Drifter observations of Hurricane Rita (September 2005)

Rick Lumpkin
Physical Oceanography Division
NOAA/AOML

Collaborators:

Bill Scuba and Peter Niiler
Scripps Institution of Oceanography

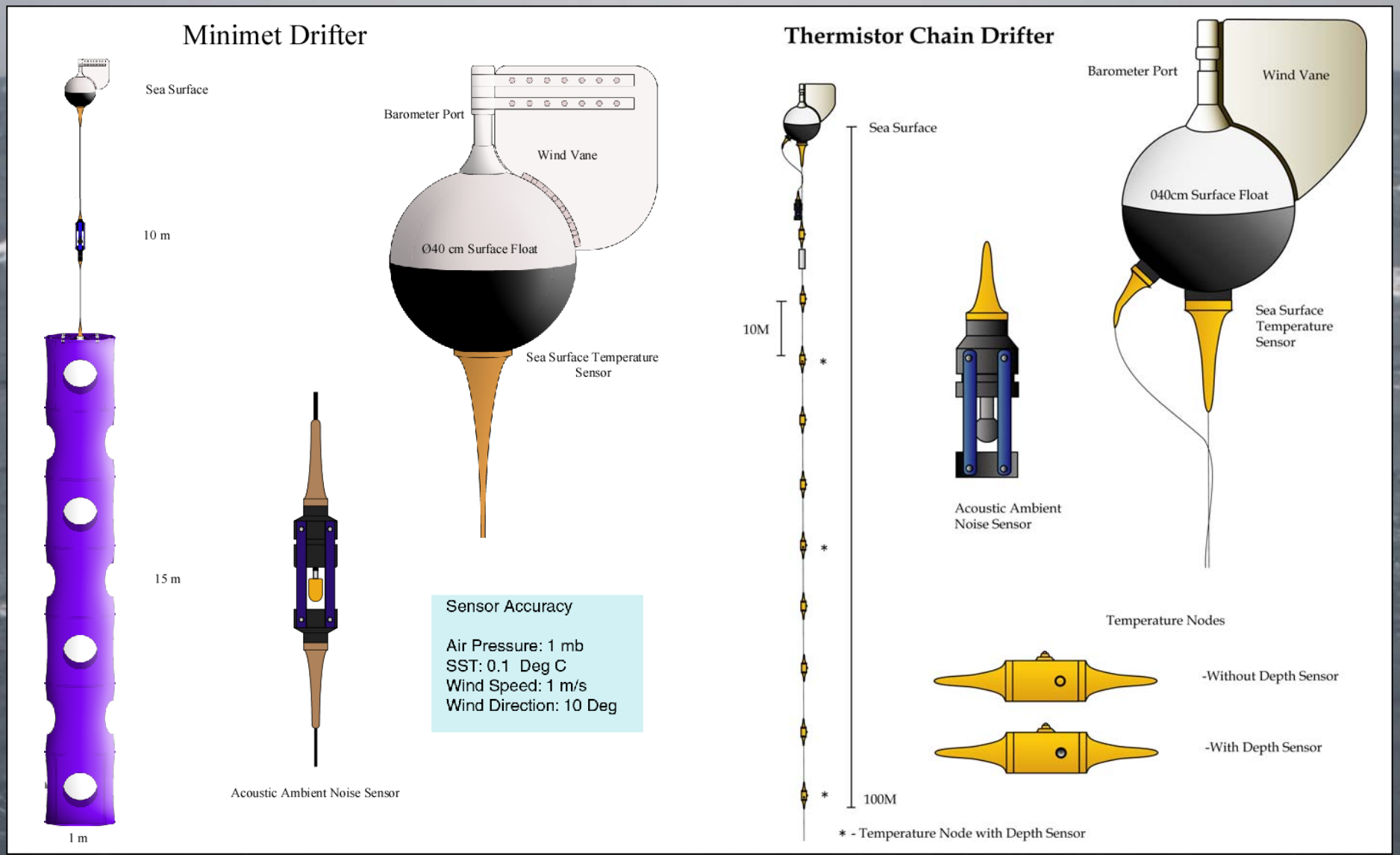
Pete Black
Hurricane Research Division, NOAA/AOML

Jan Morzel
NorthWest Research Associates (NWRA), Inc.

Goals of Hurricane Drifter deployments

- Provide real time data on the Global Telecommunication System (GTS) for improved weather forecasting by operational centers such as NOAA's Environmental Modeling Center (EMC).
- Study wind-driven mixing and its impacts on upper ocean heat content.
- Validate and calibrate satellite-based products (SST, wind, upper ocean heat content).
- Evaluate coupled ocean-atmosphere models (e.g., HWRF) for improved hurricane intensity forecasting.

Drifter Schematics



Previous deployments

- Aircraft crews trained, air-deployment containers tested.
- *September 4, 2003*: 16 Minimet drifters deployed in front of Fabian (Cat. 4, winds >60 m/s). Success rate: 8 of 16 drifters (50%).
- *August 31, 2004*: 14 Minimet, 8 Thermistor Chain, 14 SVP with 100m drogue, and 3 standard SVP-B drifters deployed in front of Frances (Cat. 4, winds >55 m/s). Success rate: 35 of 39 drifters (90%). Thermistor chain data: 0% transmission. Twenty days later, the array sampled Hurricane Jeanne.

2005 deployments

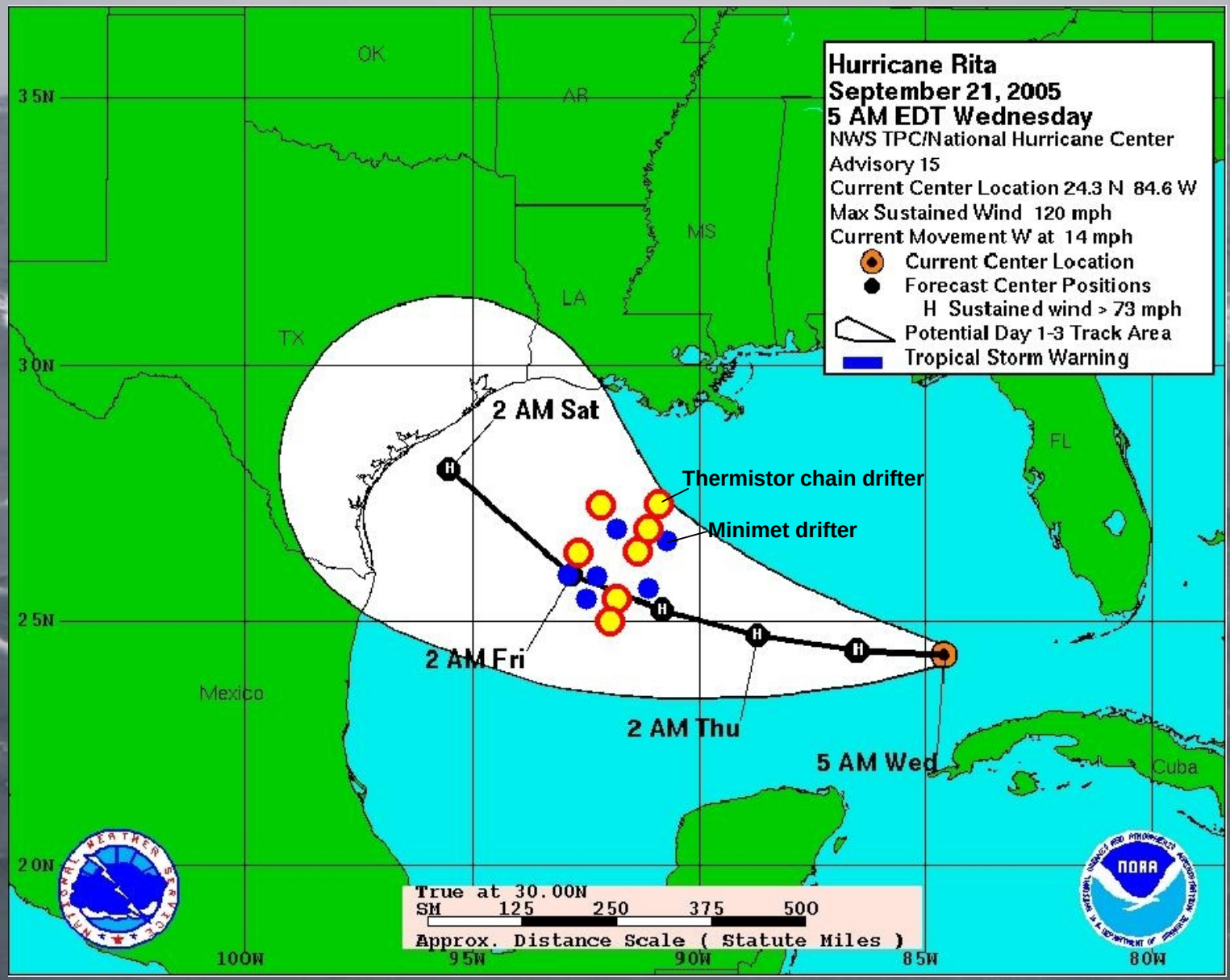
August 20, 2005: 12 Minimet and 8 thermistor chain drifters assembled for air deployment via WC-130 Hercules of the 53rd Weather Reconnaissance Squadron "Hurricane Hunters", Keesler Air Force Base (AFB), Biloxi, Mississippi.

August 27-28: hurricane Katrina passes over warm, deep water in the Gulf of Mexico and rapidly intensifies to Category 5. The subsequent landfall greatly damages Keesler AFB, but does not damage the drifters apart from packaging. Drifter array, and operations of the 53rd, moved to Dobbins AFB, Georgia.

September 18: Tropical Storm Rita forms from tropical wave/cold front interaction in the southeast Bahamas. September 20: Rita intensifies to hurricane strength and passes between Florida and Cuba.

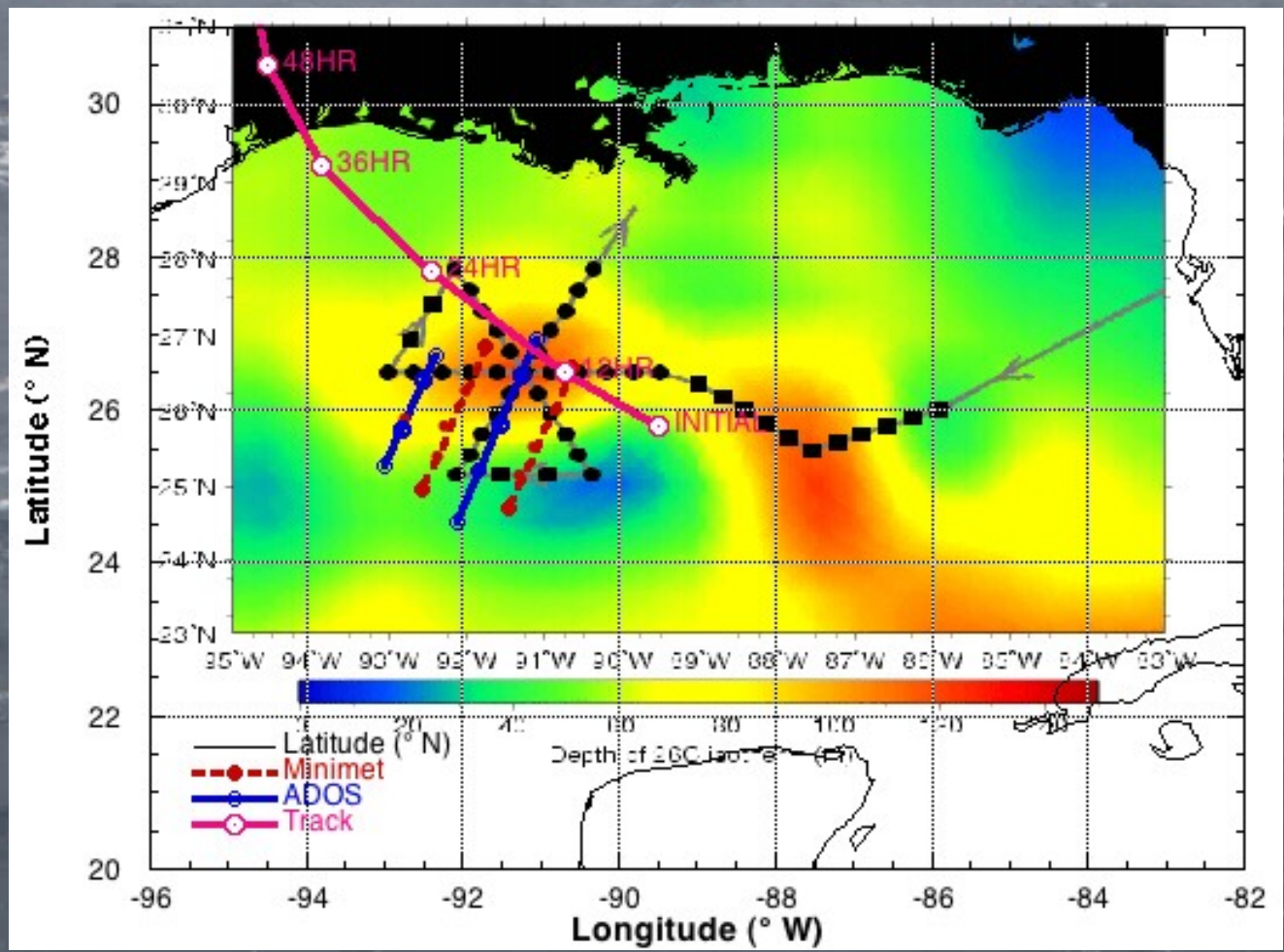
September 21: Rita rapidly intensifies from 95 kts (Cat. 2, 0000 UTC) to 145 kts (Cat. 5, 1800 UTC) over the Loop Current, in an environment with little vertical shear. By the end of the day, Rita has the fourth-lowest central pressure (895 mb) on record in Atlantic. Landfall predicted for Texas/Louisiana coast.

September 21 (continued): Hurricane Hunters renew operations, deploy the drifter array in front of Rita on the predicted westward track.

