Technical Bulletin
National Data Buoy Center

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Federal Aviation Administration/NDBC Gulf Of Mexico Air/Ground Communications Project

In June 1994, the National Data Buoy Center (NDBC) and the Federal Aviation Administration (FAA) entered into a joint interagency agreement to implement the Gulf of Mexico Project (GOMP), a program to extend air/ground communications capabilities to presently uncovered areas of the Gulf of Mexico. The GOMP uses NDBC meteorological buoys modified to accommodate air/ground communications equipment that provides a radio relay link between aircraft flying over the Gulf and the FAA's Air Route Traffic Control Center (ARTCC) in Houston, TX. NDBC's role in the GOMP includes the following responsibilities:

(1) buoy modifications
(2) power system design and fabrication
(3) technical support of the FAA during the design, acquisition, and on- and offshore testing of the Remote Buoy Communications System (RBCS)
(4) selection of the offshore test site and the implementation of the required test support infrastructure
(5) maintenance of the RBCS during offshore tests

At the present time, foreign and domestic aircraft flying over a large portion of the Gulf have no radio contact with the Air Traffic Control (ATC) systems of the United States or other countries around the Gulf. This lack of communications in some areas of the Gulf requires that aircraft be spaced at distances that ensure safety during passage through these areas. The present spacing requirements have resulted in the inability to increase the volume of air traffic in this area, and in delays and cancellations for existing flights. Air traffic over the Gulf is projected to increase dramatically in the future, and the North American Free Trade Agreement (NAFTA) ensures that this will happen. If successful, the GOMP, by extending air/ground communications to these uncovered areas of the Gulf, will enable the closer spacing of aircraft over the Gulf, resulting in a higher traffic volume and the accompanying economic benefits of this traffic.

The primary means of air/ground communications is VHF/AM radio, which is basically a line-of-sight system; that is, there must be an unobstructed direct path between the aircraft and ground station to maintain radio

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Multifunction Acquisition and Reporting System Program Review

About 4 years ago, NDBC determined that the support costs and inflexibility of existing electronic payload systems justified development of a state-of-the-art system. NDBC's payload systems acquire, process, format, and transmit weather and oceanographic data. The new system is called the Multifunction Acquisition and Reporting System (MARS). Development philosophies included careful analysis of existing systems, review of sensor technology, surveys of user needs, and a design that uses commercial-off-the-shelf (COTS) equipment. The system, hardware, and software implementation was accomplished internally using NDBC Government and contractor engineering teams.

System design began in earnest during 1992. Prototyping and early testing was conducted during 1993. The first field tests were conducted at Stennis Space Center in 1994. Following the successful tests at Stennis, MARS was installed at the National Weather Service (NWS) Upper-Air Wind Profiler Demonstration Network (Profiler) test facility in Platteville, CO. During the Platteville tests, MARS operated as expected. Based on the successful test, MARS was certified for installation at the remaining 13 Profiler Surface Observation System (PSOS) stations throughout the central United States. The PSOS installations were completed in the fall of 1995. To date, there has not been a single case of data loss or system failure related to the MARS.

NDBC's requirement to operate reliable systems in very harsh environmental conditions dictates a conservative approach to the fielding of new systems. MARS, while proven for PSOS, will be requalified for operation in NDBC's Coastal-Marine Automated Network (C-MAN). This certification is expected in early 1996. The engineering tasks to integrate MARS aboard a

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contact. Aircraft flying at an altitude of 5,486 m (18,000 ft), for example, have line-of-sight contact with points at sea level to a distance of 304 km (189 mi). Some aircraft are equipped with High Frequency (HF) communications equipment that enable them to communicate with ground stations far beyond the line-of-sight limitations due to the nature of HF radio waves. However, while HF systems are capable of two-way communications over great distances, this equipment is not available on most foreign and domestic aircraft, and is not available at FAA ATC centers. In addition to the unavailability, HF systems are also adversely affected by weather and other conditions, resulting in an availability factor that is deemed unacceptable.

