

2016 Hurricane Field Program Plan

Part II: Appendices

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Part II

Appendix A

DECISION AND NOTIFICATION PROCESS

The decision and notification process is illustrated in Figs. A-1, A-2, and A-3. 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 [F. Marks (Director, HRD), R. Rogers (Director, Hurricane Field Program), J. Dunion, M. Black, J. Cione, J. Gamache, J. Kaplan, P. Reasor, S. Murillo, J. Zhang and J. 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 Hurricane Field Program Director [R. Rogers].
- 4) Secondary personnel are notified by their primary affiliate (Table A-2).

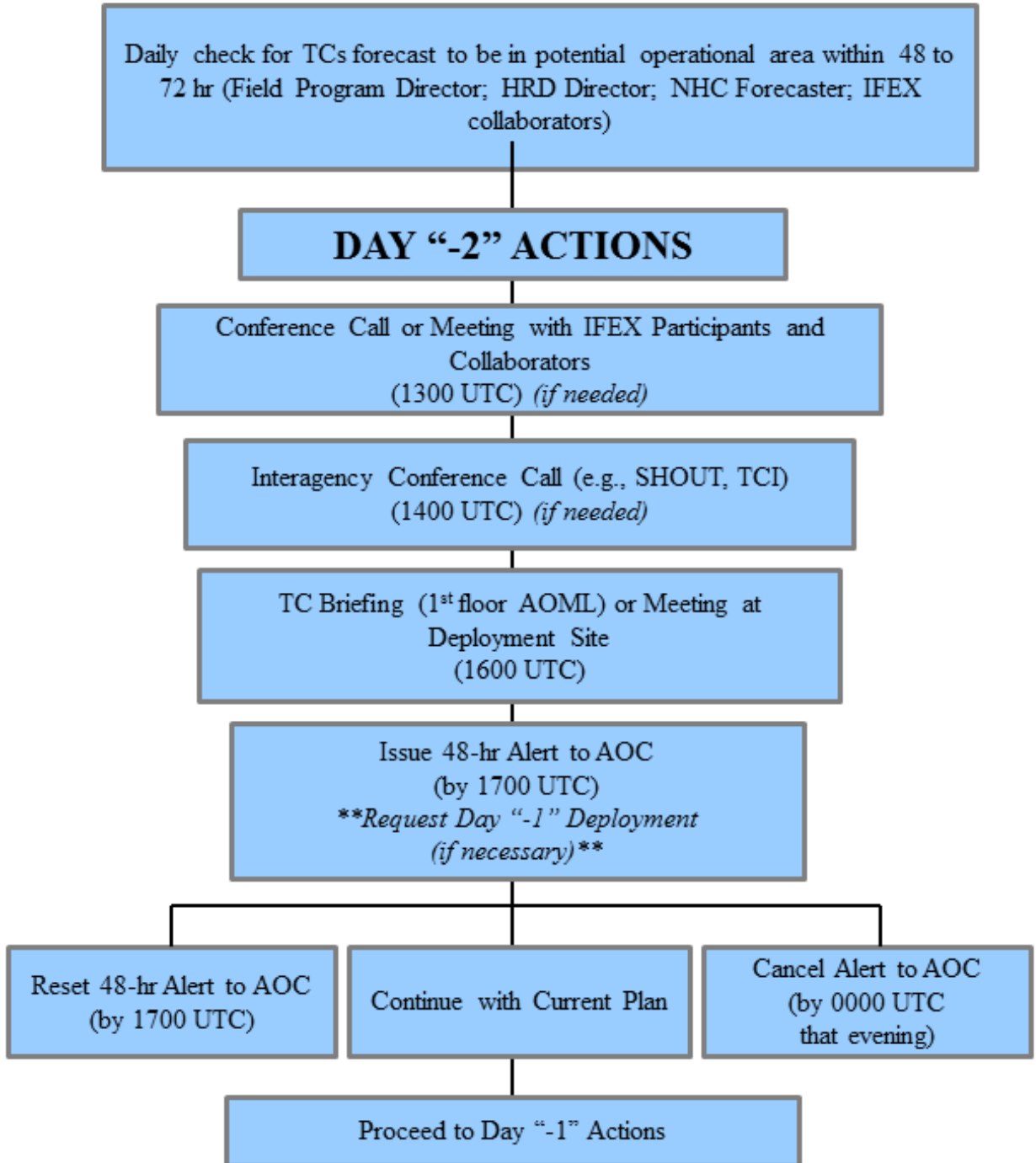
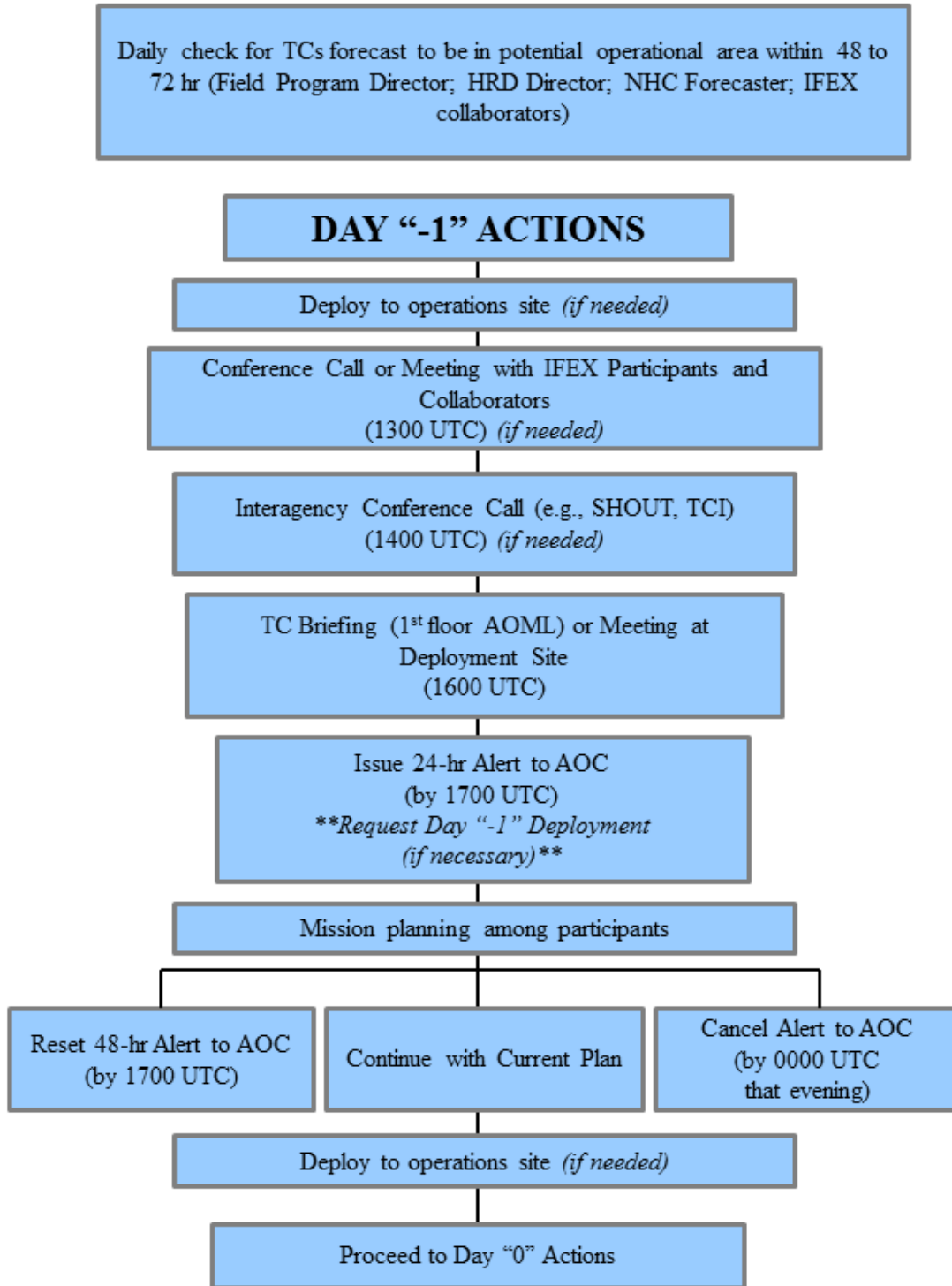
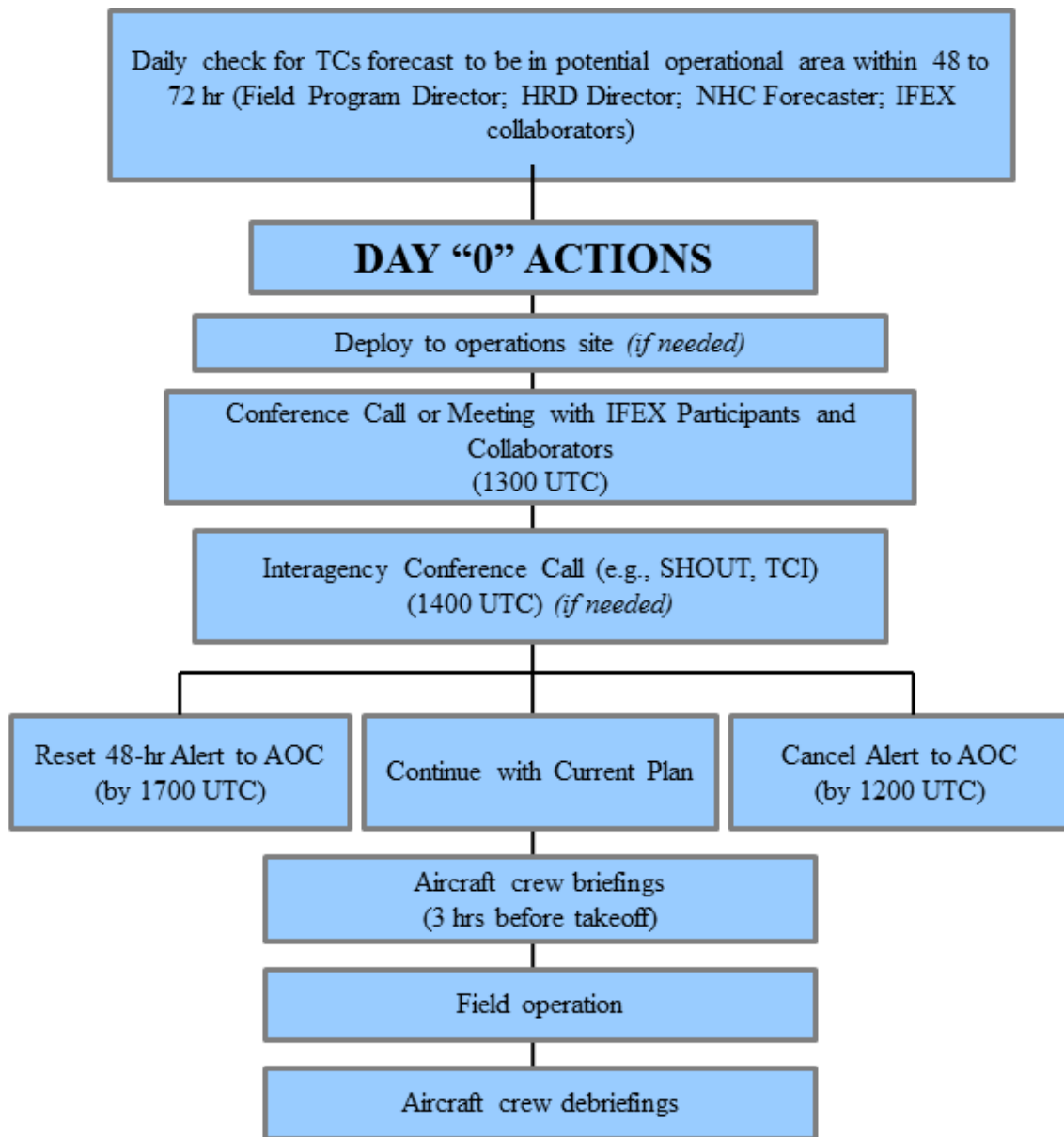


Fig. A-1: Decision and notification process for Day “-2”.



**Note: Time of briefings, conference calls, decisions, and deployments are dictated by timing limitations imposed by the AOC crew.

Fig. A-2: Decision and notification process for Day “-1”



**Note: Time of briefings, conference calls, decisions, and deployments are dictated by timing limitations imposed by the AOC crew.

Fig. A-3: Decision and notification process for Day "0"

Appendix B: Calibration

B.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. B-1.

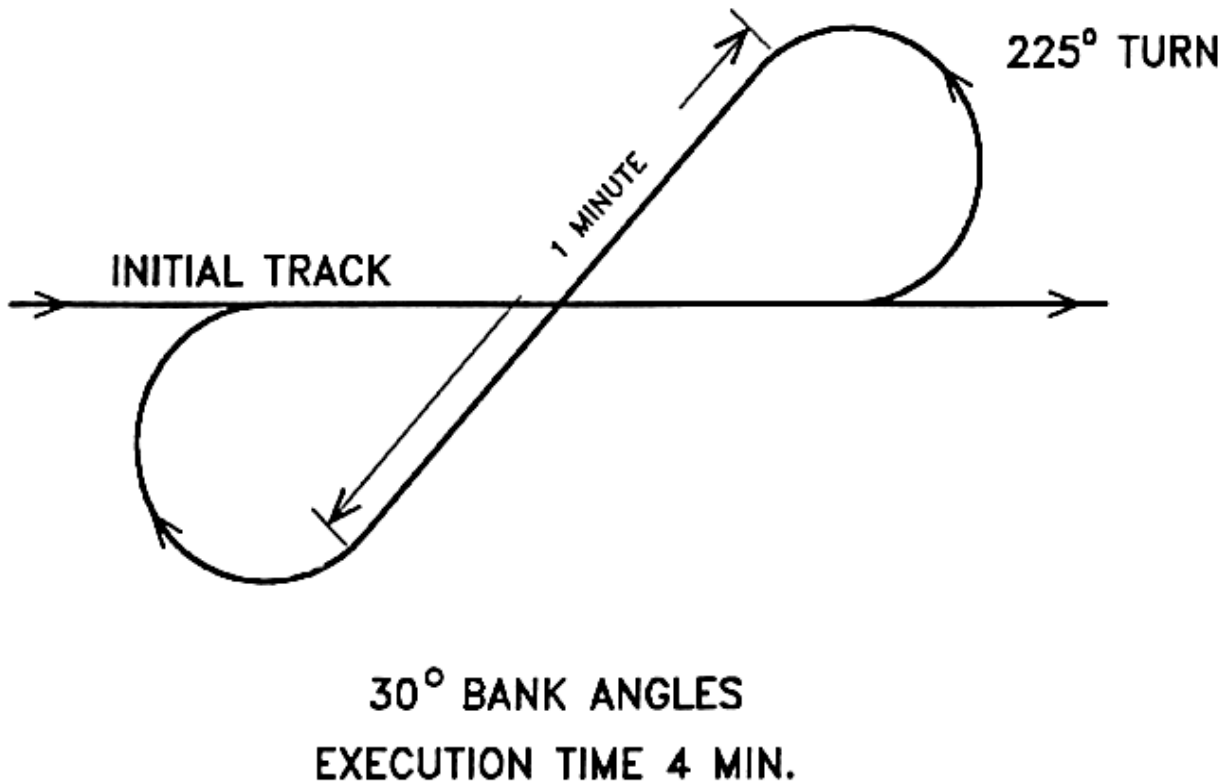
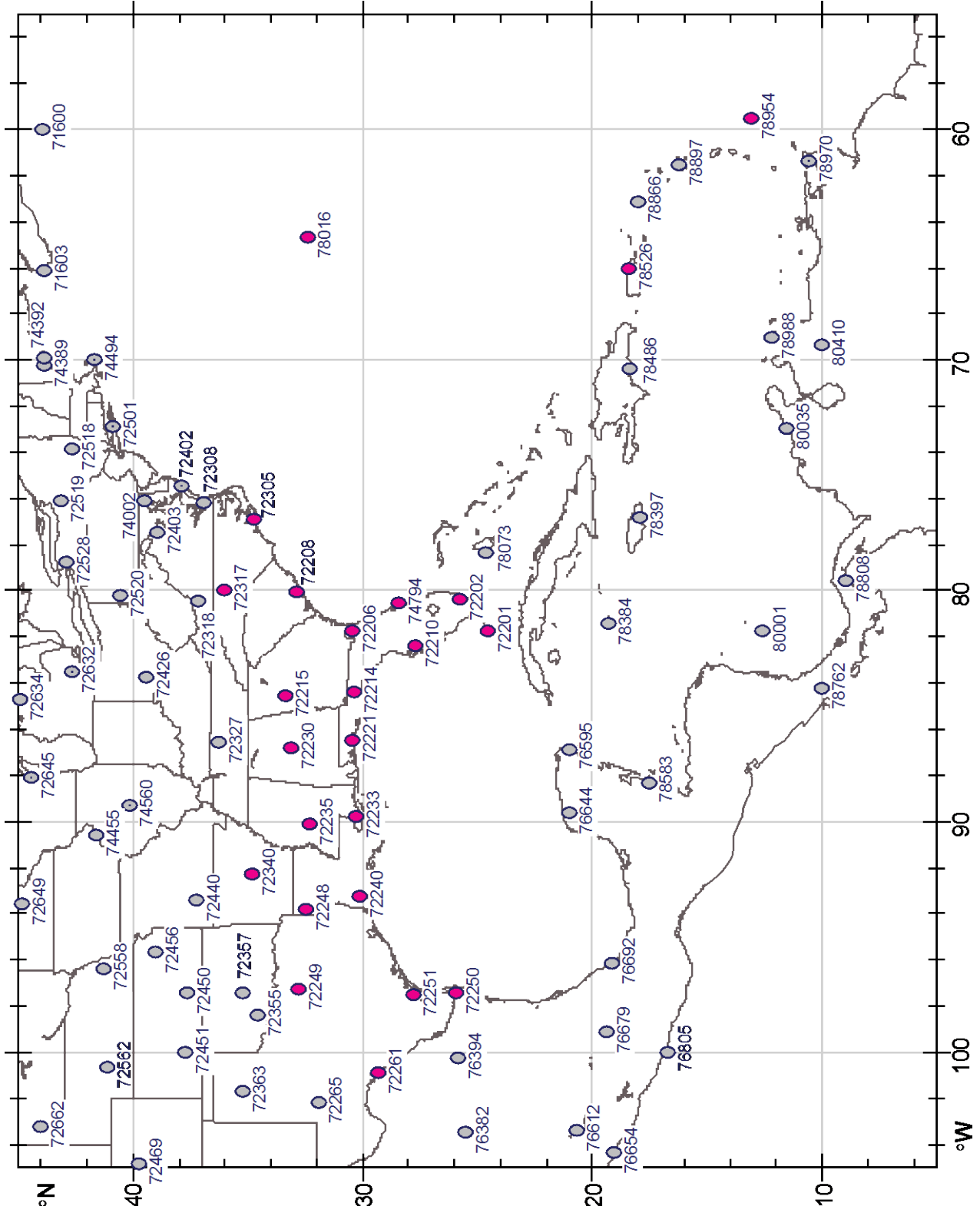
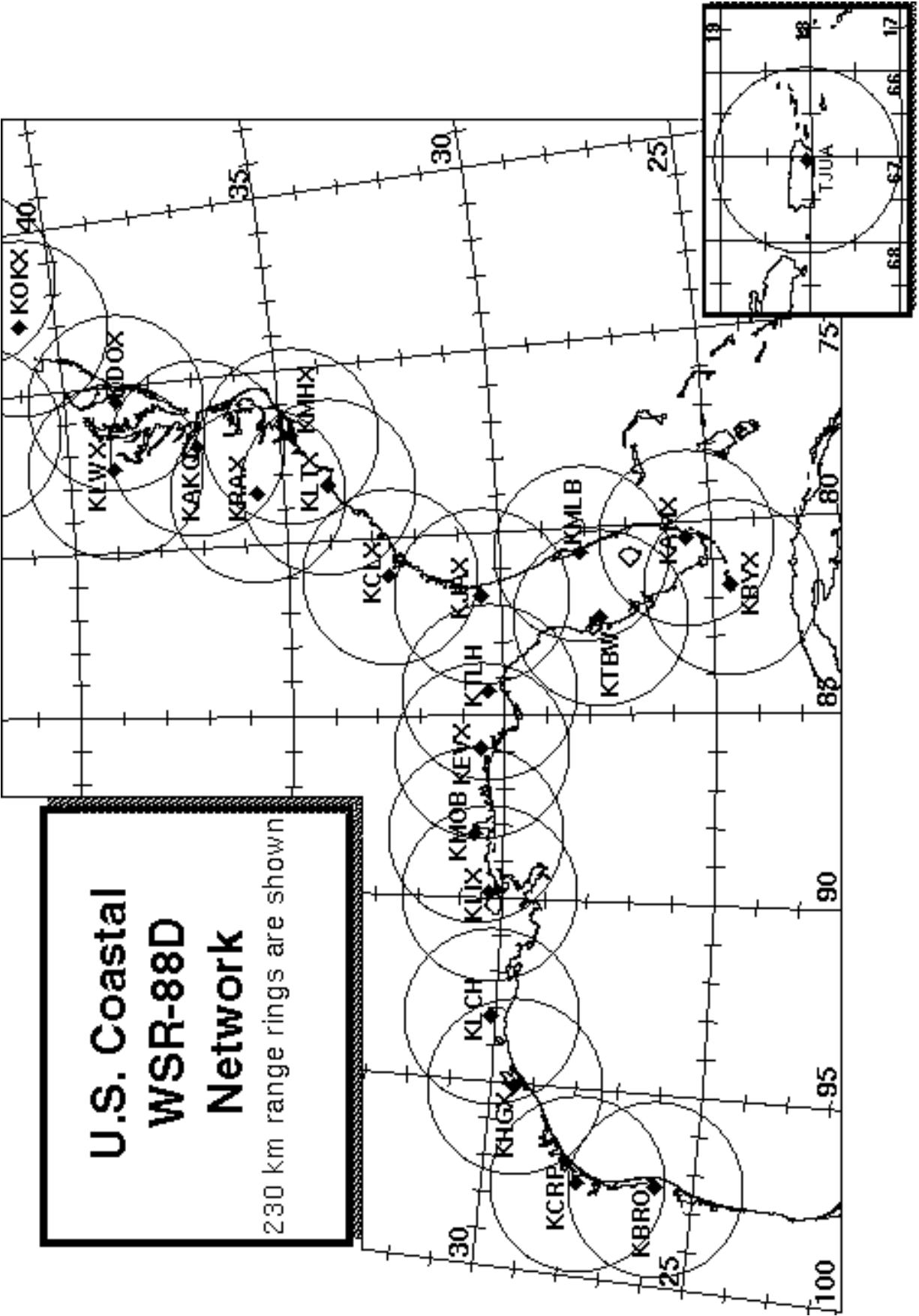


Fig. B-1 En-Route TAS calibration pattern.

Appendix C: DOD/NWS RAWIN/RAOB and NWS Coastal Land-based Radar Locations





APPENDIX D: 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 a flight suit 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.

Section 4-401, of the NOAA Safety Rules Manual state that: “Don’t let your attention wander, either through constant conversation, use of cell phone or sightseeing while operating vehicles. Drivers must use caution and common sense under all conditions. Operators and passengers are not permitted to smoke or eat in the government vehicles. Cell phone use is permitted while car is parked.”

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 nominal fee per flight.

D.1 Field Program Director/ IFEX Chief Scientist;

- (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.
- (5) Provides for pre-mission briefing of flight crews, scientists, and others (as required).
- (6) Assigns duties of field project scientific personnel. Ensures safety during the field program.

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

D.2 Assistant Field Program Director

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

D.3 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.4 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 safety, 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.5 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.6 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.7 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.
- (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 $+20^{\circ}$. This tape will allow correction of any antenna mounting biases or elevation angle corrections.

D.8 Dropsonde Scientist

- (1) Processes dropsondes observations on HRD workstation for accuracy.
- (2) Provides TEMP drop message for ASDL, transmission or insures correct code in case of automatic data transmission.

D.9 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

Hurricane Field Program Deployment Safety Checklist

The Field Program Director is responsible for making sure safety is enforced and ensuring necessary materials are in place and/or any actions have been completed before the start of the HFP. Field program participants are responsible for reviewing this checklist.

Scientist _____ Date _____

Before leaving AOML

- _____ 1. Contact the HRD Field Program Director personnel to notify departure time.
- _____ 2. Things to take
 - a. Flight bag (s)
 - b. Cell phone
 - c. List of HFP important numbers
 - d. HRD Field program plan
 - e. Flight suit

Ground transportation

- _____ 1. Arrange for ground transportation
- _____ 2. Visual inspection of government vehicle
 - a. Make sure tires do not appear to be flat
 - b. Check for any cracked/broken lights, windshield and mirrors
 - c. Check for any major dents around the vehicle
- _____ 3. Inspection inside the government vehicle
 - a. Check all lights work properly (head and tail lights, dome lights, dashboard and turn signal lights)
 - b. Make sure the engine, oil, or temperature indicator light does not flash. *If so, contact facilities management.*
 - c. **Note** the gas and mileage
- _____ 4. Contents inside the government vehicle
 - a. Make sure there is first aid kit and fire extinguisher
 - b. Proper jack and lug wrench
 - c. Spare tire
 - d. Basic auto repair kit (i.e. road hazard reflector or flares)
 - e. *Consider carrying a flashlight*
- _____ 5. If possible, return vehicle with full tank (regular unleaded gasoline)
- _____ 6. Contact the HRD Field Program Director personnel upon returning

E.1 "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 stations 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 field program director whether aircraft has operational fix responsibility and discuss with AOC flight director/meteorologist unless briefed otherwise by field program director.
- _____ 4. Contact HRD members of crew to:
 - a. Assure availability for mission.
 - b. Review field program safety checklist
 - c. Arrange ground transportation schedule when deployed.
 - d. Determine equipment status.
- _____ 5. Meet with AOC flight director and navigator at least 3 hours before take-off for initial briefing.
- _____ 5. Meet with AOC flight crew at least 2 hours before take-off for crew briefing. 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 Field Program Director.
- _____ 7. Before take-off, brief the on-board GPS dropsonde operator on times and positions of drop times.
- _____ 7. Make sure each HRD flight crew members have life vests
- _____ 7. Perform a headset operation check with all HRD flight crew members. Make sure everyone can hear and speak using the headset.
- _____ 8. Collect “mess” fee (generally ~\$2.00) from all on-board HRD flight crew members as needed.

E.2.2 In-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 Lead Project Scientist Form.
- _____ 5. Check in with the flight director to make sure the mission is going as planned (i.e. turns are made when they are supposed to be made).