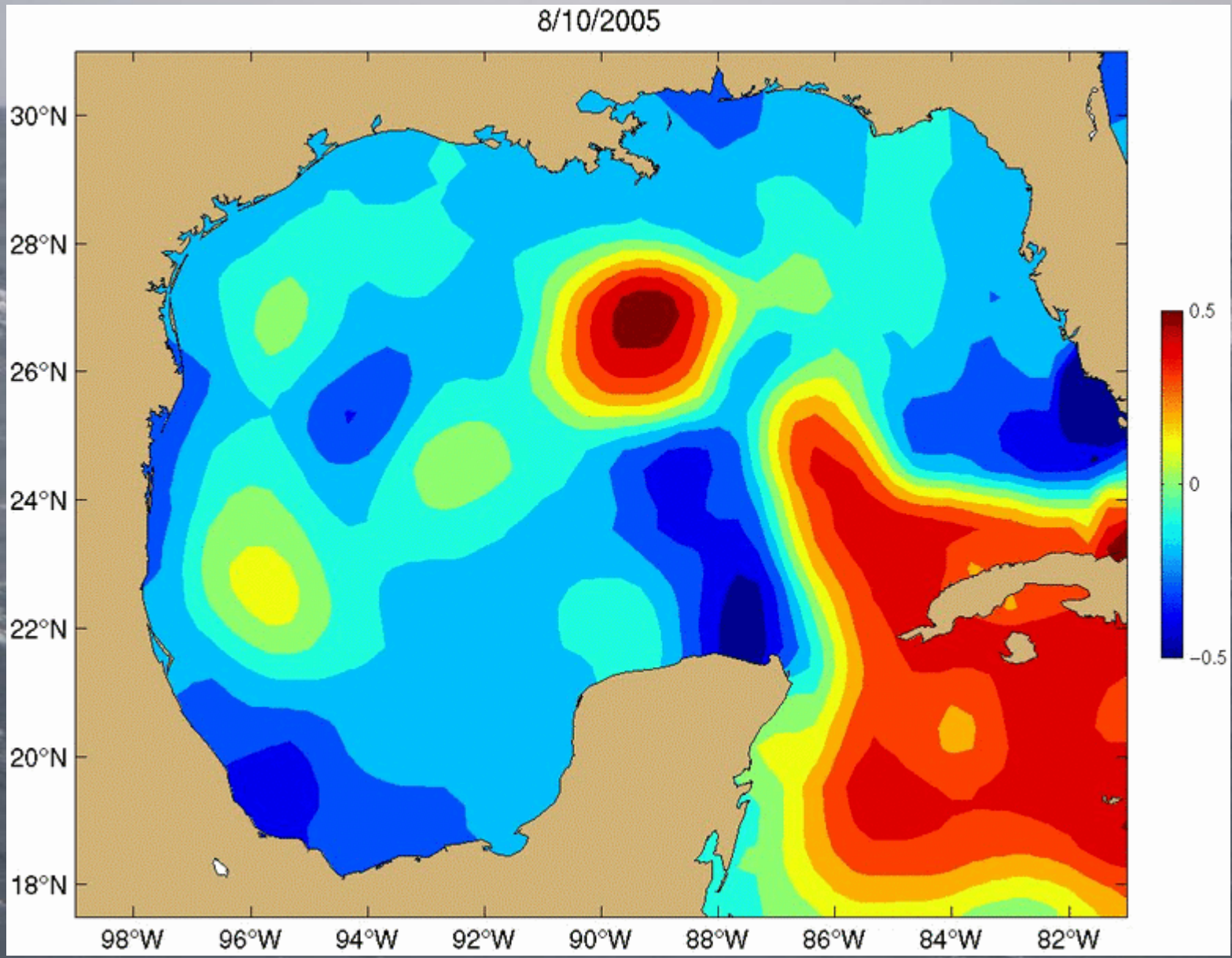


September 22-23: Rita veers right from predicted track; drifters mainly sample left-hand side of storm. Closest approach: Rita's center passed within 11 km of a drifter on 0730 UTC, 23 September 2005 while at Cat. 4 strength.

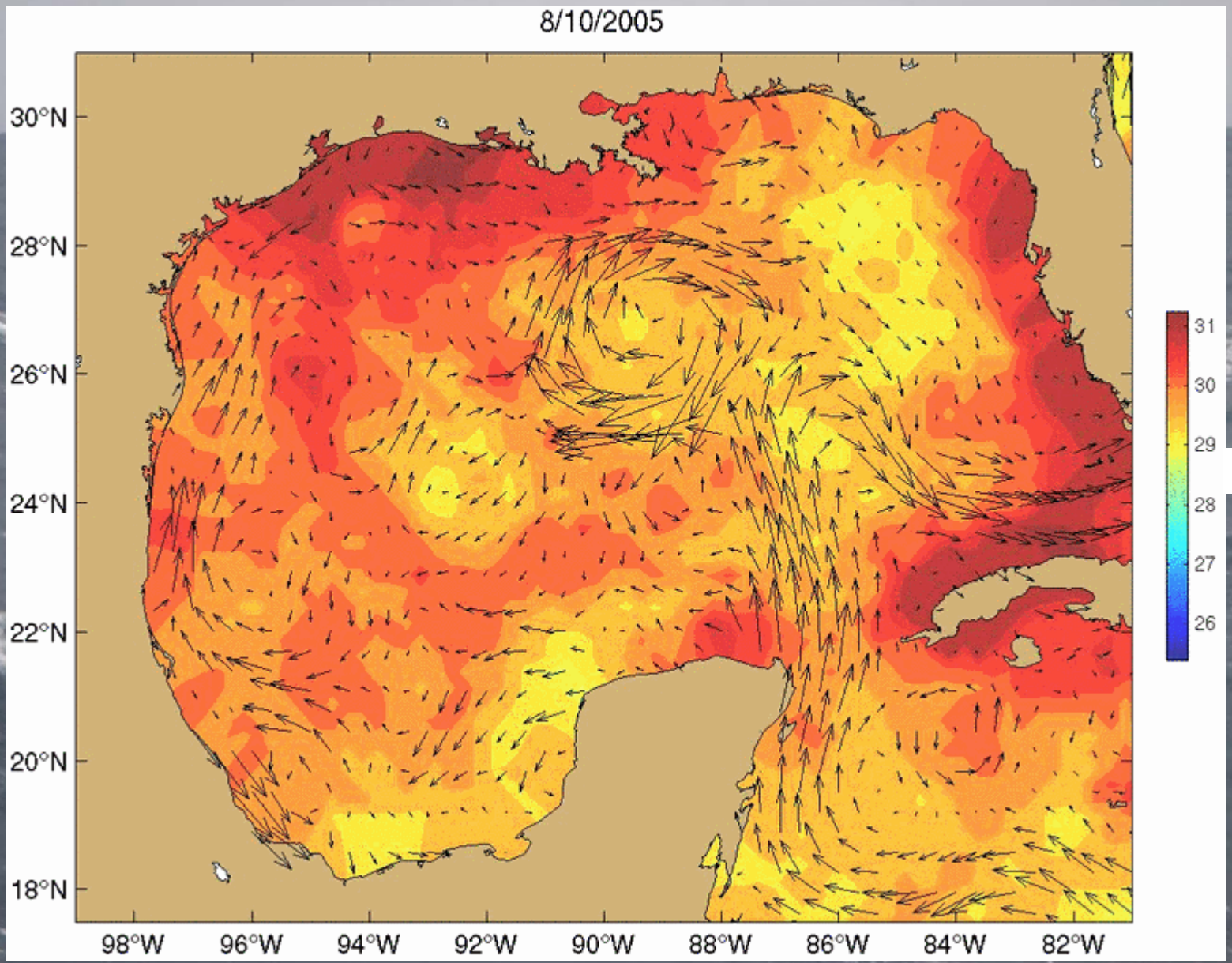
Rita reaches peak intensity of 155 kts (Cat. 5) at 0600 UTC, Sep. 22; steadily weakens thereafter. Landfall: 100 kts (Cat. 3), 0740 UTC, Sep. 24.



Sea level height (AVISO Altimetry)



SST (TMI/AMSRE)



2005 Hurricane Drifter observations

Overview:

All 20 drifters survived deployment and provided data.

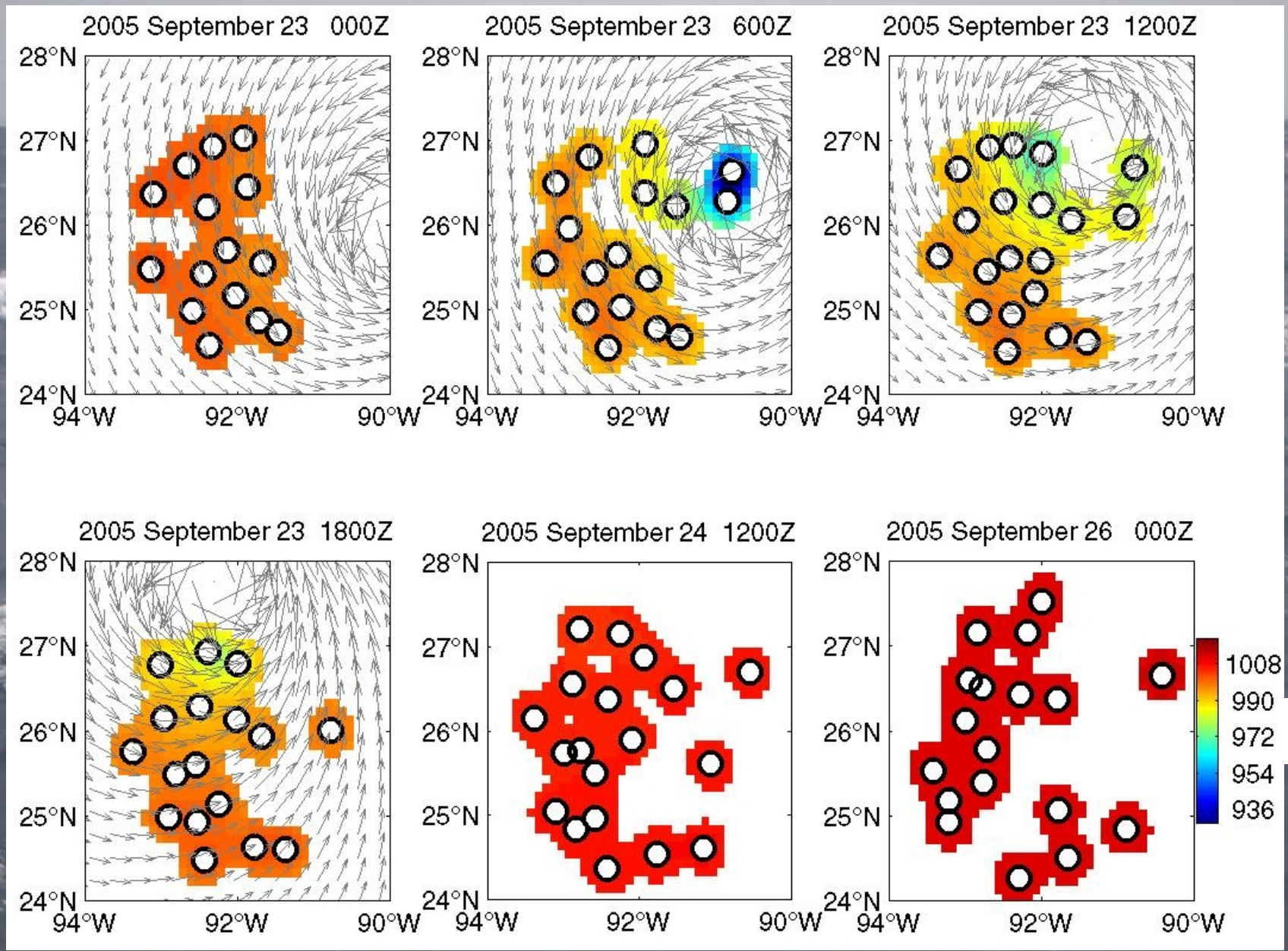
One drifter (ID 56303; thermistor chain) died after four days.
Three minimet drifters grounded (Feb, Apr, May 2006).
Two minimet drifters still alive.

Lifetimes (days): 4, 24, 54, 63, 86, 90, 92, 94, 100, 138, 142, 156, 166, 179, 201, 251, 253, 259, N/A, N/A (orange: thermistor chain)

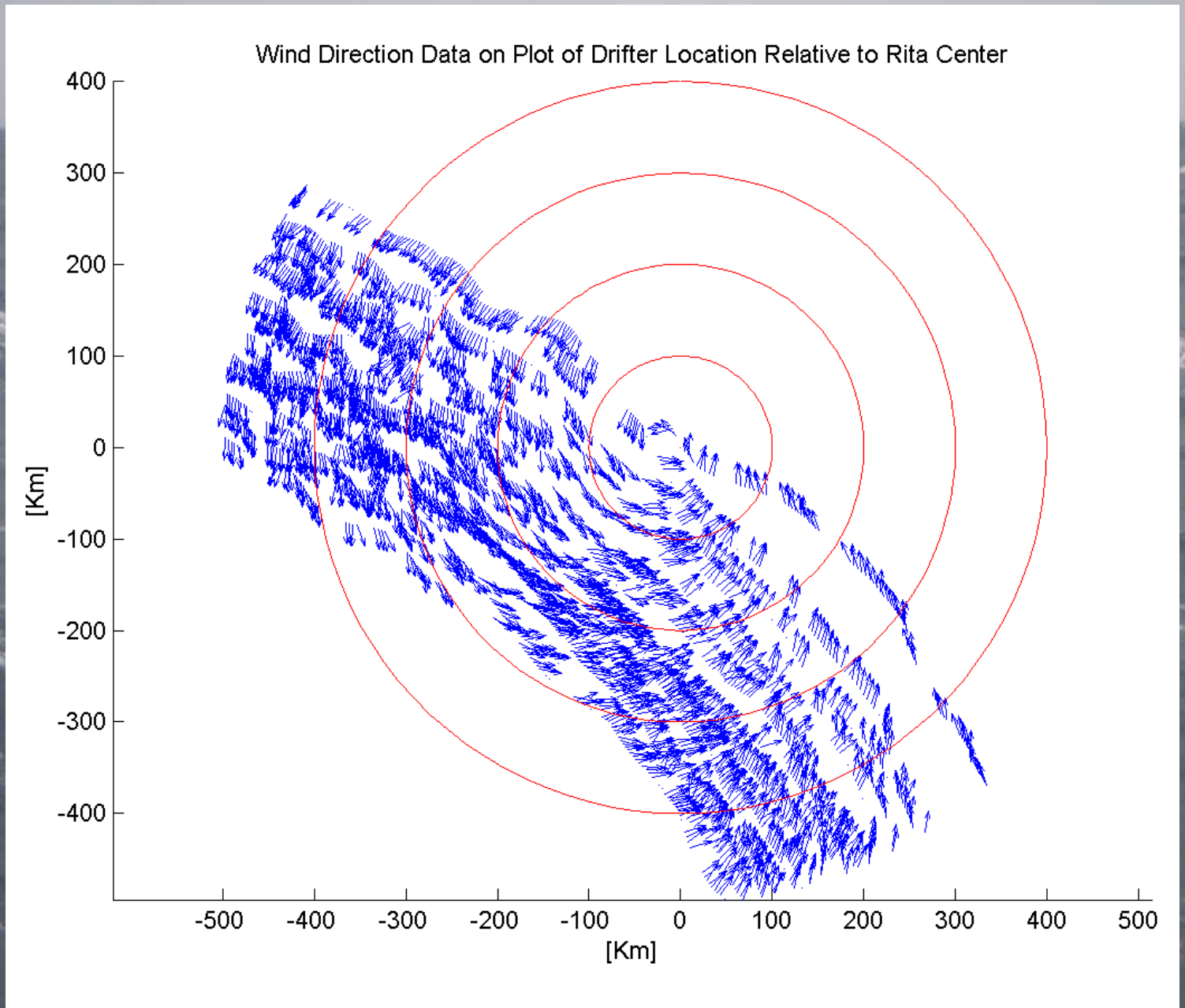
Half-life of array:
140 days overall / 184 days (minimet) / 91 days (Thermistor chain)