A Request for Proposals (RFP) was originated by the FAA, with technical support from NDBC, resulting in the selection of the Transcomm Division of Harris Corp. to furnish the RBCS. The second RBCS design review was held at the Harris facility in Melbourne, FL, on January 30-31, 1996. The schedule calls for the first pre-production prototype RBCS to be delivered in July 1996 for installation on an NDBC buoy. Shore tests will be conducted prior to installation on the buoy, followed by an intensive series of dockside, near-shore (about 64 km (40 mi) offshore) and operating site (about 483 km (300 mi) offshore) tests. NDBC personnel will be responsible for all aspects of buoy operations and for the power systems and will furnish technical support during all equipment installation and testing. NDBC will also be responsible for logistics functions such as on-site maintenance of the RBCS during all test operations, line replaceable unit storage, arrangements for boat transportation, and shipping and receiving of RBCS hardware.

The RBCS consists of redundant VHF/AM transmitters and receivers, a K_u band satellite communications system, and interfaces, controls, and monitoring systems required for system operation. The communications path will be via VHF/AM between aircraft and buoy, and K_u band satellite link between the buoys and the ARTCC in Houston (see Figure 1). NDBC has designed a power system, consisting of photovoltaic (solar) cells and secondary batteries capable of continuous power output of 800 watts at 24 VDC to support the operation of the RBCS. This is an output far greater than that of systems normally installed on buoys to operate meteorological data payloads. The buoy selected for the GOMP is the 12-m Large Navigational Buoy (LNB). The large deck space available on the LNB is required to accommodate the large number of solar power panels required.

A diesel generator that will be programmed to operate automatically, depending on conditions, and that can also be controlled remotely will be installed to furnish a backup system should conditions arise that prevent the solar panels from recharging the batteries.

When the GOMP becomes operational, a total of four buoys will be on station. Two buoys, one primary and one backup deployed about 80 km (50 mi) apart, will be in the eastern Flight Information Region (FIR), and two buoys will be in the western FIR.

The GOMP buoys, like all NDBC buoys, will furnish meteorological data to the NWS and other users for weather forecasting, research, and other functions.

