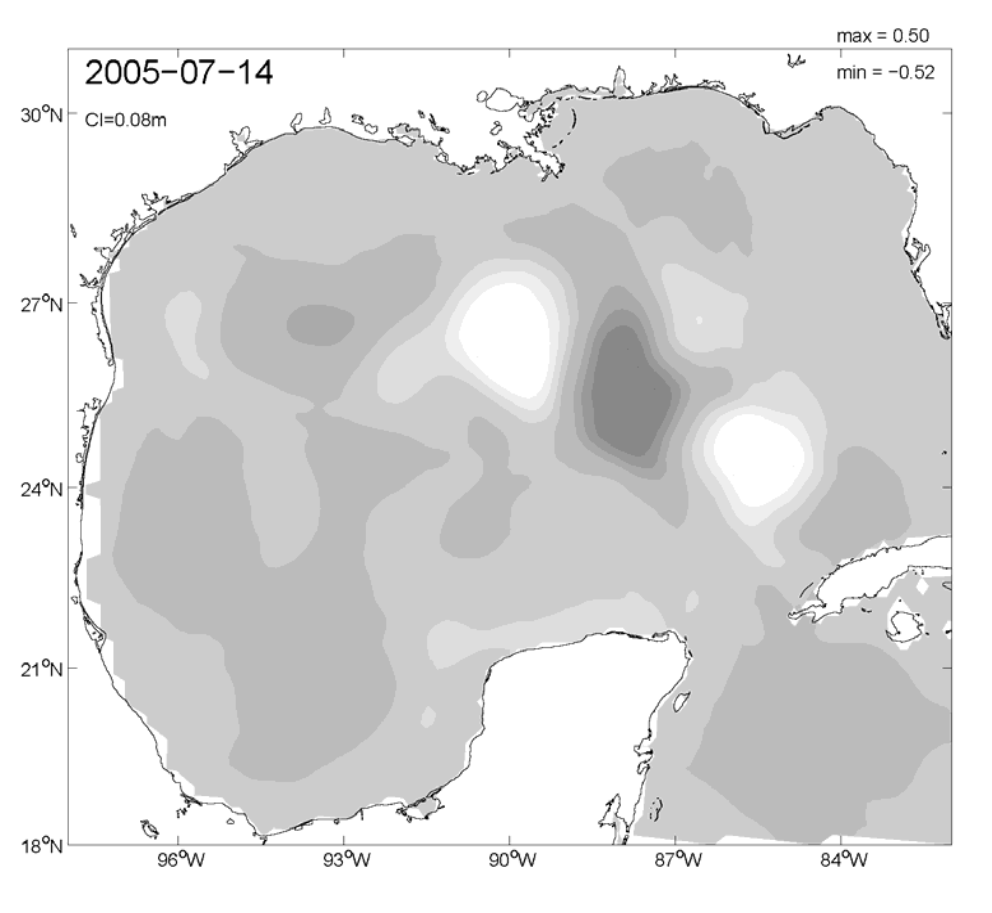


Initial Field

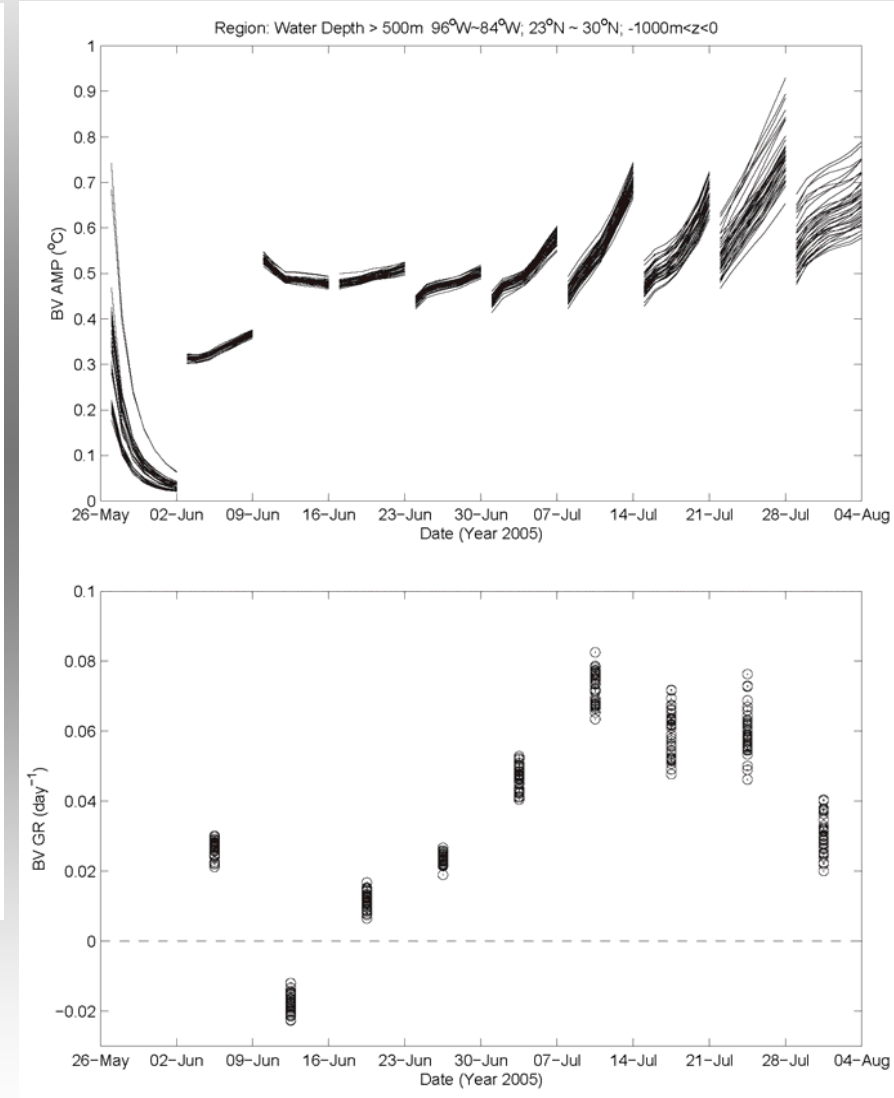

Obser-vations
Random Perturb.
Control Analysis(0)
k = 1
Perturbed Analyses(0)
k = 1
time
Control Forecast(kN)
Perturbed Forecasts(kN)
Bred-V, Scaling
Obser-vations
Control Analysis(kN)
Perturbed Analyses(kN)
k = K ?
NO
YES
Ensemble Forecasts
Breeding Cycle
Conventional Straight Forecast
Ensemble Breeding Cycle
Ensemble Forecasts