Sea level air pressure

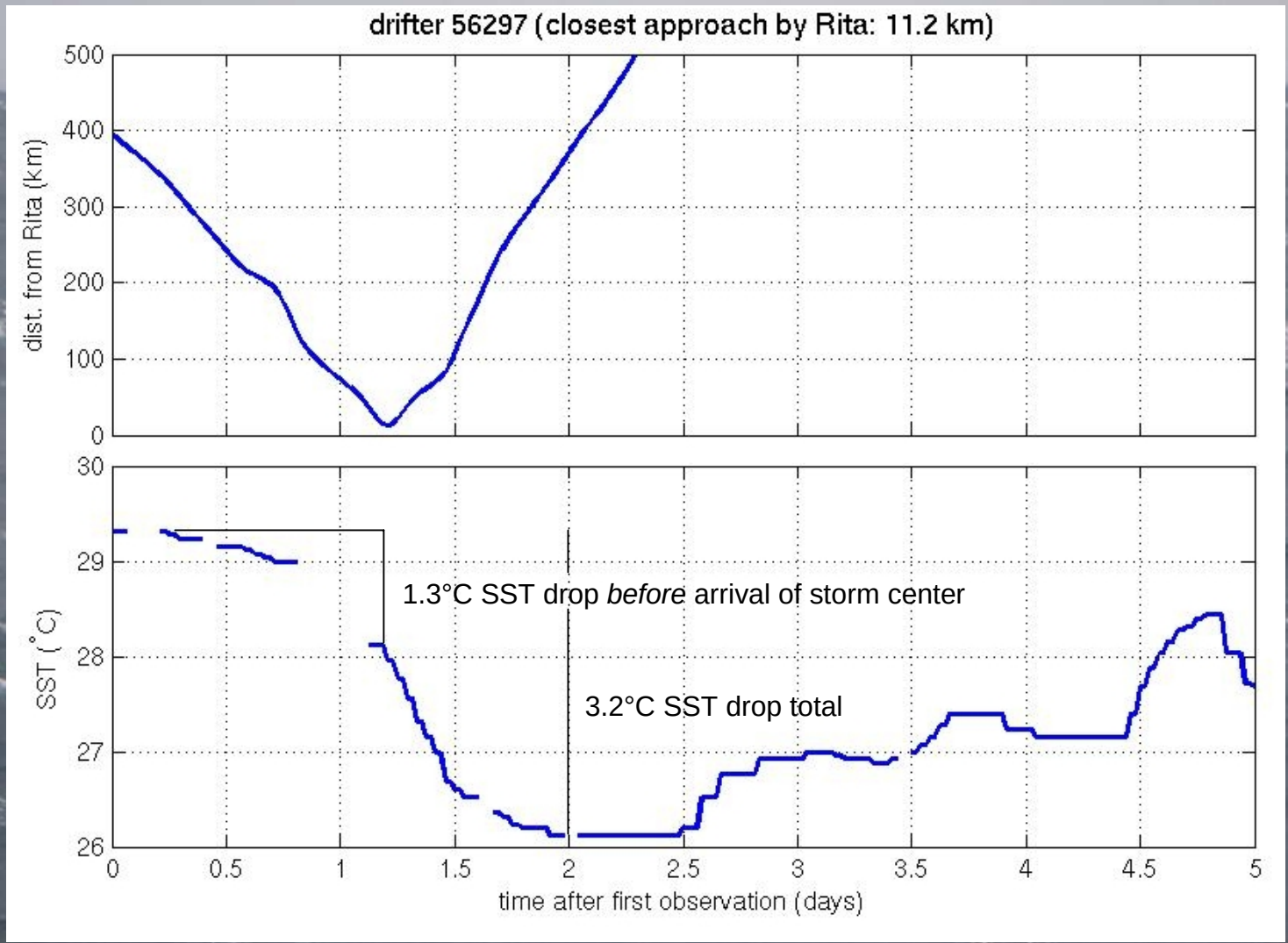
Lowest observed pressure:
926.2 mb (drifter 56297)



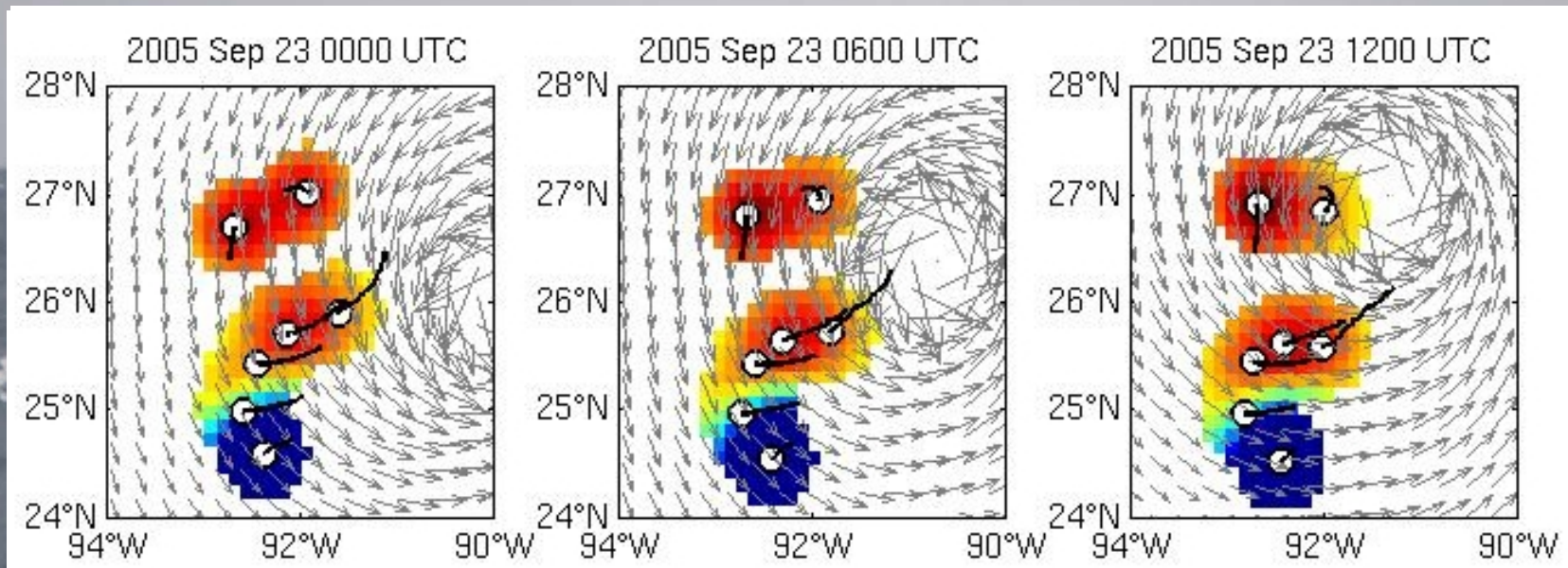
Winds


Wind Direction Data on Plot of Drifter Location Relative to Rita Center
400
300
200
100
0
-100
-200
-300
-400
[Km]
-500
-400
-300
-200
-100
0
100
200
300
400
500
[Km]