Hal Brown,
NDBC Program Management

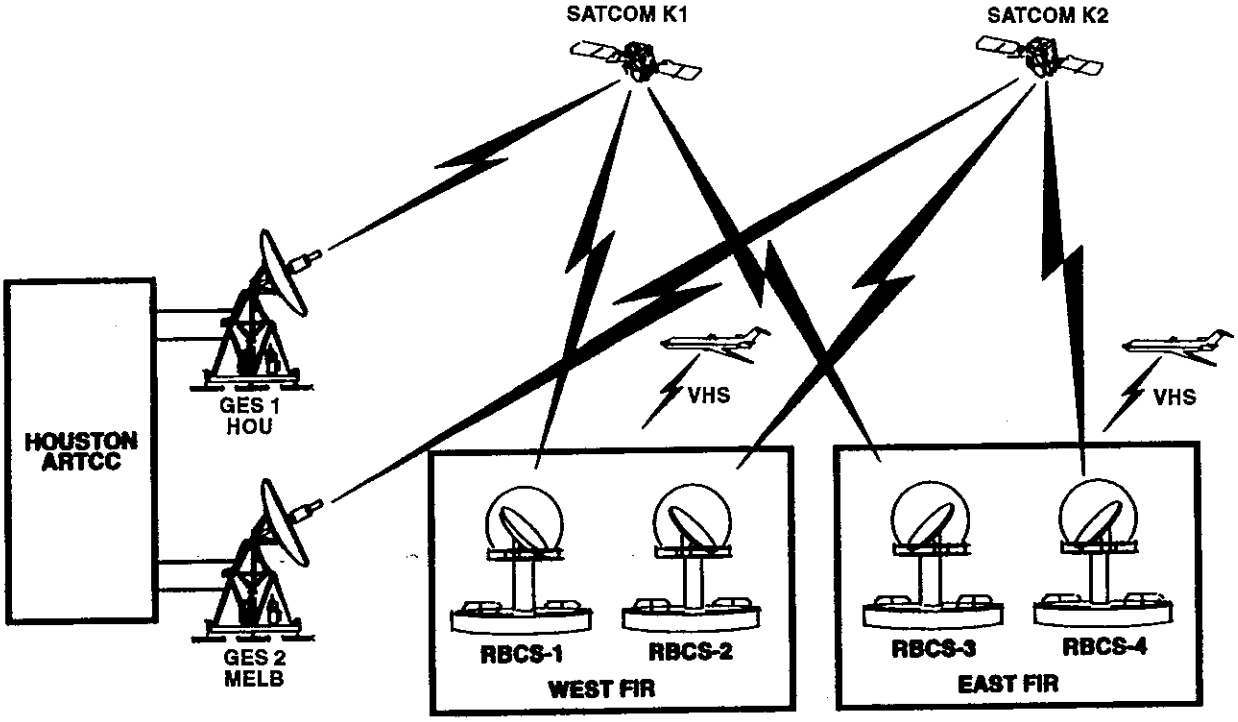

Figure 1. FAA Communications Paths

NDBC Stations Encounter An Active '95 Hurricane Season

The 1995 Atlantic tropical storm and hurricane season was extremely active. Nineteen named tropical cyclones developed; of these 19 storms, 11 developed into hurricanes. Four hurricanes and one tropical storm hit the United States. Although landfall was centered on the states bordering the Gulf of Mexico (Texas, Florida, and Alabama), these storms' power was felt throughout the eastern United States, causing nearly 150 fatalities and over $7.7 billion of wind and water damage in the United States, Canada, Mexico, and the Caribbean islands.

NDBC moored buoys and C-MAN sites are often valuable during tropical cyclones, because they continuously measure and transmit meteorological and oceanographic data to forecasters and scientists for use in manual analyses, short-term advisories and warnings, and numerical weather prediction models. In many cases, buoy and C-MAN reports are the only sources of *in situ* data, as ships of opportunity usually stay away from tropical weather systems.

The three largest hurricanes to hit the United States during 1995 were Allison, Erin, and Opal. This report will focus on measurements and performance of NDBC stations as a result of these storms.

Hurricane Allison

Hurricane Allison formed in early June in the Caribbean Sea. By June 4, Allison had moved into the central Gulf of Mexico midway between the Yucatan Peninsula and Cuba and began to move northward. Station 42003 in the eastern Gulf of Mexico reported its maximum values at 1600 Z: sustained wind speeds (8-min average) of 27.2 m/s (52.8 kn) with 5-s peak wind to 33.8 m/s (65.6 kn) and a sea-level pressure of 992.3 hPa. At approximately the same time, Allison was 55.6 km (30 nmi) to the west of that station and National Hurricane Center (NHC) advisories reported maximum sustained winds of 33.5 m/s (65 kn) and a minimum central pressure of 988 hPa. Allison continued on a northward track and changed little in strength for the next 13 hours. At 0800 Z, station 42036 in the northeast Gulf of Mexico reported its lowest sea-level pressure of 995.4 hPa; that station reported its highest sustained wind speeds of 19.7 m/s (38.2 kn) with gusts to 24.3 m/s (47.1 kn) at 1200 Z.

As Allison turned towards the northeast and moved toward the Big Bend region of Florida, it passed between NDBC stations at Cape San Blas, FL (CSBF1), and Keaton Beach, FL (KTNF1). The maximum sustained winds (2-min average) were reported at KTNF1, 19.9 m/s (38.6 kn) with peak 5-s gusts to 23.8 m/s (46.2 kn).

Approximately 92 percent of the scheduled hourly observations from the NDBC station were successfully reported while Hurricane Allison was within 6 hours of closest approach.

Hurricane Erin

Hurricane Erin's track took it very close to Settlement Point, Grand Bahama Island (SPGF1), before she crossed Florida and entered the Gulf of Mexico. Maximum 2-min average winds at SPGF1 were 17.3 m/s (33.6 kn).

