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AN INTRODUCTION TO AIR FORCE WC-130 WEATHER RECONNAISSANCE

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Abstract

The U.S. Air Force operates Lockheed WC-130 "Hercules" weather reconnaissance aircraft on a wide variety of missions for many different military and civilian agencies. A brief description of the WC-130 aircraft, its crew complement, and some operating characteristics is presented to provide background material for subsequent sections. Air Force weather reconnaissance organization is briefly considered before proceeding to discussions of data acquisition, dissemination, and accuracy. The tropical cyclone reconnaissance mission is perhaps the best known weather reconnaissance mission and is discussed in general detail. Aspects of other specialized missions, such as the East Coast winter storms mission, are briefly considered along with some remarks concerning weather modification. Improvements to the current weather reconnaissance system are considered along with a brief discussion of the planned capabilities of the Improved Weather Reconnaissance System.

1. INTRODUCTION

Christopher Columbus lost six ships to a hurricane that struck their anchorage in Isabella Harbor. A hurricane averted possible warfare in 1889 in Samoa by sinking American and German warships during a confrontation of American, German, and British naval vessels. The British ship *Calliope* managed to steam out of harm's way. The almost legendary Admiral William Halsey lost three destroyers, 800 men, and over 140 aircraft in seas whipped by the 150 mph winds of a typhoon in the Philippine Sea on December 17, 1944. The damage to his fleet was so severe that fleet operations had to be suspended while repairs were made.

Those who survived the wrath of Camille, Carmen, Beulah, Nora, *et. al.*, and the nameless hurricanes and typhoons of the past know that the fury of these storms is visited upon the lands and the coasts as well as upon ships at sea and naval forces. For three and a half decades the men and women of the U.S. Air Force's weather reconnaissance units have helped mitigate the destructive impact of these storms by flying into them to locate their centers, track their progress, and measure their strength. The emphasis on this mission is reflected in the nicknames of the units, "Storm Trackers," "Hurricane Hunters," and "Typhoon Chasers," and the goal of the effort is reflected in the motto of the 41st Rescue and Weather Reconnaissance Wing, "Serving Mankind." The purpose of this paper is to provide a brief introduction to the small but very active world of Air Force aerial weather reconnaissance.

2. THE WEATHER RECONNAISSANCE PLATFORM

The central principle in operational Air Force weather reconnaissance consists of placing a manned meteorological sensor platform in the atmosphere at the time, place, and altitude requested by a "customer," collecting data according to the customer's requirements, and relaying those data to the customer in a usable, coded form. The primary Air Force weather reconnaissance sensor platform for over a decade has been the Lockheed WC-130 "Hercules" as modified for the weather reconnaissance role from transport and rescue versions of the C-130. WC-130E and WC-130H versions of the aircraft (and a single, specially-modified WC-130B) are operated by three weather reconnaissance squadrons.

The WC-130 is an all-metal, four-engine, high-wing monoplane with retractable tricycle landing gear. The aircraft was originally designed as an assault transport although the aircraft's versatility has permitted adapting the airframe to perform a variety of other missions, including aerial weather reconnaissance. The aircraft fuselage is divided into a cargo compartment and the flight station or flight deck by a bulkhead at the forward end of the cargo compartment. The aircraft is entered through a crew entrance door near the nose of the aircraft, a paratroop door on either side of the fuselage aft of the wing, or a cargo-loading ramp and door at the rear of the cargo compartment beneath the tail of the aircraft. Figure 1 is a photograph of a WC-130H and illustrates the general configuration of the aircraft.

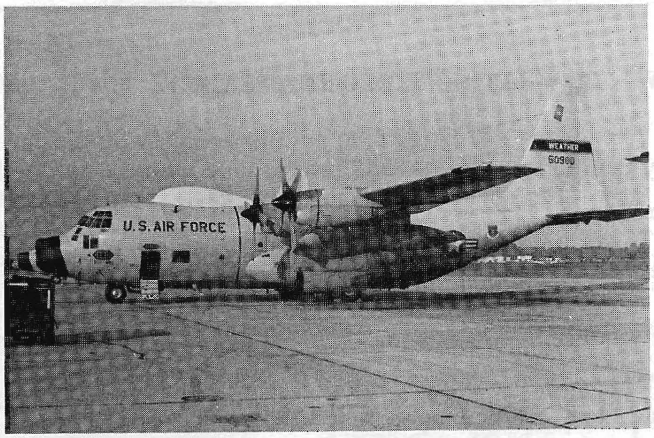


Figure 1. A WC-130H of the 920th WRG at Keesler AFB, Mississippi.

Air Force WC-130's carry meteorological sensor systems for measuring atmospheric parameters at the aircraft flight level and in soundings beneath the aircraft. The systems used to measure flight level parameters are generally referred to as the horizontal meteorological system (horizontal metsystem) and systems used to produce atmospheric soundings as the vertical meteorological system (vertical metsystem). Table 1 lists some of the components of the horizontal metsystem, the vertical metsystem, and other aircraft systems that are used to provide data for weather reconnaissance observations.

The WC-130 requires a basic crew of six: pilot (Aircraft Commander), copilot, flight engineer, navigator, Aerial Reconnaissance Weather Officer (ARWO), and Dropsonde System Operator (DSO). The ARWO and DSO provide the crew's meteorological expertise on operational missions as well as performing other aircrew duties. The ARWO is primarily concerned with coordinating the crew's effort to satisfy the customer's mission requirements as well as with using the horizontal metsystem to provide "horizontal observations." All the instruments used in producing horizontal observations are in the aircraft cockpit at or near the ARWO's instrument panel. The DSO performs a wide variety of duties in addition to his primary job of operating the vertical metsystem to produce atmospheric soundings ("vertical observations"). Vertical metsystem components are installed at or near the DSO's console in the aft cargo compartment near the right paratroop door.