E.2.3 Post flight

- _____ 1. Debrief scientific crew.
- _____ 2. Report landing time, aircraft, crew, and mission status along with supplies (tapes, *etc.*) remaining aboard the aircraft to the HRD Field Program Director.

- _____ 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. Obtain a copy of the radar DAT tapes and if possible a copy of the radar data-packet files should be copied onto a flash drive. Turn in with completed forms.
- _____ 6. Obtain a copy of the all VHS videos form aircraft cameras (3-4 approx.). Turn in with completed forms.
- _____ 7. Obtain a copy of CD with all flight data. Turn in with completed forms.
- _____ 8. Determine next mission status, if any, and brief crews as necessary.
- _____ 9. Notify HRD Field Program Director as to where you can be contacted and arrange for any further coordination required.
- _____ 10. Prepare written mission summary using **Mission Summary** form (due to Field Program Director 1 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	_____
Radar	_____	Pilots	_____
Workstation	_____	Navigator	_____
Cloud Physics	_____	Systems Engineer	_____
Photographer/Observer	_____	Data Technician	_____
/Guests	_____	Electronics Technician	_____
Dropwindsonde	_____	Other	_____
AXBT/AXCP	_____		

B. Take-off and Landing Locations:

Take-Off: _____ Location: _____

Landing: _____ Location: _____

Number of Eye Penetrations: _____

C. Past and Forecast Storm Locations:

Date/Time	Latitude	Longitude	MSLP	Maximum Wind

D. Mission Briefing:

E. Equipment Status (Up ↑, Down ↓, Not Available —, Not Used O)

Equipment	Pre-Flight	In-Flight	Post-Flight	# DATs / Cds /Expendables/ Printouts
Radar/LF				
Doppler Radar/TA				
Cloud Physics				
Data System				
GPS sondes				
AXBT/AXCP				
Ozone instrument				
Workstation				
Videography				

REMARKS:

Mission Summary
Storm name
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)

Expendables used in mission:

GPS sondes : _____

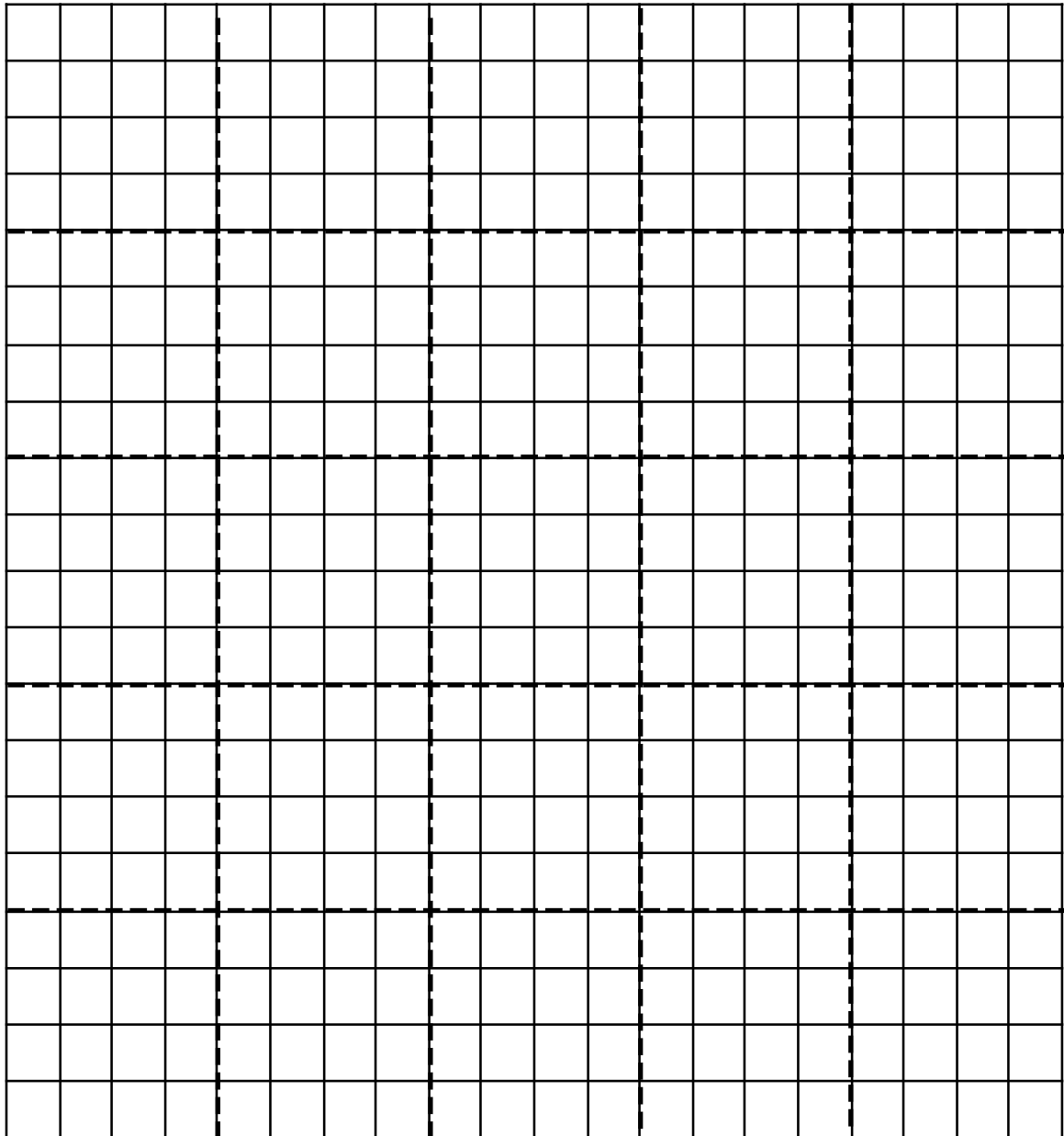
AXBTs : _____

Sonobuoys: _____

Observer's Flight Track Worksheet

Date _____ Flight _____ Observer _____

Latitude (°)



Longitude (°)

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 manual.

E.3.2 In-Flight

- _____ 1. Operate instruments as specified in the cloud physics operator's manual 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 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 HRD Field Program Director or the hotel during a deployment.
- _____ 5. Determine the status of future missions and notify HRD Field Program Director 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
DMT CCP			
DMT PIP			
SEA LWC			
King Probe			
DRI Field Mills			
King Probe			
DMT PADS data system			

B. —Remarks:

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 LPS.
- _____ 3. Select the mode of operation for instruments after consultation with the HRD/BLS and the LPS.
- _____ 4. Complete appropriate preflight check lists as specified in the ASI manual and as directed from the 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 forms.
- _____ 2. Brief the on-board LPS on equipment status and turn in completed checklists to the LPS.
- _____ 3. Debrief as necessary at HRD Field Program Director or the hotel during a deployment.
- _____ 4. Determine the status of future missions and notify HRD Field Program Director as to where you can be contacted.

AXBT and Sonobuoy 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:

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 lead project scientist (LPS).
- _____ 2. Confirm mission and pattern selection from the LPS.
- _____ 3. Select the operational mode for radar system(s) after consultation with the 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 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 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 AOML/HRD. [**Note:** all data removed from the aircraft by HRD personnel should be cleared with the AOC flight director.]
- _____ 4. Debrief at AOML/HRD or the hotel during a deployment.
- _____ 5. Determine the status of future missions and notify HRD Field Program Director 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:

E.6 Dropsonde Scientist

The 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 the AVAPS and HAPS. Report results to the LPS.
- _____ 2. Confirm the mission and pattern selection from the LPS and assure that enough dropsondes are on board the aircraft.
- _____ 3. Modify the flight pattern or drop locations if requested by AOC to accommodate changes in storm location or closeness to land.
- _____ 4. Complete the appropriate preflight set-up and checklists.

E.6.2 In-Flight

- _____ 1. Operate the system as specified in the operator's manual.
- _____ 2. Ensure the AOC flight director is aware of upcoming drops.
- _____ 3. Ensure the AVAPS operator has determined that the dropsonde is (or is not) transmitting a good signal. Recommend if a backup dropsonde should be launched in case of failure.
- _____ 4. Report the transmission of each drop and fill in the Dropwindsonde Scientist Log.

E.6.3 Post flight

- _____ 1. Complete Dropwindsonde Scientist Log.
- _____ 2. Brief the LPS on equipment status and turn in reports and completed forms.
- _____ 3. Hand-carry all dropwindsonde data tapes or CDs as follows:
 - a. Outside of Miami-to the LPS or PI.
 - 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 at the AOML/HRD or the hotel during a deployment.
- _____ 5. Determine the status of future missions and notify HRD Field Program Director as to where you can be contacted.

APPENDIX F: SYSTEMS OF MEASURE AND UNIT CONVERSION FACTORS

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

Quantity	SI Unit	Early Metric	Maritime	English
<i>length</i>	meter (m)	centimeter (cm)	foot (ft)	foot (ft)
<i>distance</i>	meter (m)	kilometer (km)	nautical mile (nm)	mile (mi)
<i>depth</i>	meter (m)	meter (m)	fathom (fa)	foot (ft)
<i>mass</i>	kilogram (kg)	gram (g)		
<i>time</i>	second (s)	second (s)	second (s)	second (s)
<i>speed</i>	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)		
<i>temperature-sensible</i>	degree Celsius (°C)	degree Celsius (°C)	---	degree Fahrenheit (°F)
<i>-potential</i>	Kelvin (K)	Kelvin (K)	---	Kelvin (K)
<i>force</i>	Newton (N) (kg m s ⁻²)	dyne (dy) (g cm s ⁻²)	poundal (pl)	poundal (pl)
<i>pressure</i>	Pascal (Pa) (N m ⁻²)	millibar (mb) (10 ³ dy cm ⁻²)	inches (in) mercury (Hg)	inches (in) mercury (Hg)

Table F-2. Unit conversion factors

Parameter	Unit	Conversions
<i>length</i>	1 in	2.540 cm
	1 ft	30.480 cm
	1 m	3.281 ft
<i>distance</i>	1 nm (nautical mile)	1.151 mi 1.852 km 6080 ft
	1 mi (statute mile)	1.609 km 5280 ft
<i>depth</i>	1° latitude	59.996 nm 69.055 mi 111.136 km
	1 fa	6 ft 1.829 m
	1 kg	2.2 lb
<i>mass</i>	1 N	10 ⁵ dy
<i>force</i>	1 mb	102 Pa
<i>pressure</i>	1 lb ft ⁻²	0.0295 in Hg 4.88 kg m ⁻²
	1 m s ⁻¹	1.94 kt 3.59 kph
<i>speed</i>	1° lat. 6 h ⁻¹	10 kt

APPENDIX G: AIRCRAFT SCIENTIFIC INSTRUMENTATION

Instrument	Parameter	PI	Group
Navigational			
INE1/2	lat, lon		AOC
GPS1/2	lat, lon		AOC
Honeywell HG9550 altimeter	Radar altitude		AOC
Standard Meteorological			
Buck1101c, Edgetech Vigilant, Maycom TDL	T_d		AOC
Rosemount temp	T, T'		AOC
Static pressure	p		AOC
Dynamic pressure	p'		AOC
Horizontal wind	V_h		AOC
Vertical wind	w		AOC
Infrared Radiation			
Side CO ₂ radiometer	T		AOC
AOC down radiometer	SST		AOC
Weather Radar			
LF radar	R	Gamache	AOC
TA Doppler radar, French antenna	V, R	Gamache	AOC
Passive Microwave			
AOC SFMR/pod	V_{10} , Z	Goldstein	AOC
Airborne Ocean Profiler			
AOC AXBT (MK-21) receivers	TS vs z	Smith (N. Shay)	AOC (UM)
Drosonde Systems			
GPS AVAPS Drosonde-8CH	V, T, RH, p vs z	Smith	AOC
Video Systems			
Down video	F(%), WD	Cione	AOC
Side, nose video	LCL		AOC
On board processing			
PC/LINUX workstation	Radar - Radar processing, Web, xchat	Hill	AOC
PC/LINUX laptop	LPS - x-chat, Web, AAMPS	Hill	AOC
PC/LINUX workstation	Drosonde - ASPEN, Web, xchat	Hill	AOC
Real-time data communications systems	FL, radar data	Chang, Carswell	NESDIS, RSS
Active Microwave			
IWRAP (CSCAT, KSCAT) (from 8/15-30 to 9/30)	V_{10} , Z, V vs z	Chang	NESDIS
ProSensing WSRA (until 8/15-30)	HS, WPS, WDS	Fairall	ESRL, NHC
Passive GPS			
GPS bistatic altimeter	ocean height	Fairall	ESRL
Cloud Microphysics/Sea Spray			
DMT CCP probe	Cloud particle spectra	R. Black	AOC
DMT PIP probe	Precipitation particle spectra	R. Black	AOC
DMT CAS probe	Aerosol/cloud droplet spectra	R. Black	AOC
DMT DAS	processor	R. Black	AOC
SEA probe	liquid water	R. Black	AOC, HRD
W-band radar	V, R	Cione, Fairall	ESRL
Weather Radar			
Doppler Wind Lidar (until 8/15-30)	V, R	Atlas	HRD
Turbulence Systems			
Friehe radome gust probe system	U', V', W', T'	J. Zhang, Drennan	HRD, UM
LICOR-750 water vapor analyzer	q'	J. Zhang, Drennan	HRD, UM, AOC
UAS			
Coyote (P-3 deployed)	V, T, RH, p vs z and IR SST	Cione, Fairall	HRD, ESRL

Table G.2: NOAA/AOC WP-3D (N43RF) instrumentation

APPENDIX G: AIRCRAFT SCIENTIFIC INSTRUMENTATION (CONT'D)

Instrument	Parameter	PI	Group
Navigational			
INE1/2	lat, lon		AOC
GPS1/2	lat, lon		AOC
Honeywell HG9550 altimeter	Radar altitude		AOC
Standard Meteorological			
Buck1101c, Edgetech Vigilant, Maycom TDL	T_d		AOC
Rosemount temp	T, T'		AOC
Static pressure	p		AOC
Dynamic pressure	p'		AOC
Horizontal wind	V_h		AOC
Vertical wind	w		AOC
Weather Radar			
TA Doppler radar	V, R	Gamache	AOC
Passive Microwave			
SFMR	V_{10}, Z	Goldstein	AOC
Dropsonde Systems			
GPS AVAPS Dropsonde-8CH	V, T, RH, p vs z	Smith	AOC
On board processing			
Real-time data communications systems	FL, radar data	Chang, Carswell	AOC
PC/LINUX Computer	radar data, sondes	Goldstein	AOC

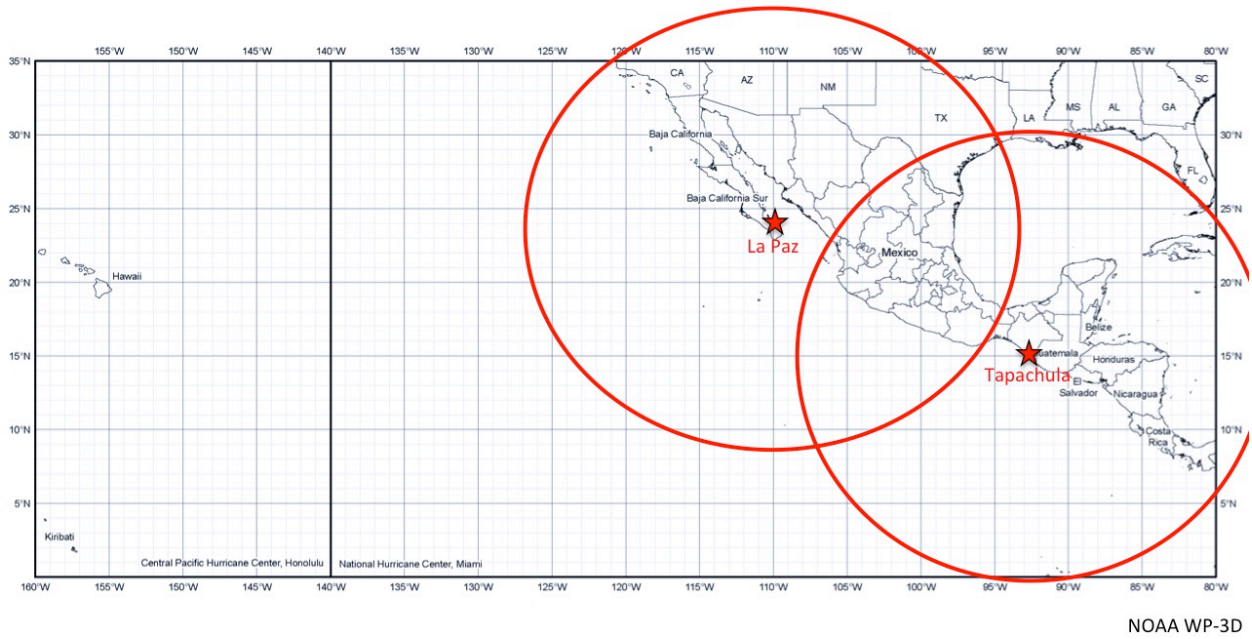
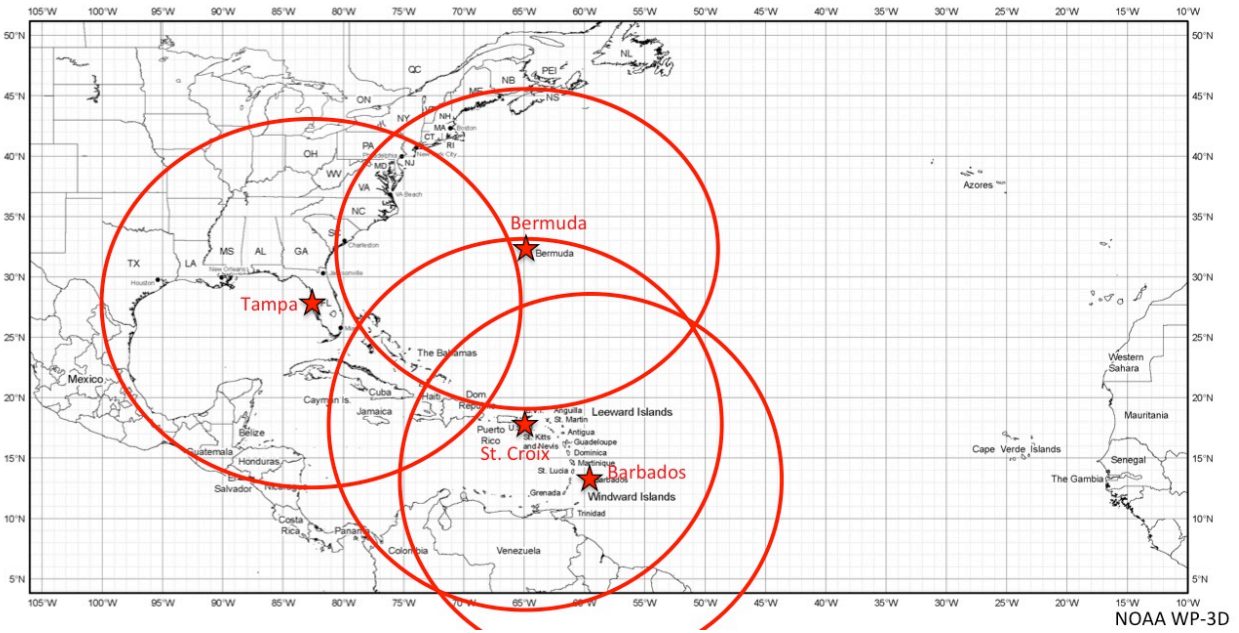
Table G.3 (Cont'd): NOAA/AOC G-IV (N49RF) instrumentation

APPENDIX H: NOAA EXPENDABLE AND MEDIA

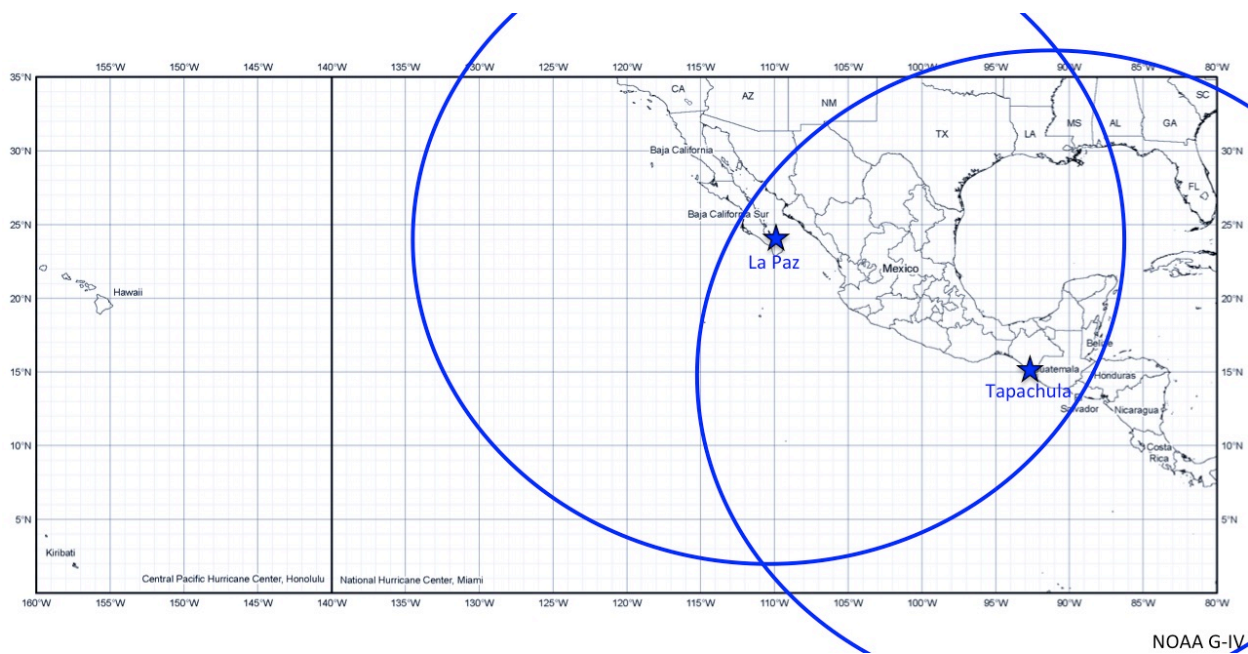
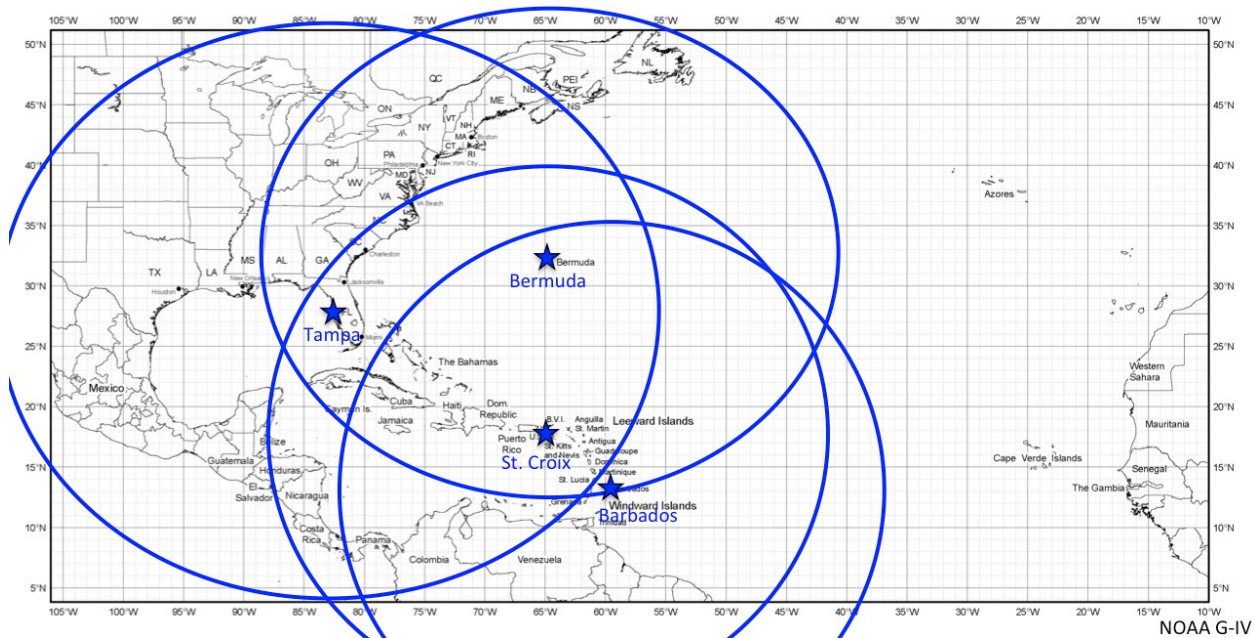
Experiment	GPS Dropwindsondes		AXBTs	CADs
	<i>G-IV</i>	<i>P-3</i>	<i>P-3</i>	<i>P-3</i>
P-3 3D Doppler Winds	-	20	10	10
G-IV Tail Doppler Radar	20	20	10	10
DWL	-	25	-	-
SUAVE	-	20	15	15
Ocean Winds	-	5	-	-
SFMR Hi-Incidence Ang	-	1	1	1
Offshore Wind	-	10	-	-
East Wave Genesis	25	15	-	-
EastPac Genesis	20	-	-	-
Rapid Intensification	25	25	15	15
TC in Shear	25	40	-	-
TC Diurnal Cycle	25	10	-	-
TC-Ocean Interaction	-	20	15	15
TC Landfall	-	20	5	5
Rapid Weakening	20	20	10	10
Convective Burst	-	15	-	-
Eye-eyewall mixing	-	-	-	-
SEF/ERC	25	35	10	10
TC Warm Core	20	10	-	-
Hurricane PBL	-	30	-	-
SALEX Arc Cloud	-	10	-	-

Table H-1: Estimates of maximum number of expendables needed for 2016 standalone experiments and modules for a single mission of the P-3 and the G-IV. Many of these experiments/modules will be combined with other experiments/modules; when this is the case the actual number of expendables used will be lower than a simple addition would suggest. For media, most data are now recorded on USB sticks.