Erin subsequently passed within 44.4 km (24 nmi) of station 42036 in the northeast Gulf, where 8-min average winds reached 17.7 m/s (34.3 kn) and significant wave heights were 4.5 m. Other NDBC stations that felt the affects of Erin were Cedar Key, FL (CDRF1), CSBF1, Dauphin Island, AL (DPIA1), and moored buoy 42007. Most of these stations experienced maximum sustained wind speeds over 15 m/s (29.1 kn). Approximately 97 percent of the scheduled observations were delivered while Hurricane Erin was within 6 hours of closest approach.

Hurricane Opal

The worst tropical cyclone to hit the United States in 1995 was Hurricane Opal. After drifting slowly for 1 week over the southern Gulf of Mexico near the Yucatan Peninsula, Opal strengthened tremendously in just a few hours on October 2 and by 1100 Z, October 4, Opal had reached its lowest pressure of 916 hPa, and its maximum sustained winds of 67.1 m/s (130.2 kn).

Although no NDBC station was in Opal's direct path, NDBC moored buoys and C-MAN sites did provide a plethora of data for the computer models and forecasters. Opal passed about 31.5 km (17 nmi) to the southeast of station 42001 in the central Gulf at 0600 Z, October 4. At this time, the buoy reported a sea-level pressure of 963.7 hPa, 8-min average winds of 26.3 m/s (51.0 kn), and peak 5-s gusts to 32.4 m/s (62.9 kn). Significant wave height was over 8.0 m.

Twelve hours later, Opal passed 213 km (115 nmi) to the east of Southwest Pass, LA (BURL1), a C-MAN station near Buras, LA. BURL1 was in the area of hurricane force winds and reported 2-min average wind speeds of 34.0 m/s (66.0 kn). Grand Isle, LA (GDIL1), 238.4 km (153 nmi) to the west of Opal, reported a maximum sustained wind speed of 20 m/s (39 kn). A few hours later, moored buoy 42007 reported maximum sustained wind speeds of 26 m/s (50 kn) and a minimum sea-level pressure of 979 hPa. At 2200 Z, Opal passed 120.4 km (65 nmi) to the east of DPIA1. DPIA1, in the region of tropical storm force winds, reported wind speeds of 27.0 m/s (52.4 kn) and a sea-level pressure of 973 hPa.

The only serious casualty to the NDBC network occurred at CSBF1 when the station collapsed due to severe beach erosion caused by waves and high surge generated by Opal. The highest sustained wind speed of 20.0 m/s (38.8 kn) and peak 5-s wind 26.0 m/s (50.4 kn) came at 2000 Z on October 4. This was CSBF1's last transmission; CSBF1 had not missed a report previously during Opal's approach.

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MARS ... (continued from page 1)

moored buoy have started. Operational buoy tests are expected to begin in late 1996 or fiscal year 1997.

MARS System Architecture

MARS was designed and built to autonomously acquire data from a specified set of sensors at regular intervals. MARS will process the data into geophysical units, format the data, and transmit the data over selected communication links. It is required to operate as a fixed (land- or ocean-structure-based) platform or as a moored buoy station and will be deployed for up to 3 years. The payload was designed to connect to virtually all sensors providing analog (DC voltage) data, pulse-based data, or serial data strings. The types of sensors connected to MARS include those measuring wind speed and direction; barometric pressure; air temperature; sea surface temperature; buoy heading; humidity; and wave height, period, and direction. MARS will also process and transmit system housekeeping data including power system voltage and charge condition. The designed-in flexibility of MARS permits the configuration of the system to meet all expected operational requirements for land- and buoy-based stations. The MARS enclosure footprint matches NDBC's Value-Engineered Environmental Payload (VEEP), and an interface cable was made allowing MARS to connect to the VEEP sensor junction box directly replacing the older VEEP payload. As MARS becomes operational for C-MAN and moored buoy stations, the sensor cabling will be upgraded on NDBC's various platforms, separating the analog sensor data lines from the digital data lines.

MARS is made up of three basic system sections as illustrated in Figure 2. The following paragraphs summarize each of these sections and gives an appreciation for MARS capabilities.

