Hurricane Erika

From 4 to 8 September 1997 scientists from the Hurricane Research Division of AOML and aircraft crews from the Aircraft Operations Center flew a NOAA's WP-3D research aircraft (N43RF) and the new G-IVSP jet aircraft (N49RF) into Hurricane Erika. The storm, a category 3 storm based on ~65 m s^{-1} surface winds measured by dropsonde on 8 September, was an ideal candidate for three experiments:

(1) the Synoptic Surveillance Experiment: flown by N49RF alone on 4 September, and by N49RF and N43RF on 5 September as Erika approached the U.S. Virgin Islands;

(2) a modified version of the Extended Cyclone Dynamics Experiment (XCDX), termed Sonde Fest I (7 September), where GPS sondes were dropped in the storm (including numerous GPS sonde drops in the eyewall) and the surrounding environment N and W of the storm; and

(3) the Tropical Cyclone Air-Sea Interaction Experiment, termed Sonde Fest II (8 September), where simultaneous GPS sondes and AXBTs were dropped within 185 km of the storm center (including numerous simultaneous GPS sonde and AXBT drops in the eyewall).

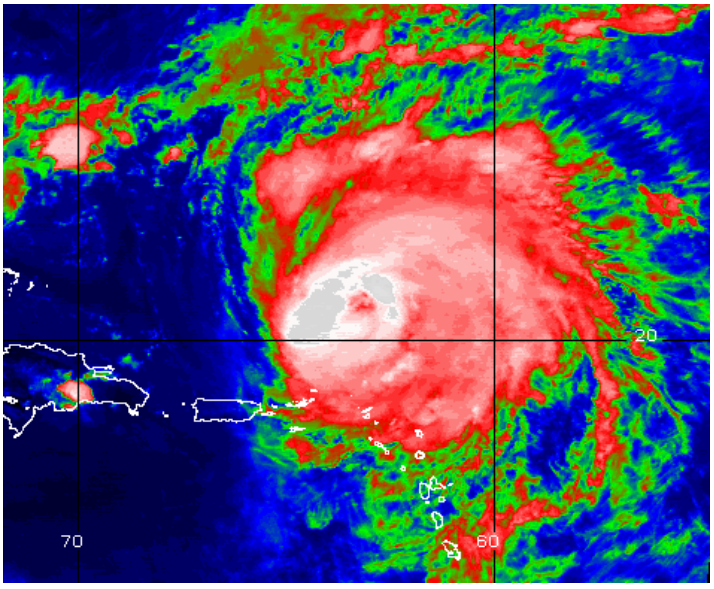
These are excellent data sets for determining the thermodynamic and kinematic structure of a category 3 hurricane. Data from the Synoptic Surveillance flights will be used in post-storm evaluations of ensemble models, and in real-time track predictions for Erika in an area of poorly-defined flow in the track model runs as the storm was slowing down and starting to recurve.

Erika Sonde Fests I and II are the second and third data sets collected this season with GPS sondes in the eyewall of a mature hurricane. Erika data showed similar eyewall boundary layer wind profiles to those found in Hurricane Guillermo, with numerous low-level wind maxima. Data will be used in post-storm evaluations of hurricane vertical structure and in real-time for track predictions of Erika.

The mission on 8 September represents a landmark data set for determining the vertical thermodynamic and dynamic structure of the atmospheric and oceanic boundary layers in a hurricane from 2 km in the atmosphere to 200 m depth in the ocean. These data were used in real-time for improved intensity estimations of Erika by NHC forecasters. GPS sonde and AXBT data will be used for evaluation of SFMR surface wind estimates and for evaluation of real-time boundary layer models used to estimate surface winds from flight-level data. These data allow for inclusions of the effects of and improved estimates of surface fluxes.

In addition to the in situ data, collaborating scientists at CIRA, NRL West, and the University of Wisconsin orchestrated acquisition of rapid-scan GOES imagery, 85 GHz SSMI data, and water vapor winds respectively over a larger domain around Erika. Together, the radars, dropsondes, AXBTs, flight level instruments, and satellites produced a complete portrait of the atmospheric and upper oceanic structure in Erika.

