Mission Summary
Hurricane Humberto
20010923H Aircraft: N42RF

Scientific Crew:

Lead Project Scientist	Frank Marks
Cloud Physics Scientist	Bob Black
Radar/Workstation Scientist	John Gamache
GPS-sonde Scientist	Chris Landsea
CCN scientist	Jim Hudson (DRI)

Aircraft Crew:

Pilots	Tennesen, Taggert
Flight Engineer	Bast, Curry
Navigators	Newman
Flight Director	Damiano
Engineers	McMillan, Delgado, Rogers

MISSION BRIEF:

HRD scheduled a Coordinated Observations of Vortex Evolution and Structure (COVES) mission into Tropical Storm (soon to be Hurricane) Humberto with N42RF, N43RF, and the NASA DC-8 and ER-2 aircraft for 23 September 2001. N42RF and N43RF would take off at 1700 UTC from MacDill AFB and recover in Wilmington, NC. The NASA aircraft would take off at 1730 UTC from Jacksonville. All four aircraft would do a coordinated pattern in the core of Humberto as described in the Hurricane Field Program Plan (HFP) Fig. 3, while N49RF would fly a surveillance pattern around the storm. The DC-8 and ER-2 would fly a butterfly pattern with six 218 nm radial legs from the center at 37000 ft and 65000 ft, respectively. N43RF would do a similar butterfly pattern with 108 nm radius legs at 6000 ft, while N42RF would do a similar butterfly pattern with 135 nm radial legs at 14000-17000 ft, but rotated 90° upwind of N43RF, DC-8 and ER-2 pattern (see Fig. 1). See Fig. 2 for the GPS-sonde and AXBT drop locations. N43RF would do eye fixes and GPS-sonde drops in the center on the first and third passes and N42RF would fix the center and drop a GPS sonde on the second pass through the center. All legs would be coordinated in time with leg lengths adjusted to keep time coordination. N42RF would be in charge of maintaining aircraft coordination, passing estimated center locations to the other aircraft 30 min before reaching the beginning of the next leg across the storm.

MISSION SYNOPSIS:

N42RF departed MacDill AFB at 1709 UTC. We checked communications with N43RF at 1737 UTC as we passed off the east coast of Florida. At 1810 UTC we found out that N49RF had a mechanical problem and would be delayed by 2 h. Over the next hour of transit we realized we would have a problem with AXBT drops as both aircraft had the same mix of channels to drop (Channel 12 and 16). So Barry Damiano contacted Stan Czyzyk to arrange for each aircraft to drop different channels on each leg to avoid interference. At 1845 UTC we established communication with the two NASA aircraft. At 1925 UTC we received the last AFRES fix and adjusted the IP for all of the aircraft to reflect the new position (see Table 1). We also learned that the DC-8 was having a problem getting airspace clearance and was starting their first leg at 28000 ft. We decided to descend from 17000 ft to 14,000 ft when we were within 60 nm of the core to avoid lightning and graupel.

We reached our IP, 135 nm west of the center, at 2000 UTC and dropped a GPS sonde as we headed east to the center. As we proceeded eastward we dropped sondes according to the plan (Fig. 2). As we tracked toward the center the radar suggested the center was open to the south and had a diameter of about 22 nmi (Fig. 3). We also noted some very intense reflectivity exceeding 50 dBZ in the NE eyewall, indicative of graupel (Fig. 4). At 2016 UTC we started our descent to 14000 ft 54 nmi from the center as we entered the first rainband. We reached 14000 ft by the next drop location at 2018 UTC. At 2025 UTC we passed through the west eyewall dropping a GPS sonde where the SFMR-estimated surface wind was 82 kt. We passed the wind center at 2027 UTC making a visual siting of N43RF as they passed below us. The NASA aircraft passed through the center within 2 minutes of the two WP-3D aircraft. The DC-8 got permission to climb to 39000 ft (they couldn't get clearance to fly between 28000-39000 ft) and started their climb on the way out through the north eyewall. We also learned that the ER-2 pilot had received no launch indication for the first two GPS sondes. He was concerned that the mechanism was jammed, so he planned one more attempt before deciding to stop launching altogether (it turned out to be a faulty indicator and the sondes were launched successfully). After passing out of the eyewall region we passed the estimated center location to all the aircraft for the second pass through the center. We climbed back to 17000 ft at 2037 UTC 54 nmi east of the center. We proceeded east dropping GPS sondes and AXBTs following the plan (Fig. 2) and reached our eastmost point (**2**) at 2056 UTC. (**2**) was right over Bermuda so no GPS-sonde was dropped over the island as they launch a 0000 UTC radiosonde. We turned and tracked through a large stratiform region and rainbands toward (**3**) 135 nm NNE of the center, reaching (**3**) at 2121 UTC. At (**3**) we insured all aircraft were at their starting points for the next leg through the storm.