MARS Power and Signal Conditioning Section

MARS will be operated at remote land stations and aboard deep-sea moored buoys. To conserve power, sensor and processor power is turned on and off. This switching is accomplished under the control of the MARS data processing section CPU, based on operating parameters entered by the user. Each MARS sensor is powered by a module having a specific system address. These power modules are stamp-size, plug-in, circuit cards. Several modules were designed to provide a variety of voltages matching the needs of the sensors and MARS. The power modules plug into a custom motherboard. Each of the 13 motherboard sockets is addressed and supplies battery power (12 VDC) to the modules. The power-switching motherboard resembles an STD circuit card and is installed in a custom backplane similar to the STD bus.

Sensor signal conditioning was implemented using the same motherboard-daughter board strategy. Data from weather and oceanographic sensors are typically analog voltages, frequency-based signals, or serial data strings. The custom analog/counter motherboard holds up to 16 daughter boards. The purpose of the conditioning is to provide the data processing section signals that are within the capabilities of the analog-to-digital convertor system.

Data Processing Section

Once conditioned, the signals are routed to either an analog-to-digital

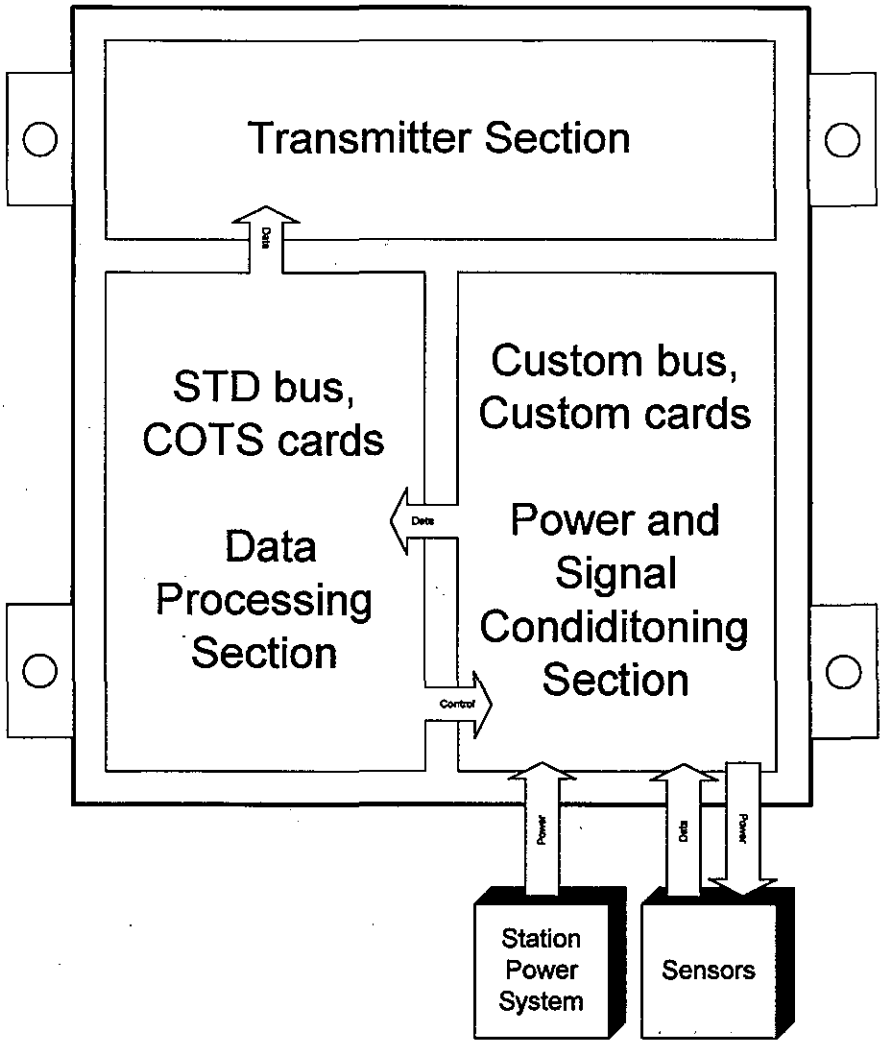

Figure 2. MARS Basic System Sections

converter or a counter/timer in the STD bus of the data processing section. The signals are then sampled, processed, formatted, and stored for transmission. The data processing section is also the basic brain and heartbeat of MARS. MARS software is stored in nonvolatile memory, as are the configuration parameters. The data processing section also provides the MARS user with interface capabilities over a test set port or modem.

