Mission Summary
Hurricane Humberto
20010924H 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 Hurricane Humberto with N42RF, N43RF, and the NASA DC-8 and ER-2 aircraft for 24 September 2001. N42RF and N43RF would take off at 1830 UTC from Wilmington, NC and recover back in Wilmington, NC. The NASA aircraft would take off at 1800 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 Wilmington, NC at 1838 UTC. We checked communications with N43RF at 1953 UTC as we passed off the east coast of North Carolina. As the day before, Barry Damiano and Stan Czyzyk arranged for each aircraft to drop different AXBT channels on each leg to avoid interference. At 2000 UTC we established communication with the two NASA aircraft. At 2020 UTC we adjusted the IP for all of the aircraft because the LF radar indicated that the center was further east and south than expected. Because of the adjustment to the IP we arrived 10-15 min earlier than the other aircraft and loitered near our IP waiting for them to get

into position. Because of the encounter with the graupel shower the day before, and the fact that the storm was further north, we decided to descend from 17000 ft to 13500 ft when we were within 60 nm of the core to avoid graupel.

We started our pattern at the IP, 135 nm west of the center, at 2053 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 LF radar suggested the storm had weakened and the center was open to the south with a diameter of about 25 nmi (Fig. 3). The northeast eyewall still had the most intense reflectivity exceeding 45 dBZ (Fig. 4). At 2107 UTC we started our descent to 13000 ft 54 nmi from the center as we entered the first rainband. We reached 13500 ft by the next drop location at 2110 UTC. On the inbound leg the folks on N43RF (and N49RF) got excited by the LF radar structure, suggesting a double eyewall. It turned out to just be a rainband forming on the NE side of the center that rotated into the north eyewall. At 2116 UTC we passed through the open west side noting a sharp increase in CN concentration as we crossed the radius of maximum wind. We passed the wind center at 2119 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. After passing out of the eyewall region we passed the estimated center location to all the aircraft for the second pass through the center at 2128 UTC. We climbed back to 17000 ft at 2137 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 2150 UTC. We turned and tracked through a large stratiform region and rainbands toward (**3**) 135 nm NNE of the center, reaching (**3**) at 2220 UTC. Along this leg we learned that the ER-2 had to abandon the pattern to return to Jacksonville because the forecast called for strengthening crosswinds. The DC-8 agreed to pick up as many of the ER-2's remaining drops as possible. 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 13500 ft at 2231 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 2234 UTC we crossed the rainband cores. We penetrated the NNE eyewall at 2245 UTC where there were cores of >45 dBZ reflectivity, but no lightning or graupel as the night before. We fixed the center at 2250 UTC dropping a GPS sonde in the center, but a surface pressure of 992 hPa. We saw N43RF pass underneath us once again and our sonde splashed within 1 nmi of their fix location. The DC-8 hit the center 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. We climbed back to 17000 ft within 25 nmi of the center. The ride through the SSW eyewall was choppy and we noted 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 We proceeded in the clear to (**4**) 135 nmi SSW of the center arriving there at 2320 UTC. We turned east to (**5**) arriving at 2352 UTC and we insured all the aircraft were in position before turning inbound for our last coordinated pass through the center.

Our leg from the SSE to the center passed through mostly clear air. At 0018 UTC, roughly 60 nmi from the center, we descended to 13500 ft as the anvil descended to our altitude and we proceeded into the center through the mamatus and virga once again. It was dark on this pass, but we did see N43RF's lights pass below us in the center and reported the DC-8 directly over our position in the center. We proceeded through the strongest reflectivity in the NNW eyewall at

0033 UTC. We climbed back up to 18000 ft at 0043 UTC roughly 60 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 0100 UTC, 25 September. 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 0325 UTC 25 September.

Penetrations: 3
Expendables: 49 GPS-sondes/5 bad (1 no launch detect and 2 no winds)
17 AXBTs/0 bad
4 video tapes, 1 flight level DAT, 1 radar DAT and 1 Cloud Physics DAT

SUMMARY

WOW!!! Overall a phenomenal mission! Magnificent 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 descended to 13500 ft altitude within 50-80 nm of the center to insure we stayed out of heavy graupel (much to the consternation of Bob Black). The only deviation from the plan was the ER-2 departing after only one coordinated leg because of terminal weather problems. The DC-8 picked up the majority of the ER-2 drops locations, emphasizing the end points over those at 54 nmi radius.