F. Marks



Mission Summary
970905I Aircraft 43RF
Erika Synoptic Flow

Scientific Crew (43RF)

Lead Scientist	P. Black
Radar	F. Marks
Workstation	P. Leighton
GPS sonde scientist	S. Aberson, S. Feuer
Trainee	J. Dunion

Mission Briefing:

This flight was a synoptic flow mission to drop GPS sondes between the U.S. East Coast and Bermuda for the purpose of augmenting G-IV (N49RF) GPS dropsondes in the environment around Hurricane Erika. This flight covers the area of high ensemble variability off the coast along the leading edge of an upper trough, and behind a surface cold front. The flight departed Opa Locka (KOPF) at 1735 UTC, 5 Sept. and terminated at Bermuda International (TXKF) at 0330 UTC, 6 September. Figure 1 shows the flight tracks of N43RF and N49RF.

Mission Synopsis:

This flight revealed a low-level frontal boundary off the FL coast with NW aloft and NE winds below the inversion near 850 mb. Less than 20% humidities above and typical 70-80% humidities below the inversion off FL. Throughout the remainder of the flight primarily NW to W flow was observed at all levels from offshore JAX to offshore BOS. Winds were weaker than forecasted at 500 mb with main jet stream further to the north than forecasted. Entered north boundary of 90 kt southwesterly jet streak at 0030 UTC after crossing trough axis at 00 UTC near NE corner of pattern (40N, 65W). 850 mb ridge protrudes further east than models predicted.

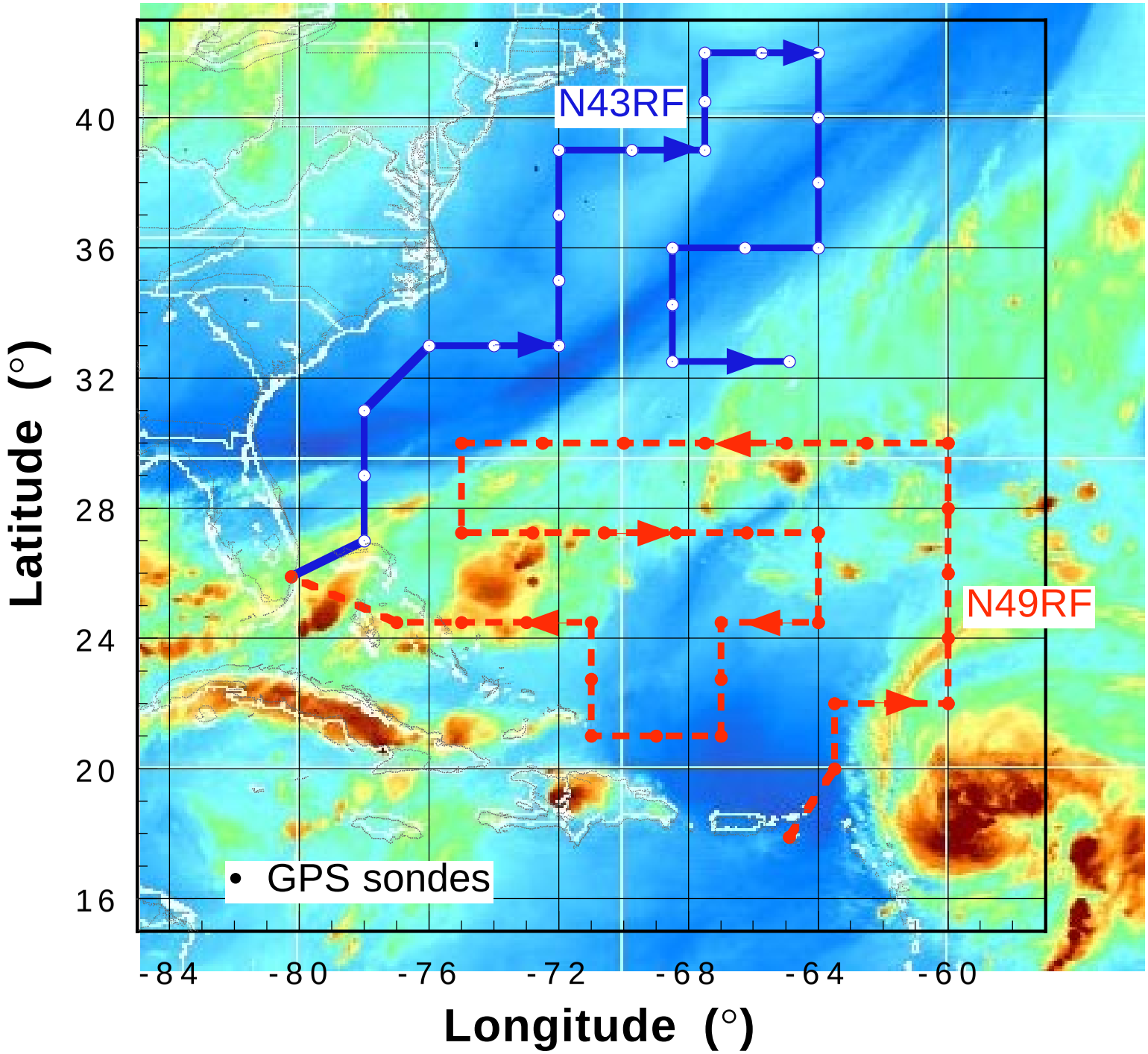
Evaluation:

This will be an excellent example of obtaining sonde data in an area of poorly-defined flow in model simulations. Data will be used in post-storm evaluations of ensemble model use as well as in real-time track predictions for Erika.

Problems:

Work station and AVAPS systems went down from 2222-2242, resulting in partial loss of sonde data on one drop, no data transmission on a second drop and a third aborted drop, not in a critical area. Problem may have resulted from sonde being turned on as a backup, then being turned off, then being turned on again. This operation may have corrupted file on the workstation. Problem occurred again at 0200 UTC resulting in the last 2 sondes not being transmitted. All other systems functioned nominally.

Peter G. Black


N43RF
N49RF
• GPS sondes
40
36
32
28
24
20
16
-84
-80
-76
-72
-68
-64
-60
Latitude (°)
Longitude (°)

Mission Summary
970907I Aircraft 43RF
Erika Sonde Fest/ XCDX

Scientific Crew (43RF)

Lead Scientist	P. Black
Radar	F. Marks
Workstation	P. Leighton
GPS sonde scientist	S. Aberson, S. Feuer
Observer	J. Dunion

Mission Briefing:

The purpose of the mission was to drop GPS sondes in the environment between Bermuda and Erika, along a Fig 4 pattern within Erika, and between Erika and the Bahamas to discern the environment around Hurricane Erika and the vertical cross section of winds and θ_e within Erika.

Mission Synopsis:

The flight departed Bermuda International (TXKF) at 1447 UTC, 7 September and landed at Opa Locka (KOPF) at 2330 UTC, 7 September. A total of 36 of 39 GPS sondes dropped during this mission were good, of which 9 were dropped in the environment enroute to and from the storm and 27 were dropped within the storms inner core. Two radial cross sections were obtained of both winds and thermodynamics (Fig. 1). The figure 4 legs were oriented N-S and E-W. Max winds were 85 kt at flight level and 110 kt at 800-900 m. Minimum pressure was 966 mb and eye diameter was 28 nmi. Storm motion was 300° at 6 kt. A surface front with strong convection was located 9° north of Erika. However, no mid or upper level strong winds were measured. Low level SW winds were observed ahead of the front.

The eyewall was very well defined with two main areas of convection located N and SE of the center (Fig. 1). The northern complex rotated around to the E during the flight. New cells were forming in the SE eyewall throughout the flight. Multiple intense bands existed south of the center extending outward over 200 nmi. and spiraling into the NE eyewall. A large area of intense banded stratiform precipitation covered the east semicircle (Fig. 1).

Multiple sondes were dropped at the inner edge of the eyewall in the north, south, east and west walls. All revealed low level wind maxima at around 200-900 m. Each showed surface winds which ranged from 64-84% of the wind maximum. Over half indicated superadiabatic layers within the eyewall boundary layer. This is the first time such a mission has been accomplished with dropsondes.

Excellent tail Doppler and lower fuselage radar data were obtained. Airborne Doppler data indicated a mean flow from 1-9 km altitude of 330° at 4 m s^{-1}, very close to the measured motion vector for the storm. Doppler data also indicated a NW shear of approximately 12 m s^{-1}. Mean flow was SE at 6 m s^{-1} at 1 km and NW at 6 m s^{-1} at 9 km. SFMR surface data were also obtained.