At (**3**) we turned and tracked 210° toward the center dropping GPS sondes and AXBTs as in Fig. 2. We were in heavy precipitation and the pilots chose to descend to 14000 ft at 2134 UTC roughly 120 nmi from the center. We were in a region of a very strong bright band around 2139 UTC just outside a very intense rainband with scalloped cores (as in Bonnie) about 100 nm from the center. At 2142 UTC we crossed the rainband cores. Fortunately, after we got through this band the radar froze for about 5 min, coming back just before we penetrated the NNE eyewall at 2156 UTC. Going through the eyewall there were cores of >50 dBZ reflectivity, lightning, and graupel. We fixed the center at 2157 UTC dropping a sonde in the center, which had no winds, but a surface pressure of 983 hPa. We saw N43RF pass underneath us once again and our sonde splashed within 1 nmi of their fix location. The NASA aircraft hit the center at different times but within 2-3 min of the WP-3D aircraft. We proceeded out of the open side of the eyewall under a large anvil with mamatus and virga hanging down to our altitude. The ride through the SSW eyewall was choppy and we noted increased white caps on the ocean below us. After passing out of the eyewall region we passed the estimated center location to all the aircraft for the third and last pass through the center. We proceeded SSW dropping sondes and AXBTs as in Fig. 2, climbing back to 17000 ft roughly 80 nm from the center. We proceeded in the clear to (**4**) 135 nmi SSW of the center arriving there at 2226 UTC. Jim Hudson reported that the air near

(**4**) was the dirtiest he encountered on the flight. We turned east to (**5**) arriving at 2258 UTC and turned inbound for our last pass through the center.

Our leg from the SSE to the center passed through mostly clear air. At 2318 UTC, roughly 60 nmi from the center, we descended to 14000 ft as the anvil descended to our altitude and we proceeded into the center through the mamatus and virga once again. The SFMR estimated the surface wind SSE of the center was 87 kt despite the lack of an eyewall on that side. As we crossed into the eye Jim Hudson reported a sharp decrease in the CN concentration (20 l^{-1}). It was dark on this pass, but we did see N43RF's lights pass below us in the center. We proceeded through the strongest reflectivity in the NNW eyewall at 2329 UTC, noting lightning in the NE eyewall. Just through the eyewall we hit an intense graupel shower at 2332 UTC (removed some paint off of the leading edges and props), which presented a phenomenal visual display of static discharge on the cockpit windscreen (like blue fireflys). We climbed back up to 17000 ft at 2339 UTC roughly 70 nmi from the center as we exited the rainbands NNW of the center. We proceeded to (**6**) 135 nmi NNW of the center dropping GPS sondes and AXBTs according to Fig. 2 reaching the end of the pattern at 2357 UTC. At this point the pilots took over the flight and routed us back to Wilmington, NC. Along the way we dropped the last AXBT at 2359 UTC about 140 nmi from the center. We landed in Wilmington at 0132 UTC 24 September.

Penetrations: 3
Expendables: 48 GPS-sondes/5 bad (2 no launch detect and 3 no winds)
18 AXBTs/3 bad
4 video tapes, 1 flight level DAT, 1 radar DAT and 1 Cloud Physics DAT

SUMMARY

Overall a very good mission! One down and one more to go! Great coordination with N43RF, DC-8, and ER-2 by the N42RF crew (primarily Carl Newman and Barry Damiano). We completed the pattern as briefed with a few wrinkles to maintain coordination with the other aircraft and flight safety. We didn't drop a sonde at the farthest east point because it was over Bermuda and would be covered by their 0000 UTC radiosonde. We descended to 14000 ft altitude within 50-80 nm of the center to insure we stayed out of static discharges and heavy graupel (much to the consternation of Bob Black). However, that didn't seem to guarantee success as we ran into a heavy graupel shower on our last pass through the north eyewall, which had intense (>50 dBZ) reflectivity most of the time we were in the storm.

The storm was apparently sheared from the SW to the NE and had a very evident tilt to the eyewall convection. It resembled Hurricane Olivia on 25 September 1994 in appearance, with the strongest reflectivity on the north side of the storm and a large region of stratiform precipitation extending 150-200 nmi NE of the center. There also appeared to be a clear wave #2 asymmetry in the eyewall shape. There was a strong rainband 70-100 nmi NE of the center that contained scalloped cores similar to those we sampled in Hurricane Bonnie near landfall. They may contain mesocyclone signatures embedded in the strong winds. We had some of our worst bumps passing through that band and we experience the most intense bright-band just radially outward from the band. The HVPS seemed to work the best it had all year thanks to Bob Black's and Sean McMillen's constant attention. Unfortunately, it didn't work when we penetrated the intense graupel shower on the last leg through the NNW eyewall.

The GPS-sonde coverage from the combined aircraft was phenomenal. Figures 6 and 7 show the sonde distribution around the storm from the three NOAA aircraft and the two WP-3D aircraft, respectively. Adding in the sondes from the ER-2 (3) and DC-8 (24) it represents the most complete three-dimensional mapping of any storm in history (over 110 GPS sondes alone). It will provide data for model simulations, both operational and new higher resolution research models. Unfortunately, most of the operational models can't utilize such a high density of GPS-sonde coverage. However, the data set should set the standard for all future tropical cyclone model development.

