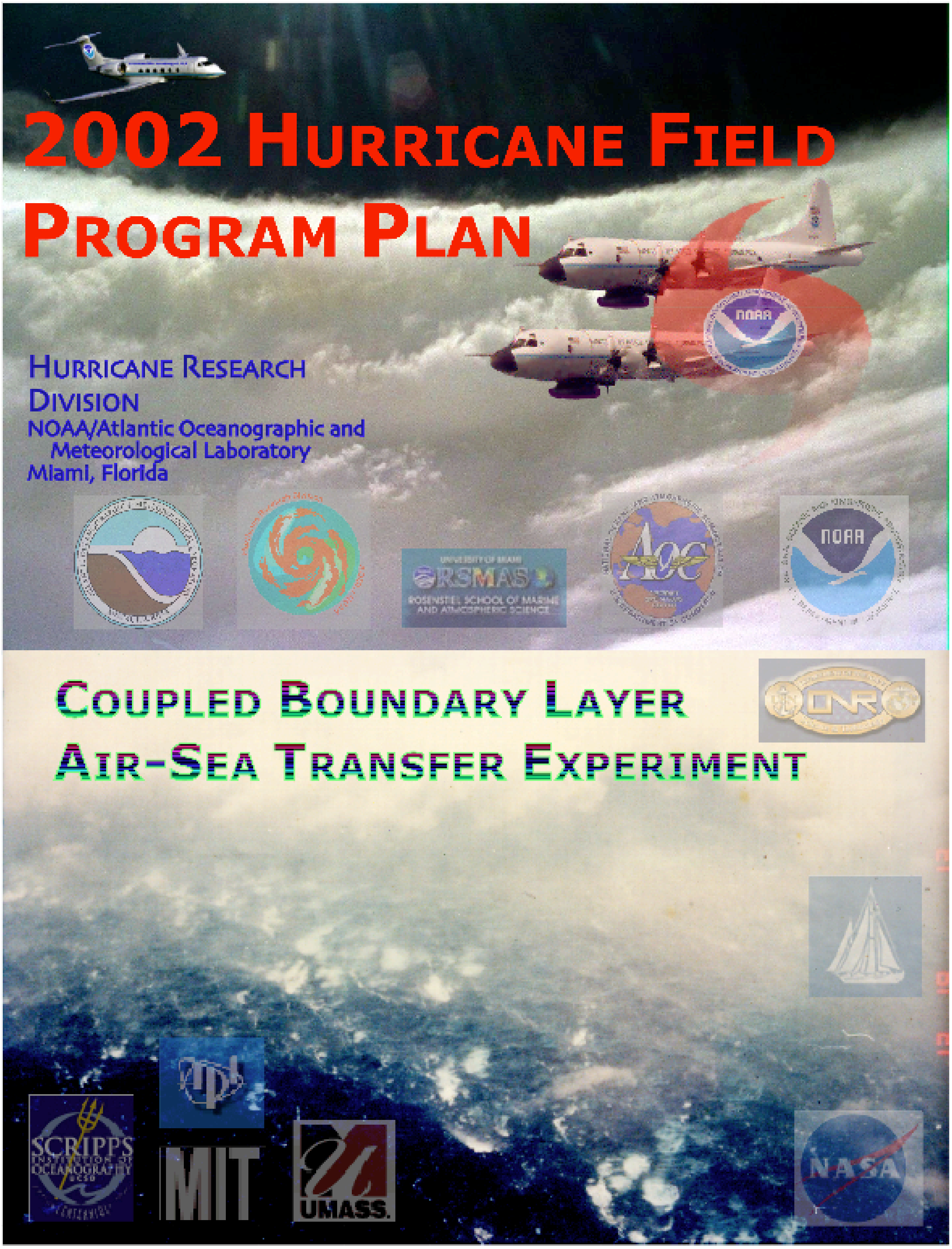
2002 Hurricane Field Program Plan

Hurricane Research Division
NOAA/Atlantic Oceanographic and Meteorological Laboratory
Miami, Florida

Coupled Boundary Layer Air-Sea Transfer Experiment



2002 Hurricane Field Program Plan

National Oceanic and Atmospheric Administration
Atlantic Oceanographic and Meteorological Laboratory
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Cover:
Top Panel: eyewall of Hurricane Olivia taken by P. Black from a NOAA WP-3D aircraft on September 24, 1994. Superimposed are Photos of the NOAA aircraft and logos of some of HRD collaborators.
Bottom Panel: Photo of the sea-surface and eyewall cloud base of Hurricane Gilbert on September 13, 1988. Photo from M. Black taken from the WP-3D aircraft at 10,000 ft altitude. Logos of some of the collaborators involved in CBLAST are superimposed on the photo.

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INTRODUCTION

The objective of the National Oceanic and Atmospheric Administration (NOAA) hurricane research field program is the collection of descriptive data that are required to support analytical and theoretical hurricane studies. These studies are designed to improve the understanding of the structure and behavior of hurricanes. The ultimate purpose is to develop improved methods for hurricane prediction.

Six major experiments have been planned, by principal investigators at the Hurricane Research Division (HRD)/Atlantic Oceanographic and Meteorological Laboratory (AOML) of NOAA for the 2002 Hurricane Field Program. These experiments will be conducted with the NOAA/Aircraft Operations Center (AOC) WP-3D and Gulfstream IV-SP aircraft.

(1) Hurricane AIR-Sea INteraction Experiment (HAIRSIN): This experiment is a *multi-option*, *single or dual aircraft* experiment designed to determine the contribution of pre-existing and storm-induced ocean features to changes in TC intensity and surface wind field structure. The experiment is composed of single or dual aircraft modules to be flown on *three successive days*. This experiment seeks to address this issue through single-level aircraft penetrations using GPS-sondes, flight-level data, air-deployed drifting buoys, AXBTs, AXCPs, AXCTDs, Scanning Radar Altimeter (SRA), Ku-band scatterometer (Ku-SCAT)/profiler, stepped frequency microwave radiometer (SFMR) and airborne Doppler radar observations on the synoptic, meso, and convective scales. It will focus particularly on both thermodynamic and wind field transformations in the boundary and lateral interactions between the TC and its synoptic-scale environment.

(2) Coupled Boundary Layer Air-Sea Transfer (CBLAST) Experiment: This experiment is a *multi-option*, *single or dual aircraft* experiment designed to improve our understanding of air-sea surface flux processes in high winds, specifically in the complex conditions of tropical cyclones where swell, sea spray and secondary boundary layer circulations play a significant role. The experiment is composed of single or dual aircraft modules to be flown on *two successive days*. This experiment seeks to improve our understanding of the physical processed at and near the air-sea interface with in-situ aircraft data, GPS-sondes, air-deployed drifting buoys, AXBTs, AXCPs, AXCTDs, Scanning Radar Altimeter (SRA), Ku-band scatterometer)/profiler (SCSCAT/KSCAT, stepped frequency microwave radiometer (SFMR) and airborne Doppler radar observations on the meso- and convective- scales.

(3) Tropical Cyclone Wind Fields Near Landfall: This experiment is a *multi-option*, *single-aircraft* experiment designed to study the changes in TC near surface wind structure near and after landfall. An accurate description of the TC surface wind field near and after landfall in real-time is important for warning, preparedness, and recovery efforts. HRD is developing a real-time surface wind analysis system to aid the TPC/NHC in the preparation of warnings and advisories in TCs. The analyses could reduce uncertainties in the size of hurricane warning areas. Flight-level and Doppler wind data collected by a NOAA WP-3D will be transmitted to TPC/NHC where they could result in improved real-time and post-storm analyses. Doppler data collected near a WSR-88D would yield a time series of three-dimensional wind analyses showing the evolution of the inner core of TCs near and after landfall.

(4) Hurricane Synoptic-Flow Experiment: Since the arrival of the new NOAA Gulfstream IV-SP high-altitude jet (G-IV), the HRD Hurricane Synoptic Flow Experiment has made the transition from a research program to operations. Beginning in 1997, the G-IV started conducting routine "hurricane surveillance" missions that are essentially HRD Synoptic Flow experiments. When coordinated with these operational

G-IV flights, the HRD Synoptic Flow experiment now becomes a *single-option, multi-aircraft* experiment. As in previous years, the experiment seeks to obtain accurate, high-density wind and thermodynamic data sets from the environment and vortex regions of tropical cyclones (TC) that are within 72 h of potential landfall. The availability of the G-IV, however, greatly increases the amount of environment sampled. GPS-based dropwindsondes (GPS-sondes) deployed from the G-IV and the two NOAA/AOC WP-3D aircraft provide these data over the normally data-void oceanic regions at distances up to 810 nm (1500 km) from the TC center. Mandatory and significant level GPS-sonde data, transmitted in real time, are used to prepare official forecasts at the Tropical Prediction Center/National Hurricane Center (TPC/NHC). These data are also incorporated into objective statistical and dynamical TC prediction models at TPC/NHC and the National Centers for Environmental Prediction (NCEP). In a research mode, these data help improve short and medium term (24-72 h) TC track predictions, study the influence of synoptic-scale fields on vortex track and intensity, and assess methods for obtaining satellite soundings.

(5) Extended Cyclone Dynamics Experiment: This is a *multi-option, single-aircraft* experiment which uses in–situ and radar data from the WP-3Ds flying at 500 mb, the G-IV at 200 mb, to monitor the structure and evolution of a TC on a spatial scales ranging from the convective and mesoscale in the vortex core (10-100 nm [18-185 km] radius) to the synoptic-scale (1,000 nm [1,850 km] radius) in the surrounding large-scale environment over a nominal period of 48 h. The WP-3D and G-IV data will be augmented by flight–level data from Air Force WC-130s flying reconnaissance at 700 mb within 110 nm (200 km) of the center The experiment goal is a better understanding of how lateral interactions between the vortex and the synoptic–scale environment control TC intensity and motion.

(6) Saharan Air Layer Experiment: This is a *multi-option, single aircraft experiment* which uses GPS dropwindsondes launched from the NOAA WP-3D aircraft flying at 400 mb or, if available, from the NOAA G-IV at 200 mb to examine the thermodynamic structure and characteristic strong low-level wind surge of the Saharan Air Layer (SAL) and its potential impact on tropical cyclone (TC) genesis and intensity change. This experiment is designed to study the mechanisms by which the SAL's embedded dust silicates, thermodynamic properties, and low-level wind surge affect Atlantic tropical cyclone genesis and intensity change. The GPS sonde drop points will be pre-selected using information from the UW-CIMSS/HRD GOES SAL tracking product that can identify suspended dust silicates and dry lower tropospheric air that are characteristic of the SAL. The goal of this experiment is to better understand how the low-level wind surge, lower tropospheric dry air, and suspended dust silicates associated with the SAL affect Atlantic TC activity.

CONCEPT OF OPERATIONS

1. Location

The primary base of operations for the NOAA aircraft will be Tampa, Florida, with provision for deployments to Bermuda, Barbados, Puerto Rico, and St. Croix for storms in the Atlantic basin (including the Atlantic Ocean and the Caribbean Sea).

Deployments of the NOAA aircraft may be implemented to U.S. coastal locations in the western Gulf of Mexico for suitable Gulf storms and to western Mexico for eastern Pacific storms. Occasionally, post mission recovery may be accomplished elsewhere.

2. Field Program Duration

The hurricane field research program will be conducted from 5 August through 31 October 2002.

3. Research Mission Operations

The decision and notification process used for hurricane research missions is illustrated, in flow chart form, by Fig. A-1 (Appendix A). The names of those persons who are to receive primary notification at each decision/notification point shown in Fig. A-1 are in Tables A-1 and A-2 (Appendix A). In addition, contacts are maintained each weekday among the directors of HRD/AOML, TPC/NHC, and AOC to discuss the "storm outlook."

Research operations must consider that the research aircraft are required to be placed in the National Hurricane Operations "Plan of the Day" (POD) 24 h before a mission. If operational "fix" requirements are accepted, the research aircraft must follow the operational constraints described in section 7.

4. Task Force Configuration

One NOAA/AOC WP-3D aircraft (N42RF), equipped as shown in Table B (Appendix B), will be available for research operations throughout the 2002 Hurricane Field Program (on or about 6 August through 31 October). When possible, the G-IV jet aircraft will be used with the WP-3D during the Synoptic-Flow Experiment.

5. Field Operations

5.1 Scientific Leadership Responsibilities

The implementation of HRD's 2002 Hurricane Field Program Plan is the responsibility of the field program director, who is, in turn, responsible to the HRD director. The field program director will be assisted by the field program ground team manager. In the event of deployment, the field program ground team manager shall be prepared to assume overall responsibility for essential ground support logistics, site communications, and HRD site personnel who are not actively engaged in flight. Designated lead project scientists are responsible to the field program director or designated assistants. While in flight, lead project scientists are in charge of the scientific aspects of the mission being flown.

5.2 Aircraft Scientific Crews

Tables C-2.1 through C-2.10 (Appendix C) list the NOAA scientific crewmembers needed to conduct the 2002 hurricane field experiments. Actual named assignments may be adjusted on a case-by-case basis. Operations in 2002 will include completion of detailed records by each scientific member while on the aircraft. General checklists of NOAA science-related functions are included in E.2 through E.6 (Appendix E).

5.3 Principal Duties of the Scientific Personnel

A list of primary duties for each NOAA scientific personnel position is given in D.1 through D.12 (Appendix-D).

5.4 HRD Communications

The HRD/Miami Ground Operations Center (MGOC) will operate from offices at AOML on Virginia Key (4301 Rickenbacker Causeway, Miami, Florida) or from TPC/NHC (11691 S.W. 17th Street, Miami, Florida).

During actual operations, the senior team leader of the MGOC, or his designee, can be reached by commercial telephone at (305) 221-4381 (HRD/TPC/NHC) or at (305) 361-4400 (HRD/AOML). At other times, an updated, automated telephone answering machine [(305) 221-3679] will be available at the MGOC. In addition, MGOC team leaders and the field program director can be contacted by calling their respective telepager phone number (available at a later date).

MGOC, operating from AOML or TPC/NHC, will serve as "communications central" for information and will provide interface with AOC, TPC/NHC, and CARCAH (Chief, Aerial Reconnaissance Coordinator, All Hurricanes). In the event of a deployment of aircraft and personnel for operations outside Miami, HRD's field program ground team manager will provide up-to-date crew and storm status and schedules through the field program director or the named experiment lead project scientist. HRD personnel who have completed a flight will provide information to MGOC, as required.

6. Data Management

All requests for NOAA data gathered during the 2002 Hurricane Field Program should be forwarded to: Director, Hurricane Research Division/AOML, 4301 Rickenbacker Causeway, Miami, Florida 33149.

7. Operational Constraints

Hurricane research missions are routinely coordinated with hurricane reconnaissance operations. As each research mission is entered into the planned operation, a block of time is reserved for that mission and operational reconnaissance requirements are assigned. A mission, once assigned, *must be flown in the time period allotted and the tasked operational fixes met.* Flight departure times are critical. Scientific equipment or personnel not properly prepared for flight at the designated pre-take-off or "show" time will remain inoperative or be left behind to insure meeting scheduled operational fix requirements.

8. Calibration of Aircraft Systems

Calibration of aircraft systems is described in Appendix C (en-route calibration). True airspeed (TAS) calibrations are required for each NOAA flight, both to and from station and should be performed as early and as late into each flight as possible (Fig. C-1).

EXPERIMENTS

9. Hurricane AIR-Sea INteraction (HAIRSIN) Experiment

Program Significance: Research over the last two decades suggests that several environmental controls influence the change in TC intensity and structure, including wind shear, upper ocean heat potential and upper-tropospheric interactions. Also important are the internal physics of the vortex, including dynamic and thermodynamic characteristics.

The HAIRSIN experiment is designed to collect data from a single TC using two NOAA WP-3D aircraft, which involves capturing complete snapshots of a TC's structure, horizontally within 170 nm (300 km) of the center and vertically from the top of the troposphere to at least 1000 m below the ocean surface, for use in intensification studies. By combining NOAA's aircraft resources (two WP-3D and a supplemental G-IV) from the Hurricane Field Program, HAIRSIN provides a unique opportunity to obtain a thorough depiction of the storm and its environment through a coordinated interagency effort that employs a greater variety of instruments than is usually available during the Hurricane Field Program.

One of the primary atmospheric instruments utilized is the GPS-sonde. In this experiment, GPS-sondes are capable of being deployed from the HAIRSIN aircraft to measure pressure, temperature, relative humidity, and winds every 0.5 s as they descend (~5 m vertical resolution near the surface). Since their introduction in 1996, reliability has proven to be outstanding and observational accuracy is quite high; the average error is less than 0.5° C for temperature, within 10% for humidity, and 1-2 m s^{-1} for winds. Most notably, the probes have helped to document extremely fine thermodynamic and kinematic variations in vertical structure, particularly in the boundary layer, and have permitted highly accurate point measurements near the surface in turbulent conditions.

The HAIRSIN experiment will add context to the airborne Doppler observations often made in TCs. Recent studies using Doppler radar data collected by two WP-3D aircraft flying simultaneous orthogonal tracks have found that the wind structure in a TC can change drastically in as little as three hours. For example, in Hurricane Olivia (1994) increasing environmental shear eventually affected the eyewall circulation and caused as much as a 15-20 m s^{-1} decrease of the mean swirling wind in the mid-to-upper troposphere in less than 3 h. These data will provide a complete depiction of the vortex structure, and when combined with GPS sonde data will allow us a better understanding of the dropsonde signals both in and outside the vortex.

HAIRSIN combines many dropsonde observations in the TC inner core and rainband regions out to 170 nm (300 km) from the center with Doppler radar observations within ~22 nm (40 km). The drops will be particularly dense immediately outside the Doppler coverage area but will be spaced farther apart at larger radial distances. This data distribution will help us to verify our present theories concerning both the interaction of the vortex with environmental shear and the modification of the vortex by upper-tropospheric interactions. The data may also be supplemented with other environmental observations within 540 nm (1000 km) of the center, including sondes dropped by the G-IV. It is hoped that data gathered at larger scales away from the center than those available when observing Hurricane Olivia will allow for accurate intercomparisons with nested models. The combination of *in situ* GPS-sonde and Doppler radar data will also permit small-scale dynamic features to be studied more extensively, such as vortex Rossby waves; results from Hurricane Olivia suggest that Rossby waves may be important features in the inner core circulation of developed TCs.

Of particular interest here is to relate modifications of the TC wind and pressure fields to oceanic thermodynamic influences are accomplished in two general fashions. First, pre-existing ocean temperature and circulation features modify the fluxes at the air-sea boundary as the storm passes over them. Such features include permanent currents, such as the Gulf Stream and Gulf Loop Current; semi-permanent circulations, such as the Gulf of Mexico Warm Eddies; and transitory features, such as cold wakes from previous storms. Second, immediate modifications of SST and ocean mixed layer depth under the storm itself will affect the surface fluxes. To address these issues, the HAIRSIN patterns will be used to map upper ocean heat potential and isotherm depths by deploying a combination of Upper ocean current, temperature, and salinity during TC passage will also be mapped using Airborne Expendable Current Probes (AXCPs) and Airborne Expendable Conductivity, Temperature, and Depth (AXCTDs) probes at regularly space intervals from N43RF and Airborne Expendable Bathythermographs (AXBTs) from N42RF. To fully understand the ocean's impact on intensity, pre-storm, storm and post-storm missions are required as per the NSF grant in support of USWRP.

In addition to the aircraft expendables, Lagrangian ocean mixed layer floats and surface drifters may be deployed during the pre-storm mission with the ocean grid in conjunction with CBLAST objectives. These profiling floats add turbulence measurements to the current, temperature and salinity fields and provide very high-resolution measurements within the Oceanic Mixed Layer (OML). These floats were deployed in Hurricane Dennis with reasonably good success.

It is important to separate other environmental influences from those of the ocean. Surface and tropospheric wind field measurements from instruments including the GPS-sondes, Doppler radar, the vertically-pointing Doppler wind profiler, Ku/C-band Scatterometer (Ku/CSCAT), and Stepped Frequency Microwave Radiometer (SFMR) out to several hundred km from the center will help achieve this. Finally, surface-wave observations will be made by a Scanning Radar Altimeter (SRA) to provide information on the distribution of low-frequency swell.

Rainbands and outer eyewalls are internal components of the TC that modify the thermodynamic characteristics of the boundary layer air flowing into the storm. Their circulations tend to suppress convection and the secondary circulation in the inner eyewall. They may also protect the inner eyewall from the full effect of environmental wind shear. The large number of GPS-sondes dropped both in the inner core and rainband regions should help to monitor the effects of rainbands and the degree to which surface fluxes are able to restore the warm moist properties of the inflow air modified by regions of storm-induced SST decreases. Additionally, the near-surface inflow will be determined from Doppler profiler, SFMR and Ku/CSCAT data collected along the flight tracks.

Goal: The long-term goal of this experiment is to improve our understanding of the mesoscale ocean processes in modifying the tropical cyclone intensity structure and wind field by the air-sea interactions. Main research themes are isolating physical effects such as vertical mixing, and horizontal advection on the upper ocean's three-dimensional heat, momentum and haline budgets, and the net effect of these processes on feedback to the atmospheric boundary layer as tropical cyclones encounter warm ocean features. A TC undergoing a period of rapid intensification or weakening will be a prime candidate. Combined with GPS-sonde observations from a simultaneous G-IV synoptic surveillance mission, observations of opportunity, and heat potential estimates from the satellite radar altimeters, a comprehensive snapshot of these mesoscale interactions will be obtained within ~170 nm (300 km) of the center.

Specific objectives are:

- To examine the relationship of environmental wind shear with TC structure, evolution, and intensity change;
- To examine the forcing by warm upper ocean features and their heat potential on enhanced surface stresses, fluxes and waves in the ABL;
- To assess the roles of shear-induced vertical mixing and surface-generated turbulence relative to horizontal advection in the three-dimensional thermal, haline and momentum budgets relative to winds and rainfall; and
- To improve satellite algorithms in retrieving upper ocean heat potential from radar altimetry.

Mission Description: In HAIRSIN, two to three aircraft provide simultaneous, coordinated observations of the TC. The aircraft involved are the two NOAA WP-3D as well as the NOAA G-IV during operational synoptic surveillance flights, which will provide most of the observations between 200 and 500 nm (300 and 800 km) from the storm center. The experiment consists of the pre-storm ocean survey and coordinated in-storm modules. Other optional modules are also presented here.

These are the following requirements for HAIRSIN:

- A hurricane category 1 or strong tropical storm within 540 nm (1000 km) of land, which is a threat to the U.S. coast, but is not expected to make landfall for 48-72 h.
- Both WP-3D aircraft must have operational tail and lower-fuselage radars, and be fully equipped to launch and monitor GPS-sondes, and AXBTs.
- Upper WP-3D (N43RF) must have working Doppler profiler, Ku/C-SCAT, and USFMR,
- Lower WP-3D, N43RF, (which will also be the pre-storm ocean survey aircraft) must have working SFMR, SRA, BAT probe or radome-mounted gust probe, and AXCP and AXCTD probes and receiver equipment.
- If AFRC WC-130 operational reconnaissance missions are carried out concurrently, coordination will be required particularly if the WC-130 is deploying floats/drifters in the pre-storm mission..
- If available, profiling floats and drifting buoy platforms should be deployed by AFRC WC-130 aircraft prior or during the pre-storm ocean survey.

Pre-Storm Survey Module: This module should be executed approximately 24-36 h prior to the storm module (i.e., HAIRSIN) The patterns shown in Fig. 1a and 1b correspond to full mission options designed to accurately measure the undisturbed structure of a (predetermined) asymmetric or a symmetric ocean feature, respectively, just prior to encountering the storm. A single WP-3D aircraft, i.e. N43RF, with AXBT/AXCP/AXCTD launching capability maps the undisturbed ocean boundary and mixed layer structure of the ocean feature at least one day before TC/ocean feature interaction occurs. These patterns should be flown with the initial leg parallel to a TOPEX/Poseidon or Jason satellite altimeter ground track (±32° inclination from true north) if possible. A constant altitude of 5,000 ft (1,500 m) RA should be maintained throughout the mission. Doppler radar should be set to F/AST mode on all legs if there is any precipitation present. A single aircraft experiment in the TC inner core using the high level aircraft (N42RF), in an experiment such as the XCDX, should ideally be conducted simultaneously with either of these options to measure internal storm structure prior to interaction.

A) Asymmetric Ocean Feature Option: This is best suited for an elongated or irregularly-shaped ocean feature, such as the Gulf Stream in the Atlantic or the Loop Current in the Gulf of Mexico. The “lawn mower” pattern (Fig. 1a) consists of flying four 135 nm (250 km) transects, bisected by the feature’s major orientation axis and spaced apart by 54 nm (100 km) intervals. Depending on the location of the grid, it may be spread out a bit more to encompass a wider swath to accommodate any track changes. These are followed by a return leg approximately 216 nm (400 km) aligned with the feature’s major axis. 10 GPS-sondes, 25 AXCTDs, and 25 AXCPs should be launched at regular intervals as shown in Fig. 1a. The AXCTDs in the spine of the feature should be deployed during the initial set of perpendicular legs. In the event the feature is the Gulf Loop Current, the positions of the other AXCTDs and the adjacent AXCPs on these legs should be reversed. The aircraft will have to temporarily slow to indicated air speeds of 195 knots when deploying AXCPs and AXCTDs at ~5,000 ft (1,500 m). The time on station needed to complete this option is about 5.5 h. Lagrangian ocean mixed layer floats should be deployed during this experiment from a separate aircraft over a broad enough region to insure that the storm will pass over them. Coordination with these float deployments is necessary at least 72 h in advance of possible storm flights.

B) Symmetric Ocean Feature Option: If the ocean feature is circular in shape, such as a Gulf of Mexico Warm Eddy, the pattern in Fig. 1b should be executed. This pattern has six radial legs (three inbound and three outbound), and two downwind legs (**2-3** and **4-5** in Fig. 1b); all have nominal length of 108 nm (200 km) and are spaced 60° apart azimuthally. During each radial leg probes will be launched at 11-14 nm (20-25 km) intervals beyond the feature center. A GPS-sonde and an AXCP will be dropped concurrently at 54 nm (100 km) and 108 nm (200 km) from the center. Another set of simultaneous GPS-sonde and AXCTD probes will be launched at the midpoint of the two downwind legs. An AXCTD will be launched at 13.5 nm (25 km) from the center on each radial leg, and a GPS-sonde will be dropped in the center during the second pass. AXCP/AXCTD will be deployed at 40 nm

(70 km), 60 nm (120 km), and 90 nm (170 km) from the center during each radial leg; and an AXBT will be released at 30 nm (50 km) and 80 nm (150 km) from the center. The aircraft will have to temporarily slow to indicated air speeds of 195 knots when deploying AXCPs and AXCTDs at ~5,000 ft (1,500 m). The time on station needed to complete this option is about 5.5 h.

Primary Storm Survey Modules: This pattern will require roughly 5.5 h on station. The aircraft will have to temporarily slow to indicated air speeds of 195 knots when deploying AXCPs and AXCTDs at ~5,000 ft (1,500 m). The lower aircraft will come into the pattern along leg 7 while the upper aircraft will start at leg 1 for coordination purposes. Throughout this experiment, the aircraft will follow the flight plan on orthogonal legs to maximize the radar sampling as well as the simultaneous ocean mapping in support of the objectives. However, an additional option is to have the two WP-3D aircraft fly ‘in trail’, i.e. entering the pattern on the same heading, and operating the tail Doppler radars in fore/aft scan (FAST) mode.

In the lower WP-3D module (Fig. 2), N43RF releases 32 GPS-sondes and 32 AXCPs, and 18 AXCTDs. There will be 5 sondes and 5 AXCPs per radial leg dropped at radii 13.5 nm (25 km), 27 nm (50 km), 54 nm (100 km), 81 nm (150 km), and 108. nm (200 km). There will be 3 AXCTDs released at 40.5 nm (75 km), 67.5 nm (125 km) and 94.5 nm (175 km) along each leg. The two remaining AXCPs will be deployed in the eye on the first and last penetrations with GPS sondes. This aircraft will also measure the surface waves from the SRA as well as the surface winds from the SFMR. The high data rate BAT probe, Lyman alpha probe, IRGA probe and radome gust probe should also be turned on for the experiment to address CBLAST objectives.

The upper aircraft (N42RF) will be at altitudes of 8,000 to 10,000 ft launching 37 GPS sondes and 36 AXBTs. In the upper WP-3D, 7 GPS and 7 AXBTs will be deployed at radii of 13.5 nm (25 km), 27 nm (50 km), 40.5 nm (75 km), 54 nm (100km), 81 nm (150 km), 108 nm (200 km) and 135 nm (250 km) along each flight leg. One GPS sonde will be deployed in the eye from each aircraft.

HAIRSIN EXPERIMENT

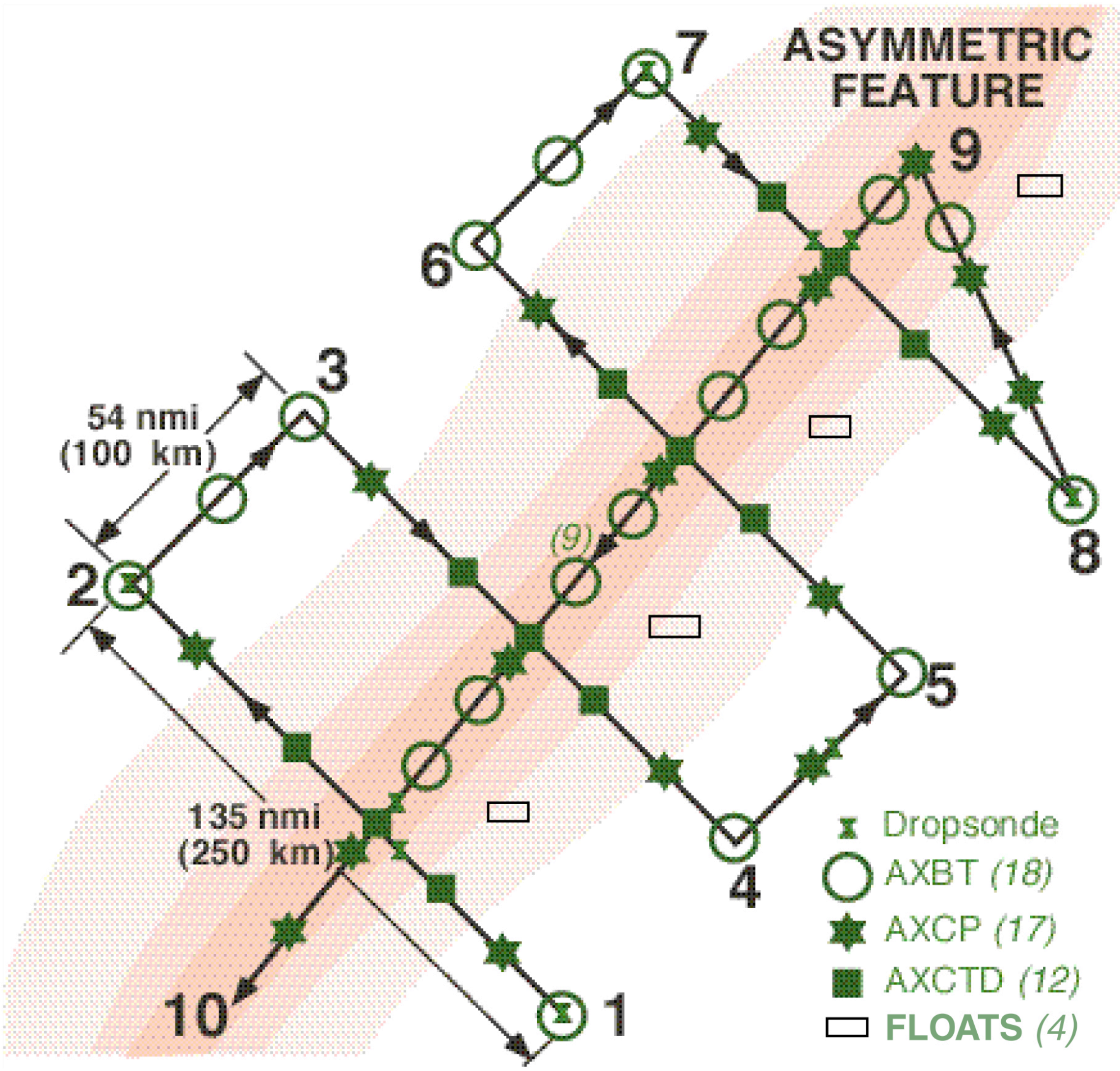


Fig. 1. (a) Pre-storm Ocean Survey Pattern

• Note 1.	Flight altitude should be 5,000 ft RA.
• Note 2.	IAS should be decreased to 195 kt when launching AXCPs and AXCTDs.
• Note 3.	Lagrangian ocean mixed layer floats should be deployed near the pre-storm ocean measurements from another aircraft.

HAIRSIN EXPERIMENT

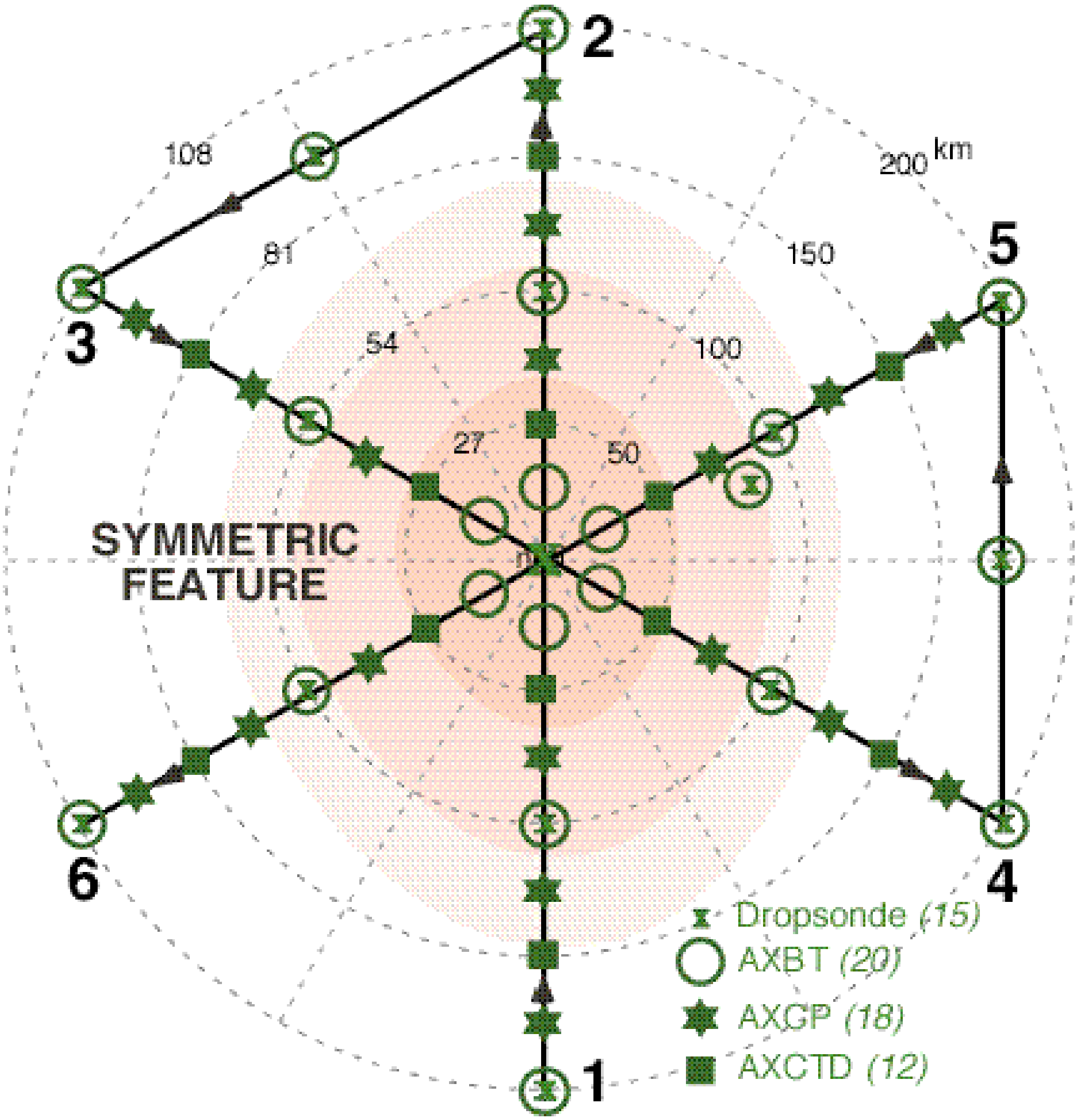


Fig. 1. (b) Pre-storm Ocean Survey Pattern

• Note 1.	Flight altitude should be 5,000 ft RA
• Note 2.	IAS should be decreased to 195 kt when launching AXCPs and AXCTDs.

HAIRSIN EXPERIMENT

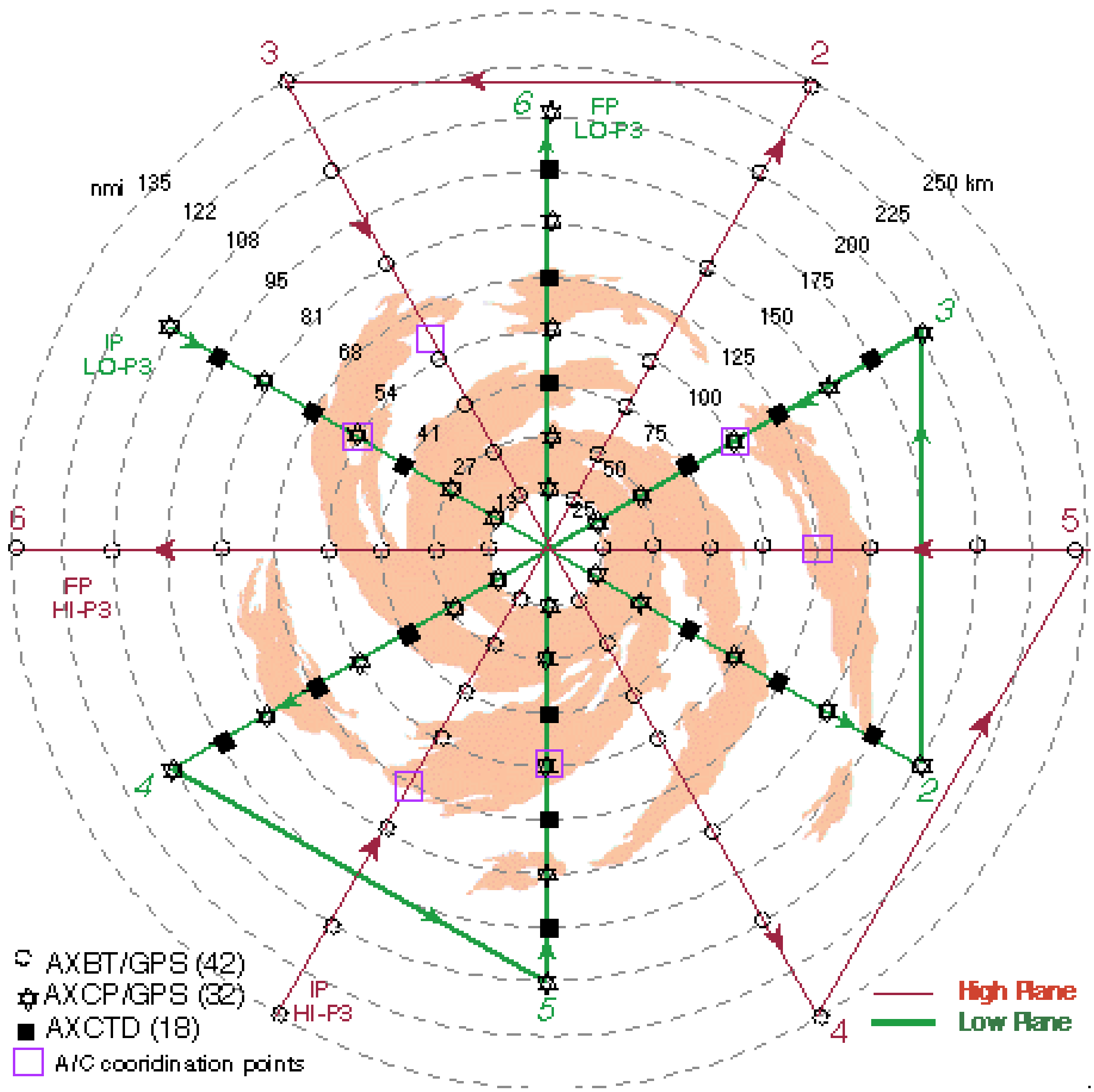


Fig. 2. Coordinated WP-3D HAIRSIN Pattern

• Note 1.	Aircraft should not deviate from pattern to find the center in the eye.
• Note 2.	The pattern may be entered at any compass heading, with higher WP-3D entering 90° downwind of lower WP-3D or on same heading 'in trail'.
• Note 3.	Aircraft should reach their respective **IP's** as simultaneously as possible, and the upper WP-3D is responsible to ensure that all aircraft depart the coordination points together.
• Note 4.	Upper WP-3D should begin the pattern at 8,000 ft, then climb to maintain maximum safe altitude. Lower WP-3D aircraft should fly at 5000 ft below the upper WP-3D at IAS of 195 kt when deploying AXCPs and AXCTDs.
• Note 5.	WP-3D Doppler radar should be operated in F/AST mode at a single PRF ≥2400 and 20° tilt.
• Note 6.	Lower WP-3D sondes and AXCPs within the eye are launched at the discretion of the lead scientist.