Transmission Section

For most NDBC systems, the MARS transmitter will be a Geostationary Operational Environmental Satellite (GOES) unit. The GOES transmitter is a "smart" system that can be configured through the MARS data processing section. The GOES transmitter sends the data, based on control signals from the data processing section. MARS can connect to any communication system capable of transmitting ASCII characters. MARS includes the capability to use modems and cellular telephones.

Conclusion

MARS is the first payload system to be designed and built by the engineers at NDBC, and it is truly modular in nature. The growth potential achieved through the software and hardware is one of the more important success stories for MARS. The flexibility allows it to easily work with virtually all sensors or communication systems. The hardware and software were designed and carefully documented to allow for efficient maintenance, fault correction, and enhancement. Following the limited production run that supported the PSOS installations, the complete MARS documentation package was used to develop a specification for commercial production. The first MARS from this full-scale production run should be available in the spring of 1996. The use of commercial circuit cards will allow MARS to mature as technology advances. MARS is the payload that will take NDBC into the next century.

CDR John Harrington, USCG
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The purpose of this Bulletin is to inform persons involved in automated acquisition or use of environmental data, at sea and on land, as to the systems under development or in use, primarily by NOAA, that perform that function. Relevant articles are encouraged from non-NOAA sources. Subject matter should be current and in the general style illustrated by articles in this issue. Photographs must be 8- by 10-inch black and white prints. The right to edit all submissions is reserved. Articles ready for publication should be submitted to the:

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'95 Hurricane Season ...

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CSBF1 will be rebuilt at or near the previous location. While a similar tower design will be used, the tower foundation will probably be modified to increase its chances of survival in the future. The U.S. Army Corps of Engineers is also involved in the rebuilding of this C-MAN site.

Excluding data losses after the CSBF1 tower collapsed, NDBC stations successfully reported 98 percent of scheduled observations while Opal was within 6 hours of closest approach.

The year 1995 was the second most active Atlantic Hurricane season ever. When the data were most needed, NDBC stations delivered better than 95 percent of its scheduled reports helping operational forecasters who issue warnings to the coastal population.

Ian M. Palao, Meteorologist,
Computer Sciences Corporation
NDBC Technical Services Contractor

Rapid Response Drifting Buoy Deployments

During the unusually active 1995 hurricane season, NDBC participated in a test with the National Hurricane Center; Hurricane Research Division, Atlantic Oceanographic and Meteorological Laboratory (AOML); Naval Research Laboratory; U.S. Air Force Reserve; and Office of the Federal Coordinator for Meteorology designed to test the feasibility and the usefulness of a rapid response drifting buoy capability in a major storm environment.

Every element of the system was under test. This included readiness, response, deployment, data density and dissemination, and the ultimate value to hurricane forecasters and forecast models. NDBC's participation in the test consisted of air deploying Wind Speed/Direction (WSD) drifting buoys (utilizing wind speed and direction, barometric pressure, air- and sea-temperature sensors) in the paths of Hurricanes Luis and Marilyn. Though these buoys were designed to survive the harsh conditions encountered, the effort would also become one to test the sheer ruggedness of the drifting buoy package in extreme conditions. An *in situ* environmental test of the buoy had been duplicated only once before in Hurricane Josephine (Black et al., 1988).

Originally, three WSD drifting buoys were deployed into the path of Hurricane Luis by NDBC and the U.S. Air Force Reserve. These buoys returned such useful data to hurricane forecasters that a second deployment was requested 1 week later for Hurricane Marilyn. The deployment locations can be seen in Figures 3 and 4. An unplanned bonus occurred when Hurricane Marilyn continued on a path that took it directly over the first three drifting buoys that had been deployed in Luis. After surviving not one, but two hurricanes, these three WSD drifting buoys were well worn, but still reported useful data.