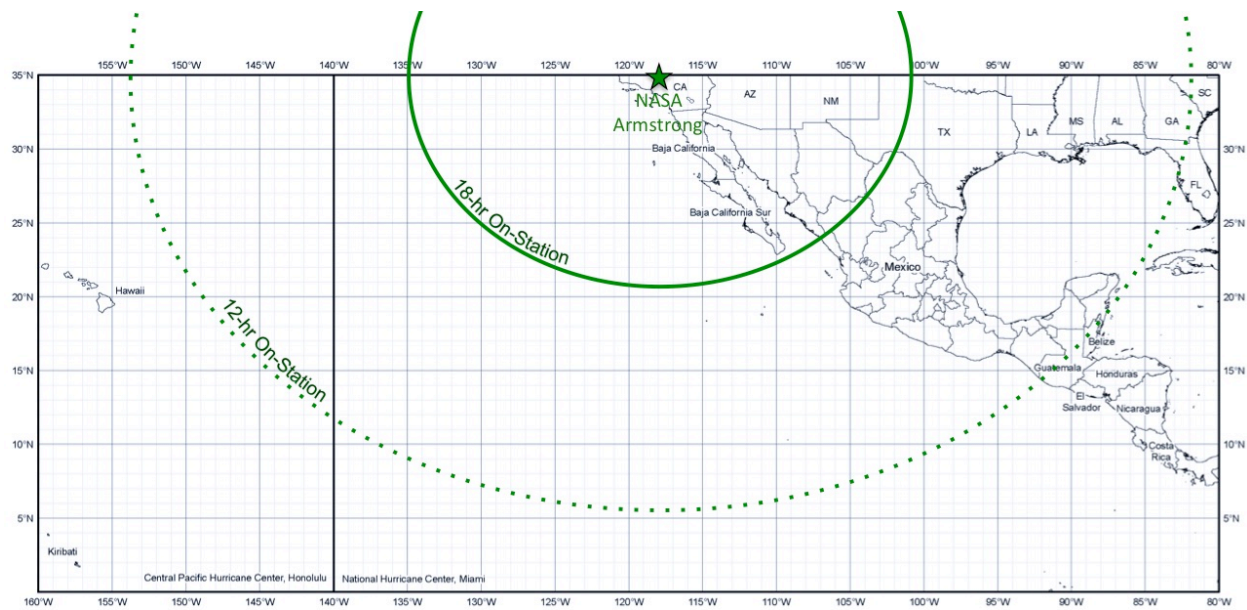
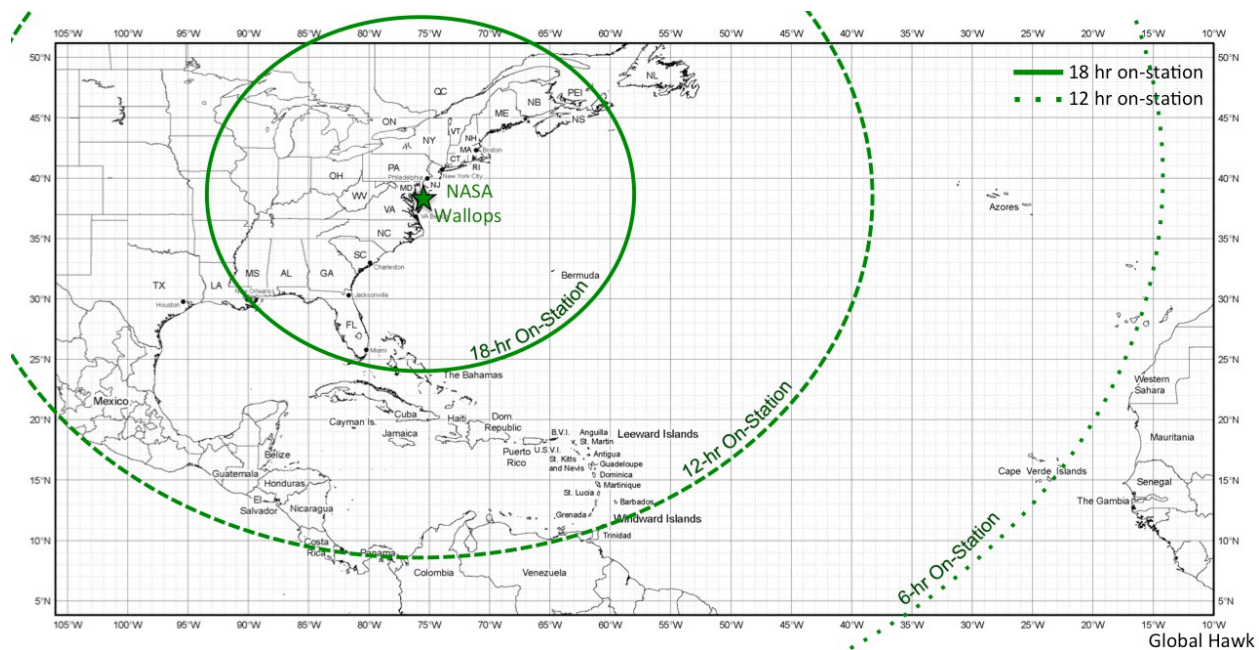
APPENDIX I: OPERATIONAL MAPS



Map 1. Primary Atlantic and East Pacific operating bases and ranges (assuming ~2-h on-station time) for P-3.



Map 2. Primary Atlantic and East Pacific operating bases and ranges (assuming ~2-h on-station time) for G-IV.



Map 3. Primary Atlantic and East Pacific operating bases and ranges for Global Hawk.

APPENDIX J: FLIGHT PATTERNS

J.1 Patterns from Experiments

P-3 Lawnmower pattern

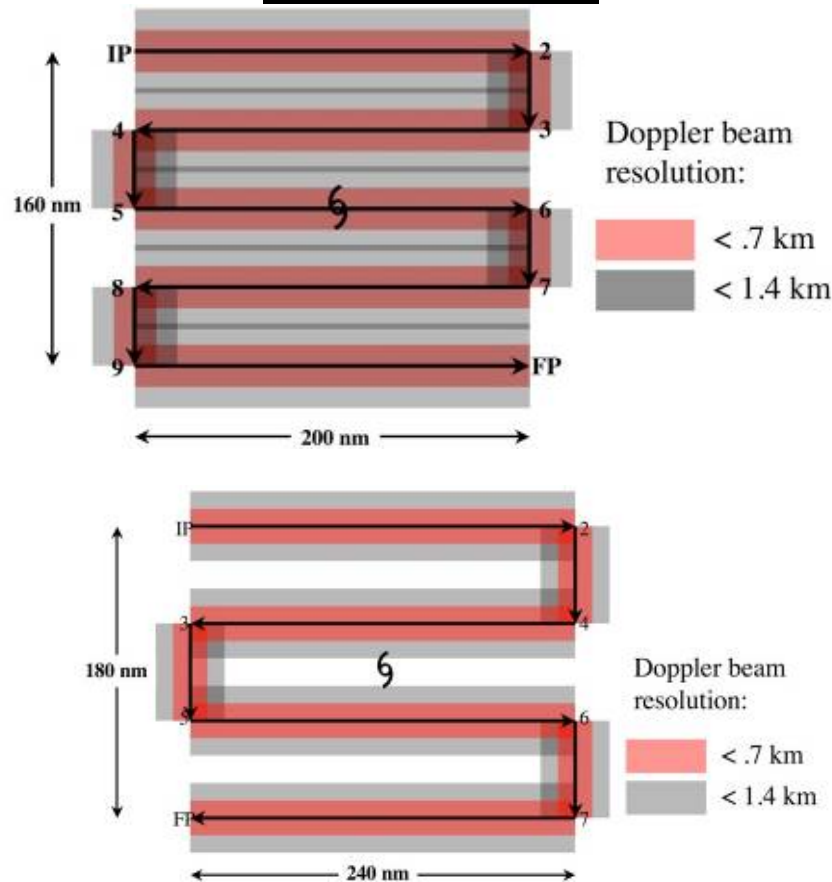


Figure 1: Display of Doppler coverage for A (upper panel) and B (lower panel) lawnmower patterns. Pink region shows areas where vertical beam resolution is better than 0.7 km and gray regions delineate areas where vertical beam resolution is better than 1.4 km. Maximum extent of gray area is approximately 40 km from flight track, generally the maximum usable extent of reliable airborne Doppler radar coverage. Total flight distance is 1160 nm for A and 1140 nm for B, and flight times are 4.8 and 4.75 hours, respectively.

Note 1. This is to be flown where even coverage is required, particularly in tropical depressions and tropical storms. Aircraft flies IP-2-3-4-5-6-7-FP. No attempt should be made to fix a center of circulation unless it is an operational request.

Note 2. Doppler radars should be operated in single-PRF mode, at a PRF of 2100. Radar scientist should

verify this mode of operation with AOC engineers. If there is no assigned radar scientist, LPS should verify. *This is crucial for the testing and implementation of real-time quality control.*

Note 3. Assure that transmitter is switching between fore and aft antennas, by examining the real time display.

Note 4. IP can be at any desired heading relative to storm center

Note 5. To maximize dropwindsonde coverage aircraft should operate at highest altitudes that still minimize icing

Note 6. If dropwindsondes are not deployed, aircraft can operate at any level below the melting level, with 10,000 ft preferred. Aircraft might also fly lower, if circulation not evident at 10,000 ft.

Note 7. Dropwindsondes are not a required part of this flight plan and are optional

P-3 Box-spiral patterns

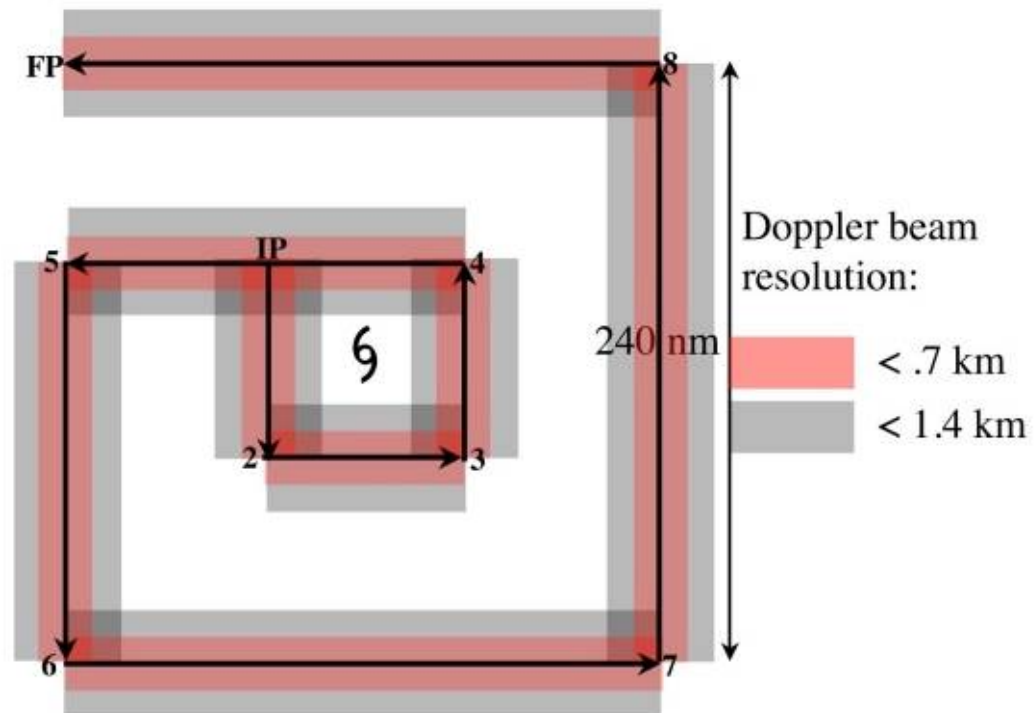


Figure 2: Doppler radar coverage for box-spiral pattern A. Pink region shows areas where vertical beam resolution is better than 0.7 km and gray regions delineate areas where vertical beam resolution is better than 1.4 km. Maximum extent of gray area is approximately 40 km from flight track, approximately the maximum usable extent of reliable airborne Doppler radar coverage. Flight distance in pattern above is 1280 nm, and flight time is 5.33 hours.

Note 1. This is to be flown where even coverage is required, particularly in tropical depressions and tropical storms. Aircraft flies IP-2-3-4-5-6-7-8-FP. No attempt should be made to fix a center of circulation unless it is an operational request.

Note 2. Doppler radars should be operated in single-PRF mode, at a PRF of 2100. Radar scientist should

verify this mode of operation with AOC engineers. If there is no assigned radar scientist, LPS should verify. *This is crucial for the testing and implementation of real-time quality control.*

Note 3. Assure that transmitter is switching between fore and aft antennas, by examining the real time display.

Note 4. IP can be at any desired heading relative to storm center

Note 5. To maximize dropwindsonde coverage aircraft should operate at highest altitudes that still minimize icing

Note 6. If dropwindsondes are not deployed, aircraft can operate at any level below the melting level, with

10,000 ft preferred. Aircraft might also fly lower, if circulation not evident at 10,000 ft.

Note 7. Dropwindsondes are not a required part of this flight plan and are optional.

P-3 Box-spiral patterns

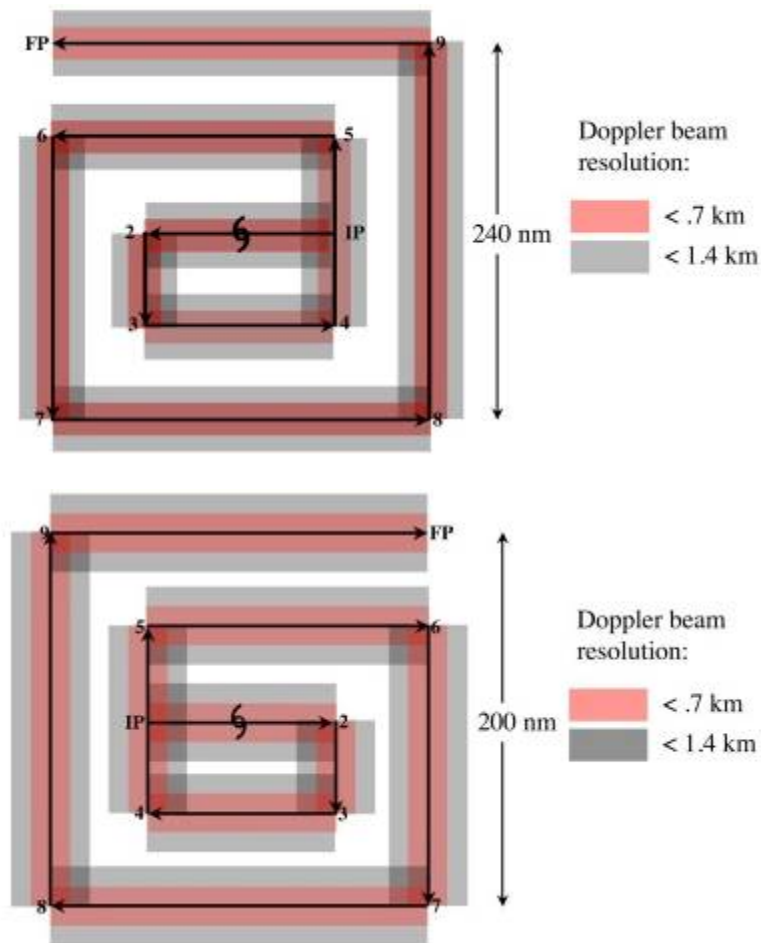


Figure 3: Doppler radar coverage for box-spiral pattern with 200- (top) and 240- (bottom) nm legs. Pink region shows areas where vertical beam resolution is better than 0.7 km and gray regions delineate areas where vertical beam resolution is better than 1.4 km. Maximum extent of gray area is approximately 40 km from flight track, approximately the maximum usable extent of reliable airborne Doppler radar coverage. Upper pattern is 1500 nm and uses 6.25 hours, while lower pattern is 1250 nm and uses 5.2 hours.

Note 1. Pattern flown where even coverage is required, particularly in tropical depressions and tropical storms. Doppler radars should be operated in single-PRF mode, at a PRF of 2100. Radar scientist should verify this mode of operation with AOC engineers. If there is no assigned radar scientist, LPS should verify. *This is crucial for the testing and implementation of real-time quality control.*

Note 2. Assure that transmitter is switching between fore and aft antennas, by examining the real time display.

Note 3. IP can be at any desired heading relative to storm center

Note 4. To maximize dropwindsonde coverage aircraft should operate at highest altitudes that still minimize icing.

Note 5. Maximum radius may be decreased or increased within operational constraints.

Note 6. Dropwindsondes are not a required part of this flight plan and are optional.

Note 7. Maximum radius may be changed to meet operational needs while conforming to flight-length constraints.

Note 8. If dropwindsondes are not deployed, aircraft can operate at any level below the melting level, with 10,000 ft preferred. Aircraft might also fly lower, if circulation not evident at 10,000 ft.

P-3 Rotating Figure-4 patterns

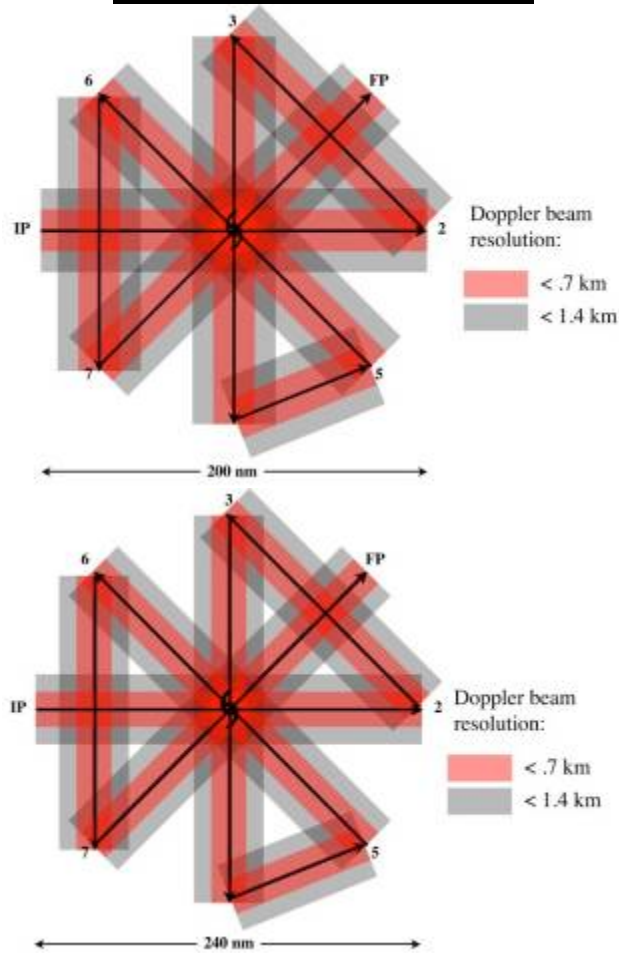


Figure 4: Doppler radar coverage for radial extents of 100 (top) and 120 (bottom) nm of the rotating figure-4 patterns. Pink region shows areas where vertical beam resolution is better than 0.7 km and gray regions delineate areas where vertical beam resolution is better than 1.4 km. Maximum extent of gray area is approximately 40 km from flight track, approximately the maximum usable extent of reliable airborne Doppler radar coverage. Flight distances for 100, 120 and 150 nm radial extents are 1160, 1395, and 1745 nm. Corresponding flight times are: 4.8, 5.8, and 7.3 h.

P-3 Rotating Figure-4 patterns

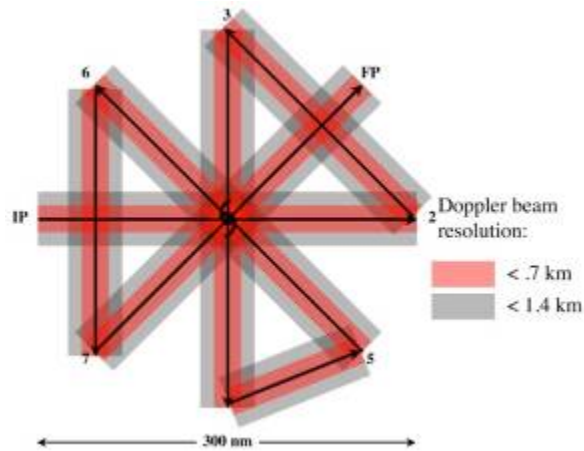


Figure 4 (continued): Doppler radar coverage for 150-nm legs for a rotating figure-4. Flight distances for 100, 120 and 150 nm radial extents are 1160, 1395, and 1745 nm. Corresponding flight times are: 4.8, 5.8, and 7.3 h.

Note 1. This pattern should be flown in strong tropical storms and hurricanes, where the circulation extends from 100 nm to 150 nm from the center. Doppler radars should be operated in single-PRF mode, at a PRF of 2100. Radar scientist should verify this mode of operation with AOC engineers. If there is no assigned radar scientist, LPS should verify. *This is crucial for the testing and implementation of real-time quality control.*

Note 2. Assure that transmitter is switching between fore and aft antennas, by examining the real time display.

Note 3. IP can be at any desired heading relative to storm center

Note 4. To maximize dropwindsonde coverage aircraft should operate at highest altitudes that still minimize icing

Note 5. Maximum radius may be decreased or increased within operational constraints

Note 6. Dropwindsondes shown are not a required part of this flight plan and are optional.

Note 7. Flight pattern should be centered around either the 03, 09, 15, or 21 UTC so Doppler observations are available for both surrounding observation periods.

Note 8. Maximum radius may be changed to meet operational needs while conforming to flight-length constraints.

P-3 Butterfly-4 patterns

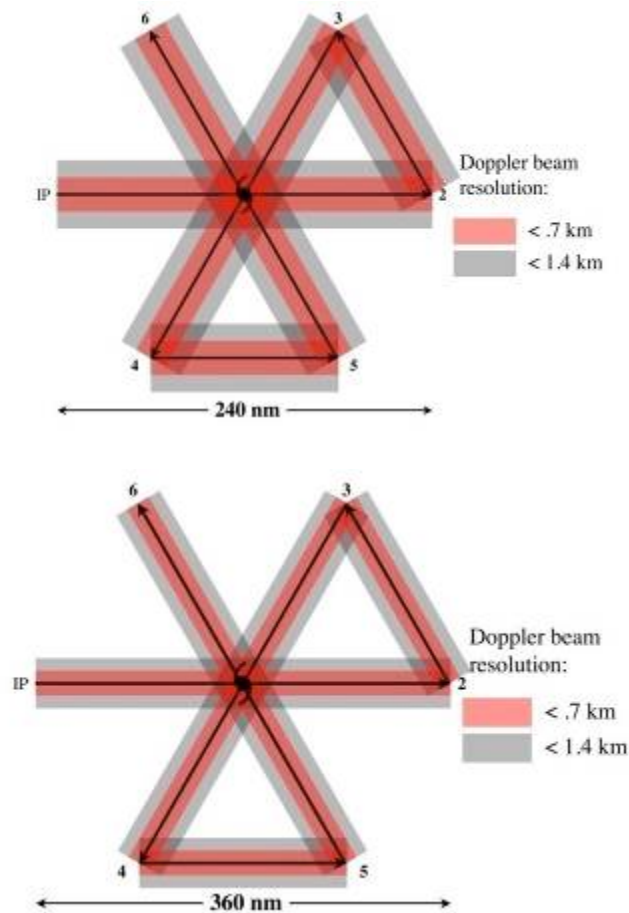


Figure 5: Doppler radar coverage for 120- (top) and 180- (bottom) nm legs for the Butterfly pattern. Pink region shows areas where vertical beam resolution is better than 0.75 km and gray regions delineate areas where vertical beam resolution is better than 1.5 km. Maximum extent of gray area is approximately 40 km from flight track, approximately the maximum usable extent of reliable airborne Doppler radar coverage. Flight distances for the patterns with 120 and 180 nm radials legs are 960 and 1440 nm. Corresponding flight durations are 4 and 6 h.

Note 1. This pattern will be flown in large tropical storms, as well as hurricanes. Doppler radars should be operated in single-PRF mode, at a PRF of 2100. Radar scientist should verify this mode of operation with AOC engineers. If there is no assigned radar scientist, LPS should verify. *This is crucial for the testing and implementation of real-time quality control.*

Note 2. Assure that transmitter is switching between fore and aft antennas, by examining the real time display.

Note 3. IP can be at any desired heading relative to storm center

Note 4. To maximize dropwindsonde coverage aircraft should operate at highest altitudes that still minimize icing

Note 5. Maximum radius may be decreased or increased within operational constraints

Note 6. Dropwindsondes are not a required part of this flight plan and are optional.

Note 7. Flight pattern should be centered around either 03, 09, 15, or 21 UTC so Doppler observations are available for both surrounding observation periods.

Note 8. Maximum radius may be changed to meet operational needs while conforming to flight-length constraints.

P-3 Figure-4 patterns

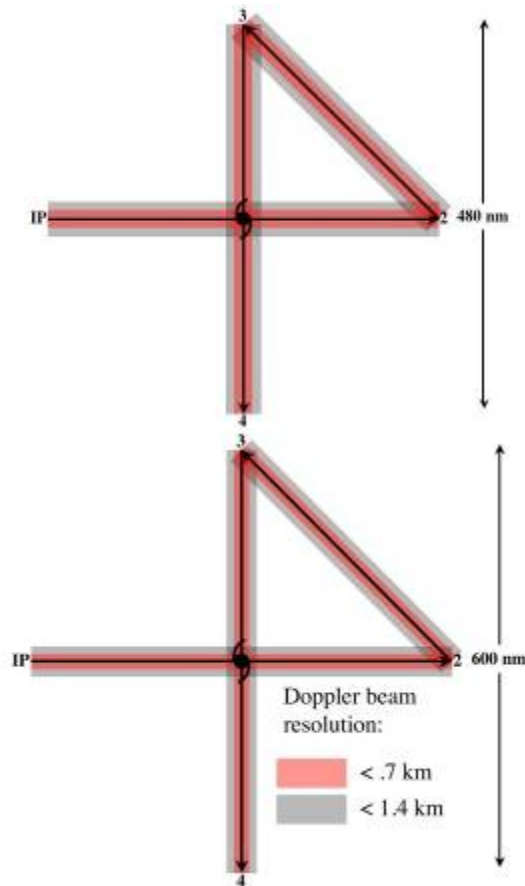


Figure 6: Doppler radar coverage for 300-nm legs for a single figure-4 pattern. Pink region shows areas where vertical beam resolution is better than 0.75 km and gray regions delineate areas where vertical beam resolution is better than 1.5 km. Maximum extent of gray area is approximately 40 km from flight track, approximately the maximum usable extent of reliable airborne Doppler radar coverage. Flight distances for radial extents of 240 and 300 nm are 1300 and 1645 nm, respectively. Corresponding flight times are 5.4 and 6.8 h.

Note 1. Pattern for large storms, to obtain as full a radial extent of observations of the full storm circulation as possible. Doppler radars should be operated in single-PRF mode, at a PRF of 2100. Radar scientist should verify this mode of operation with AOC engineers. If there is no assigned radar scientist, LPS should verify. *This is crucial for the testing and implementation of real-time quality control.*

Note 2. Assure that transmitter is switching between fore and aft antennas, by examining the real time display.