Performance characteristics of the WC-130 generally limit operational missions to altitudes up to and including the 300-mb level and typical mission durations of 11 to 13 hours depending on crew duty day, fuel load, altitudes required, and many other factors. Airspeeds flown at the typical operating altitudes (which are selected to correspond to standard pressure levels) vary considerably. Operating airspeeds at 850 mb, for example, range from around 200 to 240 knots TAS (True Air Speed) while at 300 mb a typical range is from 270 to 310 knots TAS. The range of airspeeds for each altitude is selected to reduce the effect of airspeed variations on instrument calibrations and still provide reasonable cruise airspeeds. Range and fuel economy considerations have considerable weight in the airspeed selection process.

Range and endurance are two of the primary factors in planning weather reconnaissance missions. Thirteen hour missions may cover in excess of 3500 miles. Maximum "time on station" in area type reconnaissance operations such as tropical cyclone missions depends heavily on flying time to and from the area and the oprating flight levels required in the area of interest. On some tropical cyclone missions the center of the cyclone is so far from the forward operating location (FOL) that time on station is severly limited and may only permit one "fix" before returning to the FOL or an alternate base. The number of factors which must be considered in range and endurance estimations is quite large and complete consideration of all such factors is well beyond the scope of this paper.

3. AIR FORCE WEATHER RECONNAISSANCE ORGANIZATION

Any consideration of weather reconnaissance organization must be prefaced by remarks concerning the rapid changes in organizational structure that occur in weather reconnaissance forces. Since 1973 at least five major changes have occurred in weather reconnaissance organizational structure ranging from the deactivation of a squadron of WB-57's to the establishment of an Air Force Reserve weather reconnaissance organization. Since organizational change is a way of life in weather reconnaissance forces, any guide to weather reconnaissance organization can be expected to become rapidly outdated.

Operational weather reconnaissance is performed by Military Airlift Command (MAC) and U.S. Air Force Reserve (AFRES) units. Active duty weather reconnaissance units are assigned to the Aerospace Rescue and Recovery Service (ARRS) and to the Air Weather Service (AWS). AFRES weather reconnaissance units are assigned to the Fourth Air Force (AFRES) in time of peace and to MAC in time of war. Figure 2 illustrates weather reconnaissance organization under MAC and AFRES.

ARRS exercises control of active duty weather reconnaissance squadrons through the 41st Rescue and Weather Reconnaissance Wing (41st RWRW) at McClellan AFB, California. The 41st RWRW has two primary missions: combat rescue and aerial weather reconnaissance. The weather

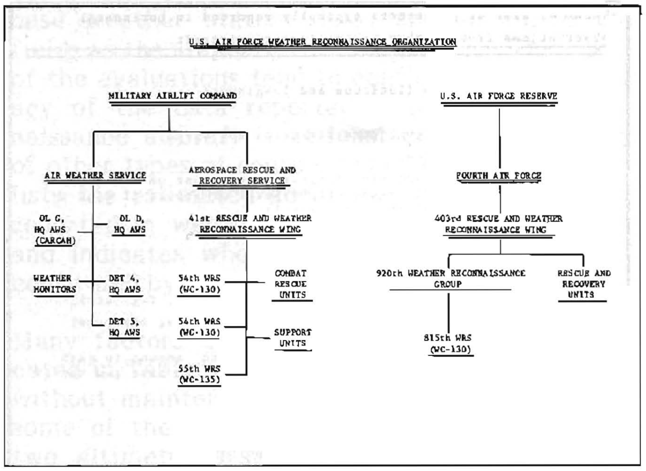


Figure 2. Operational U.S. Air Force weather reconnaissance organization under the Military Airlift Command and U.S. Air Force Reserve.

reconnaissance capability in the 41st RWRW is embodied in three squadrons: the 54th Weather Reconnaissance Squadron (54th WRS), Andersen AFB, Guam; the 53rd Weather Reconnaissance Squadron (53rd WRS), Keesler AFB, Mississippi; and the 55th Weather Reconnaissance Squadron (55th WRS), McClellan AFB, California. The 54th WRS and the 53rd WRS operate WC-130's on a variety of weather reconnaissance and atmospheric sampling missions. The 55th WRS operates Boeing WC-135B aircraft primarily on atmospheric sampling missions.

Perhaps the most significant recent change in weather reconnaissance organization occurred when the Air Force Reserve converted a tactical airlift group to weather reconnaissance duty in 1976. The AFRES weather reconnaissance organization differs from the ARRS organization due to the much heavier training activity associated with AFRES units and the need to maintain units to perform functions normally provided by host air base organizations or by higher headquarters. AFRES weather reconnaissance organization under the Fourth Air Force (AFRES) begins with the 403rd Rescue and Weather Reconnaissance Wing (403rd RWRW), Selfridge ANG Base, Michigan.

The 403rd RWRW is composed of one weather reconnaissance group and four rescue and recovery squadrons. The central impetus in the AFRES weather reconnaissance effort is provided by the 403rd RWRW's weather reconnaissance group, the 920th Weather Reconnaissance Group (920th WRG) which is stationed at Keesler AFB, Mississippi. The 920th WRG provides command and staff support to several subordinate organizations at Keesler AFB and to the 815th Weather Reconnaissance Squadron (815th WRS). The 815th WRS is the flying organization within the 920th WRG, is also located at Keesler AFB, and operates WC-130H aircraft on a variety of operational weather

TABLE 1. Components of the WC-130 horizontal metsystem, other aircraft systems used for producing meteorological data, and the vertical metsystem.

a. Horizontal metsystem and other aircraft systems. (See note 1).