Evaluation:

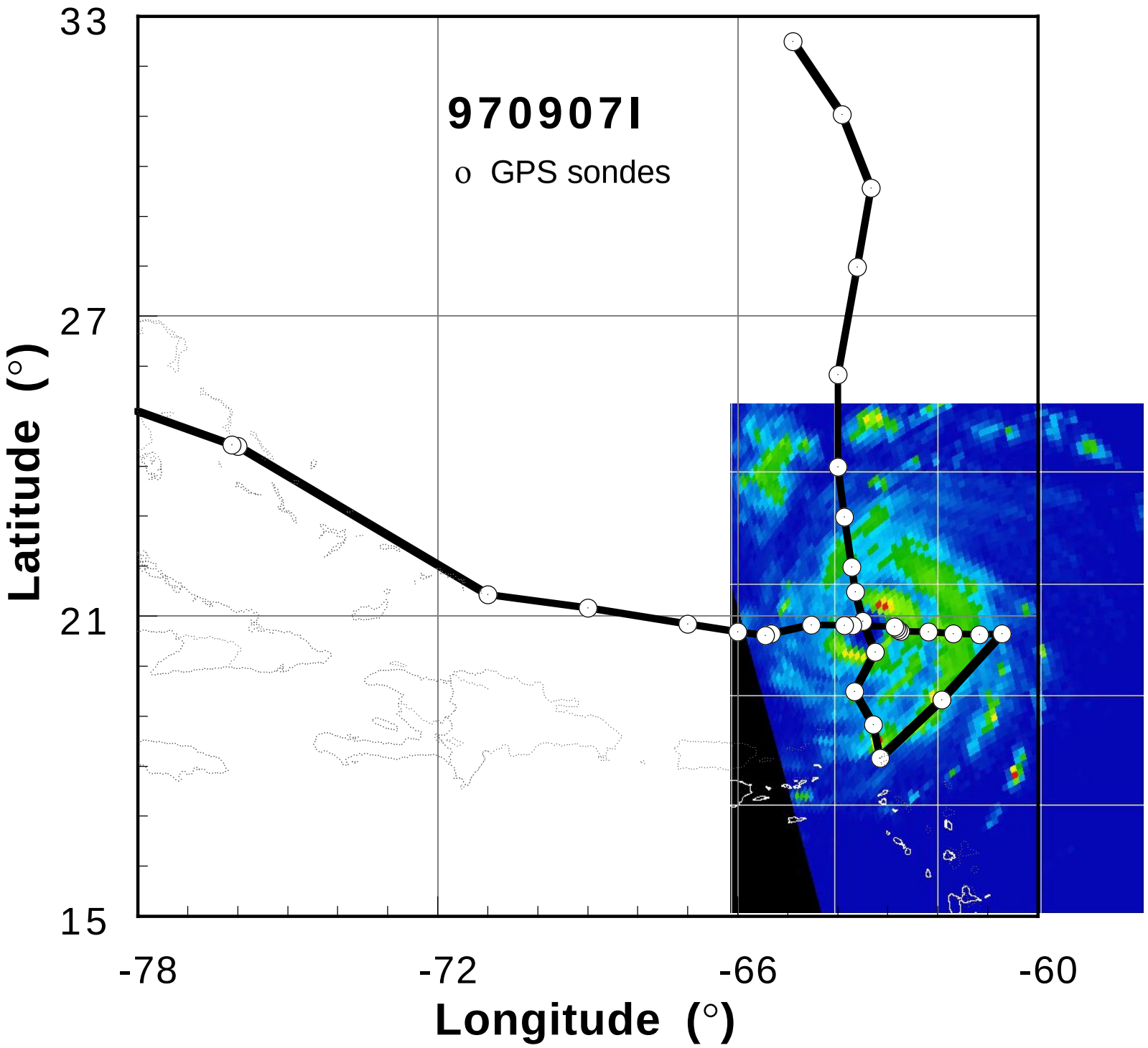
This will be an excellent data set for determining the vertical thermodynamic and dynamic structure of a CAT 2 hurricane. This is the second data set collected this season with GPS dropsondes in the eyewall of a mature hurricane. These data showed similar eyewall boundary layer wind profiles to those found in Hurricane Guillermo, with numerous low-level wind maxima. Data will be used in post-storm evaluations of hurricane vertical structure as well as in real-time for track predictions of Erika. GPS sonde data will also be used for evaluation of SFMR

surface wind estimates and for evaluation of real-time boundary layer models used to estimate surface winds from flight level data.

Problems:

All systems functioned nominally. Three sondes failed to obtain winds, but were replaced with backup sondes.