HAIRSIN Track-Dependant SST-Change Module

Program Significance: The importance of the ocean on tropical cyclone (TC) genesis and maintenance has been well-known for decades. Through air-sea interactive processes, the ocean provides the necessary energy required to establish and maintain deep convection. Recent studies conducted by Shay et al. (2000) and Bosart et al. (2000) showed that in some instances, warm upper-ocean features may act to significantly impact TC intensity. While findings from these case studies are significant, the results do not present a clear understanding of how (and to what extent) storm-to-storm variations in upper-ocean thermal structure directly impacts changes in storm intensity.

However, recent (multi-storm) findings clearly depict a statistical linkage between upper ocean temperature change and subsequent Tropical Cyclone (TC) intensity change. For a 21-storm (1975-2000) sample, it was shown that the magnitude of SST change (high wind inner-core SST minus ambient SST ahead of the storm) was statistically linked to subsequent changes in TC intensity. Findings from this study also illustrate that relatively small changes in inner core SST can dramatically alter sea-air fluxes within the high wind storm environment. In fact, inner core SST reductions (or inaccurate representation of actual SST conditions) by as little as ±0.5° C can result in total enthalpy flux errors on the order of 22% or more.

These findings highlighted the importance of accurately (and routinely) documenting inner core SST change (relative to the ambient SST environment ahead of the storm) and provide the basis for the motivation for developing an HFP experiment designed to regularly and systematically document “SST change” for as many HFP hurricanes as possible in order to dramatically increase our storm sample size over a relatively short period of time. To that end this experiment will be kept simple in the hopes that it will also be used in most/all other HFP experiments as a one-plane, single mission module (as time/resources permit). The two basic components to the experiment are: (1) the “out ahead” module; and (2) the inner core verification module. Depending on resources and flying opportunities, there are several possibilities that can be executed ranging from a single day one-plane mission (out ahead module only) to a three day mission that includes a one-plane “out ahead” mission on day one, a two-plane effort on day two (inner core verification with a concurrent out ahead module), and an inner core verification flight on day three. However, instead of highlighting all the possible flight possibilities, the two basic flight missions that make up this experiment are described. AXBTS and GPS dropwindsondes are all that are required. Assuming an average 220 kt airspeed, on-plane mission duration should range between 3.4 h (for the full “inner core” module) and 4.6 h (for the full “out ahead” module). Flight level is assumed 10,000 ft (3 km) unless stated otherwise. The “out ahead” module could be flown at lower altitude (i.e. likely 5,000 ft (1.5 km)) if necessary (weather permitting).

HAIRSIN Experiment
SST CHANGE AHEAD OF THE STORM MODULE
(Single Plane Mission)

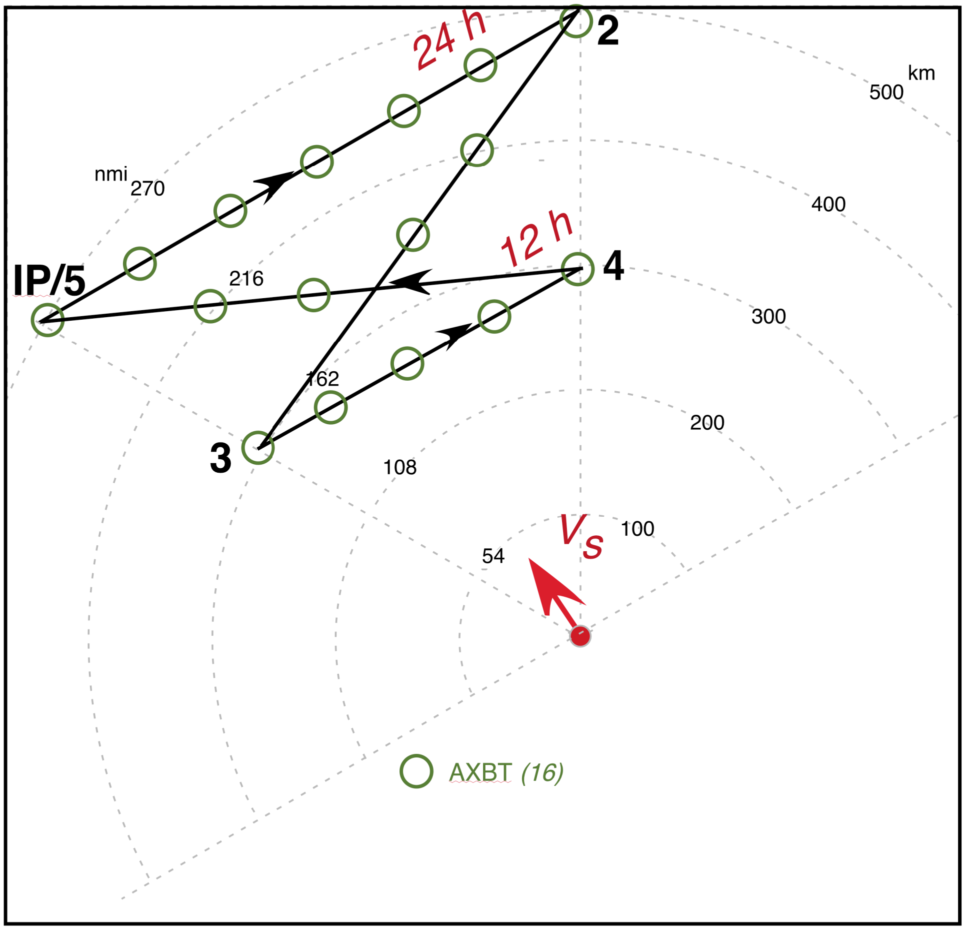


Fig. 3 HAIRSIN module ahead of projected storm track

• Note 1. GPS Sondes may be released with AXBTs, resources permitting.

HAIRSIN Experiment
SST CHANGE INNER-CORE VERIFICATION
(Single plane option)

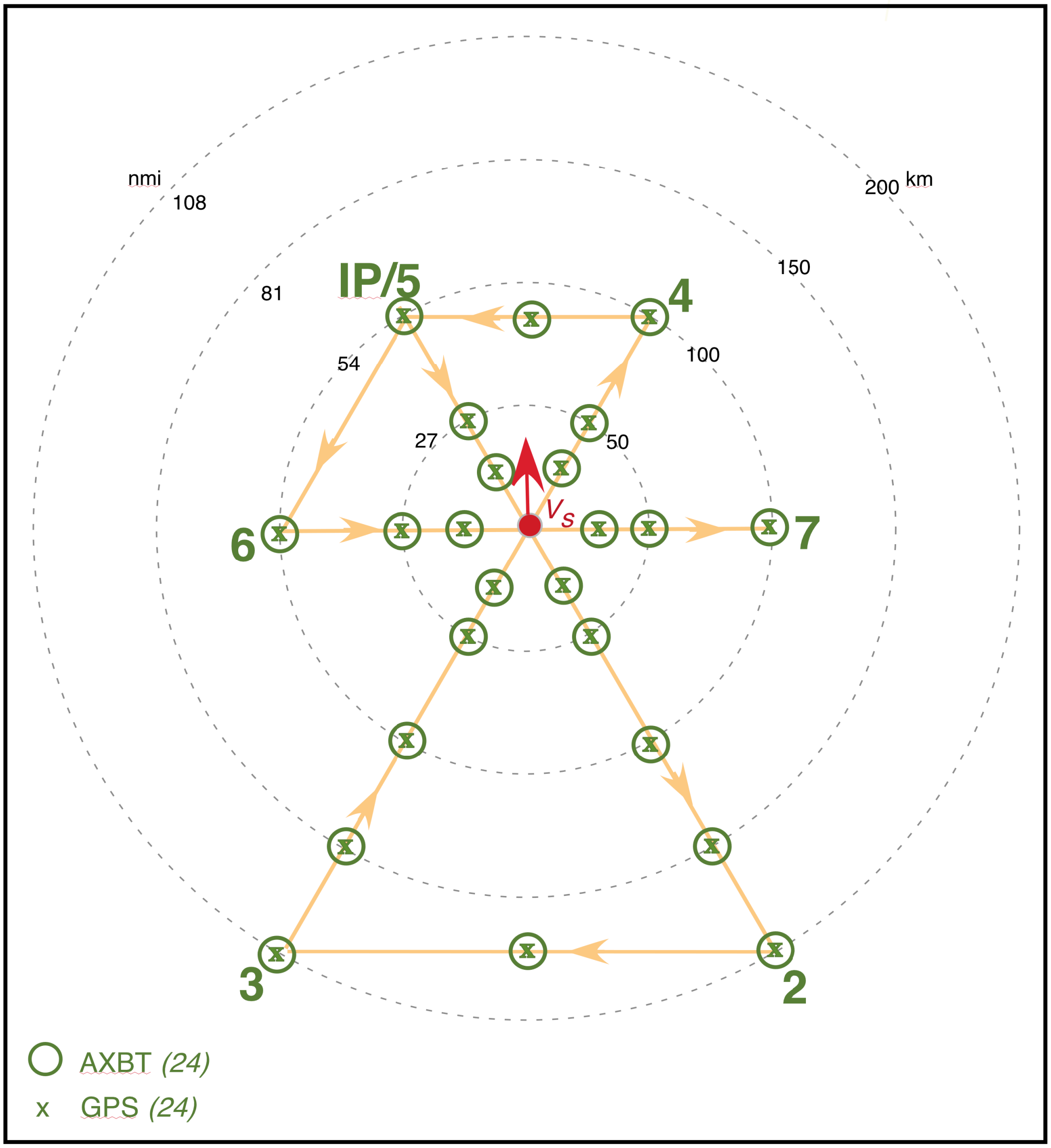


Fig. 4. Optional single plane in-storm module

- Note 1 . Pattern to be aligned with storm motion (arrow)
- Note 2 . Pattern may be flown IP-eye-3-2-eye-4-5-6-7 to avoid upwind leg in strong storms.

10. Coupled Boundary Layer Air-Sea Transfer (CBLAST) Experiment

Program significance: Our primary goal is to improve our understanding of air-sea surface flux processes in high winds, specifically in the complex conditions of tropical cyclones where swell, sea spray and secondary boundary layer circulations play a significant role.

The Hurricane Component of the Office of Naval Research (ONR) Coupled Boundary Layer Air-Sea Transfer (CBLAST) Departmental Research Initiative aims to measure, analyze, understand, and parameterize the air-sea fluxes in the tropical cyclone environment. Unlike mid-latitude cyclones where baroclinic processes are important, tropical cyclones draw their energy supply from the ocean. Fluxes of sensible heat and water vapor enrich the immediate atmospheric boundary layer (ABL). The momentum flux destroys the gradient balance and creates the cross-isobaric inflow transports the warm and moist air into the tropical cyclone inner region or rainbands to fuel the convective release of latent. Thus, the inward transport and air-sea fluxes ultimately determine the conversion of atmospheric available potential energy into kinetic energy of the storm. The significant air-sea flux exchanges greatly modify the near surface ocean temperature and current by mixing and three-dimensional transport. Under stationary or slow-moving hurricanes, the induced sea-surface temperature (SST) decrease can reach several degrees and the induced current can extend to great depths. The altered oceanic state can then feed back to modify the behavior of the overlaying tropical cyclone; they are indeed the most interesting and complex natural laboratory for air-sea interaction study.

The air-sea interfacial boundary under high wind is not well defined, and physical processes there are not properly quantified. The ocean surface waves and swell are characterized by limited fetch in the strongly forced regime. High winds and strong vertical wind shear mechanically form ocean spray, which is found to have significant effect on the thermal structure of ABL and may play an important role in hurricane thermodynamics, dynamics and intensity change. The ocean mixed layer is filled with air bubbles that can affect the air-sea exchange. This forms the basis for microwave and acoustic remote sensing of surface wind stress and allows inference of the surface wind. Standard boundary layer parameterizations, based on observations mostly taken at wind speeds below 20 m s^{-1} (39 kt), have not been validated for tropical cyclone conditions and highly disturbed sea states. Observation, understanding, and, eventually, the modeling of the structure and physical processes in the coupled hurricane-ocean boundary layer are the main objectives of the CBLAST Hurricane Component.

The research effort in the CBLAST Hurricane Component consists of re-examination of existing observations of hurricane-ocean boundary layer, wave conditions, and hurricane energetics. The effort also includes limited sensor development and calibration, and a refinement of observing strategies.

The objective of the work during the 2002 hurricane season, primarily in FY2002, is to conduct initial instrument and flight plan tests. The effort will culminate in a coordinated campaign in the 2003 or 2004 hurricane season of coincident airborne in situ and remote sensing measurements, together with air-deployed drifting buoys and floats from AFRC WC-130 or other contract aircraft. The airborne measurements will be conducted with the two NOAA WP-3Ds, equipped with radome and nose-boom mounted turbulence packages for direct measurement via eddy correlation methods of momentum, heat and moisture fluxes. Other onboard measurements include the University of Massachusetts (UMASS) scatterometers (SCSCAT/KSCAT) with improved horizontal resolution at 15 m and coherency to obtain the ABL wind profiles. A Particle Measurement System (PMS) will be used to measure spray droplet size distribution down to flight levels of 200 ft (60 m) in the rain-free, high-wind ABL. The surface-wind measurements will be supplemented with QuickSCAT and TRMM imagery.

The GPS-sondes and AXBTs will be deployed to obtain vertical sounding of atmospheric and oceanic structure along the flight path. TOPEX/POSEIDON satellite altimetry will be utilized to analyze ocean heat content changes during hurricane passage. An additional set of GPS-sondes will be densely deployed in the inner high-wind core regions of developed hurricanes to infer surface fluxes and momentum and enthalpy based on the budget technique of Hawkins and Rubsam. The NASA airborne Scanning Radar Altimeter (SRA) will provide measurements of wave topography in all quadrants of hurricanes over open water. Directional wave and swell spectra will be deduced in real-time during the field experiment from

SRA wave topography. A laser altimeter will be utilized to measure one-dimensional wave spectra between rainbands in order to estimate the high-frequency portion of the ocean wave field not resolved by the SRA. A wave-following camera system will be utilized to document wave breaking processes and generation of foam and spray. In addition to the AXBTs, neutrally buoyant, Lagrangian floats will be deployed to measure three-dimensional mean ocean currents and large eddy turbulence properties in the upper ocean. Wave spectra and momentum fluxes will be obtained from measurements by ambient noise sensors carried by these Lagrangian floats. Modified SOLO/ARGO floats, to be deployed by AFRC WC-130 aircraft, will carry additional sensors to measure surface wave heights, breaking, voids, heat fluxes, rainfall, wind-speed, and thermal-salinity structure of the upper ocean. The detailed planning of logistics and coordination of aircraft operations necessary for the multi-sensor, simultaneous, hurricane-ocean measurement program to be successful, will be conducted at HRD/AOML. The CBLAST hurricane field measurements will be complemented in experimental design and cross validation with the modeling component of CBLAST.

The CBLAST hurricane field experiment will be coordinated with USWRP Hurricane Landfall Program. The CBLAST field measurements are closely coordinated with three complimentary studies sponsored by other federal agencies. The National Science Foundation (NSF) is supporting an airborne hurricane-ocean interaction field study to be flown in concert with CBLAST, that will relate ocean heat content changes in the Gulf of Mexico Loop Current and associated warm eddies to changes in hurricane intensity. NESDIS is supporting an Ocean Winds project to validate satellite scatterometer algorithms at high wind speed that will make use of UMASS remote sensing equipment developed in part by CBLAST. NESDIS is also supporting the testing of new, high-speed aircraft-satellite communication links. NASA is supporting an investigation of the structure of secondary circulations in the hurricane atmospheric boundary layer that are revealed in SAR imagery from RADARSAT, ERS-2 and other satellites.

Long-Term Objective: Our ultimate goal and prime motivation for this work is to improve the accuracy of hurricane intensity and intensity change prediction.

Short-Term Objectives: This work intends to use airborne platforms to develop new surface wave-dependent flux parameterizations for the high wind hurricane ABL containing secondary (roll-vortex) circulations over fetch limited seas in the presence of sea spray, one or more swell components and ocean boundary layer secondary (Langmuir) circulations. We propose to test the following hypotheses:

1. that surface momentum exchange coefficients increase with wind speed for moderate winds (>30 m s^{-1} or 58 kt), are enhanced by fetch-limited waves or opposing swell, but level off or decrease above a high wind threshold (>45 m s^{-1} or 87 kt), especially in quadrants where swell has a significant downwind component,
2. that compensating mechanisms for enhanced surface air-sea enthalpy fluxes over and above current parameterizations must exist for storm maintenance and growth above some high-wind threshold wind speed, and
3. that candidate physical mechanisms are separable and can be estimated, such as (a) enhanced turbulent fluxes due to wave interactions, (b) spray evaporation and (c) secondary flow circulations (roll-vortex type) in the ABL.

Mission Description:

This experiment requires a minimal category 2 hurricane (winds>43 m s-1 or 84 kt) containing an identifiable eyewall structure. The primary measurement philosophy of this experiment is to treat the two WP-3D aircraft as a single “super” airborne platform. All phases of the initial CBLAST test flights will rely on the two WP-3D’s flying ‘in trail’, with one aircraft following the other at safe horizontal and vertical separation. Our approach is to conduct an initial survey pattern with high-density dropsonde sampling in the eyewall. This survey would be followed by several flight segments in at least two quadrants of a storm. These flight segments should cover as many as seven levels ranging from just above the top of the primary wind maximum, located just above the top of the ABL, to as close to the surface as is considered safe by the aircraft commander (in the range of 30-50 m or 200-500 ft).

The experiment is viewed as a two-day mission. Day one would consist of a survey pattern plus ABL modules at two wind radii in a selected storm sector. Day two would consist of an abbreviated survey, most likely a single radial leg followed by ABL modules at two wind radii in two storm sectors.

These two missions will be conducted in coordination with deployment by AFRC WC-130 aircraft operated by the 53rd Weather Squadron of drifting buoys and subsurface floats ahead of the storm. These systems will be deployed over a target area. normal to the forecast hurricane track, roughly 36 h in advance of the storm. The first two legs of the initial survey pattern on day one would be oriented to overfly as many buoy and float positions as possible during the initial survey pattern. AXBTs and/or AXCPs/AXCTDs would be deployed at buoy/float positions along the flight track in coordination with GPS-sonde deployments.

For 2002, six subsurface floats, and up to 12 drifting buoys are anticipated to be deployed. However, AFRC WC-130 airdrop capability is not expected to be available until the latter half of the hurricane season, and may not be conducted on earlier CBLAST missions.

In route to the survey pattern Initial Point (IP), or alternatively, on return to base from the end of the flight pattern, a series of calibration maneuvers will be executed by the WP-3D aircraft (N43RF) that are designed to ensure proper post-flight calibration of aircraft turbulence sensors. These maneuvers are described in the turbulence calibration module. It is anticipated that these maneuvers may require about 30 min of flight time. If done in route to the start of the survey pattern, which would be the first choice, then N42RF would then delay takeoff by 30 min to rendezvous together at the IP.

For the initial survey pattern, nominal constant radar altitude (RA) for N43RF for the first penetration is 5,000 ft (1.5 km. Conditions permitting, N43RF would then descend to 2,500 ft (750m) for the remainder of the flight. N42RF would fly at 7,000 ft (2.1 km). For category 4 or 5 storms with intense turbulence, constant pressure altitudes would be flown with N43RF flying at 8,000 ft (2.4 km) and N42RF flying at 12,000 ft (3.6 km). AFRC WC-130 reconnaissance aircraft would most likely be flying at 10,000 ft (3 km). N43RF would lead N42RF to ensure a clear vertical path for dropsondes and AXBTs.

The nominal short survey pattern will be a figure-4 pattern that is designed to be flown on two successive days in coordination with maximum radial distances for N43RF of 108 nm (200 km) and for N42RF of 119 nm (220 km) (Figs. 5 and 6). The pattern is designed to be flown in 2.5 h. Should the storm be close to a staging base, and more time is available for the survey, a three-legged long ‘butterfly’ pattern will be flown with maximum flight legs of 97 nm (180 km) for N43RF and 109 nm (200) km for N42RF, and requiring 4 h, as shown in Fig. 7.

The prime purpose of the survey pattern is to record data that will (1) allow the large scale structure of the storm to be analyzed, (2) allow bulk aerodynamic flux estimates to be computed using a variety of existing parameterizations and (3) to deploy sequences of GPS-sondes at short time intervals during eyewall penetration. Alignment of the pattern will depend on storm direction of motion, ABL shear orientation and distribution of pre-storm floats/buoys. We are proposing to use an 8-channel dropsonde receiving system on N42RF, where 8 GPS-sondes at 10-20 s intervals will be deployed following 4 GPS-sondes from N43RF to obtain a sequence of up to 12 GPS-sondes along four radial legs through the eyewall. Three AXBTs, at the beginning, middle and end of the 12-sonde sequence, will be deployed from N43RF. Four additional sondes and AXBTs will be deployed from N42RF at 27 nm (50 km) intervals for the outer portion of each flight leg. The primary purpose of this measurement strategy is to diagnose the surface drag and enthalpy exchange coefficients at high winds using budget methods developed at the Massachusetts Institute of Technology (MIT).

Along the final leg of the survey pattern on day one, two relatively clear areas between rainbands will be determined in the right-rear quadrant of the storm relative to the storm motion vector. Three sectors representative of differing wave/swell conditions have been defined: (1) the rear quadrant representative of steep growing waves, (2) the right and right-front quadrants representative of mature swell moving approximately with the wind, and (3) the left-front and left quadrants where the swell that is moving at approximate right angles to the wind. The right-rear quadrant is also characterized by maximum ocean mixed layer currents, current shears at the base of the mixed layer and minima in SST, which are factors that may influence surface fluxes. The right quadrant typically contains the strongest inflow and active outer band convection. The downshear left quadrant typically contains the strongest eyewall convection.

Upon exiting from the initial survey pattern, the two aircraft will then proceed to the closest selected rain-free sector of interest at the 34-50 kt wind radius. First, a radial boundary layer flight leg normal to the wind will be flown prior to the multi-level flight leg module at as many as 8 levels parallel to the wind. The radial leg will consist of an out and back 5.5 min, 19 nm (35 km) leg (11 min, 38 nm (70 km) total) with N43RF flying in the middle of the ABL at roughly 600 ft and N42RF flying near the top of the ABL at 5,000 ft (1.5 km). N42RF will conduct a 12 sonde drop sequence at the start of the leg, and a second at the end of the return leg. AXBTs will be deployed from N42RF at the beginning, middle and end of the outbound radial flight leg. The purpose of these observations is to identify the structure of ABL secondary circulations. The aircraft will then execute the boundary layer multilevel module in the along wind direction.

Following the first completed ABL flight module at the 34-50 kt (17-26 m s^{-1}) wind radii, the two aircraft would proceed to the second rain-free sector at a hurricane force wind radius of 64-80 kt (33-41 m s^{-1}) in the same sector and repeat the sequence. Once the second ABL pattern is completed on day one, the aircraft would return to base with the N43RF executing the calibration maneuvers if they had not been done on the inbound flight.

On day two, following the in-route calibration maneuvers an initial radial leg will be flown, which will simply be a single leg of the survey pattern at an RA of 5,000 ft (750 m). The aircraft would again select a region free of convection in the right-front quadrant and repeat the ABL pattern at the two wind radii. Following the initial pair of ABL patterns, the aircraft would proceed to a second sector in the left or left-rear quadrant which is identified as clear of strong convection. The ABL sequence should then be repeated for the two wind radii. The aircraft would then return to base.

Boundary Layer multi-level module: This module (Fig. 8), consists of roughly 27 nm (50 km) flight legs parallel to the wind, which will be about 6 min downwind and 9 min upwind in 34-50 kt (17-26 m s^{-1}) winds (5 min down wind, 11 min upwind in 64-80 kt (33-41 m s^{-1}) winds) at each level. N42RF will deploy 6 GPS sondes at 5.4 nm (10 km) intervals along the first flight leg from 7,000 ft (2.1 km). N43RF will commence its first leg at 3,500 ft (1 km). Flight legs will then be flown at 2,000 ft (600 m), 1,000 ft (300 m), 600 ft (180 m), 400 ft (120 m)and if possible at 200 ft (60 m). Each level will be limited to 17 min flight time, including the 180° turn. Completion of the six levels will require 1.5 h flight time.

Turbulence Calibration Module: The following maneuvers are requested for turbulence sensor calibration:

- Pitch Up/Down maneuvers: One series, with pitch variations of ±8-10°, containing 10-20 complete sinusoids. Sinusoids in the series will have periods of roughly 5-6 s (the plane should actually react to this, i.e., change altitude).
- Dynamic sideslip: 1/2- to full-ball sideslips with 10-20 complete sinusoids. Series slow (5-6 s period).
- Steady-state Yaw: 1/2-ball, held for 10-15 s, full-ball held for 10-15 s, 1/2-ball, held for 10-15 seconds. Repeated on other side.

NOTE: above maneuvers should be done while trying to hold everything else constant (i.e. during side-slips and yaws, pilot should allow plane to lose altitude instead of increasing attack angle).

- Wind Circles: Two 360° standard rate turns: first clockwise, then counter-clockwise. We need 360° of data to be in a coordinated turn, so after the pilot enters the turn and it is coordinated, only then 'start the clock'.
- Acceleration/Deceleration runs (AC/DC): Start at slowest possible flight speed, accelerate to fast flight speed, decreasing attack angle. Then decelerate to slow flight speed. Two runs.
- Wind box: Straight and level box, 2 min on each side, standard rate 90° turn on the corners.

All of these maneuvers should be aligned with the wind. The boxes should have legs parallel and perpendicular to the wind. We should attempt to complete the calibrations at the mean radar altitude where we will be making the measurements, or roughly 1,000 ft (300 m). The maneuvers should be conducted in smooth air (as smooth as possible).

CBLAST EXPERIMENT

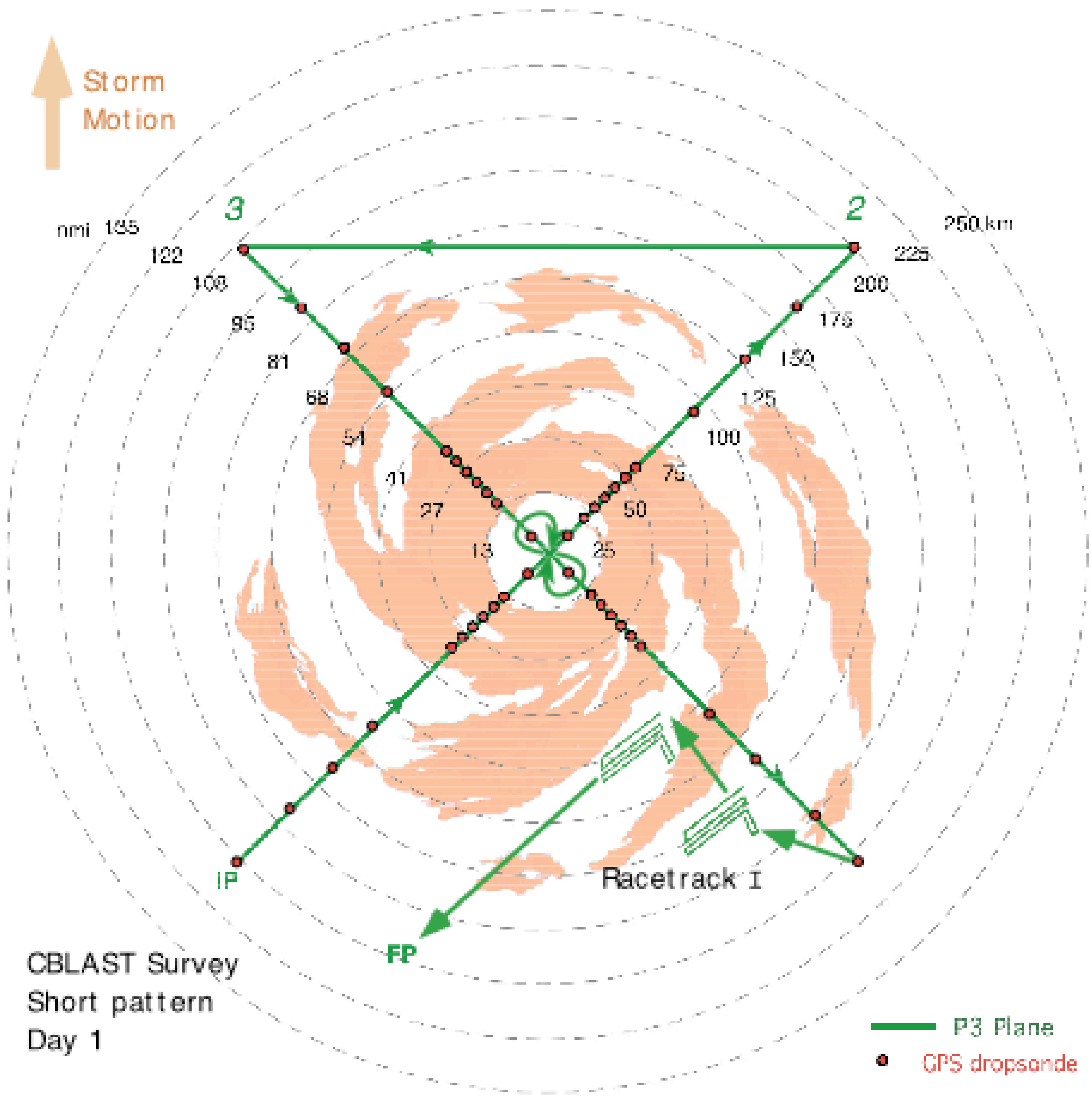


Fig. 5. CBLAST short pattern, Day 1.

• Note 1.	The pattern should be aligned 45° from storm heading. Preferred **IP** is in left-rear quadrant, but can be in any quadrant.
• Note 2.	The two WP-3Ds fly 'in trail' with high plane at 7,000 ft RA (12,000 ft in CAT 4 or 5) and low plane at 5,000 ft RA from **IP** to **2**, 2,500 ft RA thereafter, conditions permitting (8,000 ft for CAT 4 or 5). The lower WP-3D will lead the upper WP-3D.
• Note 3.	Aircraft should reach their respective **IP's** as simultaneously as possible, with the **IP** for upper WP-3D at a radius of 120 nm, and the **IP** for the lower WP-3D at a radius of 108 nm.
• Note 4.	The lower WP-3D will commence a sequence of four near-eyewall drops on inbound legs at approximately $2R_{MAX}$ or twice the eyewall thickness radially-outward. High-level aircraft should commence series of 8 eyewall drops 30 s after end of low plane drops, ending at inner edge of eyewall. Orbit in the center until all drops have cleared. Reverse the sequence on the outbound legs.

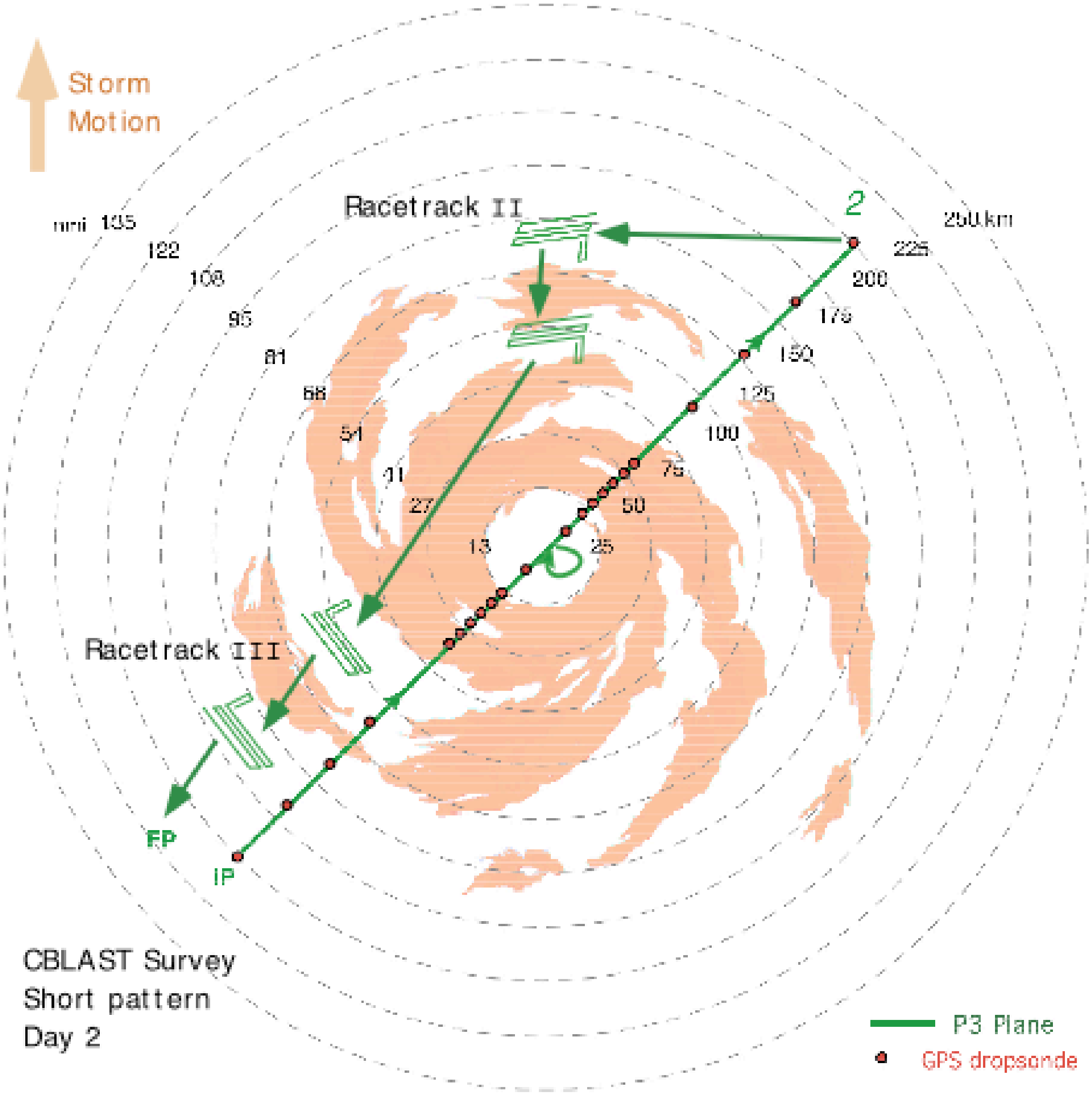


Fig. 6. CBLAST short pattern, Day 2.

• Note 1.	The pattern should be aligned 45° from storm heading. Preferred **IP** is in left-rear quadrant.
• Note 2.	The two WP-3Ds fly 'in trail' with high plane at 7,000 ft RA (12,000 ft in CAT 4 or 5) and low plane at 5,000 ft RA from **IP** to **2**, 2,500 ft RA thereafter, conditions permitting (8,000 ft for CAT 4 or 5). The lower WP-3D will lead the upper WP-3D.
• Note 3.	Aircraft should reach their respective **IP's** as simultaneously as possible, with the **IP** for upper WP-3D at a radius of 120 nm, and the **IP** for the lower WP-3D at a radius of 108 nm.
• Note 4.	The lower WP-3D will commence a sequence of four near-eyewall drops on inbound legs at approximately $2R_{MAX}$ or twice the eyewall thickness radially-outward. High-level aircraft should commence series of 8 eyewall drops 30 s after end of low plane drops, ending at inner edge of eyewall. Orbit in the center till all drops have cleared. Reverse the sequence on the outbound leg.

CBLAST EXPERIMENT

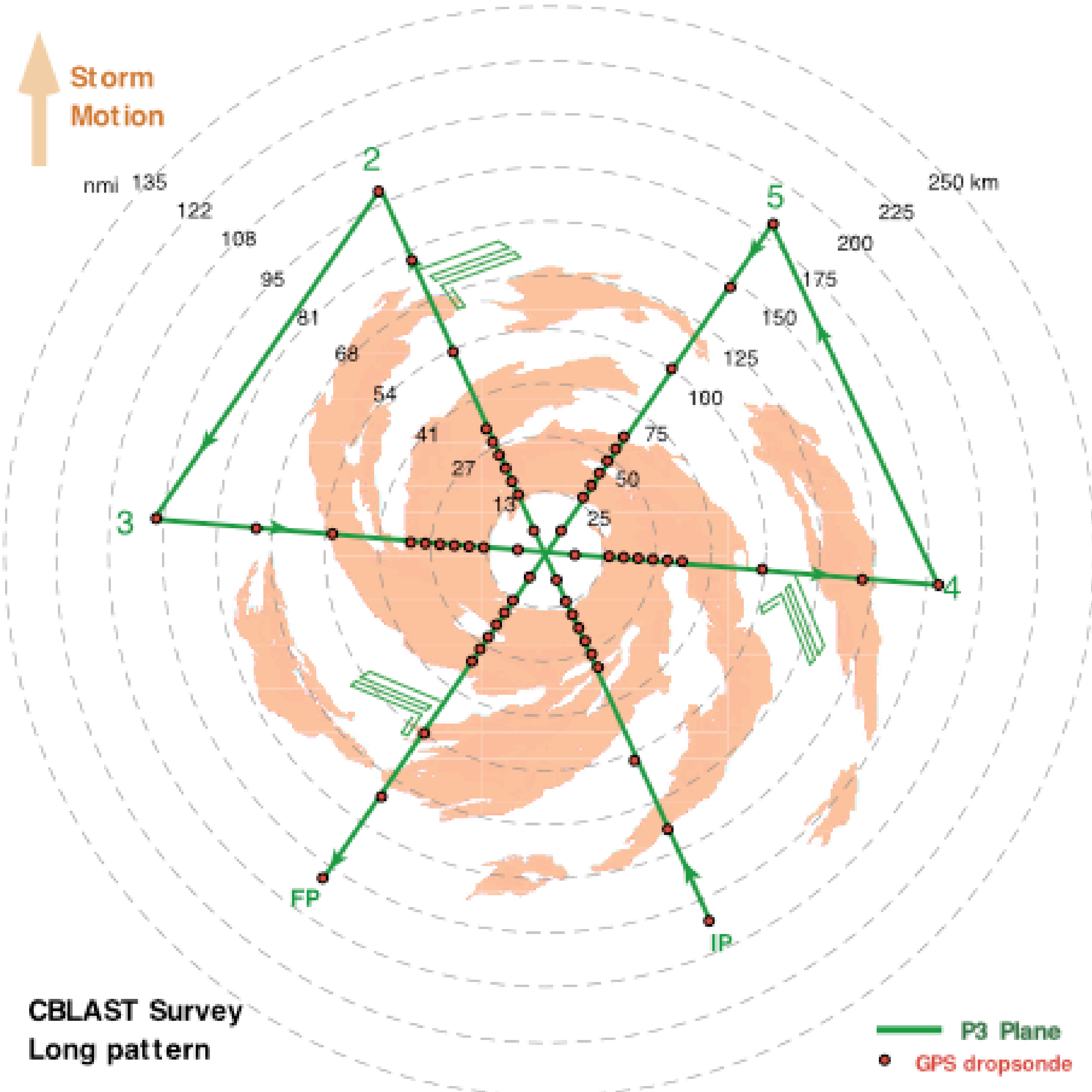


Fig. 7. CBLAST long pattern.

• Note 1.	The pattern should be aligned 30° from storm heading. Preferred **IP** is in left-rear quadrant, but can be in any quadrant.
• Note 2.	The two WP-3Ds fly 'in trail' with high plane at 7,000 ft RA (12,000 ft in CAT 4 or 5) and low plane at 5,000 ft RA from **IP** to **2**, 2,500 ft RA thereafter, conditions permitting (8,000 ft for CAT 4 or 5). The lower WP-3D will lead the upper WP-3D.
• Note 3.	Aircraft should reach their respective **IP's** as simultaneously as possible, with the **IP** for upper WP-3D at a radius of 108 nm, and the **IP** for the lower WP-3D at a radius of 97 nm.
• Note 4.	The high WP-3D will commence a sequence of six eyewall drops on inbound legs at approximately 1.5R_{MAX} or near the outer edge of the eyewall, ending at inner edge of eyewall. Reverse the sequence on the outbound legs.