Component:	Parameter sensed:	WC-130E:	WC-130H:
1301A Pressure Transducer System. (See note 2).	Atmospheric pressure.	Yes.	Yes.
AIMS Counterdrum-pointer Aneroid Altimeter (pilot's instrument panel). (See note 3).	Pressure altitude.	Yes.	Yes.
Rosemount AN/AMQ-28 Total Temperature System. (See note 4).	Atmospheric temperature.	Yes.	Yes.
C-3 Outside Air Temperature System (navigator's panel). (See note 4).	Atmospheric temperature.	Yes.	Yes.
Cambridge System's AN/AMQ-34 Aircraft Hygrometer System.	Atmospheric dewpoint.	Yes.	Yes.
AN/APN-42A Radar Altimeter. (See note 5).	Absolute altitude.	Yes.	Yes.
SCR-718 or AN/APN-133 Radio Altimeter. (See note 5).	Absolute altitude.	Yes.	No. (See note 5).
AN/APN-150 Radar Altimeter (pilot's instrument panel). (See note 5).	Absolute altitude.	Yes.	Yes. (See note 5).
Barnes Engineering Company PRT-5 Precision Radiation Thermometer.	Sea surface temperature.	Yes.	Yes.
Doppler navigation system (AN/APN-147/AN/ASN-35 at the navigator's position).	Flight-level wind.	Yes.	Yes.
Hewlett-Packard HP-97 Programmable Calculator.	—	Yes.	Yes.
Data Recording System.	—	Yes.	No.
AN/APN-59 Aircraft Radar.	—	Yes.	Yes.

b. Vertical metsystem.

Subsystem:	Subsystem Components:	Remarks:
AN/AMT-13 Radio Dropsonde.	—	A cylindrical radiosonde 18 in long, 3.5 in in diameter, and weighing 4.7 lb. A small parachute deploys the transmitter antenna and slows the fall rate to approximately 4600 feet-per-minute.
AN/AMQ-29 Dropsonde Data Recording System.	MX-9133/AMQ-31 Radiosonde Dispenser.	Used to arm the dropsonde and eject it from the aircraft.
	Unitron Frequency Converter.	Converts normal aircraft 400Hz electrical power to 60Hz power required by some systems.
	R1196/AMQ-19 Radiosonde Receiver.	—
	C-8804/AMQ-25A Power Vertical Subsystem Control Panel	Controls on this panel permit energizing equipment, selecting the operating mode, and tuning the receiver in the manual mode
	Manual Pressurization/ Depressurization Control Panel.	—
	Hewlett-Packard Components: 5332A Preset Controller/ Counter. 5216A Electronic Counter. 562ARC10 Digital Recorder. 7128A Strip Chart Recorder. 3310A Function Generator. 9100B Programmable Calculator. (See note 6).	

Notes:

1. All components of the horizontal metsystem are located at the flight deck ARWO position unless otherwise indicated.
2. In the process of being replaced by the Garrett Airesearch Digital Pressure Encoder.
3. Provides secondary pressure altitude data for height of surface computations.
4. Requires true air speed information for normal use. The C-3 system is rarely used as a backup meteorological system.
5. Absolute altitude data is used along with pressure height data from the 1301A or AIMS in computing heights of standard pressure surfaces and sea-level pressures. The AN/APN-133 is programmed for installation on the WC-130H by 1979 and will provide a backup absolute altitude capability like that currently available on the WC-130E. The AN/APN-150 will continue to provide a low altitude backup capability on the WC-130H only until AN/APN-133 installation is complete.
6. The Hewlett-Packard HP-9100B calculator is being replaced by the newer HP-97.

reconnaissance missions including tropical cyclone reconnaissance for the National Hurricane Center.

Another recent change in weather reconnaissance organization occurred in April, 1977 when ARWO's and DSO's were removed from the ARRS squadrons and placed in Air Weather Service detachments at Keesler and Andersen AFB's. These new detachments are subordinate to AWS Headquarters and provide weather personnel for operational missions and staff meteorological support to the weather reconnaissance squadrons. An Operating Location (OL) has been established at McClellan AFB to support the 41st RWRW. AWS continues to provide weather monitor functions at selected locations as indicated in the next section.

4. DATA ACQUISITION, DISSEMINATION, AND ACCURACY

Meteorological data acquired on weather reconnaissance missions typically is of two basic types: "horizontal data" consisting of measured data from the horizontal metsystem and parameters subjectively estimated by the ARWO and "vertical data" from the vertical metsystem operated by the DSO. Horizontal data take many forms and have a varying content depending upon the requirements of the individual customer. Parameters typically reported in horizontal observations are listed in Table 2. Vertical data are acquired using the vertical metsystem and an expendable radiosonde referred to as a "dropsonde." The AN/AMT-13 radio dropsonde is released from the aircraft and transmits pressure, temperature, relative humidity, and reference signals by radio to the aircraft as the dropsonde falls. The data transmitted to the aircraft are reduced and encoded in a special TEMP SHIP format by the DSO. Completed soundings contain pressure, temperature, and dew-point depression data from the aircraft flight level to termination of the signal.

The ARWO on each crew is responsible for the accurate and timely acquisition and dissemination of all meteorological data, including vertical observations. Acquired data are encoded, checked for accuracy, and transmitted from the aircraft over high-frequency (HF) radio phone patches to weather monitors who copy the observations, check them again for accuracy and consistency, and enter the observations into the dedicated weather communications system. Phone patch radio traffic is handled through a network of high frequency radio stations, the USAF Aeronautical Stations, in selected locations around the world. Table 3 lists weather monitors and the HF Aeronautical Stations which normally handle weather reconnaissance phone patches to them.

The nature of the data dissemination process occasionally permits considerable delay in the transmission of encoded data from the reconnaissance aircraft to the mission customer. HF Aeronautical Stations provide a number of services to military aircraft, and delays frequently occur in establishing phone patches between the reconnaissance aircraft and the mission customer while other radio traffic is handled. Additional delays are encountered while the monitor checks the observations and enters the data in the dedicated weather communications system. Every effort is made to minimize the inherent delays in the current dissemination system and still maintain effective quality control of the data. However, delays of from 10 to 15 minutes up to half an hour are not uncommon in getting observations from the aircraft into the dedicated weather communications system.