The storm was more strongly sheared from the SW to the NE than the day before, 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..

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 (5) and DC-8 (28) 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.

As on the day before, 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 as we crossed the radius of maximum wind on the west side of the center. This penetration was totally devoid of cloud and precipitation, suggesting that the aerosol discontinuity was associated with the wind discontinuity. I think this is the first time we have a

data set to indicate the sharpness of the air-mass boundary at the radius of maximum wind. 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 to depart the storm after only one leg across the center (south-north) because of high crosswinds forecast for Jacksonville later in the evening. The DC-8 tried to pick up as many of the missed ER-2 drops as possible focusing on the end points rather than those at 54 nmi radius.

Frank Marks
Frank.Marks@noaa.gov
8 October 2001

TABLES:

Table 1. Storm center locations from N43RF fixes at 6000 ft altitude.

Time (UTC)	Latitude	Longitude	Central Press. (hPa)	Maximum wind (kt)
2120	36.34	-64.70	992	74
2255	36.56	-64.48	992	70
2320	36.80	-64.29	992	

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	003135327	2052	35.93	-67.33	32516	33517	33516	LST WND 021
2	003338074	2056	36.00	-67.00	-999	-999	-999	No wind
3	991515002	2102	36.00	-66.39	35028	34027	34528	
4	003338051	2104	36.01	-66.12	34026	34530	34528	
5	003515067	2107	36.02	-65.81	35532	34537	36035	LST WND 015 SST 261
6	003248074	2110	36.04	-65.55	35032	34540	35536	
7	003338052	2113	36.06	-65.25	33541	33547	34547	
8	003825238	2116	36.10	-65.00	-999	-999	-999	EYEWALL 270 No wind
9	010748072	2121	36.23	-64.47	19548	21039	20050	EYEWALL 090
10	003115092	2124	36.31	-64.21	15070	18069	15575	LST WND 011 SST 262 EYEWALL 090
11	003338140	2127	36.34	-63.94	15049	17064	15556	RAINBAND
12	011245367	2131	36.35	-63.66	15549	17057	15552	RAINBAND Missed AXBT
13	003248003	2134	36.37	-63.38	-999	17551	15039	LST WND 174 RAINBAND
14	002428043	2137	36.39	-63.11	15044	17551	15550	SST 265
15	003115400	2144	36.40	-62.54	15532	17540	15537	SST 269
16	003135118	2150	36.39	-61.95	14529	18034	15031	LST WND 012 SST 269
17	002428046	2219	38.43	-63.31	12528	14027	13030	SST 270
18	003515041	2224	38.14	-63.61	11023	12529	11526	SST 274
19	003135122	2231	37.74	-63.95	10028	11537	10033	SST 271 RAINBAND
20	002428040	2234	37.56	-64.11	09536	11045	09541	RAINBAND
21	003115023	2237	37.38	-64.25	09551	12047	10052	SST 275
22	003115196	2241	37.18	-64.39	09533	11039	09536	
23	003135147	2244	36.91	-64.55	06548	09050	07552	SST 272 RAINBAND
24	003135120	2247	36.70	-64.54	06054	08534	07054	LST WND 013 EYEWALL 030
25	003115406	2249	36.54	-64.51	05511	01507	04512	EYE
26		2254	36.28	-64.58	-999	-999	-999	No launch detect
27	003115125	2257	36.05	-64.66	29042	29546	29044	
28	003115403	2300	35.83	-64.81	26539	29543	27540	
29	003115401	2303	35.65	-64.96	26540	29041	27041	SST 261
30	003135296	2307	35.46	-65.12	27539	29037	27540	
31	002428041	2310	35.27	-65.28	27531	28532	28032	
32	003248049	2316	34.90	-65.58	26527	28528	27030	SST 260
33	003115408	2320	34.67	-65.77	27525	28024	27526	LST WND 012
34	003135303	2351	34.71	-62.80	21025	22031	21527	
35	003135152	0006	35.34	-63.16	20537	22542	21038	SST 271
36	010715174	0012	35.74	-63.39	21048	22545	21047	LST WND 020
37	003148160	0015	35.93	-63.52	20548	22548	21048	LST WND 016 RAINBAND
38	003115124	0018	36.14	-63.65	20557	23051	20556	LST WND 012 SST 265
39	990435485	0021	36.32	-63.77	20551	23056	20559	
40	010715165	0024	36.56	-63.95	19554	22054	20062	SST 264
41	003248063	0027	36.73	-64.07	-999	21026	–999	
42	003115127	0032	37.07	-64.38	-999	07565	06573	LST WND 211 EYEWALL 330
43	003115020	0036	37.29	-64.48	06047	08048	06553	
44	990415188	0039	37.50	-64.62	07047	08544	08052	LST WND 011 RAINBAND
45	003115128	0042	37.69	-64.78	07035	09043	08040	SST 260 RAINBAND
46	003148005	0045	37.89	-64.92	06525	08536	07029	
47	990435486	0048	38.08	-65.06	04521	08528	06022	LST WND 018 SST 260
48	003115019	0054	38.47	-65.34	06522	09021	07524	
49	003148002	0059	38.86	-65.62	07016	09018	08018	