CBLAST EXPERIMENT

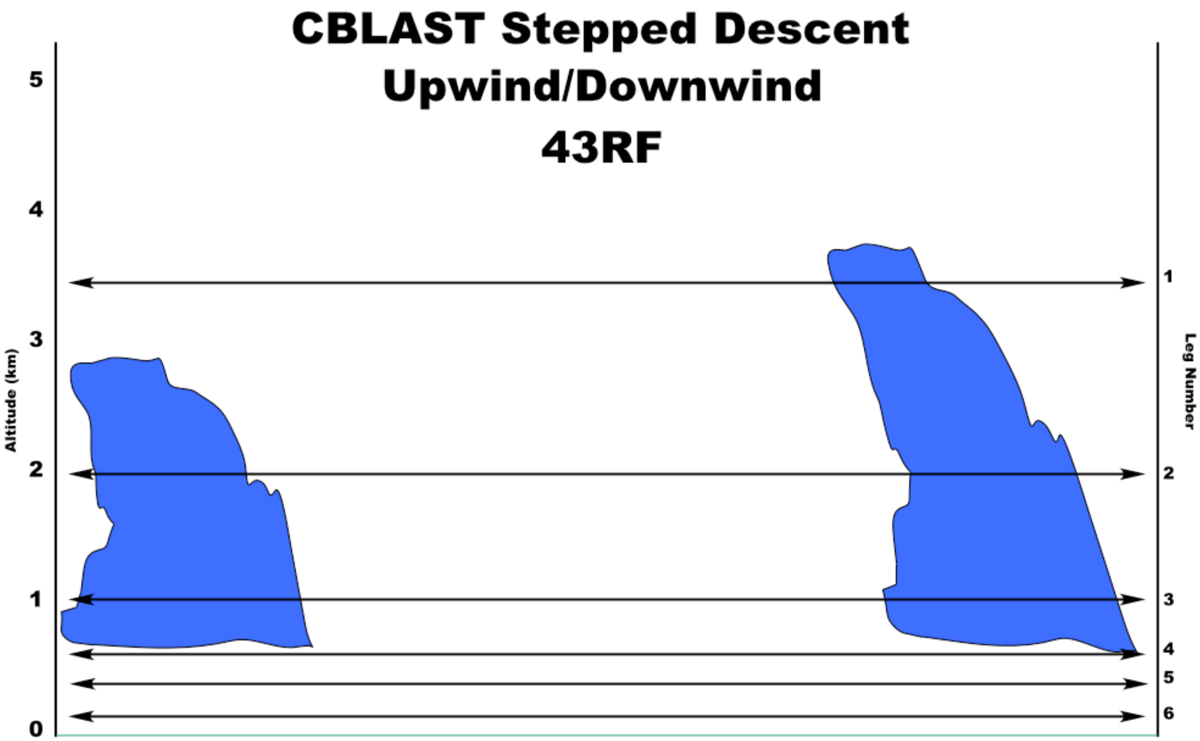


Fig. 8. CBLAST stepped descent pattern (racetracks) in upwind/downwind direction.

• Note 1.	The high WP-3D flies at 8,000 ft deploying six sondes along the track of the low WP-3D for the first leg. The low WP-3D leads and orbits past the endpoint until the last sonde has splashed.
• Note 2.	Legs are flown out and back at the same altitude. A spiral descent is executed at the end of each out and back leg.

11. Tropical Cyclone Wind Fields at Landfall Experiment

Program Significance: An accurate real-time description of the TC surface wind field near and after landfall is important for warning, preparedness, and recovery efforts. During a hurricane threat, an average of 300 nm (550 km) of coastline is placed under a hurricane warning, which costs about $50 million in preparation per event. The size of the warned area depends on the extent of hurricane and tropical storm force winds at the surface, evacuation lead-times, and the forecast of the storm's track. Research has helped reduce uncertainties in the track and landfall forecasts, but now there is an opportunity to improve the accuracy of the surface wind fields in TCs, especially near landfall.

HRD is developing a real-time surface wind analysis system to aid the TPC/NHC in the preparation of warnings and advisories in TCs. The real-time system was first tested in Hurricane Emily of 1993, and the system is now being evaluated by hurricane specialists at TPC for use in operational forecasts and warnings. The surface wind analyses should reduce uncertainties in the size of hurricane warning areas and are now used for post-storm damage assessment by emergency management officials. The surface wind analyses are also used to validate and calibrate an operational inland wind forecast model that HRD has developed under Federal Emergency Management Agency (FEMA) sponsorship. The operational storm surge model (SLOSH) could also be run in real-time with initial data from the surface wind analysis.

As a TC approaches the coast, surface marine wind observations are normally only available in real-time from National Data Buoy Center (NDBC) moored buoys, C-MAN platforms, and a few ships. Surface wind estimates must therefore be based primarily on aircraft measurements. Low-level (<5,000 ft (1.5 km] altitude) NOAA and Air Force Reserve aircraft flight-level winds are adjusted to estimate surface winds. These adjusted winds, along with C-SCAT and SFMR wind estimates, are combined with actual surface observations to produce surface wind analyses. These surface wind analyses were initially completed after Hurricane Hugo's landfall in South Carolina and Hurricane Andrew's landfall in South Florida in support of post-landfall damage surveys conducted by FEMA. In recent years, these analyses have been produced in real-time for operational use by the NHC for many of the TCs that have affected the Western Atlantic basin, including such notable landfalling storms as Opal (1995), Fran (1996), Georges (1998), Bret (1999), and Floyd (1999).

Dual-Doppler analysis provides a more complete description of the wind field in the inner core. While these techniques are still too computationally intensive for real-time wind analysis, the data are quite useful for post-storm analysis. An observational study of Hurricane Norbert (1984), using a PDD analysis of airborne radar data to estimate the kinematic wind field, found radial inflow at the front of the storm at low levels that switched to outflow at higher levels, indicative of the strong shear in the storm's environment. Another study used PDD data collected in Hurricane Hugo near landfall to compare the vertical variation of winds over water and land. The profiles showed that the strongest winds are often not measured directly by reconnaissance aircraft.

While collection of dual-Doppler radar data by aircraft alone requires two WP-3D aircraft flying in well-coordinated patterns, time series of dual-Doppler data sets have been collected by flying a single WP-3D toward or away from a ground-based Doppler radar. In that pattern, the aircraft Doppler radar rays are approximately orthogonal to the ground-based Doppler radar rays, yielding true Dual-Doppler coverage. Starting in 1997 the Atlantic and Gulf coasts were covered by a network of Doppler radars (WSR-88D) deployed by the National Weather Service (NWS), Department of Defense, and Federal Aviation Administration (Fig C-5 in the Appendix). Each radar archives (and will soon transmit in real-time) the base data (Archive Level II). In precipitation or severe weather mode the radars collect volume scans every 5-6 min.

TROPICAL CYCLONE WINDFIELDS NEAR LANDFALL EXPERIMENT

Ground-based/Airborne Doppler Scanning Strategy

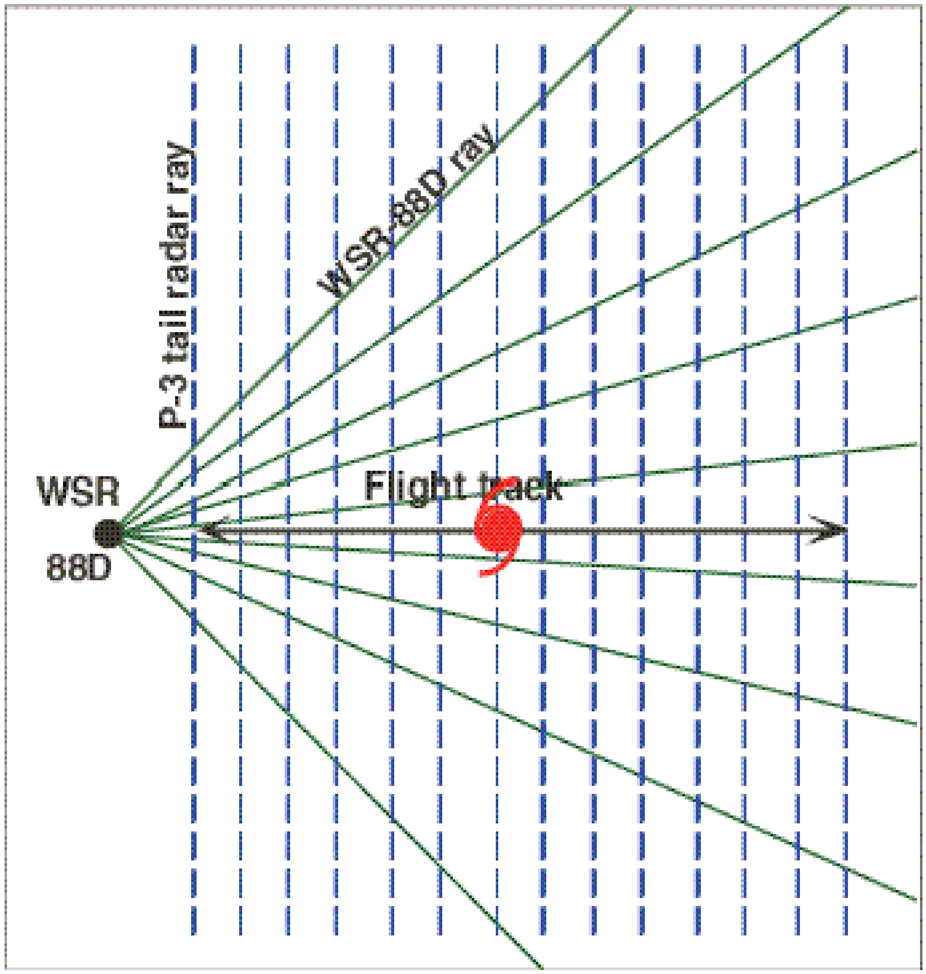


Fig. 9. Airborne Doppler Radar Flight Track

• Note 1.	The legs through the eye may be flown along any compass heading along a radial from the ground-based radar.
• Note 2.	Set airborne Doppler radar to scan continuously perpendicular to the track on all legs.

TROPICAL CYCLONE WINDFIELDS NEAR LANDFALL EXPERIMENT

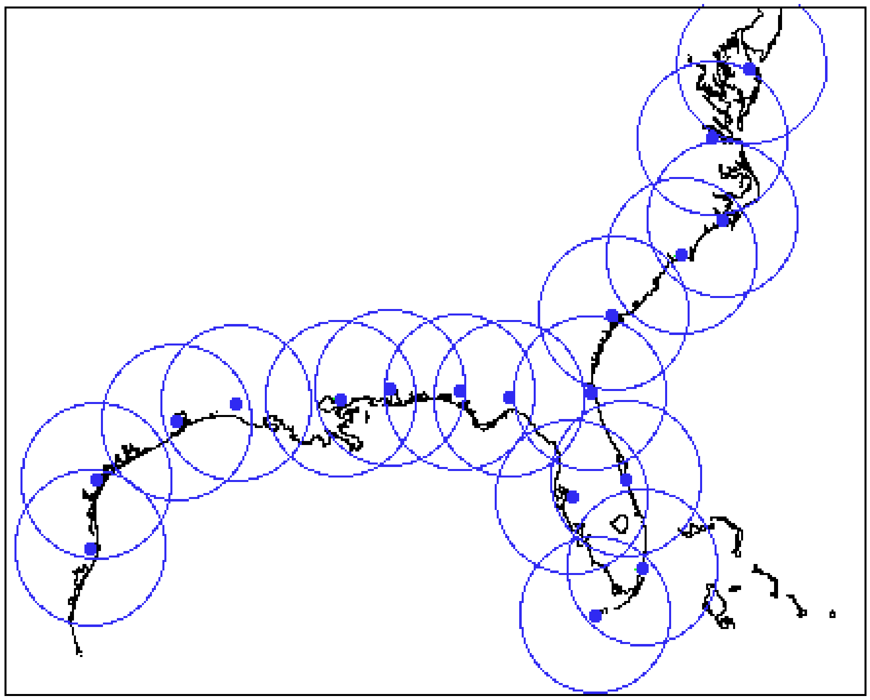


Fig. 10. The locations of the WSR–88D coastal radar sites. Range rings are at 125 nm (230 km) radius.

If a significant tropical cyclone moves within 215 nm (440 km) of the coast of the Eastern or Southern United States, then a WP-3D will obtain Doppler radar data to be combined with data from the closest WSR-88D radars in dual-Doppler analyses. The tail radar is tilted to point 20% forward and aft from the track during successive sweeps (the fore-aft canning mode: F/AST). These analyses could resolve phenomena with time scales <10 min, the time spanned by two WSR-88D volume scans. This time series of dual-Doppler analyses will be used to describe the storm's inner core wind field and its evolution. The flight pattern for this experiment is designed to obtain dual-Doppler analyses at intervals of 10-20 min in the inner core. Unfortunately, these WSR-88D /aircraft dual-Doppler analyses will not be available in real-time, but the Doppler wind fields could be incorporated into post-storm surface wind analyses. The data set will also be useful for development and testing of TC algorithms for the WSR-88D. The Doppler data will be augmented by dropping GPS-sondes near the coast, where knowledge of the boundary-layer structure is crucial for determining what happens to the wind field as a strong storm moves inland. GPS-sondes will also be dropped in the eyewall in different quadrants of the hurricane. To augment the inner core analyses, dual-Doppler data can also be collected in the outer portions of the storm, beyond the range of the WSR-88D, because the alternating forward and aft scans in F/AST mode intersect at 40%, sufficient for dual-Doppler synthesis of winds.

Recent GPS sondes dropped at and inside the flight-level radius of maximum winds (RMW) in strong hurricanes have shown remarkable variations of the wind with height. A common feature is a wind speed maximum at 300-500 m altitude. Theoretical and numerical modeling of the hurricane boundary layer suggest that the low-level jets are common features. The height of the jet varies by storm quadrant, and modeling indicates that this variation can be enhanced as a hurricane crosses land. Careful observations during hurricane landfall could help document these changes, as well as help us better understand how the boundary layer adjusts at the coast in offshore flow. This could further help reduce uncertainties in reduction of flight level winds to surface (10 m) values in operational wind analyses of landfalling hurricanes.

Previous observational studies have shown that the primary mechanism responsible for the decay of TCs after landfall is the large reduction in latent and sensible heat fluxes. These post-landfall reductions in surface fluxes have been shown to be the result of decreases in land temperature beneath the storm. It also has been shown that these decreases in land temperature are due to the limited heat capacity of the soil subsurface. Several studies have also shown that the rate of TC decay after landfall is proportional to the landfall intensity and that the winds associated with landfalling TCs decrease rapidly within the first few kilometers of the coastline. However, the above findings have typically relied upon a relatively sparse observational network and/or compositing techniques that assume stationarity over a considerable length of time. Clearly, collecting high resolution landfall data sets against which the above findings can be verified is a worthwhile task, particularly in light of the substantial damage and loss of life that occurred in inland regions during Hurricanes Hugo (1989), Andrew (1992), Opal (1995), Fran (1996), and Floyd (1999).

There are outstanding questions on tropical cyclone rainbands and electrification that can be studied during a landfall mission. Spiral-shaped patterns of precipitation characterize radar and satellite images of tropical cyclones. The earliest radar observations of tropical cyclones detected these bands, which are typically 3-36 nm (5-50 km) wide and 55-160 nm (100-300 km) long. Nevertheless, many aspects of their formation, dynamics, and interaction with the symmetric vortex are still unresolved. The precipitation-free lanes between bands tend to be somewhat wider than the bands. The trailing-spiral shape of bands and lanes arises because the angular velocity of the vortex increases inward and distorts them into equiangular spirals. As the tropical cyclone becomes more intense, the inward ends of the bands approach the center less steeply approximating arcs of circles. A dynamical distinction exists between convective bands that spiral outward from the center and convective rings that encircle the center.

The lack of rainband observations leaves us to infer and assume critical elements of rainband structure that may be of fundamental importance to our understanding of the tropical cyclone. It seems clear that concentric eyewalls can affect hurricane intensity, and available evidence suggests that convectively-active non-concentric rainbands may play a role in the intensity changes in the hurricane core. It is extremely important that we understand the structure of rainbands and secondary eyewalls and how they may impact the hurricane environment. The rainband module is designed to address these issues by gathering kinematic data in and around hurricane rainbands. In addition, with the new GPS-sondes, it is possible to sample some of the thermodynamic aspects of the hurricane boundary layer. Our understanding of the fluxes at the top of either the mixed layer or the thicker inflow layer is not well known. There are no reliable measurements of the flux at the top of the inflow layer, nor are there reliable estimates of the depth of the inflow. This is despite the conclusions from budget studies and simple numerical models that identify the mixing at the top of these layers as a vital part of the hurricane circulation.

Recent analyses of an intense rainband in Hurricane Gilbert (1988) support the hypothesis that the fluxes at the top of the inflow layer are large and downward into the inflow layer. This is counter to the typical situation where the flux of energy is out of the layer and into the middle troposphere. These fluxes can rival the fluxes at the air-sea interface. There appeared to be regions in Gilbert where the inflow layer rapidly increased in θ_e, and other regions where the flux divergence of θ_e resulted in very slowly changing conditions. Rainband circulations have been implicated in this highly asymmetric input of energy into the storm's inflow layer. Strong rainbands like the one sampled in Gilbert are similar in circulation to an eyewall. We hypothesize that the eyewall circulation itself will have a profound affect on its own inflow, and may lead to a recycling of high θ_e, into the top of the inflow layer.

Neither the microphysical nor the electrical structure of TC clouds that exhibit lightning is known. Laboratory experiments have shown that more charge is separated when ice crystals collide with a rimed target in the presence of supercooled water than is separated without supercooled water. They also showed that the sign of the charge transferred reversed at about –20° C. Other laboratory experiments showed that the growing conditions encountered by the ice particles determined the sign of the charge that was transferred between them during collisions. Observations in continental thunderstorms support this hypothesis and suggest that charge separation occurs most rapidly on the boundary between the main updraft and the downdraft near –15° C. More recent observations showed that sublimating graupel acquire negative charge and graupel undergoing deposition acquire positive charge. As these processes depend critically upon the graupel temperature and cloud liquid water content, it is highly desirable to obtain suitable measurements in natural clouds.

In mature hurricanes, updraft velocities are usually low. In addition, graupel and ice particles are plentiful, but supercooled cloud water is rare in hurricanes at temperatures as warm as -5 C. Studies of two mature Atlantic hurricanes have shown that the little supercooled water present in the strongest eyewall updrafts was immediately adjacent to areas that contained high concentrations of small ice particles. When one considers the lack of supercooled water in mature hurricanes, it is not surprising that mature hurricanes are not always electrified. However, the National Lightning Detection Network (NLDN) detected lightning in several hurricanes and tropical storms as they approached land.

A recent investigation noted that there appeared to be a relationship between the occurrence of CG lightning in the eyewall and a subsequent intensification of the hurricane. A similar relationship was proposed by studies of lightning observations in two developing TCs. In each case, lightning was qualitatively associated with exceptionally strong convection, which occurred when the storms were rapidly intensifying. In addition, recent observational studies of CG lightning in TCs using data from the NLDN showed that CG lightning is most prevalent in the outer convective rainbands of hurricanes with little CG lightning near the eyewall. An apparent paradox is thus created as research shows that vertical velocities in rainbands are weaker than those in the eyewall. It is important to note, however, that rainbands >54 nm (100 km) outside of the eyewall remain virtually unsampled. Based upon the above findings, we hypothesize that supercooled water and charge separation occasionally occur in the strong convection in TCs. The recent additions of the four rotating vane field mills that measure the vector electric field and an induction ring that measures the charge on individual particles to the suite of instrumentation already on board the WP-3D aircraft will help to confirm or refute this hypothesis.

Objectives:

1. Collect flight level wind data and make surface wind estimates to improve real-time and post-storm surface wind analyses in hurricanes.
2. Collect airborne Doppler radar to combine with WSR-88D radar data in post-storm three-dimensional wind analyses.
3. Document thermodynamic and kinematic changes in the storm during and after landfall.
4. Determine the kinematic and thermodynamic characteristics inside (toward the eye) and outside of hurricane rainbands, including those that form convective rings.
5. Measure the characteristics of the middle troposphere and the hurricane boundary layer through utilization of GPS-sonde data.
6. Determine how different inflow trajectories that may pass over land, and warmer or cooler waters alter the energy content of the inflow.
7. Measure the sign and magnitude of the vector electric field near the eyewall and in an outer convective rainband.
8. Determine the polarity and magnitude of the charge on ice precipitation at several temperature levels above the melting level.
9. Estimate the transport of electrical charge in the storm.
10. Record the types and concentrations of all particle types observed in the electrically active portions of the storm.
11. Document changes in microphysics and rainfall characteristics in the storm during and after landfall.
12. Obtain a remote sensing database suitable for evaluation and improvement of satellite and ground validation rainfall estimation algorithms for landfalling TCs.

Mission Description:

This experiment is designed to be conducted by flying one or two single aircraft missions with a NOAA WP-3D aircraft when a hurricane moves within 215 nm (400 km) of the U.S. coastline. The first of these 2 flights will typically consist of the real-time module followed by either the rainband , electrification , or post-landfall module. If the storm either moves parallel to the coastline or moves slowly inland and resources permit, the experiment may be repeated with a second flight. While the storm's location relative to the coastline will dictate which combination of these modules will be ultimately flown, the real-time module will generally precede all of the other modules. In addition, the rainband and electrification modules will only be flown while the storm is still over water.

This mission requires that the aircraft have working lower fuselage and tail radars. The HRD workstation should be on board, so we can transmit GPS sonde and radar images back to TPC/NHC. Microphysical data should be collected, to compare rainfall rates with those used in the WSR-88D precipitation products. The SFMR should be operated, to provide estimates of wind speed at the surface. If the C-SCAT is on the aircraft then it should also be operated to provide another estimate of the surface winds. All efforts should be made to ensure that Level II data are recorded at the WSR-88D radars closest to landfall and the initial inland

If the portable Doppler radars (Doppler on Wheels DOW), portable profilers and portable wind towers are able to participate in the experiment then they should be deployed between ~65 and 130 km inland in the onshore flow regime as depicted in Fig. 11. If possible, one of the DOWs should be positioned relative to the nearest WSR-88D such that the dual-Doppler lobes cover the largest area of onshore flow possible. In the schematic shown below (Fig. 11), one of the DOWs is positioned north-west of the Melbourne WSR-88D so that one dual-Doppler lobe is over the coastal waters and the other covers the inland region. The profiler is positioned in the inland dual-Doppler lobe to provide independent observations of the boundary layer to anchor the dual-Doppler analysis.

The primary module of the experiment, the "real-time module", will support real-time and post-storm surface wind analyses. Two dual-Doppler options can be flown if the storm is near a WSR-88D radar. The flight patterns will depend on the location and strength of the storm relative to surface observing platforms and coastal radars.

Real-time module:

The real-time module combines passes over marine surface platforms with one or more figure four patterns in the core of the hurricane. The aircraft flies at or below 5,000 ft (1.5 km) (ideally at 2,500 ft [750 m]), so that flight level winds can be adjusted to 30 ft (10 m) to combine with measurements from marine surface platforms. Flight-level data and GPS-sondes dropped near the platforms will be used to validate the adjustment method. Note that if the storm is outside of WSR-88D Doppler range then the figure-4 pattern could be repeated before returning home, or the rainband or electrification module could be flown.

The landfall flight pattern should take advantage of buoys or C-MAN sites nearby, if those platforms are expected to experience winds > 25 m/s.. The aircraft descends at the initial point and begins a low-level figure-4 pattern, possibly modifying the legs to fly over the buoys (Fig. 11). The radar will be in F/AST mode. If time permits the aircraft would make one more pass through the eye and then fly the dual-Doppler option. In this example, the pattern would be completed in about 2.5 h. GPS-sondes would be dropped near the buoys or C-MAN sites, and additional sondes will be dropped at or just inside the flight level radius of maximum winds (RMW).

If the timing is such that the storm is farther off the coast than desired for landfall, then the aircraft can execute the Rainband Module (see Fig. 12 below) to map the thermodynamic structure of the inflow. The flight pattern should overfly any buoys or C-MAN sites that are in high wind regimes and include legs coordinated with a WSR-88D.

Dual-Doppler Option: If the TC moves within Doppler range of a coastal WSR-88D 125 nm (230 km), then we will fly a second module, to collect a time-series of dual-Doppler data from the storm's inner core. Note that the optimal volume scans for this pattern will be obtained when the storm is 32-80 nm (60-150 km) from the radar, because beyond 80 nm (150 km) the lowest WSR-88D scan will be above 5,000 ft (1.5 km) which is too high to resolve the low-level wind field. Within 32 nm (60 km) the volume scan will be incomplete, because the WSR-88D does not scan above 19.5%.

The pattern will depend on the location of the storm relative to the coastal radar. Depending on safety and operational considerations, the aircraft could fly this portion of the experiment at a higher altitude, although 5,000 ft (1.5 km) would still be preferred. After completing the real-time module the aircraft flies to an initial point on the track intersecting the storm center and the coastal radar. The aircraft then makes several passes through the eyewall (A-B in Fig. 11). Depending on the size of the eyewall each pass should last 10-20 min. It is essential that these passes be flown as straight as possible, because turns to fix the eye will degrade the Doppler radar coverage. After each pass the aircraft turns quickly and heads back along the same track, adjusted to keep the storm center and the coastal radar on the same line. In 2 h, 6-12 volume scans will be collected. The last pass should be followed by a pass through the eye perpendicular to the other legs, to provide data for dual Doppler analyses. If time permits, the real-time module could be repeated before returning home, or the coastal-survey, rainband, electrification, or post-landfall module could be flown.

Coastal Survey module:

When the hurricane is making landfall, this module will provide information about the boundary layer in the onshore and offshore flow regimes. On the first coastal pass the WP-3D would fly parallel 10-15 km offshore to obtain SFMR surface winds (1-2 in Fig. 16). The track should be adjusted so that the SFMR footprint is out of the surf zone. The second pass should as close to the coast as safety permits, to sample the boundary layer transitions at the coast in onshore and offshore flow (3-4 in Fig. 16). The first pass should be at 5,000 ft (1.5 km) or less, and the aircraft could climb to higher altitudes for the second pass. On both of these passes the aircraft should fly to 150 km or the radius of gale-force winds and drop GPS-sondes at the RMW and at intervals of 12.5, 25, 50, 75 and 100 or 125 km on either side of the storm track, to sample both onshore and offshore flow regimes. Finally, to better sample the adjustment of the off shore flow from land to ocean a short leg would be flown from the coast spiraling towards the storm center. 3-4 sondes would be dropped quite near the coast, followed by 3-4 sondes spaced every 20-30 km along the trajectory. The Doppler radar will be in F/AST mode, to provide wind estimates on either side of the aircraft track. This module could be flown when the hurricane is making landfall or after the storm moves inland. The pattern could be flown in ~2 h.

Rainband module:

The single aircraft rainband thermodynamic structure module has been designed to be flown with other experiments in "rainbands of opportunity" and last 30-60 min (Fig. 12). The goal of the module is to gather data inside, outside, and across several rainbands of several storms over several seasons. While individual data sets will increase our understanding of the structure of rainbands, the primary objective here is to develop a database of rainband observations for future comprehensive study.

This module requires one WP-3D flying above the inflow layer (8,000 to 10,000 ft). The WP-3D deploys 6-8 GPS-sondes and an occasional AXBT along a curved track approximately 60 nm (100 km) long that roughly mimics the inflow trajectory for air in the subcloud and lower cloud layers. Deployment of the GPS-sondes occurs between the eyewall outer edge and the inner edge of any convective rainband found at greater radial distance. If there are no rainbands then sonde deployment may cease at approximately 60 nm (100 km) radial distance from the circulation center. Fig. 12a is a plan view of the experiment, Fig. 12b is a radius-height cross-section of the scheme. Note that shorter times between each GPS launch are preferred when the aircraft is near the eyewall. A sonde should also be deployed in the eye. A typical spiral path should be 20-40 from a tangent to a given radius. Flight time for 60 nm (100 km) is about 15-20 min.

GPS-sondes are deployed every 6-9 nm (10-15 km) starting from about 6 nm (10 km) from the outer edge of the eyewall to insure that the sonde falls outside of the main updraft and rain. After four sondes are in the air and the first sonde splashes down a new one may be deployed. The design assumes that 4 sondes may be in the air simultaneously and that the sonde descends at about 10 m s-1.

A single spiral in or out will provide a view of how energy content changes along a trajectory for one portion of the storm. If several trajectories are sampled then energy content and cyclone intensity can be studied. Judicious choice of the inflow trajectories to be flown is made by the airborne mission scientist and would likely include sampling inflow from the southeast and from the northwest as shown in Fig. 12a.

Electrification Modules:

The aircraft must be equipped with the DRI electric field instruments in addition to the standard instrumentation. The PMS probes must be the best available, and the radars must be fully operational. The experiment is composed of three options. In all options, it is desirable to have 4 to 6 GPS-sondes to obtain soundings outside the convection in the inflow near the areas of interest.

Rainband option: If a convective outer rainband is available >80 nm (150 km) from the eye, it should first be surveyed for evidence of electric fields. The survey consists of flying along the band until the field mills register a space charge or the Doppler radar reveals the presence of vigorous convection. When an interesting area is located, the aircraft should either seek a clear area and climb to maximum altitude or descend to the 0 C (~16,000 ft [4.8 km]) altitude, whichever is closer, and start making passes downwind (Fig. 13a) through the middle of the band. Each downwind pass (Fig. 13a) should maintain a track along the axis of the band and be about 50 nm (93 km) long and 1,500 ft (500 m) higher (lower) than the previous one. During this portion of the pattern, the Doppler radar should make 360% scans normal to the aircraft track. After the downwind pass is completed, the aircraft should exit the band on the outer side, climb (descend), and return (Fig. 13a, 3-4) upwind to the start of the band. The Doppler data will be obtained on the upwind pass using the F/AST method. This pattern will require about 20 min to execute. Pass length may be altered as circumstances dictate. Repeat this pattern until the maximum altitude is reached, or seek a new area as desired. As an alternate, a zigzag path downwind through the convective band may be flown if necessary for flight safety.

Landfalling storm option: The purpose of this option is to investigate the relationship between cloud physics, vertical velocity, and the occurrence and location of CG lightning. Outer convective rainbands are of primary interest since they are the most likely features to be electrified. Vertically pointing Doppler rays are used to estimate vertical air motions during passes through active convection in both tropical storms and hurricanes. Along with the vertical velocities, coincident microphysics and electric field measurements are made at heights above the melting level.

The aircraft should initially fly a survey figure-4 pattern (Fig. 13b) at ~18,000 ft (5.5 km) altitude. The figure-4 pattern would be completed in 1.5-2.0 h with radial legs 80 nm (150 km) in length. The second part of this option (Fig. 13b) concentrates on rainbands that are located within the useful range of the NLDN. Upon exiting the eye at 4, the aircraft should climb as high as possible on the way to the rainband of interest (5). A sawtooth pattern is flown downwind (Doppler operating in standard mode) with repeated crossings of the rainband to 6. We prefer to fly directly down the band, but for reasons of safety, a sawtooth pattern may be flown. An upwind leg, flown outside of the band, is performed with the tail radar operating in the F/AST mode. The sawtooth pattern across the band is repeated with an exit toward the eye at 7. After entering the eye, the aircraft turns toward the second rainband at 8. The sawtooth crossings and the F/AST downwind leg are repeated as in the first rainband. About one hour should be spent in each of the rainbands. If only one rainband is present within the useful range of the NLDN, a second study of the same band can be performed after a circuit through the storm center.

Post-Landfall Module:

This module is designed to collect kinematic and thermodynamic data ~1-2 h prior to and up to 6 h after a hurricane makes landfall. It is essential that ground based measurements are obtained in conjunction with those that are being made by aircraft, since the primary goal of this module is to determine the kinematic and thermodynamic changes that occur after a hurricane makes landfall, throughout the depth of the lower troposphere.

The WP-3D will fly a coastal survey pattern followed by a figure-4 pattern (Fig. 14) over land with leg lengths ~150 km at an altitude of ~15,000 ft (5 km). The WP-3D tail radar should be in F/AST mode. These data will aid in rainfall estimation and will help document the changes in vortex and rainband structure over land that are crucial to understanding the environment that supports tornado and mesovortex development.

Over land, available portable wind towers, mesonet stations, profilers and DOW radars should be deployed along the path of the landfalling hurricane to identify the changes in storm structure as the hurricane moves inland. The wind towers and mesonet stations will obtain high-resolution surface wind, temperature, pressure, relative humidity, and perhaps rainfall measurements. A profiler will be placed at the center of each line of mesonet stations. The profilers and RASS sounder will provide wind and temperature measurements within the lowest 3 and 1 km, respectively. Rain gauges should be located at each profiler and DOW radar site to obtain high-resolution rainfall measurements, both for calibrating the radar rainfall algorithms and for documentation of storm rainfall.

The first set of towers and mesonet stations should be placed as close as possible to the coastline (<10 km) to enable accurate documentation of the surface wind field just after landfall. Other towers or mesonet stations should be placed ~65 and 135 km inland respectively; however, these distances will vary depending upon the intensity and speed of motion of the landfalling storm as well as safety considerations. Fig. 15 shows the estimated time after landfall that is required for the TC winds to decay to various wind threshold levels as determined using the HRD empirical inland wind decay model. The spacing between the mesonet stations located within each group should be ~30 nm (50 km) perpendicular to the track to maximize the likelihood that one of the mesonet stations will be located near the radius of maximum wind of the landfalling storm.

If the inland profilers are mobile, it will be possible to follow severe weather producing rainbands if safety and logistical considerations allow. The DOW Doppler radars should be placed roughly halfway between the two rear lines of mesonet and profiler stations. The DOW radars in combination with the profilers with RASS will aid in documenting the changes in kinematic and thermodynamic structure of the hurricane after landfall. An accurate analysis of such changes is crucial to learning more about the development of mesovortices and/or tornadoes spawned by landfalling hurricanes. They will also help document the changes in winds within the PBL of a landfalling hurricane. Finally, the radars will aid in the measurement of the rainfall associated with the landfalling hurricane.

TROPICAL CYCLONE WINDFIELDS NEAR LANDFALL EXPERIMENT

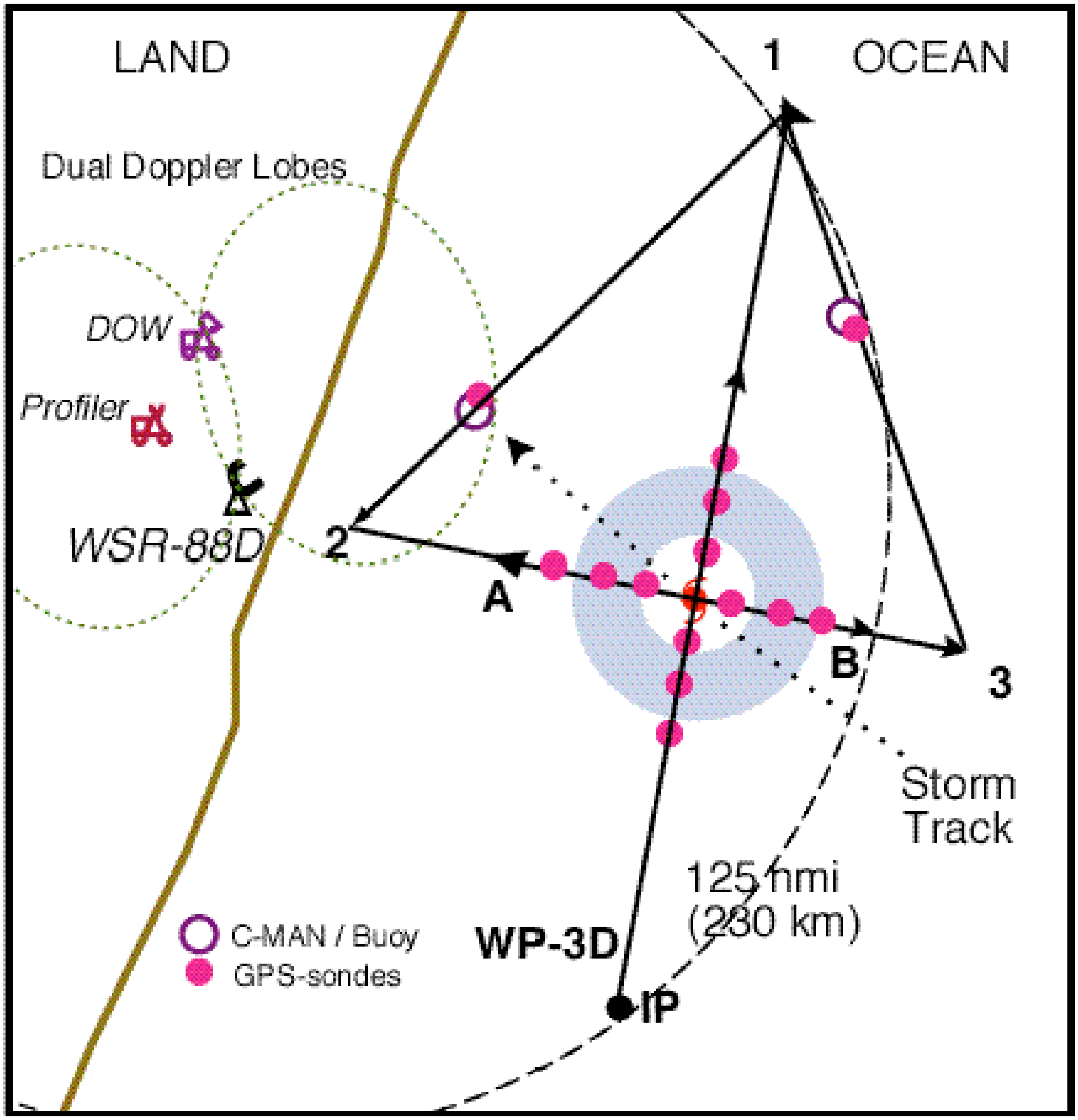


Fig. 11. Flight track for the real-time module with over flights of moored buoys for a storm passing within range of a coastal WSR-88D.

• Note 1.	True airspeed calibration required.
• Note 2.	The legs through the eye may be flown along any compass heading along a radial from the ground-based radar. The **IP** is approximately 100 nm (185 km) from the storm center. Downwind legs may be adjusted to pass over buoys.
• Note 3.	If possible, the WP-3D should fly legs along the WSR-88D radials. Set airborne Doppler radar to F/AST scanning on all legs.
• Note 4.	All aircraft should avoid penetration of intense reflectivity regions (particularly those over land). Wind center penetrations are optional.

TROPICAL CYCLONE WINDFIELDS NEAR LANDFALL EXPERIMENT

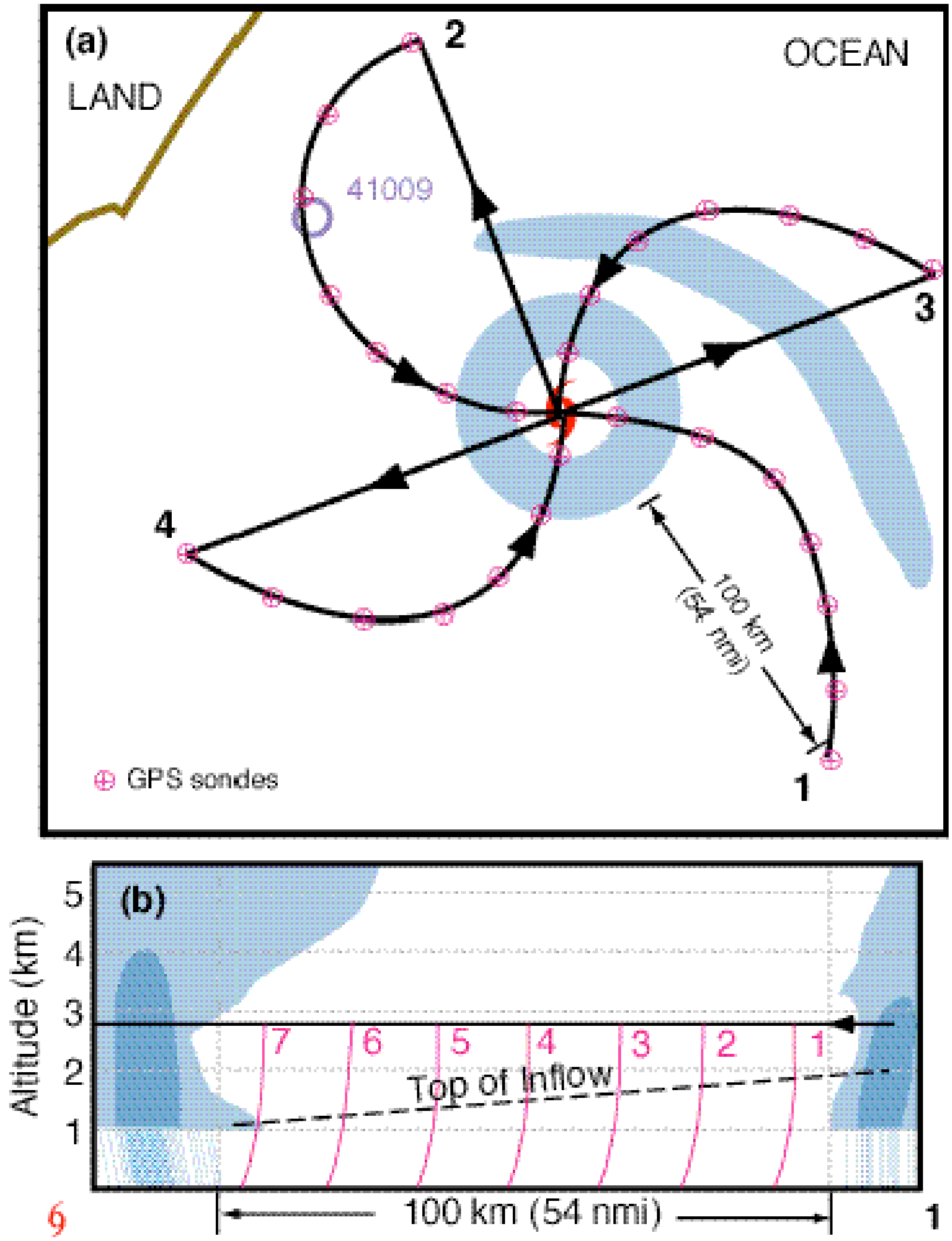


Fig. 12. Rainband Thermodynamic Structure Module (a) Plan view; and (b) track-height depiction.