TABLE 2. List of parameters typically reported in horizontal observations from weather reconnaissance aircraft.

- Position (latitude and longitude).
- Time.
- Flight level wind direction and speed.
- Turbulence.
- Flight condition (approximate amount of cloud above and/or below flight level or amount of time in cloud at flight level).
- Absolute altitude.
- Flight level temperature.
- Flight level dewpoint.
- Present weather (precipitation, haze, fog, etc).
- Height of standard pressure surface or sea level pressure.
- Clouds including number of layers, amount in each layer, type, and altitudes of the base and top of each layer.
- Surface wind direction and speed.
- Icing.
- Significant weather observed off course.
- Significant weather changes observed along track.
- Radar data.
- Visibility at flight level.
- Sea surface temperature.

TABLE 3. Air Weather Service weather monitors responsible for collecting weather reconnaissance data, their locations, and USAF Aeronautical Stations typically used in contacting each weather monitor.

Weather Monitor	Monitor Location	USAF Aeronautical Station
Miami Monitor	OL G, HQ AWS Coral Gables, Florida	MacDill Airways
Swan Monitor	Det 2, 1WW Andersen AFB, Guam	Andersen Airways
Lajes Monitor	Det 19, 15WS Lajes Field, Azores Islands	Lajes Airways
Mather Monitor	Det 7, 24WS Mather AFB, California	McClellan Airways
Elmendorf Monitor	Det 1, 11WS Elmendorf AFB, Alaska	Elmendorf Ai ways
Letterman	Base Weather Branch Hickam AFB, Hawaii	Hickam Airways
Yokota Metro	Yokota AB, Japan	Yokota Airways
Clark Monitor	Base Weather Branch Clark AB, Philippines	Clark Airways
Kindsbach Monitor	Det 21, 2WW Kindsbach, Germany	Croughton Airways
Incirlik Monitor	TUSLOG Det 2 Incirlik, Turkey	Incirlik Airways

Objective appraisals of the accuracy of meteorological data are very difficult to make. Weather reconnaissance operations are routinely conducted into so-called "data sparse areas" where most weather data consist of ship reports, satellite imagery, and, possibly, the reports of one or more island weather stations. Comparison of measured and computed atmospheric data from WC-130's with conventional upper-air data obtained by radiosonde is difficult and usually inconclusive due to the impossibility of matching the aircraft flight profile with that of the radiosonde, the different methods used in computing heights of standard pressure surfaces, the use of different sensors with different sensor accuracies, and the economic constraints which prevent performing enough comparisons to produce a statistically significant result.

Many efforts have been made within the weather reconnaissance organizations to evaluate the accuracy of the parameters reported in horizontal and vertical observations. Most of the evaluations have used radiosonde data as the standard against which reconnaissance data has been compared. Other evaluations have used ground camera networks, a laser altimeter (rangefinder), base weather station data, and smoothed data fields as the standard for comparison. The results of the evaluations tend to confirm that the accuracy of the data reported from weather reconnaissance aircraft is at least comparable to that of other types of routine upper-air data. Table 4 lists the estimated accuracies of the parameters reported in weather reconnaissance observations and indicates where these accuracies have been confirmed by operational tests.

Many factors can influence the accuracies indicated in Table 4. Protracted periods of operation without maintenance may reduce the accuracy of some of the measured parameters. The use of two altimeter systems in computing heights of standard pressure surfaces and sea-level pressures compounds the errors inherent in the sensors themselves. In addition, special calibration procedures are used to reduce the differences between aircraft height of standard pressure surface and sea level pressure data and comparable radiosonde and surface station data. Occasionally, errors in aircraft data result from the "historical corrections" produced by the calibration process due to sensor drifts with time and other influences. Human errors in computations and encoding also influence the accuracy of reported parameters. Extensive quality control and altimetry (calibration) programs in the weather reconnaissance units help to minimize the overall impact of these factors to the extent that the accuracies in Table 4 may be used with reasonable confidence in most cases.

TABLE 4. Estimated accuracies of the parameters reported in routine weather reconnaissance horizontal observations.

Parameter	Accuracy
Temperature (flight level)	±1°C.
Dewpoint (flight level)	±1°C above 0°C (See Note 1) ±1.5°C at or below 0°C.
Sea surface temperature	±0.5°C.
Sea level pressure	±1 mb.
Absolute altitude	±10 m (See Note 1).
Height of standard pressure surface	±3 m at or below 700 mb ±10 m above 700 mb (See Note 2).

Note 1. Confirmed by operational tests.

Note 2. Estimating height of standard pressure surface accuracy is very difficult since the computational procedure is somewhat involved and for other reasons. Operational experience indicates that these estimates are reasonable in most cases.

5. TROPICAL CYCLONE RECONNAISSANCE

One of the Air Force's largest, continuing, humanitarian missions involves locating and tracking tropical cyclones in support of hurricane and typhoon warning centers. The Air Force provides by far the major portion of the reconnaissance effort in the Atlantic, Caribbean, Gulf of Mexico, and Eastern Pacific areas and all of the routine tropical cyclone reconnaissance effort in the Central and Western Pacific areas. Tropical cyclone missions are flown for the National Hurricane Center (NHC), Coral Gables, Florida; for the Eastern Pacific Hurricane Center (EPHC), Redwood City, California; for the Central Pacific Hurricane Center (CPHC), Honolulu, Hawaii; and for the Joint Typhoon Warning Center (JTWC), Nimitz Hill, Guam. These agencies collect data from weather reconnaissance missions and many other sources for use in forecasting the intensity and movement of tropical cyclones.