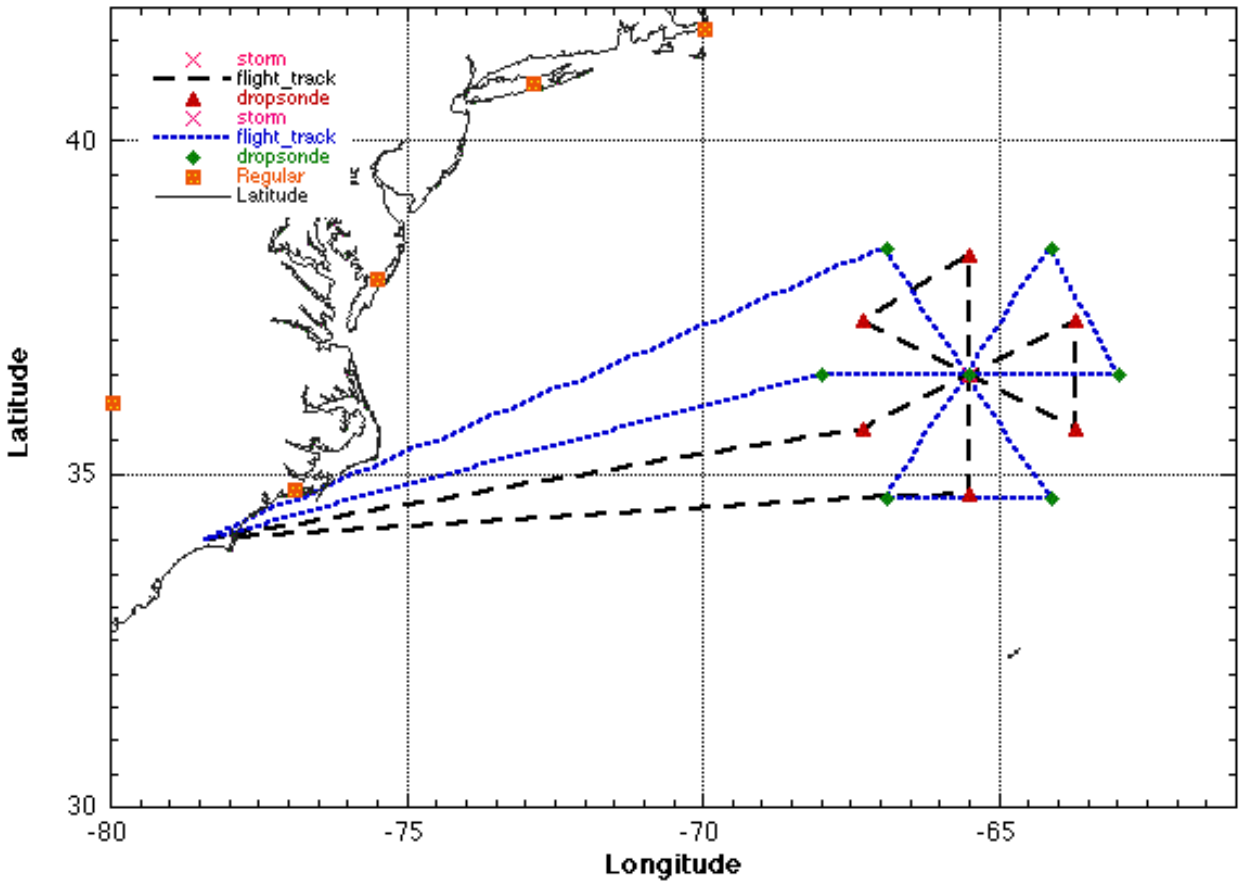

Fig. 1. Planned flight tracks for N42RF (blue) and N43RF (black).