In contrast to Erin, the CN measurements indicated that the eye was relatively clean with concentrations ~20 l^{-1}. Jim Hudson reported the dirtiest air was 100-200 nmi south of the circulation center. Jim also pointed out that he was seeing pretty dramatic radial gradient on the CN and CCN concentrations alternating between relatively dirty and clean air. These data are going to be fascinating to analyze in the context of the other observations.

PROBLEMS:

1) No King liquid water probe, broken wire.

2) Had to juggle AXBT launches with N43RF as we both had a similar mix of channel 12 and 16 sondes. The coordination went really well thanks to the two flight directors (Damiano and Czyzyk).

3) ER-2 had drop indicator problems and decided not to drop any GPS sondes after the first three (turned out the drops worked fine, it was just a faulty indicator light). DC-8 tried to pick up missing ER-2 drops.

4) DC-8 had a major clearance problem. They couldn't fly between 28000 and 39000 ft because of ATC. So on the first leg they started at 28000 ft and passing through north eyewall they climbed to 39,000 ft and stayed there for the rest of the flight.

Frank Marks
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7 October 2001

TABLES:

Table 1. Storm center locations

Time (UTC)	Latitude	Longitude	Central Press. (hPa)	Maximum wind (kt)
1800	31.92	-67.35		
1916	32.16	-67.34	983	
2027	32.34	-67.26	983	
2158	32.51	-67.10	982	
2320	32.80	-67.05	981	85

Table 2. GPS-sondes dropped during mission and their splash locations.

#	Sonde ID	TIME (UTC)	Lat.	Lon.	150-m wind	DLM wind	MBL wind	Comments
1	003438003	1959	32.28	-69.84	36017	36021	01017	**IP**
2	003438032	2004	32.29	-69.44	01519	00525	01519	
3	003438053	2010	32.30	-68.92	36024	00529	36025	
4	003338085	2012	32.29	-68.66	36029	00534	00529	
5	003148152	2015	32.26	-68.37	36036	36037	01038	SST 272
6	003115065	2018	32.22	-68.12	35036	36040	35542	RAINBAND
7	003338035	2021	32.20	-67.84	-999	36049	-999	RAINBAND
8		2025	32.20	-67.51	-999	-999	-999	No wind EYEWALL 270
9		2031	32.30	-67.00	-999	-999	-999	No wind EYEWALL 090
10	011378107	2034	32.39	-66.72	15062	17570	16070	AXBT bad
11	011378103	2037	32.38	-66.45	16049	17556	16053	
12	010715169	2040	32.38	-66.20	15545	17551	15548	SST 272
13	011245188	2043	32.38	-65.91	15538	17547	16043	
14	011245375	2046	32.38	-65.64	16035	17543	16042	SST 270
15	003338032	2052	32.38	-65.12	13531	17039	14036	No AXBT, near Bermuda (**2**)
16	011378104	2126	34.58	-65.86	09017	14017	10518	SST 262 (**3**)
17	003475095	2133	34.13	-66.20	08024	11526	09025	RAINBAND SST 261
18	011345110	2139	33.73	-66.48	07530	10537	08034	RAINBAND AXBT bad
19	011315007	2143	33.55	-66.61	07037	11543	08041	RAINBAND
20	011245373	2146	33.34	-66.76	06535	10544	07039	RAINBAND AXBT bad
21		2149	33.13	-66.83	-999	-999	-999	No launch detect
22	011245409	2152	32.96	-67.08	06558	10059	07560	RAINBAND
23	003515038	2156	32.68	-67.23	01581	07059	02589	EYEWALL 030
24	011245423	2157	32.60	-67.10	-999	-999	-999	EYE No winds
25	011315008	2202	32.29	-67.21	29569	30573	30579	EYEWALL 210
26	011345108	2205	32.09	-67.33	29535	29545	30542	
27	011378110	2209	31.89	-67.46	-999	-999	-999	No wind
28	011245022	2211	31.69	-67.58	27526	29530	28029	SST 262
29	011335044	2214	31.48	-67.71	28026	29527	28527	
30	011315006	2218	31.30	-67.90	-999	-999	-999	No wind
31	003115281	2223	30.89	-68.09	30016	30519	30017	
32	011378105	2226	30.63	-68.23	30014	31016	30015	(**4**)
33	003135322	2256	30.97	-65.57	20522	21028	21024	(**5**)
34	004255073	2302	31.37	-65.82	20527	21031	21028	SST 275
35	003115195	2308	31.80	-66.06	20532	21037	20534	LST WND 017
36		2312	31.90	-66.23	-999	-999	-999	No launch detect
37	004255044	2315	32.16	-66.34	20041	21043	20042	SST 279
38	011315004	2318	32.36	-66.46	19048	20549	19551	LST WND 013
39	003825183	2321	32.57	-66.61	17560	20064	18063	LST WND 012 SST 272
40	003115199	2324	32.80	-66.76	14590	19085	16094	LST WND 012 EYEWALL 150
41	003135157	2330	32.98	-67.20	02085	04581	02588	EYEWALL 330
42	011245235	2333	33.18	-67.34	03057	06055	03560	RAINBAND
43	011378109	2336	33.38	-67.53	03547	06044	04052	RAINBAND
44	004255062	2338	33.53	-67.68	05043	05538	05046	LST WND 011 RAINBAND SST 259
45	003115230	2342	33.70	-67.87	05036	06033	05538	RAINBAND
46	003115197	2345	33.87	-68.05	05031	06026	05532	SST 259
47	011345095	2351	34.22	-68.43	-999	-999	-999	No wind AXBT bad
48	011245346	2356	34.52	-68.77	05513	05015	06515	LST WND 011 SST 263 **FP**