- Note 1. True airspeed calibration required.
- Note 2. WP-3D Doppler radar should be operated in F/AST mode at a single PRF ≥2400 and 20° tilt

TROPICAL CYCLONE WINDFIELDS NEAR LANDFALL EXPERIMENT

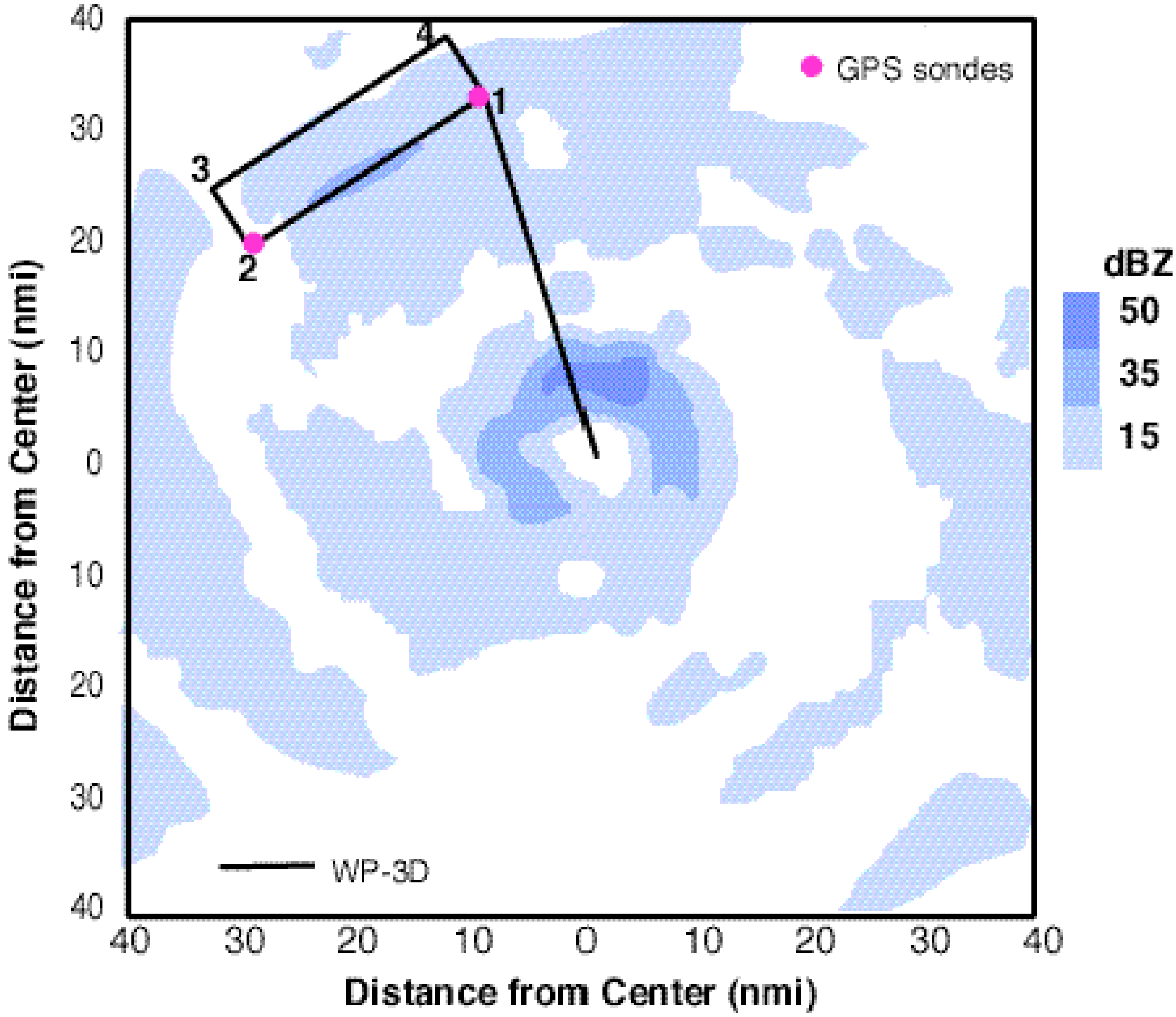


Fig. 13a. Electrification rainband module flight pattern.

• Note 1.	True airspeed calibration is required.
• Note 2.	The pattern may be flown along any compass heading.
• Note 3.	Rainband passes **1-2** are separated by 1500 ft (500 m) altitude. Climbs (descents) occur along **3-4** outside the convection.
• Note 4.	Set airborne Doppler radar to continuously scan perpendicular to the track from **1-2**, and in F/AST mode at a single PRF ≥2400 and 20° tilt on all other legs.

TROPICAL CYCLONE WINDFIELDS NEAR LANDFALL EXPERIMENT

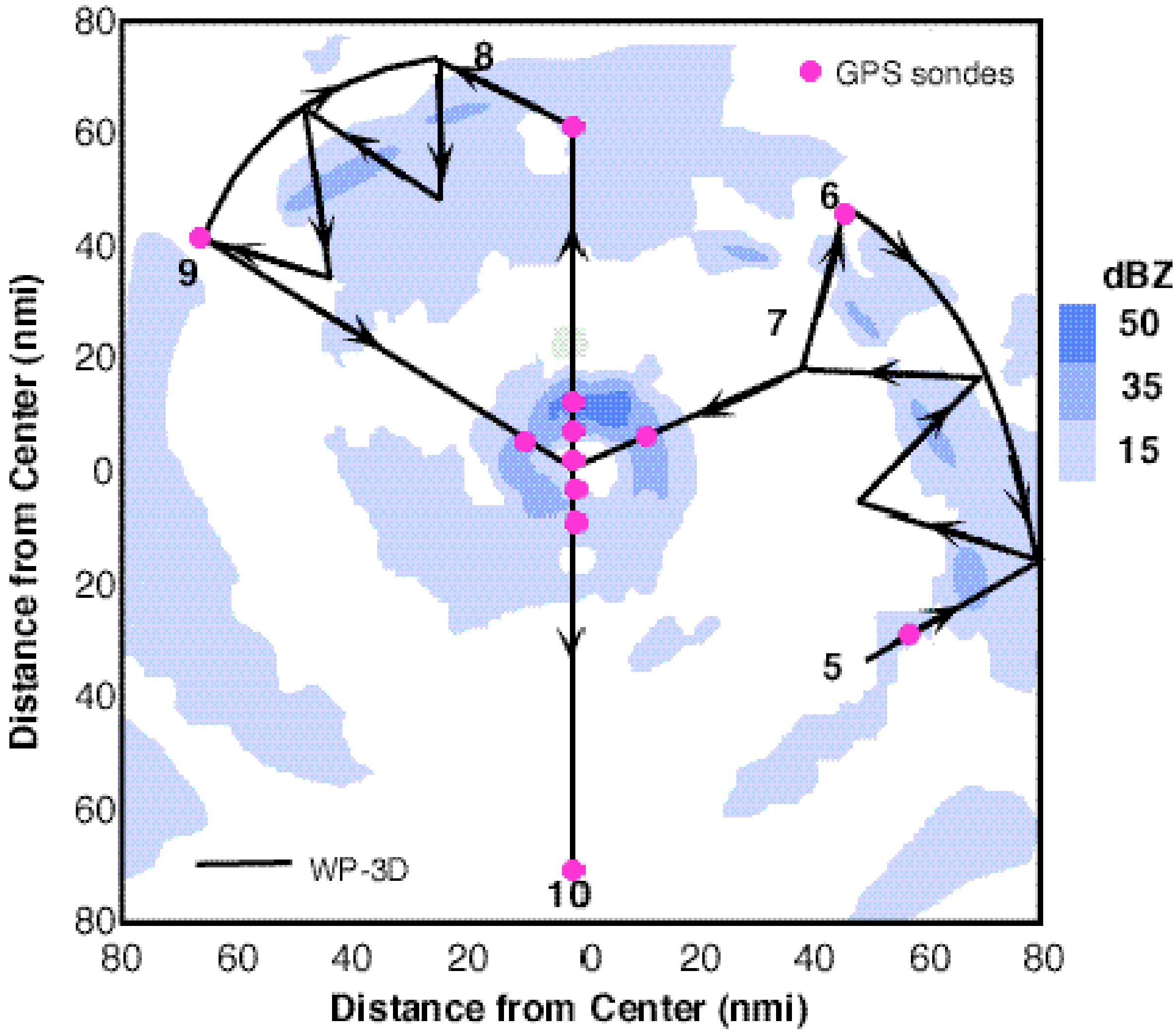


Fig. 13b. Electrification landfall module flight pattern.

• Note 1.	Fly zigzag legs **5-6** and **8-9** at highest possible altitude. Each leg is approximately 25 nm (45km) long. Outside turns of 270°-300° are at the end of each zigzag leg.
• Note 2.	At **6** and **9** fly upwind leg along rainband at highest possible altitude to a point near the beginning of the zigzag legs.
• Note 3.	Repeat pattern in different parts of the storm as time permits.
• Note 4.	Set airborne Doppler radar to scan in F/AST mode on all legs.

TROPICAL CYCLONE WINDFIELDS NEAR LANDFALL EXPERIMENT

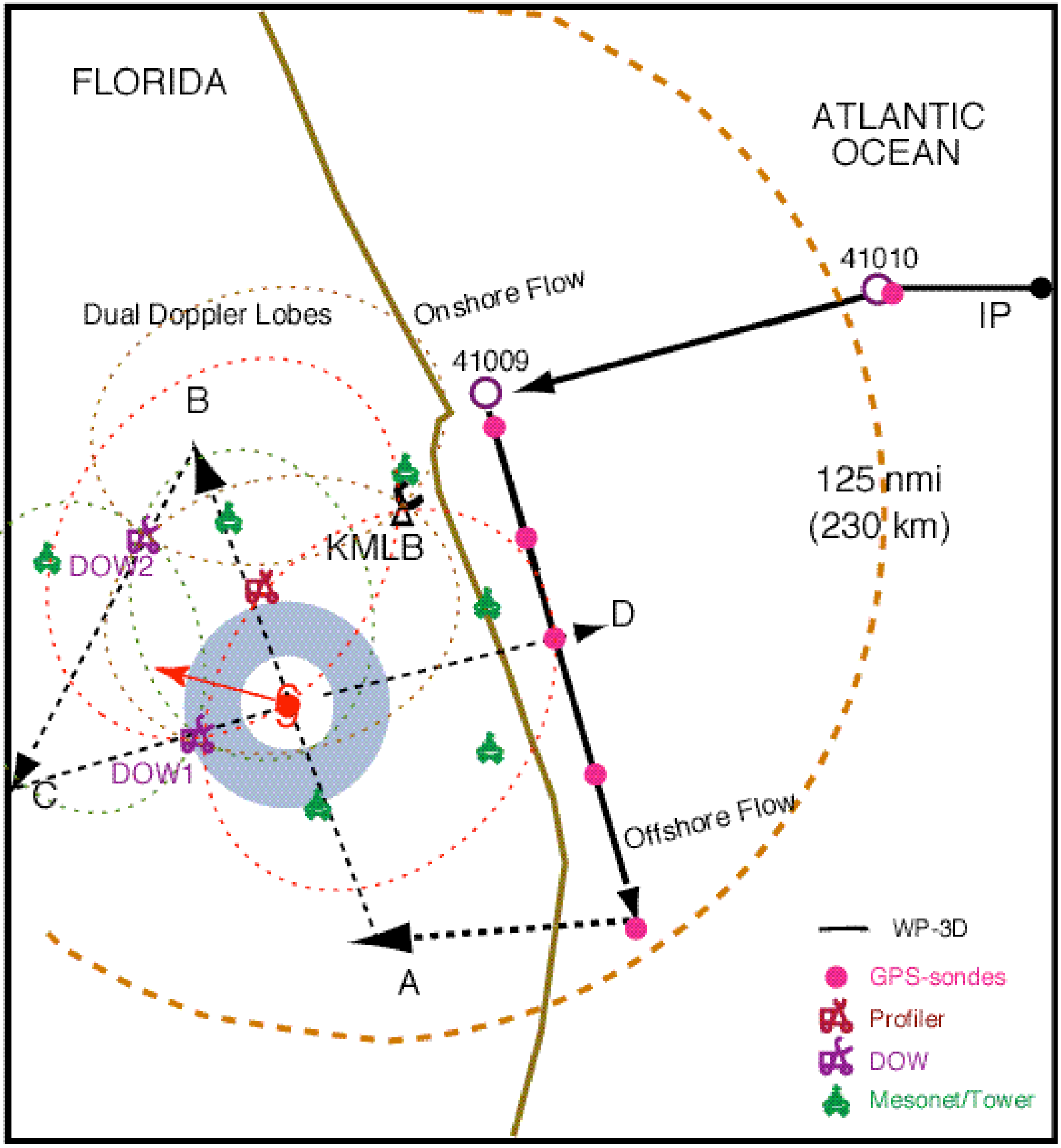


Fig. 14. Post landfall module flight pattern.

• Note 1.	The WP-3D should fly a coastal survey pattern (sold line) at an altitude of ~10,000-15,000 ft (3-4 km) dropping GPS-sondes near buoys of opportunity and within 10-20 km of the shore in both the onshore and offshore flow regimes.
• Note 2.	The WP-3D executes a figure-4 pattern (dashed line) centered on the storm with leg lengths of ~80 nm (150 km) at an altitude of ~15,000 ft (5 km).
• Note 3.	If possible, the WP-3D should fly legs along the WSR-88D radials. Set airborne Doppler radar to F/AST scanning on all legs.
• Note 4.	All aircraft should avoid penetration of intense reflectivity regions (particularly those over land). Wind center penetrations are optional.

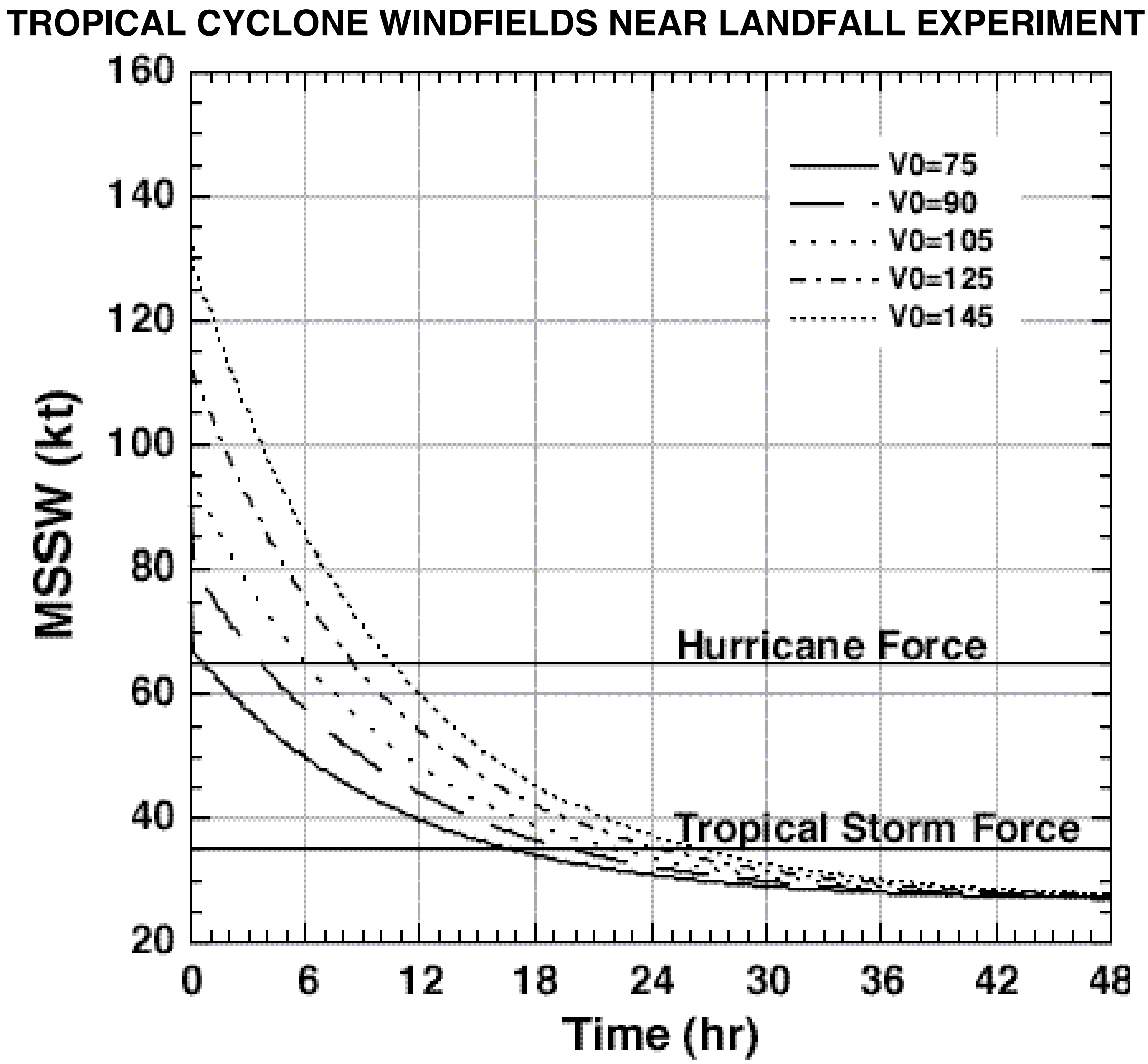


Fig. 15. **Maximum sustained surface winds (MSSW) after landfall estimated using the Kaplan/DeMaria inland wind decay model for TCs with landfall intensities (V0) of 75,90,105,120, and 145 kt.**

TROPICAL CYCLONE WINDFIELDS NEAR LANDFALL EXPERIMENT

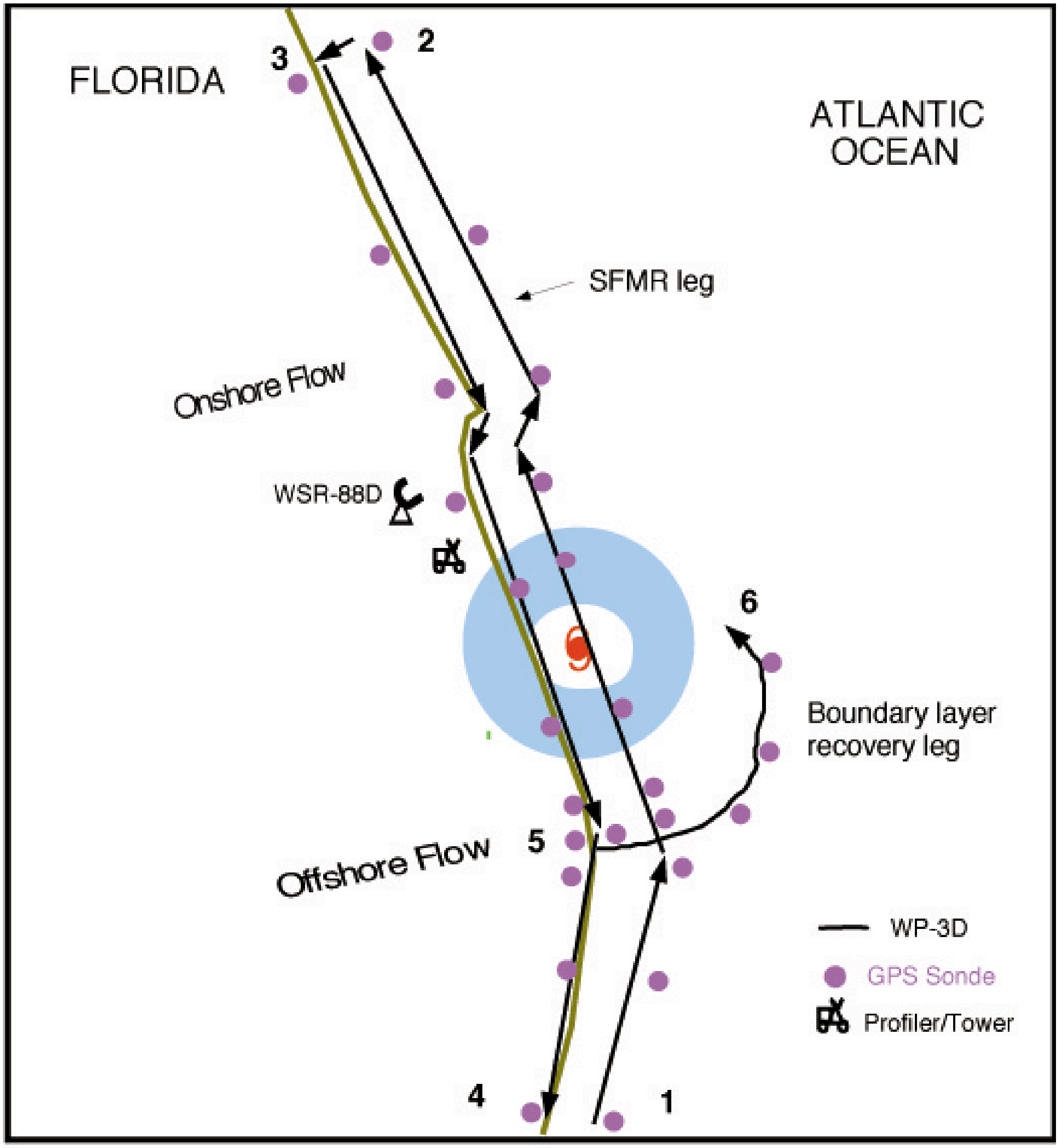


Fig. 16. Coastal Survey pattern.

- Note 1. True airspeed calibration required.
- Note 2. First pass starts 150 km from center or radius of gale-force winds, whichever is closer. Pass from **1-2** should be 10-15 km offshore for optimum SFMR measurements.
- Note 3. Sondes are dropped at RMW, and 12.5, 25, 50 , 75 and 100 or 125 km from RMW on ether side of storm in legs **1-2** and **3-4**.
- Note 4. Sondes should be deployed quickly at start of leg **5-6**, and then every 10-15 km hereafter.
- Note 5. Set airborne Doppler to scan in F/AST scanning on all legs, with single PRF > 2400 and 20% tilt.
- Note 6. Aircraft should avoid penetration of intense reflectivity regions (particularly those over land).

12. Hurricane Synoptic-Flow Experiment

Program Significance: Accurate numerical TC forecasts require the representation of meteorological fields on a variety of scales, and the assimilation of the data into realistic models. Omega dropwindsonde (ODW) observations from WP-3D aircraft obtained between 1982 and 1996 during the Hurricane Synoptic Flow Experiment produced significant improvement in the guidance for official track forecasts. Since 1997, fifty operational "Synoptic Surveillance" missions have been flown with the NOAA G-IV jet in the environments of TCs threatening the United States coastline; almost half of these have been supplemented with dropwindsonde observations from one or two WP-3D aircraft during Hurricane Synoptic Flow Experiments. An improved dropwindsonde based on the Global Positioning System has been developed by the National Center for Atmospheric Research and has replaced the ODW. With further operational use of the G-IV aircraft, and as other mobile observing platforms become available, optimal sampling and utilization techniques must be devised to provide the greatest possible improvement in initial condition specification.

Objectives: The goal of the HRD synoptic flow experiment is to improve landfall predictions of TCs by releasing dropwindsondes in the environment of the TC center. These data will be used by TPC/NHC and NCEP to prepare objective analyses and official forecasts through their assimilation into operational numerical prediction models. Because the atmosphere is known to be chaotic, very small perturbations to initial conditions in some locations can amplify with time. However, in other locations, perturbations may result in only small differences in subsequent forecasts. Therefore, targeting locations in which the initial conditions have errors that grow most rapidly may lead to the largest possible forecast improvements. Locating these regions that impact the particular forecast is necessary. When such regions are sampled at regularly-spaced intervals the impact is most positive. The optimal resolution of these intervals is an ongoing area of research.

A number of methods to find targets have been investigated, mainly in the wintertime extratropics. Potential vorticity diagnosis can help to find the cause of forecast failure. Singular vectors of the linearized equations of motion can estimate the growth of small perturbations in the model. This method is relatively expensive, and full implementation in the Tropics where adiabatic processes dominate has proven difficult, and the linear assumption tends to break down at the 72 h forecast time necessary for the posting of hurricane watches and warnings. Related strategies involve the sensitivity vector, and quasi-inverse linear method. All these methods may depend on the accuracy of the initial conditions determined without the supplemental data.

A fully nonlinear technique uses the breeding method, the operational NCEP perturbation technique in which initially random perturbations are repeatedly evolved and rescaled over a relatively short cycling time. These vectors are related to local Lyapunov vectors and, therefore, define the fastest growing modes of the system. Changes to initial conditions due to dropwindsonde data obtained from operational synoptic surveillance missions during the 1997 and 1998 hurricane seasons grow (decay) in regions of large (small) perturbation in the operational NCEP Ensemble Forecasting System. Therefore, these bred-modes provide a good estimate of the locations in which supplemental observations are likely to have the most impact. However, though the breeding method can find locations of probable error growth in the model globally, it does not distinguish those locations which impact the particular forecast from those which do not.

A more generalized method which can use any dynamical ensemble forecast system is the ensemble transform. This method transforms an ensemble of forecasts appropriate for one observational network into one appropriate for other observational networks. Ensemble forecasts corresponding to adaptations of the standard observational network are computed, and the expected prediction error variance at the observation time is computed for each potential network. The prediction error variance is calculated using the distances between the forecast tracks from all ensemble members and the ensemble mean. This method has shown promise during previous synoptic flow experiments.

Mission Description: To assess targeting strategies a relatively uniform distribution of GPS-sonde soundings will be collected over a minimum period by both NOAA/AOC WP-3D aircraft operating *simultaneously within and surrounding the TC, and in coordination with operational surveillance missions of the G-IV.* Specific flight tracks will vary depending on such factors as the location of the storm, relative both to potential bases of operation and to particular environmental meteorological features of interest, and the operational pattern being flown by the G-IV.

A sample mission is shown in Fig. 17. The two WP-3D aircraft and the G-IV will begin their missions at the same time. Subject to safety and operational constraints, each WP-3D will climb to the 500-mb level (about FL 180) or above, then proceed, step-climbing, along the routes assigned during preflight. *It is particularly important that both aircraft climb to and maintain the highest possible altitude as early into the mission as aircraft performance and circumstances allow, and attain additional altitude whenever possible during the mission.*

GPS-sondes are released in one of two modes. Beyond 40 nm (75 km) from the storm center, drops are made at pre-assigned locations, generally every 25 min or 120 nm (222 km). These drop locations are provided with the particular mission flight tracks 2 h before departure. Within 40 nm (75 km) of the TC's center, drop locations are specified relative to the center's position (e.g., 40 nm (75 km) north of the eye). During in-storm portions of the mission, drops will be made with possible spacing <8 min or 40 nm (75 km). Dropwindsondes should generally be released *after the turn is complete*.

At least one aircraft will fly through the TC center and execute a figure-4 pattern. This aircraft's Doppler radar should be set to scan perpendicular to the aircraft track. *"Hard" center fixes are not desirable*. On the downwind leg of the figure-4, the Doppler should be set to record forward and aft (F/AST) continuously. If both aircraft penetrate the storm, the figure-4 pattern will generally be executed by the *second* aircraft through the storm, and the first aircraft through will collect vertical incidence Doppler data. Coordination with potential USAF reconnaissance is necessary to ensure adequate aircraft separation. The in-storm portion of the missions is shown schematically in Fig. 18, although the actual orientation of these tracks may be rotated.

Of paramount importance is the transmission of the GPS-sonde data to NCEP and TPC/NHC for timely incorporation into operational analyses, models, forecasts, and warnings. Operational constraints dictate an 0600 or 1800 UTC departure time, so that the GPS-sonde data will be included in the 1200 or 0000 UTC analysis cycle. Further, limiting the total block time to 9 h allows adequate preparation time for aircraft and crews to repeat the mission at 24-h intervals. These considerations will ensure a fixed, daily real-time data collection sequence that is synchronized with NCEP and TPC/NHC's analysis and forecasting schedules.

HURRICANE SYNOPTIC FLOW EXPERIMENT

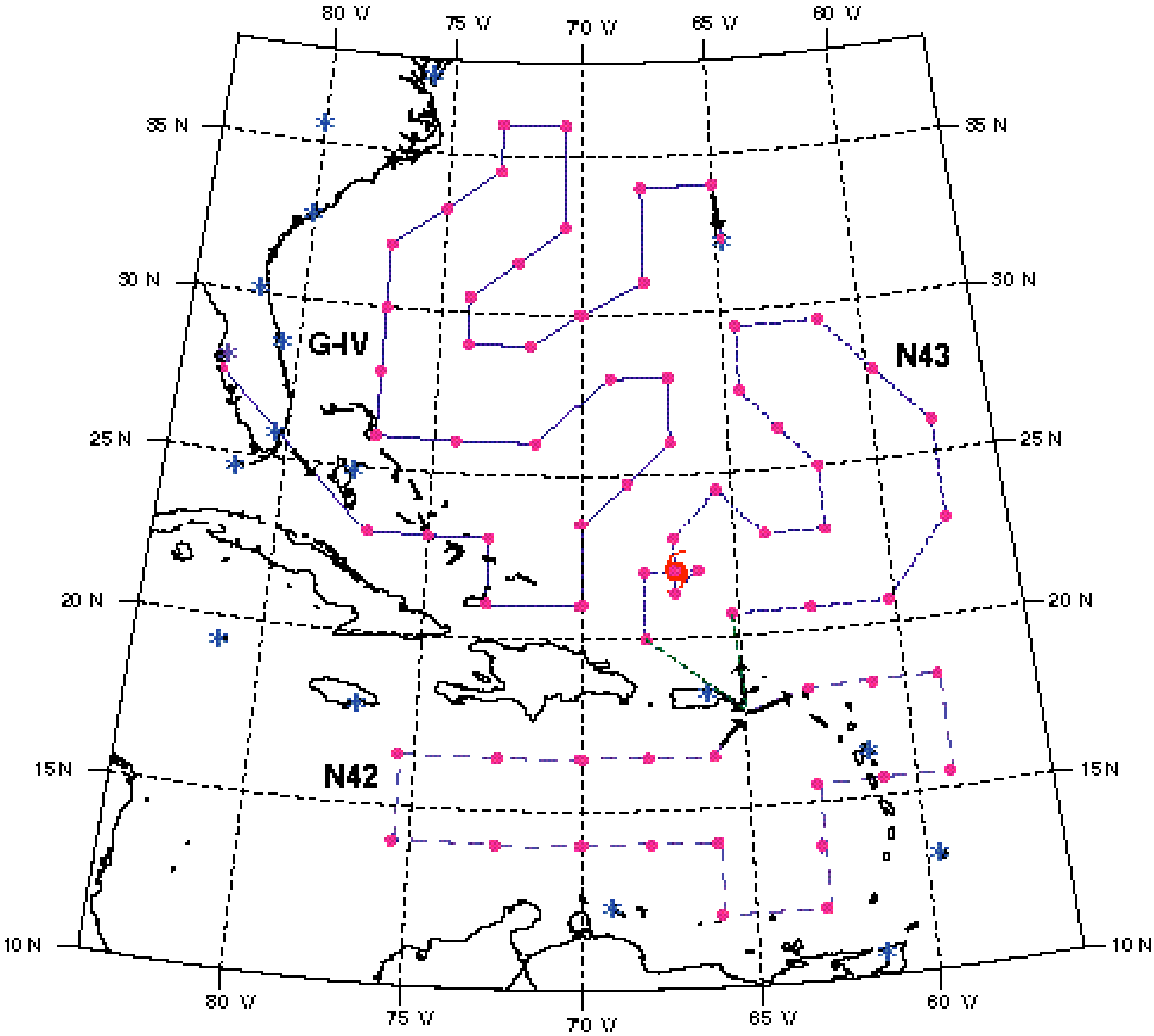


Fig. 17.Sample Environmental Patterns

• Note 1.	During the ferry to the **IP**, the WP-3D aircraft will climb to the 500 mb level (about FL 180). The 400 mb level (about FL 250) should be reached as soon as possible and maintained throughout the remainder of the pattern, unless icing or electrical conditions require a lower altitude.
• Note 2.	During the ferry to the **IP**, The G-IV should climb to the 41,000 ft (200 mb) as soon as possible and climb as feasible to maintain the highest altitude for the duration of the pattern.

HURRICANE SYNOPTIC FLOW EXPERIMENT

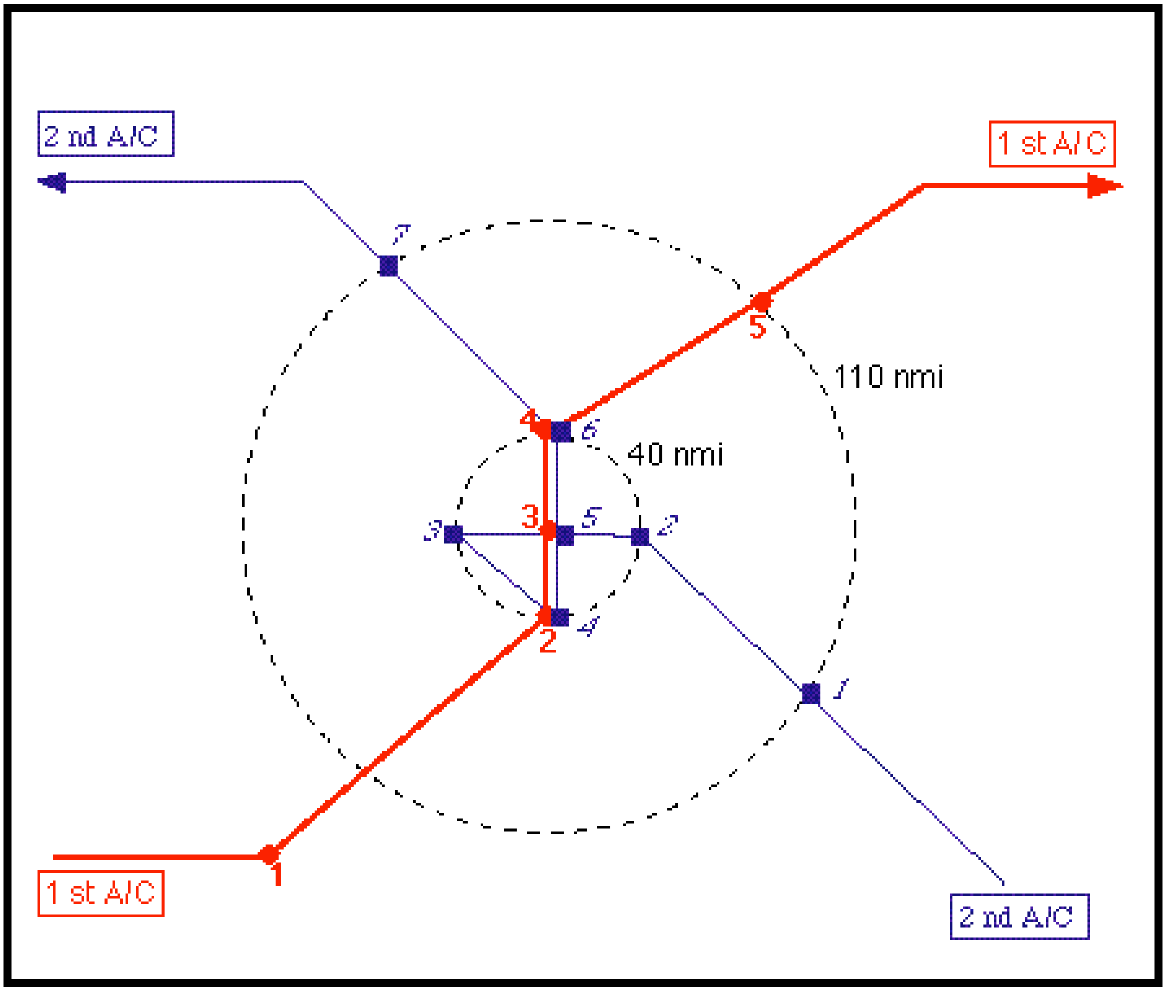


Fig. 18 In-Storm Patterns

• Note 1.	Within the 40 nm (75 km) range ring, all legs are on cardinal tracks.
• Note 2.	The second aircraft through the storm will execute the Doppler "figure-4" pattern. The Doppler radar should be set to continuously scan perpendicular to the track during radial penetrations and to F/AST on the downwind leg.
• Note 3.	Numbered symbols (◆, ■) reflect scheduled drops for each aircraft.
• Note 4.	Drop #5 in the "figure-4" pattern occurs on the second pass through the eye.
• Note 5.	A/C 1 should collect vertical incidence Doppler data during storm penetration.
• Note 6.	If missions are not repeated, then block times may exceed 9 h. In addition to the GPS-sonde data, *3-4 RECCO's* h^{-1} *should be transmitted during each mission.*

Special Notes: Missions similar to the Synoptic Flow missions may be flown in non-hurricane conditions to collect GPS-sonde data sets for satellite sounding evaluations. These missions differ from the normal experiment as follows:

- Block times are 10 h, and the experiment is not repeated on the following day.
- In-storm portion of the pattern (Fig. 17) is omitted and no Doppler data are collected.
- The G-IV does not participate in the mission

13. Extended Cyclone Dynamics Experiment (XCDX)

Program significance: Starting in the early 1980s, the Vortex Dynamics Experiment was the focus of observational studies of the evolution of the TC's inner core. It accumulated an archive of more than 3000 radial passes in 50 different Atlantic and Eastern Pacific TCs. The main scientific result was formulation of an observationally based model in which TC intensity and structure change were explained in terms of convective rings, circles of convection coincident with maxima of the swirling wind that intensify and propagate inward. Remaining unanswered questions were the dynamics of the rings' formation and factors that control timing and amount of intensity changes.

Since 1991, HRD has received the flight–level observations from routine reconnaissance flights by the IWRS-equipped WC-130Hs of the 53rd Weather Squadron. Although these observations have proven to be of excellent quality, their value is compromised by a lack of vertical velocity, microphysics, or radar reflectivity data. The USAF aircraft typically remain on station for 4–6 h, flying figure-4 (ALFA) patterns at 850 or 700 mb (5,000 or 10,000 ft (1.5 or 3.0 km) altitude) with 150 nm (278 km) legs oriented along the cardinal directions. Between sorties, there is usually a gap of 6–7 h during which no aircraft is in the TC, except near landfall when the interval between fixes decreases to 3 h. Experience with USAF observations from the 1991 through 1998 seasons shows that they document the evolution of the TC core well, but that they are even more valuable when augmented by occasional sorties of the NOAA WP-3Ds. The advent of the G-IV and introduction of GPS–based dropwindsondes present a long–awaited opportunity to study vortex interaction with vertical shear of the environmental wind and with upper tropospheric waves that are hypothesized to control TC intensification through eddy influxes of angular momentum.

The conventional reason offered for shear's negative effect on intensification has been that it ventilates the vortex by blowing warm air out of the core aloft to raise the hydrostatic surface pressure. Recent theoretical work suggests that the asymmetric stability and distribution of convection associated with shear–induced tilt of the vortex may be more significant. The net result of eddy momentum import is not a direct spin up of the swirling wind but outflow near the tropopause, which destabilizes the tropospheric column and strengthens the convection. Rapid intensification, apparently triggered by this mechanism, is a one of the most challenging problems that forecasters face. Jet airplanes and the new dropwindsondes are ideal tools to address this problem.

Objective: This experiment is designed to study the mechanisms by which environmental shear and eddy fluxes control TC intensity changes. A secondary objective is to obtain a time series of eye soundings to study the thermodynamics of intensity change.

Mission Description: The Vortex Option uses Air Force flight-level data to monitor the vortex core and frequent dropwindsondes and Radar data from the WP-3Ds or G-IV to monitor interactions with the environment. If only the WP-3Ds are available, they fly successive star patterns out to 200–300 km at 600–500 mb {15,000-18,000 ft [5-6 km)}. If jet aircraft are available, they will fly at or near their ceiling dispensing dropwindsondes through nearly the whole tropospheric column, either in a pattern similar to the WP–3Ds or in a circumnavigation. Thus, the combined flights can observe both the near–field environmental forcing and the vortex response.

The ideal target is a northward moving TC that has a fairly small Central Dense Overcast (CDO) and is expected to interact with vertical shear, an approaching mid-latitude trough, or a upper-level low.

The WP-3Ds will fly at 500–600 mb isobaric level {15,000-18,000 ft [5-6 km)} in a pattern of three equilateral triangles with common vertices at the TC's center (Fig. 19). Altitude will be the highest attainable that avoids too much aircraft icing and electrical charging. It is crucial to the analysis that a fixed pressure altitude is maintained throughout. The nominal leg length will be 250-300 nm (460-550 km), but the size of the pattern will be adjusted to make the legs as long as possible given the available aircraft range. The WP-3D will deploy dropwindsondes in a symmetrical pattern to map the vertical structure of the secondary circulation below flight level. On each passage through the center it will deploy a pair of sondes as close to the axis of vortex rotation as possible to study the thermodynamic transformations of the eye. The basic XCDX is three maximum-endurance sorties in 42 h or four in 56 h, with alternating aircraft and crews. Nominal flight duration will be 10 h with 4 h gaps between flights. The second aircraft will take off 14 h after the first. The third sortie, the second flight by the first aircraft, will depart 14 h after the second sortie or 18 h after the first sortie landed. Thus, take-off times by the same aircraft and crew will shift 4 h later in the next day on subsequent flights. The aircraft may, depending upon altitude, spend a third or a quarter of its time in icing conditions under the CDO, which may compromise range. A variation of the XCDX is one or more sorties at the same altitude with shorter legs and more frequent drops in the eye to focus on eye thermodynamics.