Note 3. IP can be at any desired heading relative to storm center

Note 4. To maximize dropwindsonde coverage aircraft should operate at highest altitudes that still minimize icing

Note 5. Maximum radius may be decreased or increased within operational constraints

Note 6. Dropwindsondes are not a required part of this flight plan and are optional.

Note 7. Flight pattern should be centered around either the 03, 09, 15, or 21 UTC so Doppler observations are available for both surrounding observation periods.

Note 8. Maximum radius may be changed to meet operational needs while conforming to flight-length constraints.

G-IV Square spiral (outward) pattern

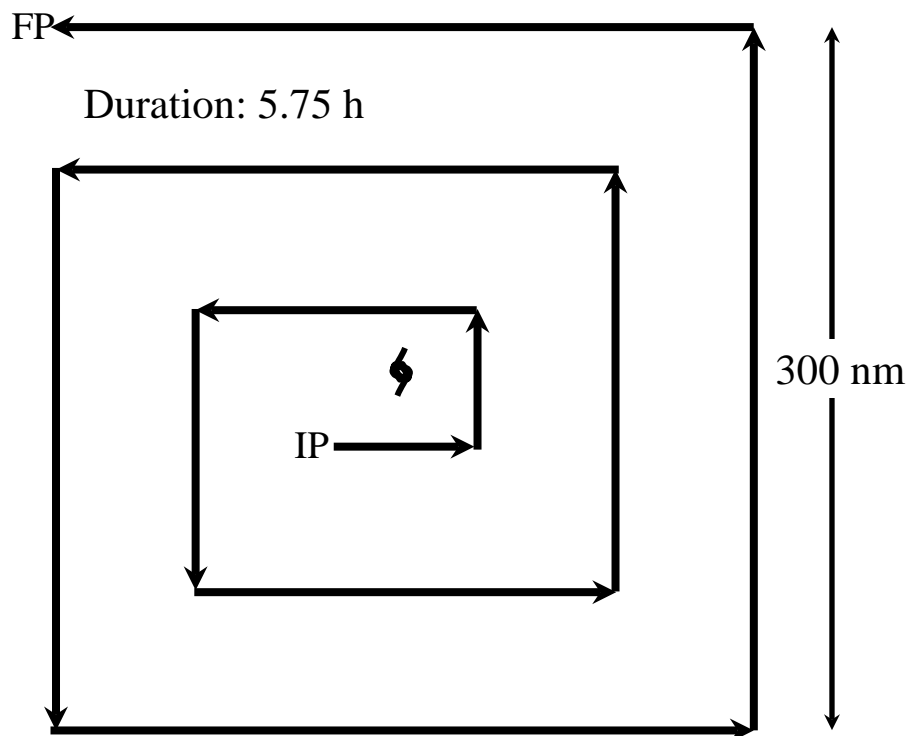


Figure 7: G-IV tail Doppler radar pattern – Square Spiral (outward)

- Note 1. G-IV begins 30 nm to south and west of estimated circulation center (with proper rotation starting point can be NE, NW, SW, or SE of center)
- Note 2. Fly 60 nm due east (due north, west, south, for IP SE, NE, or NW of center, respectively)--left turn--60 nm--left turn--120 nm--left turn--120 nm--left turn--180 nm--left turn--180 nm--left turn--240 nm--left turn--240 nm--left turn--300 nm--left turn--300 nm--left turn--300 nm
- Note 3. Duration: 2100 nm, or 4.75 hour + 1 hour for deviations--covers 150 nm (2.5 deg) in each cardinal direction from center
- Note 4. Aircraft should operate at its maximum cruising altitude of ~40-45 kft
- Note 5. On all legs, deviate to avoid weather deemed to pose possible hazard
- Note 6. As flight duration and ATC allow, attempt to sample as much of regions that require deviation
- Note 7. Tail Doppler radar should be run in single PRF mode, 3000, since dual PRF is often in error when there is a strong vertical gradient of tangential wind.
- Note 8. If flying above 40,000 ft, pattern may be flown clockwise, if preferred.

G-IV Square spiral (inward) pattern

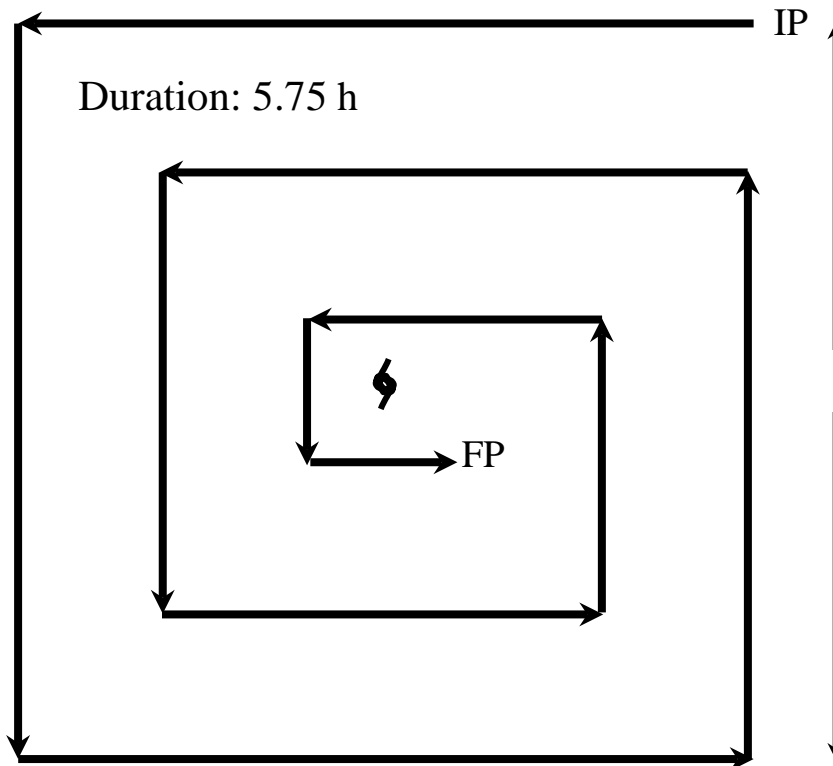


Figure 8: G-IV tail Doppler radar pattern – Square Spiral (inward)

Note 1. G-IV begins 150 nm to north and east of estimated circulation center (with proper rotation starting point can be NE, NW, SW, or SE of center)

Note 2. Fly 300 nm due west (due south, east, north, for IP NW, SW, or SE of center, respectively)--left turn--300 nm--left turn--300 nm--left turn--240 nm--left turn--240 nm--left turn--180 nm--left turn--180 nm--left turn--120 nm--left turn--120 nm--left turn--60 nm--left turn--60 nm

Note 3. Duration: 2100 nm, or 4.75 hour + 1 hour for deviations--covers 150 nm (2.5 deg) in each cardinal direction from center

Note 4. Aircraft should operate at its maximum cruising altitude of ~40-45 kft Note 5. On all legs, deviate to avoid weather deemed to pose possible hazard

Note 6. As flight duration and ATC allow, attempt to sample as much of regions that require deviation

Note 7. Tail Doppler radar should be run in single PRF mode, 3000, since dual PRF is often in error when there is a strong vertical gradient of tangential wind.

Note 8. If flying above 40,000 ft, pattern may be flown clockwise, if preferred.

G-IV Rotating Figure-4 pattern

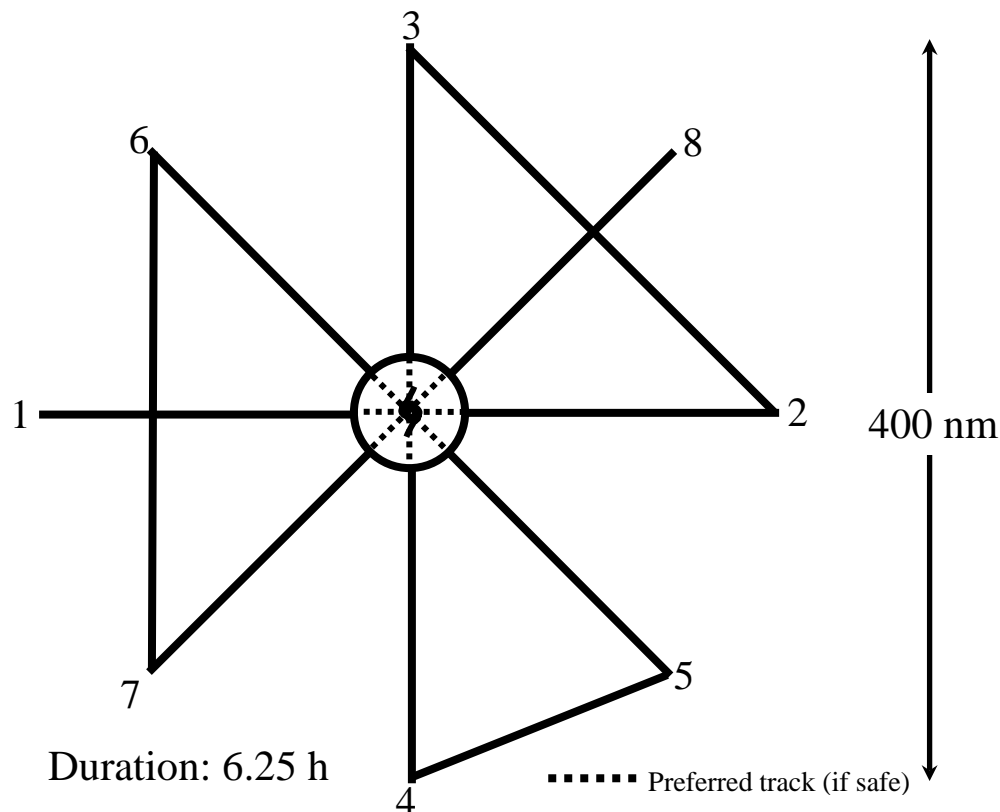


Figure 9: G-IV Doppler radar pattern – Rotating Figure-4

Note 1. IP is 200 nm from storm center

Note 2. Fly 1-2, deviating around eyewall if conditions require (eyewall assumed to extend 20 nm from center). If deviation is required, fly to right of convection if possible. If conditions permit, fly through center of circulation.

Note 3. Fly 2-3, deviating around convection if necessary

Note 4. Fly 3-4, as described in Note 2.

Note 5. Fly 4-5, deviating around convection, if necessary

Note 6. Fly 5-6-7-8 in the same manner as 1-2-3-4

Note 7. Duration: 2317 nm, or 5.25 hours + 1 hour for deviations

Note 8. Aircraft should operate at its maximum cruising altitude of ~40-45 km

Note 9. As flight duration and ATC allow, attempt to sample with TDR as much of regions that require deviations as possible.

Note 10. Tail Doppler radar should be operated in single PRF at 3000 per second

Note 11. If flying above 40,000 ft, pattern may be flown clockwise, if preferred.

G-IV Butterfly pattern

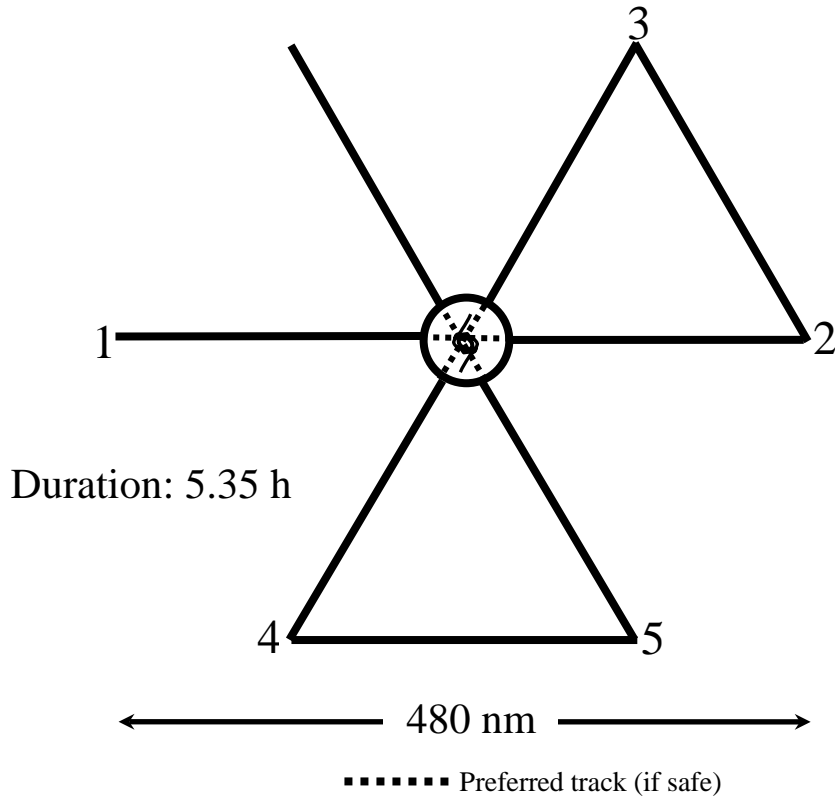


Figure 10: G-IV tail Doppler radar pattern – Butterfly

- Note 1. IP is 240 nm from storm center at desired heading from storm center
- Note 2. Fly 1-2, deviating around eyewall if conditions require (eyewall assumed to extend 20 nm from center in the figure). If deviation is required fly to right of convection if possible. If conditions permit, fly through center of circulation
- Note 3. Fly 2-3, deviating around convection, if necessary.
- Note 4. Fly 3-4, as described in Note 2.
- Note 5. Fly 4-5, deviating around convection if necessary.
- Note 6. Fly 5-6, as describe in Note 2.
- Note 7. Aircraft should operate at its maximum cruising altitude of ~40-45 kft
- Note 8. Duration: 1920 nm, or 4.35 hours + 1 hour for deviations
- Note 9. As flight duration and ATC allow, attempt to sample with TDR, as much of regions missed by deviations.
- Note 10. Tail Doppler radar should be operated in single PRF, 3000 per second.
- Note 11. If flying above 40,000 ft., pattern may be flown clockwise, if preferred.

G-IV Figure-4 pattern

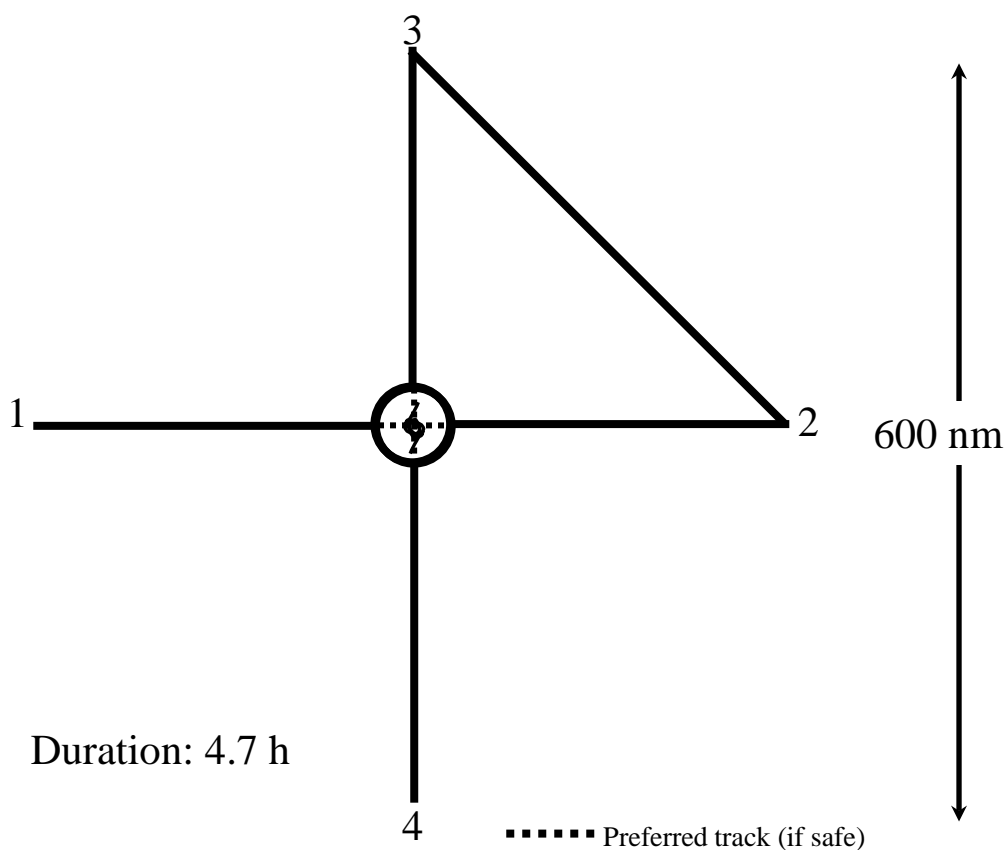


Figure 11: G-IV tail Doppler radar pattern – Single Figure 4.

Note 1. IP is 300 nm from storm center

Note 2. Fly 1-2, deviating around eyewall if conditions required (eyewall assume to extend 20 nm from center in this figure). If deviation is required, fly 1.5 circles around eyewall before continuing to point 2. Otherwise if conditions permit, fly directly through circulation center.

Note 3. Fly 2-3, deviating around convection, if necessary.

Note 4. Fly 3-4, as describe in segment 1-2; however if full circle done in first pass, only half circle is required.

Note 5. Duration 1624 nm, or 3.7 hours + 1 hour for deviations—pattern could be extended if time allows for greater radial coverage

Note 6. Aircraft should operate at its maximum cruising altitude of ~40-45 kft

Note 7. As flight duration and ATC allow, attempt to sample with TDR, as much of regions missed by deviations.

Note 8. Tail Doppler radar should be operated in single PRF, 3000 per second.

Note 9. If flying above 40,000 ft., pattern may be flown clockwise, if preferred.

G-IV Surveillance/TDR combination pattern

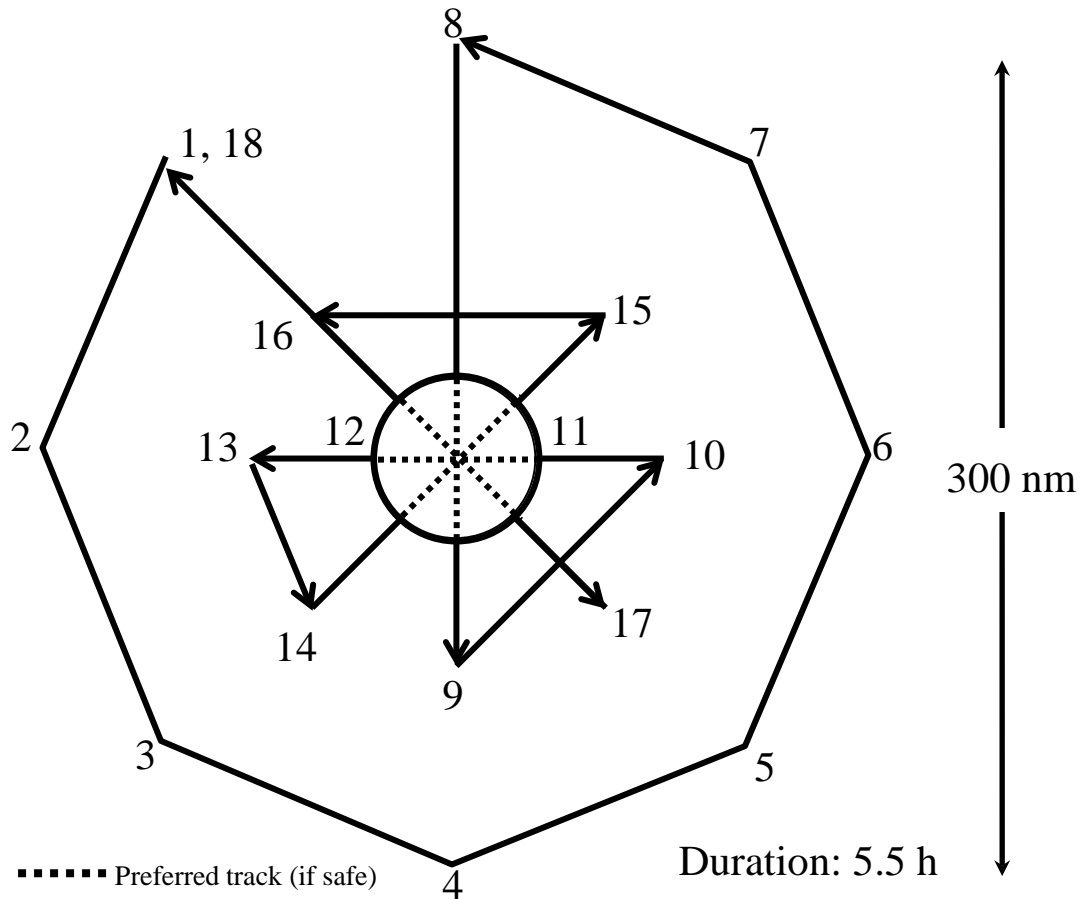


Figure 12: G-IV tail Doppler radar pattern – Surveillance/TDR combination

Note 1. IP is 150 nm from storm center

Note 2. Fly 1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-16-17-18, deviating around eyewall if conditions require (eyewall assumed to extend 30 nm from center). If deviation is required, fly to right of convection if possible. If conditions permit, fly through center of circulation.

Note 3. Dropsondes should be launched at all numbered points (except 11 and 12). If the aircraft is able to cross the center, a sonde should be dropped there. Extra sondes may be requested.

Note 4. On-station duration: ~1933 nm, or about 4.5 hours + 1 hour for deviations.

Note 5. Aircraft should operate at its maximum cruising altitude of ~40-45 kft

Note 6. As flight duration and ATC allow, attempt to sample with TDR, as much of regions missed by deviations.

Note 7. Tail Doppler radar should be operated in single PRF, 3000 per second.

Note 8. If flying above 40,000 ft., pattern may be flown clockwise, if preferred.

G-IV Easterly Wave Genesis Experiment – Environmental Survey

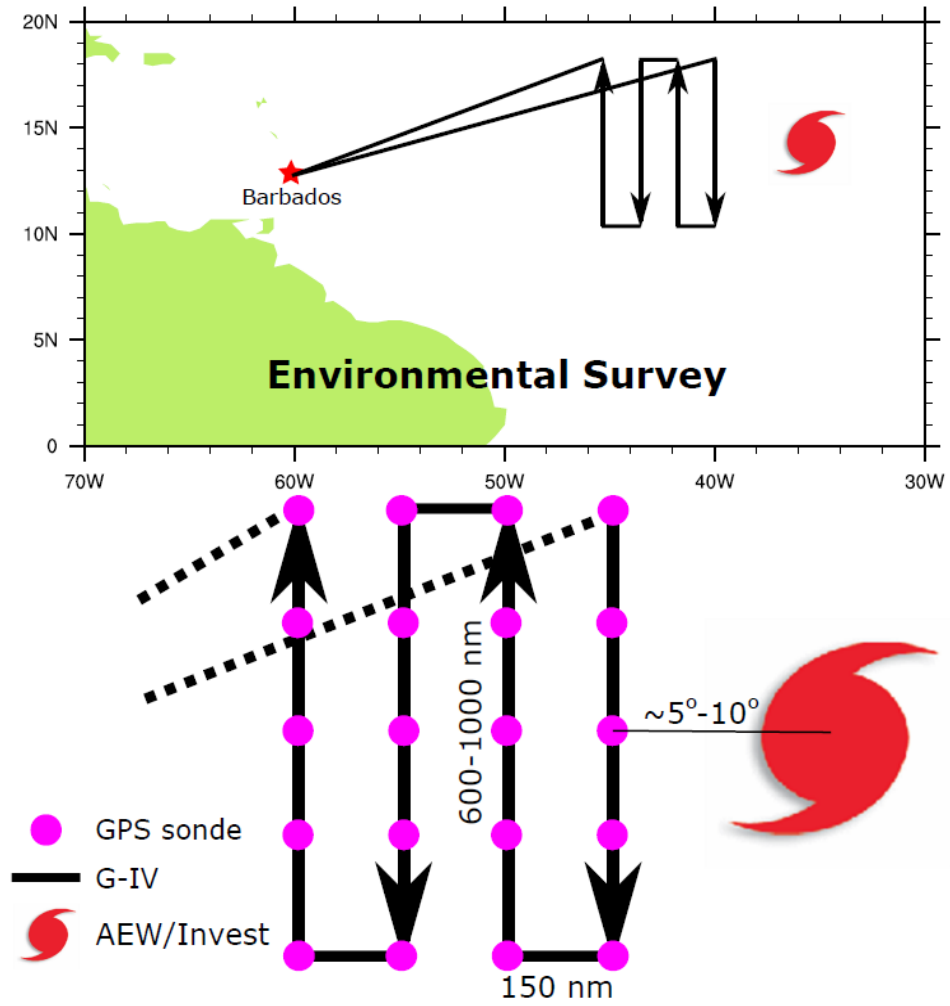


Figure 13. The Environmental Survey pattern.

G-IV Easterly Wave Genesis Experiment – AEW Survey

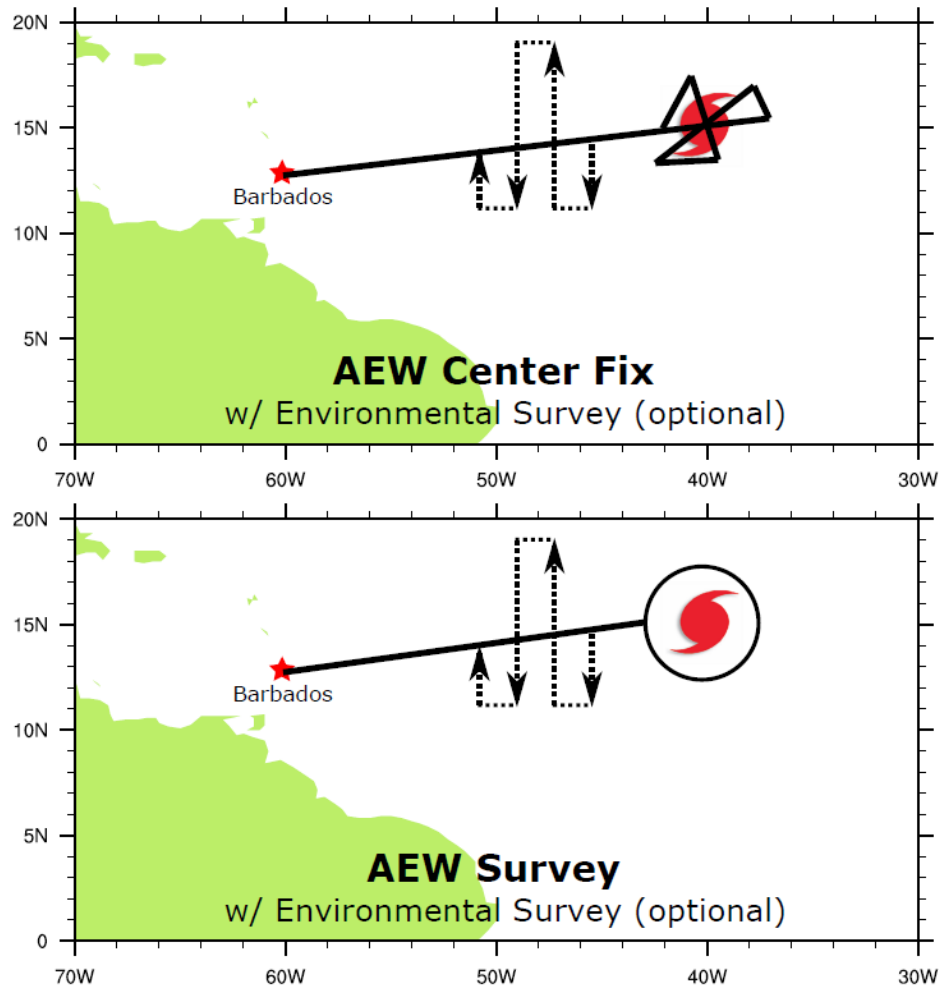


Figure 14. The AEW Survey pattern. (Top) AEW Center Fix option with optional Environmental Survey module. (Bottom) AEW Survey option with Environmental Survey module.