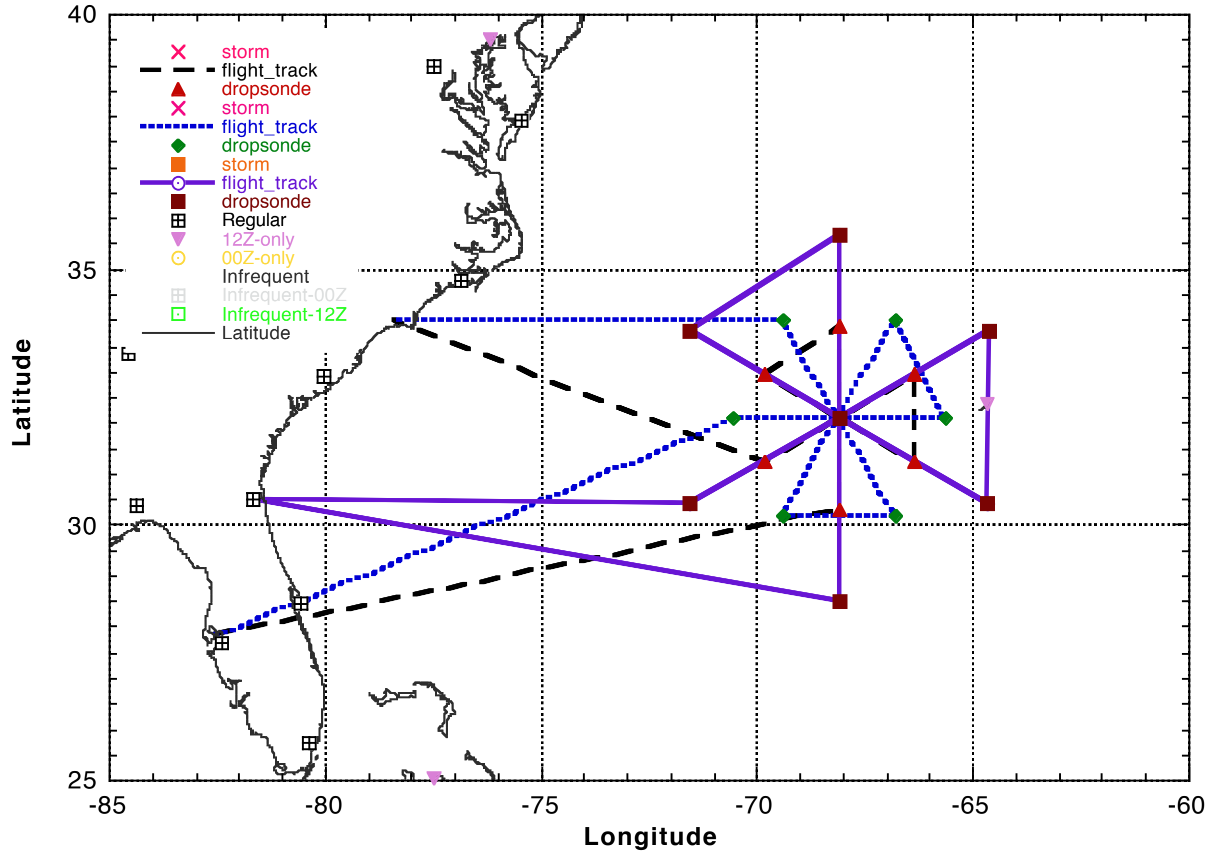

Fig. 1. Planned flight tracks for N42RF (blue), N43RF (black), and NASA DC-8/ER-2 (purple).