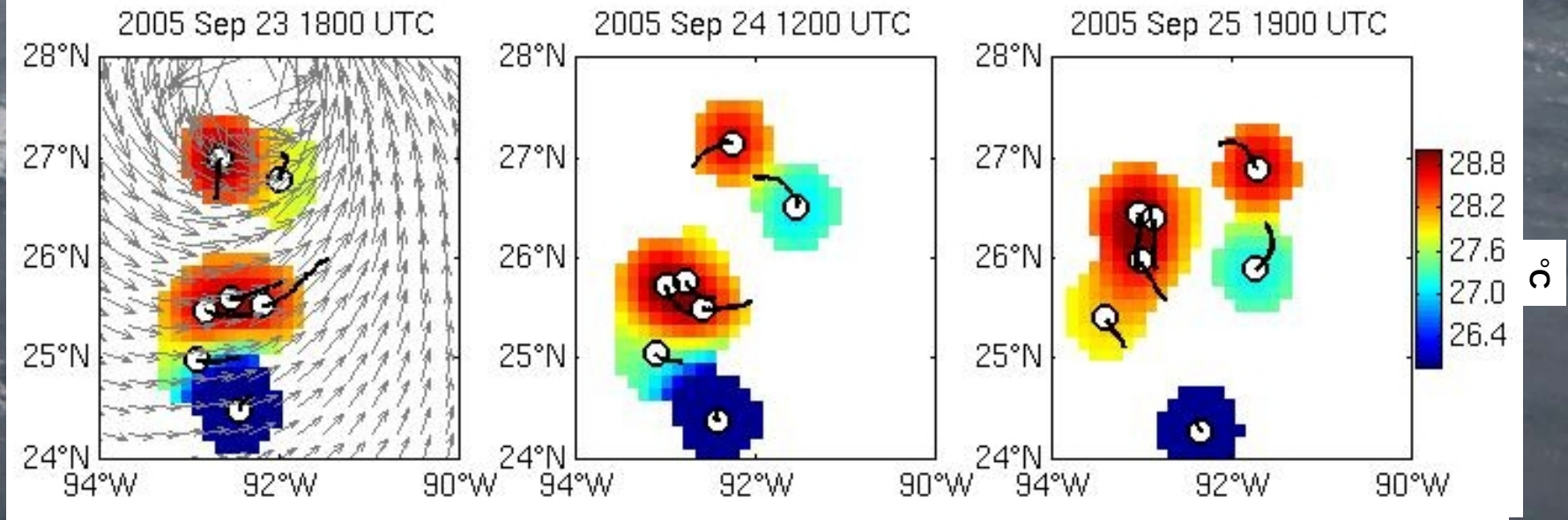
Sea Surface Temperature



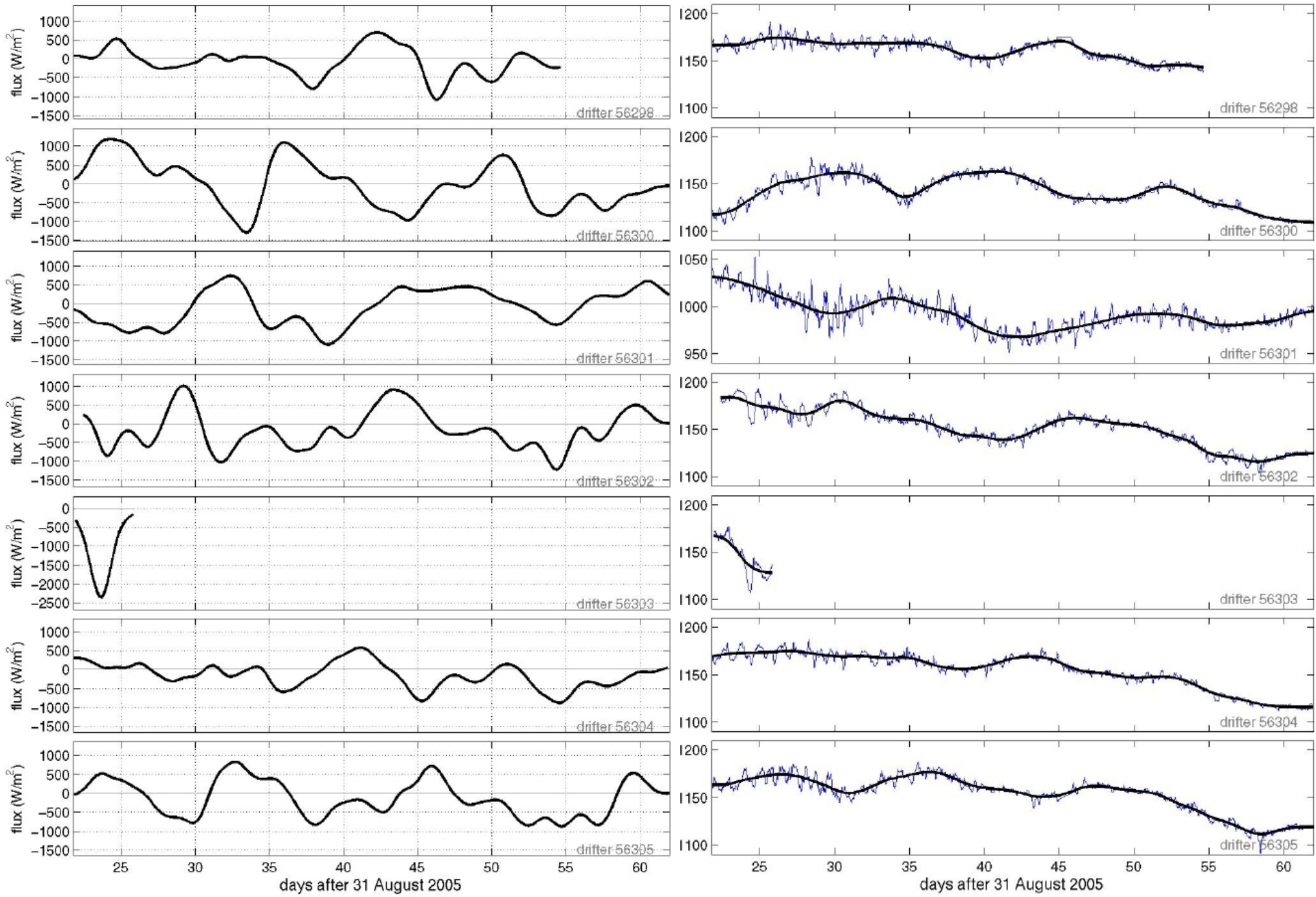
Subsurface Temperature

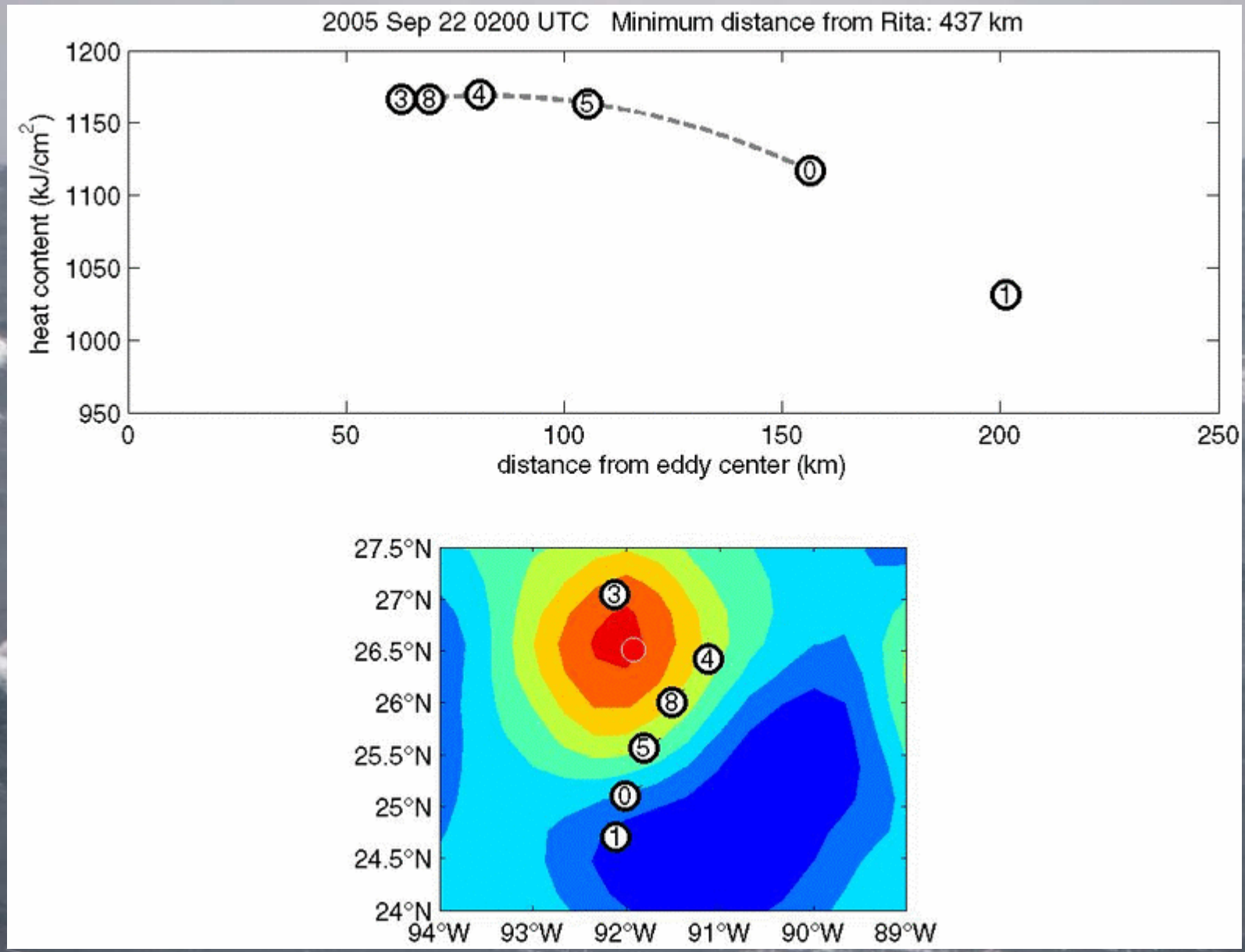


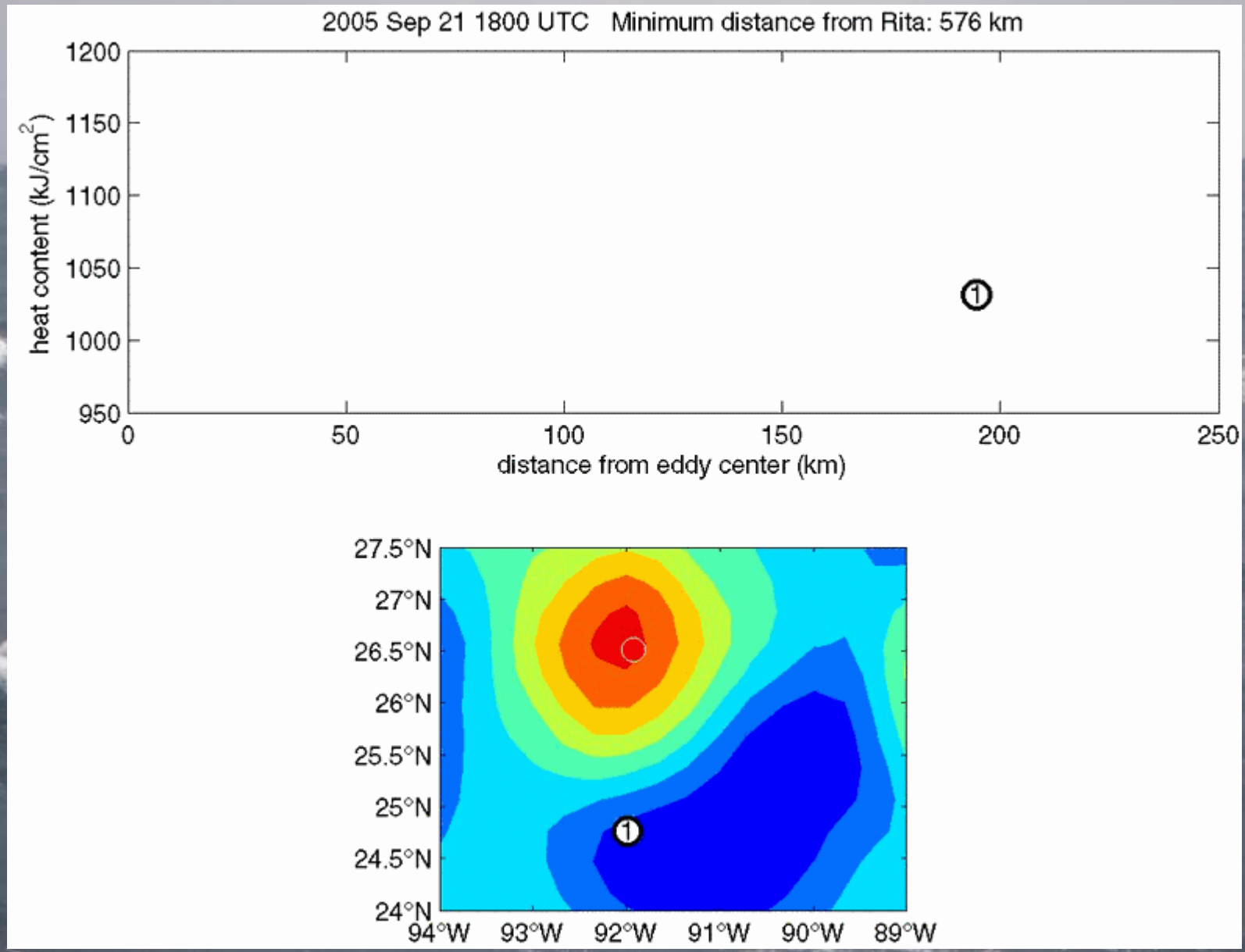
Temperature at 60m



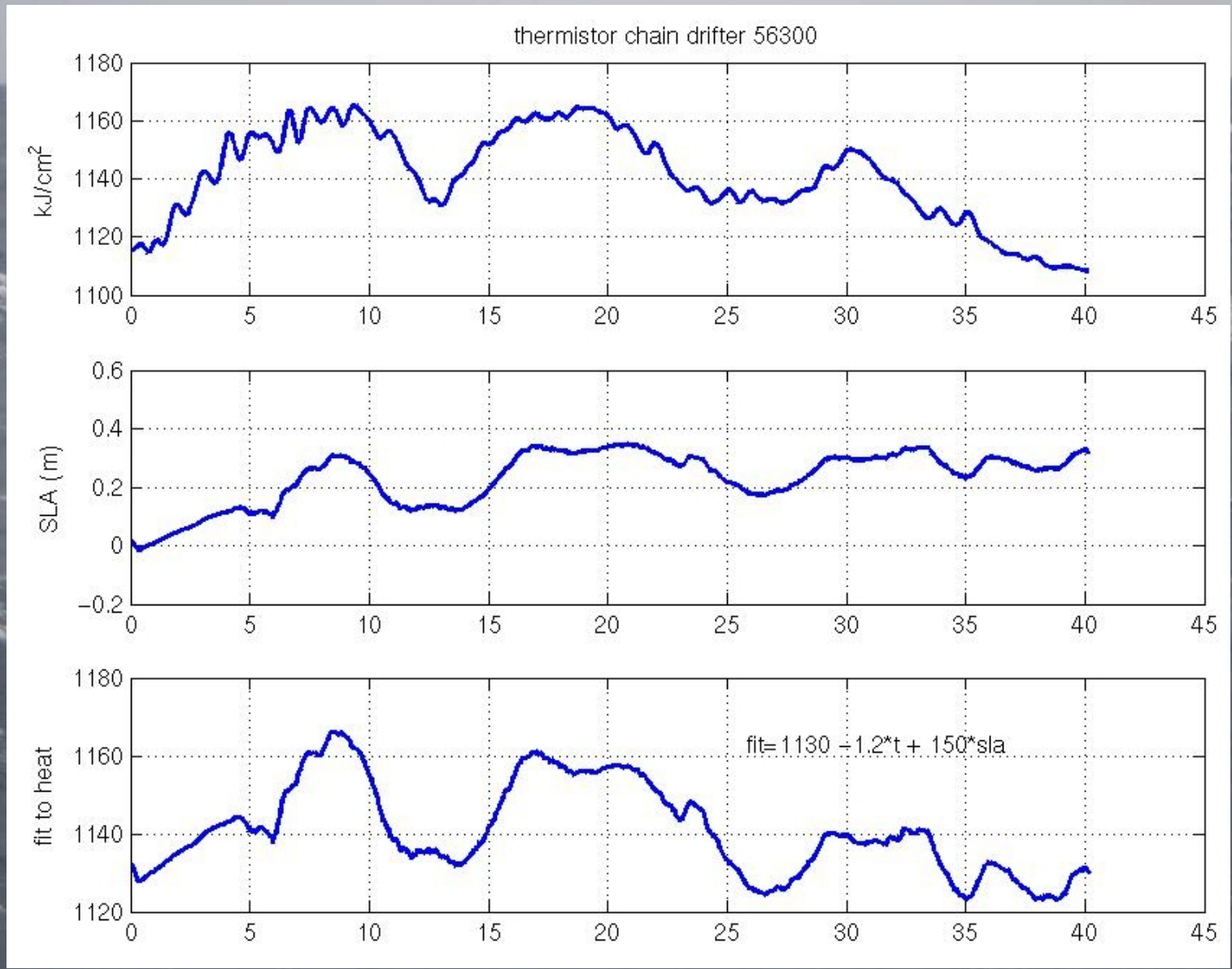
Temperature profiles

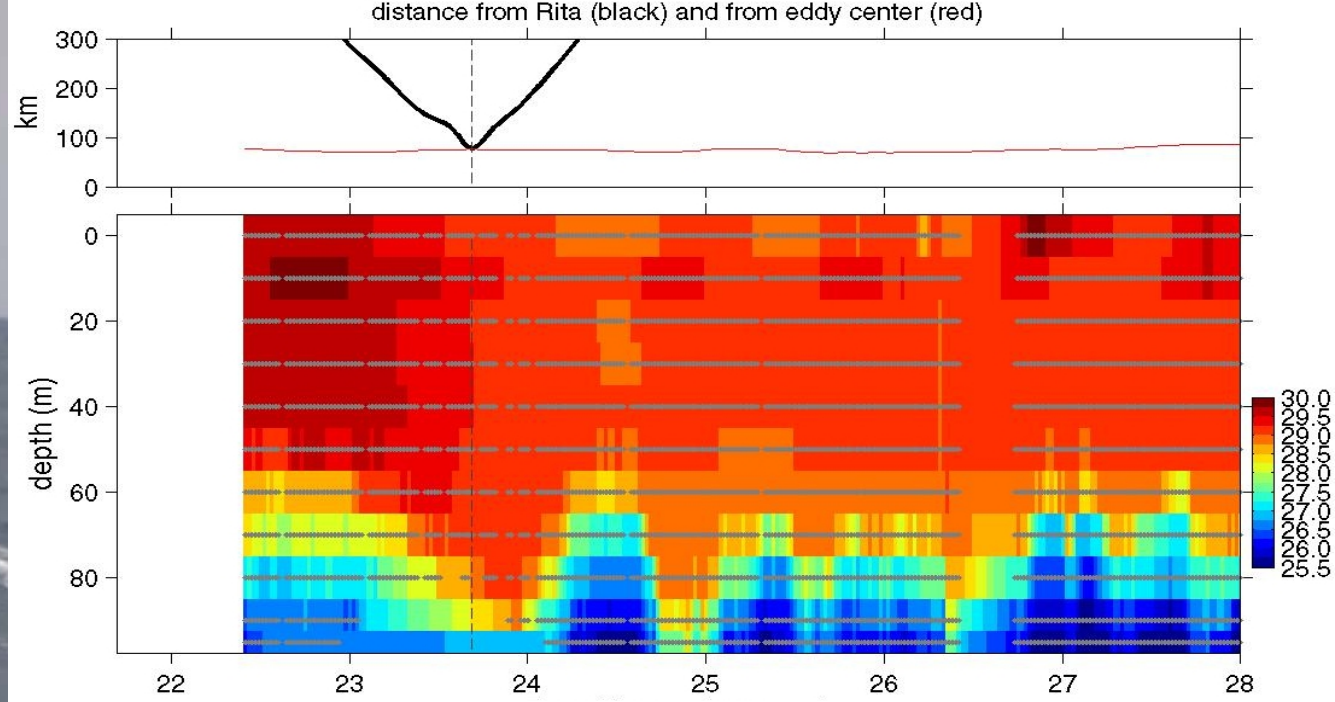



2005 Sep 22 0200 UTC Minimum distance from Rita: 437 km
heat content (kJ/cm^2)
1200
1150
1100
1050
1000
950
0
50
100
150
200
250
distance from eddy center (km)
3
8
4
5
0
1
27.5°N
27°N
26.5°N
26°N
25.5°N
25°N
24.5°N
24°N
94°W
93°W
92°W
91°W
90°W
89°W