The primary objective of tropical cyclone reconnaissance is the location of the tropical cyclone center, the measurement of meteorological parameters in the center, and the reporting of the center location and meteorological data to the appropriate forecast agency. Locating the cyclone center is normally accomplished by flying the aircraft into the center using the AN/APN-59 3-cm radar, visual scanning of surface winds, doppler flight-level winds, and data from the horizontal metsystem. Flying to the center of the tropical cyclone is referred to as a "penetration" and locating the center by penetration as a "vortex fix." The types of data reported for vortex fixes are listed in Table 5. Under some conditions penetration is not possible and a "radar fix" of the tropical cyclone is attempted.

TABLE 5. Data typically reported on vortex fixes of tropical cyclones.

- Time of the vortex fix.
- Position (latitude and longitude) of the vortex fix.
- Minimum height of surface at standard level.
- Estimate of maximum observed surface wind and the bearing and range of that wind from the center.
- Maximum flight level wind near the center and its bearing and range.
- Minimum sea level pressure.
- Maximum flight level temperatures inside and outside the eye.
- The "character" of the eye, its shape, orientation, and diameter.
- Confirmation of the fix time and coordinates, information on how the fix was made, and the pressure level (850 mb, 700 mb, etc) at which the fix was made.
- Navigational and meteorological fix accuracy (position) estimates.
- Amplifying remarks.

Several factors must be considered in determining the location of the tropical cyclone center. The structure of tropical cyclones can vary considerably in detail from cyclone to cyclone and from one tme to the next in individual cyclones. "Centers" based on individual parameters such as temperature, pressure, the geometric wind fields, and visual and radar presentations may not coincide at exactly the same geographic location. The "tilt" of the cyclone may mean that the surface and upper-level centers are displaced horizontally by as much as tens of miles, compounding the location problem. The centers of tropical cyclones are frequently called "vortices" and the priority of vortex location from highest to lowest is generally: pressure vortex, wind vortex, cloud vortex, and radar eye.

The low-level vortex of a tropical cyclone is normally located visually from the appearance of the ocean surface and from surface winds or by finding the minimum sea-level pressure if the penetration is made at or below 1500 feet. Upper-level centers, if located, are reported relative to the low-level vortex. When the low-level vortex cannot be located due to obscuration by cloud, darkness, or due to operational constraints, then the 700-mb vortex normally is located and reported.

Every source of information available to the ARWO and navigator is used in locating the tropical cyclone vortex. Constant comparison of flight level and surface wind direction with aircraft heading is made to assure that the "left wing stays into the wind" so that direct flight to the cyclone center is possible within known and acceptable limits. The radar presentation of rainbands is used to determine the approximate location of the cyclone center. The radar "eye" return from cyclones with well-developed wall cloud structures makes the location of the general cyclone center obvious unless the return is masked by heavy convective activity. Figure 3 illustrates the well-developed wall cloud structure of a "super-typhoon." At a constant pressure altitude, the absolute altitude of the aircraft can be monitored and decreases as the center is approached. Temperature is typically observed to increase, with the maximum temperature gradient occurring at or near the wall cloud structure if a wall cloud is present. Surface winds, when visible, and flight-level winds are continuously monitored, increase toward the cyclone center, and fall off sharply as the cyclone center is penetrated. Observations are taken and recorded for transmission or for later use in reporting the vortex fix. An inflight analysis of plotted observations is normally maintained as an aid in locating the vortex and to keep track of cyclone progress and development during the mission.

In addition to locating the tropical cyclone center and reporting its characteristics, observations are made on flight patterns in the cyclone to measure the intensity and distribution of flight level and surface winds, to measure height of standard pressure surface or sea-level pressure profiles, and to determine temperature and dew-point profiles in the cyclone. Figure 4 illustrates the execution of a typical flight pattern. Altitudes flown when executing such a pattern are normally 1500 feet (absolute altitude) or 10,000 feet (approximately 700 mb). Altitudes flown in proceeding to and from the cyclone are selected to permit fuel conservation and to minimize time enroute to and from the cyclone area. Descent to the pattern execution altitude is normally made around 200 nm from the forecast location of the cyclone center.