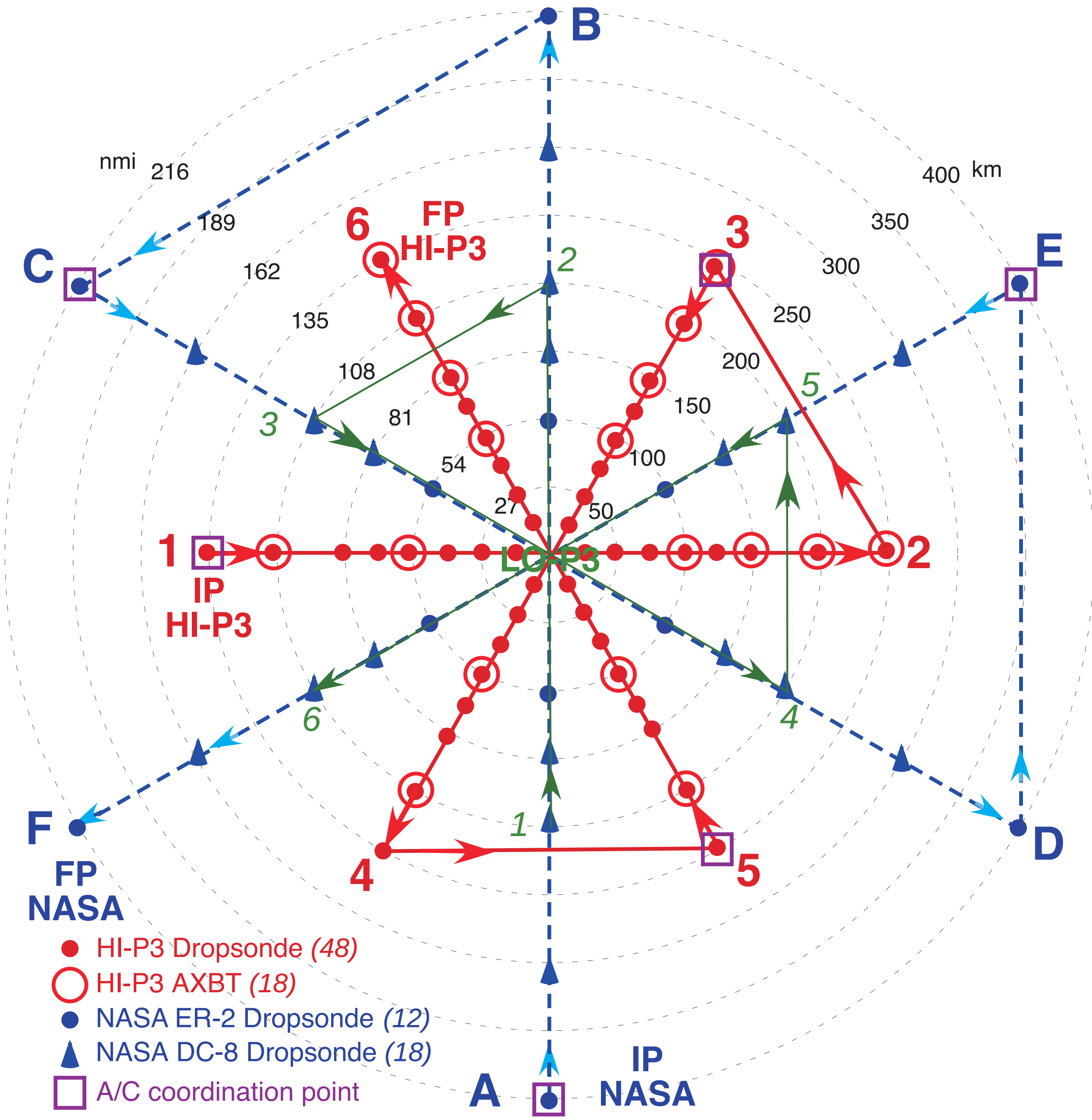

Fig. 2. N42RF (HI-P3) GPS-sonde and AXBT drop locations in storm relative coordinates.