Bred Vectors

Matured Spatial Pattern



Temporal Evolution & Growth Rate

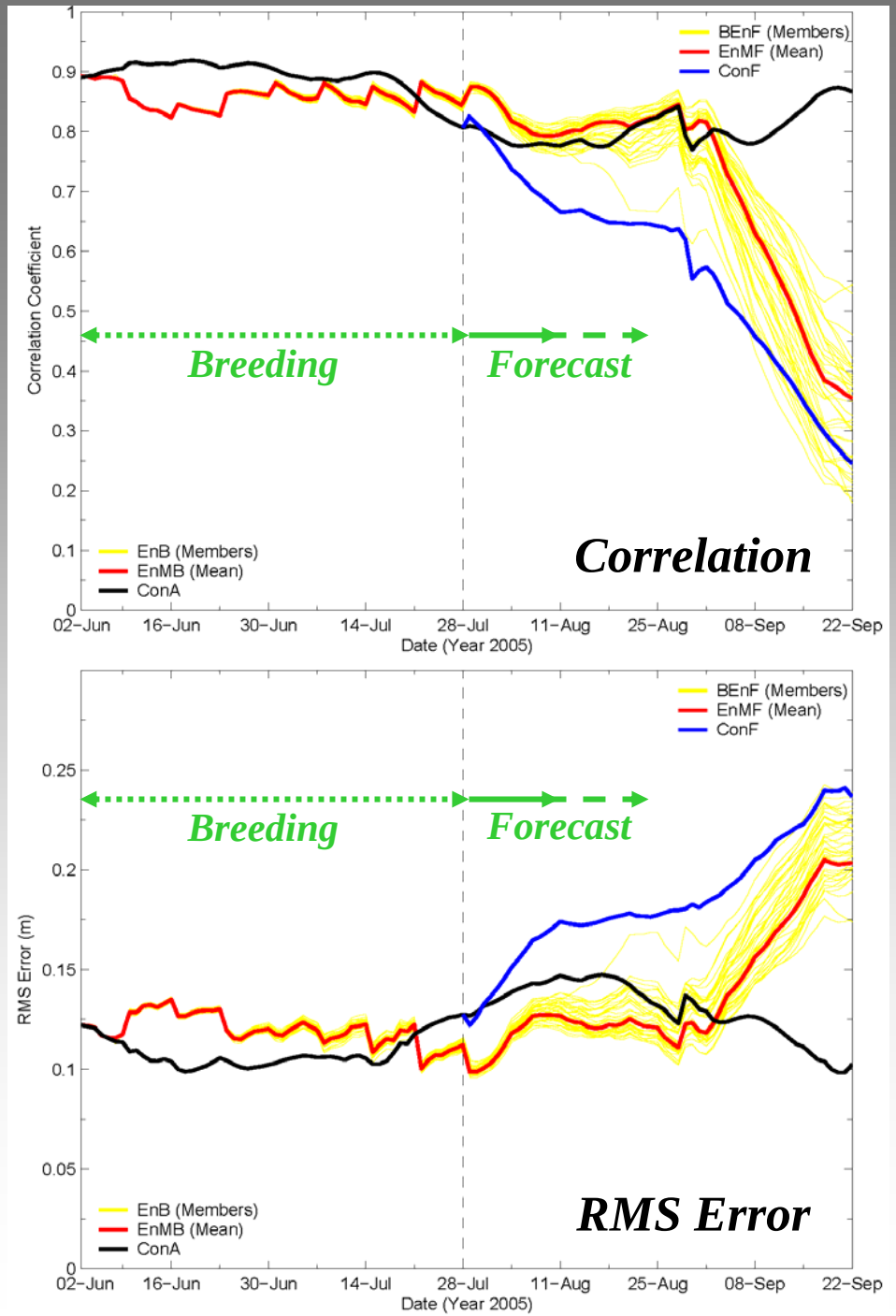


Ensemble Forecast

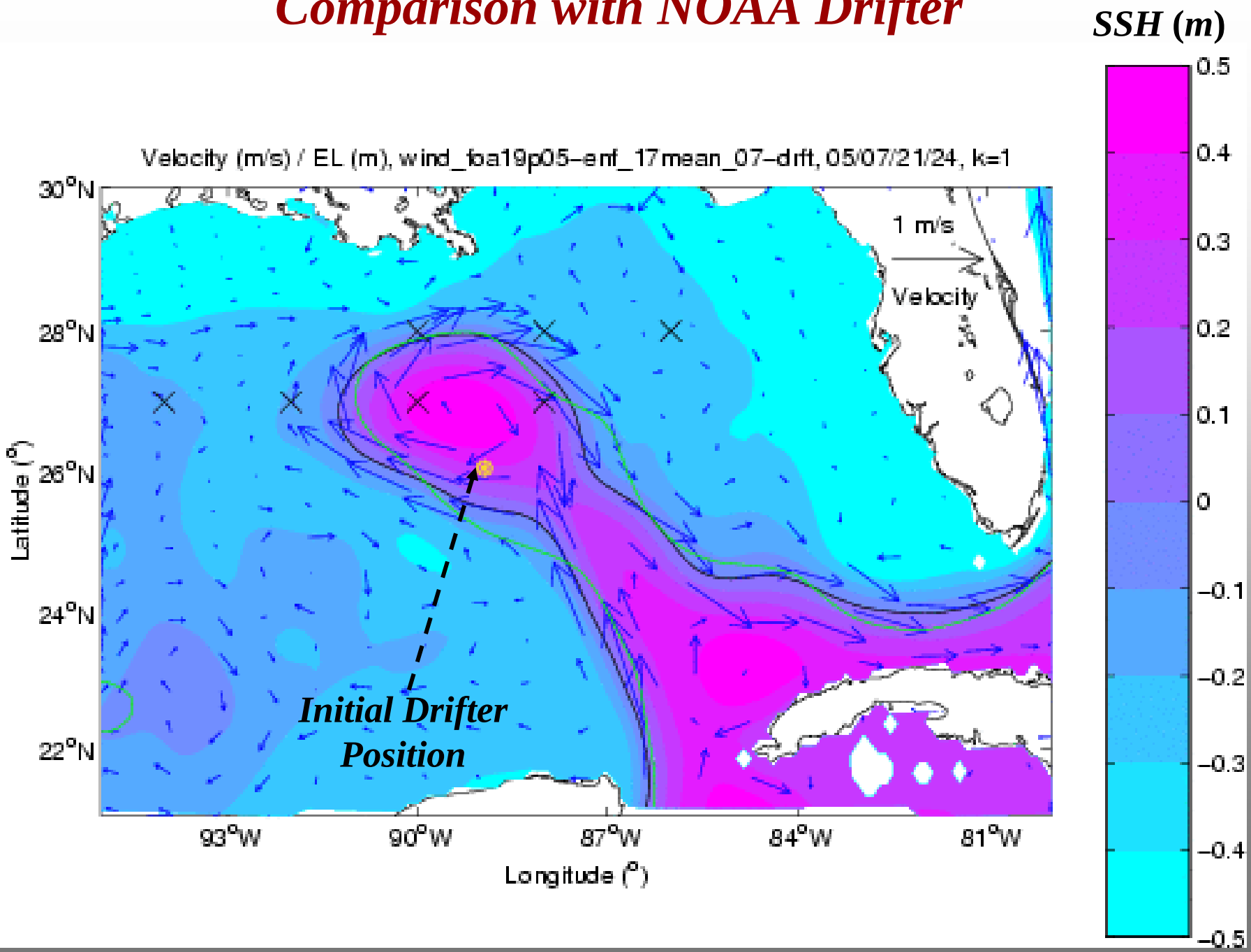
Vs.