East Pacific Easterly Wave Genesis Experiment – Panama Bight convection

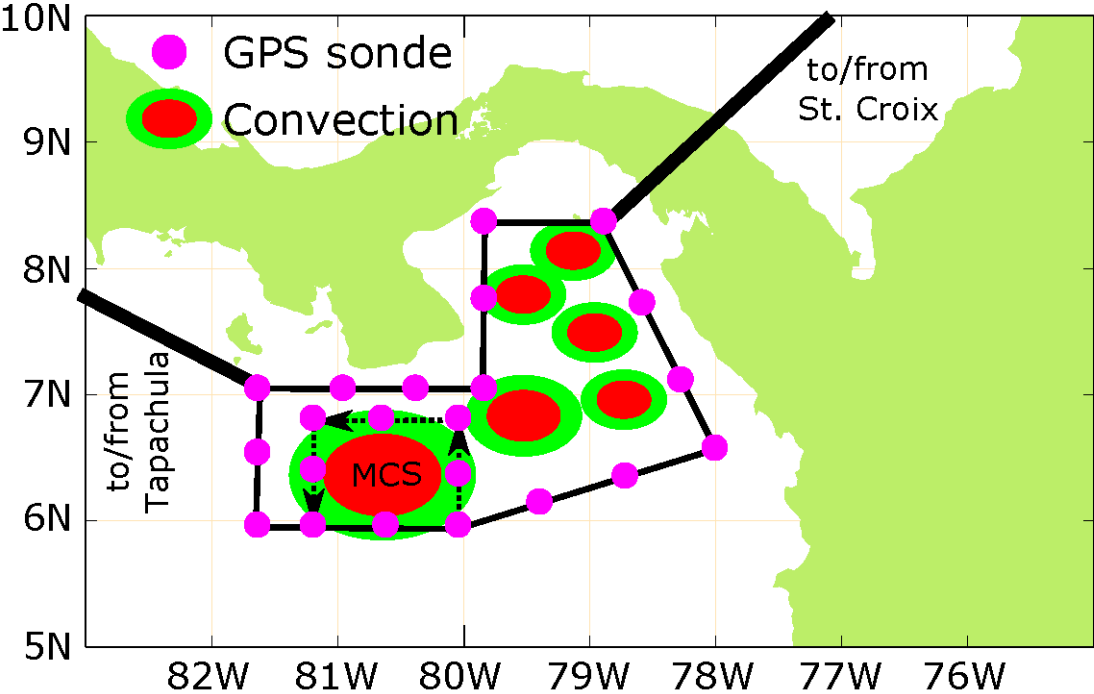


Figure 15. The Panama Bight Convection pattern.

East Pacific Easterly Wave Genesis Experiment – East Pacific Development

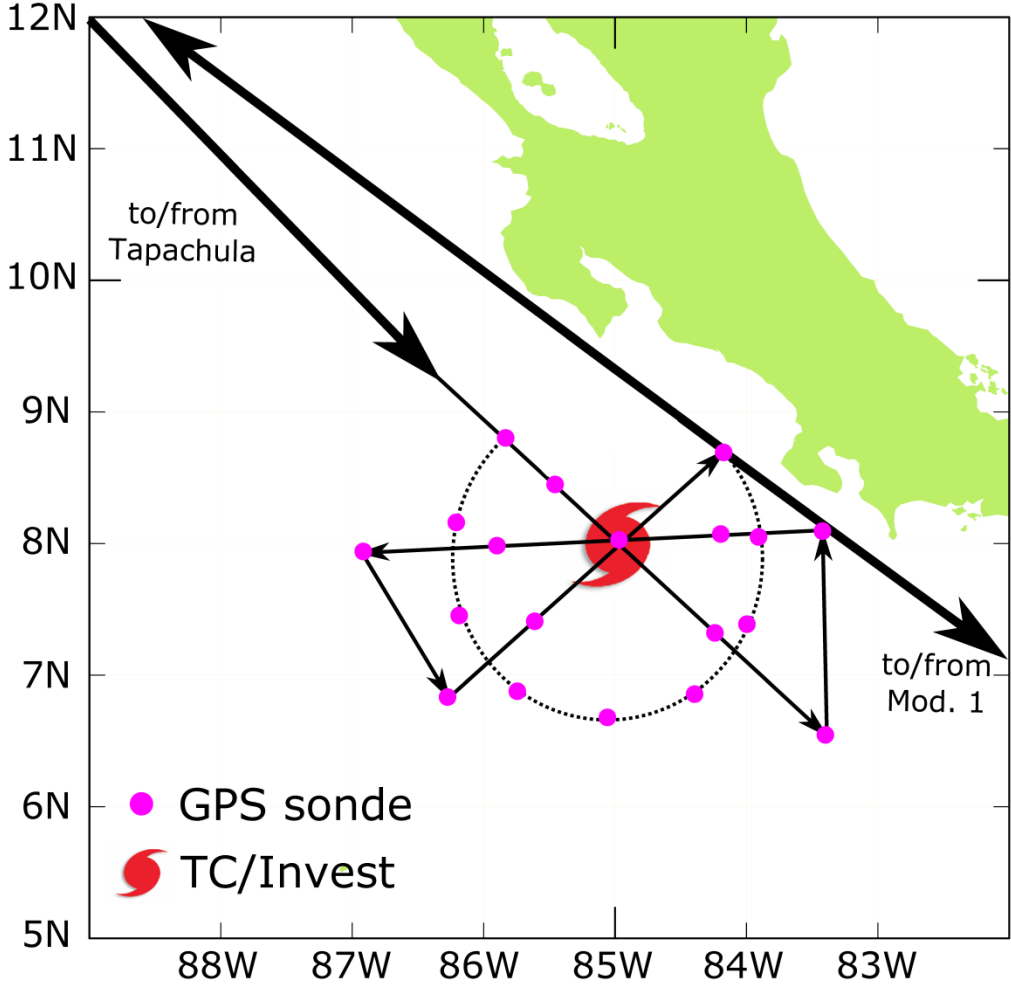


Figure 16. The East Pacific Development pattern.

East Pacific Easterly Wave Genesis Experiment – Easterly Wave Transition

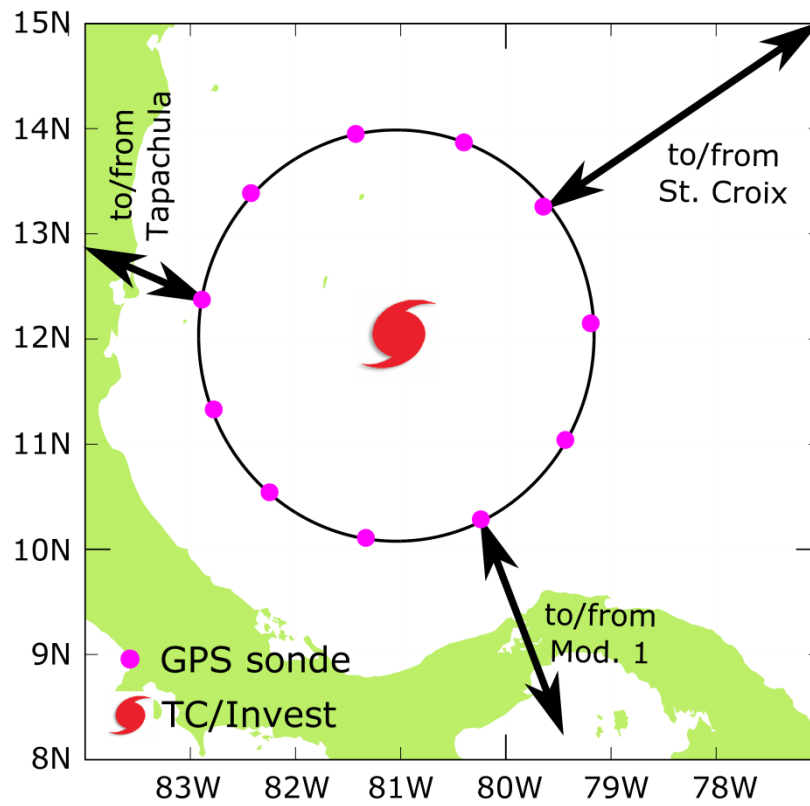


Figure 17. The Easterly Wave Transition pattern.

G-IV RAPX pattern (optimal dropsonde)

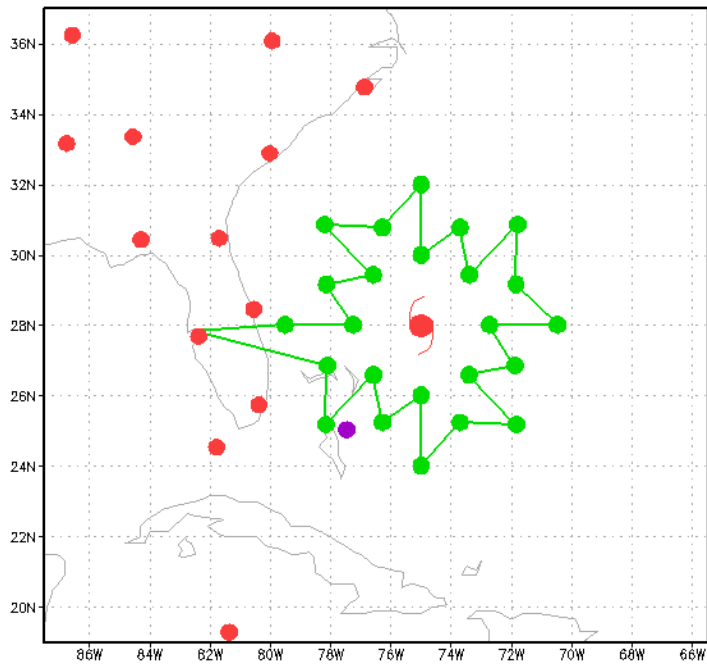


Figure 18. A sample G-IV flight pattern for the RAPX mission. The green dots denote the desired dropsonde locations at 220, 330, and 440 km radius from the storm center. Note that the end points of each leg can be rounded slightly as required for aircraft flight considerations. The flight pattern (excluding ferry time to and from the storm) requires about 6 hours to complete.

G-IV RAPX pattern (optimal radar)

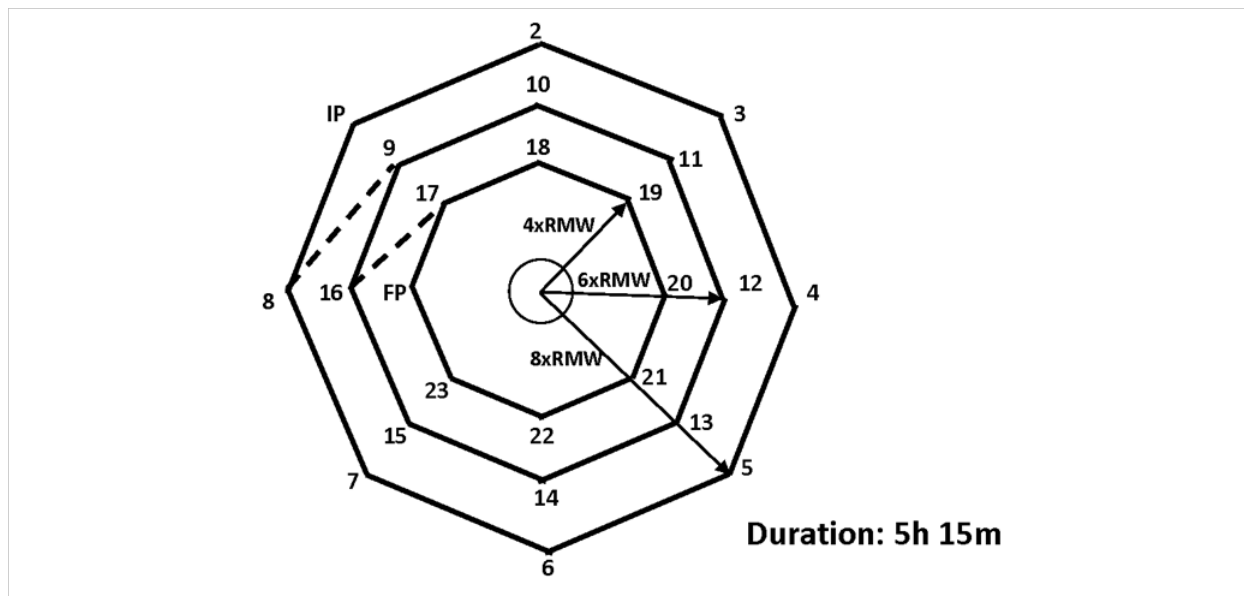


Figure 19: G-IV outer-core survey pattern

- Altitude: 40-45 kft
- Expendables: Deploy dropsondes at all turn points. No more than 24 GPS drops needed.
- Pattern: The pattern is flown with respect to the surface storm center. Three concentric octagons are flown clockwise at decreasing radii of 8xRMW, 6xRMW, and 4xRMW, where RMW is the estimated radius of maximum azimuthal-mean tangential wind (estimated from flight-level observations). For example, if RMW=18 nm, the maximum radial extent of the pattern is 144 nm. Dashed lines show transitions between rings.
- Instrumentation: Set airborne Doppler radar to scan F/AST on all legs.

G-IV TC in Shear “pre-shear” and “large tilt” outer-core survey

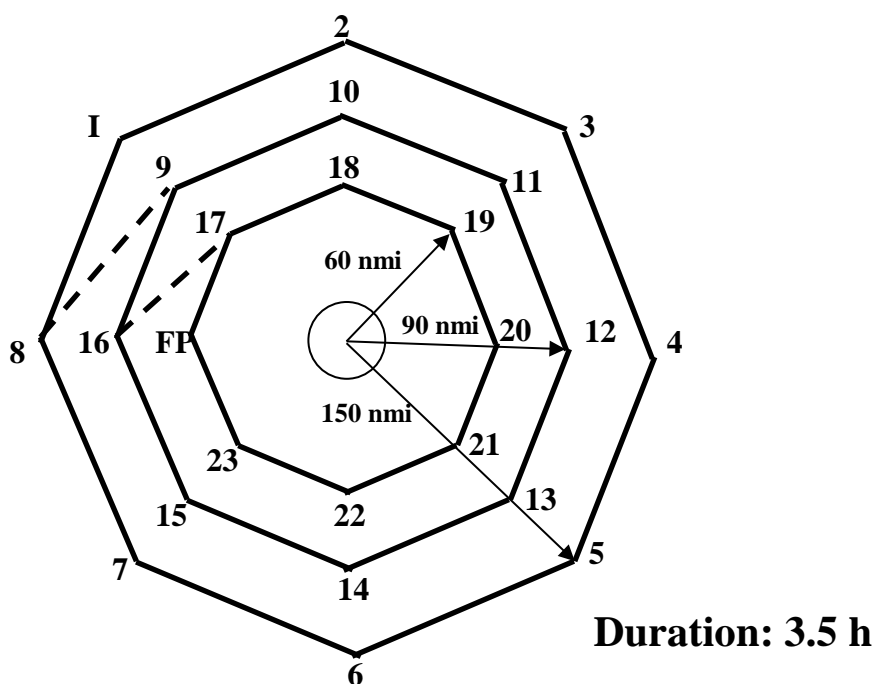


Figure 20. G-IV “pre-shear” and “large tilt” outer-core survey pattern

- Altitude: 40-45 kft
- Expendables: Deploy dropsondes at all turn points. No more than 24 GPS drops needed (18 if suboptimal hexagon pattern is flown).
- Pattern: The pattern is flown with respect to the surface storm center. Three concentric octagons (or suboptimal hexagons) are flown clockwise at decreasing radii of 150 nmi, 90 nmi, and 60 nmi. Dashed lines show transitions between rings. Time permitting, a fourth circumnavigation may be added. The vertices of the middle circumnavigation may be rotated to increase azimuthal resolution of the dropsonde observations.
- Instrumentation: Set airborne Doppler radar to scan F/AST on all legs

P-3TC in Shear – “pre-shear” core-region survey

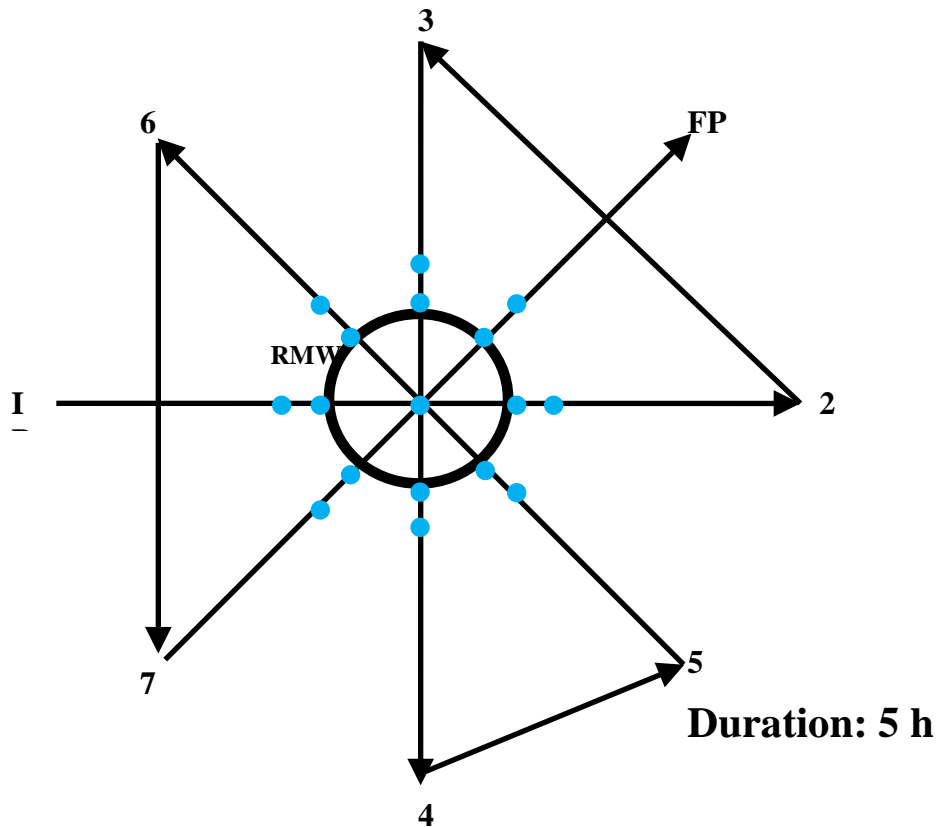


Figure 21: P-3 “pre-shear” core-region survey pattern

- Altitude: 12,000 ft (4 km) altitude preferable.
- Expendables: Deploy dropsondes at center of first and last pass, RMW, and 30 nmi (half distance to innermost G-IV circumnavigation) of Figure-4 legs. About 18 drops needed.
- Pattern: The pattern is flown with respect to the surface storm center. Radial legs of the rotated Figure-4 pattern extend 90-105 nmi.
- Instrumentation: Set airborne Doppler radar to scan F/AST on all legs.

P-3TC in Shear – “threshold shear”, “large tilt”, and “realignment/recovery” core region

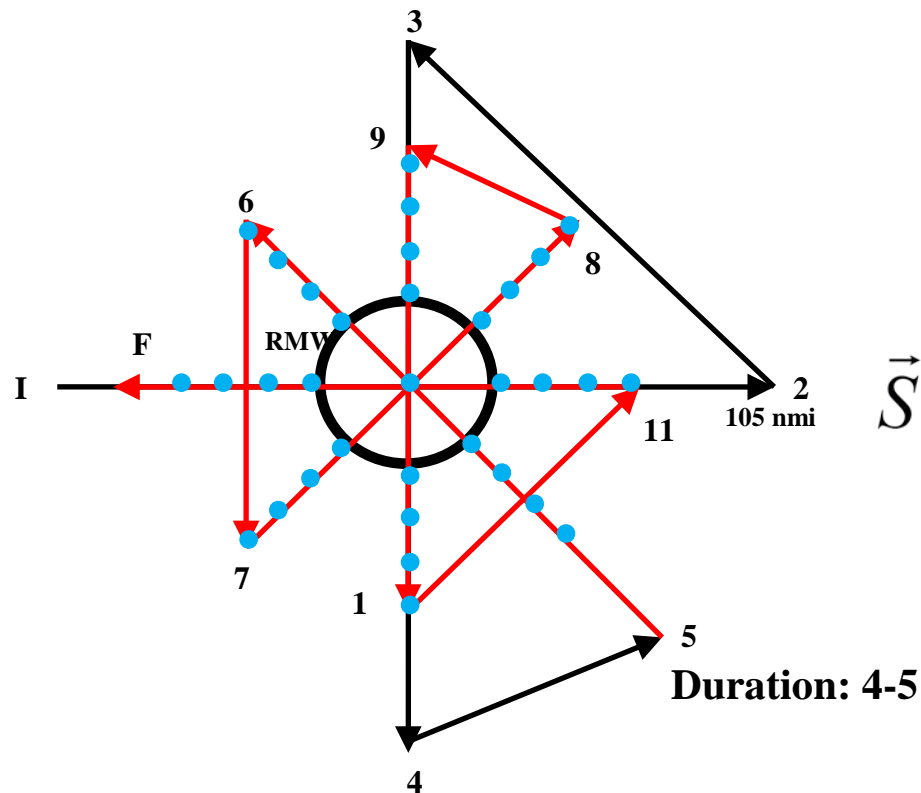


Figure 22: P-3 “threshold shear”, “large-tilt”, and “realignment and recovery” core-region survey pattern

- Altitude: 12,000 ft (4 km) altitude preferable.
- Expendables: Deploy dropsonde at center of first large-scale Figure-4 pass (if no G-IV, then also at IP and turn points). Deploy 4 equally-spaced dropsondes along each radial of the small-scale, rotated Figure-4 starting at the RMW and ending at turn point. About 33 drops needed (37 if G-IV not present).
- Pattern: The pattern is flown with respect to the surface storm center. The initial inbound leg falls along the large-scale, deep-layer shear vector. Radial legs of the initial Figure-4 pattern extend 90-105 nmi. Aircraft then flies 45 deg downwind (4 -> 5) to begin small-scale rotated Figure-4. Legs should extend just beyond the primary region of organized convection outside the eyewall (~15-30 nmi beyond RMW).
- Instrumentation: Set airborne Doppler radar to scan F/AST on all legs.

P-3/G-IV TC in Shear – Extratropical transition

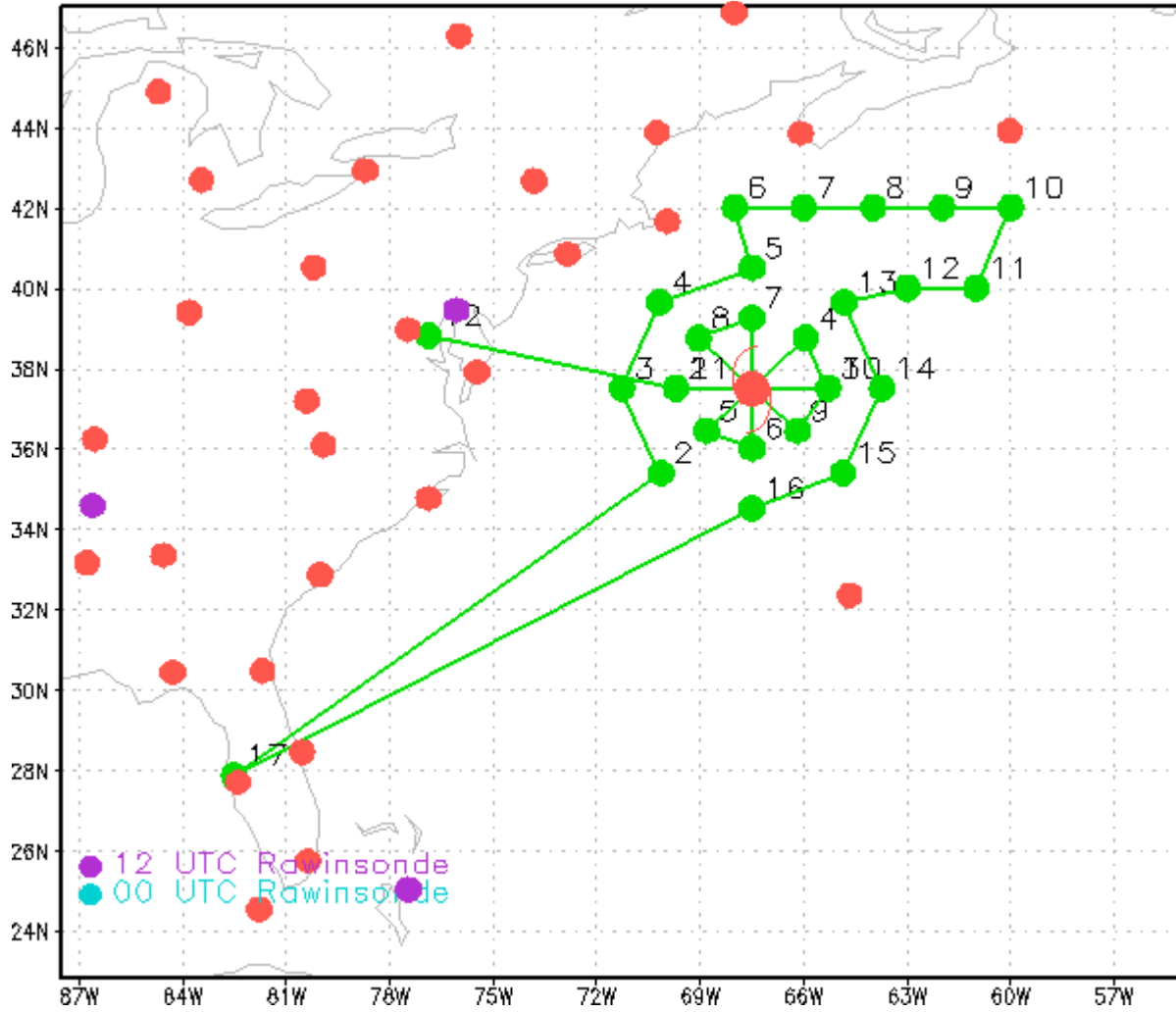


Figure 23: Extra-tropical transition module. Proposed flight tracks for G-IV and P3 aircraft.