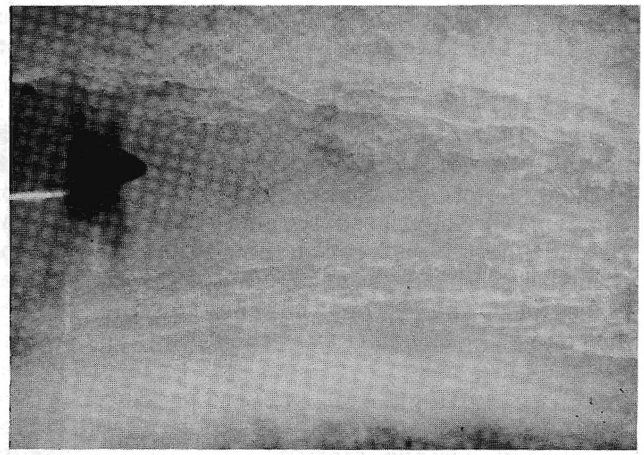


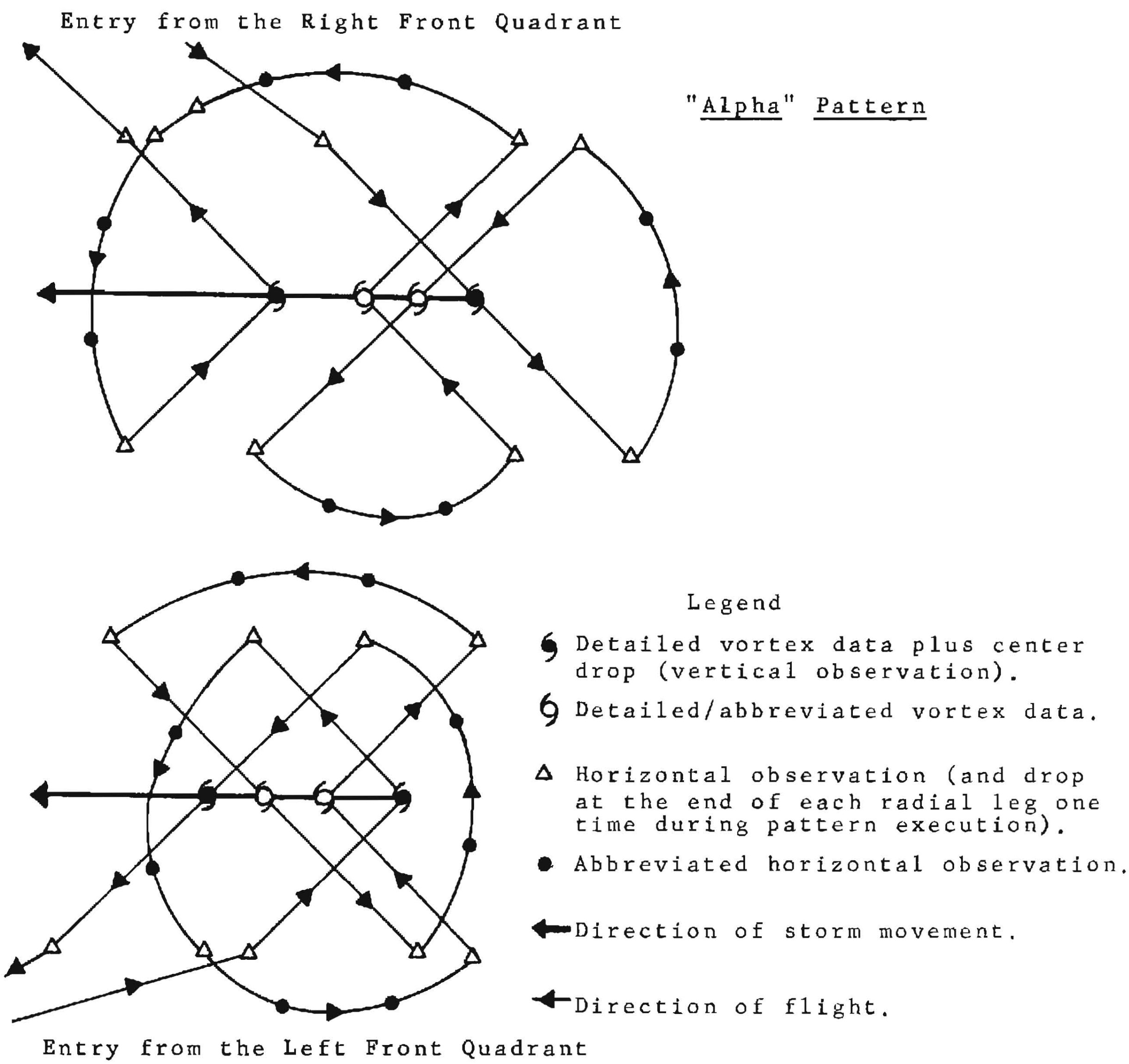
Figure 3. The eye of Typhoon "Nora" at 0015Z on the 6th of October 1973. This "super-typhoon" had an extremely well-developed wall cloud structure and a minimum sea-level pressure of 877 mb.

"Investigative" missions are flown into areas of suspected tropical cyclone development to prove or disprove the existence of a closed cyclonic circulation and, if such a circulation is found, to measure its strength and locate its center. Improved satellite data have sharply reduced the requirement for investigative missions in the Western Pacific and substantially reduced the number of missions flown in other areas. Investigative missions are almost always flown during daylight and may well be timed to arrive in the suspect area at "first light" early in the morning or "last light" in the evening. In the high-pressure environment of tropical cyclone reconnaissance, investigative missions frequently are among the most challenging to the skills of the aircrew. Weak pressure gradients, large calm areas, and light winds coupled with areas of heavy convective activity can make vortex fixes difficult to make on the weak circulations usually encountered.

The tropical cyclone reconnaissance mission forms a large part of the operational weather reconnaissance effort and is the mission with which most people are familiar. Many other missions are flown by weather reconnaissance units, however, and a few of these are considered in the following section.

6. SPECIALIZED RECONNAISSANCE AND WEATHER MODIFICATION

The variety of missions flown by weather reconnaissance units ranges from routine weather



Additional data is collected at the 15 nm, 30 nm, 45 nm, and 80 nm points on each radial leg (measured from the cyclone center) and is transmitted as vortex profile data in supplementary vortex data messages (observations).

Similar procedures are followed for entry from the Right Rear and Left Rear Quadrants of the storm.

Figure 4. Execution of a typical tropical cyclone reconnaissance flight pattern, the "Alpha Pattern" of the National Hurricane Operations Plan.

reconnaissance tracks over broad ocean areas to weather modification activities. Missions are flown for many different customers involved in operations in different parts of the world. Typical weather reconnaissance missions are probably best examined by briefly considering the Volant Met, Volant Cross, and Volant Coast missions along with some remarks concerning weather modification operations.

A. Volant Met. Volant Met is the nickname associated with missions flown to support the operations of Air Force Global Weather Central (AFGWC), Offutt AFB, Nebraska. AFGWC often requires upper-air data in "data sparse areas" such as the Gulf of Alaska and Gulf of Mexico. These missions are flown most frequently during the winter months to provide 400-mb and 300-mb data for updating numerical models. Horizontal and vertical observations are taken as required by published reconnaissance tracks or as required by computer flight plans produced for these missions.

Most AFGWC support missions in the past three years have been flown from McChord AFB, Washington, by both MAC and AFRES crews. Occasional missions in the Gulf of Mexico are normally flown from Keesler AFB. Routine training missions over the Gulf of Mexico may also satisfy AFGWC requirements when "hard-tasked" missions are not levied.