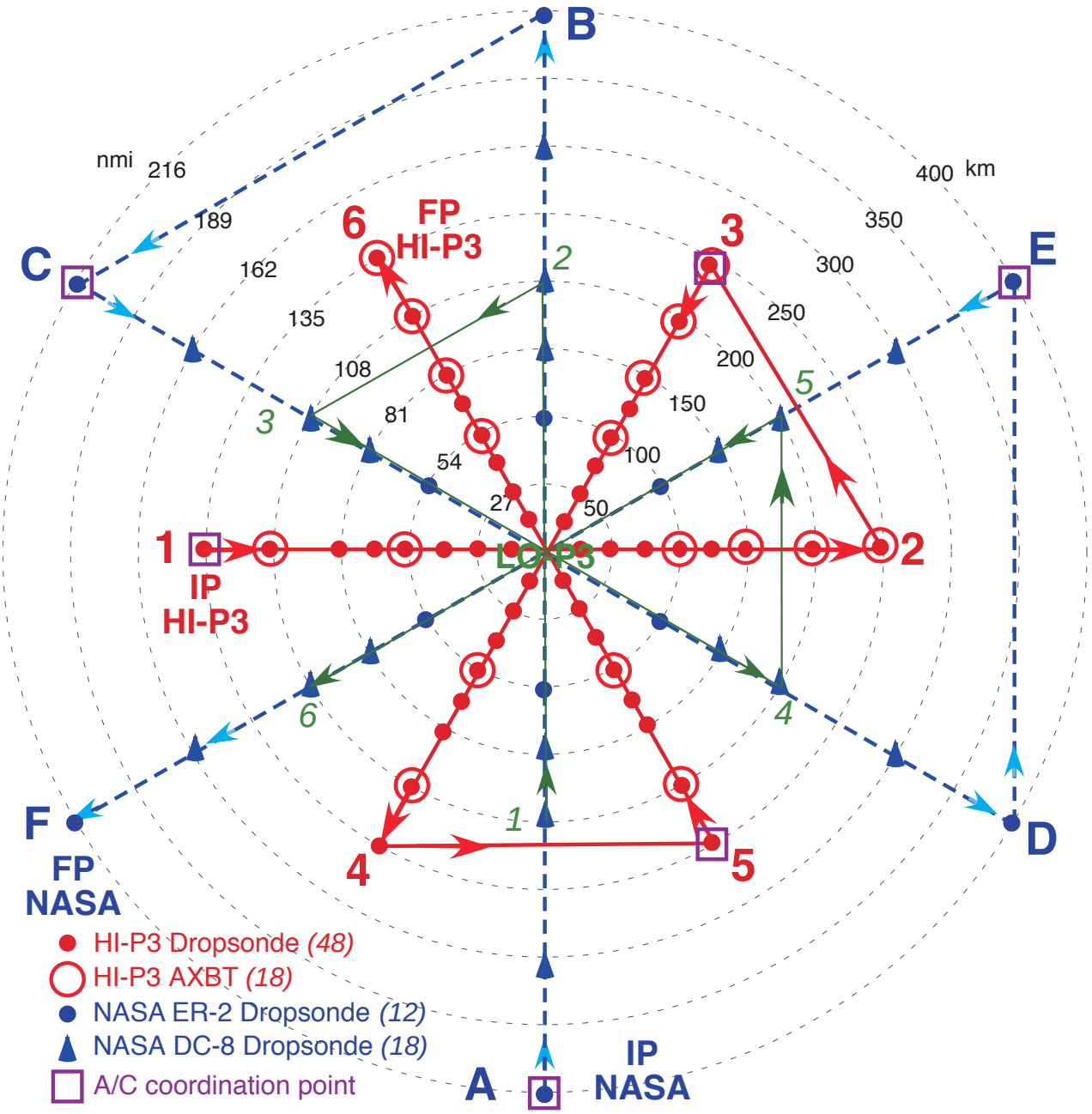

Fig. 2. N42RF (HI-P3) GPS-sonde and AXBT drop locations in storm relative coordinates.