The G–IV, if available, will fly a hexagonal circumnavigation of the storm at 600 nm (1,110 km) radius, dispensing up to five dropwindsondes on each of the six sides of the pattern (Fig. 20). The aircraft will dispense dropwindsondes frequently along track. Since the purpose of the pattern will be to observe asymmetric structure and compute eddy correlations, the turn points will need to move with the TC, placing a premium on accurate navigation.

XCDX EXPERIMENT

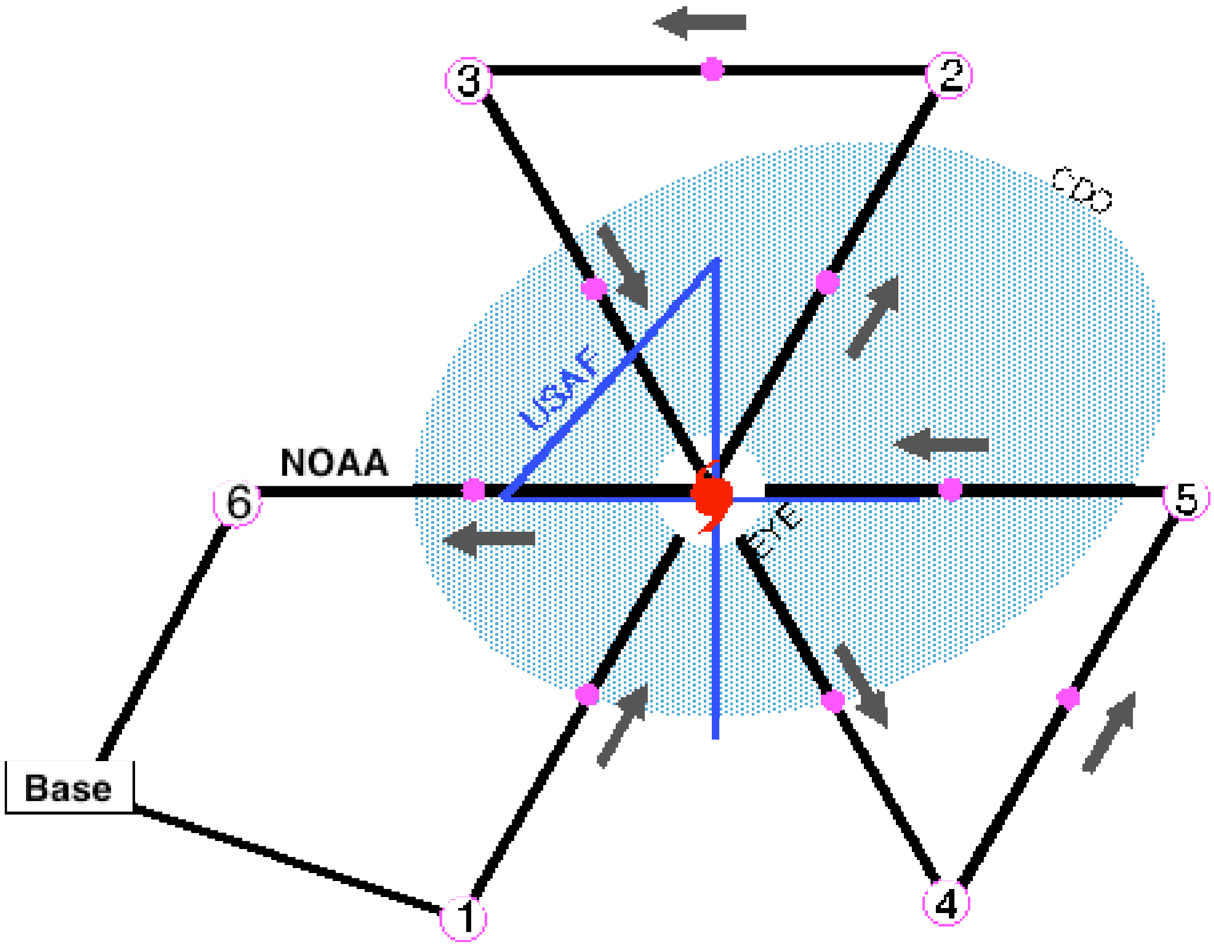


Fig. 19. WP-3D pattern

• Note 1.	WP-3Ds fly **1–§–2–3–§–4–5–§–6** at 500 mb pressure altitude if the CDO is small, or at 15,000 ft (4.5 km) radar altitude to avoid icing if it is large. The leg length is the longest possible given aircraft range and ferry distance to the storm.
• Note 2.	Dropwindsonde observations occur at the midpoints of the legs, after turns, and in pairs as close to the axis of rotation as possible on each passage through the eye.
• Note 3.	Each WP-3D sortie will take off is 19 h after the previous one.
• Note 4.	Airborne Doppler radar scans perpendicular to the aircraft track within 50 nm (95 km) of the center on penetration and exit, and on F/AST elsewhere.

XCDX EXPERIMENT

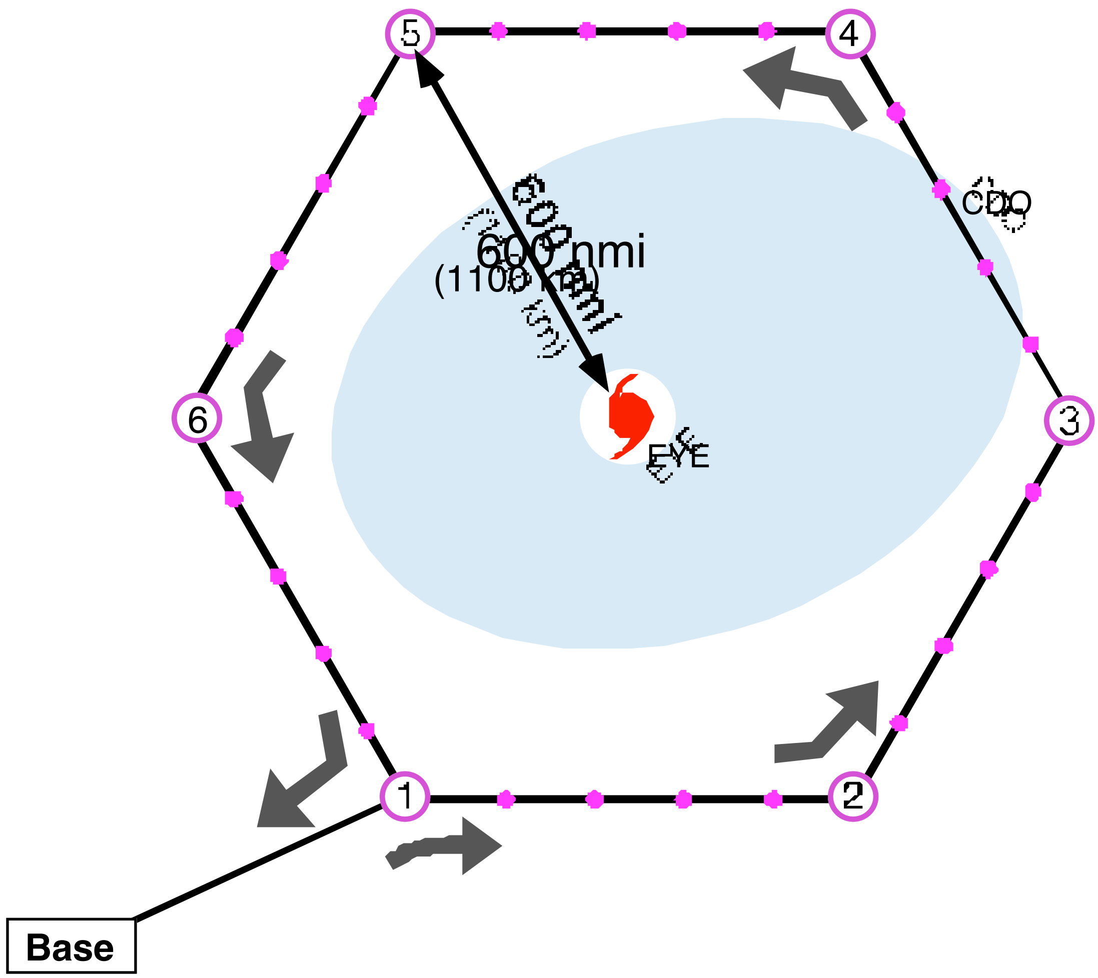


Fig. 20. G-IV pattern

• Note 1.	The G–IV flies **1–2–3–4–5–6**. The entire pattern is at 200 mb pressure altitude with turn points positioned relative to the moving TC center point. Leg length (pattern radius) will be adjusted to use the available range.
• Note 2.	Four or five GPS-sondes will be deployed on each leg.

14. Saharan Air Layer Experiment

Program Significance: The Saharan Air Layer (SAL) has been investigated extensively during the past several decades, buts its role in influencing Atlantic TC activity has not been thoroughly examined. The SAL is characterized by a well-mixed layer that originates over the arid regions of the Sahara and often extends up to ~500 mb over the African continent. This air mass is extremely warm and dry, with surface temperatures of 38-42 C and mixing ratios of 3-6 g/kg. The SAL is often associated with a low-level easterly surge centered at about 700 mb and concentrated along its southern boundary.

SAL outbreaks typically move westward off the northwestern African continent every 3-5 days during the summer months. There are several characteristics of these outbreaks that can act to suppress Atlantic TC formation:

1) **Dust silicates** suspended within the SAL absorb solar energy and subsequently release longwave infrared energy. These thermal emissions can act to warm the low-levels of the SAL and can re-enforce the tropical inversion that already exists in the north Atlantic basin. This warming can act to stabilize the environment as well as limit vertical mixing through the SAL, allowing it to maintain its distinctive structure for extended periods of time.
2) The dust acts as a tracer for **dry, stable air** associated with the SAL. This relatively denser dry air can diminish local convection by promoting downdrafts and hence suppressing TC formation.
3) The dust also acts as a tracer for the **low-level wind surge** typically associated with the SAL that can greatly increase the local atmospheric vertical wind shear. The low-level circulations of TCs under the influence of this surge tend to race out ahead of their mid-level convection, decoupling the storm and weakening it.

Objectives: This experiment is designed to study the mechanisms by which the SAL's embedded dust silicates, thermodynamic properties, and low-level wind surge affect Atlantic tropical cyclone genesis and intensity change.

WP-3D Mission Description: The WP-3D (flying at 18-20 kft or 550-600 mb) GPS sonde drop points will be based on a flight pattern selected using information from the UW-CIMSS/HRD GOES SAL tracking product. Specific effort will be made to gather atmospheric information within the SAL, the transitional environment along its boundaries, and the immediate surrounding tropical environment. Several SAL/TC interaction scenarios are candidates for this mission:

Option 1: Classic two-disturbance scenario with connecting "rooster tail" of convection. This convection represents the leading edge of the westward advancing SAL. The northern TC (A) typically intensifies as it recurves and leaves the negative influences of the SAL behind. The southern TC (B) is often overrun by the SAL and dramatically weakened. If both WP-3D's are available, TCs A and B will be investigated Fig. 21). If one WP-3D is available, the TC of interest will be selected on a case by case basis.

a) GPS sonde transects (~20 km spacing) will be made across the region of the "rooster tail" south of TC A and the SAL's NW leading edge NE of TC A. Particular attention will be focused on the transitional environment along the SAL's leading edge. The aircraft will then fly through the TC A's center and execute a figure-4 pattern with legs that extend 100 km beyond the outer rain bands. GPS sondes are released at the end of each leg with a focus on dry SAL air being advected into the NW and SW quadrants of the TC A as well as SAL enhanced vertical wind shear in the eastern quadrants of the TC A.

b) GPS sonde transects (~20 km spacing) will be made across the region of the "rooster tail" NW of TC B. Particular attention will be focused on the transitional environment along the SAL's leading edge. The aircraft will then fly through TC B's center and execute a figure-4 pattern with legs that extend 100 km beyond the outer rain bands. GPS sondes are released at the end of each leg with a focus on dry SAL air being advected into the NW and SW quadrants of TC B as well as SAL induced vertical wind shear in the eastern quadrants of the TC B.

SAL Experiment

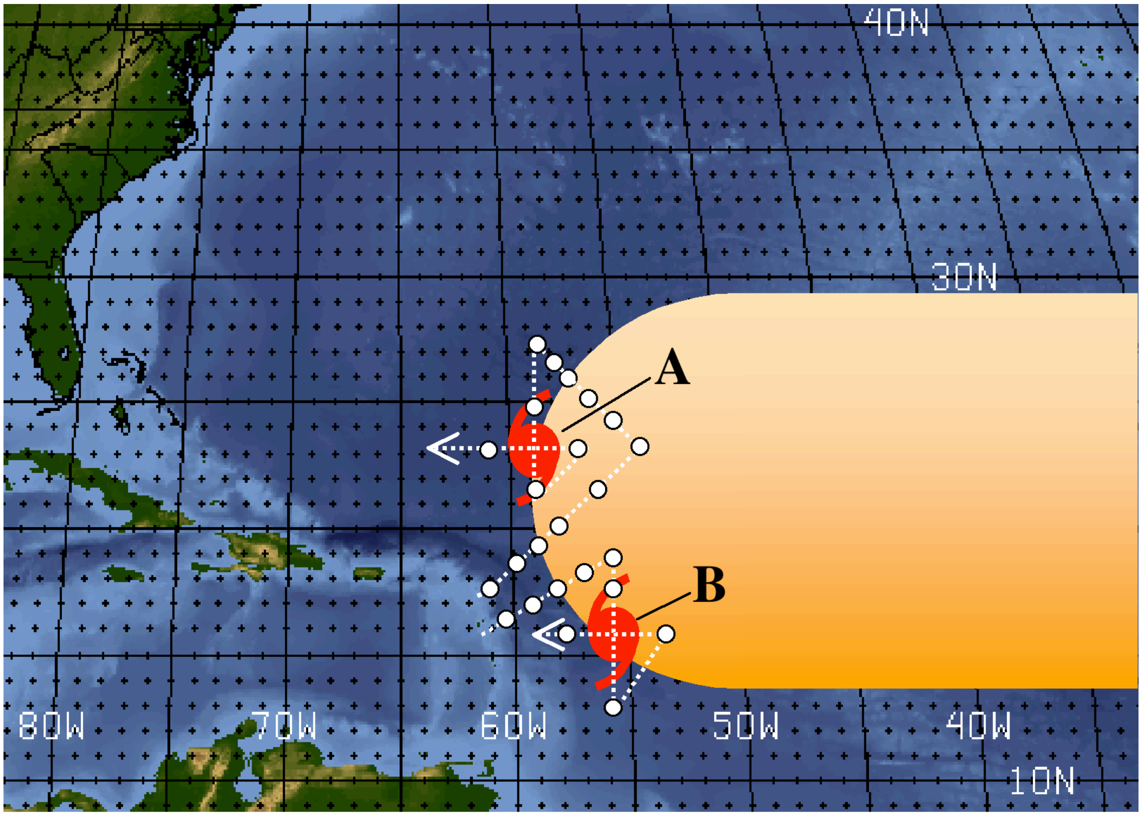


Fig. 21. Sample flight track for A) Single WP-3D and B) if second WP-3D is available

Option 2: Single tropical disturbance moving W or NW is embedded in the SAL and intensifies upon emerging. These systems are often candidates for rapid intensification. GPS sonde transects (~20 km spacing) will be made south and NE of the TC across the leading edge of the advancing SAL. The aircraft will then fly through the TC center and execute a figure-4 pattern with legs that extend 100 km beyond the outer rain bands. GPS sondes are released at the end of each leg with a focus on the SAL's dry air being advected into the NW and SW quadrants of the TC as well as SAL enhanced vertical wind shear in the rear quadrants of the TC. Focus will also be made on the non-SAL environment in the front quadrants of the TC that the storm is moving into.

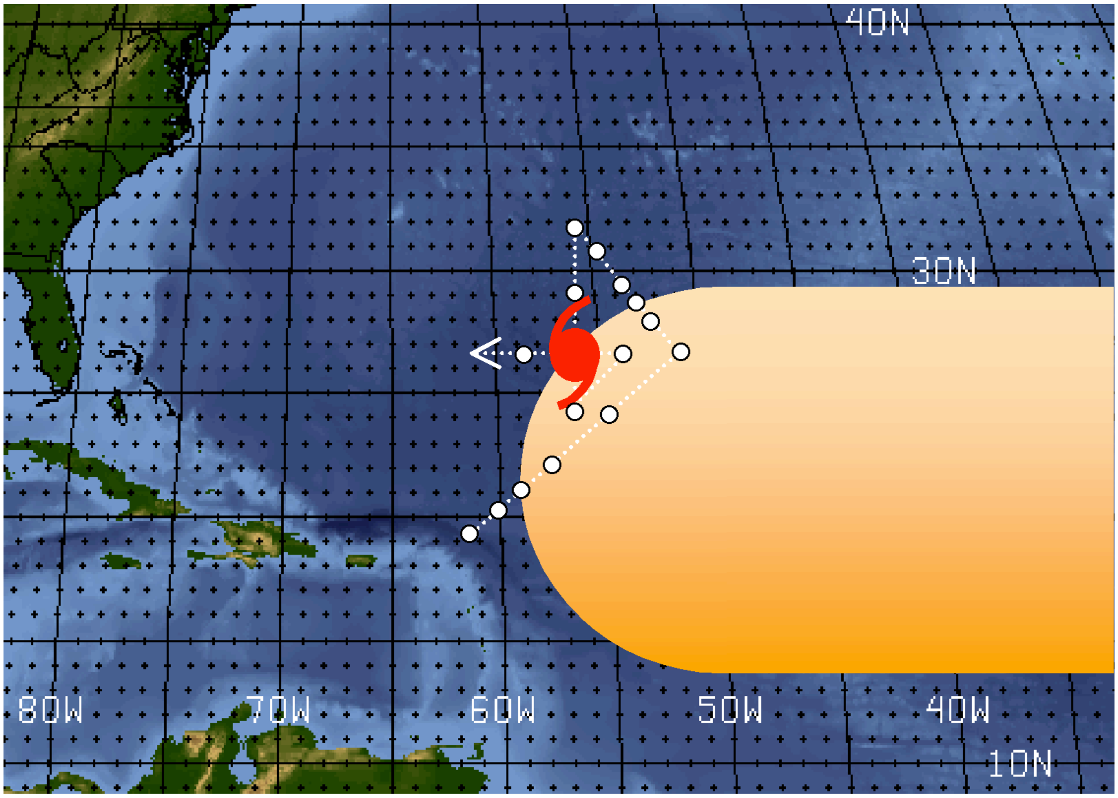


Fig. 22. Sample flight track for single WP-3D with storm on the edge of the dust outbreak

Option 3: Single tropical disturbance is embedded in the SAL for its entire life cycle. These systems struggle to intensify and are often characterized by their low-level circulation racing out ahead (west) of their mid-level convection. A south to north GPS sonde transect (non-SAL environment) to the west of the TC will be made. The aircraft will then fly through the TC center and execute a figure-4 pattern with legs that extend 100 km beyond the outer rain bands. GPS sondes are released near the outer rainbands and at the corners of each leg with a focus on the SAL's dry air and enhanced vertical wind shear. The initial NW to SE and final NE to SW legs will contain GPS sonde transects that focus on the transitional environment along the SAL's leading edges. The south to north figure-4 leg (SAL environment) to the east of the TC will contain a GPS sonde transect.

SAL Experiment

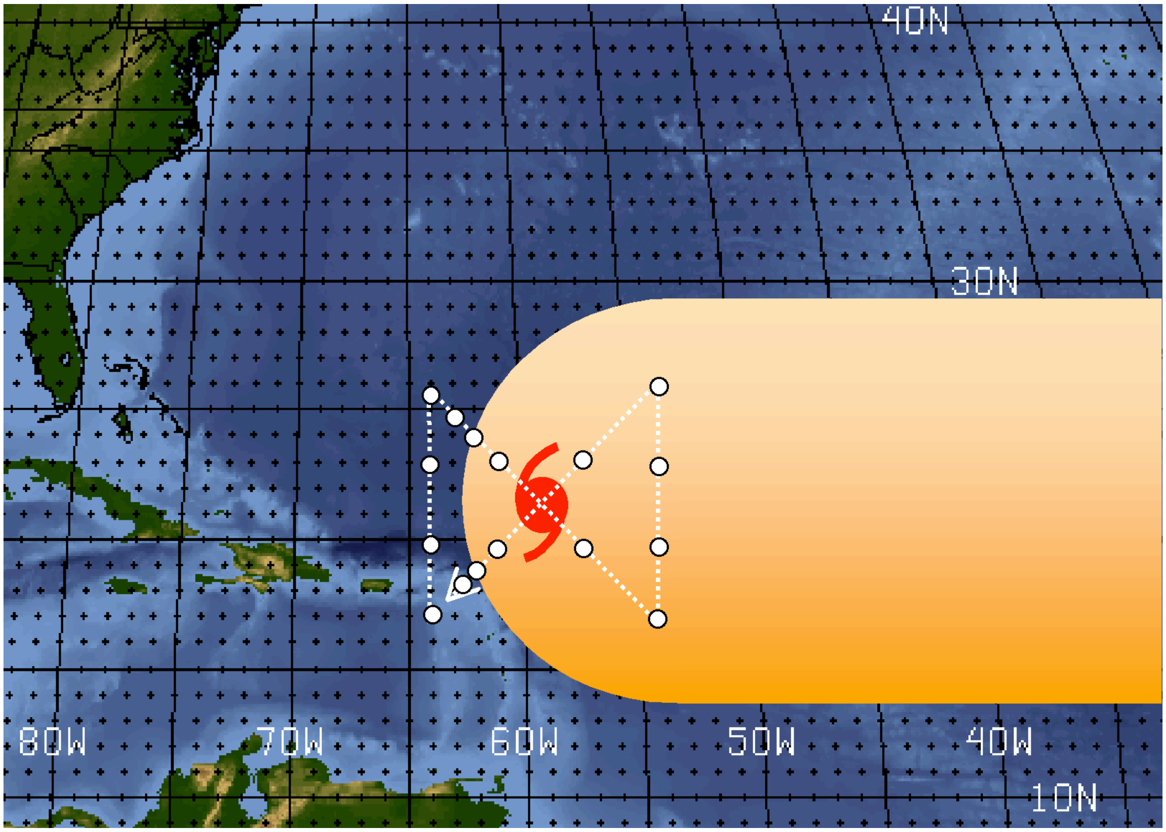


Fig. 23 : Sample flight track for single WP-3D with storm embedded within the dust outbreak

G-IV Mission Description: The G-IV (flying at ~150 mb) GPS sonde drop points will be based on slight modifications to a synoptic surveillance flight pattern selected using information from the UW-CIMSS/HRD GOES SAL tracking product. Specific effort will be made to gather atmospheric information within the SAL, the transitional environment along its boundaries, and the immediate surrounding tropical environment (as part of the surveillance mission). Several SAL/TC interaction scenarios are candidates for this mission:

SAL Experiment

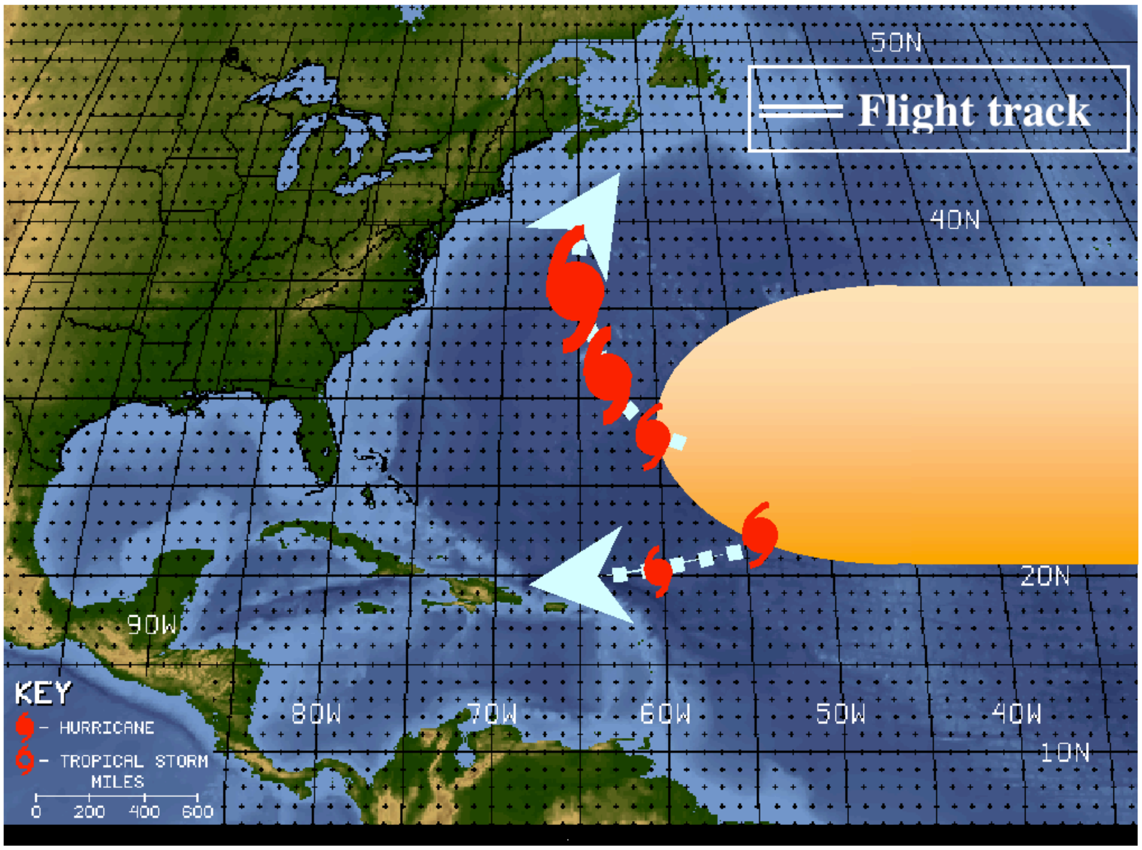


Fig. 24. Classic two-disturbance scenario with connecting "rooster tail" of convection. This convection represents the leading edge of the westward advancing SAL. The northern disturbance typically intensifies as it recurves and leaves the negative influences of the SAL behind. The southern disturbance is often overrun by the SAL and dramatically weakened. GPS sonde transects (20 km spacing) can be made to run perpendicular to the region of the "rooster tail".

SAL Experiment

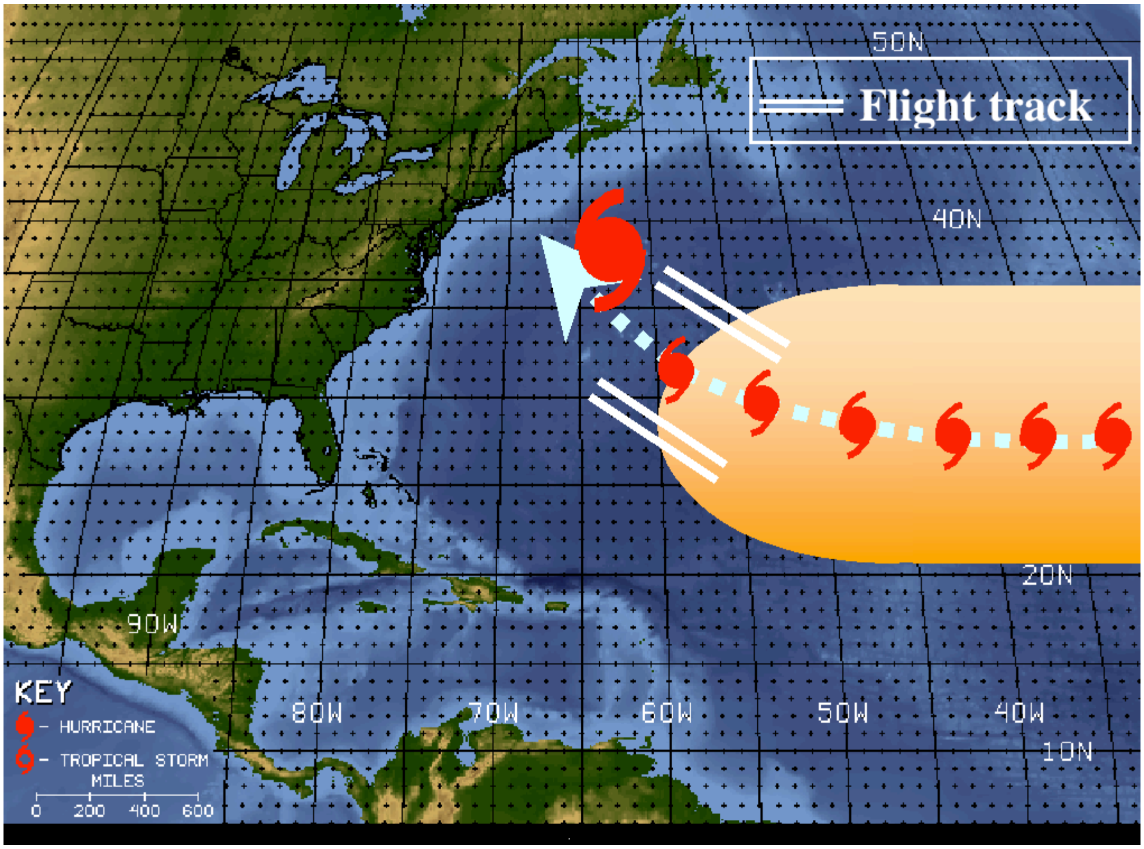


Fig. 25. Single tropical disturbance is embedded within the SAL and intensifies upon emerging. These systems are often candidates for rapid intensification. GPS sonde transects (20 km spacing) perpendicular to the leading edge of the advancing SAL and near to possible points of the tropical disturbance's emergence from the SAL are desirable.

SAL Experiment

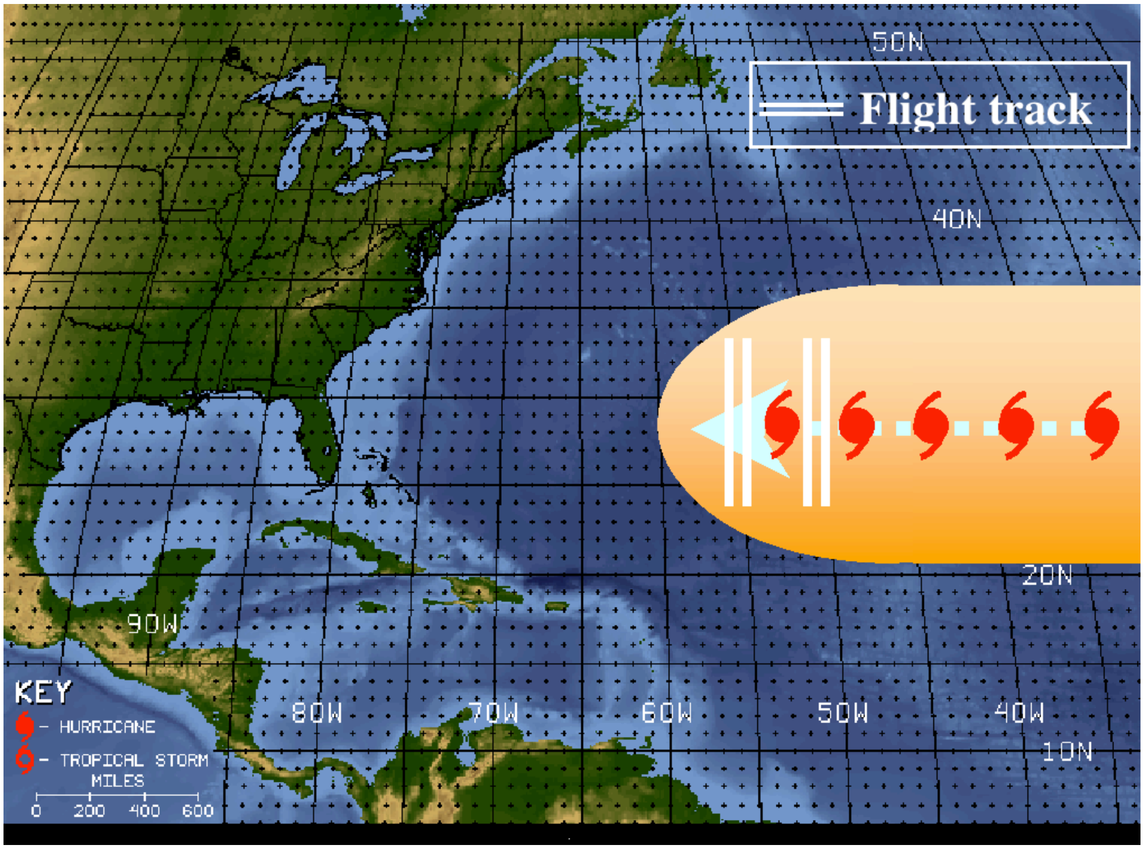


Fig. 26. Single tropical disturbance is embedded within the SAL for its entire life cycle. These systems struggle to intensify and are often characterized by their low-level circulation racing out ahead (west) of their mid-level convection. North/south GPS sonde transects (50 km spacing) on the west and especially east sides of the tropical disturbance are desirable.

APPENDIX A

DECISION AND NOTIFICATION PROCESS

APPENDIX A

DECISION AND NOTIFICATION PROCESS

The decision and notification process is illustrated in Fig. A-1. This process occurs in four steps:

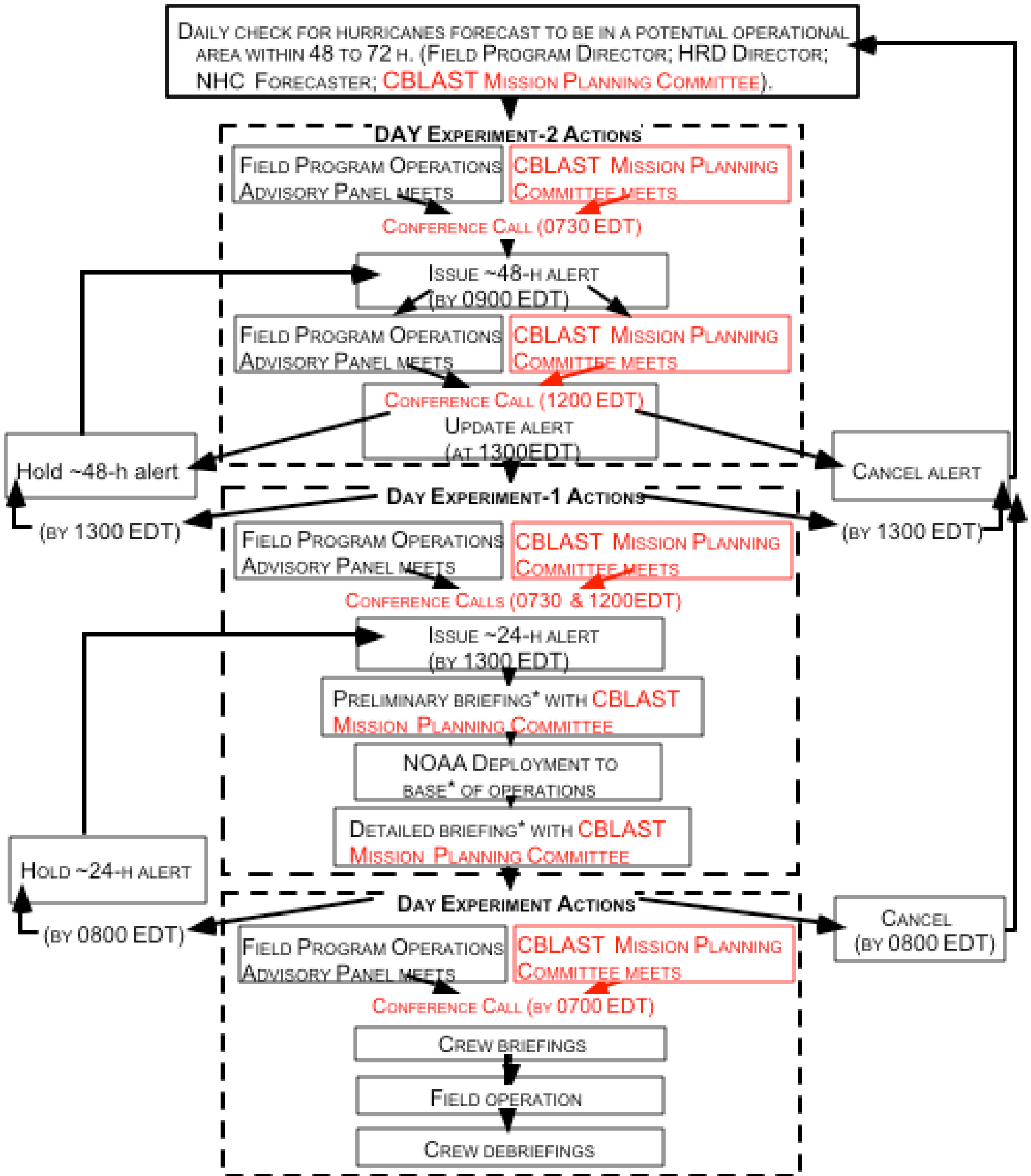
1) A research mission is determined to be probable within 72 h [field program director]. Consultation with the director of HRD, and the AOC Project Manager determines: flight platform availability, crew and equipment status, and the type of mission(s) likely to be requested.

2) The Field Program Advisory Panel [Director, HRD, M. Black, P. Black, Cione, Dodge, Dunion, Gamache, Kaplan, Powell, Landsea, White, and McFadden (or AOC designee) meets to discuss possible missions and operational modes. Probable mission determination and approval to proceed is given by the HRD director (or designee).

3) Primary personnel are notified by the field program director [M. Black].

4) Secondary personnel are notified by their primary affiliate (Table A-2).

General information, including updates of program status, are provided continuously by tape. Call (305) 221-3679 to listen to the recorded message. During normal business hours, callers should use (305) 361-4400 for other official inquiries and contacts. During operational periods, an MGOC team member is available by phone at (305) 229-4407 or (305) 221-4381. MGOC team leader, and the HRD field program director. (Appropriate telepager phone numbers will be provided to program participants before the start of the field program.)



* Time of briefings and deployments are dictated by the crew, scientist, aircraft and storm locations and conditions.

Fig. A-1. Decision and notification process.