Peter G. Black


970907I
o GPS sondes
33
27
21
15
Latitude (°)
-78
-72
-66
-60
Longitude (°)

Mission Summary
970908I Aircraft 43RF
Erika Sonde Fest II/ Air-Sea Interaction

Scientific Crew (43RF)

Lead Scientist	P. Black
Radar	F. Marks
Workstation	P. Leighton
GPS sonde scientist	S. Aberson
AXBT scientist	J. Cione

Mission Briefing:

This mission called for concurrent GPS sondes and AXBTs dropped within the inner core of Hurricane Erika, using a rotating Fig 4 pattern for the purpose of discerning the radial/vertical profiles of winds and θ_e, the available heat content of the ocean, and the radial variation of surface wind speed and the air-sea virtual potential temperature difference.

Mission Synopsis

The flight departed Opa Locka (KOPF) at 1507 UTC, 8 September and landed at St. Croix International (TISX) at 0130 UTC, 9 September. A total of 31 GPS sondes and 30 AXBTs were dropped during this mission, 29 of which were coincident. Eight GPS sondes were partial failures (no winds or no PTH- only one total failure) and 9 AXBTs failed (no signal). Of the 29 coincident drops, 12 functioned perfectly. However, with SST extrapolation, 9 additional pairs provided useful data for a total of 21 out of 29 useful dual GPS/AXBT soundings.

Four radial cross sections of winds and thermodynamics were obtained in the atmosphere between 750 mb and the surface as well as four radial cross sections of ocean temperature between the surface and 200 m. The figure 4 legs were oriented N-S, E-W, NE-SW and NW-SE (Fig. 1). Maximum flight-level winds were 125 kt and 150 kt at 850-950 mb. Minimum central pressure was 945 mb and the eye diameter was 28 nmi. Storm motion was 015° at 6 kt. A surface front with strong convection was located 5° north of Erika, and some interaction of mid-level dry air seemed to be occurring.

The eyewall was very well defined with two main areas of convection located N and SE of the center. The northern complex rotated around to the NW during the flight. New cells were forming in the SE eyewall throughout the flight. The eyewall was open in the SW sector. Multiple intense bands existed SE of the center extending outward over 200 nmi. and spiraling into the NE eyewall. A large area of intense banded stratiform precipitation covered the north semicircle, where continuous moderate turbulence was encountered.

Multiple sondes were dropped at the inner edge of the eyewall in the N, S, E, W, NE, SW and SE walls. All revealed pronounced low-level wind maxima at around 200-900 m. Each showed surface winds which ranged from 64-84% of the wind maximum. Several indicated superadiabatic layers within the eyewall boundary layer, as was prominently observed on 7 September. This is the first time that concurrent GPS sondes and AXBTs have been launched, enabling simultaneous atmospheric and oceanic soundings to be obtained.

Initial analysis of the variation of air-sea temperature differences versus wind speed indicate a rapid increase between 20 and 35 m s^{-1} surface wind speed, confirming earlier moored buoy observations. Furthermore, these observations indicated a leveling-off of air-sea temperature differences at a value of -4 C for wind speeds above 35 m s^{-1}.

With warm SSTs of order 28-29 C having been measured and relatively deep mixed layer depths of order 45-60 m, and a minimum pressure of only 945 mb having been measured, the

question arises as to what factors in the atmosphere prevented this storm from reaching its potential intensity? Analysis of this data set should provide an answer to this question.

Excellent tail Doppler and lower fuselage radar data were also obtained, as were SFMR surface wind data. Airborne Doppler data indicated a mean flow from 1-9 km of 020° at 4 m s^{-1}, very close to the measured motion vector for the storm. Doppler data also indicated a NW shear of approximately 13 m s^{-1}, nearly identical to the shear vector measured on 7 September. Mean flow was SE at 6 m s^{-1} at 1 km and NW at 7 m s^{-1} at 9 km.