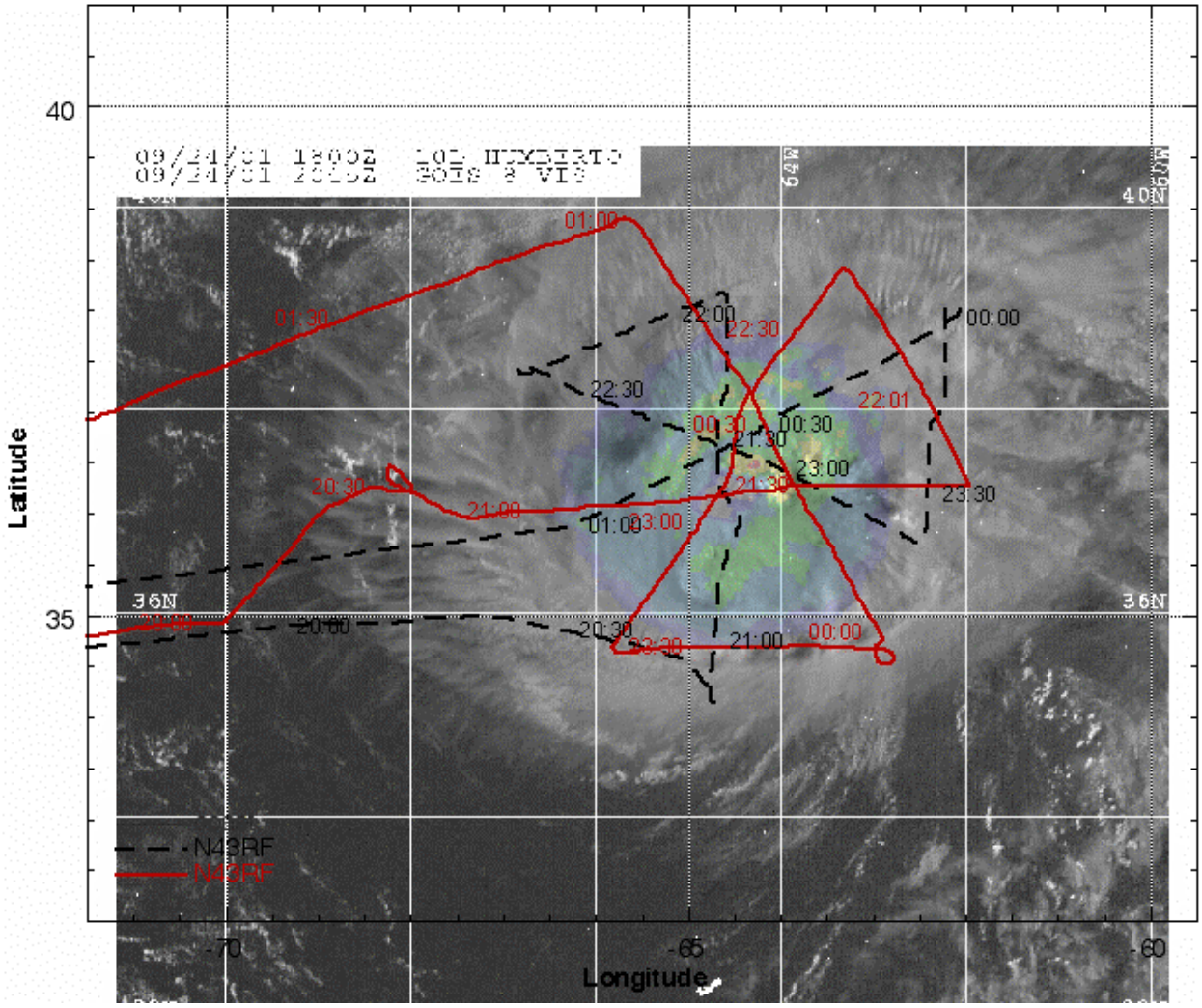

Fig. 3 N42RF and N43RF flight tracks on 24 September 2001 superposed on visible satellite image at 2100 UTC and N43RF LF radar composite from 2119-2122 UTC.