Table A-1. Primary Contacts

Name/Agency	Title	Home phone	Work phone
F. Marks/ HRD	Acting Director	305-271-7443	305-361-4321
M. Black/ HRD	Field Program Director	305-383-0908	305-361-4371
P. Dodge/ HRD	Assistant Field Program Director	305-285-8864	305-361-4424
P. Black/ HRD	CBLAST Chief Scientist	305-859-7784	305-361-4320
H. Friedman/ HRD	MGOC Senior Team Leader	954-962-8021	305-361-4319
J. McFadden/ AOC	Project Manager for Hurricane Research	305-666-3622 813-839-7550	813-828-3310 x3076
J Parrish/ AOC	Project Manager for Hurricane Surveillance	813-933-2302 813-833-3275	813-828-3310 X3077
J. Pavone/ CARCAH	Liaison	305-248-3422 434-3420[1]	305-229-4474
D. Rogers/ OAR	Director, Office of Weather and Air Quality	TBA	301-713-0460, x120
S. Chang/ ONR	CBLAST Program Manager	301-294-6088	703-588-2553
Paul Chang/ NESDIS-ORA	Ocean Winds Program Manager	703-670-8285	301-763-8231 x167
J. Abraham,	Canada Convair 580	TBA	
P. Bowyer/ AES		TBA	(902) 426-9181
Synoptic Analysis Branch	NESDIS/Liaison		301-763-8444 301-763-8445
K. Katsaros/ AOML	Director	305-361-5543	305-361-4302 305-361-4300
Jana Goldman/ OAR	PR		301-713-2483
Erica Van Coverden/AOML	PR		305-361-4541
F. Lepore/ TPC/NHC	PA	305-235-6670	305-229-4404
MacDill Global[2]			813-828-3109 813-828-3356 813-828-3881

1 DSN: Defense Switched Network.

2 MacDill Global phone patch; used to contact the NOAA aircraft during missions.

Table A-2. Secondary Contacts

Name/group	Home phone	Work phone	Contacted by
HRD participants			M. Black/MGOC
AOC participants			J. McFadden
Deputy Dir./AOC			J. DuGranrut
FAA			AOC
COL R. Gale Carter, AFRC/WRS	601-928-7681	601-377-3207	CARCAH
53rd Wea. Reconnaissance. Squadron		228-377-2409	
M. Mayfield/TPC/NHC		305-229-4402	M. Black/MGOC
C. Burr/TSAF/TPC/NHC	305-667-9932	305-229-4430	M. Black/MGOC
Sr. Duty Meteorologist/NCEP	--	301-763-8298	M. Black/MGOC
		301-763-8364	
		301-763-8076	
R. Elsberry/NPS	831-659-3795	831-656-2373	M. Black/MGOC
W.-C. Lee/NCAR	303-939-8281	303-497-8814	M. Black/MGOC
S. Lord/NCEP	301-249-7713	301-763-8005	S. Aberson
C. Velden/U. Wisconsin	608-274-5500	608-262-9168	S. Aberson
Sharan Majumdar/UM-RSMAS		305-361-4779	S. Aberson
Brian Etherton/UM-RSMAS		305-361-4745	S. Aberson
Julian Heming/UKMO		44-0-1344-854494	S. Aberson
Rolf Langland/NRL		831-656-4786	S. Aberson
Zoltan Toth/NCEP		301-763-8545	S. Aberson
Nick Shay/ UM-RSMAS-MPO	305-235-2951	305-361-4075	P. Black
D. McLaughlin/ UMASS-MIRSL	413-549-7467	413-545-4867	P. Black
A. Zhang/UMASS-MIRSL	413-665-9391	413-545-4867	P. Black
J. French/ARL-FRD		208-526-0566, -2329	P. Black
W. Drennan/UM-RSMAS		305-361-4798	P. Black
K. Emanuel/MIT		617- 253-2462	P. Black
E. Walsh/NASA-GSFC	303-447-1694	303-497-6357	P. Black
E. D'Asaro/UW-APL	206-524-5267	206-685-2982	P. Black
E. Terrill/SIO	858-481-5425	858-822-3101	P. Black
C. Fairall/ETL	303-449-8222	303-497-3253	P. Black
K. Melville/SIO		858-524-0478	P. Black
R. Dumont/OFCM	TBD	301-427-2002	P. Black, M. Black/MGOC
P. Vachon/AES	613-825-8425	613-995-1575	E. Uhlhorn, P. Black
E. Meindl/NDBC	228-466-9529	228-688-1717	M. Powell
M. Burdett/NDBC	601-798-1151	228-688-2868	M. Powell
T. Reinhold/Clemson University	--	864-656-5941	M. Powell
J. Straka/U. Oklahoma	--	405-325-6561	M. Powell
R. Jensen/USACE	--	601-634-2101	M. Powell
S. Gill/NOS	--	301-713-2840	M. Powell
K. Knupp/U. Alabama/Huntsville	--	256-961-7762	P. Dodge
B. McCaul/U. Alabama/Huntsville	--	256-961-7837	P. Dodge
J. Schroeder/TTU		806-742-3476x288	P. Dodge

APPENDIX B

Aircraft Scientific Instrumentation

Table B1. NOAA/AOC WP-3D (N42RF, N43RF) instrumentation

Instrument	Parameter	PI	Group	Electronics Location	Instrument Location	42RF	43RF
Navigational							
INE1/2	LAT, LON		AOC			X	X
GPS1/2	LAT, LON		AOC			X	X
APN-159 altimeter (C-band)	Radar altitude		AOC			X	X
Standard Meteorological							
CSI dew point	Td		AOC			X	X
Rosemount temp	T, T’		AOC			X	X
Static pressure	P		AOC			X	X
Dynamic pressure	P’		AOC			X	X
Horizontal wind	U, V		AOC			X	X
Vertical wind	W		AOC			X	X
Infrared Radiation							
Side CO2 radiometer	T		AOC			X	X
AOC down radiometer	SST		AOC	Under floor,	Down radiometer port	X	X
FRD down radiometer [3]	SST	French	ARL/FRD	Station C3X	LIPA		X
Weather Radar							
LF radar	RR	Marks	HRD	Station 3	Lower fuselage	X	X
TA Doppler radar	U, V, W vs Z, RR	Marks	HRD	Station 3	Fuselage tail	X	X
Passive Microwave							
HRD SFMR/horn ant.	U10, RR	P. Black, Uhlhorn	HRD	Laser hole	LIPF		X
AOC SFMR/pod[1]	U10, RR	Goldstein	AOC	pod	Inner right pylon		X
USFMR (UMASS)	U10, RR	Zhang/ Chang	UMASS/ MIRSL	Station 7	Laser hole	X	
Active Microwave							
IWRAP (CSCAT, KSCAT)	U10, V10; RR; U, V, W vs Z	Zhang/ Chang	UMASS/ MIRSL, NESDIS	Station 7	Fore & aft pressure domes	X	
SRA	$HS_{1/3}$, WPS, WDS, RR	Walsh	NASA/ GSFC,ETL	Station 7	Fore Press Dome		X
Laser Systems							
Laser Altimeter	$H_{1/3}$, WP	Terrill	SIO	Station 7	Vert. Camera port		X
Airborne Ocean Profiler							
AXCP, AXCTD Receivers/Processors, DAT Recorders (4)	TS, S, VS vs Z	Shay	UM/RSMAS	Station 2	Free-fall chute (aft station 5)		X
AOC AXBT receivers	TS vs Z	Smith	AOC	Station 5		X	X
AXBT/SFMR laptop	processor	Uhlhorn	HRD	Station 2	------------------	X	X
Sonobuoy receiver	U10, RR	Terrill	SIO	Station 2		X	
Dropsonde Systems							
GPS AVAPS Dropsonde-4CH	U, TA, RH vs Z	Smith	AOC	Station 5	Aft station 5		X
GPS AVAPS Dropsonde-8CH	U, TA, RH vs Z	Smith	AOC	Station 5	Aft station 5	X	
GPS Dropsonde- ‘full up system’	U, TA, RH vs Z	Smith	AOC	Station 5	Aft station 5	X	
Video Systems							
AOC video down	F(%), WD		AOC		Vert. Camera port	X	
Side, nose video	LCL		AOC		Side, nose camera port	X	X

Instrument	Parameter	PI	Group	Electronics Location	Instrument Location	42RF	43RF
MASS (video down)	WC(%), F(%), WD	Terrill, Melville	SIO	Station 7	Vert. Camera port		X
Down IR camera [3]	Wave breaking	Melville	SIO		Aft pressure Dome		X
Cloud Microphysics/ Sea Spray							
2D-P PMS mono probe	Precip size spectra, RR	R. Black	HRD/AOC	Station 4	Outer left pylon		X
FSSP-100 probe	Aerosol, small cloud size spectra	R. Black	HRD/AOC	Station 4	Outer left pylon	X	X
DMT CIP probe	Spray spectra	Fairall	ETL	Station 2	Outer left pylon		X
DMT CIP probe	Cloud LWC	Fairall	ETL	Station 2	Outer left pylon		X
DMT DAS	processor	Fairall	ETL	Station 2	------------		X
2D-C PMS mono probe	Cloud size spectra	R. Black	HRD/AOC	Station C3X	Outer left pylon	X	
2D-P PMS grey probe	Precip size spectra, RR	R. Black	HRD/AOC	Station C3X	Outer left pylon	X	
HVPS (replaces 2DP grey probe)	Precip size spectra, RR	R. Black	HRD/AOC /NASA	Station C3X		X	
SEA M200 DAS	processor		AOC	Station 4	------------	X	X
Johnson-Williams hot wire	Cloud liquid water	R. Black	HRD		Station x	X	
King probe	Total liquid water	R. Black	HRD			X	
Electric field mills (5)	3-axis electric field	R. Black	HRD			X	
Particle Dynamics Analyzer [2]	Sea spray	Asher	UW/APL	Station C3X	Station 3- window blank		X
Water salinity isotope analyzer [3]	Sea spray	Lawrenc e, Geller	UHOU		Station 3- window blank	X	
Water vapor isotope analyzer [3]	Sea spray	Lawrenc e, Geller	UHOU		Station x- window blank	X	
TECO Ozone sampler [2]	ozone	Carsey	AOML			X	X
Turbulence Systems							
Friehe radome gust probe system	U',V',W',T'	Drennan	UM/ RSMAS	Nose radome bulkhead	Nose radome	X	X
BAT probe	U',V',W',T'	French, Crawford	ARL/FRD	C3X	Nose boom		X
Lyman-alpha Hygrometer [3]	RH, q'	Drennan, Hubler	UM/RSMAS ,AL		fuselage		X
LICOR-750 water vapor analyzer[1]	q'	Drennan	RSMAS/ AOC	Nose radome bulkhead	Nose Radome bulkhead	X	X
On board processing							
HRD Workstation	GPS sonde, LF radar processing	Griffin	HRD	Station 3		X	X
AOC Workstation [4]	Real time data processing	Smith	AOC	C3X		X	X

[1] Late season 2002 or 2003 installation
[2] 2003 installation
[3] Lower priority, installation as time permits, 2002-03
[4] 2004 installation

- STD- data on standard DAT tape and CD- one each per aircraft

APPENDIX C

Calibration; Scientific Crew Lists; Data Buoys; DOD/NWS RAWIN/RAOB and NWS Coastal Land-based Radar Locations/Contacts

Calibration; Scientific Crew Lists; Data Buoys; DOD/NWS RAWIN/RAOB and NWS Coastal Land-based Radar Locations/Contacts

C.1 En-Route Calibration of Aircraft Systems

Instrument calibrations are checked by flying aircraft intercomparison patterns whenever possible during the hurricane field program or when the need for calibration checks is suggested by a review of the data. In addition, an over flight of a surface pressure reference is advisable en route or while on station when practicable. Finally, all flights enroute to and from the storm are required to execute a true airspeed (TAS) calibration pattern. This pattern is illustrated in Fig. C-1.

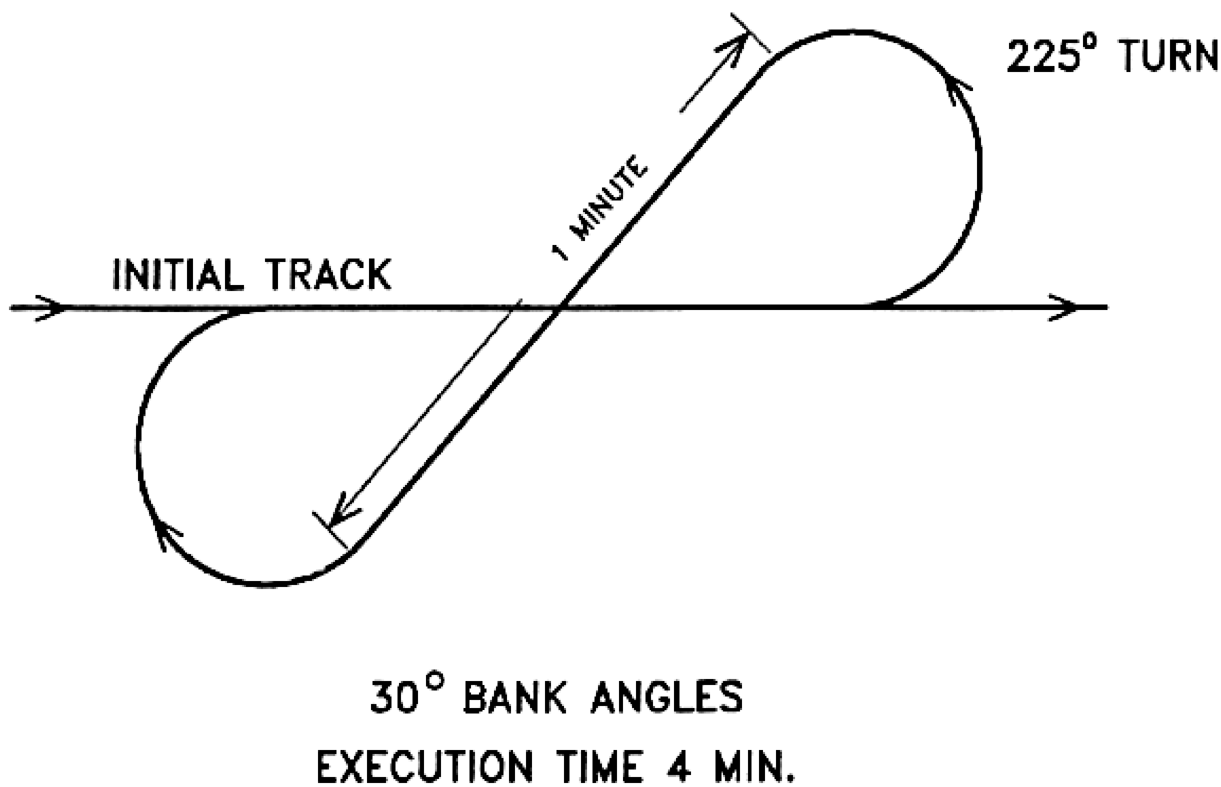


Fig. C-1 En-Route TAS calibration pattern.

C.2 Aircraft Scientific Crew Lists

Table C-2.1 Hurricane AIR-Sea INteraction (HAIRSIN) Experiment (dual-aircraft mission)

Position	N42RF	N43RF
Lead Project Scientist	P. Chang	P. Black
Cloud Physics Scientist	R. Black	(radar scientist)
Radar Scientist	M. Black	P. Dodge
Dropsonde Scientist	(radar scientist)	AOC
Workstation Scientist	P. Leighton	-----------
IWRAP/USFMR/SRA Scientist	A. Zhang	E. Walsh
Observer/AXCP-AXCTD Scientist	NESDIS	T. Cook, L. Shay

Table C-2.2 Track-dependent SST module (HAIRSIN experiment, single or dual plane mission)

Position	N42RF	N43RF
Lead Project Scientist	P. Chang	P. Black
Cloud Physics Scientist	-----------	(radar scientist)
Radar Scientist	M. Black or P. Leighton	P. Dodge
Dropsonde Scientist	(radar scientist)	AOC
Workstation Scientist	M. Black or P. Leighton	-----------
IWRAP/USFMR/SRA Scientist	A. Zhang	E. Walsh
Observer/AXCP-AXCTD Scientist	NESDIS	T. Cook, L. Shay

Table C-2.3 Coupled Boundary Layer Air-Sea Transfer (CBLAST) Experiment (dual-aircraft mission)

Position	N42RF	N43RF
Lead Project Scientist	P. Chang	P. Black
Cloud Physics Scientist	R. Black	C. Fairall
Radar Scientist	M. Black	P. Dodge
Dropsonde Scientist	(radar scientist)	AOC, LPS
Workstation Scientist	P. Leighton	-----------
IWRAP/USFMR/SRA Scientist	A. Zhang	E. Walsh
Observer/AXBT Scientist	NESDIS	(LPS)
Turbulence Scientist	------------	J. French
MOSS/altimeter Scientist	------------	P. Matusov

Table C-2.4 Extended Cyclone Dynamics Experiment (single-option, single-aircraft mission)

Position	N42RF or N43RF
Lead Project Scientist	H. Willoughby
Cloud Physics Scientist	R. Black
Radar Scientist	M. Black
Dropsonde Scientist	S. Goldenberg
Workstation Scientist	P. Leighton
Ku/C-SCAT/SFMR/SRA Scientist	P. Chang or E. Walsh

Table C-2.5 Tropical Cyclone Wind fields Near Landfall Experiment (dual-option, single-aircraft mission)

Position	N42RF or N43RF
Lead Project Scientist	P. Dodge or F. Marks
Cloud Physics Scientist	(radar scientist)
Radar Scientist	J. Gamache
Dropsonde Scientist	C. Landsea
Workstation Scientist	P. Leighton
Ku/C-SCAT/SFMR/SRA Scientist	P. Chang or E. Walsh

Table C-2.6 Hurricane Synoptic-Flow Experiment (single-option, single-aircraft mission)

Position	N42RF or N43RF
Lead Project Scientist	S. Aberson
Cloud Physics Scientist	(radar scientist)
Radar Scientist	F. Marks
Dropsonde Scientists	R. Rogers
Workstation Scientist	P. Dodge
Ku/C-SCAT/SFMR/SRA Scientist	P. Chang or E. Walsh

Table C-2.7 Saharan Air Layer Experiment: (single-option, single or dual-aircraft mission)

Position	N42RF	N43RF
Lead Project Scientist	J. Dunion	C. Landsea
Cloud Physics Scientist	(radar scientist)	(radar scientist)
Radar Scientist	P. Dodge	M. Black
Dropsonde Scientist	S. Aberson	J. Cione
Workstation Scientist	P. Leighton	R. Rogers
Ku/C-SCAT/SFMR and SRA Scientists	J. Carswell	E. Walsh

C.3 Buoy/Platform Over flight Locations[1]

Table C-3.1 Moored Buoys

Station Identifier	Type of Station[2]		Location Lat. (N)	Location Lon (W)	Area	Special Obs/ Comments[4]
44007*	3D	/D	43.53	70.14	PORTLAND	A
44005*[3]	6N	/D	43.17	69.22	GULF OF MAINE	A
44013*	3D	/D	42.35	70.69	BOSTON	--
44011*	6N	/D	41.06	66.58	GEORGES BANK	A
44008*[3]	3D	/V	40.50	69.43	NANTUCKET	A
44025*	3D	/D	40.25	73.17	LONG ISLAND	DW
44004*	6N	/D	38.50	70.47	HOTEL	--
44009*[3]	3D	/V	38.46	74.70	DELAWARE BAY	--
44014	3D	/D	36.58	74.84	VIRGINIA BEACH	DW
41001	6N	/D	34.68	72.23	E. HATTERAS	A
41004*	3N	/D	32.50	79.10	EDISTO	DW
41002*	6D	/D	32.36	75.46	S. HATTERAS	--
41008*[3]	3D	/V	31.40	80.87	GRAYS REEF	--
42007*	3D	/D	30.09	88.77	BOLOXI	A
41012[3]	3D	/A	30.00	80.50	ST. AUGUSTINE	A, CSI
42035*	3D	/D	29.25	94.42	GALVESTON	--
42040	3D	/D	29.21	88.20	MOBILE SOUTH	A
41010	6N	/D	28.89	78.55	CANAVERAL EAST	--
42039	3D	/D	28.78	86.06	PENSACOLA S.	A
42036*	3D	/D	28.51	84.51	W. TAMPA	DW
41009	6N	/V	28.50	80.18	CANAVERAL	--
42019*[3]	3D	/D	27.92	95.35	LANEILLE	--
42041	3D	/D	27.50	90.50	N. MID GULF	A
42020*	3D	/D	26.95	96.70	EILEEN	--
42002*	10D	/M	25.17	93.42	WESTERN GULF	A
42003*	10D	/M	25.88	85.95	E.AST GULF	A
42001*	10D	/M	25.93	89.68	MID GULF	A

[1] Tables C-3.1 and C-3.4 were updated with information from the **Data Platform Status Report (June 27, 2002)**, NOAA/National Data Buoy Center (NDBC), Stennis Space Center, MS 39529-6000, for the period **June 20 – June 27, 2002**. (Also, the NDBC report lists the location of drifting buoys o/a **June 20 – June 27, 2002**). See subsequent editions of this weekly NDBC report for later information. Tables C-3.2, C-3.3, and portions of C-3.4 were updated with information from **National Weather Service Offices and Stations** (June 2002), NOAA/NWS, W/MB31, Silver Spring, MD.

[2] Hull Type — Anemometer Height

10D - 10-m discus buoy 10.0 m
6N - 6-m NOMAD buoy 5.0 m
3D - 3-m discus buoy 5.0 m

Payload types: /A = ARES; /D = DACT; /V = VEEP; /M = MARS.

[3] Note remarks section of NDBC report (**June 27, 2002**); see latest edition of NDBC **Data Platform Status Report** for current status.

[4] A = 10-min data (continuous); R = rainfall; DW = directional wave spectra; CSI = Coastal storm initiative

* Base funded station of the National Weather Service (NWS); however, all stations report data to NWS.

Table C-3.2 C-MAN sites[1]

Station Identifier	Station Name/ Payload Type	Location Lat. (N)	Location Lon (W)	Area	Comments[3]	Height (m)
MDRM1*[2]	Mt. Desert Rock, ME/D	43.97	68.13	ME COAST	--	22.6
MISM1*	Matinicus Rock, ME/D	43.78	68.86	ME COAST	--	16.5
IOSN3*[2]	Isle of Shoals, NH/D	42.97	70.62	NH COAST	--	19.2
BUZM3*[2]	Buzzards Bay, MA/M	41.40	71.03	MA COAST	A	24.8
ALSN6*[2]	Ambrose Light, NY/V	40.45	73.80	NY COAST	--	49.1
TPLM2*	Thomas Point, MD/M	38.90	76.44	MD COAST	--	18.0
CHLV2*[2]	Chesapeake Light, VA/D	36.91	75.71	VA COAST	A	43.3
DUCN7*	Duck Pier, NC/V	36.18	75.75	NC COAST	A	20.4
DSLN7*[2]	Diamond Shoals Light, NC/D	35.15	75.30	NC COAST	A, DP	46.6
CLKN7*	Cape Lookout, NC/M	34.62	76.53	NC COAST	A	9.8
FPSN7*	Frying Pan Shoals, NC/D	33.49	77.59	NC COAST	A	44.2
FBIS1*[4]	Folly Island, SC/M	32.69	79.89	SC COAST	A	9.8
SPAG1	US Navy Tower R2	31.38	80.57	GA COAST	--	50.0
SPGF1*	Settlement Point, GBI/M	26.70	78.99	GR BAHAMA	A	9.8
SAUF1*	St. Augustine, FL/V	29.86	81.27	FL COAST	A	16.5
LKWF1*	Lake Worth, FL/M	26.61	80.03	FL COAST	A	13.7
FWYF1*[4]	Fowey Rocks, FL/M	25.59	80.10	FL COAST	A	43.9
MLRF1*	Molasses Reef, FL/V	25.01	80.38	FL COAST	--	15.8
SMKF1*[2]	Sombrero Key, FL/M	24.63	81.11	FL COAST	--	48.5
SANF1*[4]	Sand Key, FL/M	24.46	81.88	FL COAST	A	13.1
LONF1*	Long Key, FL/M	24.84	80.86	FL COAST	--	7.0
DRYF1*[2]	Dry Tortugas, FL/M	24.64	82.86	FL COAST	--	5.7
VENF1*	Venice, FL/M	27.07	82.45	FL COAST	A	11.6
CDRF1*	Cedar Key, FL/V	29.14	83.03	FL COAST	A	10.0
CSBF1*[4]	Cape San Blas, FL/M	29.67	85.36	FL COAST	A	9.8
KTNF1*	Keaton Beach, FL/M	29.82	83.59	FL COAST	A	10.0
DPIA1*	Dauphin Island, AL/V	30.25	88.07	AL COAST	--	17.4
BURL1*	Southwest Pass, LA/M	28.91	89.43	LA COAST	A	30.5
GDIL1*[4]	Grand Isle, LA/M	29.27	89.96	LA COAST	A	15.8
SRST2*[4]	Sabine, TX/M	29.67	94.05	TX COAST	A	12.5
PTAT2*	Port Aransas, TX/M	27.83	97.05	TX COAST	A	14.9

[1] Coastal-Marine Automated Network (C-MAN) stations are located on coastal headlands, piers, or offshore platforms. Payload types, shown next to the station's name (after the "/") are: D = DACT; V = VEEP; M=MARS; and I = Industry-supplied. C-MAN anemometer heights are listed in the **C-MAN User's Guide**.

[2] Note remarks section of NDBC report (**June 27, 2002**); see latest edition of NDBC **Data Platform Status Report** for current status.

[3] A = 10-min data (continuous); DP = dew point; R = rainfall; DW = directional wave spectra.

[4] Hurricane Landfall (HL) Systems whose exposure characteristics are stored on the HRD Surface Wind Analysis database and on NCDC's website.

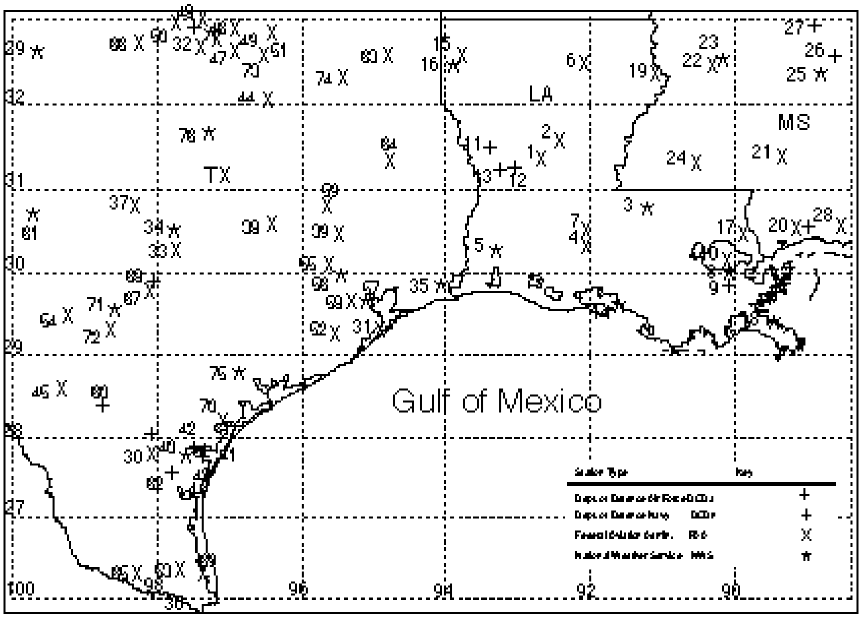
* Primarily for National Weather Service (NWS) support; however, all stations report data to NWS.

Table C-3.3 NOS National Water Level Observation Network (NWLON)*

Station ID	Station Name	Location Lat. (N)	Location Lon (W)
8410140	Eastport Bay, ME	44.90	66.98
8519483	Bergen Point West Reach, NY	40.64	74.14
8531680	Sandy Hook, NJ	40.47	74.01
8577330	Solomons Island, MD	38.32	76.45
8573364	Tolchester Beach, MD	39.21	76.25
8632200	Kiptopeke, VA	37.17	75.98
8635750	Lewisetta, VA	37.99	76.46
8635750	Sewells Point, VA	36.95	76.32
8638863	Chesapeake Bay Bridge Tunnel, VA	36.97	76.10
8651370	Duck, Pier, NC	36.18	75.74
8654400	Cape Hatteras Fishing Pier, NC	35.22	75.64
8720218	Mayport (Bay Pilots Dock), FL	30.39	81.43
8720587	St. Augustine Beach, FL	29.86	81.26
8721604	Trident Pier, FL	28.42	80.59
8723214	Virginia Key, FL	25.73	80.15
8725110	Naples, FL	26.13	81.80
8725520	Fort Myers, FL	26.65	81.87
8726520	St. Petersburg, FL	27.76	82.62
8726667	McKay Bay Entrance, FL	27.91	82.42
8726724	Clearwater Beach, FL	27.98	82.83
8728690	Apalachicola, FL	29.73	84.98
8729210	Panama City Beach, FL	30.21	85.88
8747766	Waveland, MS	30.28	89.37
8761724	Grand Isle, LA	29.26	89.96
8770613	Morgans Point, TX	29.68	94.98
8771013	Eagle Point, TX	29.48	94.92
8771510	Galveston Pleasure Pier, TX	29.28	94.79
8772440	Freeport, TX	28.95	95.31
8775870	Corpus Christi, TX	27.58	97.22
8779770	Port Isabel, TX	26.06	97.26

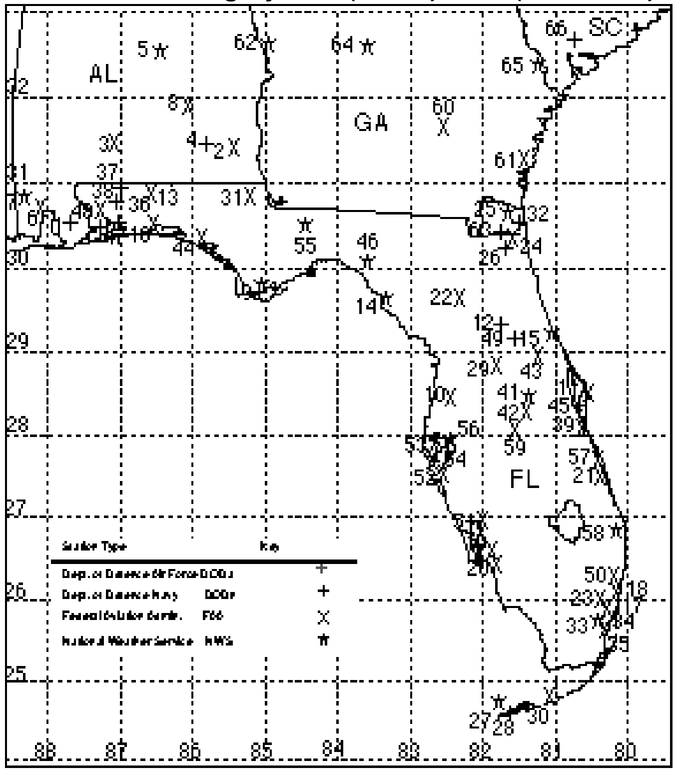
* Quality controlled data from these platforms can be obtained from NDBC's **Seaboard Bulletin Board Service** soon after the fact. For information contact NDBC .

Table C-3.4 Automated Surface Observing System (ASOS) sites



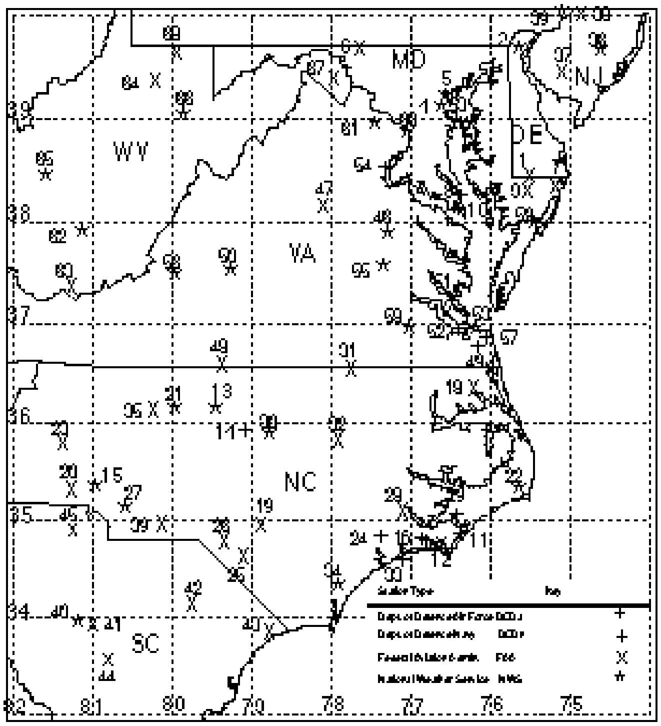
#	ID	Agency	Site Name	Lat. (N)	Lon (W)	#	ID	Agency	Site Name	Lat. (N)	Lon (W)
1	KAEX	FAA	Alexandria, LA	31.33	92.56	39	KCXO	FAA	Conroe, TX	30.36	95.41
2	KESF	FAA	Alexandria, LA	31.40	92.29	40	KCRP	NWS	Corpus Christi, TX	27.77	97.51
3	KBTR	NWS	Baton Rouge, LA	30.54	91.95	41	KNGP	DODn	Corpus Christi, TX	27.68	97.29
4	KLFT	FAA	Lafayette, LA	30.20	91.99	42	KNGW	DODn	Corpus Christi, TX	27.72	97.44
5	KLCH	NWS	Lake Charles, LA	30.12	93.23	43	KNVT	DODn	Corpus Christi, TX	27.63	97.31
6	KMLU	FAA	Monroe, LA	32.51	92.03	44	KCRS	FAA	Corsicana, TX	32.03	96.40
7	KARA	FAA	New Iberia, LA	30.29	91.99	45	KCOT	FAA	Cotulla, TX	28.45	99.22
8	KMSY	NWS	New Orleans, LA	29.99	90.02	46	KDAL	FAA	Dallas, TX	32.85	96.86
9	KNBG	DODn	New Orleans, LA	29.84	90.02	47	KRBD	FAA	Dallas, TX	32.68	96.86
10	KNEW	FAA	New Orleans, LA	30.05	90.03	48	KDFW	NWS	Dallas/Fort Worth, TX	32.90	97.02
11	FTPK1	DODa	Fort Polk, LA	31.41	93.30	49	KFTW	FAA	Fort Worth, TX	32.83	97.36
12	FTPK2	DODa	Fort Polk, LA	31.11	92.97	50	KNFW	DOD	Fort Worth, TX	32.77	97.43
13	FTPK3	DODa	Fort Polk, LA	31.12	93.16	51	KAFW	FAA	Fort Worth, TX	32.97	97.32
14	KP92	NWS	Salt Point, LA	29.56	91.53	52	KGLS	FAA	Galveston, TX	29.27	94.86
15	KDTN	FAA	Shreveport, LA	32.54	93.74	53	KHRL	FAA	Harlingen, TX	26.23	97.66
16	KSHV	NWS	Shreveport, LA	32.45	93.82	54	KHDO	FAA	Hondo, TX	29.36	99.17
17	KASD	FAA	Slidell, LA	30.34	89.82	55	KDWH	FAA	Houston, TX	30.07	95.56
18	K7R1	NWS	Venice, LA	29.26	89.36	56	KIAH	NWS	Houston, TX	29.99	95.36
19	KTVR	FAA	Vicks./Tallulah, LA	32.35	91.03	57	KHOU	NWS	Houston, TX	29.64	95.28
20	KGPT	FAA	Gulfport, MS	30.41	89.08	58	KT02	FAA	Houston, TX	29.52	95.24
21	KHBG	FAA	Hattiesburg, MS	31.27	89.26	59	KUTS	FAA	Huntsville, TX	30.74	95.59
22	KHKS	FAA	Jackson, MS	32.34	90.22	60	KNMT	DODn	Ingleside, TX	28.24	98.72
23	KJAN	NWS	Jackson, MS	32.32	90.08	61	KJCT	NWS	Junction, TX	30.51	99.77
24	KMCB	FAA	McComb, MS	31.18	90.47	62	KNQI	DODn	Kingsville, TX	27.50	97.81
25	KMEI	NWS	Meridian, MS	32.34	88.75	63	KGGG	FAA	Longview, TX	32.39	94.71
26	KNMM	DODn	Meridian, MS	32.55	88.54	64	KLFK	FAA	Lufkin, TX	31.23	94.75
27	KNJW	DODn	Meridian Range, MS	32.80	88.83	65	KMFE	FAA	McAllen, TX	26.18	98.24
28	KPQL	FAA	Pascagoula, MS	30.46	88.53	66	KMWL	FAA	Mineral Wells, TX	32.78	98.06
29	KABI	NWS	Abilene, TX	32.41	99.68	67	K3R5	FAA	New Braunfels, TX	29.71	98.05
30	KALI	FAA	Alice, TX	27.74	98.02	68	KNOG	DODn	Orange Grove, TX	27.89	98.04
31	KLBX	FAA	Angelton/L. Jack., TX	29.12	95.46	69	KT31	FAA	Port Isabel, TX	26.16	97.34
32	KF54	FAA	Arlington, TX	32.66	97.10	70	KRKP	FAA	Rockport, TX	28.08	97.04
33	KBSM	FAA	Austin, TX	30.18	97.68	71	KSAT	NWS	San Antonio, TX	29.53	98.46
34	KAUS	NWS	Austin, TX	30.29	97.70	72	KSSF	FAA	San Antonio, TX	29.34	98.47
35	KBPT	NWS	Beau./Port Art., TX	29.95	94.02	73	KTRL	FAA	Terrel, TX	32.71	96.27
36	KBRO	NWS	Brownsville, TX	25.91	97.42	74	KTYR	FAA	Tyler, TX	32.36	95.40
37	KBMQ	FAA	Burnet, TX	30.74	98.23	75	KVCT	NWS	Victoria, TX	28.86	96.93
38	KCLL	FAA	College Station, TX	30.58	96.36	76	KACT	NWS	Waco, TX	31.62	97.23

Table C-3.4 Automated Surface Observing System (ASOS) sites (continued)



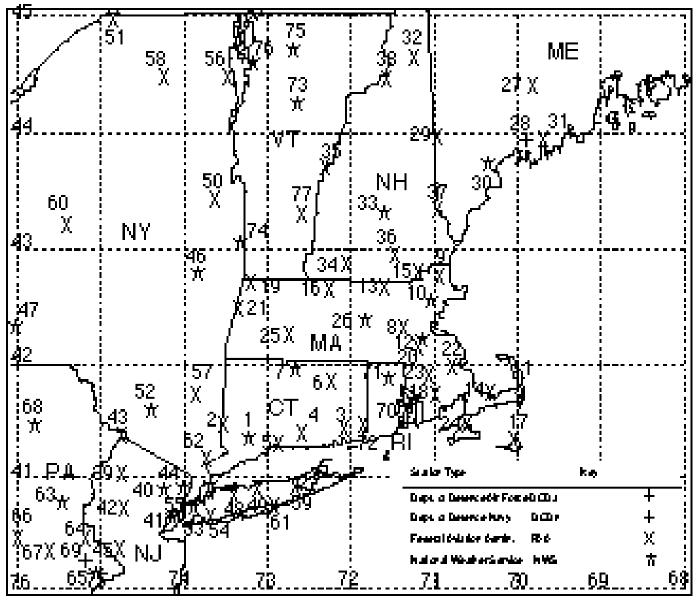
#	ID	Agency	Site Name	Lat. (N)	Lon (W)
1	KNBJ	DODn	Barin, AL	30.39	87.63
2	KDHN	FAA	Dothan, AL	31.31	85.44
3	KGZH	FAA	Evergreen, AL	31.42	87.05
4	KLOR	DODn	Fort Rucker, AL	31.36	85.75
5	KMGM	NWS	Montgomery, AL	32.30	86.41
6	KBFM	FAA	Mobile, AL	30.61	88.06
7	KMOB	NWS	Mobile, AL	30.69	88.25
8	KTOI	FAA	Troy, AL	31.86	86.01
9	KAQQ	NWS	Apalachicola, FL	29.73	85.02
10	KBKV	FAA	Brooksville, FL	28.47	82.45
11	CCAS1	FAA	Cape Canaveral, FL	28.48	80.58
12	KNZC	DODn	Cecil, FL	30.21	81.87
13	KCEW	FAA	Crestview, FL	30.77	86.52
14	KCTY	NWS	Cross City, FL	29.55	83.11
15	KDAB	NWS	Daytona Beach, FL	29.17	81.06
16	KDTS	FAA	Destin, FL	30.39	86.47
17	KFLL	FAA	Fort Lauderdale, FL	26.07	80.15
18	KFXE	FAA	Fort Lauderdale, FL	26.20	80.13
19	KFMY	FAA	Fort Myers, FL	26.58	81.86
20	KRSW	FAA	Fort Myers, FL	26.53	81.77
21	KFPR	FAA	Fort Pierce, FL	27.50	80.38
22	KGNV	FAA	Gainesville, FL	29.69	82.28
23	KHWO	FAA	Hollywood, FL	26.00	80.24
24	KCRG	FAA	Jacksonville, FL	30.34	81.51
25	KJAX	NWS	Jacksonville, FL	30.49	81.69
26	KNIP	DODn	Jacksonville, FL	30.23	81.67
27	KEYW	NWS	Key West, FL	24.55	81.75
28	KNQX	DODn	Key West, FL	24.57	81.68
29	KLEE	FAA	Leesburg, FL	28.82	81.81
30	KMTH	FAA	Marathon, FL	24.73	81.05
31	KMAI	FAA	Marianna, FL	30.84	85.18
32	KNRB	DODn	Mayport, FL	30.40	81.42
33	KMIA	NWS	Miami, FL	25.79	80.32
34	KOPF	FAA	Miami, FL	25.91	80.23
35	KTMB	FAA	Miami, FL	25.64	80.43
36	KNDZ	DODn	Milton, FL	30.70	87.02
37	KNFJ	DODn	Milton, FL	30.51	86.95
38	KNSE	DODn	Milton, FL	30.73	87.02
39	KMLB	FAA	Melbourne, FL	28.10	80.64
41	KMCO	NWS	Orlando, FL	28.42	81.33
42	KORL	FAA	Orlando, FL	28.55	81.34
43	KSFB	FAA	Orlando, FL	28.78	81.25
44	KPFN	FAA	Panama City, FL	30.21	85.89
45	PAFB1	DODa	Patrick AFB, FL	28.23	80.60
46	K40J	NWS	Perry Foley, FL	30.07	83.57
47	KNPA	DODn	Pensacola, FL	30.36	87.32
48	KPNS	FAA	Pensacola, FL	30.48	87.19
49	KNAE	DODn	Pinecastle, FL	29.14	81.63
50	KPMP	FAA	Pompano Beach, FL	26.25	80.11
51	KPGD	FAA	Punta Gorda, FL	26.92	81.99
52	KSRQ	FAA	Sar./Braden., FL	27.41	82.56
53	KPIE	FAA	St. Peter./Clear., F	27.91	82.69
54	KSPG	FAA	St Petersburg FL	27.77	82.63
55	KTLH	NWS	Tallahassee, FL	30.39	84.35
56	KTPA	NWS	Tampa, FL	27.96	82.54
57	KVRB	FAA	Vero Beach, FL	27.66	80.41
58	KPBI	NWS	West Palm Beach, FL	26.68	80.10
59	KGIF	FAA	Winter Haven, FL	28.06	81.76
60	KAMG	FAA	Alma, GA	31.54	82.51
61	KSSI	FAA	Brunswick, GA	31.15	81.39
62	KCSG	NWS	Columbus, GA	32.52	84.94
63	KNBQ	DODn	Kings Bay, GA	30.79	81.56
64	KMCN	NWS	Macon, GA	32.69	83.65
65	KSAV	NWS	Savannah, GA	32.12	81.20
66	KNBC	DODn	Beaufort, SC	32.49	80.70

Table C-3.4 Automated Surface Observing System (ASOS) sites (continued)