B. Volant Cross. Volant Cross missions are tactical support missions and generally fall into one of two basic categories: pathfinder or scout missions and area reconnaissance missions. Pathfinder or scout missions are flown along the planned route for tactical aircraft deployments to investigate flight-level winds along the route and other weather conditions of significance in the deployment. The vast majority of peacetime tactical support missions are of the pathfinder or scout type. Area reconnaissance missions are flown to support tactical operations within a specified area. These missions may involve specialized observation codes and procedures as well as armed escort or other protective measures in a combat environment.

C. Volant Coast. Because of the threat of severe winter storms along the east coast of the United States, special arrangements have been made for providing weather reconnaissance observations to use in making forecasts and warnings of the onset of such storms. Since 1969, the National East Coast Winter Storms Operations Plan has been developed and implemented to coordinate the use of surface platform, aircraft, and satellite observations for forecast and warning use and to meet the data requirements of research facilities when possible. The plan is developed to cover the period from November 1 through April 15 and involves the "area of concern" indicated in Figure 5.

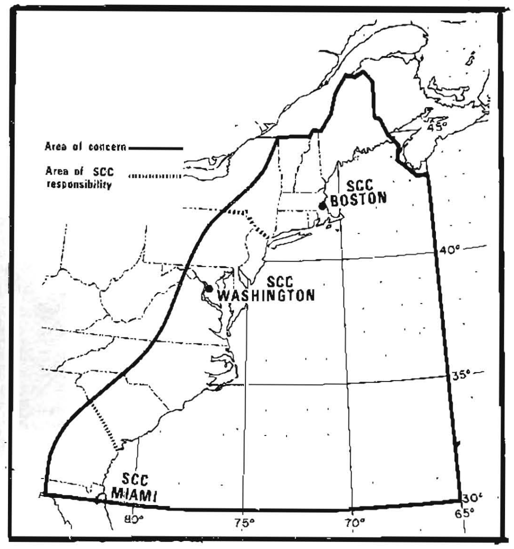


Figure 5. Area of concern for East Coast Winter Storms Plan operations.

Both the 815th WRS and 53rd WRS fly special missions off the East Coast to provide data for forecasts and analyses produced by the National Meteorological Center (NMC) and military forecast facilities. Horizontal observations are taken every 30 minutes with additional data taken at midpoints in between the horizontal observations. Vertical observations are taken as required by the Reconnaissance Winter Storm Plan of the Day (WSPOD) produced by the Storm Cordination Center (SCC) in Washington, D.C.

Several reconnaissance tracks have been designed to support the winter storms operation. All such tracks are designed to provide near-coast coverage in the area of concern. A typical reconnaissance track flown in support of winter storm forecasting is illustrated in Figure 6. Winter storms reconnaissance tracks are normally flown from Keesler AFB and may require 11 to 13 hours to complete.

D. Weather Modification. Despite the fevered wanderings of some science fiction writers and "serious" journalists, the U.S. Air Force does not have the capability to produce hurricanes, tornadoes, severe floods, thunderstorms, lightning, hail, or other cataclysmic meteorological and hydrodynamic events at will. Air Force weather reconnaissance forces do possess a modest capability to disperse "cold" fog and have exercised a precipitation augmentation capability in support of drought relief efforts in the past.

Supercooled, or cold, fog dispersal operations have been conducted by weather reconnaissance crews on an operational basis since 1967 when AWS was first assigned the cold fog dissipation mission at Elmendorf AFB, Alaska. Airborne seeding with crushed dry ice is used for dissipating the fog deck. Dry ice is dispensed on a series of lanes flown upwind of a target area such