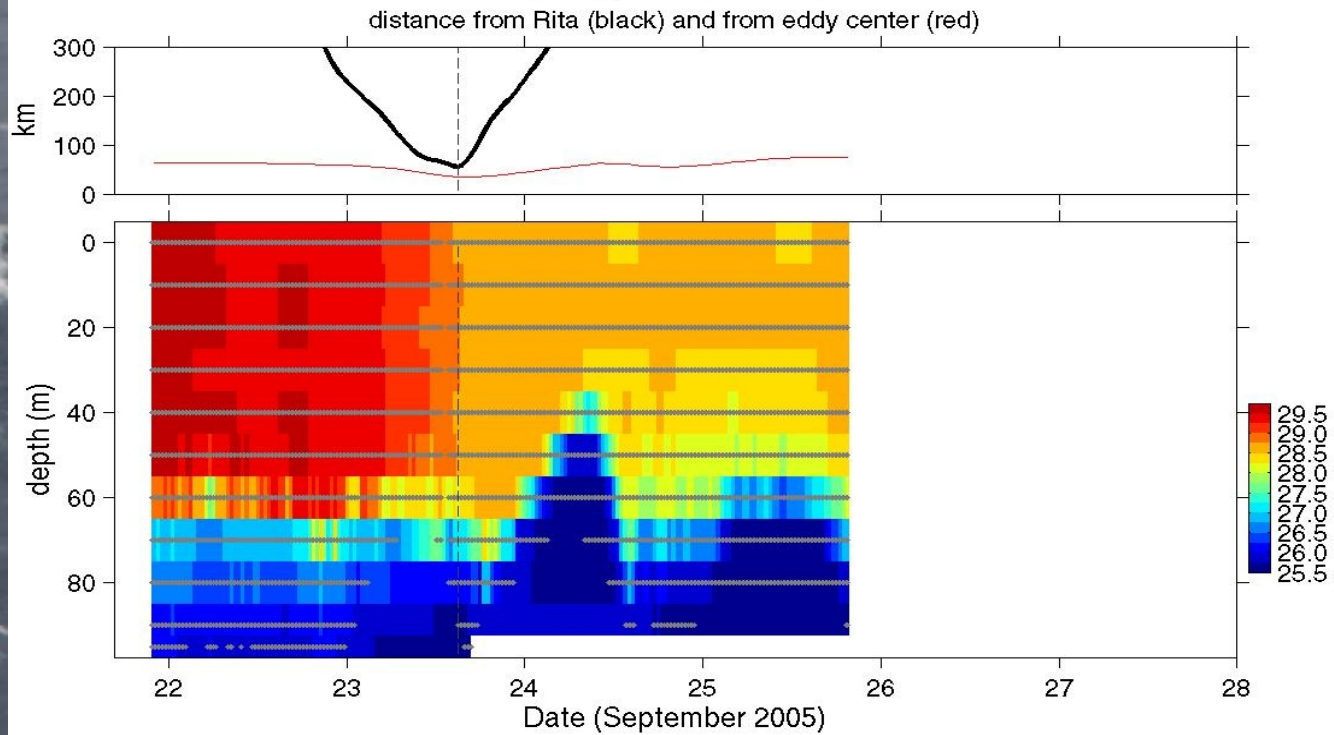

2005 Sep 21 1800 UTC Minimum distance from Rita: 576 km
heat content (kJ/cm^2)
1200
1150
1100
1050
1000
950
0
50
100
150
200
250
distance from eddy center (km)
1
27.5°N
27°N
26.5°N
26°N
25.5°N
25°N
24.5°N
24°N
94°W
93°W
92°W
91°W
90°W
89°W
1

Reducing the data




distance from Rita (black) and from eddy center (red)
km
300
200
100
0
depth (m)
0
20
40
60
80
22
23
24
25
26
27
28
30.0
29.5
29.0
28.5
28.0
27.5
27.0
26.5
26.0
25.5

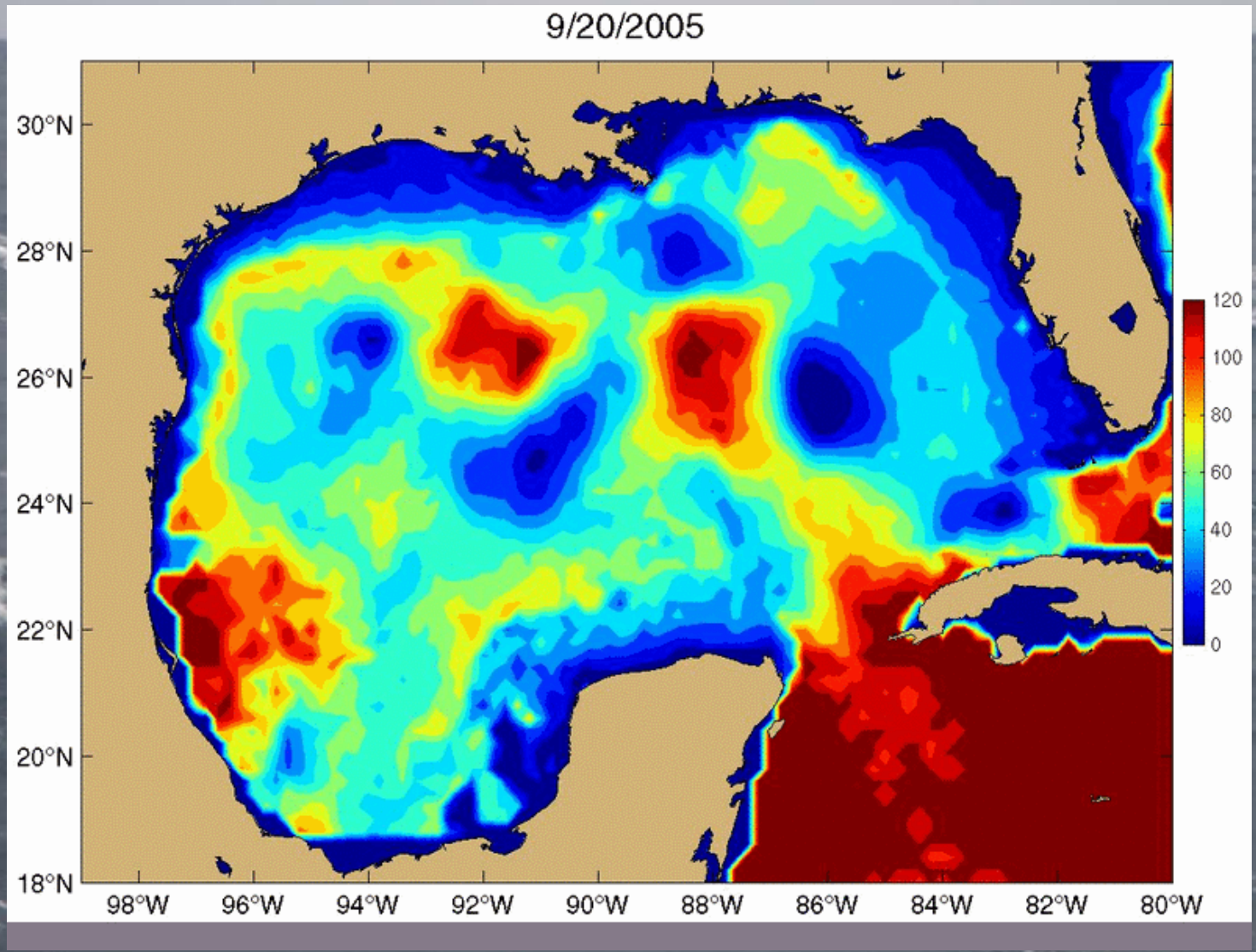
56302


distance from Rita (black) and from eddy center (red)
km
300
200
100
0
depth (m)
0
20
40
60
80
22
23
24
25
26
27
28
Date (September 2005)
29.5
29.0
28.5
28.0
27.5
27.0
26.5
26.0
25.5

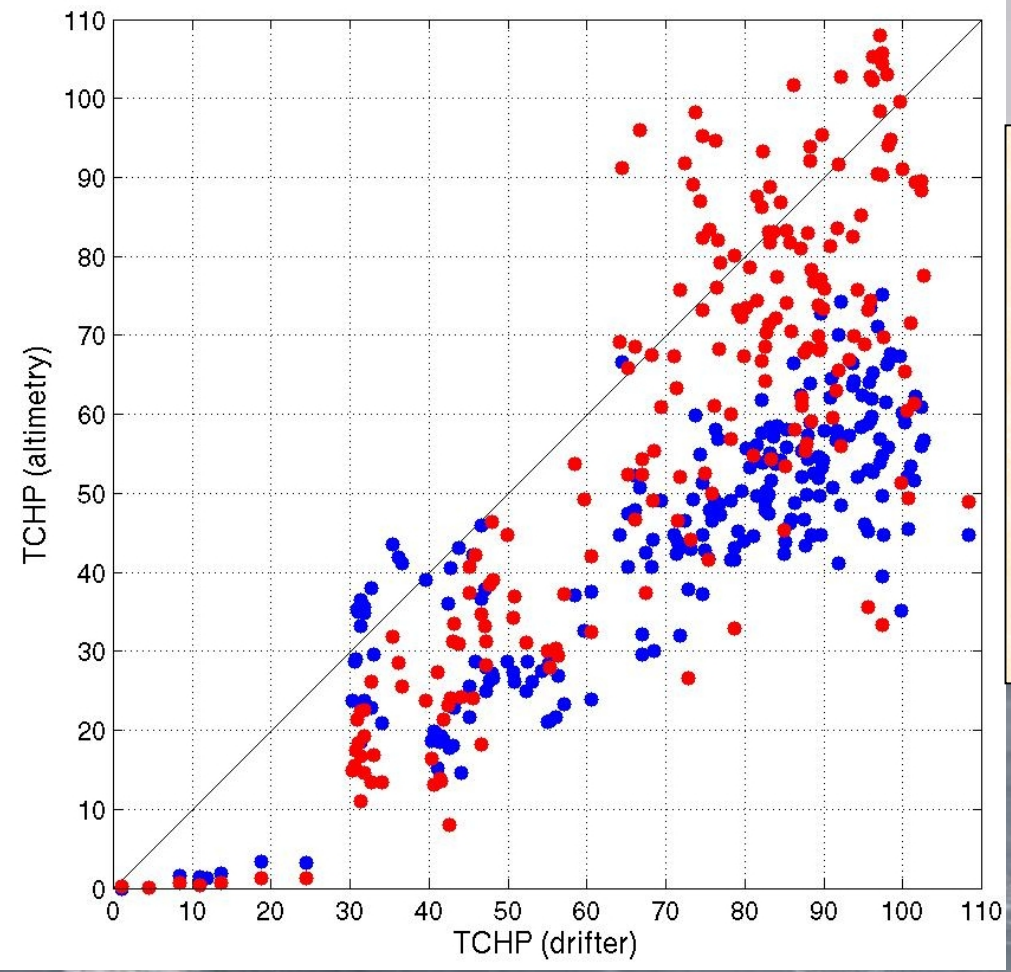
56303

Tropical Cyclone Heat Potential

$$TCHP = \int_0^{z(26^\circ C)} dz\, \rho\, c_p\, (T - 26^\circ \mathrm{C}).$$

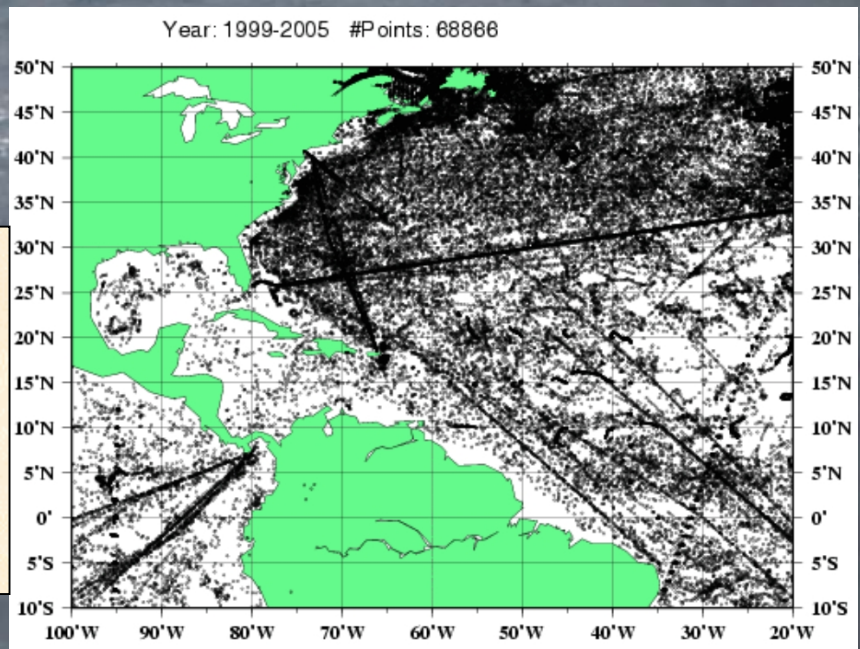


Satellite-based TCHP courtesy Gustavo Goni (NOAA/AOML)



Mean offset: 27.1 kJ/cm^2
RMS error: 30.5 kJ/cm^2
Std. deviation: 14.0 kJ/cm^2

Mean offset: 11.4 kJ/cm^2
RMS error: 20.1 kJ/cm^2
Std. deviation: 16.6 kJ/cm^2



XBT observations used to calibrate/validate satellite-derived TCHP. Note lack of high- or low-density or frequently repeated XBT transects through the Gulf of Mexico or Caribbean Sea.

Summary

In-situ observations of SST, wind, air pressure and upper ocean heat during the passage of a major hurricane can be made via air deployment of drifters. These measurements quantify upper ocean heat content in features such as warm-core rings and the Loop Current – features associated with the rapid intensification of hurricanes such as Opal (1995) and Katrina (2005).

Sea surface temperature cooled by as much as 1.3°C before the center of Rita passed the array. The upper ocean began cooling to depths of 60m before center passed. Thus, winds ahead of the eye were sufficient to mix the ocean before the arrival of the center, creating a leading cold wake.

Intensity of wake depends on prior thermal structure of ocean. Numerical simulations of this are highly sensitive to drag coefficient.