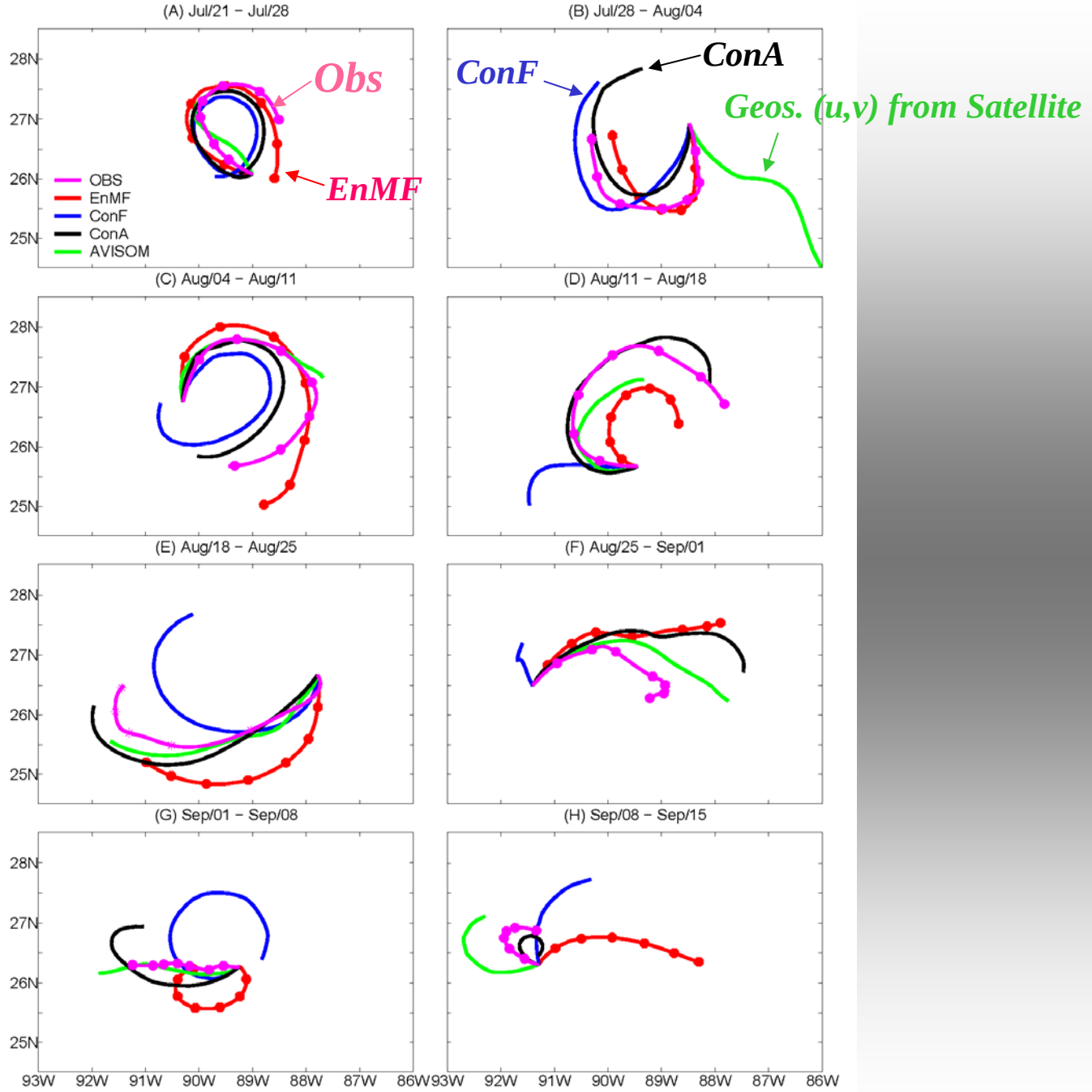
Control Forecast

Comparison with Satellite SSHA

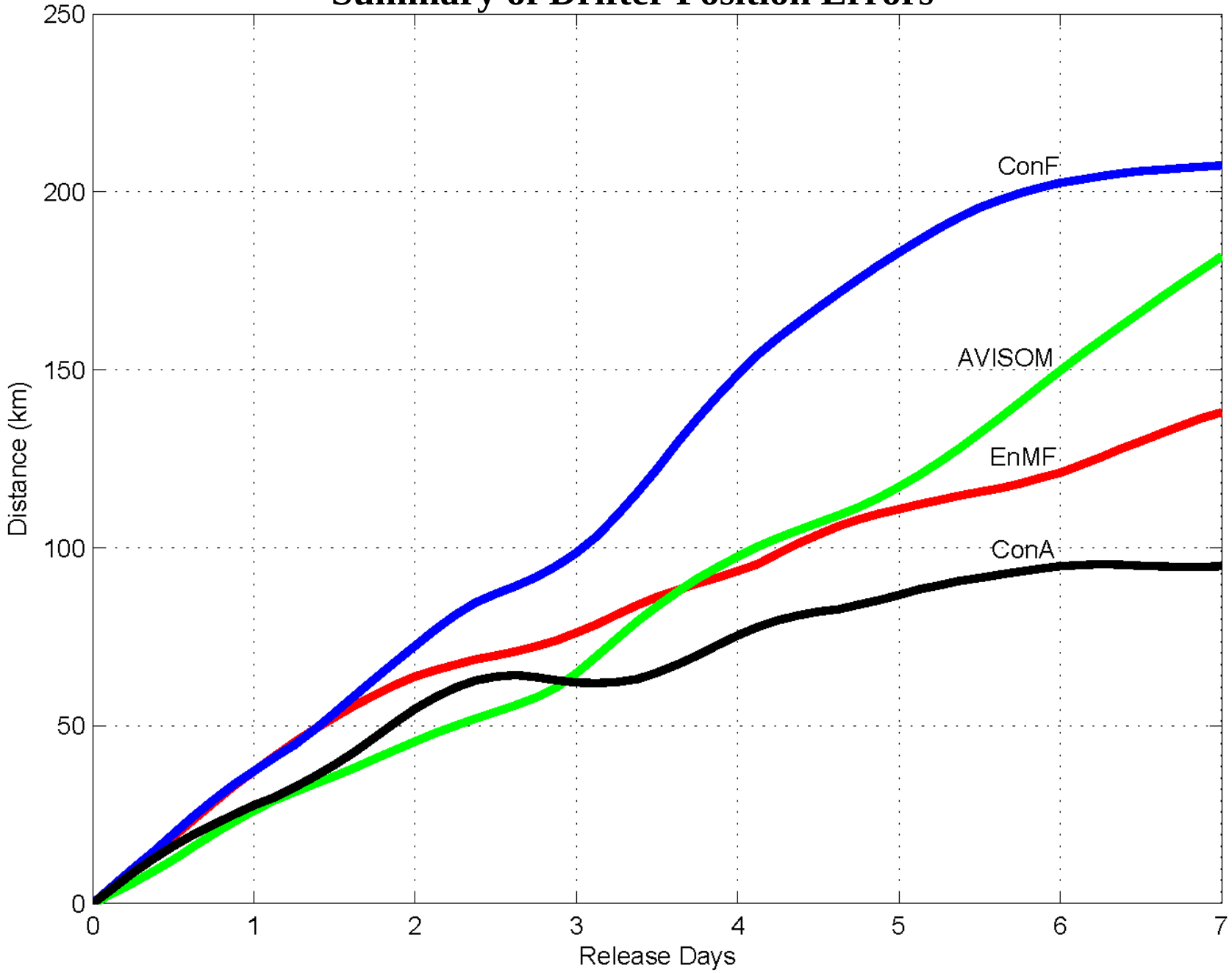


Comparison with NOAA Drifter



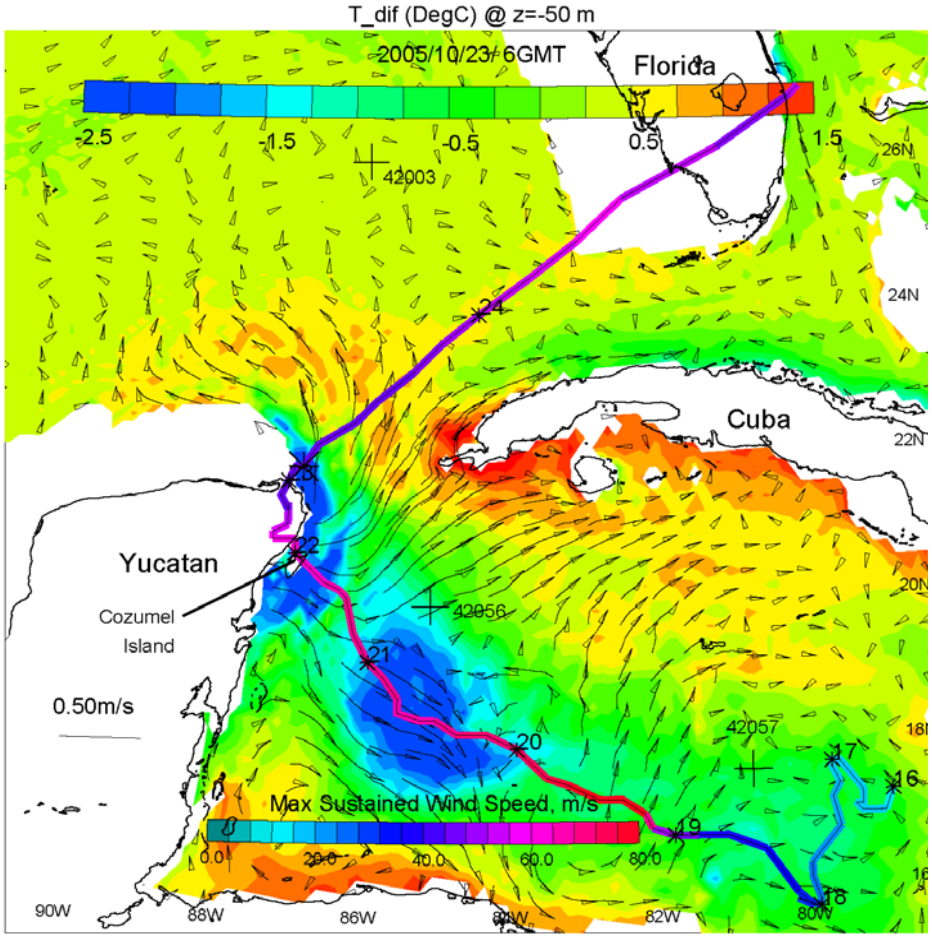

(A) Jul/21 – Jul/28
(B) Jul/28 – Aug/04
(C) Aug/04 – Aug/11
(D) Aug/11 – Aug/18
(E) Aug/18 – Aug/25
(F) Aug/25 – Sep/01
(G) Sep/01 – Sep/08
(H) Sep/08 – Sep/15
28N
27N
26N
25N
93W
92W
91W
90W
89W
88W
87W
86W
OBS
EnMF
ConF
ConA
AVISOM
Obs
EnMF
ConF
ConA
Geos. (u,v) from Satellite

Summary of Drifter Position Errors

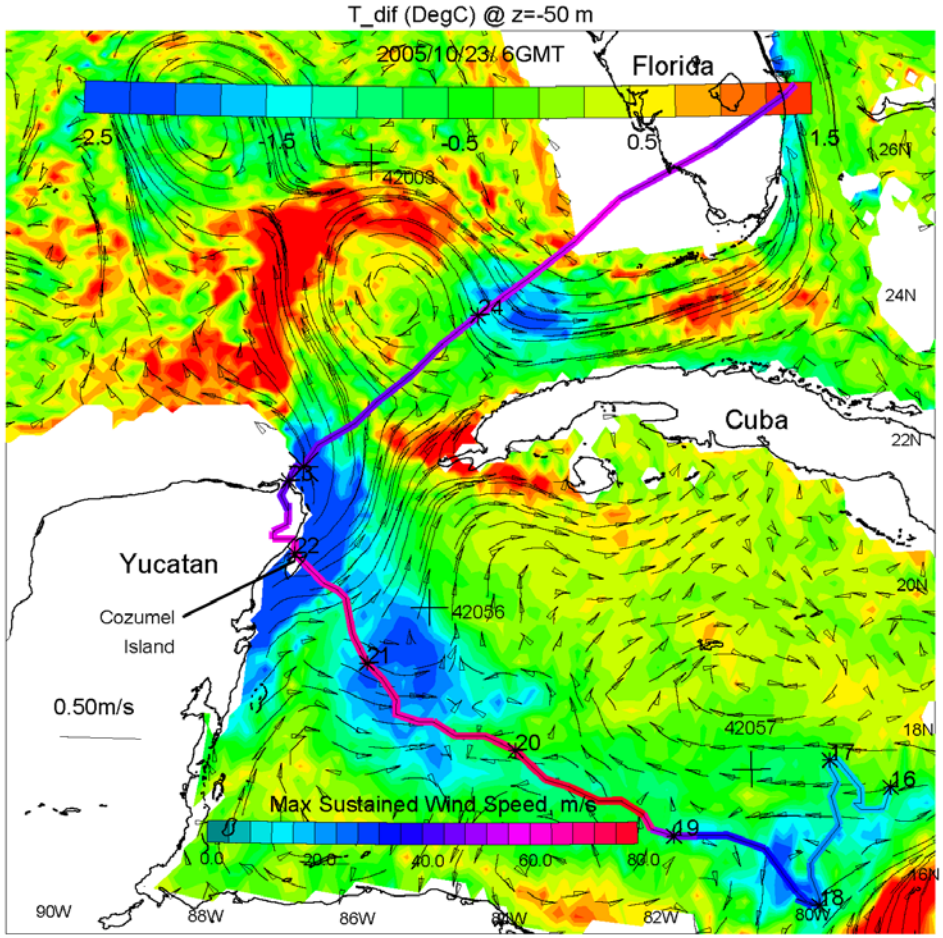


Interaction of LC with Hurricane Wilma

(A) Initially flat isopycnals:

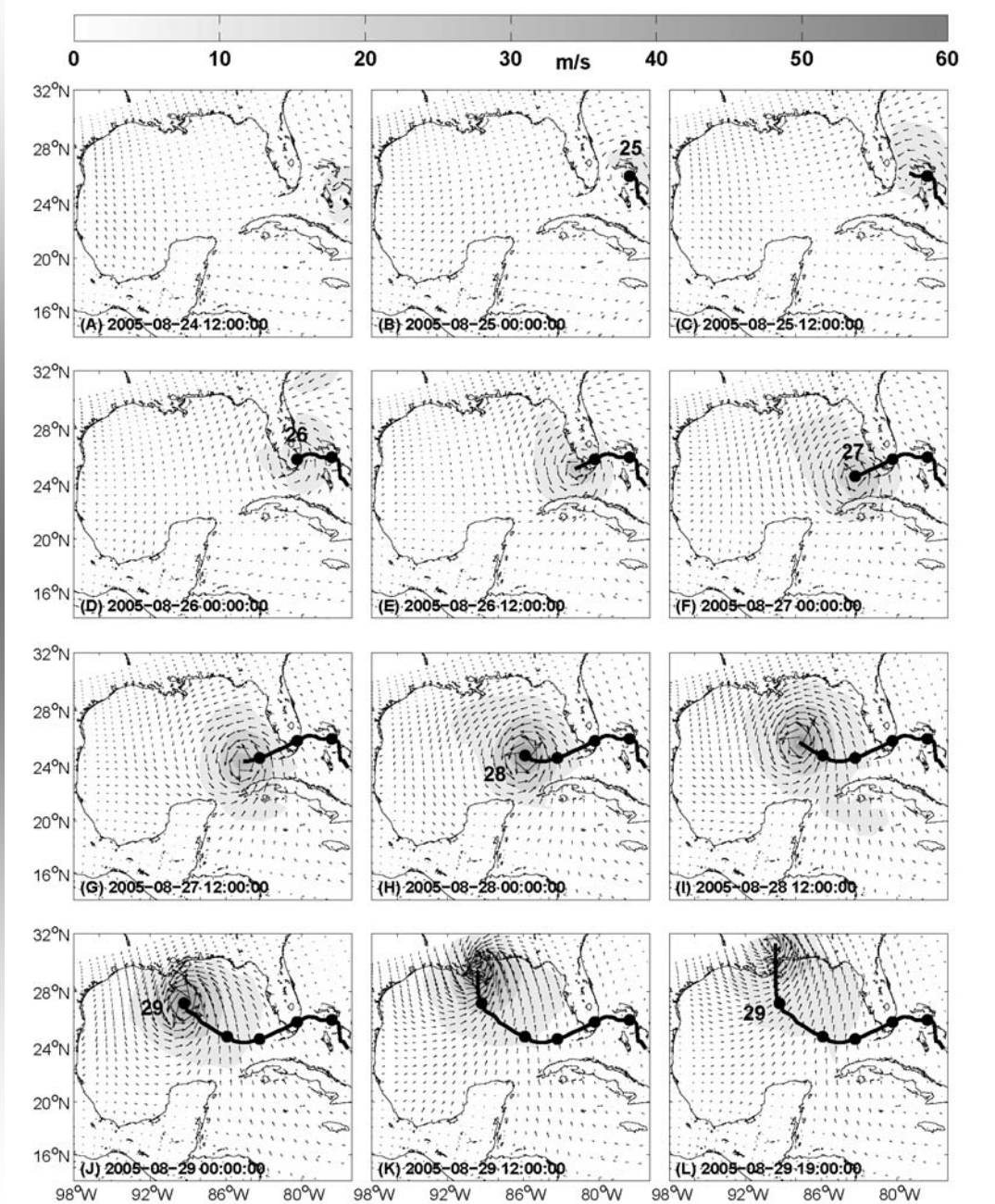


(B) Forecast:

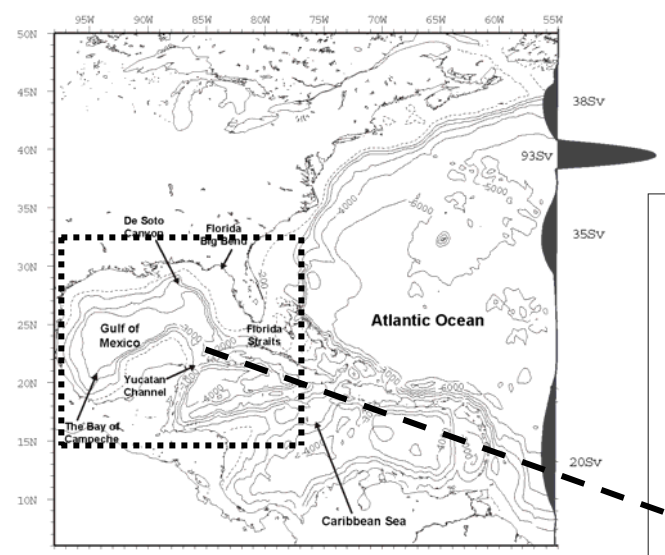


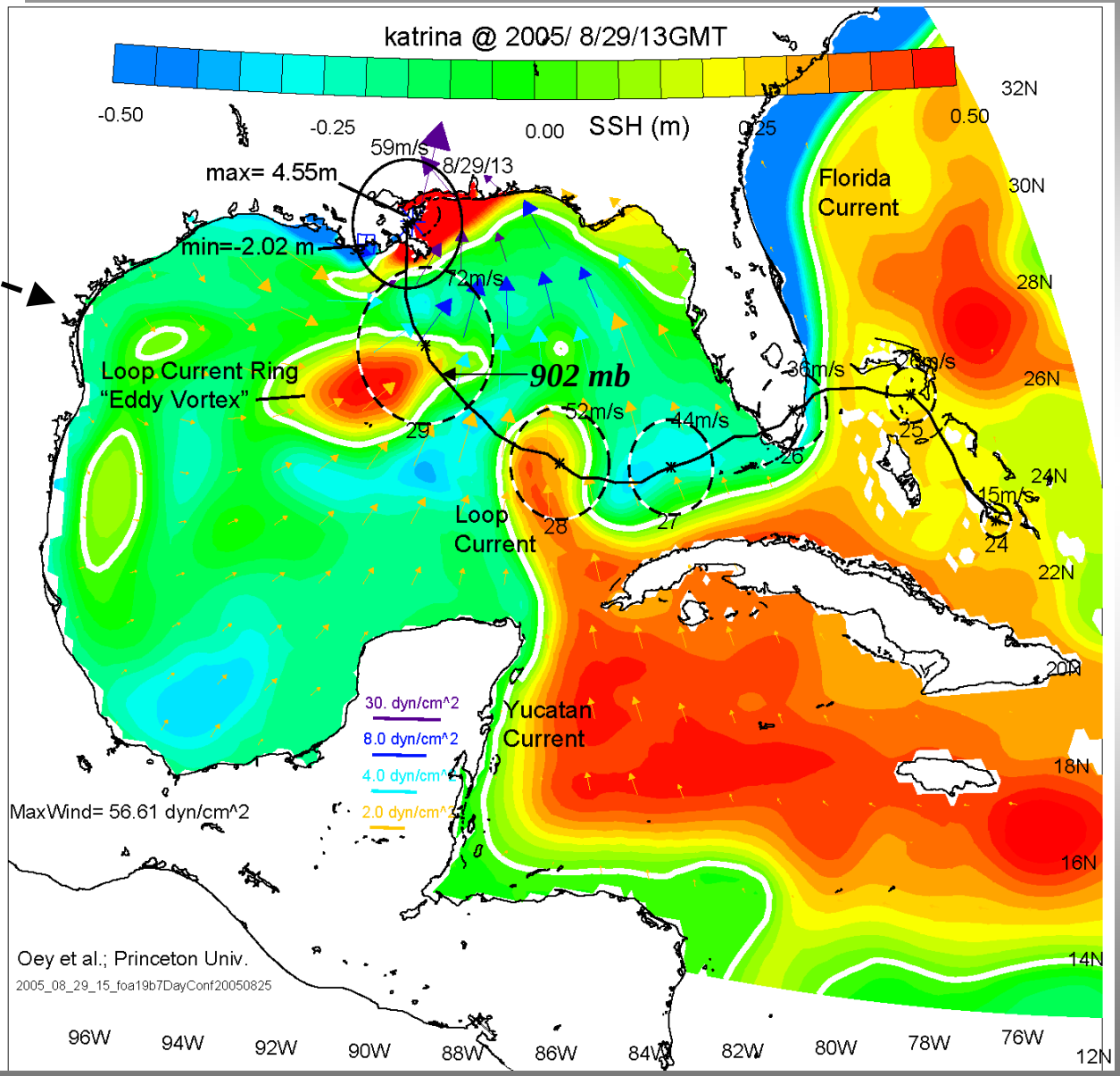
Hurricane Katrina

Katrina Wind Used for Current & Wave Modeling

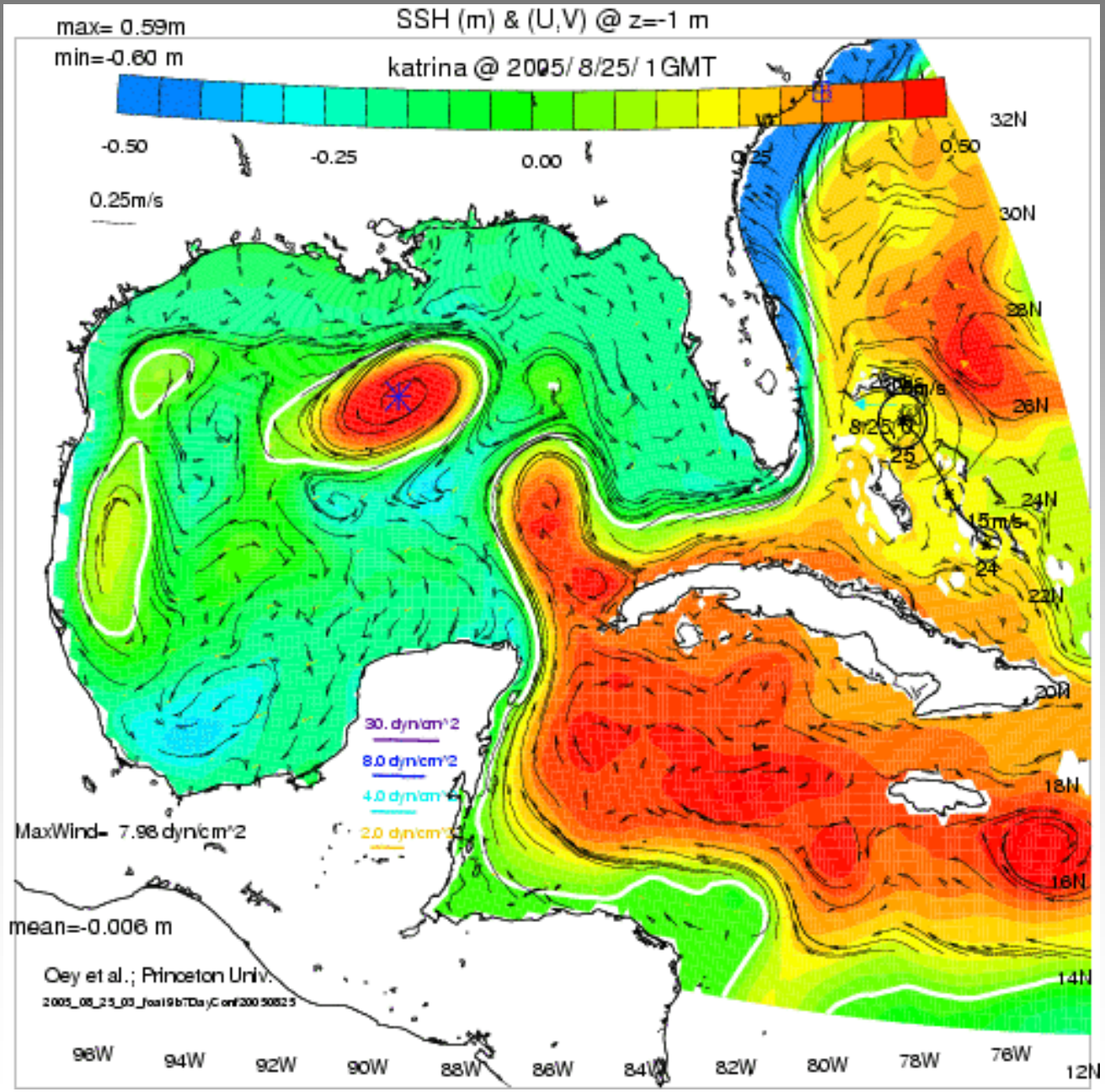


Forecast SSH & Currents shortly after Hurricane Katrina made landfall. Note the high SHH (red; max = 4.5m) and strong flow convergence near New Orleans.