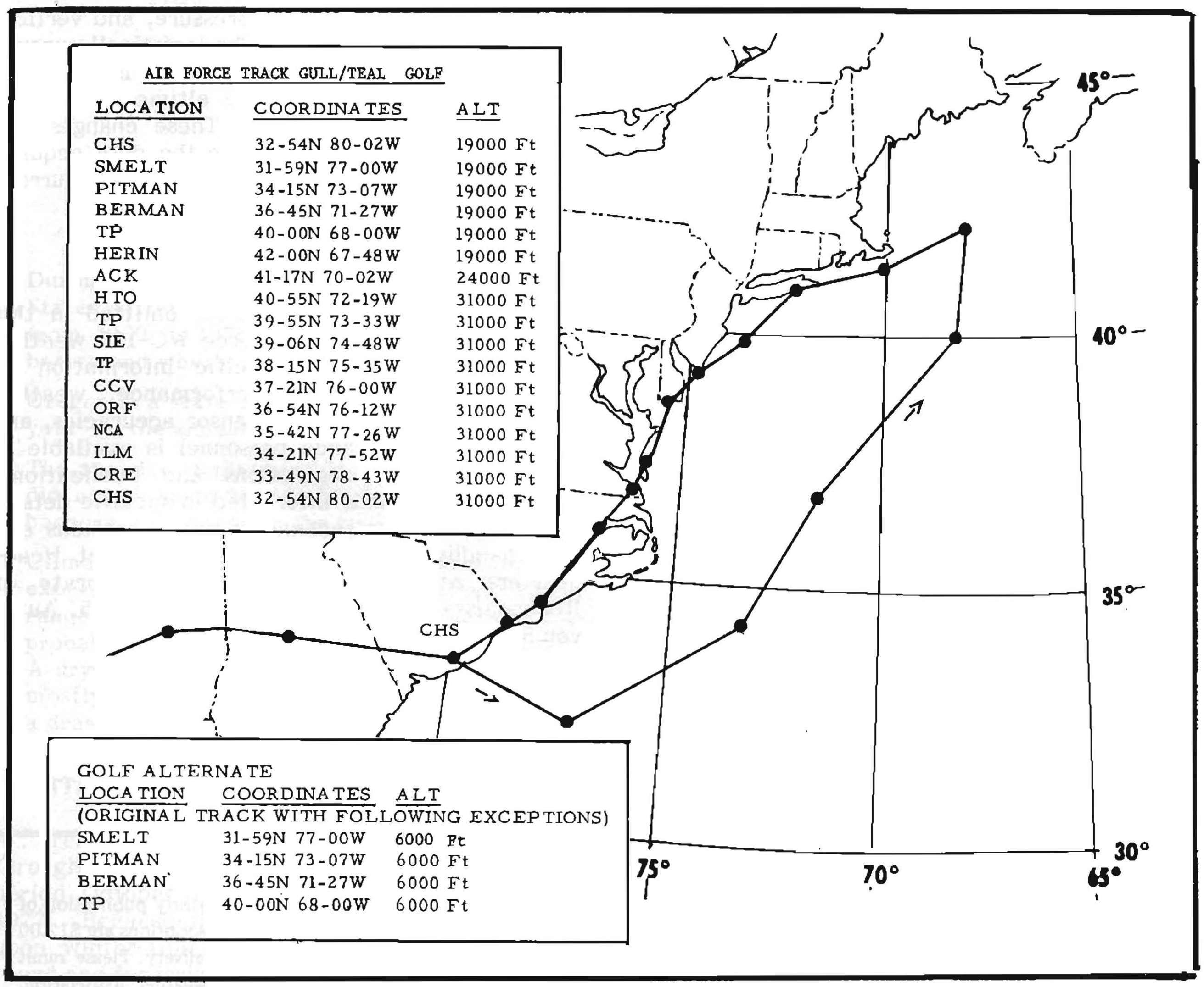


Figure 6. Typical winter storm reconnaissance track in support of the National East Coast Winter Storms Operations Plan.

as an airfield. When the resulting clearing drifts over the airfield, normal airfield operations can resume. Airborne dry ice seeding of cold fog has been replaced by the use of propane dispensers at Elmendorf AFB and a few other locations although WC-130 weather reconnaissance units continue to maintain a capability to provide contingency fog seeding operations. The contingency capability has been exercised at least once since the termination of the operational airborne fog seeding program at Elmendorf in 1973.

Precipitation augmentation involves the seeding of suitable cumuliform clouds with silver iodide flares dropped every two or three seconds while the aircraft is in the updraft region of the clouds. The silver iodide flares are dispensed from racks attached to the air deflector doors on the sides of the aircraft fuselage. The silver iodide flares produce additional condensation nuclei, increased condensation creates a broader drop-size spectrum and releases fusional heat which enhances cloud growth, and the resultant larger cloud mass may have a longer lifetime and be more efficient at producing precipitation from available moisture. In addition to more specialized operations, Air Force weather reconnaissance crews have conducted precipitation augmentation missions in support of drought relief efforts in the Republic of the Philippines and in Texas.

7. IMPROVING THE WEATHER RECONNAISSANCE FORCE

After Hurricane Camille struck the Gulf Coast in August, 1969, an improved meteorological system was installed on Air Force WC-130's under Project SEEK CLOUD. The SEEK CLOUD instrumentation was intended to provide an interim improvement in capability pending the development of a more advanced system. Most of the SEEK CLOUD instrumentation was also installed on the WC-130H aircraft as they began to come into the weather reconnaissance inventory in 1973. In 1971, development of an advanced system was directed and resulted in the installation of the present preproduction version of the AN/AMQ-32 Airborne Weather Reconnaissance System (AWRS) on a 53rd WRS WC-130B. The AWRS was developed to provide the capability of obtaining high quality data of the density expected to be required by the numerical forecasting models envisaged for the mid and late 1970's. The AWRS does provide a significant improvement in capability but is a complex and expensive system to install on the entire WC-130 fleet. As a result, concept development of a different system, generally referred to as the Improved Weather Reconnaissance System (IWRS), began in earnest in 1976.

IWRS hardware development is awaiting funding and it is possible that many of the capability improvements of an IWRS will be incorporated into the present meteorological system. Improvements expected to result from a fleet-wide installation of a modular, integrated IWRS include:

a. An improved navigation system.

b. Improved wind determination.

c. Improved flight-level sensors for more accurate measurement of meteorological parameters.

d. The capability to determine wind profiles below flight level.

e. Automatic data processing and display.

f. Improved telecommunications for transmission of weather data.

g. Improved equipment maintainability and reliability.

h. Growth capability.

The improvement in WC-130 weather reconnaissance effectiveness resulting from an IWRS capability generally would match that of fleet-wide deployment of an AWRS.

Pending development of an IWRS, the "interim" SEEK CLOUD systems remain in use. Many of the systems presently installed are rapidly aging, spares are in short supply in some cases, and the current system is not designed to provide the type of high-density, high-quality data required by some of the newer numerical forecasting models. Efforts are underway to improve the current system wherever possible. An OMEGA navigation system has been installed. Hewlett-Packard HP-97 programmable calculators were purchased in 1977 and are used to speed height of standard pressure surface, sea-level pressure, and vertical observation computations. The logistically unsupportable 1301A Pressure Transducer is being replaced and a backup absolute altimeter is being installed on the WC-130H. These changes and others are expected to improve the data acquisition capability and reliability of the current meteorological system.

8. CONCLUDING REMARKS

A great deal of detail has been omitted in this brief introduction to Air Force WC-130 weather reconnaissance. More specific information on WC-130 equipment and performance, weather reconnaissance operations, sensor accuracies, and weather reconnaissance personnel is available in many Air Force regulations and publications. Qualified individuals interested in specific details regarding weather reconnaissance operations and data handling are encouraged to contact Headquarters Air Weather Service, Directorate of Reconnaissance, Scott AFB, Illinois 62225, Autovon 638-4624.