Detailed knowledge of hurricane/ocean interaction is needed to improve realism of current and future hurricane intensity prediction models. These observations allow detailed evaluation of coupled models such as EMC's Hurricane Weather and Research Forecast system (HWRF).

2006–2007 seasons and beyond

Present NOAA resources are sufficient to support the manufacture and deployment of 8 thermistor chain drifters and 12 minimet drifters per year, enough to sample one to two hurricanes.

For the 2006-2007 hurricane seasons, 22 additional thermistor chain drifters will be funded as a one-time addition to the Global Drifter Program. The 42 drifters will be air-deployed in the paths of multiple hurricanes in operational mode. Perhaps 3 deployments of 14 drifters.

Beyond 2007: 8 thermistor, 12 minimet (1—2 deployments) per year. Funding for a larger array is being pursued.

Drifter observations of Hurricane Rita (September 2005)

Rick Lumpkin
Physical Oceanography Division
NOAA/AOML

Collaborators:

Bill Scuba and Peter Niiler

Scripps Institution of Oceanography

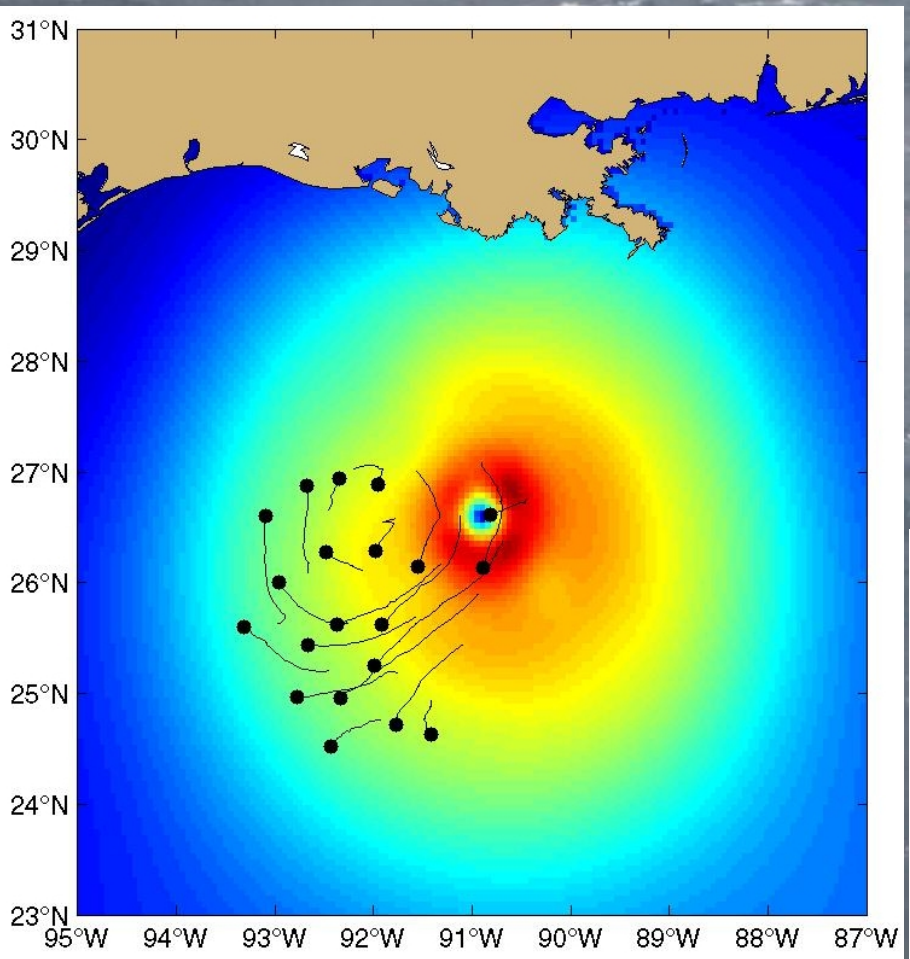
Pete Black

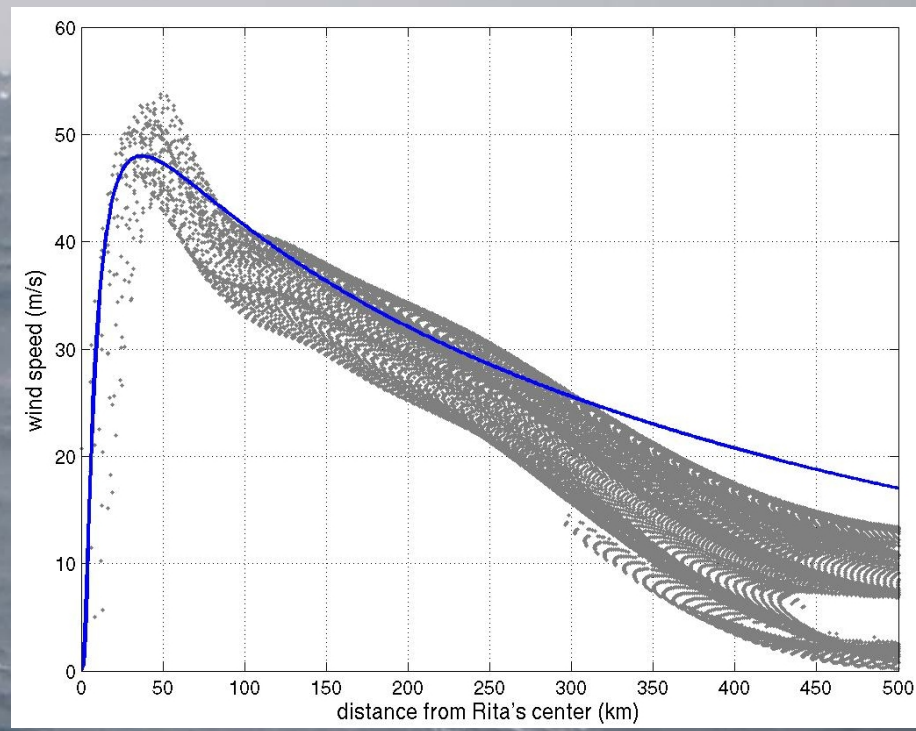
Hurricane Research Division, NOAA/AOML

Jan Morzel

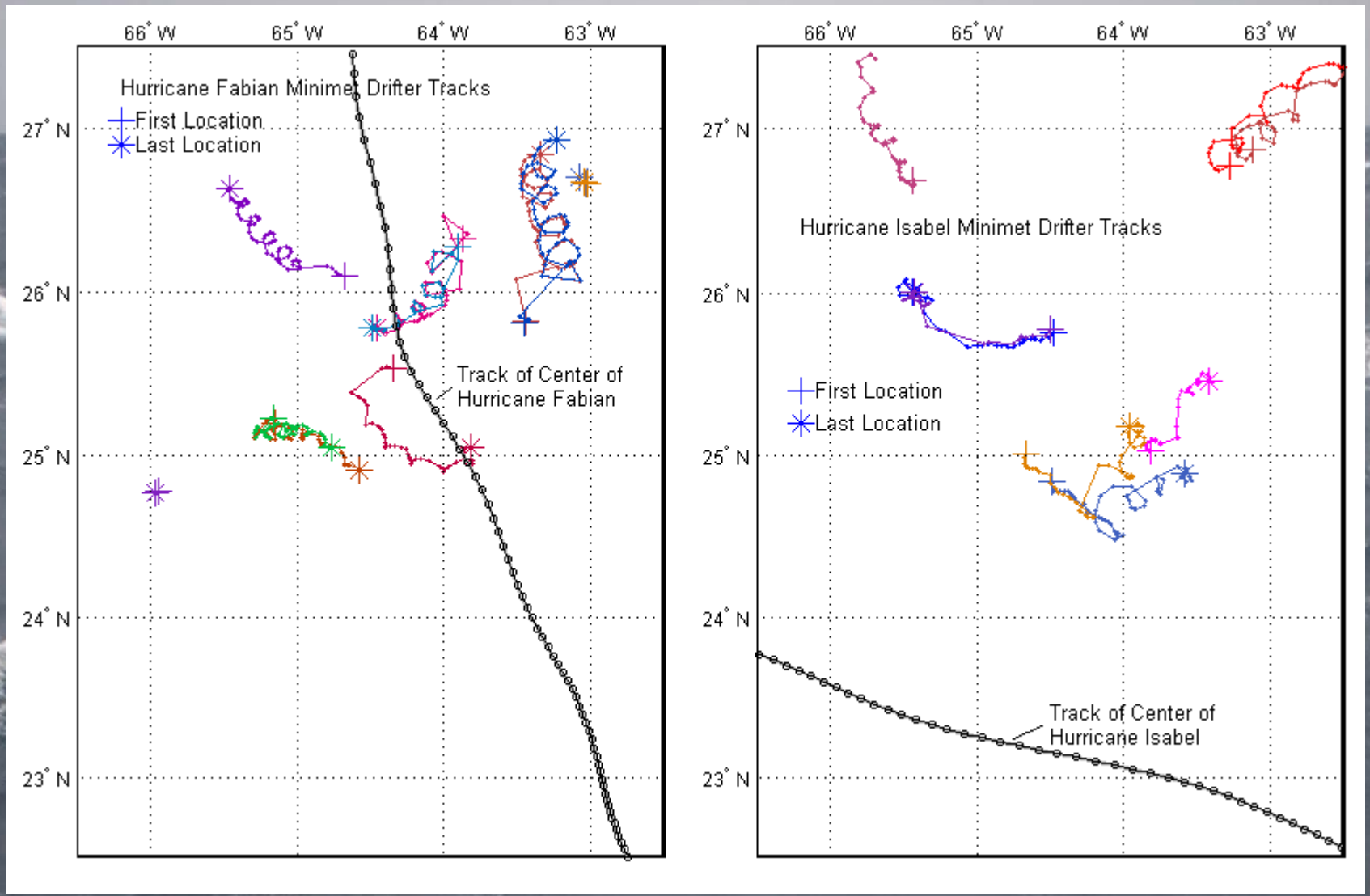
NorthWest Research Associates (NWRA), Inc.

H*Wind (gridded surface wind analysis)