Sea-Surface Height, Currents & Winds During Hurricane Katrina

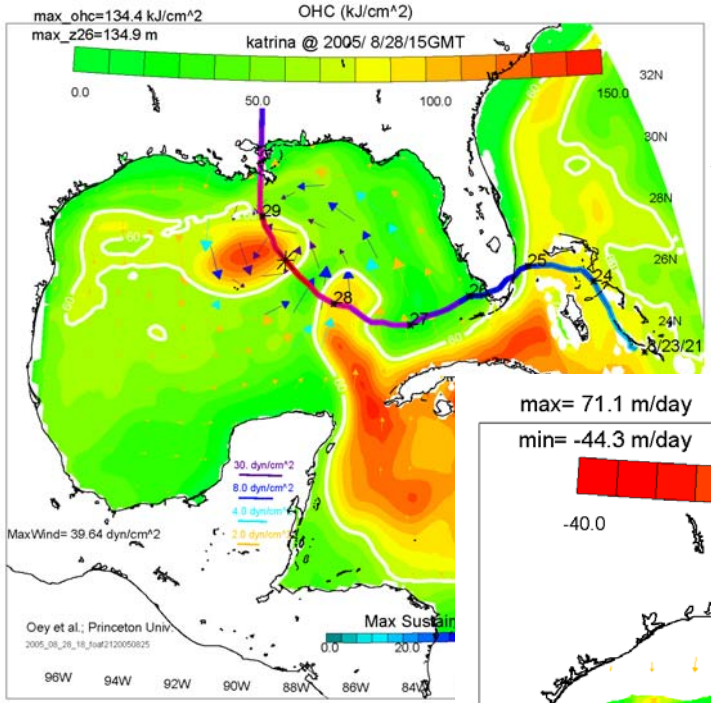


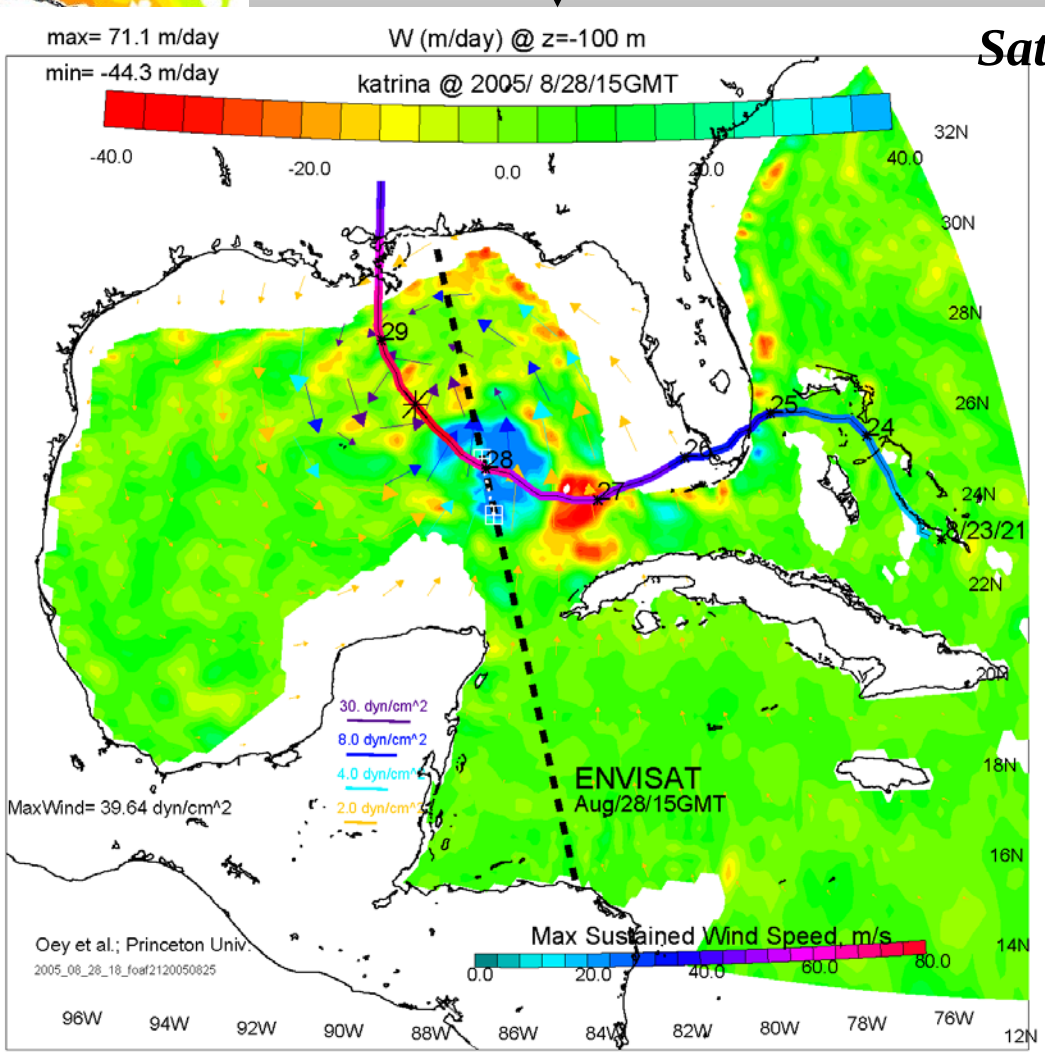
Hurricane Katrina

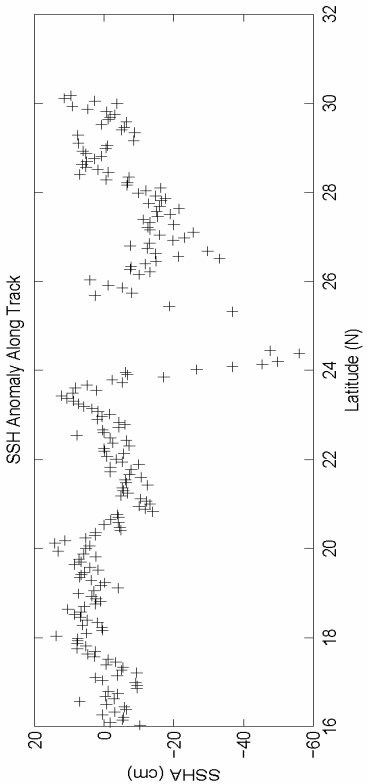
← *Ocean Heat Content (kJ/cm^2)*

Vertical Velocity (m/day) ↓

Satellite SSHA (cm) ↓







Summary

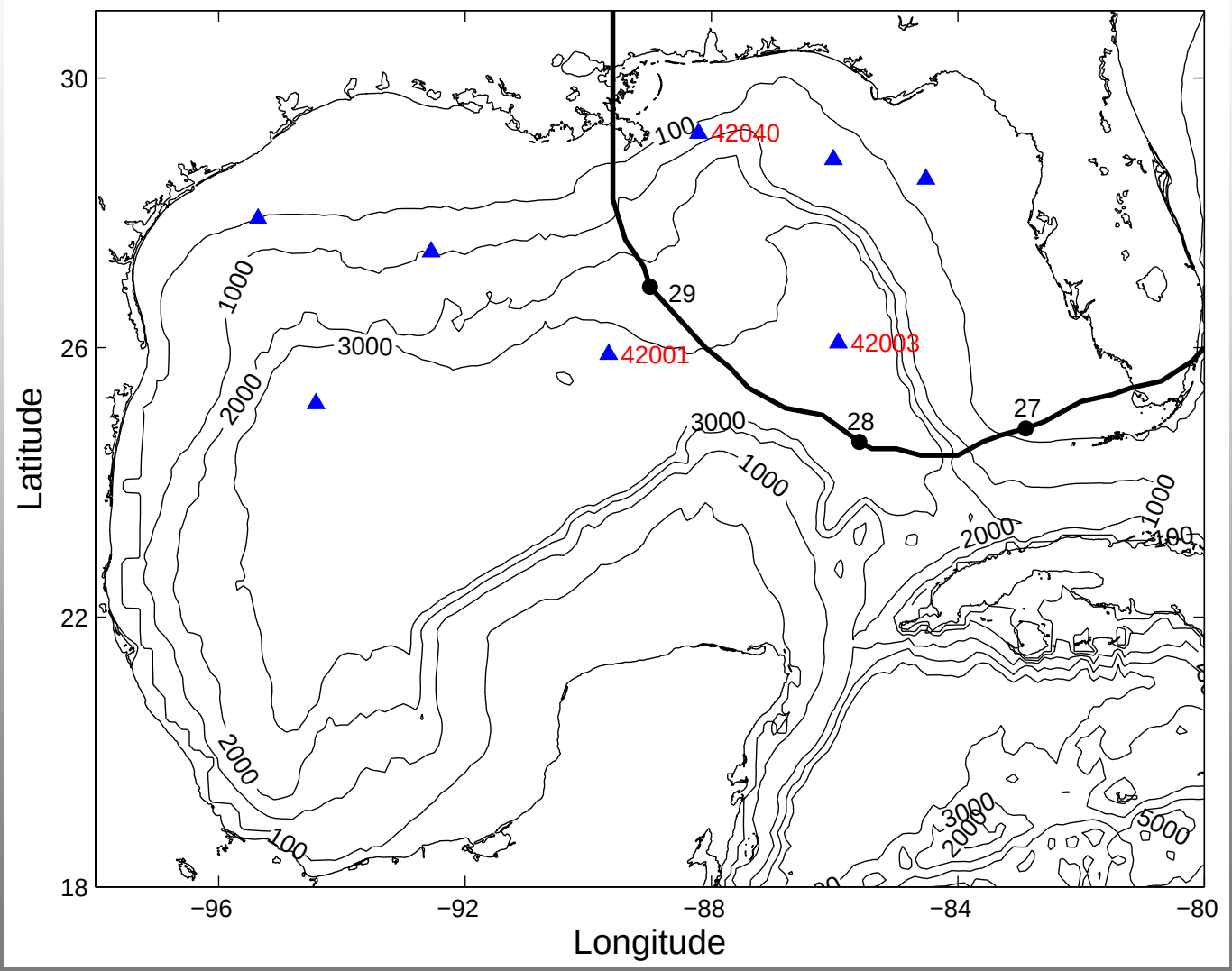
1. **Hurricane responses requires non-assimilated ("forecast") computations initialized from an analysis;**

2. **Bred-ensemble technique yields improved forecasts;**

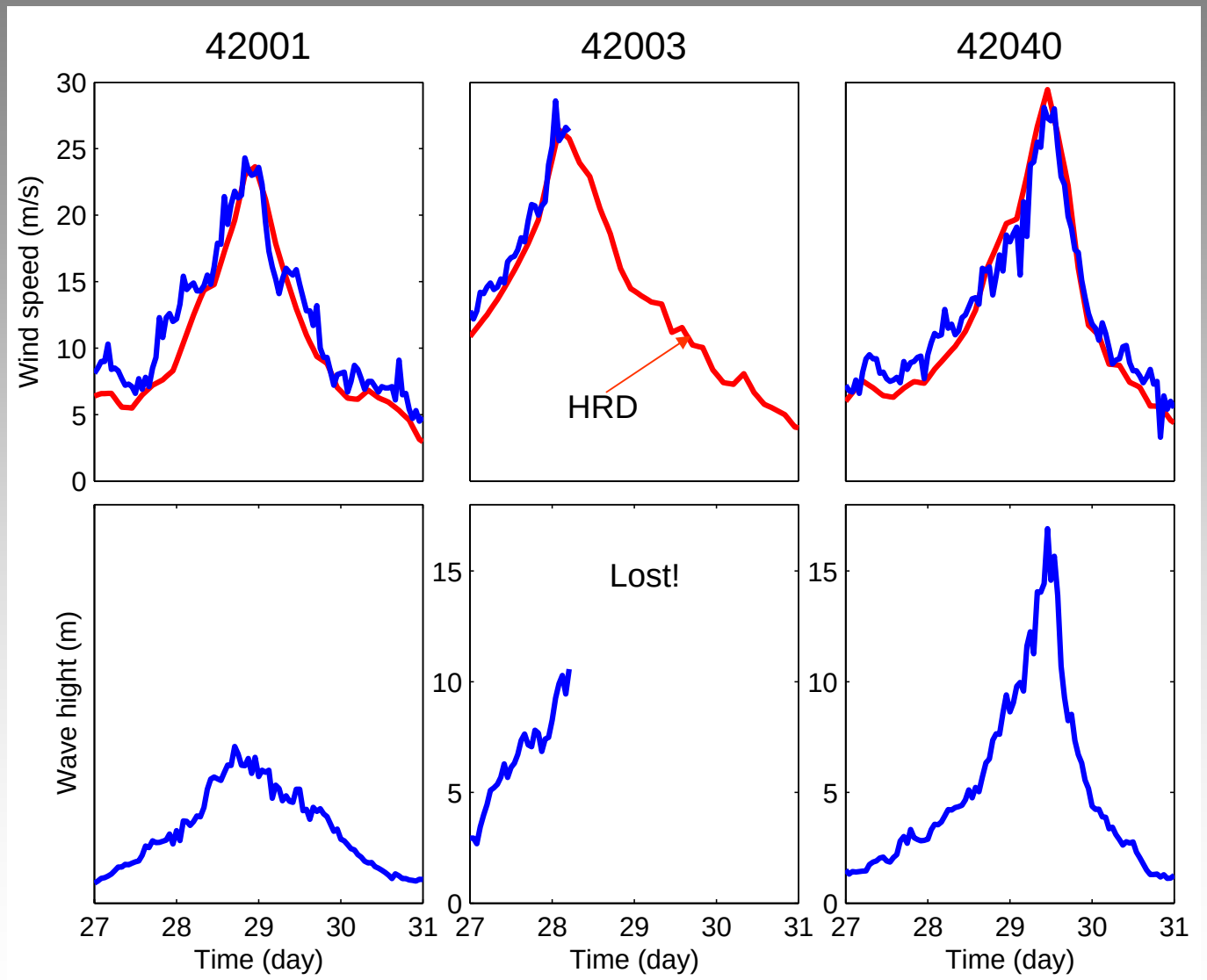
3. **Interaction between LC and hurricane responses is non-trivial …**