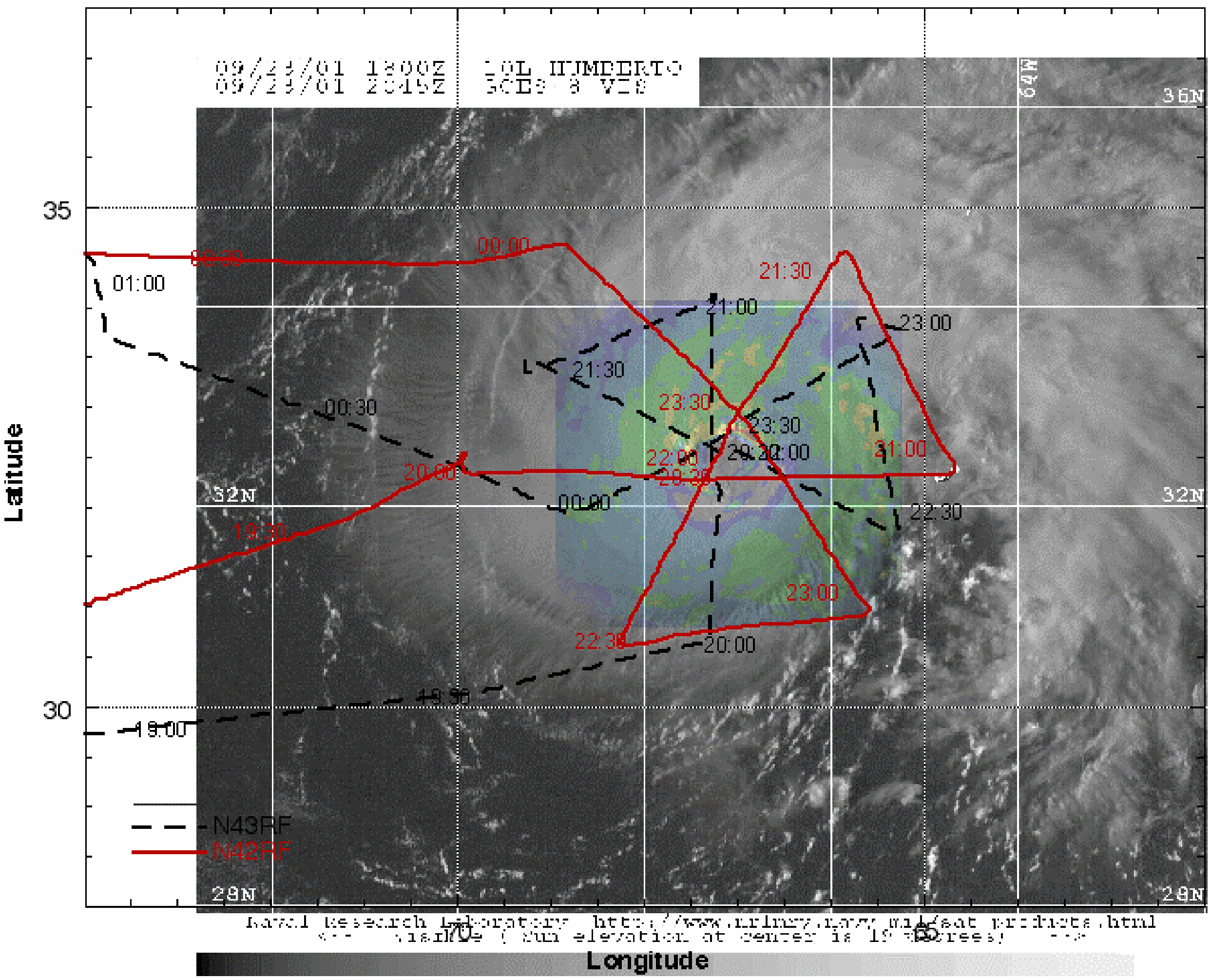

Fig. 3 N42RF and N43RF flight tracks on 23 September 2001 superposed on visible satellite image at 2045 UTC and LF radar composite from 2029-2042 UTC.