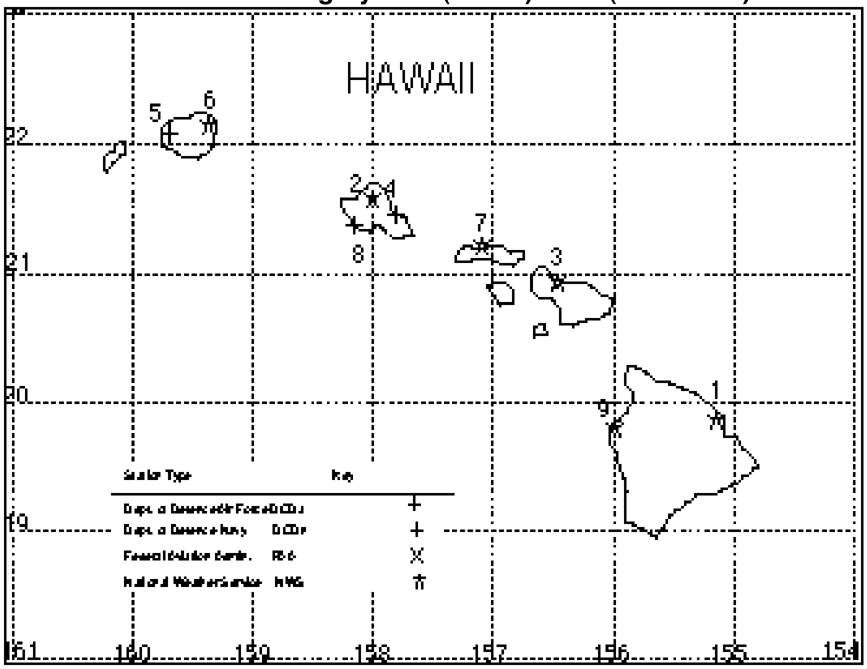
#	ID	Agency	Site Name	Lat. (N)	Lon (W)	#	ID	Agency	Site Name	Lat. (N)	Lon (W)
1	KGED	FAA	Georgetown, DE	38.69	75.36	35	KINT	FAA	Winston Salem, NC	36.13	80.22
3	KNAK	DODn	Annapolis, MD	38.99	76.43	36	KACY	NWS	Atlantic City, NJ	39.46	74.59
4	KBWI	NWS	Baltimore, MD	39.17	76.68	37	KMIV	FAA	Millville, NJ	39.37	75.08
5	KDMH	NWS	Baltimore, MD	39.28	76.61	38	KVAY	FAA	Mount Holly, NJ	39.94	74.84
6	KHGR	FAA	Hagerstown, MD	39.71	77.73	39	KPNE	NWS	Philadelphia, PA	40.08	75.01
7	KN80	FAA	Ocean City, MD	38.31	75.12	40	KCAE	NWS	Columbia, SC	33.94	81.11
8	KNHK	DODn	Patuxent River, MD	38.28	76.41	41	KCUB	FAA	Columbia, SC	33.97	80.99
9	KSBY	FAA	Salisbury, MD	38.34	75.50	42	KFLO	FAA	Florence, SC	34.18	79.73
10	KNUI	DODn	St Inigoes, MD	38.15	76.42	43	KCRE	FAA	Myrtle Beach, SC	33.82	78.72
11	KNLT	DODn	Atlantic City, NC	34.89	76.34	44	KOGB	FAA	Orangeburg, SC	33.46	80.85
12	KMRH	FAA	Beaufort, NC	34.73	76.66	45	K29J	FAA	Rock Hill, SC	34.98	81.06
13	KBUY	NWS	Burlington, NC	36.05	79.47	46	KOFP	NWS	Ashland, VA	37.71	77.43
14	KIGX	DODn	Chapel Hill, NC	35.93	79.06	47	KCHO	FAA	Charlottesville, VA	38.14	78.46
15	KCLT	NWS	Charlotte, NC	35.21	80.95	48	KDAN	FAA	Danville, VA	36.57	79.35
16	KNKT	DODn	Cherry Point, NC	34.90	76.88	49	KNFE	DODn	Fentress, VA	36.70	76.13
17	KNIS	DODn	Cherry Point, NC	34.89	76.86	50	KLYH	NWS	Lynchburg, VA	37.32	79.21
18	KECG	FAA	Elizabeth City, NC	36.26	76.18	51	KPHF	FAA	Newport News, VA	37.13	76.49
19	KFAY	FAA	Fayetteville, NC	34.99	78.88	52	KNGU	DODn	Norfolk, VA	36.93	76.30
20	KAKH	NWS	Gastonia, NC	35.20	81.16	53	KORF	NWS	Norfolk, VA	36.90	76.19
21	KGSO	NWS	Greensboro, NC	36.10	79.94	54	KNYG	DODn	Quantico, VA	38.51	77.29
22	KILG	NWS	Wilmington, DE	39.67	75.60	55	KRIC	NWS	Richmond, VA	37.51	77.32
22	KHSE	NWS	Hatteras, NC	35.23	75.62	56	KROA	NWS	Roanoke, VA	37.32	79.97
23	KHKY	FAA	Hickory, NC	35.74	81.38	57	KNTU	DODn	Virginia Beach, VA	36.82	76.03
24	KNCA	DODn	Jacksonville, NC	34.71	77.44	58	KAKQ	NWS	Wakefield, VA	36.98	77.00
25	KLBT	FAA	Lumberton, NC	34.61	79.06	59	KWAL	NWS	Wallops Island, VA	37.94	75.46
26	KMEB	FAA	Maxton, NC	34.79	79.37	60	KDCA	NWS	Washington, DC	38.84	77.03
27	KEQY	NWS	Monroe, NC	35.02	80.60	61	KIAD	NWS	Washington, DC	38.93	77.45
28	KEWN	FAA	New Bern, NC	35.07	77.05	62	KBKW	NWS	Beckley, WV	37.80	81.12
29	KNBT	DODn	Piney Island, NC	35.02	76.46	63	KBLF	FAA	Bluefield,	0.00	37.30
30	KRDU	NWS	Raleigh/Durham, NC	35.87	78.79	64	KCKB	FAA	Clarksburg, WV	39.30	80.22
31	KRZZ	FAA	Roanoke Rapids, NC	36.44	77.71	65	KCRW	NWS	Charleston, WV	38.38	81.59
32	KRWI	FAA	Rocky Mount Wil., NC	35.85	77.90	66	KEKN	NWS	Elkins, WV	38.89	79.85
33	KNJM	DODn	Swansboro, NC	34.69	77.03	67	KMRB	FAA	Martinsburg, WV	39.40	77.98
34	KILM	NWS	Wilmington, NC	34.27	77.91	68	KMGW	FAA	Morgantown, WV	39.65	79.92

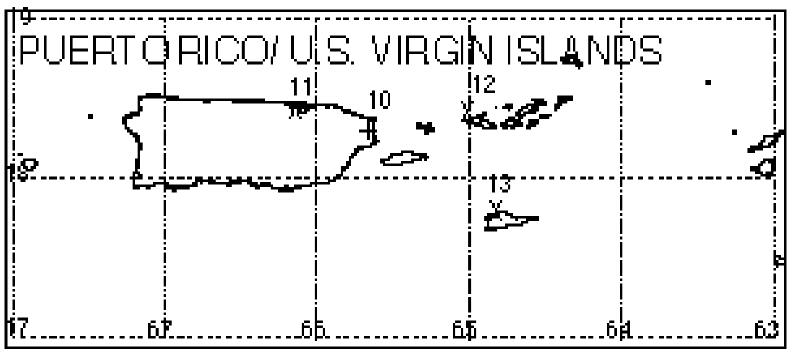
Table C-3.4 Automated Surface Observing System (ASOS) sites (continued)



#	ID	Agency	Site Name	Lat. (N)	Lon (W)	#	ID	Agency	Site Name	Lat. (N)	Lon (W)
1	KBDR	NWS	Bridgeport, CT	41.16	73.13	39	K12N	NWS	Andover, NJ	41.01	74.74
2	KDXR	FAA	Danbury, CT	41.37	73.48	40	KCDW	FAA	Caldwell, NJ	40.88	74.28
3	KGON	FAA	Groton/N. Lon, CT	41.33	72.05	41	KEWR	NWS	Newark, NJ	40.68	74.17
4	KHFD	FAA	Hartford, CT	41.33	72.65	42	KN52	FAA	Somerville, NJ	40.62	74.67
5	KHVN	FAA	New Haven, CT	41.26	72.89	43	KFWN	FAA	Sussex, NJ	41.20	74.63
6	KIJD	FAA	Willimantic, CT	41.74	72.18	44	KTEB	NWS	Teterboro, NJ	40.85	74.06
7	KBDL	NWS	Windsor Locks, CT	41.94	72.68	45	KTTN	FAA	Trenton, NJ	40.28	74.82
8	KBED	FAA	Bedford, MA	42.47	71.29	46	KALB	NWS	Albany, NY	42.75	73.80
9	KBVY	FAA	Beverly, MA	42.58	70.92	47	KBGM	NWS	Binghamton, NY	42.21	75.98
10	KBOS	NWS	Boston, MA	42.36	71.01	48	KFRG	FAA	Farmingdale, NY	40.73	73.42
11	KCQX	FAA	Chatham, MA	41.69	69.99	49	KISP	FAA	Islip, NY	40.79	73.10
12	KMQE	NWS	East Milton, MA	42.21	71.11	50	KGFL	FAA	Glens Falls, NY	43.34	73.61
13	KFIT	FAA	Fitchburg, MA	42.55	71.56	51	KMSS	FAA	Massena, NY	44.93	74.85
14	KHYA	FAA	Hyannis, MA	41.67	70.27	52	KMGJ	NWS	Montgomery, NY	41.51	74.27
15	KLWM	FAA	Lawrence, MA	42.71	71.13	53	KNYC	NWS	New York City, NY	40.78	73.97
16	KORE	FAA	Orange, MA	42.57	72.28	54	KJFK	NWS	New York City, NY	40.64	73.76
17	KACK	FAA	Nantucket, MA	41.25	70.06	55	KLGA	NWS	New York City, NY	40.78	73.88
18	KEWB	FAA	New Bedford, MA	41.68	70.97	56	KPLB	FAA	Plattsburgh, NY	44.68	73.53
19	KAQW	FAA	North Adams, MA	42.70	73.17	57	KPOU	FAA	Poughkeepsie, NY	41.63	73.88
20	KOWD	FAA	Norwood, MA	42.19	71.17	58	KSLK	FAA	Saranac Lake, NY	44.39	74.20
21	KPSF	FAA	Pittsfield, MA	42.43	73.29	59	KHWV	FAA	Shirley, NY	40.82	72.87
22	KPYM	FAA	Plymouth, MA	41.91	70.73	60	KUCA	FAA	Utica, NY	43.14	75.38
23	KTAN	FAA	Taunton, MA	41.88	71.02	61	KFOK	FAA	West Hampton Bch, NY	40.85	72.62
24	KMVY	FAA	Vineyard Haven, MA	41.39	70.62	62	KHPN	FAA	White Plains, NY	41.06	73.70
25	KBAF	FAA	Westfield, MA	42.16	72.71	63	KABE	NWS	Allentown, PA	40.65	75.45
26	KORH	NWS	Worcestor, MA	42.27	71.87	64	KN88	FAA	Doylestown, PA	40.33	75.12
27	KAUG	FAA	Augusta, ME	44.32	69.80	65	KPNE	NWS	Philadelphia, PA	40.08	75.01
28	KNHZ	DODn	Brunswick, ME	43.90	69.94	66	KRDG	FAA	Reading, PA	40.37	75.96
29	KIZG	FAA	Fryeburg, ME	43.99	70.95	67	KPTW	FAA	Pottstown, PA	40.24	75.56
30	KPWM	NWS	Portland, ME	43.64	70.30	68	KAVP	NWS	Wilkes B./Scran., PA	41.34	75.73
31	KIWI	FAA	Wiscasset, ME	43.96	69.71	69	KNXX	DODn	Willow Grove, PA	40.19	75.14
32	KBML	FAA	Berlin, NH	44.58	71.18	70	KUUU	FAA	Newport, RI	41.53	71.23
33	KCON	NWS	Concord, NH	43.20	71.50	71	KPVD	NWS	Providence, RI	41.72	71.43
34	KAFN	FAA	Jaffrey, NH	42.81	72.00	72	KWST	FAA	Westerly, RI	41.35	71.80
35	KLEB	FAA	Lebanon, NH	43.63	72.31	73	KMPV	NWS	Barre/Montpelier, VT	44.20	72.57
36	KMHT	FAA	Manchester, NH	42.93	71.44	74	KDDH	NWS	Bennington, VT	42.89	73.25
37	K6B1	FAA	Rochester, NH	43.28	70.92	75	KMPV	NWS	Burlington, VT	44.47	73.15
38	KHIE	FAA	Whitefield, NH	44.37	71.55	76	KMVL	NWS	Morrisville, VT	44.20	72.57
						77	KVSF	NWS	Springfield, VT	43.34	72.52

Table C-3.4 Automated Surface Observing System (ASOS) sites (continued)





#	ID	Agency	Site Name	Lat. (N)	Lon (W)
1	PHTO	NWS	Hilo, HI	19.72	155.05
2	PHNL	NWS	Honolulu, HI	21.32	157.94
3	PHOG	NWS	Kahului, HI	20.89	156.43
4	PHNG	DODn	Kaneohoe, HI	21.45	157.77
5	PHBK	DODn	Kekaha, HI	22.04	159.79
6	PHLI	NWS	Lihue, HI	21.98	159.34
7	PHMK	NWS	Molokai, HI	21.16	157.10
8	PHNA	DODn	Oahu, HI	21.31	158.07
9	PHKO	NWS	Kailua/Kona, HI	19.74	156.05
10	TJNR	DODn	Roosevelt Roads, PR	18.26	65.64
11	TJSJ	NWS	San Juan, PR	18.43	66.01
12	KSTT	FAA	Charlotte Amali, VI	18.34	64.98
13	KSTX	FAA	Christiansted, VI	17.70	64.81

C.4 NWS and DOD Locations/Contacts-2002

Table C-4.1 DOD RAWIN/RAOB locations/contacts

Station Identifier	Address/Location	Sqdrn. Co/Fac. Cmdr.	Telephone Numbers
COF (74795)	45th Wea. Squadron/CC 1201 Edward H. White St. Patrick AFB, FL 32925-3238	Col. Neil Wyse Squadron Commander Lt. Col. Dewey Harms Chief of Systems Hal Herring	321-494-7012 321-494-7426 DSN[1]: 854-7426 CSR: 853-8211 FAX: 321-853-4315 FAX: 321-853-8295
VPS (72221)	46th WS 601 W. Choctawhatchee Suite 60 Eglin AFB, FL 32542-5719	Lt. Col. Michael G. Bedard Squadron Commander Dave Cramblet Chief, Range Support	850-882-5449 850-882-5224 850-882-5960 850-882-5323 DSN[1]: 872-5323 FAX: 850-882-3341
TXKF[2] (78016)	P.O. Box 123 St. Georges Bermuda GEBX	Mr. Roger Williams[2]	441-293-5067 x402 FAX: 441-293-6658 Cell: 441-735-3506

[1] DSN: Defense Switched Network.

[2] The facility at Bermuda is not military. Mr. Roger Williams is the manager of the meteorology office.

Note 1: MCI can be used to call Bermuda from HRD/AOML; however, you must have an MCI FTS 2001 credit card (see Gladys Medina if you need an MCI FTS 2001 credit card for official business).

To place a call using an MCI FTS 2001 card:

(a) Follow instructions on the back of your MCI FTS 2001 credit card.

(b) Division secretaries or Gladys Medina can assist placing calls.

Note 2: In recent years, CSR operated the meteorological station at Antigua under a contract with the USAF. Meteorological operations at Antigua were terminated May 1, 1993. During the 2002 field program, if additional rawinsonde/radiosonde data from the eastern Caribbean area are required, the MGOC representative should contact the Meteorological Office, Saint Martin (Saint Maarten), Netherlands Antilles [TNCM (78866)]. Petier Trappenberg is the Director of the facility. For further information or assistance, contact Fred Branski or Walter Smith (NWS) at 301-713-0864.

Note 3: Additional rawinsondes/radiosondes from DOD rawinsonde sites, including Patrick AFB, Eglin AFB, and NAS Guantanamo (Cuba), can be requested through the CARCAH at TPC/NHC (see Appendix F, section F.3, 3g)].

Note 4: When requesting additional RAWINs/RAOBs from any DOD or other facility, the MGOC representative should:

(a) State the beginning and ending date(s) and time(s) [UTC].

(b) Specify the desired frequency of rawinsondes/radiosondes (3-, 6-, or 12-hourly intervals).

(c) State that rawinsondes/radiosondes should be "flown" (at least) to the 100-hPa level.

(d) Request that all data (*i.e.,* raw data **and** worked-up soundings) be sent to Howard A. Friedman, AOML/HRD, 4301 Rickenbacker Causeway, Miami, Florida, 33149.

Table C-4.2 NWS/Eastern Region RAWIN/RAOB locations/contacts[1]

Station Identifier	Address/Location	MIC/OIC	Telephone Numbers
CHS (72208)	NWS/WFO, NOAA 5777 S. Aviation Avenue Charleston, SC 29406	Steve Rich MIC Stephen.Rich@noaa.gov	843-744-0303 843-554-4851 FAX: 843-747-5405
GSO (72317)	NWS/WFO, NOAA Centennial Campus NCSU 1005 Capability Dr. Research Building III, Suite 300 Raleigh, NC 27606	Steve Harned MIC Steve.Harned@noaa.gov	919-515-8209 919-515-8203 FAX: 919-515-8213
MHX (72305)	NWS/WFO, NOAA 533 Roberts Road Newport, NC 28570	Thomas Kriehn MIC Thmoas.Kriehn@noaa.gov	252-223-5122 FAX: 252-223-3673
OKX (72501)	NWS/WFO, NOAA 175 Brookhaven Avenue Bld. # NWS 1 Upton, NY 11973	Michael E. Wyllie MIC Micheal.Wyllie@noaa.gov	631-924-0037 631-924-0227 631-924-0517 FAX: 631-345-2869
WAL (72402)	NWS/WSCMO[2,3] Building N162 Wallops Island, VA 23337	Bryan Cunnigham Chief, UA Section	757-824-1586 757-824-1160 FAX: 757-854-0843
	Weather Office[3,4] Building E106 Wallops Island, VA 23337	Ted Wilz[5] MIC	757-824-1325 757-824-1638 FAX: 757-824-2410

[1] Additional rawinsondes or radiosondes may be requested from the NWS/ER or NWS/SR stations listed in Tables C-4.2 and C-4.3: (a) through the duty Hurricane Specialist (NHC); or (b) directly by phone. Messages should contain a statement asking that the appropriate NWS station(s) acknowledge and confirm each request. Remember to identify the program as "**HRD/Hurricane Field Program**" and follow instructions in Note 4, at the bottom of Table C-4.1.

[2] Normal hours of operation: 0600-2230 EDT (or EST, when appropriate).

[3] If you can't reach your party on any of the numbers shown, contact the NASA switchboard operator (757-824-1000) and ask to have your party paged.

[4] Normal hours of operation: 0530-1600 EDT (or EST, when appropriate).

[5] Home phone number is 410-860-2108.

Table C-4.3 NWS/Southern Region RAWIN/RAOB locations/contacts[1]

Station Identifier	Address/Location	MIC/OIC	Telephone Numbers
BMX (72230)	NWS/WFO, NOAA 465 Weathervane Road Calera, AL 35040-5427	Kenneth E. Graham MIC Kenneth.Graham@noaa.gov	205-621-5645 205-664-3010 205-621-5650 FAX: 205-664-7821
BRO (72250)	NWS/WFO, NOAA 20 South Vermillion Road Brownsville, TX 78521-5798	Richard R. Hagan MIC Richard.Hagan@noaa.gov	956-504-3184 956-504-1432 FAX: 956-982-1766
CRP (72251)	NWS/WFO, NOAA 300 Pinson Drive Corpus Christi, TX 78406-1803	Jim Purpura MIC James.Purpura@noaa.gov	361-299-1353 FAX: 361-289-7823
EYW (72201)	NWS/WFO, NOAA International Airport 3535 S. Roosevelt Blvd. - Suite.105 Key West, FL 33040-5208	Matt Strahan MIC Matt.Strahan@noaa.gov	305-295-1316 FAX: 305-293-9987 *(call ahead)*
FFC (72215)	NWS/WFO, NOAA 4 Falcon Drive Peachtree City, GA 30269	Lans Rothfusz MIC Lans.Rothfusz@noaa.gov	770-486-1133 770-486-3592 FAX: 770-486-9333
FWD (72249)	NWS/WFO, NOAA 3401 Northern Cross Blvd. Forth Worth, TX 76137-3610	William F. Bunting MIC William.Bunting@noaa.gov	817-831-1157 817-429-2631 817-831-1581 FAX 817-831-3025
JAN (72235)	NWS/WFO, NOAA 234 Weather Service Drive Jackson, MS 39232	Jim Spefkovich MIC Jim.Spefkovich@noaa.gov	601-965-4639 601-936-2189 601-939-2786 FAX: 601-965-4028
JAX (72206)	NWS/WFO, NOAA 13701 Fang Drive Jacksonville, FL 32218	Stephen M. Letro MIC Steve.Letro@noaa.gov	904-741-5186 904-741-4370 904-741-4411 FAX: 904-741-0078

Table C-4.3 NWS/Southern Region RAWIN/RAOB locations/contacts[1] (continued)

Station Identifier	Address/Location	MIC/OIC	Telephone Numbers
LCH (72240)	NWS/WFO, NOAA 500 Airport Blvd., #115 Lake Charles, LA 70607-0669	Steve Rinard MIC Steve.Rinard@noaa.gov	337-477-5285 337-477-0626 FAX: 337-474-8705
LZK (72340)	NWS/WFO, NOAA N. Little Rock Airport 8400 Remount Road N. Little Rock, AR 72118	Renee Fair MIC Renee.Fair@noaa.gov	501-834-9102 501-834-0308 501-834-3955 FAX: 501-834-0715
MFL (72203)	NWS/WFO, NOAA 11691 S.W. 17th Street Miami, FL 33165-2149	Russell “Rusty” Pfost MIC Rusty.Pfost@noaa.gov	305-229-4500 305-229-4522 FAX: 305-229-4553 FAX: 305-559-4503
SHV (72248)	NWS/WFO, NOAA 5655 Hollywood Avenue Shreveport, LA 71109-7750	Lee Harrison MIC Lee.Harrison@noaa.gov	318-635-9398 318-631-3669 318-636-7345 FAX: 318-636-9620
LIX (72233)	NWS/WFO, NOAA 62300 Airport Road Slidell, LA 70460-5243	Paul S. Trotter MIC Paul.Trotter@noaa.gov	985-645-0899 FAX: 985-649-2907
TBW (72210)	NWS/WFO, NOAA 2525 14th Avenue, S.E. Ruskin, FL 33570 [Tampa Bay Area]	Ira Brenner MIC Ira.Brenner@noaa.gov	813-645-4111 813-645-2323 FAX: 813-641-2441 FAX: 813-641-2619
SJU (78526)	NWS/WFO, NOAA 4000 Carretera 190 Carolina, PR 00979	Israel Matos[3] MIC Israel.Matos@noaa.gov Rafael Mojica WCM	787-253-4586 FAX: 787-253-7802
TLH (72214)	NWS/WFO, NOAA Love Building 116 Palmetto Drive Tallahassee, FL 32306	Paul Duval MIC Paul.Duval@noaa.gov	850-942-8831 850-942-8833 FAX: 850-942-8850

[1] See footnote 1 in Table C-4.2.

[2] Hours: 0400-2000 CDT (or CST, when appropriate).

[3] Pager: 1-800-652-0608

Table C-4.4 NWS/Eastern Region coastal radar locations/contacts

Station Identifier/ Type Radar/ Lat./Lon.	Address/Location	MIC/OIC	Telephone Numbers
KAKQ (93773) WSR-88D 36.9839°N 77.0072°W	NWS/WFO, NOAA 10009 General Mahone Hwy. Wakefield, VA 23888	Anthony Siebers MIC Anthony.Siebers@ noaa.gov	757-899-4200 757-899-3012 FAX: 757-899-3605
KCLX (53845) WSR-88D 32.6555°N 81.0422°W	NWS/WFO, NOAA 5777 S. Aviation Avenue Charleston, SC 29406	Stephen T. Rich MIC Stephen.Rich@noaa.gov	843-744-0303 843-554-4851 FAX: 843-747-5405
KLTX (93774) WSR-88D 33.9894°N 78.4289°W	NWS/WFO, NOAA 2015 Gardner Drive Wilmington, NC 28405	Richard W. Anthony MIC Richard.Anthony@ noaa.gov	910-762-4289 910-763-8331 FAX: 910-762-1288
KLWX (93767) WSR-88D 38.9753°N 77.4778°W	NWS/WFO, NOAA 44087 Weather Service Rd Sterling, VA 20166-2001	Jim Travers MIC James.Travers@noaa.gov	703-260-0107 703-260-0106 Fax: 703-260-0809
KMHX (93768) WSR-88D 34.7761°N 76.8761°W	NWS/WFO, NOAA 533 Roberts Road Newport, NC 28570	Thomas Kriehn MIC Thomas.Kriehn@noaa.gov	252-223-5122 FAX: 252-223-3673
KOKX (94703) WSR-88D 40.8656°N 72.8639°W	NWS/WFO, NOAA 175 Brookhaven Avenue Bldg NWS-1. Upton, NY 11973	Michael E. Wyllie MIC Michael.Wyllie@noaa.gov	631-924-0037 631-924-0227 631-924-0517 FAX: 613-345-2869
KRAX (93772) WSR-88D 35.6656°N 78.4897°W	NWS/WFO, NOAA Centennial Campus NCSU 1005 Capability Dr. Research Building III, Suite 300 Raleigh, NC 27606	Steve Harned MIC Steve.Harned@noaa.gov	919-515-8209 919-515-8203 FAX: 919-515-8213

Note 1: NWS/ER point of contact for WSR-88D information is the Eastern Region/Regional Operations Center (631-244-0172).

Table C-4.5 NWS/Southern Region coastal radar locations/contacts

Station Identifier/ Type Radar/ Lat./Lon.	Address/Location	MIC/OIC	Telephone Numbers
KBRO (12919) WSR-88D 25.9161°N 97.4189°W	NWS/WFO, NOAA 20 South Vermillion Road Brownsville, TX 78521-6851	Richard R. Hagan MIC Richard.Hagan@noaa.gov	956-504-3184 956-504-1432 FAX: 956-982-1766
KCRP (12924) WSR-88D 27.7842°N 97.5111°W	NWS/WFO, NOAA 300 Pinson Drive Corpus Christi, TX 78406	Jim Purpura MIC James.Purpura@noaa.gov	361-299-1353 FAX: 361-289-7823
KBYX(92804) WSR-88D 24.5975°N 81.7031°W	NWS/WFO, NOAA Key West International Airport 3535 S. Roosevelt Blvd. #.105 Key West, FL 33040-5234	Matt Strahan MIC Matt.Strahan@noaa.gov	305-295-1316 FAX: 305-293-9987 *(call ahead)*
KHGX (03980) WSR-88D 29.4719°N 95.0792°W	NWS/WFO, NOAA 1620 Gill Road Dickinson, TX 77539	William "Bill" Read MIC Bill.Read@noaa.gov	281-534-2157 281-337-5074 281-337-5192 FAX: 281-337-3798
KJAX (13889) WSR-88D 30.4847°N 81.7019°W	NWS/WFO, NOAA 13701 Fang Drive Jacksonville, FL 32218	Stephen M. Letro MIC Steve.Letro@noaa.gov	904-741-5186 904-741-4370 904-741-4411 FAX: 904-741-0078
KLCH (03937) WSR-88D 30.1253°N 93.2158°W	NWS/WFO, NOAA 500 Airport Boulevard, #115 Lake Charles, LA 70607-0669	Steve Rinard MIC Steve.Rinard@noaa.gov	337-477-5285 337-477-0626 FAX: 337-474-8705
KLIX (53813) WFSR-88D 30.3367°N 89.8256°W	NWS/WFO, NOAA 62300 Airport Road Slidell, LA 70460	Paul S. Trotter MIC Paul.Trotter@noaa.gov	985-645-0899 FAX: 985-649-2907

Table C-4.5 NWS/Southern Region coastal radar locations/contacts (continued)

Station Identifier/ Type Radar/ Lat./Lon.	Address/Location	MIC/OIC	Telephone Numbers
KAMX (12899) WSR-88D 25.6111°N 80.4128°W	NWS/WFO, NOAA 11691 S.W. 17th Street Miami, FL 33165-2149	Russell "Rusty" Pfost MIC Rusty.Pfost@noaa.gov	305-229-4500 305-229-4522 FAX: 305-229-4553 FAX: 305-559-4503
KMLB (12838) WSR-88D 28.1133°N 80.6542°W	NWS/WFO, NOAA 421 Croton Road Melbourne, FL 32935	Bart Hagemeyer MIC Bart.Hagemeyer@noaa.gov	321-255-0212 321-254-6083 FAX: 321-255-0791
KMOB (13894) WSR-88D 30.6794°N 88.2397°W	NWS/WFO, NOAA 8400 Airport Boulevard, Bldg # 11 Mobile, AL 36608	Randall McKee MIC Randall.McKee@noaa.gov	251-633-5456 251-633-6443 251-633-7642 FAX: 251-607-9773
KTBW (92801) WSR-88D 27.7056°N 82.4022°W	NWS/WFO, NOAA 2525 14th Avenue, S.E. Ruskin, FL 33570 [Tampa Bay Area]	Ira Brenner MIC Ira.Brenner@noaa.gov	813-645-4111 813-645-2323 FAX: 813-641-2619 813-641-2441
TJUA(11655) WSR-88D 18.1156°N 66.0781°W	NWS/WFO, NOAA 4000 Carretera 190 Carolina, PR 00979	Israel Matos MIC Israel.Matos@noaa.gov Rafael Mojica WCM	787-253-4586 FAX: 787-253-7802
KTLH (93805) WSR-88D 30.3975°N 84.3289°W	NWS/WFO, NOAA Love Building 116 Palmetto Drive Tallahassee, FL 32306	Paul Duval MIC Paul.Duval@noaa.gov	850-942-8831 850-942-8833 FAX: 850-942-8850

Note 1: NWS/SR official contact for WSR-88D information is Victor Murphy (W/SR/SRH), WSR-88D Meteorologist (817-978-2367 ext. 130).

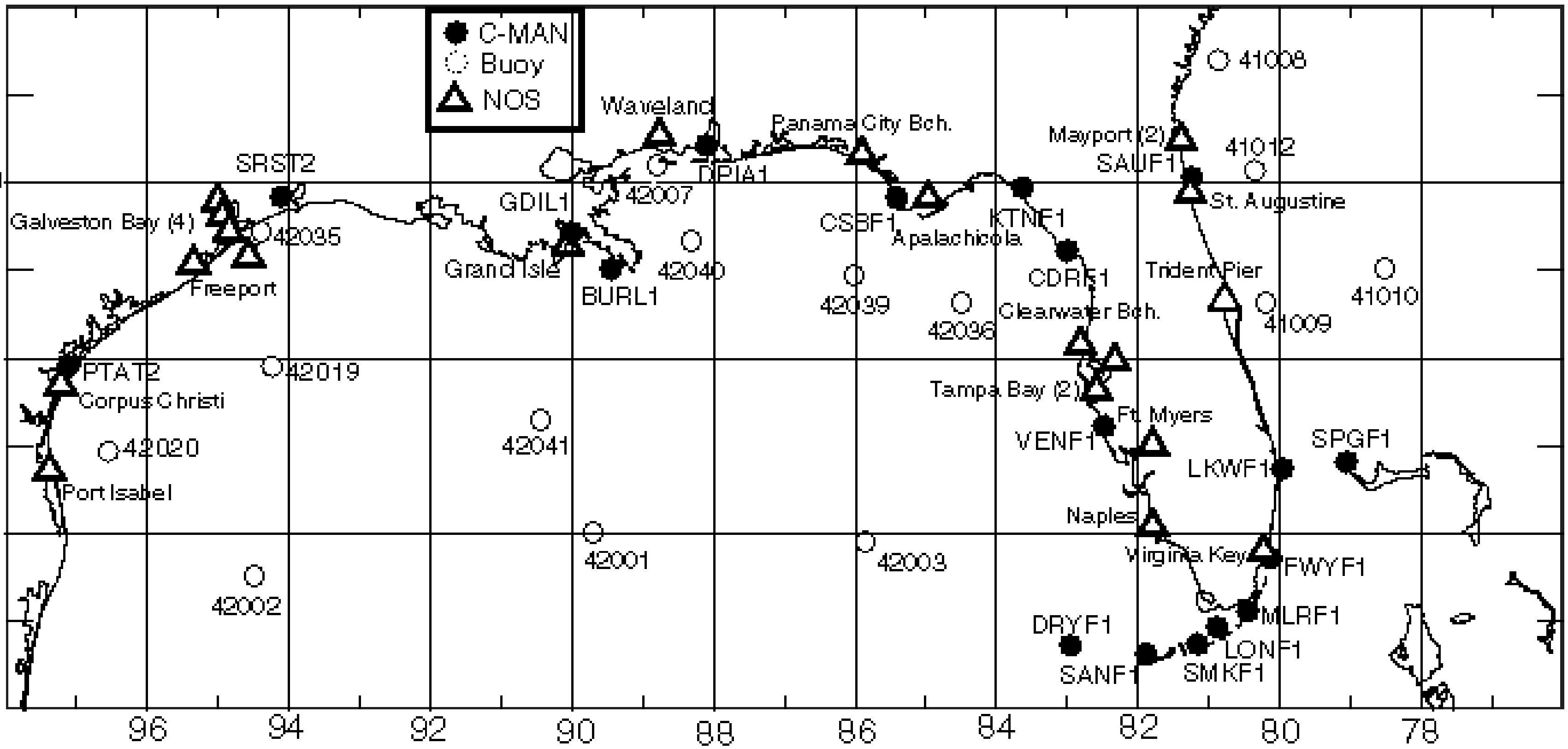


Fig. C-2. Marine buoy, C-MAN, and NOS (lower case) locations in the Gulf of Mexico, Florida, and southern Georgia. See Tables C-3.1 -- C3.3

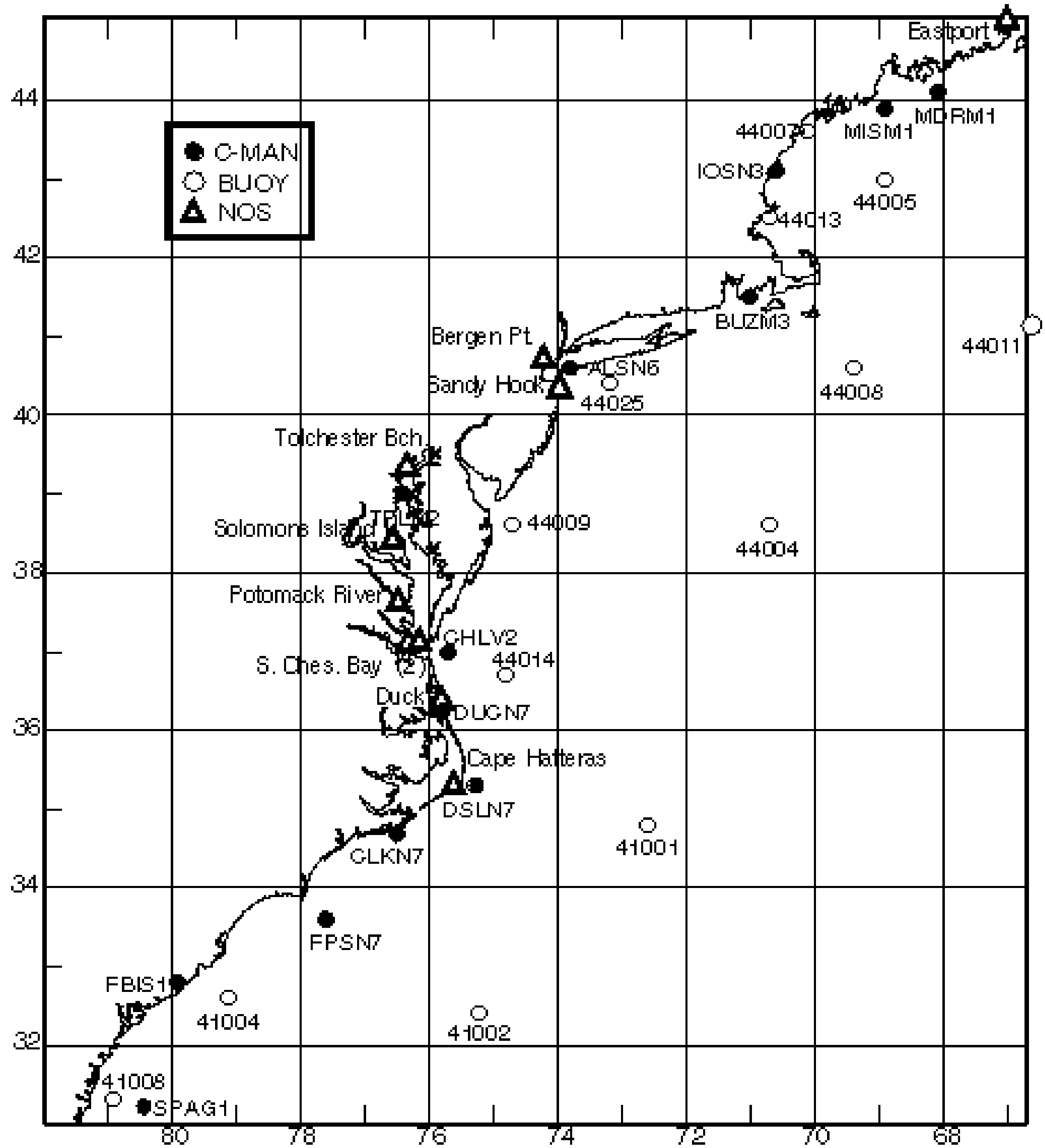


Fig. C-3. Marine buoy, C-MAN, and NOS (lower case) locations for the U.S. east coast. See Tables C-3.1 -- C-3.3.

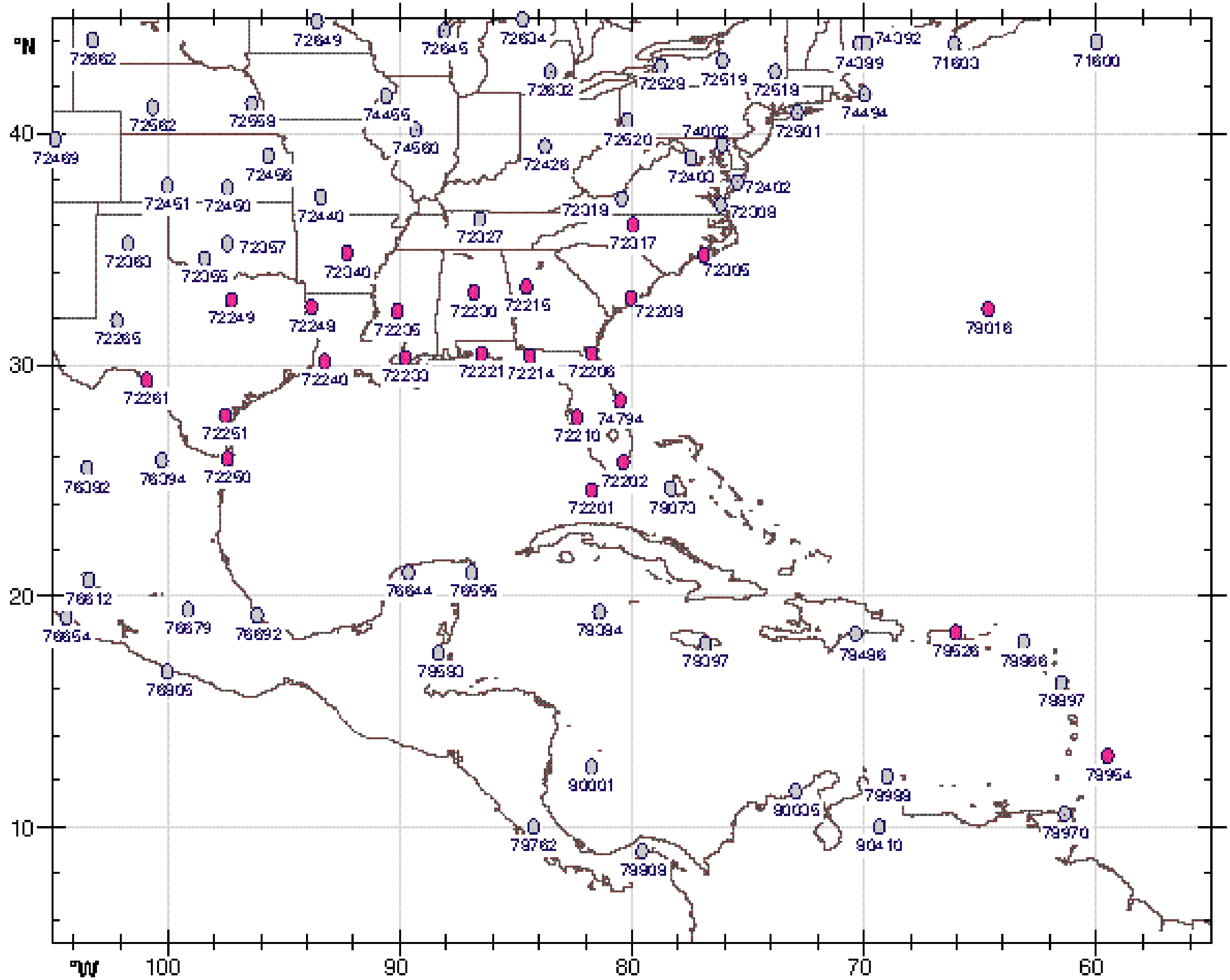


Fig. C-4. Locations of RAWIN/RAOB stations. See Tables C-4.1-C-4.5 for information about stations shown as dark circles.