Waves and Currents due to Hurricane Katrina

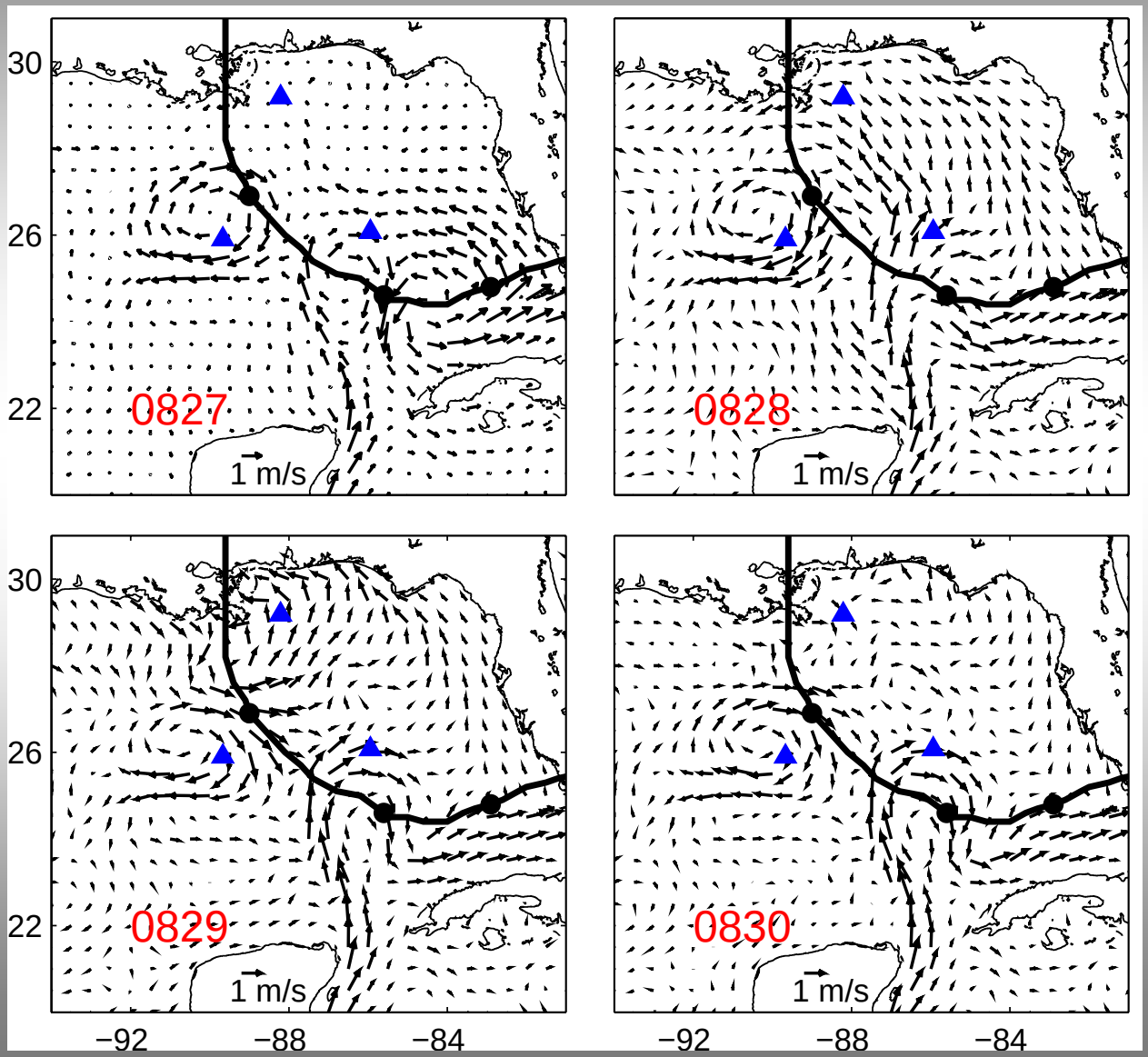
Three NDBC buoys were located near Katrina path



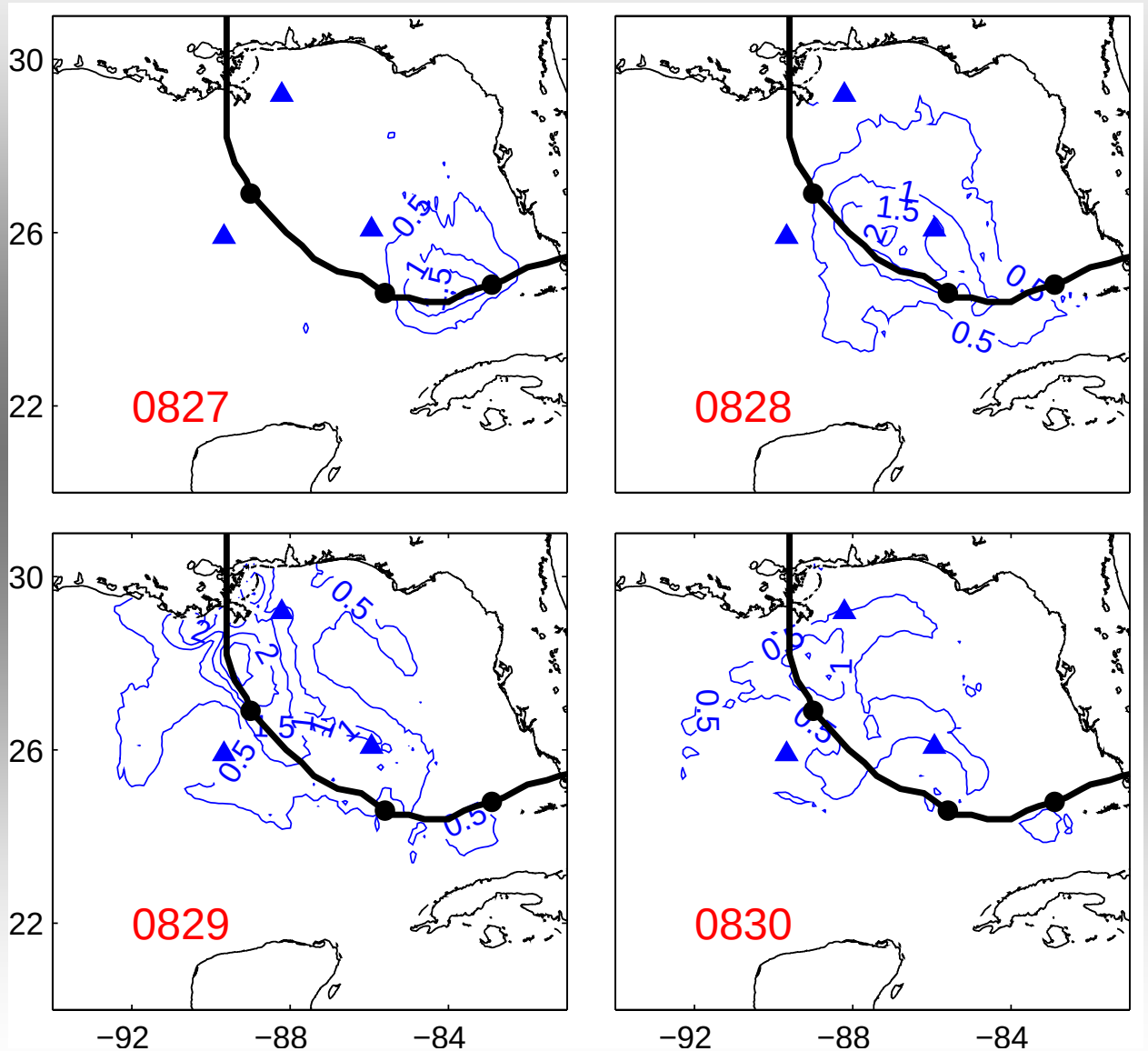
It was the first time a 10 m buoy capsized in the Gulf



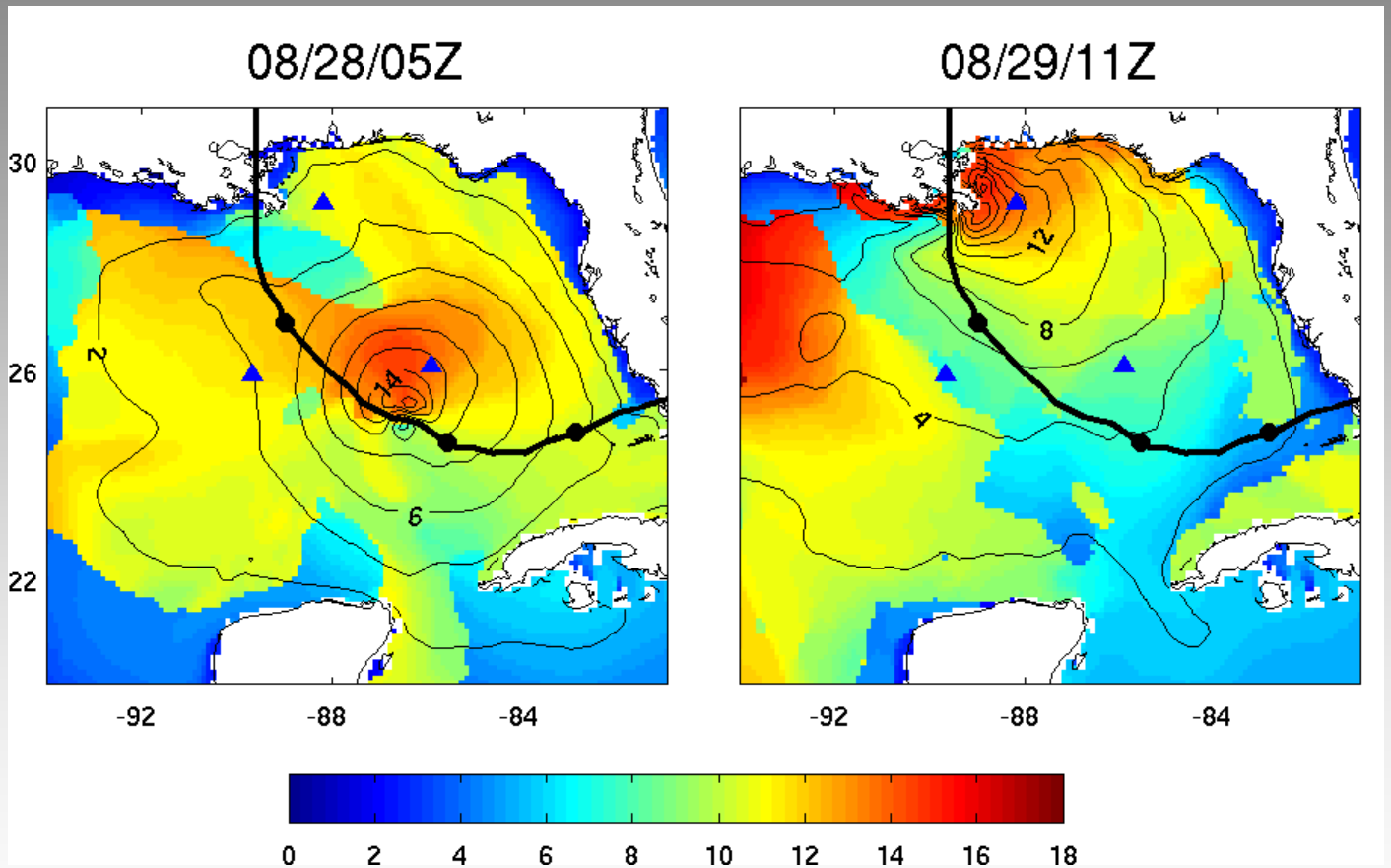
Wind-driven currents are comparable to Loop Current