G-IV Diurnal Cycle Star pattern

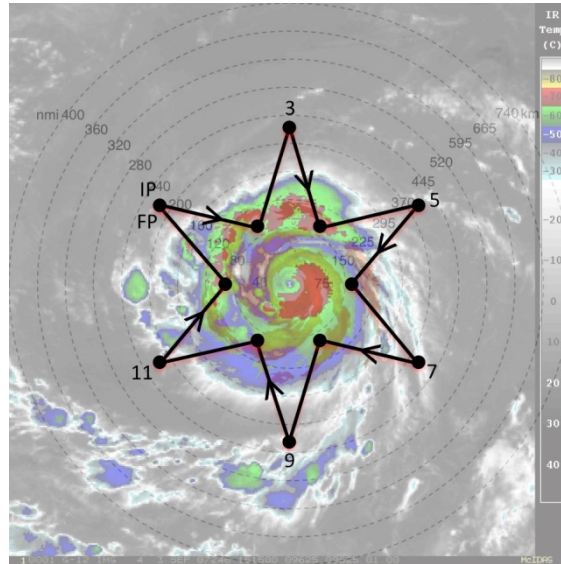


Fig. 24a. Sample G-IV star pattern with endpoints that alternate between 90 and 216 nm (165 and 400 km). The endpoints can be adjusted inward or outward depending on the exact position of the outwardly propagating diurnal pulse and the size of the TC inner core. The pattern is overlaid on (left) GOES IR imagery and (right) UW-CIMSS IR diurnal cycle imagery. Yellow to pink shading in the latter image indicates a diurnal pulse propagating away from the storm during this time and shows its typical radial evolution at ~ 1100 LST when it has reached $R \sim 300$ km.

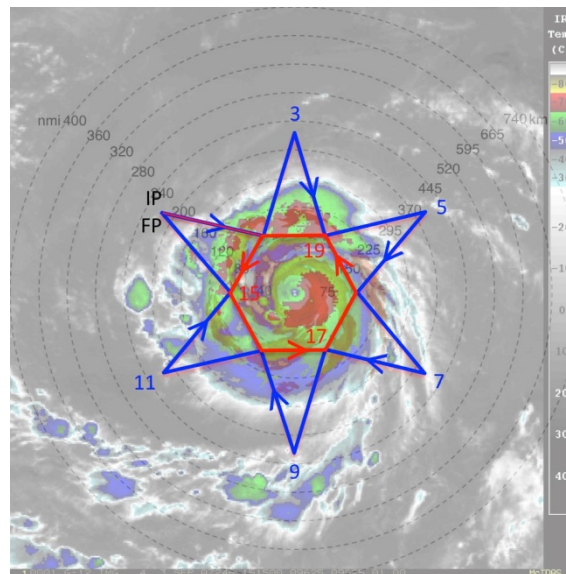


Fig. 24b. Same as in Fig. 24a, except that a circumnavigation of the storm is performed after (or before) the star pattern is completed. The hexagon circumnavigation that is shown has points that are 90 nm (165 km) from the storm center, but can be adjusted outward for safety considerations depending on the strength and size of the TC.

P-3 Pre- or post-storm Ocean survey patterns

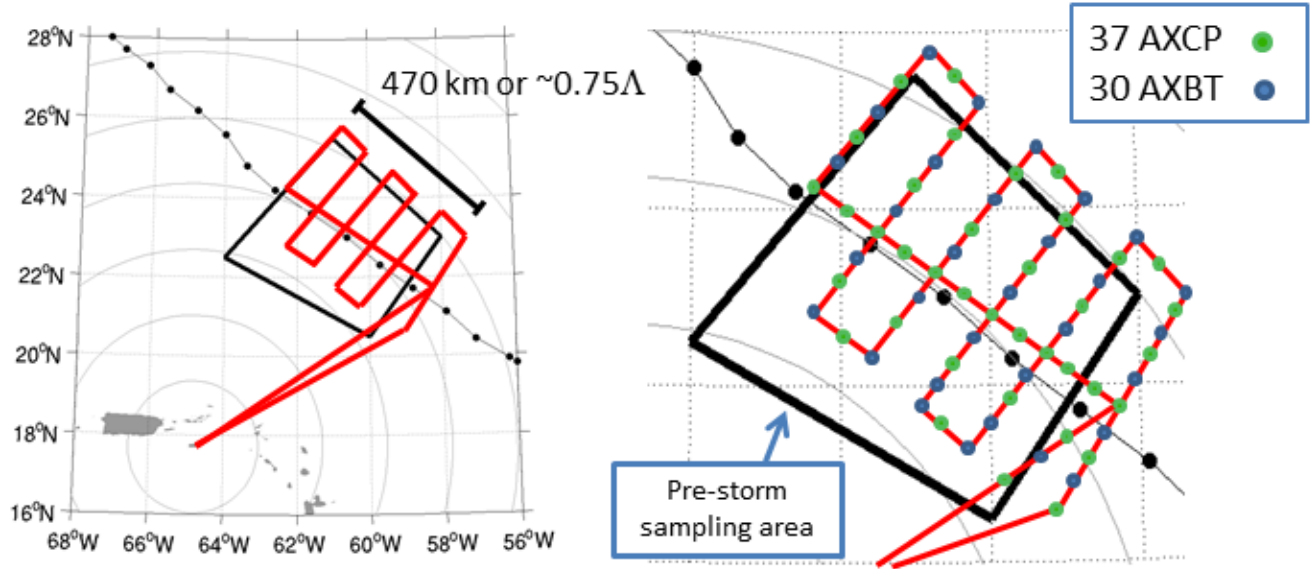


Figure 25. Left: Post-storm ocean sampling flight pattern (red line), over previously-sampled area (black box). In this example, the pattern extends around 470 km in the along-track dimension, or around 0.75 of a near-inertial wavelength. Right: Flight pattern with expendable drop locations, consisting of a combination of AXCP and AXBT probes.

P-3 Pre- or post-storm Ocean survey patterns

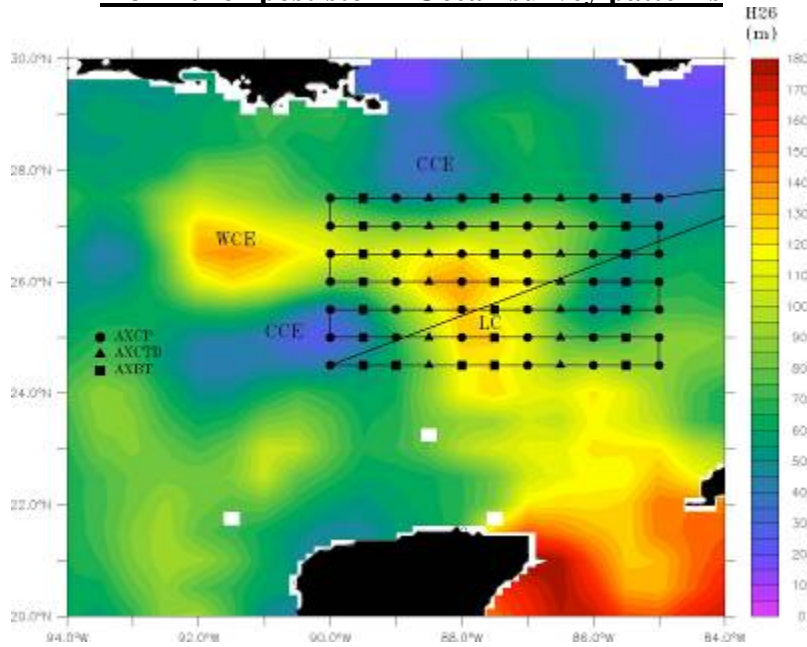


Figure 26a: Typical pre- or post-storm pattern with ocean expendable deployment locations relative to the Loop Current. Specific patterns will be adjusted based on actual and forecasted storm tracks and Loop Current locations. Missions generally are expected to originate and terminate at KMCF.

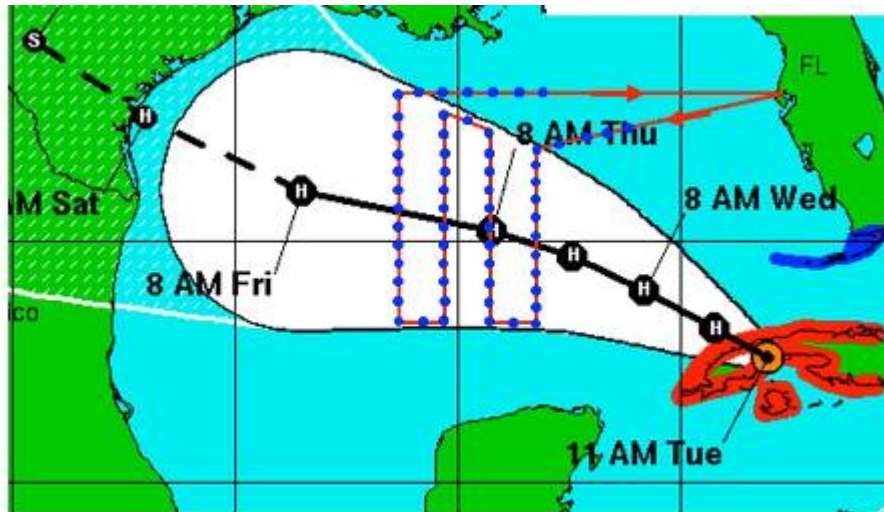
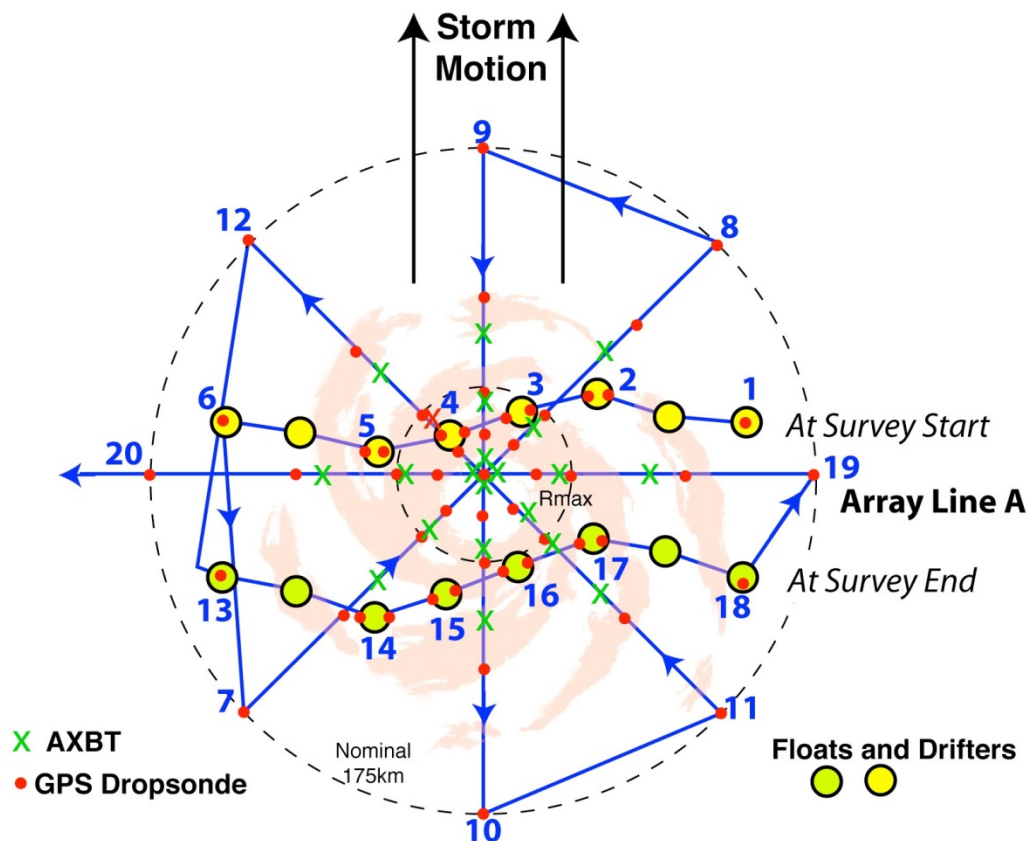


Figure 26b: Track-dependent AXBT/AXCTD ocean survey. As for the Loop Current survey, a total of 60-80 probes would be deployed on a grid (blue dots).

P-3 In-storm Ocean survey pattern (over existing drifter array)



Notes:

4 diameter lines through eye each with
 9 dropsondes. At eye, 0.5 R_{max} , R_{max} , 2 R_{max} , Line end.
 5 AXBT. At eye, R_{max} , 2 R_{max}
 2 float array lines each with
 10 dropsondes. 2 at each of 4 floats, 2 Line ends.
 Total: 56 dropsondes, 20 AXBT

Figure 27: P-3 pattern over float and drifter array. The array has been distorted since its deployment on the previous day and moves relative to the storm during the survey. The pattern includes two legs along the array (waypoints 1-6 and 13-18) and an 8 radial line survey. Dropwindsondes are deployed along all legs, with double deployments at the floats. AXBTs are deployed in the storm core.

Global Hawk Survey patterns

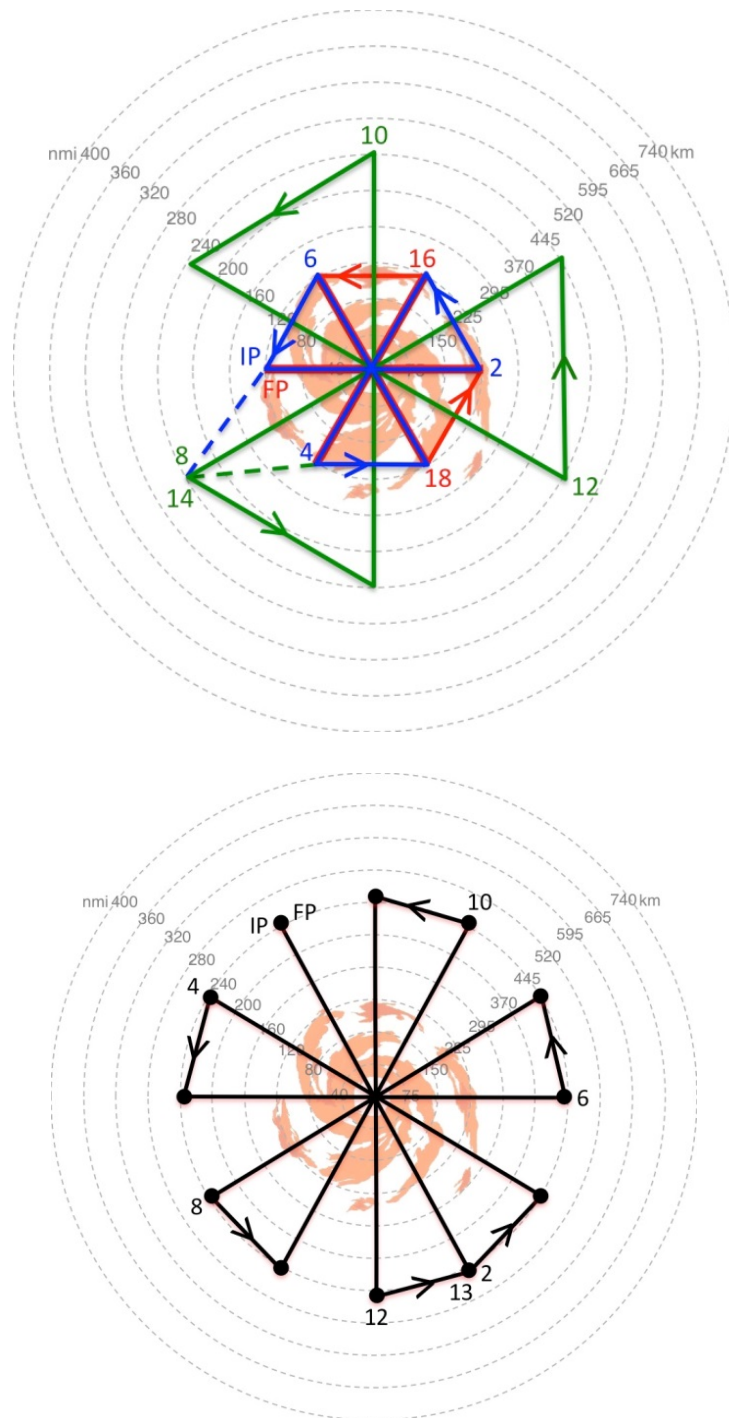


Figure 28. Sample GH flight patterns for the 2016 NOAA SHOUT field campaign. (Left) sequence of small-large-small butterflies. The small butterfly patterns have 120 nm (220 km) radial legs and take ~3-hr to complete while the large butterfly pattern has 240 nm (450 km) legs and takes ~6.5-hr to complete. (Right) rotated butterfly pattern with 30 degree rotated radials that are 240 nm (450 km) in length from the storm center. Both GH patterns would be flown in a storm relative framework.

J.2 Patterns from Modules

P-3 DWL SAL module

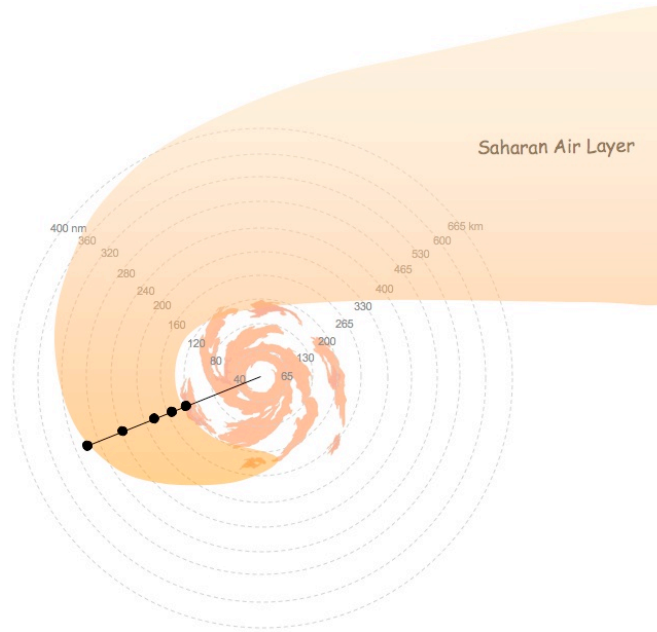
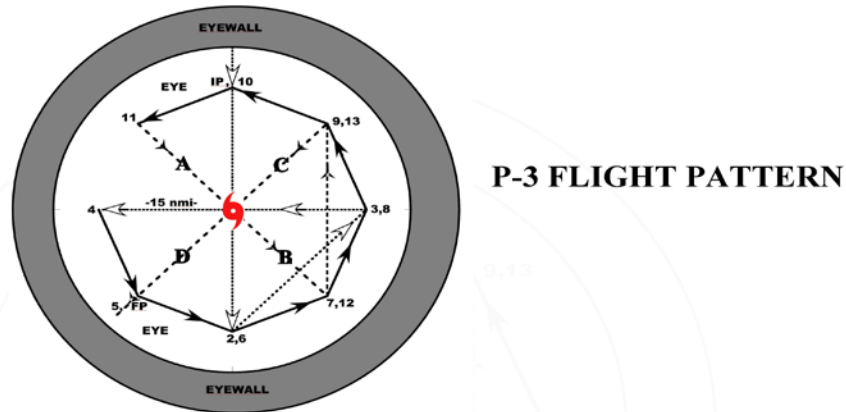


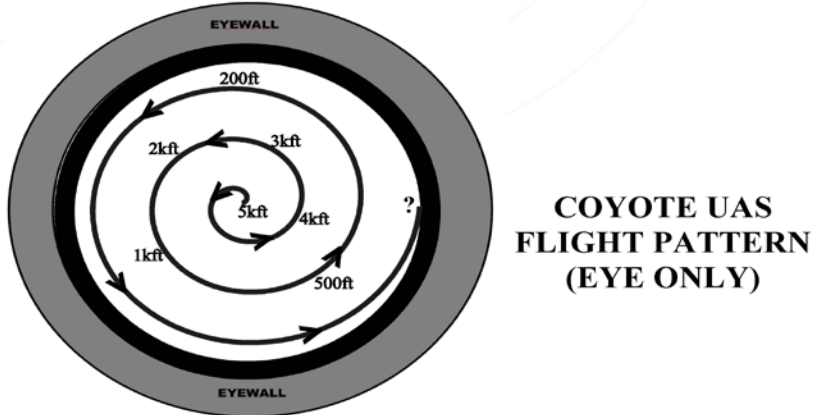
Fig. 29: Sample WP-3D flight track during the ferry to/from the storm and GPS dropsonde points for the P-3DWL SAL module.

P-3/Coyote SUAVE eye/eyewall module

Coyote UAS - P3 Mature Hurricane Eye/Eyewall Module



The P-3 approaches from the north at an altitude of 10,000ft, penetrates the eyewall into the eye, and performs a figure-4 (dotted line) in the eye. Midway during leg 3-4 the Coyote UAS is released. The P-3, remaining at 10,000ft, circumnavigates the eye in an octagon pattern and conducts another figure-4 rotated 45 degrees from the original (dashed line). Flight duration for this module should be close to 1 hour. An add-on ~45 minute duration module may also be conducted. This optional module would initiate where the preceding module ended (point 'FP'). The P-3 would proceed counterclockwise, repeating points 6-13 and completing the pattern once again at point 'FP'. 14 Dropsonde releases should be conducted during the primary 1h module at the following locations: IP;2-5;7;9;11;A-D and midway during legs IP-2 and 13-FP. In addition, 9 AXBT launches should be conducted at points 4 through 11 and midway during leg 11-12. (Note: except for AXBT drop at point 4, it is acceptable to launch all remaining 8 AXBT probes during the optional 45 minute second module.)

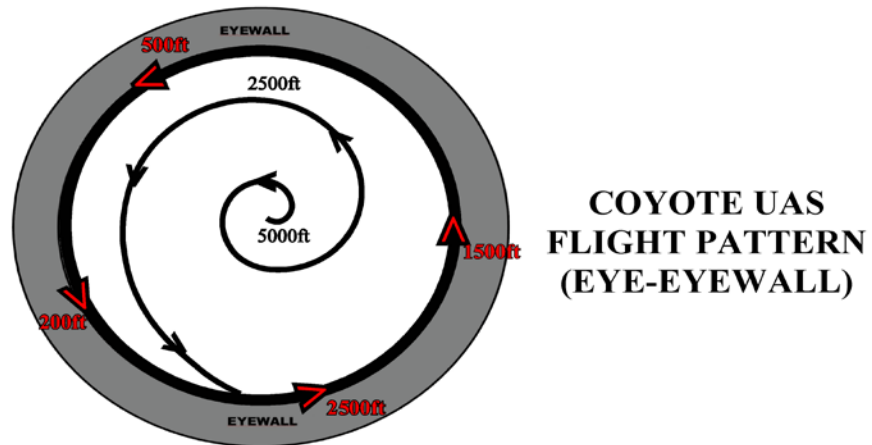


Midway during P-3 leg 3-4, the Coyote UAS is released at 10,000ft altitude. The Coyote UAS proceeds to glide (unpowered) in a downward counterclockwise spiral to an altitude of 5,000ft. At 5000ft, the UAS motor is started and the Coyote continues its counterclockwise descent in 1000ft increments. At each interval (4kft,3kft,2kft,1kft), the UAS maintains altitude for 3 minutes prior continuing its counterclockwise, radially expanding with decreasing altitude, spiral descent. After 3 minutes at 1000ft, the Coyote descends to 500ft and remains at this altitude for 3 minutes. The UAS continues to descend in 100ft increments down to 200ft, maintaining altitude for 3 minutes at each level. The remainder of the flight is conducted at 200ft until battery power is fully expended and the UAS reaches the ocean surface. (Note: If full descent to 200ft is achieved and the UAS has sufficient battery power to continue, an optional 'eyewall penetration' module may be considered if conditions present themselves. Prior to any attempted UAS eye-eyewall penetration, the Coyote should ascend from 200ft to a (minimum) altitude of 500ft.)

Figure 30. P3 (top) and Coyote (bottom) patterns for SUAVE eye/eyewall module

P-3/Coyote SUAVE eye/eyewall module (continued)

Coyote UAS - P3 Mature Hurricane Eye/Eyewall Module



Midway during P-3 leg 3-4, the Coyote UAS is released at 10,000ft altitude. The Coyote UAS proceeds to glide (unpowered) in a downward counter-clockwise spiral to an altitude of 5,000ft. At 5000ft, the UAS motor is started and the Coyote continues its counter-clockwise descent to 2500ft. The UAS maintains 2500 ft altitude and continues its outward counter-clockwise spiral until it reaches the hurricane eyewall. Once the Coyote penetrates and stabilizes within the hurricane eyewall, the UAS begins a step-decent pattern from 2500ft down to 500ft (while maintaining altitude for 3 minutes at each level). After reaching and maintaining 500ft for 5 minutes begin a steady decent down to 200ft within the eyewall. Maintain 200ft altitude within the hurricane eyewall until battery power is fully expended and the UAS reaches the ocean surface.