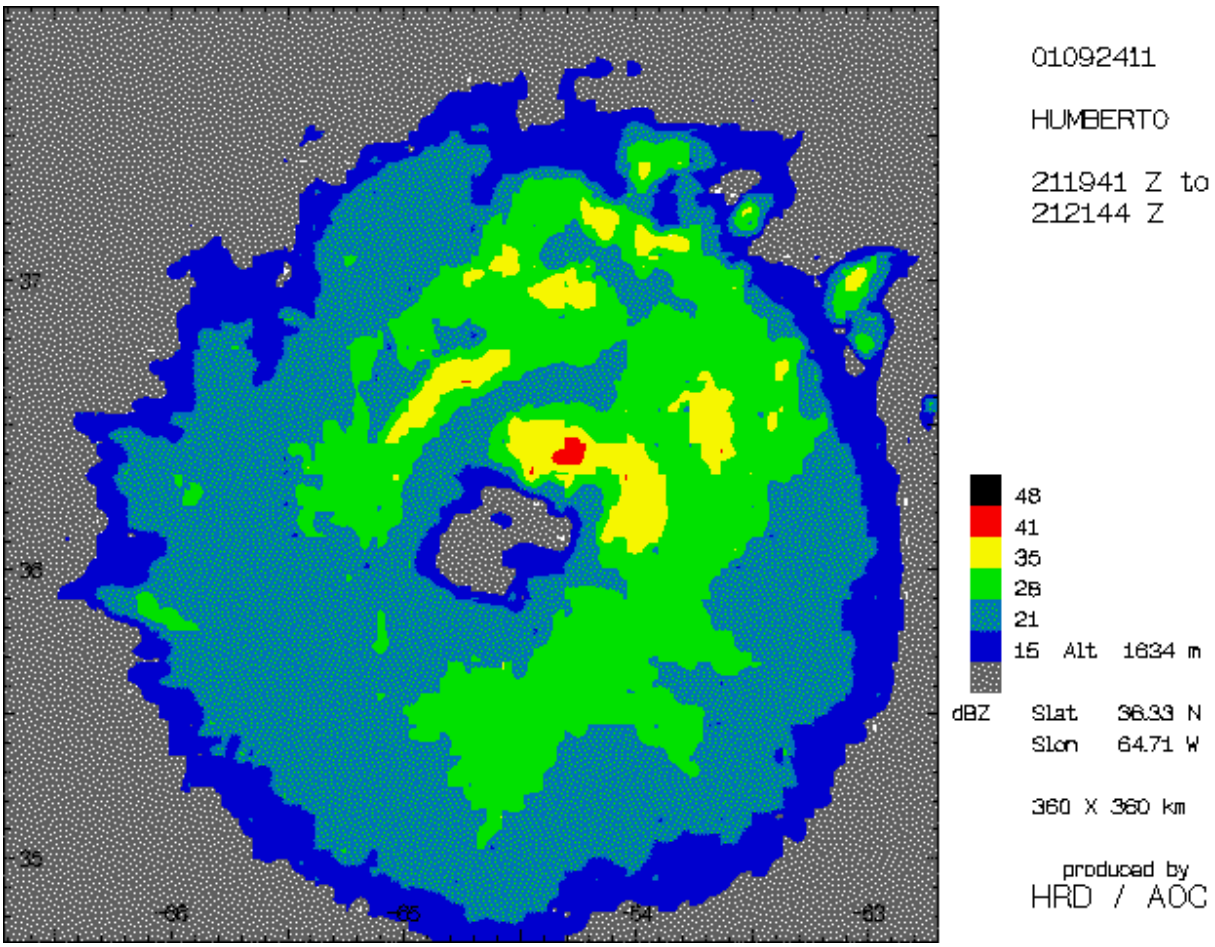

Fig. 4. N43RF LF radar composite from 2119-2122 UTC.