Katrina excited intense inertial currents to the right

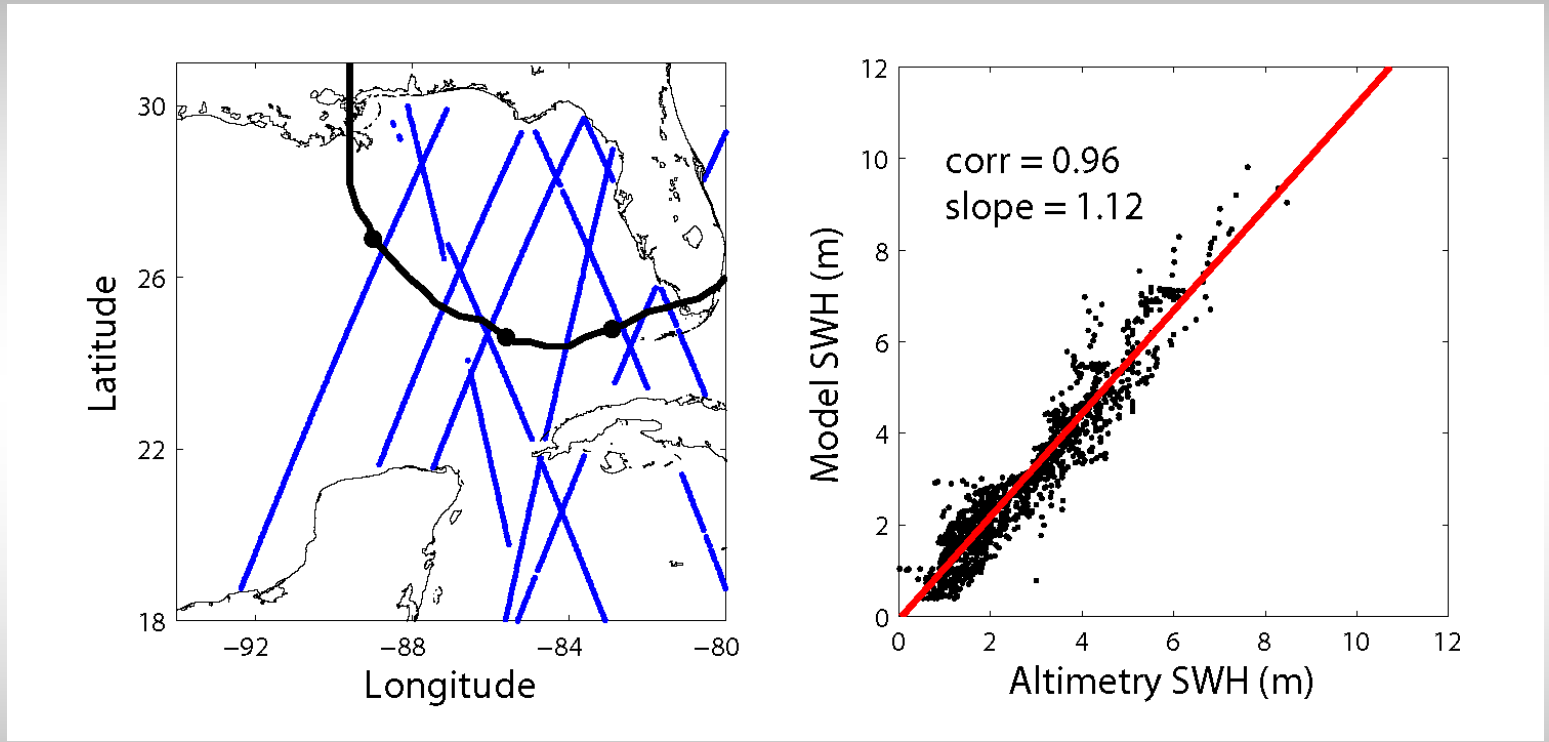


Katrina waves are much larger on the right of storm path

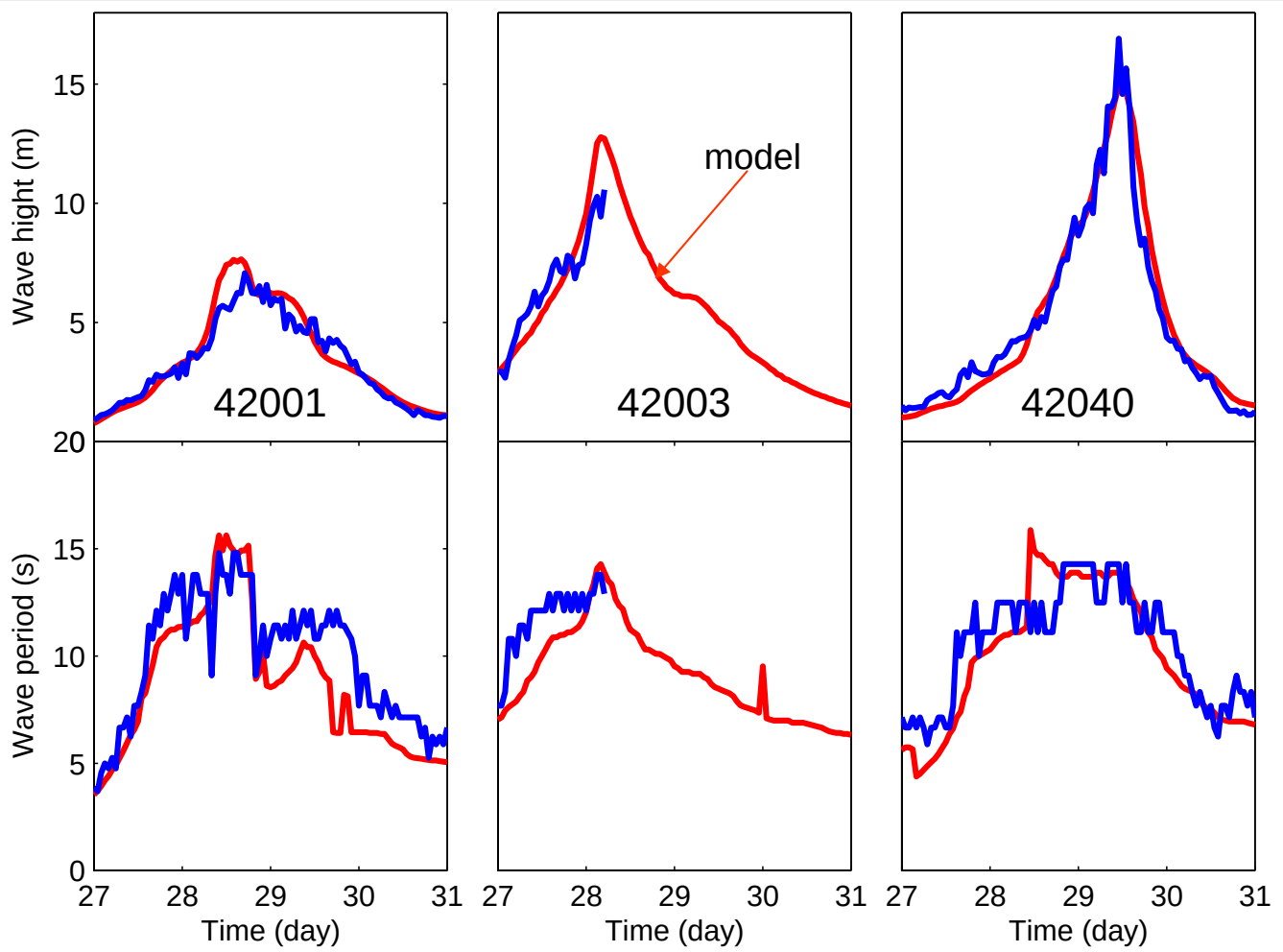


Wave period (s)

Model wave heights are validated against satellite data



Model reproduces wave amplitude and period at buoys



Summary

1. **Accurate wind field and background ocean currents have been successfully used to model ocean waves during hurricane Katrina;**

2. **In addition to the strong ‘mean’ currents associated with the Loop Current and Eddy Vortex, the wind-driven currents and the inertial amplitudes are both > 1 m/s and the significant wave heights are > 10 m;**

3. **When the waves and currents are acting together, the total force could easily exceed a traditional design criterion based on the wave or the current force alone;**

4. **That the inertial currents and waves are both strongly biased to the right of the storm path might explain the different fates of buoys 42003 and 42001 during the storm.**