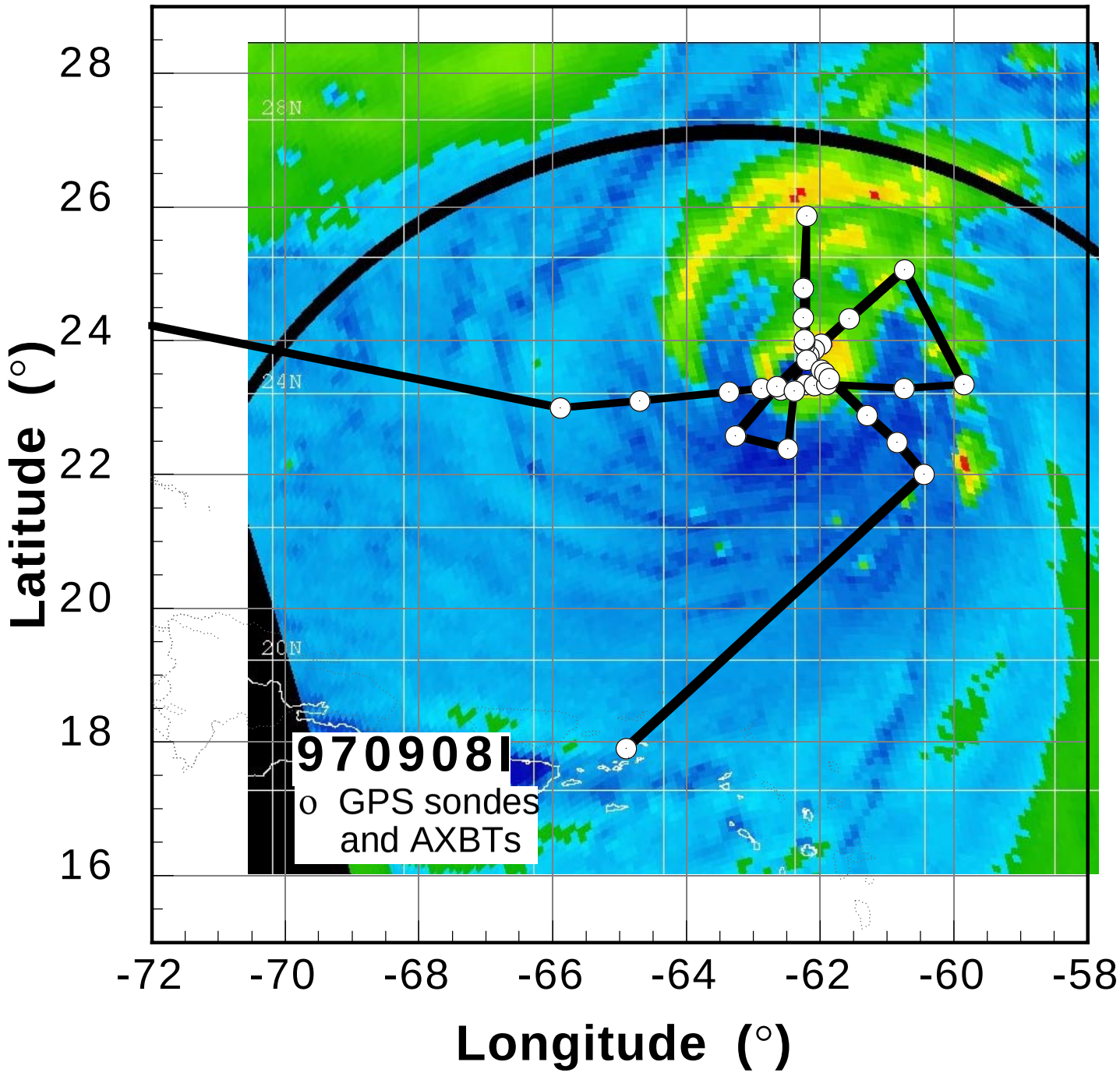
Evaluation:

This appears to be a landmark data set for determining the vertical thermodynamic and dynamic structure of the atmospheric and oceanic boundary layers from the 750 mb level in the atmosphere to the 200 m depth in the ocean in a CAT 3 hurricane. Data will be used in post-storm evaluations of hurricane vertical structure. It was used in real-time for improved intensity estimations of Erika by NHC hurricane forecasters. Sonde and AXBT data will also be used for evaluation of SFMR surface wind estimates and for evaluation of real-time boundary layer models used to estimate surface winds from flight level data. This data set will allow for inclusions of the effects of boundary layer stability on surface wind estimates. Improved estimates of surface fluxes will also be possible.

Problems:

All systems functioned nominally, with the exception of the sonde and AXBT failures noted above.

Peter G. Black


28N
24N
20N
970908I
o GPS sondes
and AXBTs
Latitude (°)
28
26
24
22
20
18
16
-72
-70
-68
-66
-64
-62
-60
-58
Longitude (°)