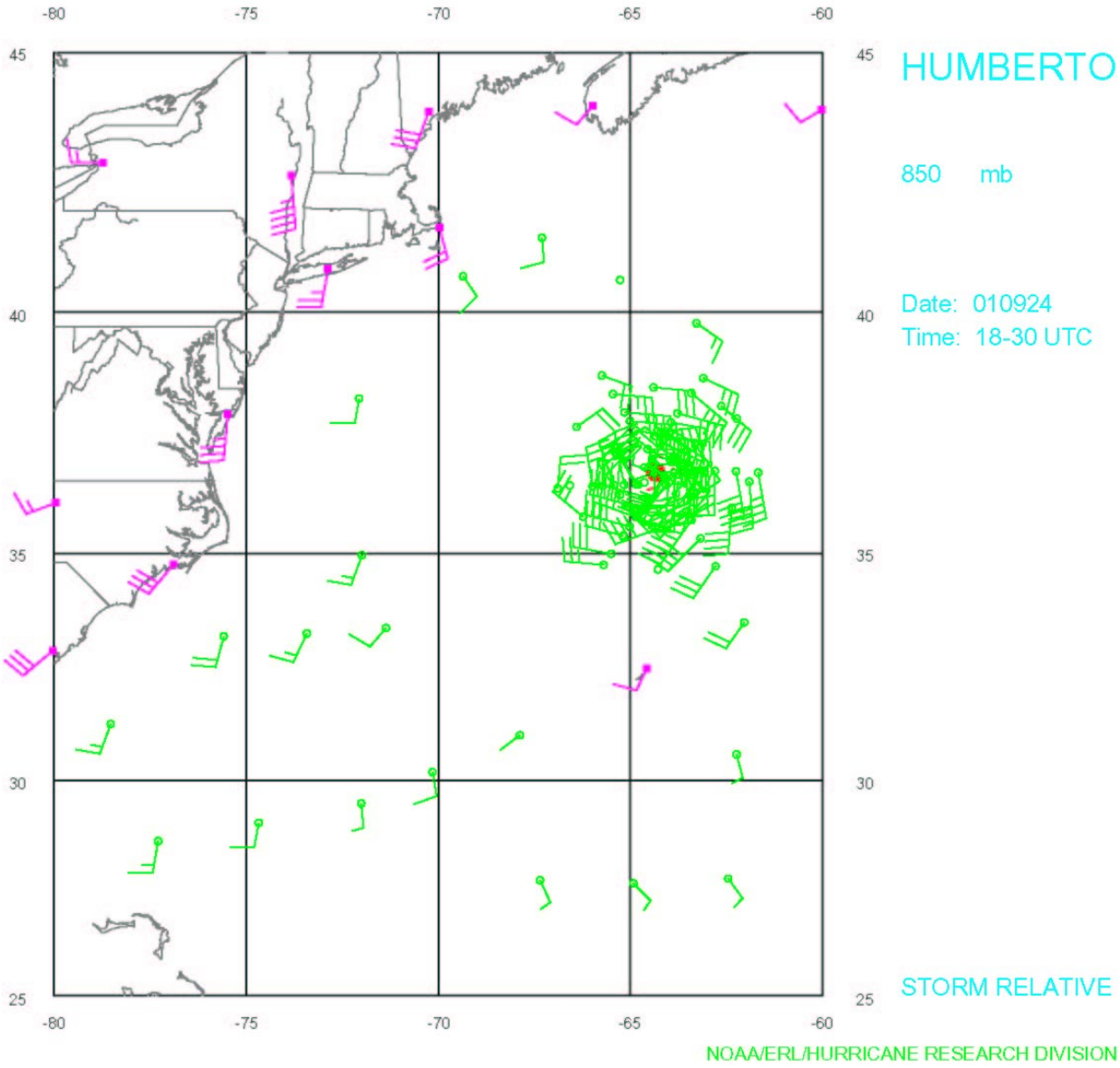

Fig. 5. GPS sonde distribution from N42RF, N43RF, and N49RF (light green) and radiosonde stations (purple) at 850 hPa. Wind direction and speed are denoted by the barbs, where the barb points in the direction the wind is coming from, and a half barb represent 5 m s^{-1}, a whole barb 10 m s^{-1}, and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