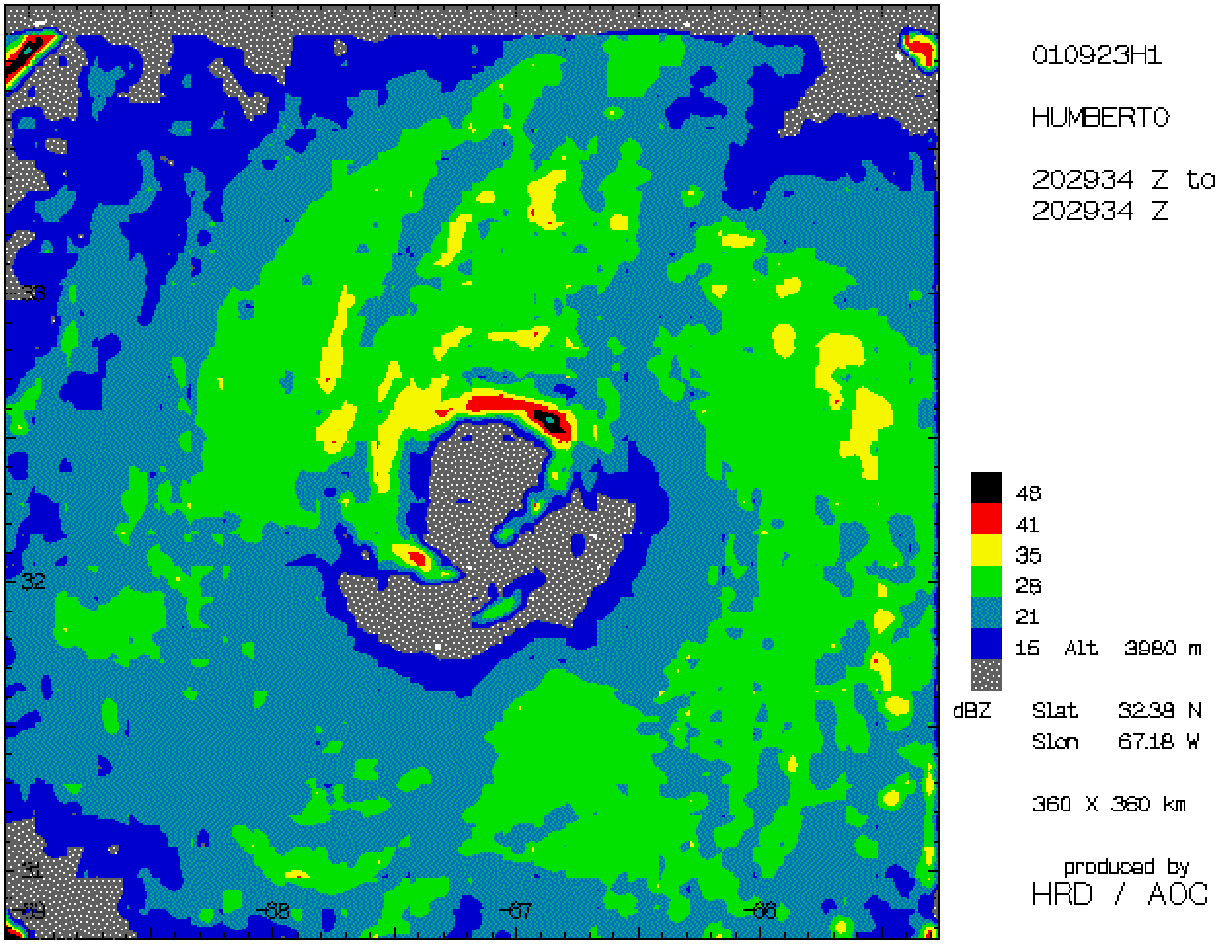

Fig. 4. LF radar sweep at 2021 UTC.