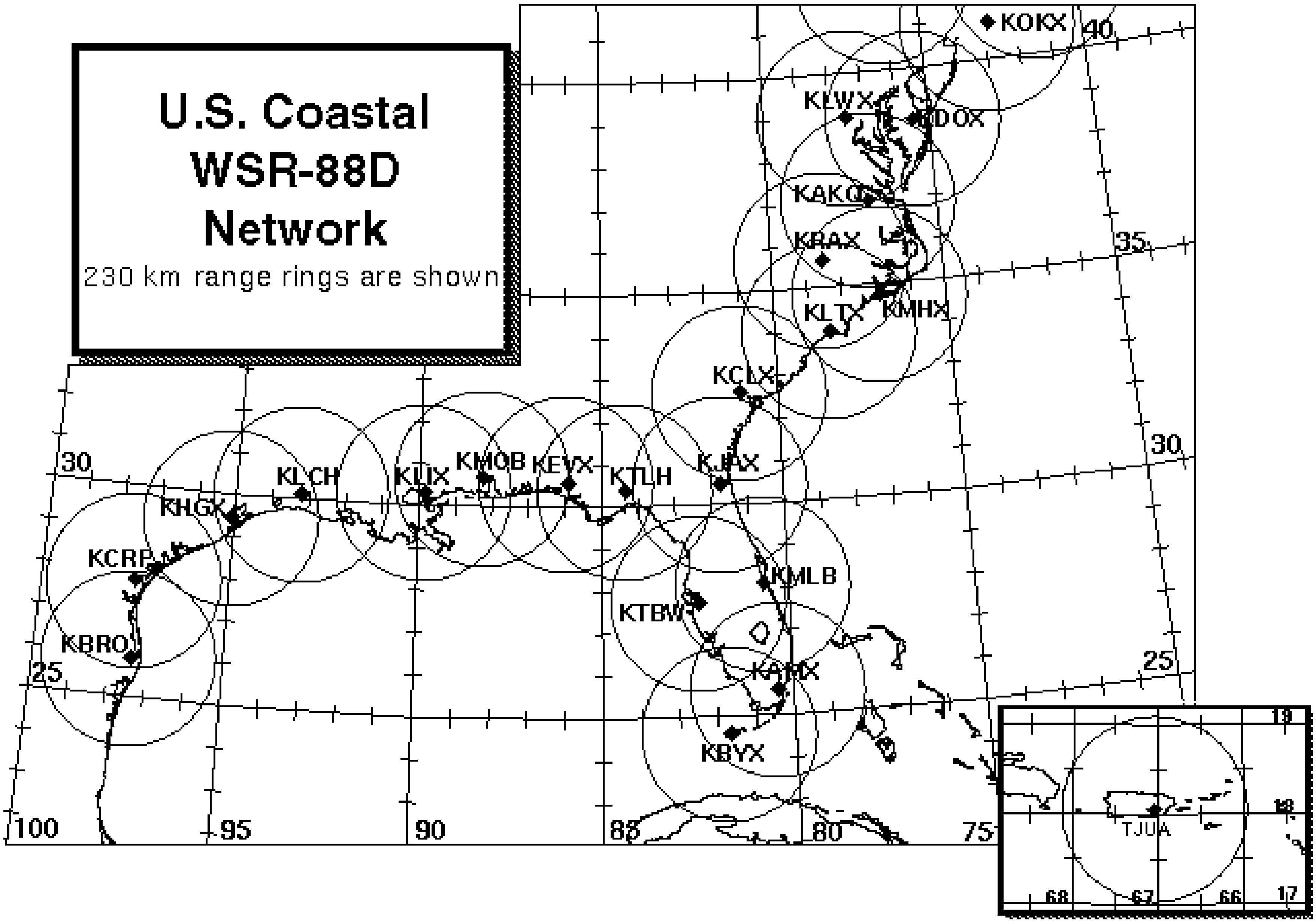


Fig. C-5. Locations of coastal WSR-88D stations. See tables C-4.1 -- C-4.5 for complete information.

APPENDIX D

PRINCIPAL DUTIES OF THE NOAA SCIENTIFIC PERSONNEL

PRINCIPAL DUTIES OF THE NOAA SCIENTIFIC PERSONNEL

CAUTION

Flight operations are routinely conducted in turbulent conditions. Shock-mounted electronic and experimental racks surround most seat positions. Therefore, for safety onboard the aircraft all personnel should wear long pants and closed toed shoes. For comfort, personnel should bring a jacket or sweater as the cabin gets cold during flight.

Smoking is prohibited within 50 ft of the aircraft while they are on the ground. No smoking is permitted on the aircraft at any time.

GENERAL INFORMATION FOR ALL SCIENTIFIC MISSION PARTICIPANTS

Mission participants are advised to carry the proper personal identification [i.e., travel orders, "shot" records (when appropriate), and passports (when required)]. Passports will be checked by AOC personnel prior to deployment to countries requiring it. All participants must provide their own meals for in-flight consumption. AOC provides a refrigerator, microwave, coffee, utensils, condiments, ice, water, and soft drinks for a mandatory **$2.00** per flight "mess" fee.

D.1 Field Program Director;

(1) Responsible to the HRD director for the implementation of the Hurricane Field Program Plan.

(2) Only official communication link to AOC. Communicates flight requirements and changes in mission to AOC.

(3) Only formal communication link between AOML and CARCAH during operations. Coordinates scheduling of each day's operations with AOC only after all (POD) reconnaissance requirements are completed between CARCAH and AOC.

(4) Convenes the Hurricane Field Program Operations Advisory Panel. This panel selects missions to be flown in comparison with others as specified in sections 9-15 of this plan.

(5) Provides for pre-mission briefing of flight crews, scientists, and others (as required).

(6) Assigns duties of field project scientific personnel.

(7) Coordinates press statements with NOAA/Public Affairs.

D.2 Assistant Field Program Director

(1) Assumes the duties of the field program director in his absence.

D.3 Miami Ground Operations Center: Senior Team Leader

(1) During operations, the MGOC senior team leader is responsible for liaison between HRD base and field personnel and other organizations as requested by the field program director, the director of HRD, or their designated representatives.

D.4 Named Experiment Lead Project Scientist

(1) Has overall responsibility for the experiment.

(2) Coordinates the project and sub-project requirements.

(3) Determines the primary modes of operation for appropriate instrumentation.

(4) Assists in the selection of the mission.

(5) Provides a written summary of the mission to the field program director (or his designee) at the experiment's debriefing.

D.5 Lead Project Scientist

(1) Has overall scientific responsibility for his/her aircraft.

(2) Makes in-flight decisions concerning alterations of: (a) specified flight patterns; (b) instrumentation operation; and (c) assignment of duties to on-board scientific project personnel.

(3) Acts as project supervisor on the aircraft and is the focal point for all interactions of project personnel with operational or visiting personnel.

(4) Conducts preflight and post flight briefings of the entire crew. Completes formal checklists of instrument operations, noting malfunctions, problems, etc.

(5) Provides a written report of each mission day's operations to the field program director at the mission debriefing.

D.6 Cloud Physics Scientist

(1) Has overall responsibility for the cloud physics project on the aircraft.

(2) Briefs the on-board lead project scientist on equipment status before takeoff.

(3) Determines the operational mode of the cloud physics sensors (i.e., where, when, and at what rate to sample).

(4) Operates and monitors the cloud physics sensors and data systems.

(5) Provides a written preflight and post flight status report and flight summary of each mission day's operations to the on-board lead project scientist at the post flight debriefing.

D.7 Boundary-Layer Scientist

(1) Insures that the required number of AXCPs, AXBTs, and AXCTDs are on the aircraft for each mission.

(2) Operates the AXCP, AXBT, and AXCTD equipment (as required) on the aircraft.

(3) Briefs the on-board lead project scientist on equipment status before takeoff.

(4) Determines where and when to release the AXCPs, AXBTs, and AXCTDs (as appropriate) subject to clearance by flight crew.

(5) Performs preflight, inflight, and post flight checks and calibrations.

(6) Provides a written preflight and post flight status report and a flight summary of each mission day's operations to the on-board lead project scientist at the post flight debriefing.

D.8 Radar Scientist

(1) Determines optimum meteorological target displays. Continuously monitors displays for performance and optimum mode of operations. Thoroughly documents modes and characteristics of the operations.

(2) Provides a summary of the radar display characteristics to the on-board lead project scientist at the post flight debriefing.

(3) Maintains tape logs and changes magnetic tape (as needed).

(4) During the ferry to the storm, the radar scientist should record a tape of the sea return on either side of the aircraft at elevation angles varying from -20° through +20°. This tape will allow correction of any antenna mounting biases or elevation angle corrections.

D.9 Dropsonde Scientist

(1) Examines dropsonde observations for accuracy.

(2) Determines the most likely values of temperature, dew-point depression, and horizontal wind at mandatory and significant (pressure) levels.

(3) Provides final code to the data system technician for ASDL, transmission or insures correct code in case of automatic data transmission.

D.10 Workstation Scientist

(1) Operates HRD's workstation.

(2) Runs programs that determine wind center and radar center as a function of time, composite flight-level and radar reflectivity relative to storm center and then process and code dropwindsonde observations.

(3) Checks data for accuracy and sends appropriate data to ASDL computer.

(4) Maintains records of the performance of the workstation and possible software improvements.

APPENDIX E

NOAA RESEARCH OPERATIONAL PROCEDURES AND CHECK LISTS

NOAA RESEARCH OPERATIONAL PROCEDURES AND CHECK LISTS

E.1 Procedures and Mission Directives: "Conditions-of-Flight" Commands

Mission participants should be aware of the designated "conditions-of-flight." There are five designated basic conditions of readiness encountered during flight. The pilot will set a specific condition and announce it to all personnel over the aircraft's PA (public address) and ICS (interphone communications systems). All personnel are expected to act in accordance with the instructions for the specific condition announced by the pilot. These conditions and appropriate actions are shown below.

CONDITION 1: TURBULENCE/PENETRATION. All personnel will stow loose equipment and fasten safety belts.

CONDITION 2: HIGH ALTITUDE TRANSIT/FERRY. There are no cabin station manning requirements.

CONDITION 3: NORMAL MISSION OPERATIONS. All scientific and flight crew stations are to be manned with equipment checked and operating as dictated by mission requirements. Personnel are free to leave their ditching stations.

CONDITION 4: AIRCRAFT INSPECTION. After take-off, crew members will perform wings, engines, electronic bays, lower compartments, and aircraft systems check. All other personnel will remain seated with safety belts fastened and headsets on.

CONDITION 5 TAKE-OFF/LANDING. All personnel will stow or secure loose equipment, don headsets, and fasten safety belts/shoulder harnesses.

E.2 Lead Project Scientist

E.2.1 Preflight

_____ 1. Participate in general mission briefing.

_____ 2. Determine specific mission and flight requirements for assigned aircraft.

_____ 3. Determine from CARCAH or field program director whether aircraft has operational fix responsibility and discuss with AOC flight director/meteorologist and CARCAH unless briefed otherwise by field program director.

_____ 4. Contact HRD members of crew to:
   a. Assure availability for mission.
   b. Arrange ground transportation schedule when deployed.
   c. Determine equipment status.

_____ 5. Meet with AOC flight crew at least 90 minutes before takeoff, provide copies of flight requirements, and provide a formal briefing for the flight director, navigator, and pilots.

_____ 6. Report status of aircraft, systems, necessary on-board supplies and crews to appropriate HRD operations center (MGOC in Miami).

E.2.2In-Flight

_____ 1. Confirm from AOC flight director that satellite data link is operative (information).

_____ 2. Confirm camera mode of operation.

_____ 3. Confirm data recording rate.

_____ 4. Complete Form E-2.

E.2.3Post flight

_____ 1. Debrief scientific crew.

_____ 2. Report landing time, aircraft, crew, and mission status along with supplies (tapes, *etc.*) remaining aboard the aircraft to MGOC.

_____ 3. Gather completed forms for mission and turn in at the appropriate operations center. [**Note**: all data removed from the aircraft by HRD personnel should be cleared with the AOC flight director.]

_____ 4. Obtain a copy of the 10-s flight listing from the AOC flight director. Turn in with completed forms.

_____ 5. Determine next mission status, if any, and brief crews as necessary.

_____ 6. Notify MGOC as to where you can be contacted and arrange for any further coordination required.

_____ 7. Prepare written mission summary using form E-2 p.3 (due to Field Program Director1 week after the flight).

Lead Project Scientist Check List

Date _______________ **Aircraft** ______________ **Flight ID** ____________________

A. —Participants:

HRD		AOC	
Function	**Participant**	**Function**	**Participant**
Lead Project Scientist		Flight Director	
Cloud Physics		Pilots	
Radar		Navigator	
Workstation		Systems Engineer	
Photographer/Observer		Data Technician	
Dropwindsonde		Electronics Technician	
AXBT/AXCP/Guest		Other	

Take-Off: ________ Location: _______________ Landing: ________ Location: _________________

Number of Eye Penetrations: ______

B. —Past and Forecast Storm Locations:

Date/Time	Latitude	Longitude	MSLP	Maximum Wind

C. —Mission Briefing:

D. —Equipment Status (Up ↑, Down ▯, Not Available **—**, Not Used **O**)

Equipment	**Pre-Flight**	**In-Flight**	**Post-Flight**	**# of DATs or Expendables**
Aircraft				
Radar/LF				
Radar/TA (Doppler)				
Cloud Physics				
Data System				
GPS sondes				
AXBT/AXCP				
Workstation				
Videography				

REMARKS:

Mission Summary
<u>Storm name</u>
YYMMDDA# Aircraft 4_RF

Scientific Crew (4 RF)
Lead Project Scientist ____________________________
Radar Scientist____________________________________
Cloud Physics Scientist____________________________
Dropwindsonde Scientist____________________________
Boundary-Layer Scientist___________________________
Workstation Scientist______________________________
Observers____

Mission Briefing: (include sketch of proposed flight track or page #)

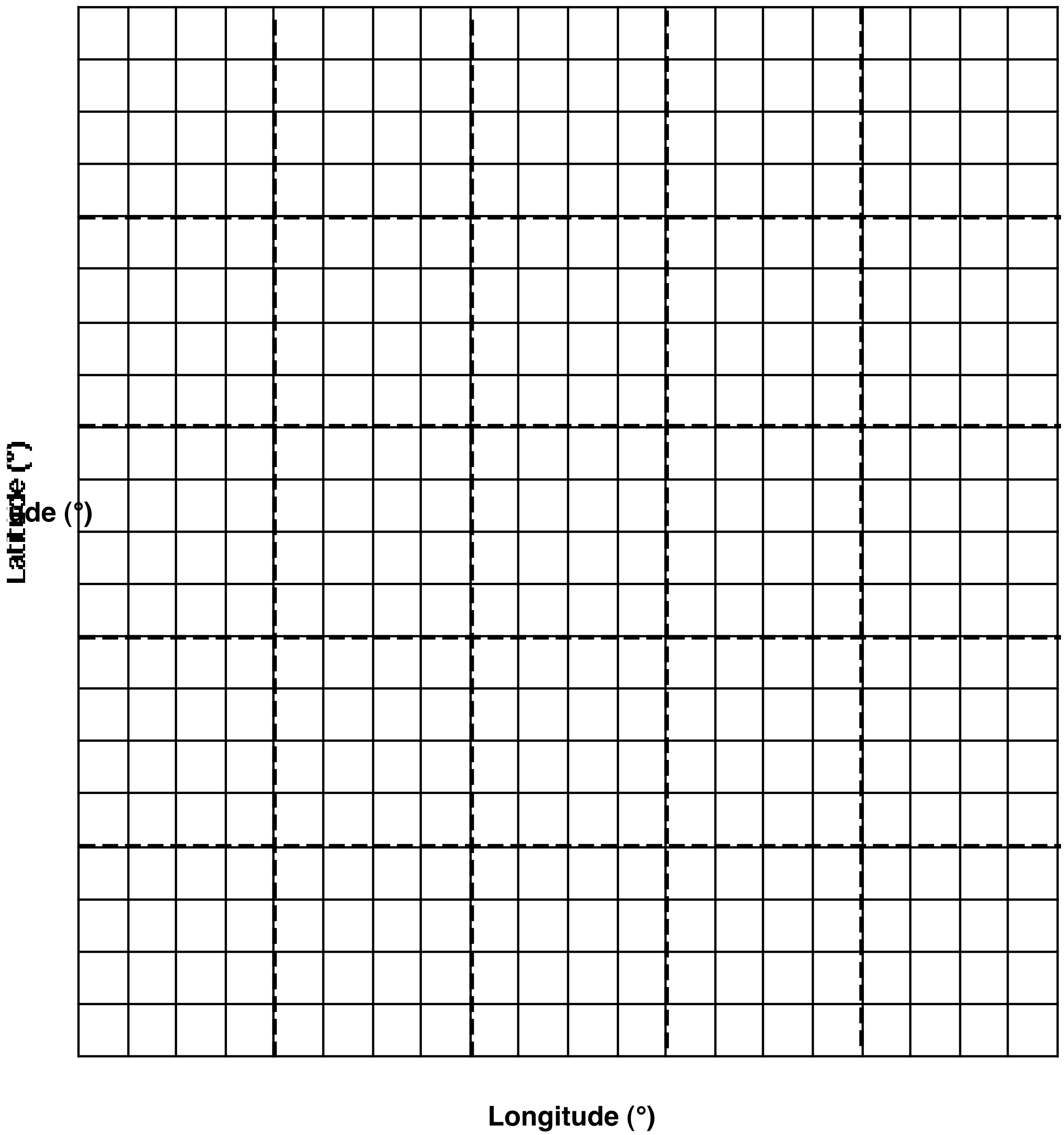
Mission Synopsis: (include plot of actual flight track)

Evaluation: (did the experiment meet the proposed objectives?)

Problems:(list all problems)

Observer's Flight Track Worksheet

Date __________________ Flight __________________ Observer ___________________



Form E-2
Page 5 of 5

Lead Project Scientist Event Log

Date ________________ **Flight** ________________ **LPS** _____________________

Time	Event	Position	Comments

E.3 Cloud Physics Scientist

The on-board cloud physics scientist (CPS) is responsible for cloud physics data collection on his/her assigned aircraft. Detailed operational procedures are contained in the cloud physics kit supplied for each aircraft. General procedures follow. (Check off and initial.)

E.3.1 Preflight

_____ 1. Determine status of cloud physics instrumentation systems and report to the on-board lead project scientist (LPS).

_____ 2. Confirm mission and pattern selection from the on-board LPS.

_____ 3. Select mode of instrument operation.

_____ 4. Complete appropriate instrumentation preflight check lists as supplied in the cloud physics operator's kit.

E.3.2 In-Flight

_____ 1. Operate instruments as specified in the cloud physics operator's kit and as directed by the on-board LPS.

E.3.3 Post flight

_____ 1. Complete summary checklist forms and all other appropriate forms.

_____ 2. Brief the on-board LPS on equipment status and turn in completed check sheets to the LPS.

_____ 3. Take cloud physics data tapes and other data forms and turn these data sets in as follows:

a. Outside of Miami-to the LPS.
b. In Miami-to AOML/HRD. [**Note**: all data removed from the aircraft by HRD personnel should be cleared with the AOC flight director.]

_____ 4. Debrief as necessary at MGOC or the hotel during a deployment.

_____ 5. Determine the status of future missions and notify MGOC as to where you can be contacted.

Cloud Physics Scientist Check List

Date ____________________ **Aircraft** _____________ **Flight ID** ___________________

A. —Instrument Status and Performance:

System	Pre-Flight	In-Flight	Downtime	# of Tapes
Johnson-Williams				
PMS Probes:				
—2D-P				
—2D-C				
—FSSP				
—Data System				
—Recorder				
FORMVAR				
DRI Charge Probe				
DRI Field Mills				
King Probe				

B. —Remarks:

Form E-3
Page 2 of 2

2-D Knollenberg Data Tape Log

Date _______________ Flight ________________ Operator __________________

__

Tape #	EOF #	Time On	Time Off	Comments

E.4 Boundary-Layer Scientist

The on-board boundary-layer scientist (BLS) is responsible for data collection from AXBTs, AXCPs, AXCTDs, BUOYs, and SST radiometers (if these systems are used on the mission). Detailed calibration and instrument operation procedures are contained in the air-sea interaction (ASI) manual supplied to each operator. General supplementary procedures follow. (Check off and initial.)

E.4.1 Preflight

_____ 1. Determine the status of equipment and report results to the on-board lead project scientist (LPS).

_____ 2. Confirm mission and pattern selection from the on-board LPS.

_____ 3. Select the mode of operation for instruments after consultation with the HRD/BLS and the on-board LPS.

_____ 4. Complete appropriate preflight check lists as specified in the ASI manual and as directed from the on-board LPS.

E.4.2 In-Flight

_____ 1. Operate the instruments as specified in the ASI manual and as directed by the on-board LPS.

E.4.3 Post flight

_____ 1. Complete summary checklist forms and all other appropriate check list forms.

_____ 2. Brief the on-board LPS on equipment status and turn in completed checklists to the LPS.

_____ 3. Debrief as necessary at MGOC or the hotel during a deployment.

_____ 4. Determine the status of future missions and notify MGOC as to where you can be contacted.

AXBT/AXCP Check Sheet Summary

Flight ________________ **Aircraft** ____________ **Operator** ________________

Number

(1) Probes dropped _______

(2) Failures _______

(3) Failures with no signal _______

(4) Failures with sea surface temperature, but terminated above thermocline _______

(5) Probes that terminated above 250 m, but below thermocline _______

(6) Probes used by channel number

CH12 _______

CH14 _______

CH16 _______

CH__ _______

NOTES:

Form E-4
Page 2 of 3

AXBT and AXCP Check Sheet

Flight Number ______________________ AXBT/AXCP Contract Number _________________

Take-Off Time ______________________ Landing Time ________________________________

Storm __________________________ Storm Direction/Speed ________________________

AXCP/ AXBT #/Type	Channel Number	Lot Number	Drop Time (HHMMSS)	Lat. Deg. Min.		Long. Deg. Min.		Surface Temp. AXBT IRT		MLD (m)	Comments
				Deg.	Min.	Deg.	Min.	AXBT	IRT		

Form E-4
Page 3 of 3

AXCP Log

Flight Number ______________________ AXBT/AXCP Contract Number _________________

Take-Off Time ______________________Landing Time ______________________________

Storm ____________________________ Storm Direction/Speed ______________________

Leg Number	Out/In	RA (m)	PMIN (hPa)	VMAX (m/s)	RMAX (km)	Time PMIN	Time VMAX	Time End Pass

Leg/ Drop #	Tube #	Channel #	Probe Type		Ground Speed	Drop Time (HHMMSS)	Latitude (deg min)	Longitude (deg min)	Status		Comments
			Slow	Reg					Good	Bad	

E.5 Radar Scientist

The on-board radar scientist is responsible for data collection from all radar systems on his/her assigned aircraft. Detailed operational procedures and checklists are contained in the operator's manual supplied to each operator. General supplementary procedures follow. (Check off and initial.)

E.5.1 Preflight

_____ 1. Determine the status of equipment and report results to the on-board lead project scientist (LPS).

_____ 2. Confirm mission and pattern selection from the on-board LPS.

_____ 3. Select the operational mode for radar system(s) after consultation with the on-board LPS.

_____ 4. Complete the appropriate preflight calibrations and check lists as specified in the radar operator's manual.

E.5.2 In-Flight

_____ 1. Operate the system(s) as specified in the operator's manual and as directed by the on-board LPS or as required for aircraft safety as determined by the AOC flight director or aircraft commander.

_____ 2. Maintain a written commentary in the radar logbook of tape and event times, such as the start and end times of F/AST legs. Also document any equipment problems or changes in R/T, INE, or signal status.

E.5.3 Post flight

_____ 1. Complete the summary checklists and all other appropriate check lists and forms.

_____ 2. Brief the on-board LPS on equipment status and turn in completed forms to the LPS.

_____ 3. Hand-carry all radar tapes and arrange delivery as follows:

a. Outside of Miami-to the LPS.
b. In Miami-to MGOC or to AOML/HRD. [**Note**: all data removed from the aircraft by HRD personnel should be cleared with the AOC flight director.]

_____ 4. Debrief at MGOC or the hotel during a deployment.

_____ 5. Determine the status of future missions and notify MGOC as to where you can be contacted.

HRD Radar Scientist Check List

Flight ID: ______________________________________

Aircraft Number: ________________________________

Radar Operators: _______________________________

Radar Technician: _______________________________

Number of digital magnetic tapes on board: ___________

Component Systems Status:

MARS __________________________ Computer ____________________________

DAT1___________________________ DAT2 _______________________________

LF _____________________________ R/T Serial # __________________________

TA _____________________________ R/T Serial # __________________________

Time correction between radar time and digital time: ___

Radar Post flight Summary

Number of digital tapes used: DAT1 _______________________

DAT2 _______________________

Significant down time:

DAT1 ______________________ Radar LF ____________________

DAT2 ______________________ Radar TA ____________________

Other Problems:

HRD Radar Tape Log

Flight _______________ **Aircraft** ________ **Operator** ________________ Sheet ____ of ____

LF RPM ________________ TA RPM _______________

(Include start and end times of DATs, as well as times of F/AST legs and any changes of radar equipment status)

Tape #	F/AST On?	Event Time (HHMMSS)	Event

Form E-5
Page 3 of 3

HRD Radar Down-Time Log

Flight _______________ **Aircraft** _________ **Operator** _______________ Sheet ____ of ____

Item	Time Down (HHMMSS)	Time Up (HHMMSS)	Problem

Item List: DAT1, DAT2, COMP, MARS, LF, and TA.

Include serial numbers of any new R/Ts.

E.6 Dropsonde Scientist

The on-board lead project scientist (LPS) on each aircraft is responsible for determining the distribution patterns for dropwindsonde releases. Predetermined desired data collection patterns are illustrated on the flight patterns. However, these patterns often are required to be altered because of clearance problems, etc. Operational procedures are contained in the operator's manual. The following list contains more general supplementary procedures to be followed. (Check off and initial.)

E.6.1 Preflight

_____ 1. Determine the status of equipment and report results to the on-board LPS.

_____ 2. Confirm the mission and pattern selection from the LPS and assure that the proper number and distribution (frequency) of dropsondes are on board the aircraft.

_____ 3. Complete the appropriate preflight calibrations and checklists.

E.6.2 In-Flight

_____ 1. Operate the system as specified in the operator's manual.

_____ 2. Obtain drop release approval (for each drop) from the AOC flight director or navigator for each specific time and location of drop.

_____ 3. Report to the LPS as soon as it is determined that the dropsonde is (or is not) transmitting a good signal.

_____ 4. Report completion of each drop and readiness for the next drop.

_____ 5. Complete Form E-6.

E.6.3 Post flight

_____ 1. Complete the summary form for GPS sondes.

_____ 2. Brief the on-board LPS on equipment status and turn in reports and completed forms to the LPS.

_____ 3. Hand-carry all dropwindsonde data tapes and printouts and inform the AOC flight director that you are arranging delivery as follows:

a. Outside of Miami-to the LPS.
b. In Miami-to AOML/HRD (temporarily), either directly or via MGOC, for conversion to 9-track magnetic tapes.

_____ 4. Debrief at the MGOC or the hotel during a deployment.

_____ 5. Determine the status of future missions and notify MGOC as to where you can be contacted.

N42/3RF HRD GPS Dropwindsonde Scientist Log (Revised 5/2002)

Storm____________ Dropwindsonde Scientists______________________________ Page ____ of ____

Flight ID__________ Flight Director__________________________ Takeoff from __________ at ______ UTC

Mission ID__________ AVAPS Operators__________________________ Recovery at __________ at ______ UTC

Drop #	Sonde ID #	Time (UTC)	Lat (°N)	Lon (°W)	Surface Pressure (mb)	Wind closest to surface dir/spd (kt)	hgt (m)	BT SST (°C)	Eye, Eyewall, Rainband (direction)	Comments	Ob #

N49RF HRD GPS Dropwindsonde Scientist Log (Revised 5/2002)

Storm__________ Dropwindsonde Scientists______________________________ Page ____ of ____

Flight ID__________ Flight Director______________________________ Takeoff from __________ at ______ UTC

Mission ID__________ AVAPS Operators______________________________ Recovery at __________ at ______ UTC

Drop #	Sonde ID #	Time (UTC)	Lat (°N)	Lon (°W)	Surface Pressure (mb)	Wind closest to surface dir/spd (kt)	hgt (m)	DLM wind (kt)	Comments	SATCOM tries	Ob #

APPENDIX F

GROUND OPERATIONS

GROUND OPERATIONS

In support of each field operation, a ground coordination team will serve on the staff of the HRD director. The ground coordination team will consist of the Miami Ground Operations Center (MGOC).

(1) Staff:

H. Friedman (senior team leader)
J. Berkeley (meteorological technical support)

(2) Operational Scheduling:

During research missions the MGOC staff will form three teams as follows: one team leader and, when necessary and available, one meteorological technician support person. Each team will work an (approximately) 8-h shift; shifts will continue for the duration of operations or until MGOC personnel are released by the field program director or his designee.

(3) General Duties:

During operations, the MGOC acts as the liaison between HRD and other organizations as required by the field program director, the HRD director, or their designated representatives. Duties of the MGOC include the following:

a. Collect, plot, and file data from NHC.

b. Update messages on the auto-phone tape at MGOC (NHC).

c. Coordinate the acquisition of satellite photos for operational and research purposes.

d. Make motel/hotel reservations at alternate recovery sites as requested by field operations personnel.

e. Handle press affairs in Miami as follows:

- Refer press inquiries to J. Goldman, OAR/PA.
- Refer forecast inquiries to NHC.

f. Communicate with AOC ground coordinator, as required.

g. Make requests for special radar and/or rawinsonde (upper air) observations, subject to approval by the HRD director.

h. Maintain a crew status report of HRD participants for current and proposed missions. When missions are being conducted away from Miami, crew status information will be reported to MGOC by the field program director or his designee.

(4) Phone numbers:

NHC Public Affairs/F. Lepore	(305)-229-4404
AOC	(813)-828-3310
AOC (FAX, J. McFadden)	(813)-828-6881
AOC (auto line)	(813)-828-3310
	—— (ext. 3128)
HRD (auto line at MGOC/TPC/NHC)	(305)-221-3679
HRD (voice line at MGOC/TPC/NHC)	(305)-221-4381
HRD FAX number	(305)-361-4402
AOC's long distance auto announce phone number	(800)-729-6622

	—— (ext. 3128)
OAR/PR (J. Goldman)	(301)-713-2483
AOML/PR (E. Van Coverden)	(305)-361-4541
TPC/NHC (WFO)	(305)-229-4528
Miami Ground Operations Center (MGOC) at NHC	(305)-229-4407
Miami Ground Operations Center (MGOC) at HRD/AOML	(305)-361-4400
Zephyr/WIS Center at HRD/AOML	(305)-361-4368
TRDIS Operations at NHC	(305)-229-4429
Storm Surge Group at NHC	(305)-229-4456
WWV (for time check)	(303)-499-7111
Telepager (beeper) numbers for MGOC team leaders, F. Marks and M. Black (HRD), and J. McFadden (AOC)	—— TBA

Aircraft support contact numbers for:

Barbados

Sam Lord's Castle
(246) 423 7350
(246) 423 5918 (fax)

International Aircraft Management
(246) 428 1704
(246) 428 1686
Contact: Paul Worrell

St. Croix

Tamarind Reef Hotel
(340) 773 4455
(340) 773 3989 (fax)

Bohlke International Airways Inc:
(340) 778-9177
(340) 772-5932 (fax)

Bermuda

Princess Hotel (Hamilton)
(441) 295 3000
(441) 295 1914 (fax)

Aircraft Services
(441) 293 1333
(441) 293 8529 (fax)

Biloxi

53rd WRD/DOO
(228) 377 1940 (fax)

(5) Supplies:

a. Up-to-date phone list

b. Current copies of the following:

- HRD Hurricane Field Program Plan
- AOC Hurricane Operations Plan (if available)
- MGOC Manual (black, loose-leaf book)

(6) Information Pool:

Interface with NHC and others as required, and at appropriate times, obtain:

a. Satellite fixes at forecast times and 3-hourly intermediate fixes.

b. NHC official releases:

- Storm position and current strength and movement (including maximum wind and minimum—pressure).
- Forecast storm position and strength (wind and pressure) for 12, 24, 48, and 72 h.
- 0400, 1000, 1600, 2200 UTC and all intermediate advisories (based on synoptic 0000, 0600, 1200, and 1800 UTC).
- Public advisories.

c. NHC supplied additional data:

- 3-hourly storm positions.
- Aircraft reconnaissance reports (request extra copy from NHC Communications Unit).
- HURCAS computer product (request extra copy from NHC/Tropical Satellite and Analysis Center: 2130, 0330, 0930, 1530 EDT availability).

APPENDIX G

NOAA EXPENDABLES AND RECORDING MEDIA

Table G-1.1. Required expendables for 2002 experiments per flight day for 42RF and 43RF

Experiment	GPS sondes		AXBTs		CADs		AXCPs		AXCTDs	
	42RF	*43RF*	*42RF*	*43RF*	*42RF*	*43RF*	*42RF*	*43RF*	*42RF*	*43RF*
Saharan Air Layer	20	15	20	15	20	15				
Extended Cyclone Dynamics	30	--	20	--	20	--				
TC Wind fields at Landfall	--	25	--	20	--	20				
Hurricane Synoptic-Flow	65	--	20	--	20	--				
Hurricane Air-Sea Interaction	--	30	--	20	--	20	--	19	--	14
Pre-Storm (Linear)	--	15	--	23	--	20	--	20	--	14
Pre-Storm (Eddy)	42	32	46	--	20	--	--	40	--	22
In Storm	--	30	--	20	--	20	--	19	--	14
Post-Storm (Linear)	15	15	--	23	--	20	--	20	--	14
Post-Storm (Eddy)										
CBLAST										
Day 1	68	24	23	17	20	17				
Day 2	64	24	18	24	18	14				

Table G-1.2. Required recording media for 2002 experiments per flight day for 42RF and 43RF

	DATs[1]	**CDs**[2]	**ZIPs**	**D-Audio**	**S-VHS**
Experiment			**BAT Probe**	**AXCP,AXCTD**	**Nose/Side/Down**
Saharan Air Layer (SALEX) 42RF or 43RF	1/1/4/2=8	1/2/2/-/1/1=5	--	--	1/2/1=4
Extended Cyclone Dynamics 42RF or 43RF	1/-/4/2=7	1/2/2/-/1/1=5	--	--	1/2/1=4
TC Wind fields at Landfall 43RF	1/2/4/2=9	1/2/2/2/1/1=7	6	--	1/2/-=3
Hurricane Synoptic-Flow 42RF or 43RF	1/-/4/2=7	1/2/2/-/1/1=5	--	--	1/2/1=4
43RF	1/2/4/2=9	1/2/2/2/1/1=7	6		1/2/-=3
Air-Sea Interaction					
42RF	1/2/4/2=9	1/2/2/-/1/1=5	--	--	1/2/1=4
43RF	1/2/4/2=9	1/2/2/2/1/1=7	6	6	1/2/-=3
CBLAST					
42RF	1/2/4/2=9	1/2/2/-/1/1=5	6	--	1/2/1=4
43RF	1/2/4/2=9	1/2/2/2/1/1=7	6	--	1/2/-=3

[1]DATs required for Slow/Fast flight-level/Radar/Cloud Physics data
[2]CDs required for Slow/Fast flight-level/Cloud Physics/BAT/AVAPS/HRD workstation data

APPENDIX H

SYSTEMS OF MEASURE AND UNIT CONVERSION FACTORS

SYSTEMS OF MEASURE AND UNIT CONVERSION FACTORS

Table H-1 Systems of measure: Units, symbols, and definitions

Quantity	SI Unit	Early Metric	Maritime	English
length	meter (m)	centimeter (cm)	foot (ft)	foot (ft)
distance	meter (m)	kilometer (km)	nautical mile (nm)	mile (mi)
depth	meter (m)	meter (m)	fathom (fa)	foot (ft)
mass	kilogram (kg)	gram (g)		
time	second (s)	second (s)	second (s)	second (s)
speed	meter per second (mps)	centimeter per second (cm s^{-1})	knot (kt) (nm h^{-1})	miles per hour (mph)
		kilometers per hour (km h^{-1})		
temperature -sensible	degree Celsius (°C)	degree Celsius (°C)	---	degree Fahrenheit (°F)
-potential	Kelvin (K)	Kelvin (K)	---	Kelvin (K)
force	Newton (N) (kg m s^{-2})	dyne (dy) (g cm s^{-2})	poundal (pl)	poundal (pl)
pressure	Pascal (Pa) (N m^{-2})	millibar (mb) (10^3 dy cm^{-2})	inches (in) mercury (Hg)	inches (in) mercury (Hg)

Table H-2. Unit conversion factors

Parameter	Unit	Conversions
length	1 in	2.540 cm
	1 ft	30.480 cm
	1 m	3.281 ft
distance	1 nm (nautical mile)	1.151 mi
		1.852 km
		6080 ft
	1 mi (statute mile)	1.609 km
		5280 ft
	1° latitude	59.996 nm
		69.055 mi
		111.136 km
depth	1 fa	6 ft
		1.829 m
mass	1 kg	2.2 lb
force	1 N	10^5 dy
pressure	1 mb	102 Pa
		0.0295 in Hg
	1 lb ft^{-2}	4.88 kg m^{-2}
speed	1 m s^{-1}	1.9
	at. 6 h^{-1}	10 kt

ACRONYMS AND ABBREVIATIONS

θ_e	equivalent potential temperature
ABL	atmospheric boundary-layer
A/C	aircraft
ACLAIM	Airborne Coherent Lidar for Advanced In-flight Measurements
AES	Atmospheric Environment Service (Canada)
AFRES	U. S. Air Force Reserve
AMPR	Advanced Microwave Precipitation Radiometer
AOC	Aircraft Operations Center
AOML	Atlantic Oceanographic and Meteorological Laboratory
ASDL	aircraft-satellite data link
ATOLL	Atlantic Tropical Oceanic Lower Layer
AXBT	airborne expendable bathythermograph
AXCP	airborne expendable current probe
AXCTD	airborne expendable conductivity, temperature, and depth probe
BLS	boundary layer scientist
CARCAH	Chief, Aerial Reconnaissance Coordinator, All Hurricanes
CDO	central dense overcast
CIRA	Cooperative Institute for Research in the Atmosphere
C-MAN	Coastal-Marine Automated Network
COVES	Coordinated Observations of Vortex Evolution and Structure Experiment
CP	coordination point
CRT	cathode-ray tube
C-STAR	Conically-Scanning Two-look Airborne Radiometer
CVA	cyclonic vorticity advection
CW	cross wind
DLM	deep-layer mean
DOD	Department of Defense
DOW	Doppler on Wheels
DRI	Desert Research Institute (at Reno)
E	vector electric field
EDOP	ER-2 Doppler Radar
EHAD	ER-2 High Altitude Dropsonde
EPAC	Eastern Pacific
ETL	Environmental Technology Laboratory
EVTD	extended velocity track display
FAA	Federal Aviation Administration
F/AST	fore and aft scanning technique
FEMA	Federal Emergency Management Agency
FL	flight level
FP	final point
FSSP	forward scattering spectrometer probe
GFDL	Geophysical Fluid Dynamics Laboratory
G-IV	Gulfstream IV-SP aircraft
GOMWE	Gulf of Mexico Warm Eddy
GPS	global positioning system
HAMSR	High Altitude MMIC Sounding Radiometer
HL	Hurricanes at Landfall
HRD	Hurricane Research Division
ICATS	NASA DC-8 Information Collection and Transmission System
INE	inertial navigation equipment
IP	initial point (or initial positionIWRS Improved Weather Reconnaissance System
JW	Johnson-Williams
Ku-SCAT	Ku-band scatterometer
LASE	Lidar Atmospheric Sensing Experiment
LF	lower fuselage (radar)
LIP	Lightning Instrument Package
LPS	Lead Project Scientist

MAS	MODIS Airborne Simulator
MCS	mesoscale convective systems
MGOC	Miami Ground Operations Center
MLD	Mixed Layer Depth
MMS	Meteorological Measuring System
MODIS	Moderate Resolution Imaging Spectroradiometer
MPO	Meteorology and Physical Oceanography
MTP	Microwave Temperature Profiler
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDBC	NOAA Data Buoy Center
NESDIS	National Environmental Satellite, Data and Information Service
NHC	National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
ODW	Omega-based generation of dropwindsonde
OML	oceanic mixed-layer
PDD	pseudo-dual Doppler
PMS	Particle Measuring Systems
POD	Plan of the Day
PPI	plan position indicator
PR-2	dual-Frequency Airborne Precipitation Radar
PV	potential vorticity
RA	radar altitude
RAOB	radiosonde (upper-air observation)
RAWIN	rawinsonde (upper-air observation)
RECCO	reconnaissance observation
RHI	range height indicator
RSMAS	Rosenstiel School of Marine and Atmospheric Science
SFMR	Stepped-Frequency Microwave Radiometer
SLOSH	sea, lake, and overland surge from hurricanes (operational storm surge model)
SRA	Scanning Radar Altimeter
SST	sea-surface temperature
TA	tail (radar)
TAS	true airspeed
TC	tropical cyclone
TOPEX	The Ocean Topography Experiment
TPC	Tropical Prediction Center (at NHC)
UMASS	University of Massachusetts (at Amherst)
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USWRP	U. S. Weather Research Program
UTC	universal coordinated time (U.S. usage; same as “GMT” and "Zulu" time)
VICBAR	name for a barotropic hurricane track prediction model (not an acronym)
VTD	velocity-track display
XCDX	Extended Cyclone Dynamics Experiment

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