Figure 30. Coyote pattern for SUAVE eye/eyewall module

P-3 SUAVE “short-leg” figure-4

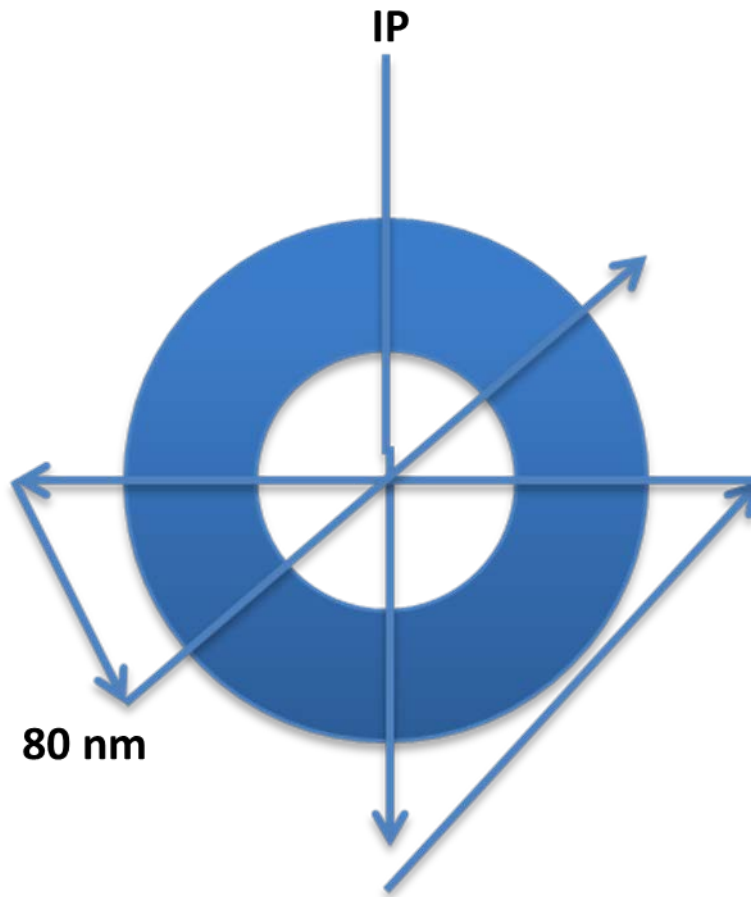


Figure 31. (P-3 ‘short leg’ figure 4 pattern)

P-3/Coyote SUAVE PBL entrainment flux module

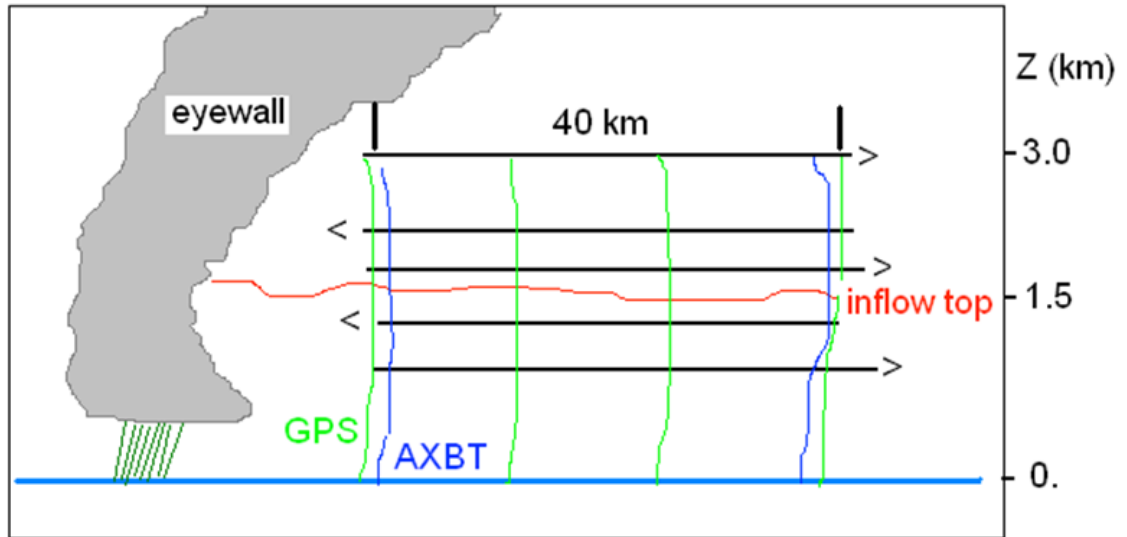


Figure 32. Vertical cross-section of the stepped-descent module. P3 pattern is in black, low altitude Coyote UAS in heavy blue. Alternatively, the P3 could stay at the highest altitude shown here (i.e., 3.0 km), while the Coyote performs the stepped descent.

P-3/Coyote SUAVE Boundary Layer inflow module

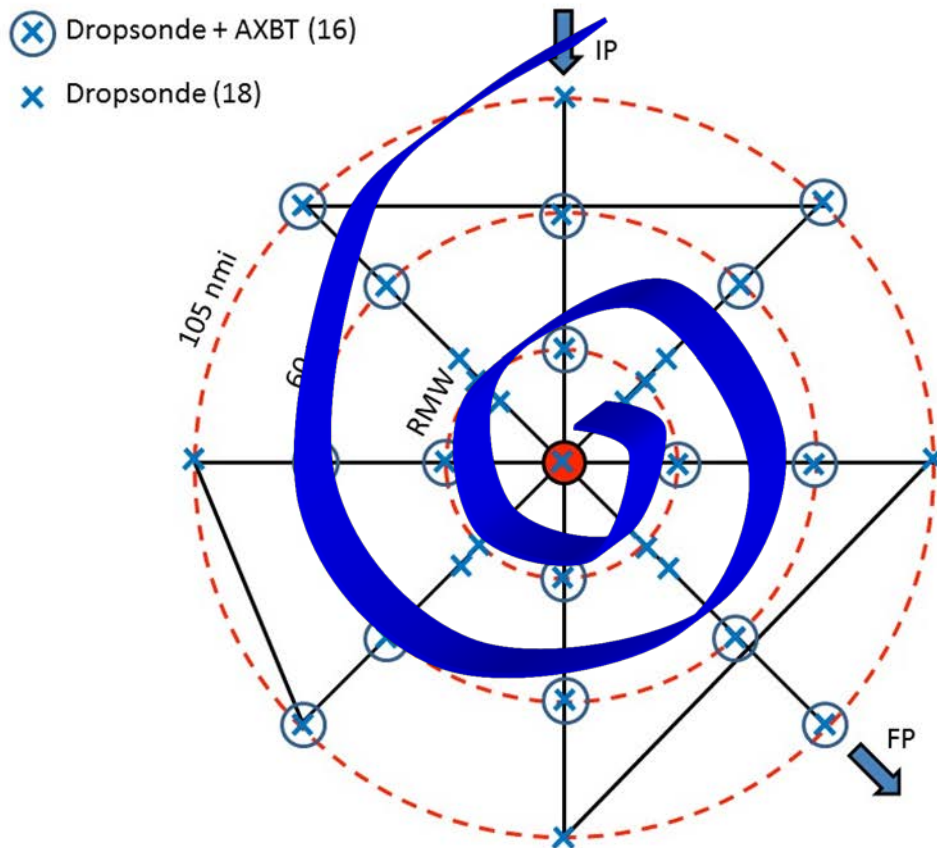


Figure 33 (from the HFP Boundary Layer Inflow Experiment): Boundary Layer Inflow Module. GPS dropwindsondes (34 total) are deployed at 105 nmi and 60 nmi radii and at the radius of maximum wind along each of 8 radial legs (rotated alpha/figure-4 pattern). On 4 of the 8 passes across the RMW, rapid deployment (~1 min spacing) of 3 sondes is requested. Center drops are requested on the initial and final pass through the eye. AXBT (16 total) deployments are paired with dropsondes at the indicated locations. Flight altitude is as required for the parent TDR mission, and initial and final points of the pattern are dictated by these same TDR mission requirements. Projected Coyote UAS spiral inflow pattern (in heavy blue) is overlaid.

Coyote SUAVE RMW mapping module

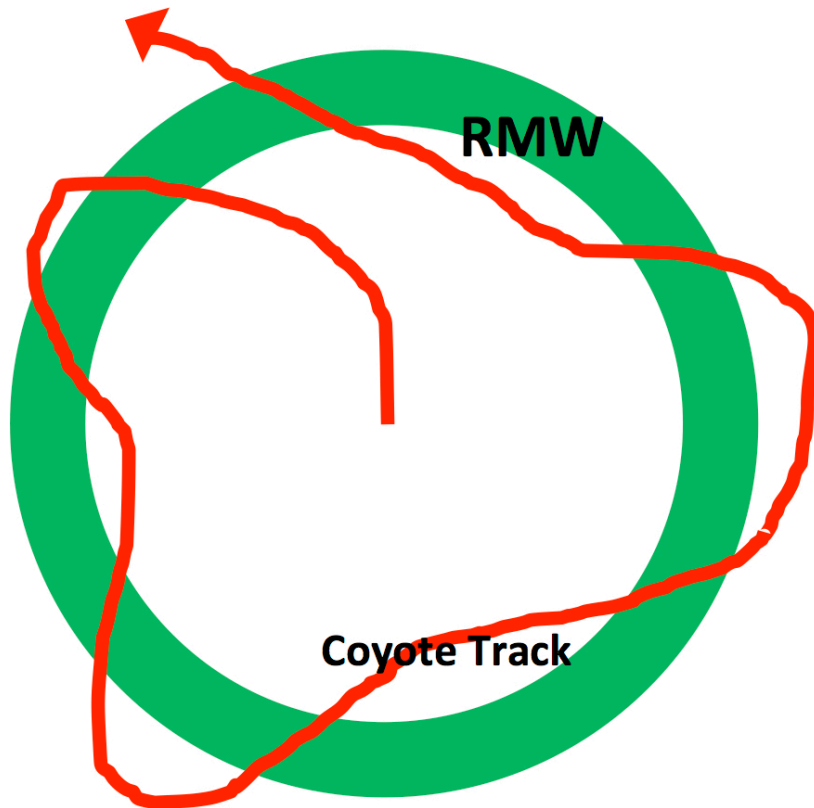


Figure 34: Radius of Maximum Wind (RMW) Mapping. For this module the NOAA P3 pattern is shown in Figure 4-2a. P3 would not be required to continuously loiter. However, P3-UAS range considerations would need to be taken into consideration. Optimally up to 10 GPS/IR sondes would be deployed along with 5 AXBTs. These data would be used to compare with similar ocean/atmospheric data collected by the Coyote UAS. Coyote UAS track is shown in red while the hurricane RMW is denoted by a green ring. Once the UAS is deployed from the P3 within the eye, the Coyote descends to the desired altitude of 300m. Once at this level, the UAS proceeds to the eyewall and begins a counter clockwise flight path. Once the RMW is reached, the UAS continues radially outward and downwind until the maximum wind attained by the platform decreases by ~10-20%. Once this is level is achieved, the Coyote heads inbound and downwind until it enters the storm eye. This sequence would continue for the duration of the mission.

Coyote SUAVE Eddy dissipation module

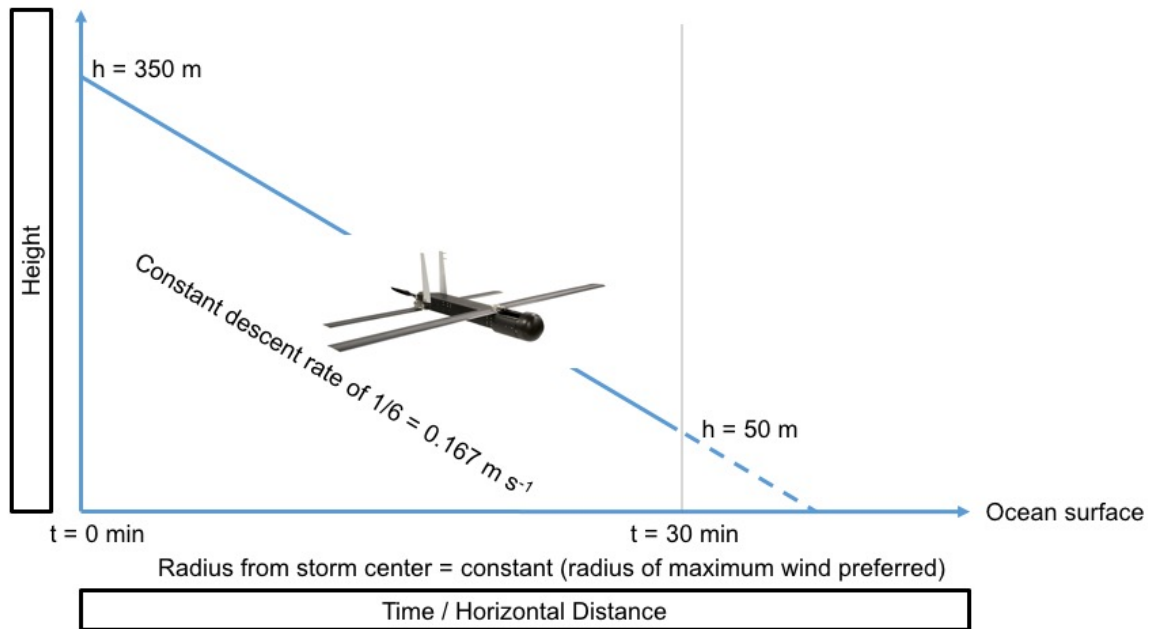


Figure 35: Eddy dissipation measurements. The Coyote begins the experiment at a height of 350 m, descends at a constant rate of $1/6 = 0.167 \text{ m s}^{-1}$, and reaches a height of 50 m after 30 minutes. The entire descent is conducted at a constant radius from the storm center (preferably at the radius of maximum wind).

P-3 SFMR-HI module

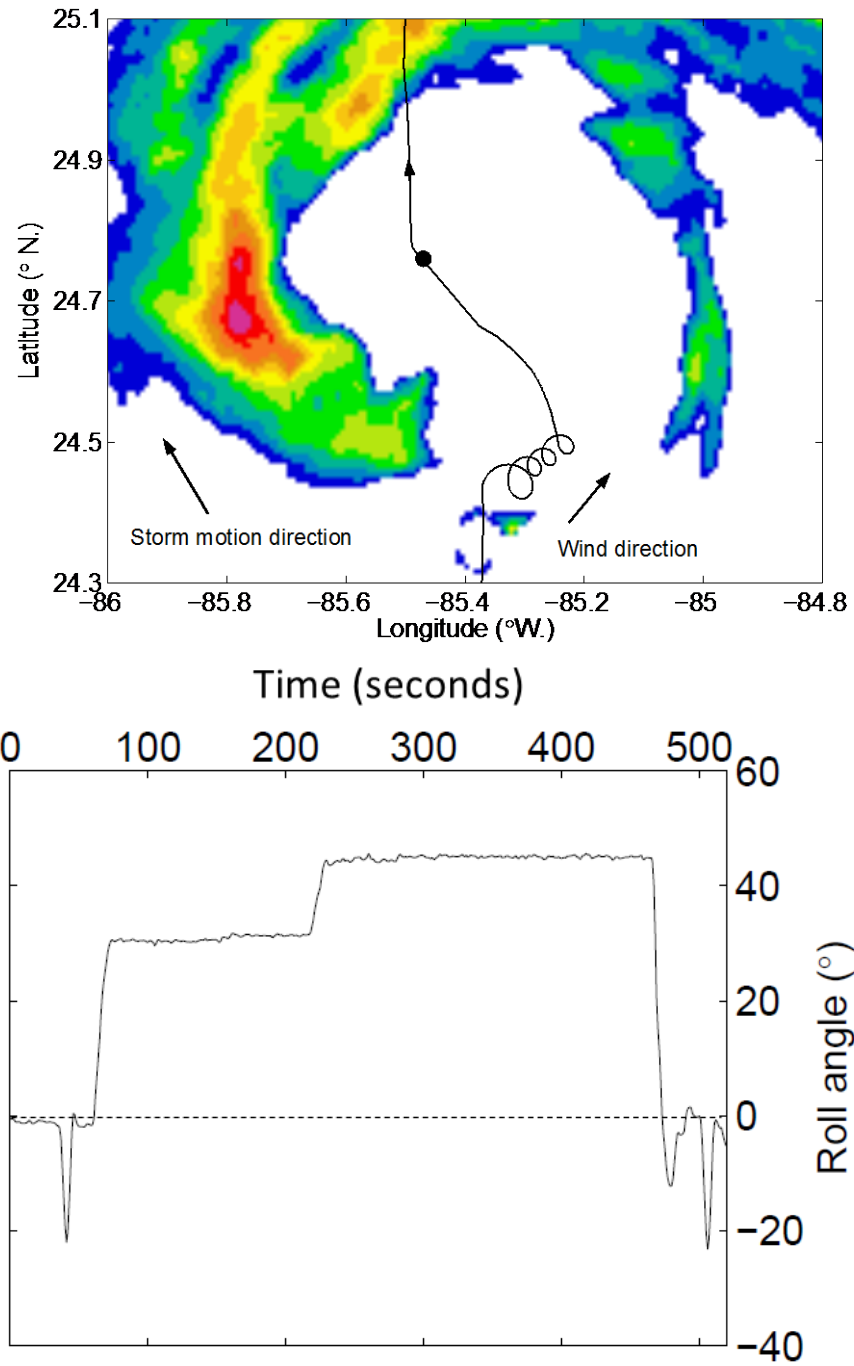


Figure 36: Flight pattern for module flown in Hurricane Gustav (2008) in a rain-free portion of the eyewall experiencing approximately 35 ms^{-1} surface winds (top panel). Time series of P-3 roll angle during period of turns in Gustav (bottom panel).

P-3 Offshore Wind Module

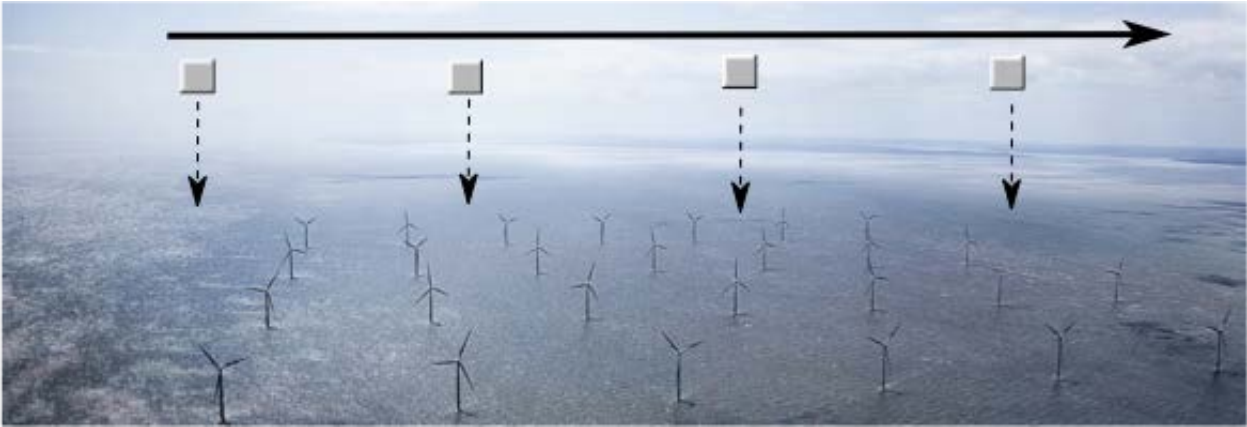


Figure 37: Schematic of piggyback pattern showing hypothetical wind farm fly-by with expendable launches at a 2-4 km interval. No U.S. wind farms are yet in operation. (Dong Energy Gunfleet Sands 1 farm off SE England)

P-3 Offshore Intense Convection Module

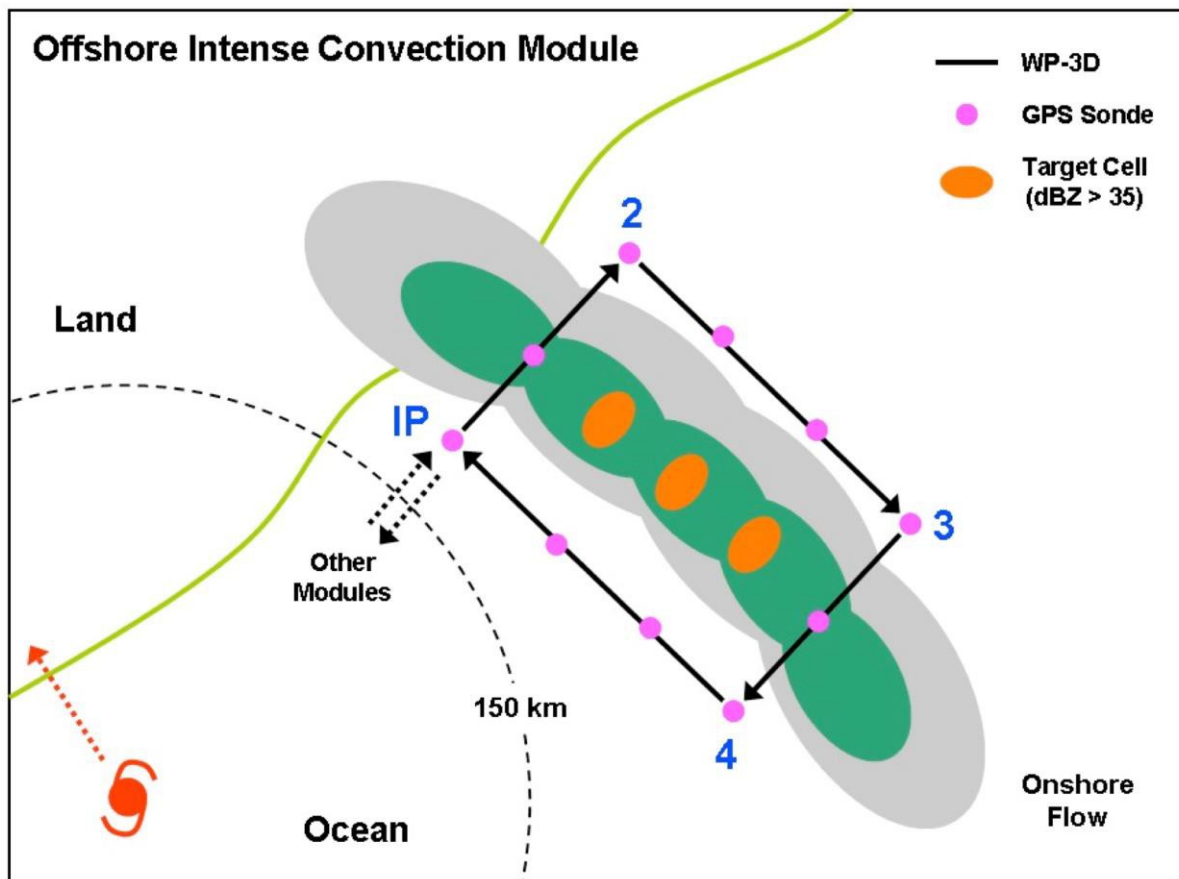


Fig. 38. Offshore Intense convection module.

Notes:

- The **IP** should be a minimum of 90 nm (150 km) from the storm center. The first leg (**IP-2**) starts 13 km (25 km) inside the rain band axis. Legs **IP-2** and **3-4** should be ~10-13 (20-25 km) downwind and upwind of the target cells to ensure adequate Doppler coverage. Legs **2-3** and **4-IP** should be 13 nm inside and outside the rain band axis. The length of legs **2-3** and **4-IP** can be adjusted but should be 40 nm (75 km) at a minimum.
- Deploy GPS dropwindsondes at the start or end points of each leg, at the band axis crossing points, and at ~10-13 nm intervals along each leg parallel to the band. The interval at which GPS dropwindsondes are deployed depends on how many are available, but **at least 2 GPS dropwindsondes should be deployed on either side of the convection and at least 1 dropwindsonde should be deployed each time the band-axis is crossed (for a minimum of 6 GPS dropwindsondes)**.
- Aircraft altitude should be at 10,000 ft. (3.0 km) or higher. Set airborne Doppler to scan in F/AST mode on all legs. Aircraft should avoid penetration of intense reflectivity regions (particularly over land).

P-3 Coastal Survey Module

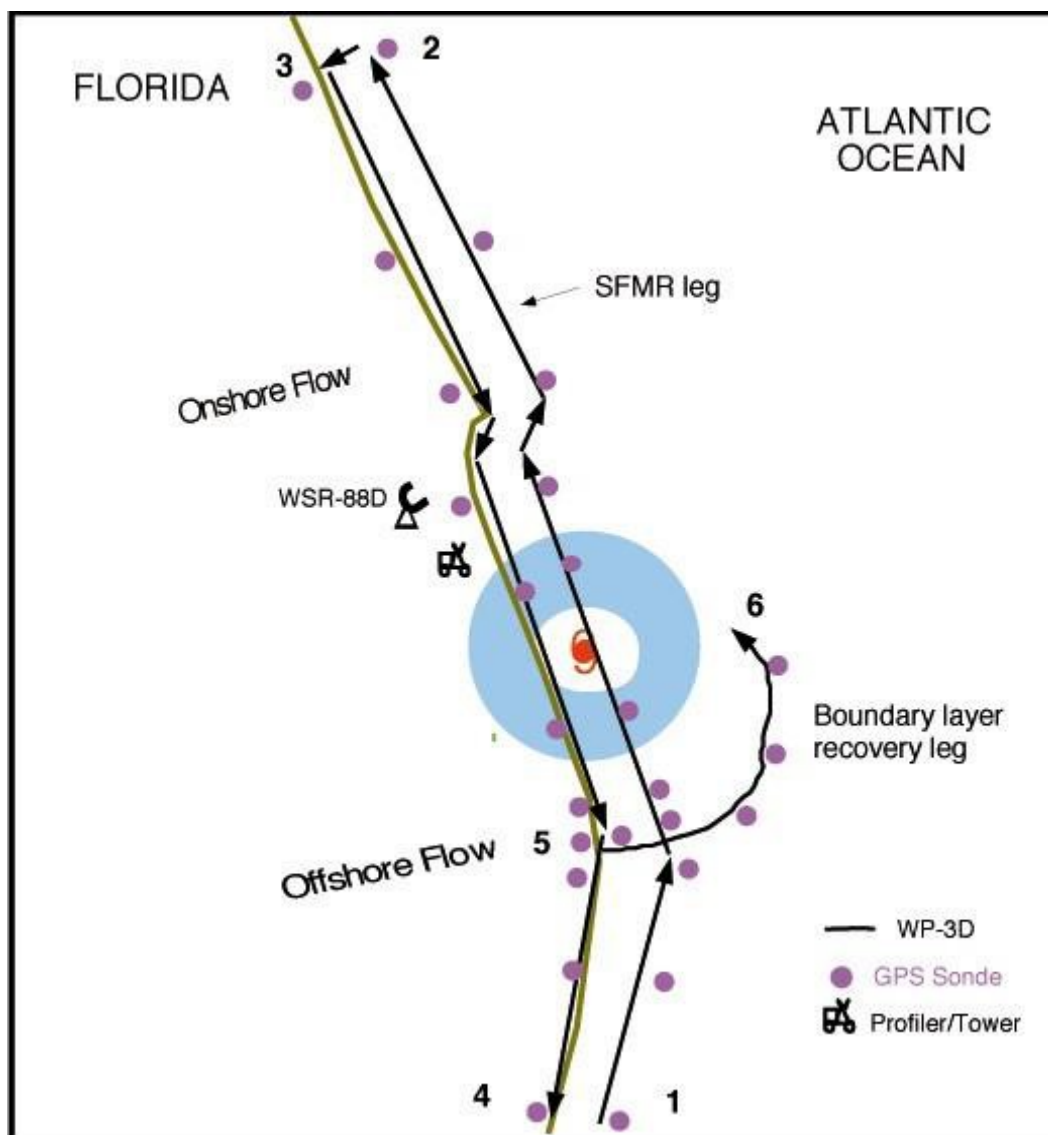


Fig. 39. Coastal Survey module.