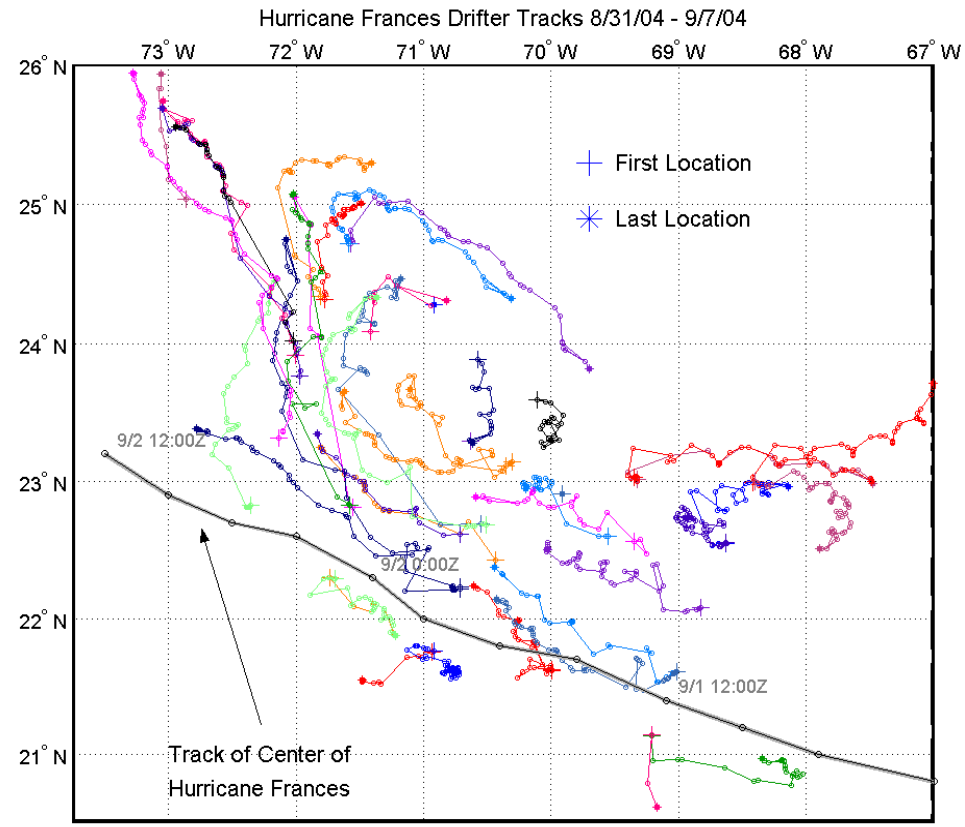


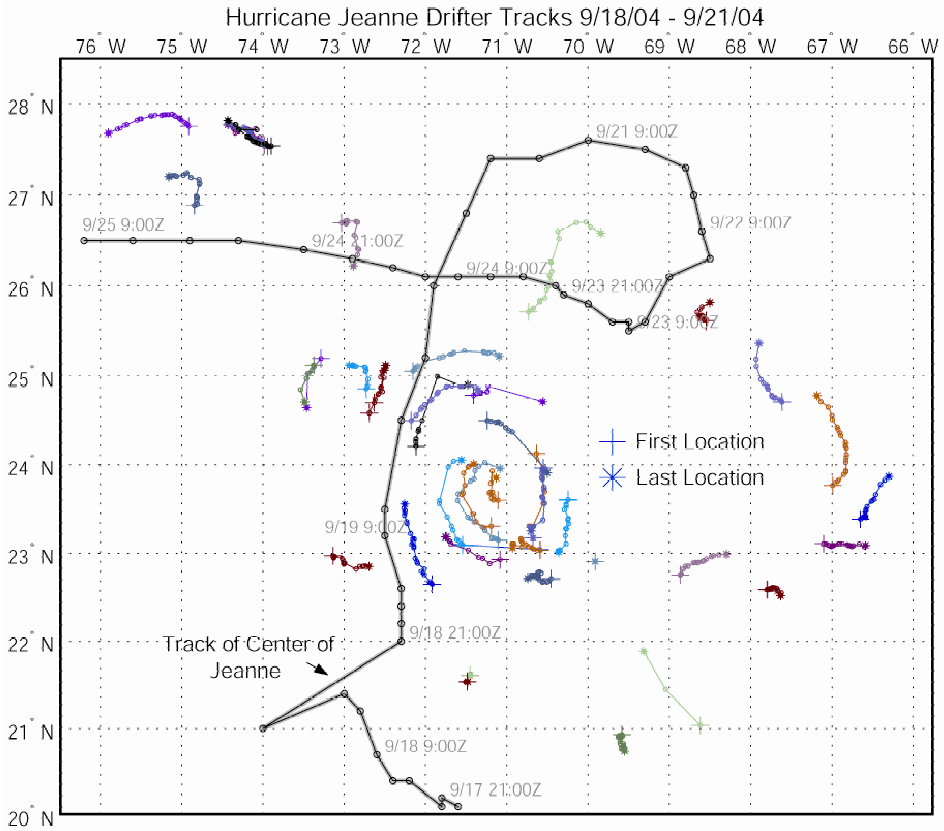


2003 drifter trajectories

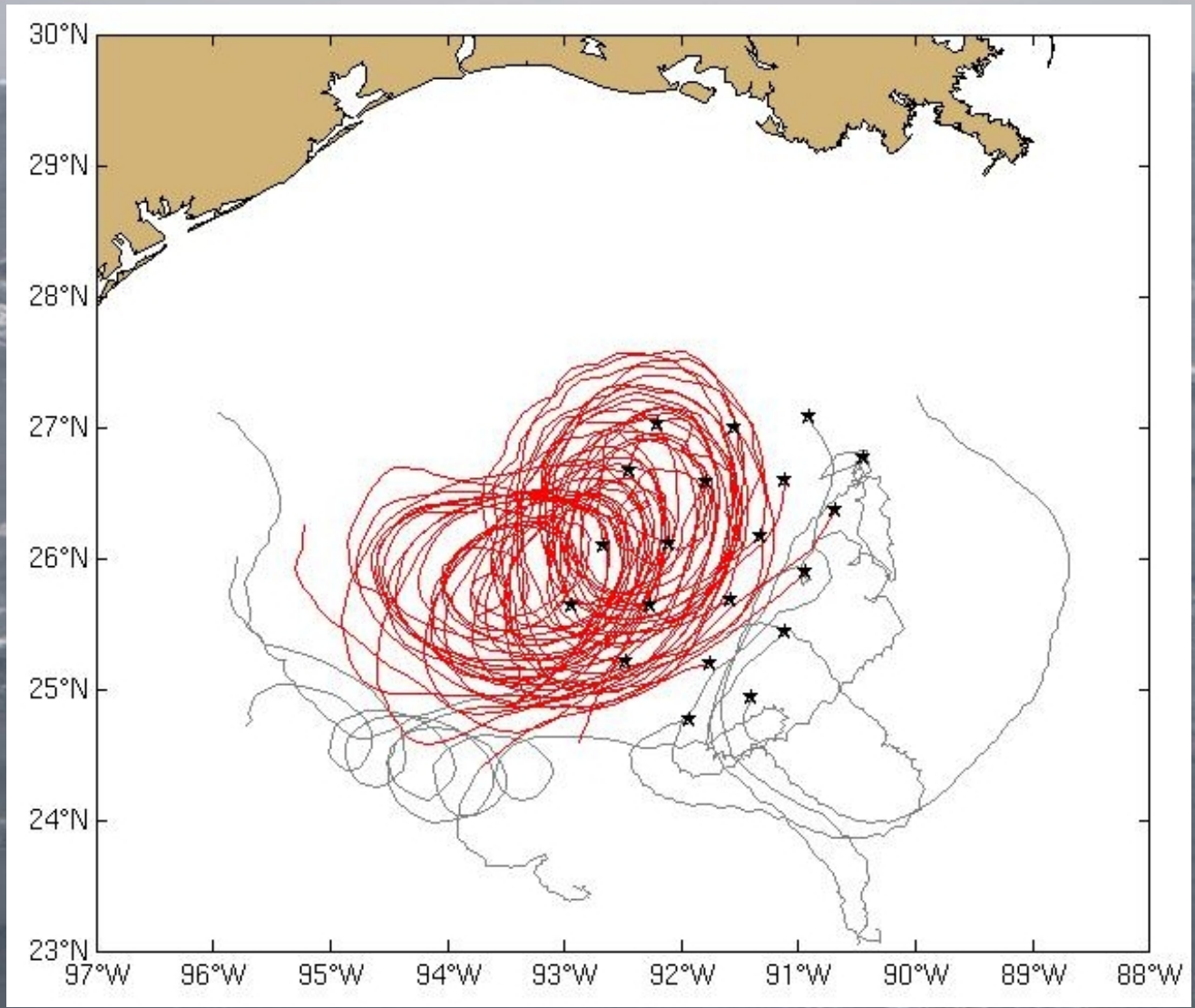


2004 drifter trajectories



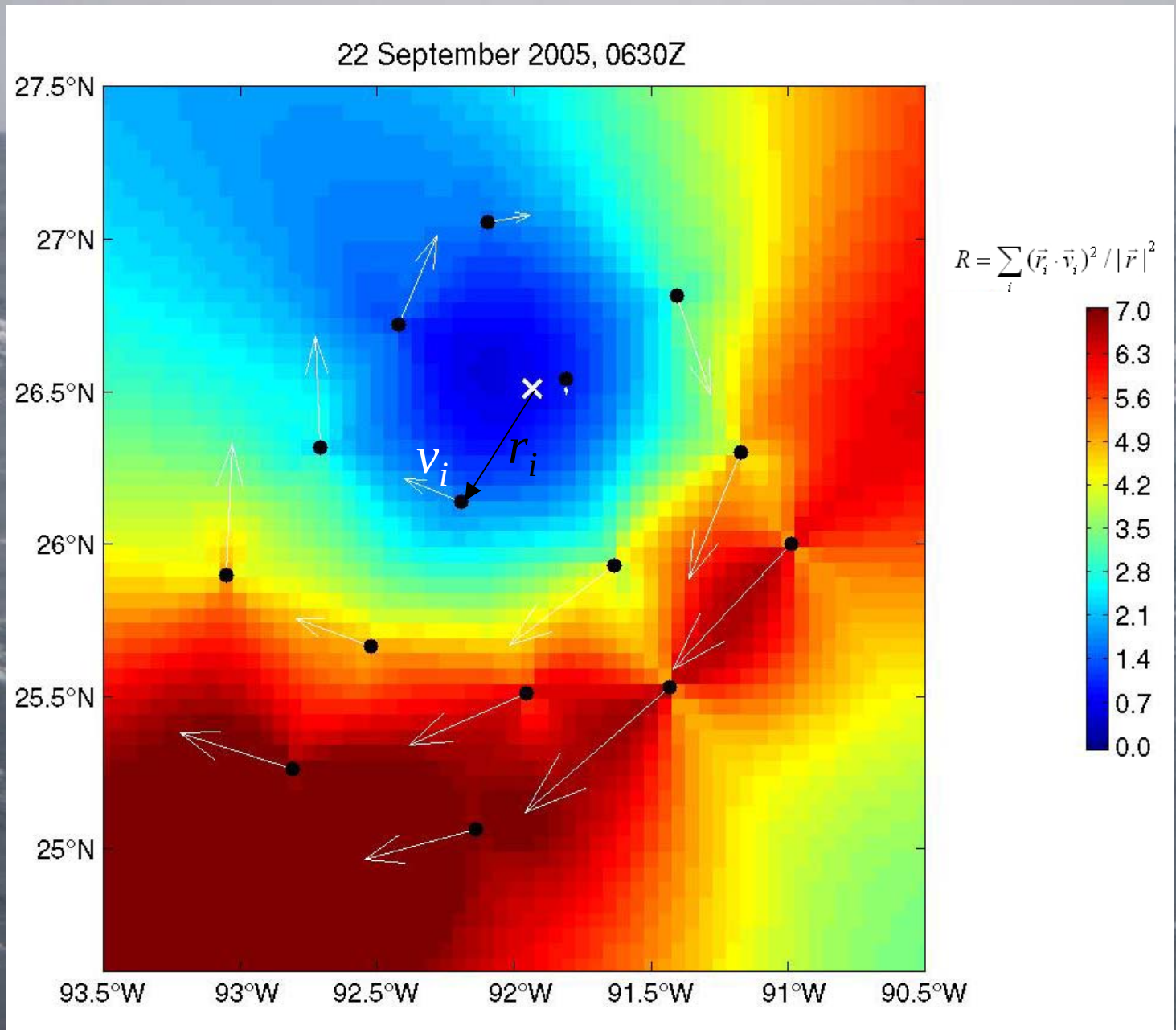


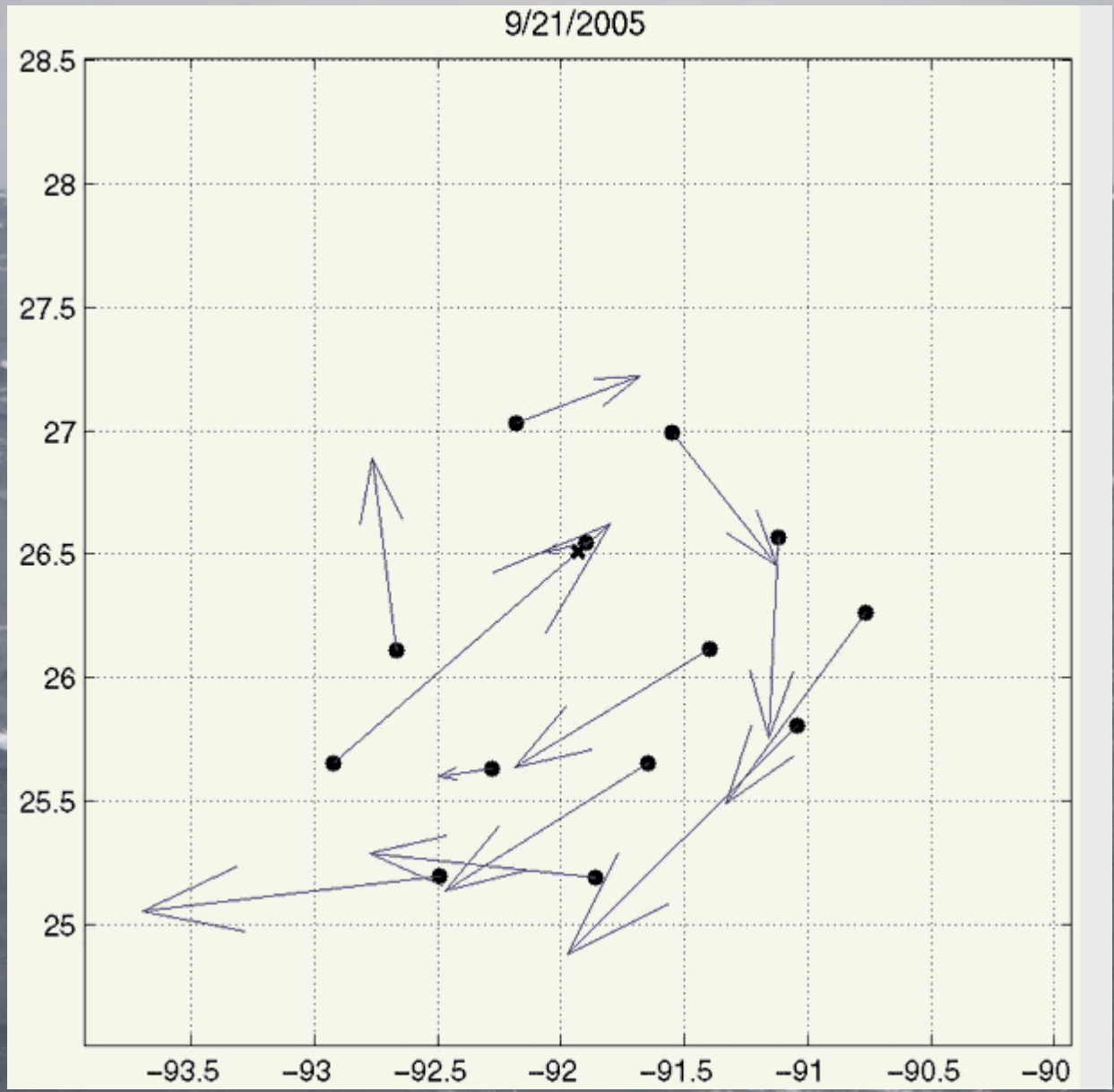
Trajectories



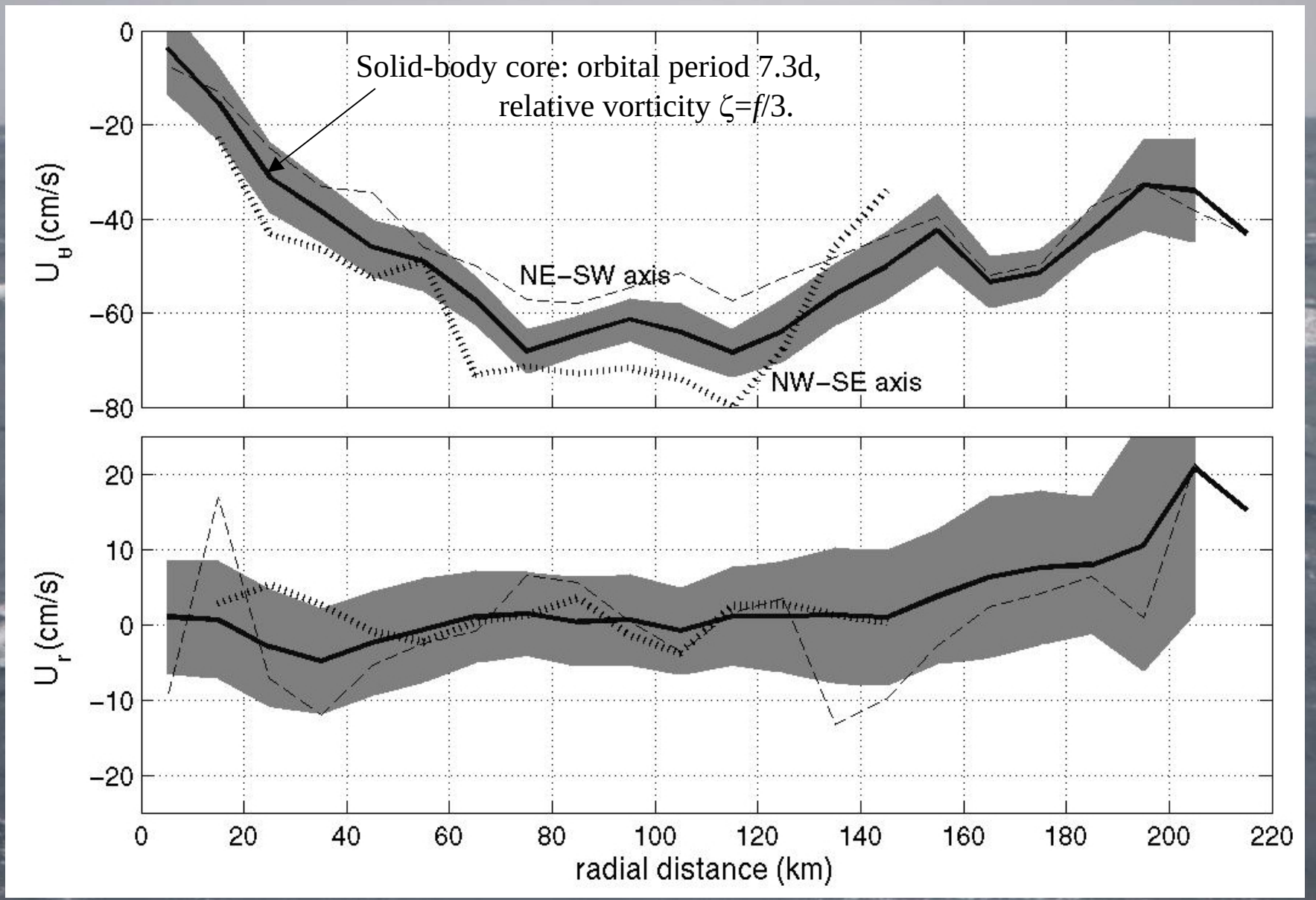
21 September to 1 November 2006

Identifying the eddy's center

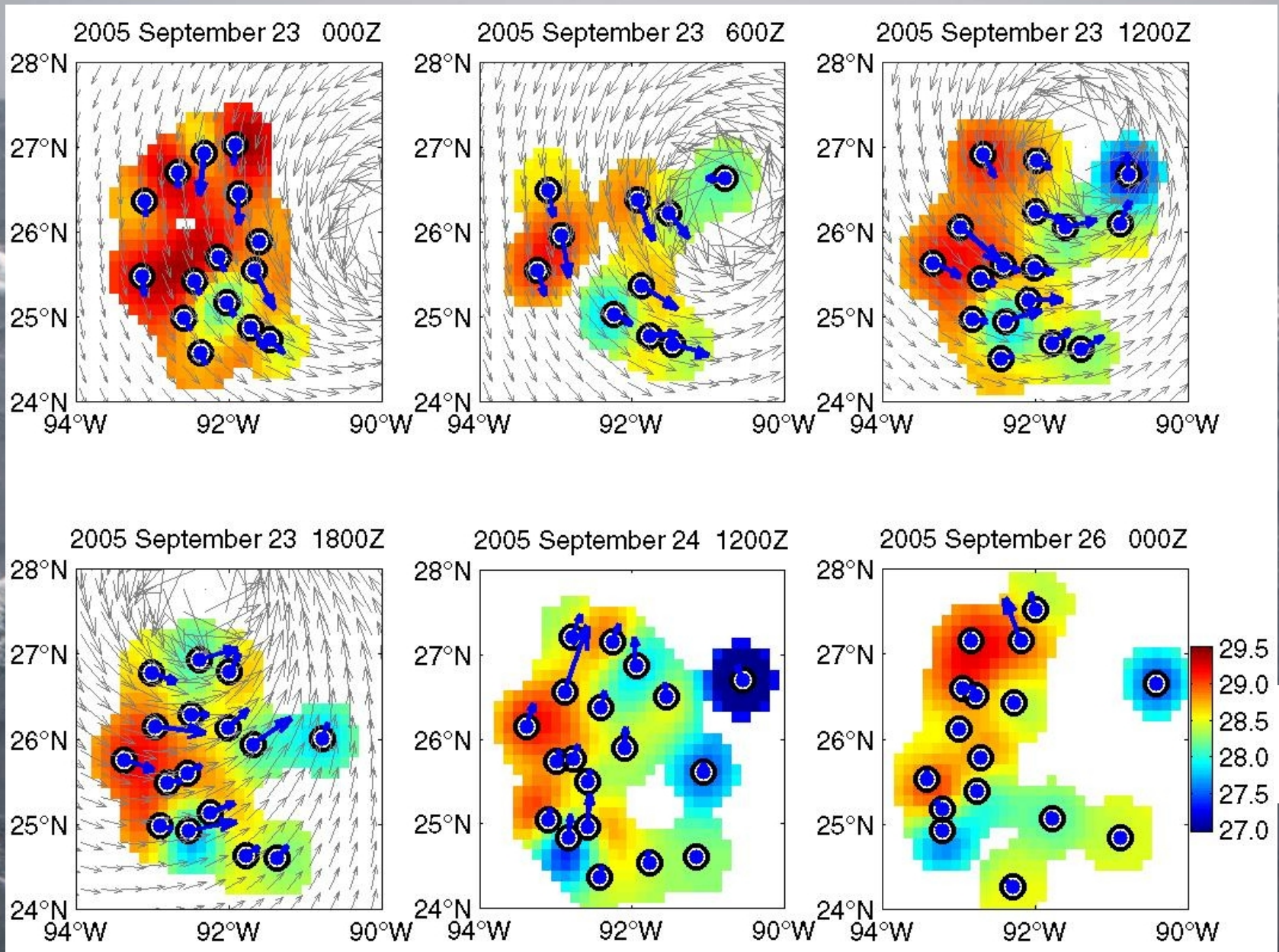



9/21/2005
28.5
28
27.5
27
26.5
26
25.5
25
−93.5
−93
−92.5
−92
−91.5
−91
−90.5
−90

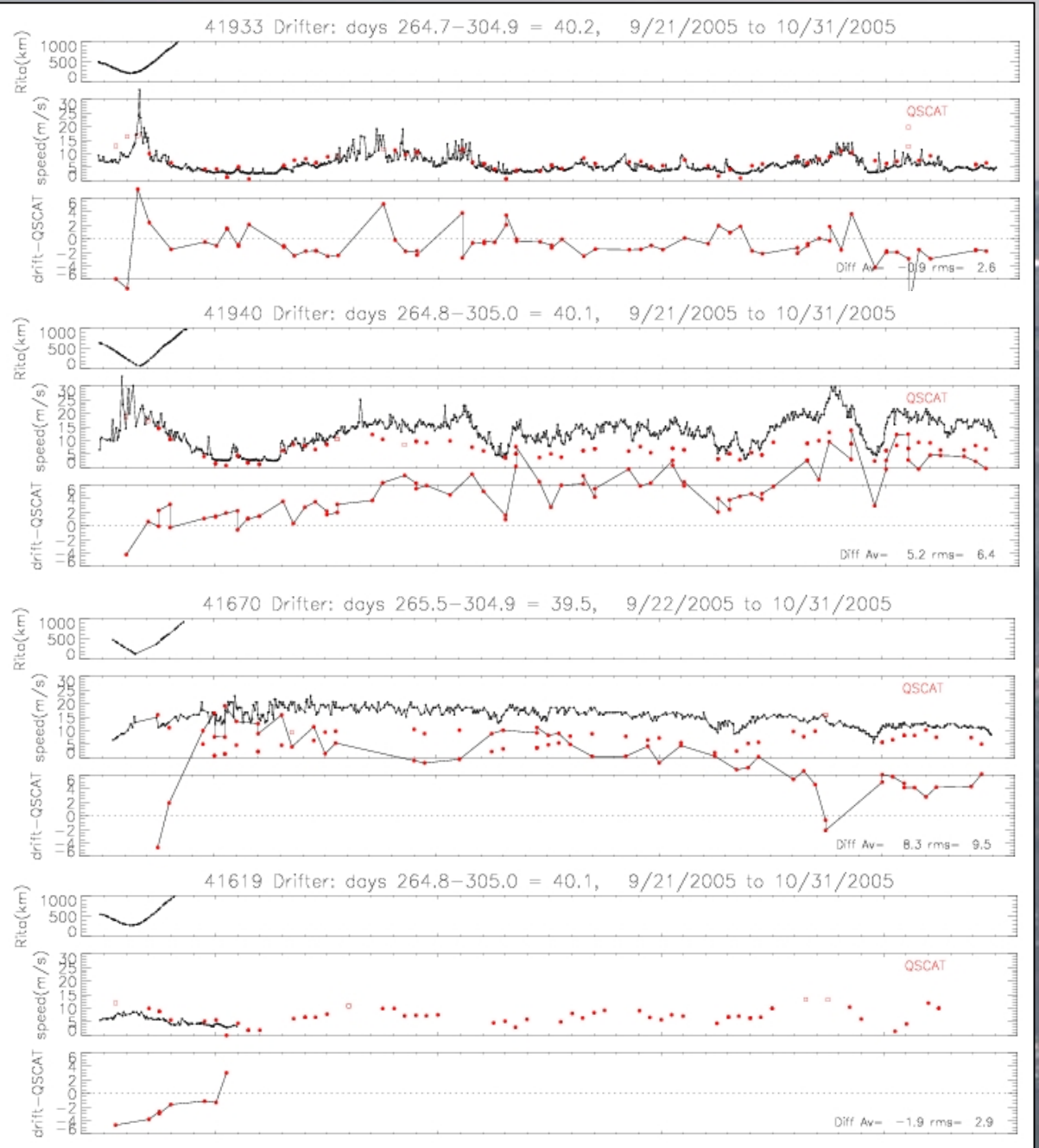
Eddy velocity structure



Wind Observations



Wind speed



Comparisons:

Hourly averaged drifter wind speed (solid) with QuikSCAT (dots, rain-flagged=open squares)

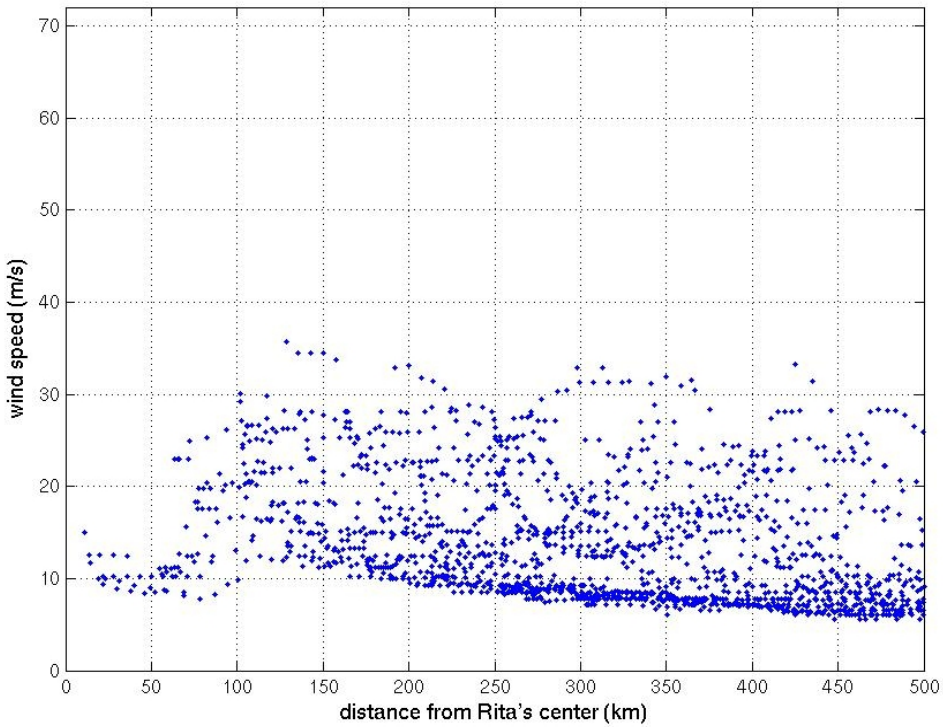