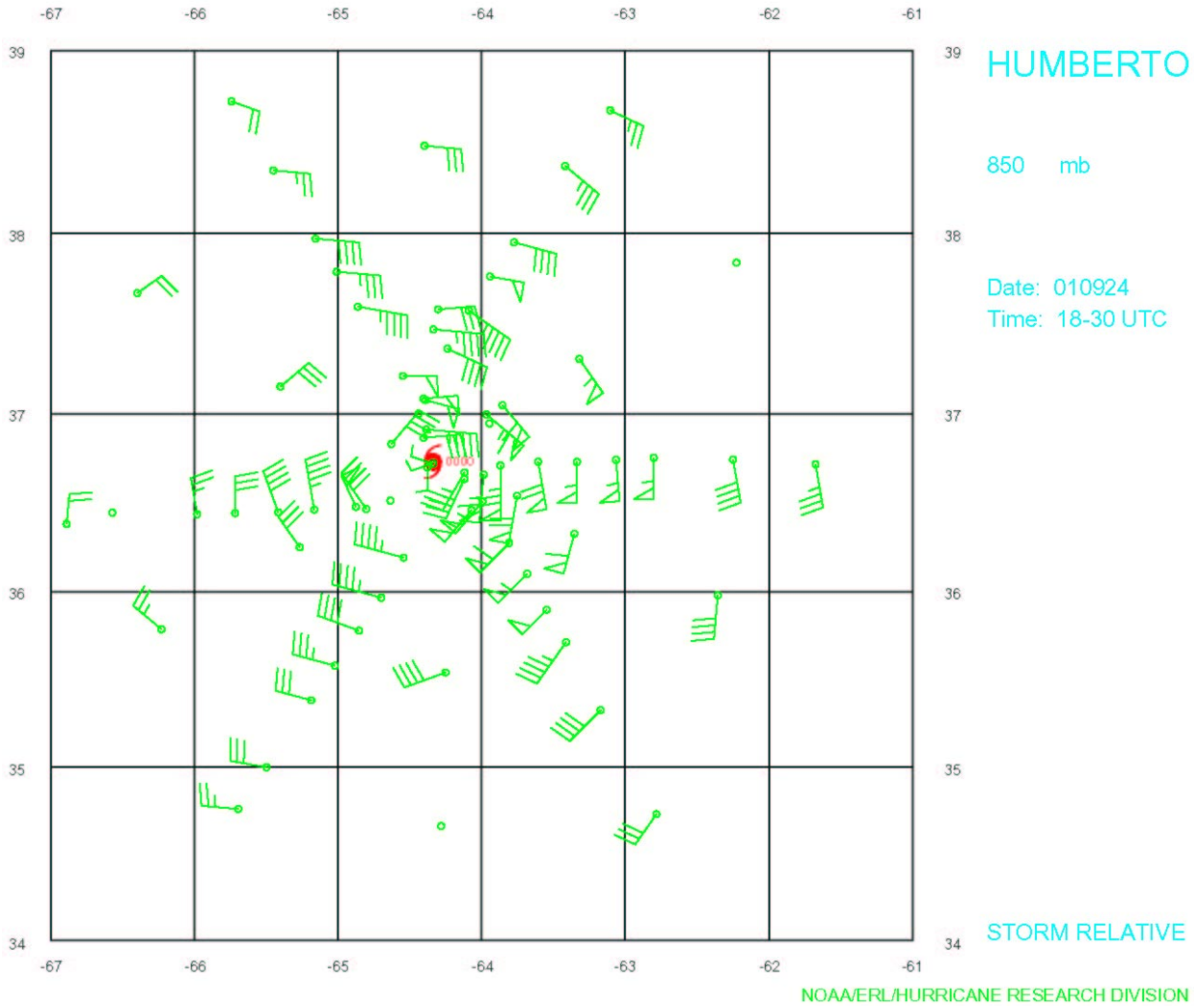

Fig. 6. GPS sonde distribution within 350 km radius from N42RF and N43RF (light green) and radiosonde stations (purple) at 850 hPa, Wind direction and speed are denoted by the barbs, where the barb points in the direction the wind is coming from, and a half barb represent 5 m s^{-1}, a whole barb 10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