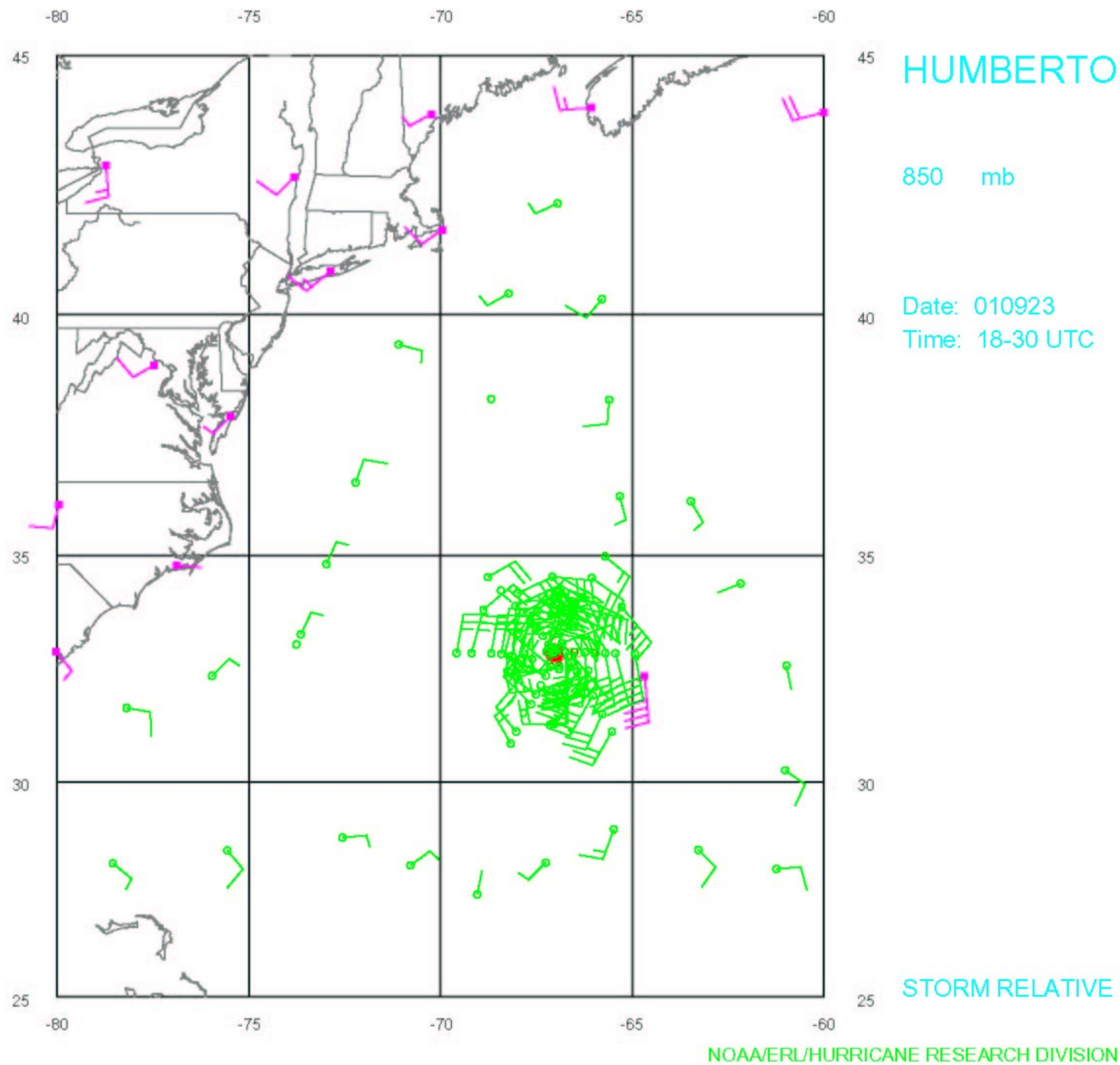

Fig. 5. GPS sonde distribution from N42RF, N43RF, and N49RF (light green) and radiosonde stations (purple) at 850 hPa. Wind direction and speed are denoted by the barbs, where the barb points in the direction the wind is coming from, and a half barb represent 5 m s^{-1}, a whole barb 10 m s^{-1}, and a pennant 25 m s^{-1}.

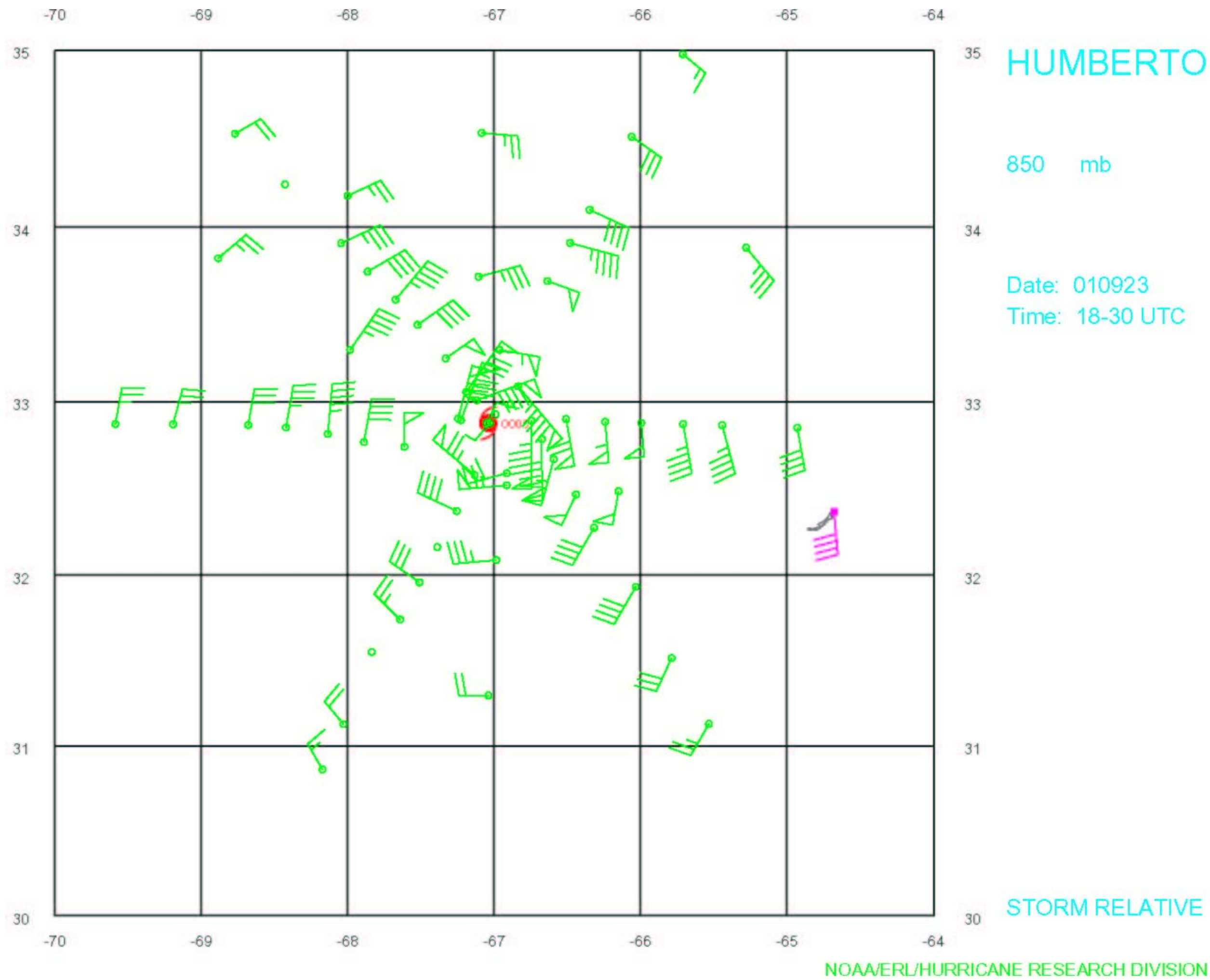

Fig. 6. GPS sonde distribution within 350 km radius from N42RF and N43RF (light green) and radiosonde stations (purple) at 850 hPa, Wind direction and speed are denoted by the barbs, where the barb points in the direction the wind is coming from, and a half barb represent 5 m s^{-1}, a whole barb 10 m s^{-1}, and a pennant 25 m s^{-1}.