Good: 11 drifters.
Mean offset: –2.1 to 1.1 m/s,
RMS: 1.9 to 3.6 m/s.

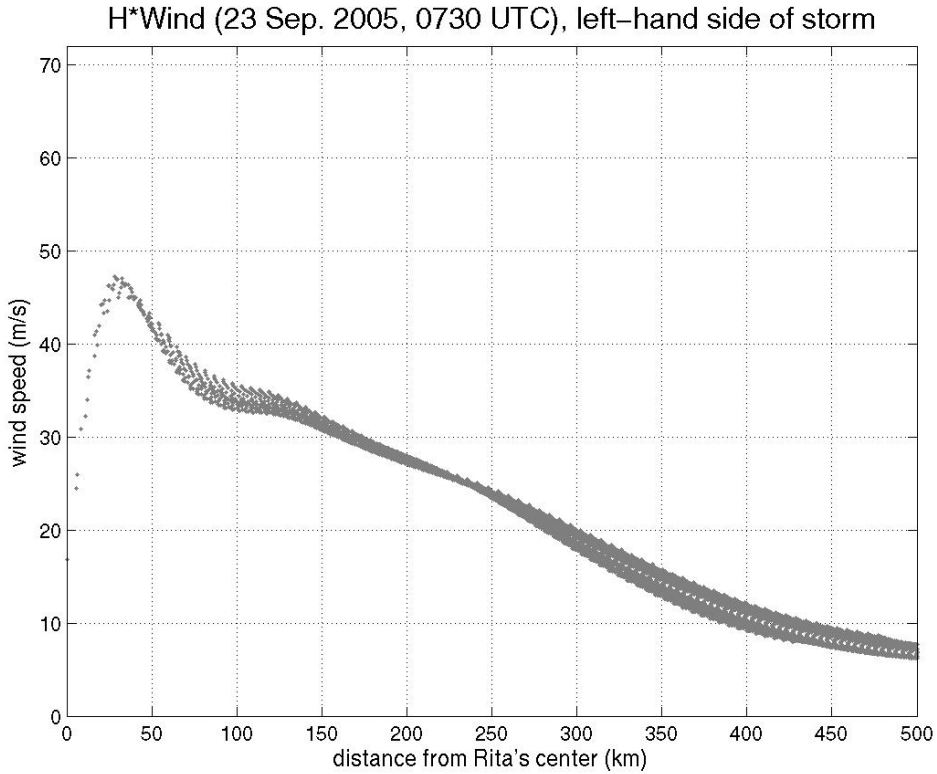
Trend: 3 drifters.
Mean offset grows with time.

Bad: 3 drifters.
Mean offset –3.4, 24.1, 8.3 m/s
RMS: 4.4, 28.2, 9.5 m/s.

Short: 3 drifters.
Quit after 9.8d, 6.2d, 4.0d.
(two continued to provide wind direction for many more days)

Wind speed during Rita passage





Left: wind speed vs. distance from Rita's center, 11 "good" drifters. Obvious issues for these very high wind regimes, including possible rain effects. Saturation at ~30 m/s.

Right: H*Wind field during passage (LHS of storm).

These data provide an opportunity to improve parameterization of wind speed from hydrophone measurements in extreme conditions.