Notes:

- First pass starts 80 nm (150 km) from center or at radius of gale-force wind speeds, whichever is closer. Pass from 1-2 should be 6-10 nm (10-15 km) offshore for optimum SFMR measurements. Release GPS dropwindsondes at RMW, and 7.5, 15, 30, 45, and 60 or 75 nm (12.5, 25, 50, 75, and 100 or 125 km) from RMW on either side of storm in legs 1-2 and 3-4. GPS dropwindsondes should be deployed quickly at start of leg 5-6, and then every 6-10 nm hereafter.
- Set airborne Doppler on all legs with single PRF > 2400 and 20% tilt. Aircraft should avoid penetration of intense reflectivity regions (particularly those over land)

P-3 Real-time Module

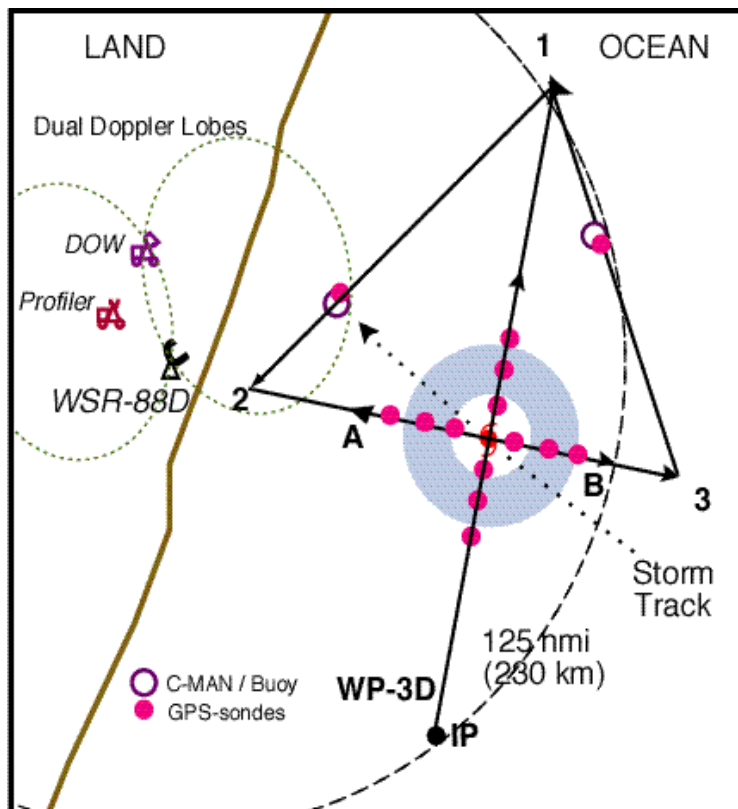


Fig. 40. Real-time module.

Notes:

- TAS calibration required. 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.
- P-3 should fly legs along the WSR-88D radials. Aircraft should avoid penetration of intense reflectivity regions (particularly those over land).
- Wind center penetrations are optional.

P-3 Convective burst Module

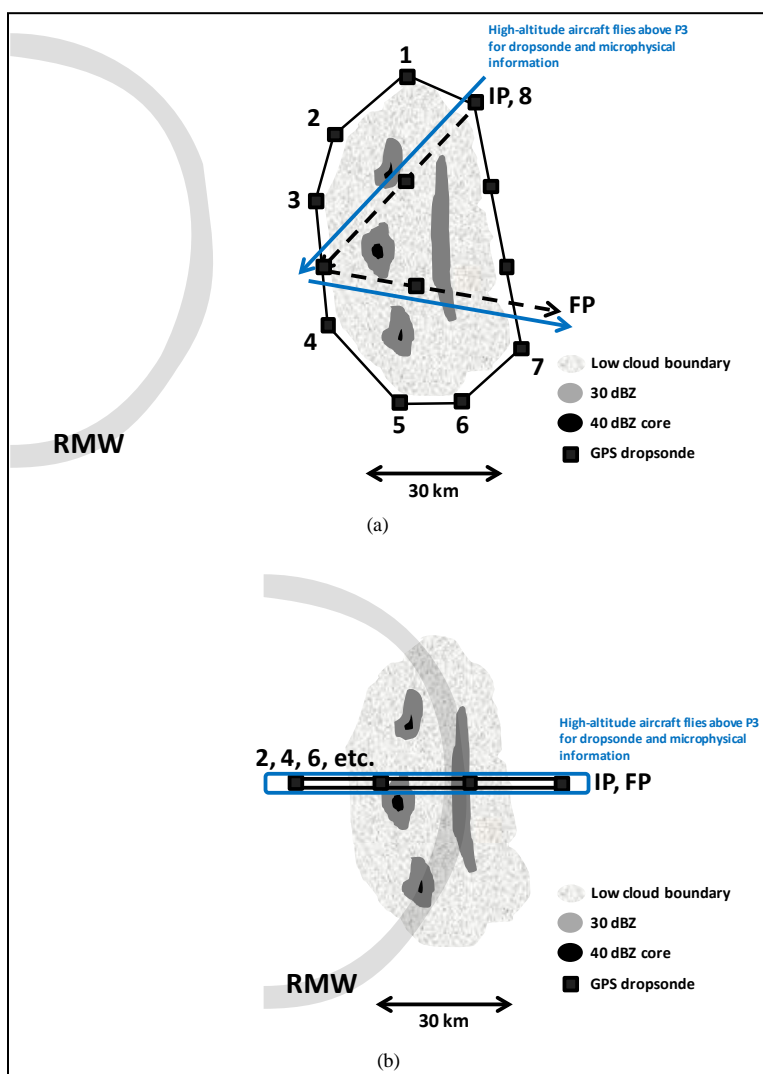


Figure 41: P-3 Convective burst module. (a) circumnavigation for when burst is well outside RMW or within a TC of tropical depression strength or less; (b) bowtie pattern for when burst is within or near RMW of tropical storm or hurricane.

- Altitude: 12,000 ft (4 km) altitude preferable.
- Expendables: Release dropsondes at turn points and at intermediate points as indicated in Figure. Additionally, release 1-2 drops during penetration of convective system. No more than 15 dropsondes needed for this module.
- Pattern: Circumnavigation (IP to point 6) by single P-3 when burst is outside RMW or in weak system. Then fly convective crossing (6-7-FP). Repeat circumnavigation (time permitting). If available, high-altitude aircraft (e.g., ER-2 or Global Hawk) flies either racetrack or bowtie pattern during P-3 circumnavigation, flies vertically aligned with P-3 during convective crossing. Repeated radial penetration (i.e. bowtie) when burst is inside or near RMW of tropical storm or hurricane.
- Instrumentation: Set airborne Doppler radar to scan F/AST on all legs.

P-3 Eye-eyewall Mixing Module

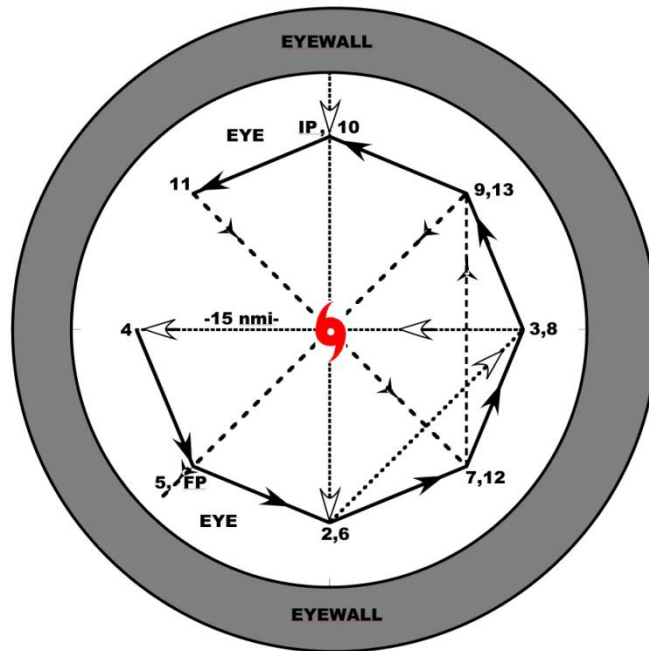


Figure 42. The P-3 approaches from the north, penetrates the eyewall into the eye, and descends below the inversion while performing a figure-4 (dotted line) in the eye. The P-3 circumnavigates the eye in an octagon or pentagon (solid line), and then ascends while conducting another figure-4 (time permitting) rotated 45 degrees from the original (dashed line).

P-3/G-IV SEF/ERC “pre-SEF” Module

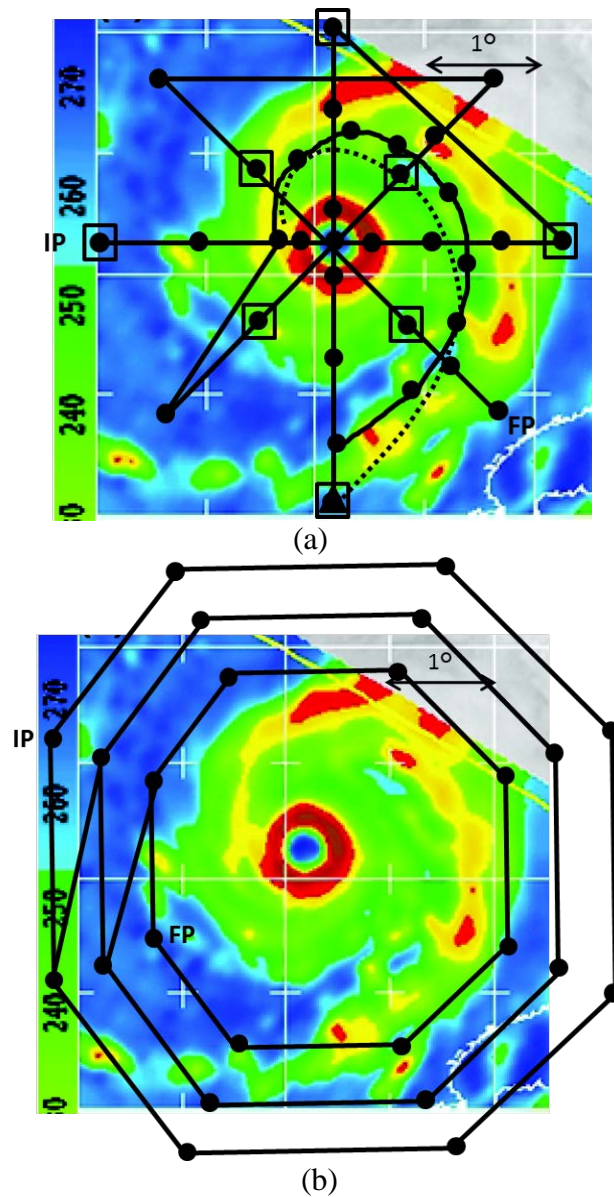
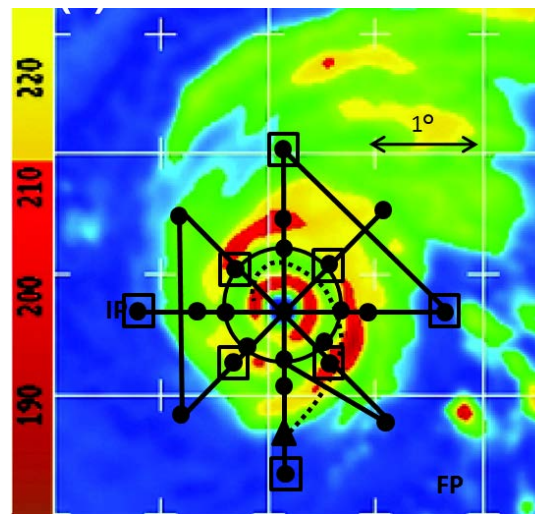
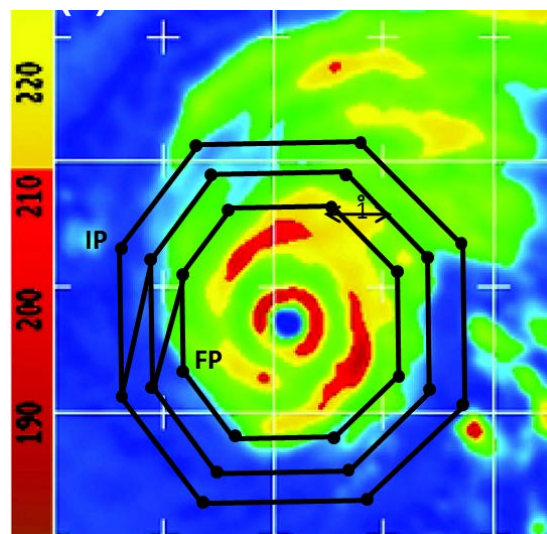


Figure 43: (a) P-3 Rotating figure-four pattern with Coyote deployed inflow path (dashed line; proposed launch point for Coyote Inflow Module indicated by triangle) overlain on a sample 85 GHz satellite image, showing pre-SEF, to depict features to target. Circles indicate dropsonde locations; open squares indicate AXBT deployment locations. Alternatively, the use of IR sondes would be preferred. This scenario may be combined with DWL Experiment. (b) G-IV circumnavigation pattern.

P-3/G-IV SEF/ERC “post-SEF” Module



(a)



(b)

Figure 44: (a) P-3 Rotating figure-four pattern with Coyote deployed inflow path (dashed line; proposed launch point for Coyote inflow module indicated by triangle) overlain on a sample 85 GHz satellite image, showing post-SEF, to depict features to target. Circles indicate dropsonde locations; open squares indicate AXBT deployment locations. Alternatively, the use of IR sondes would be preferred. This scenario may be combined with DWL module. (b) G-IV circumnavigation pattern

G-IV Warm Core (weak system) module

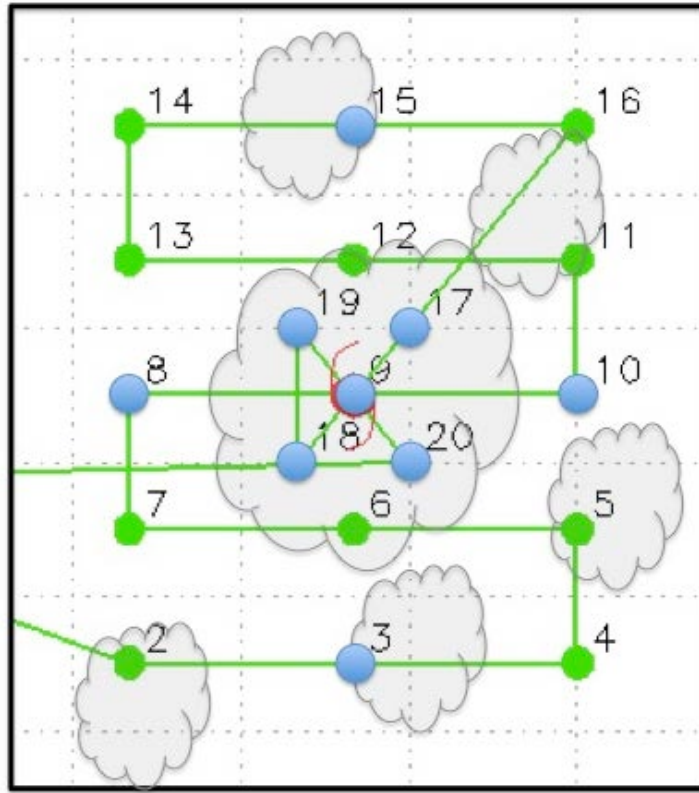


Figure 45. Sample G-IV 8x8 degree lawn mower pattern with areal coverage of ~900x900 km, leg spacing of 2 degrees, 2 center crossings made during figure 4 pattern at the end of the path, and a duration of ~8 hours. Blue dots are dropsonde deployment locations. The clouds represent the area of interest and the red symbol indicates the approximate location of the center of this region.

P-3 Hurricane Boundary Layer Stepped Descent module

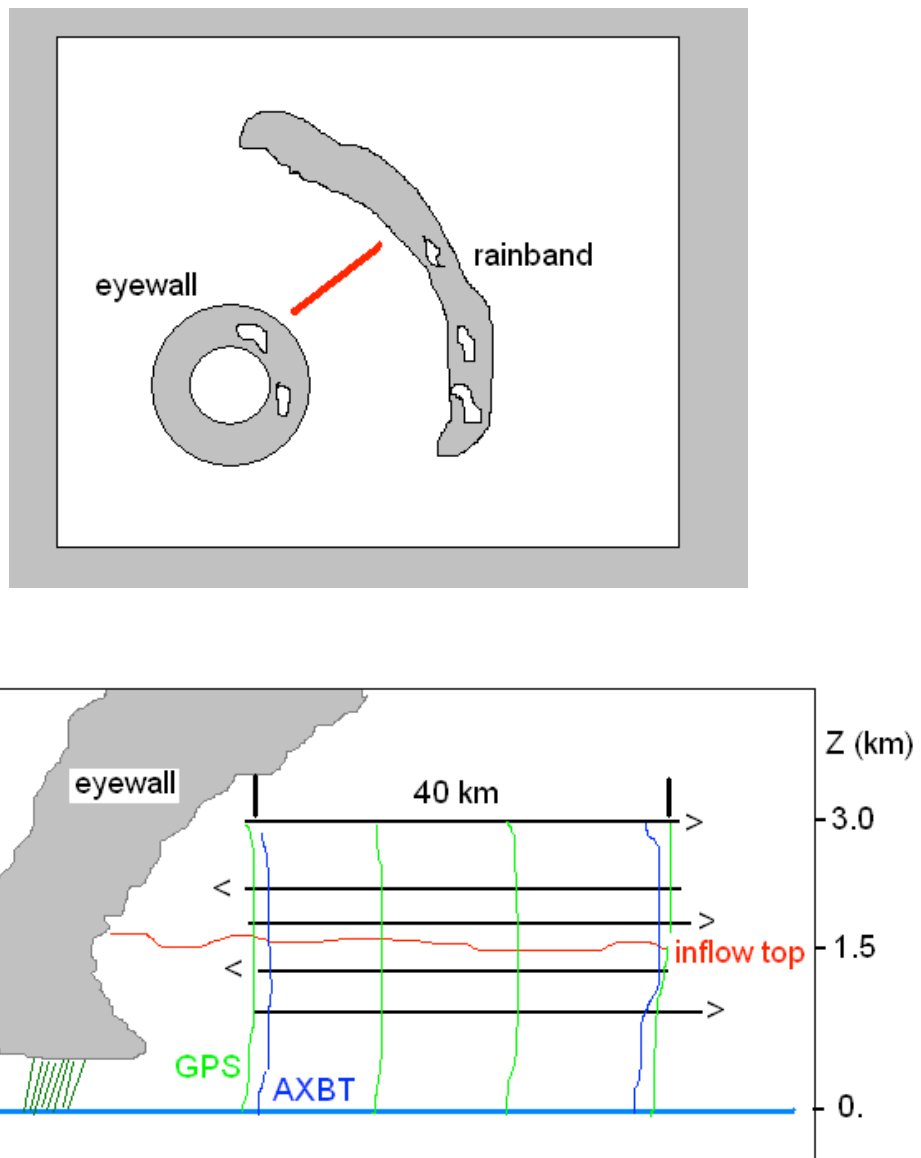


Figure 46: Plan view (top) of the preferred location for the stepped-descent module. Red line shows aircraft track. (bottom) Vertical cross section of the stepped-descent module.

P-3/G-IV Arc Cloud Module

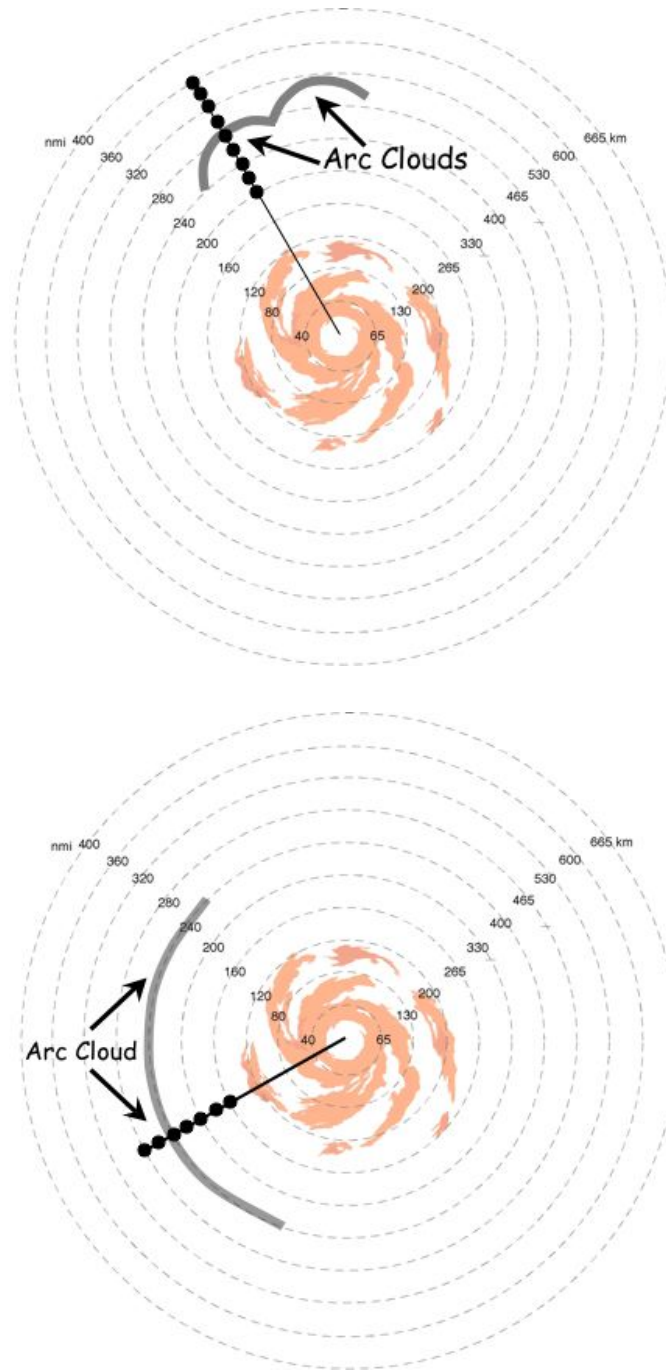


Figure 47: The G-IV (or WP-3D) flight track inbound or outbound to/from the TC/AEW. Azimuth and length of GPS dropsonde sequences during G-IV missions will be dictated by the pre-determined flight plan. For these cases, any G-IV flight legs that transect through the trailing and leading edges of the arc cloud are candidates for this module. When multiple arc clouds are present, the feature closest to the pre-determined flight track is desirable.

P-3 Arc Cloud Module (Multi-level option)

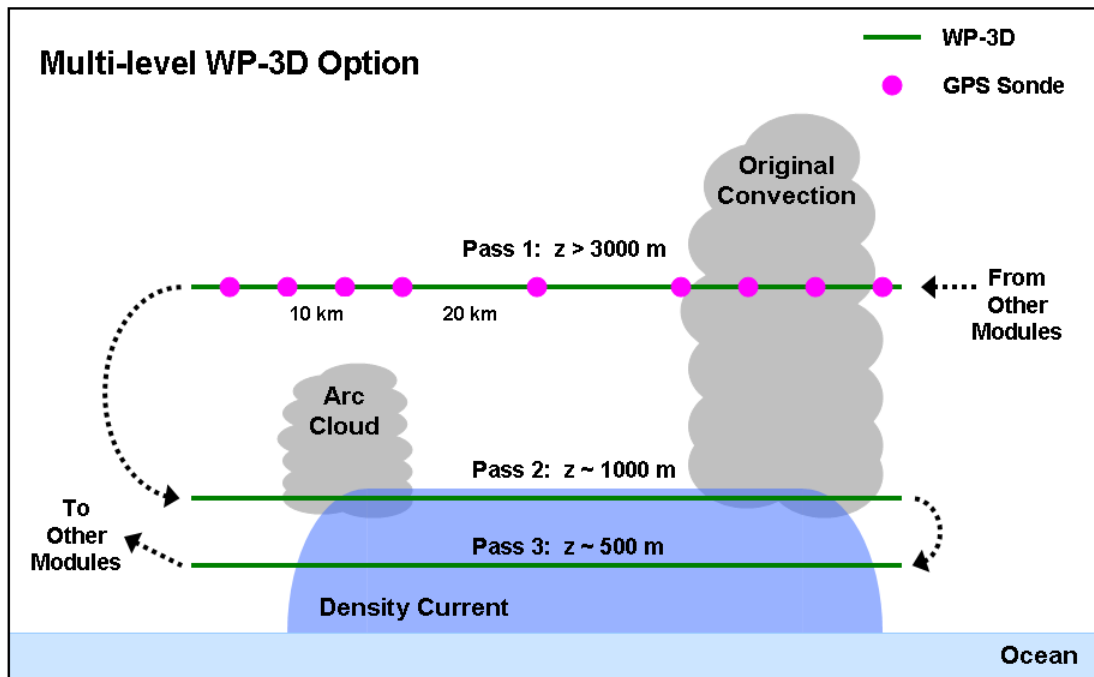


Figure 48: The WP-3D flight track for the multi-level option. Azimuth and length of initial midlevel pass with GPS dropsonde sequence will be dictated by the pre-determined flight plan. Lengths of the low-level passes should span much of the distance between the arc cloud and its initiating convection, while flight altitudes should be near the top and middle of any near-surface density currents (adjusting for safe aircraft operation as needed).

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
AOC	Aircraft Operations Center
AOML	Atlantic Oceanographic and Meteorological Laboratory
ASDL	aircraft-satellite data link
AXBT	airborne expendable bathythermograph
AXCP	airborne expendable current probe
AXCTD	airborne expendable conductivity, temperature, and depth probe
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
CP	coordination point
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
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
HL	Hurricanes at Landfall
HRD	Hurricane Research Division
INE	inertial navigation equipment
IP	initial point (or initial position)
IWRS	Improved Weather Reconnaissance System
JW	Johnson-Williams
Ku-SCAT	Ku-band scatterometer
LF	lower fuselage (radar)
LIP	Lightning Instrument Package
LPS	Lead Project Scientist
MCS	mesoscale convective systems
MLD	Mixed Layer Depth
MPO	Meteorology and Physical Oceanography

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
OML	oceanic mixed-layer
PDD	pseudo-dual Doppler
PMS	Particle Measuring Systems
POD	Plan of the Day
PPI	plan position indicator
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
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)
VTD	velocity-track display

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