All six of the buoys were outfitted with a Savonious rotor-style anemometer at 0.4 m (1.5 ft) above the buoy waterline, Paroscientific barometer, KVH compass, and YSI air- and water-temperature sensors (Figure 5). Minimal sensor related failures occurred.

Besides providing useful data to the NWS for hurricane forecasts, the data returned by the buoys also provided some valuable lessons about the feasibility of hurricane deployments. First, the buoys proved to be quite capable of sensing and reporting higher wind speeds and gusts up to approximately 50 m/s (100 kn) (Figure 6). In addition, the Paroscientific barometers returned excellent data from the hurricanes with minimum pressures in the 970-hPa range (Figures 7 and 8).

By studying the data from the hurricanes, it is clear that deployment location of the buoy is important to the clarity of the data. For example, buoys that lay directly in the path of the eye of the hurricane consistently returned lower wind speed/gusts than did buoys that lay on the outside of the hurricane track (Figures 3 and 4). This reported lower wind speed could possibly be due to the blankets of seawater spray thrown up by the incredible power of the storm. This spray may act as a damping fluid for the anemometers, returning a lower count number, and thus, a lower wind speed. The buoys on the outside of the hurricane path, however, exhibited a

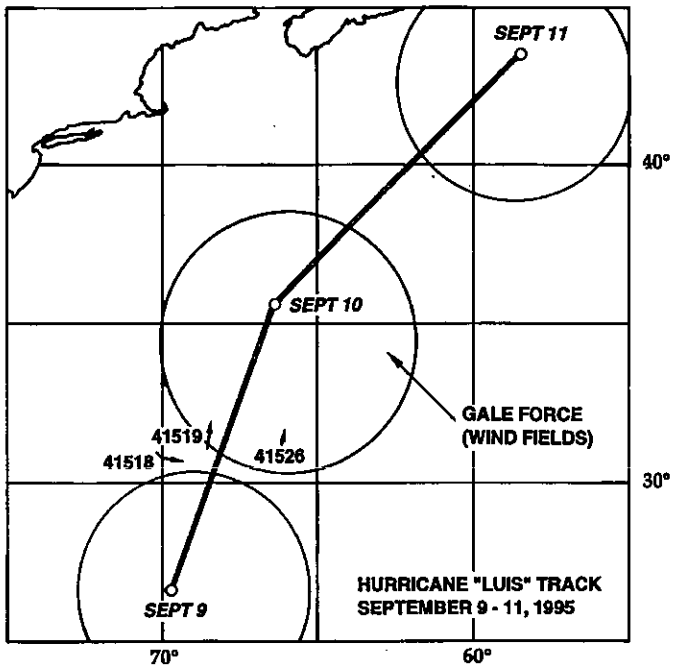

Figure 3. Deployment Locations During Hurricane Luis

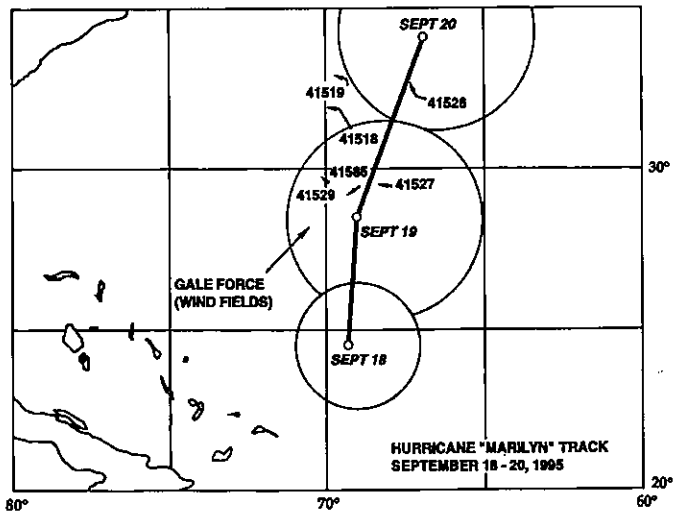

Figure 4. Deployment Locations During Hurricane Marilyn

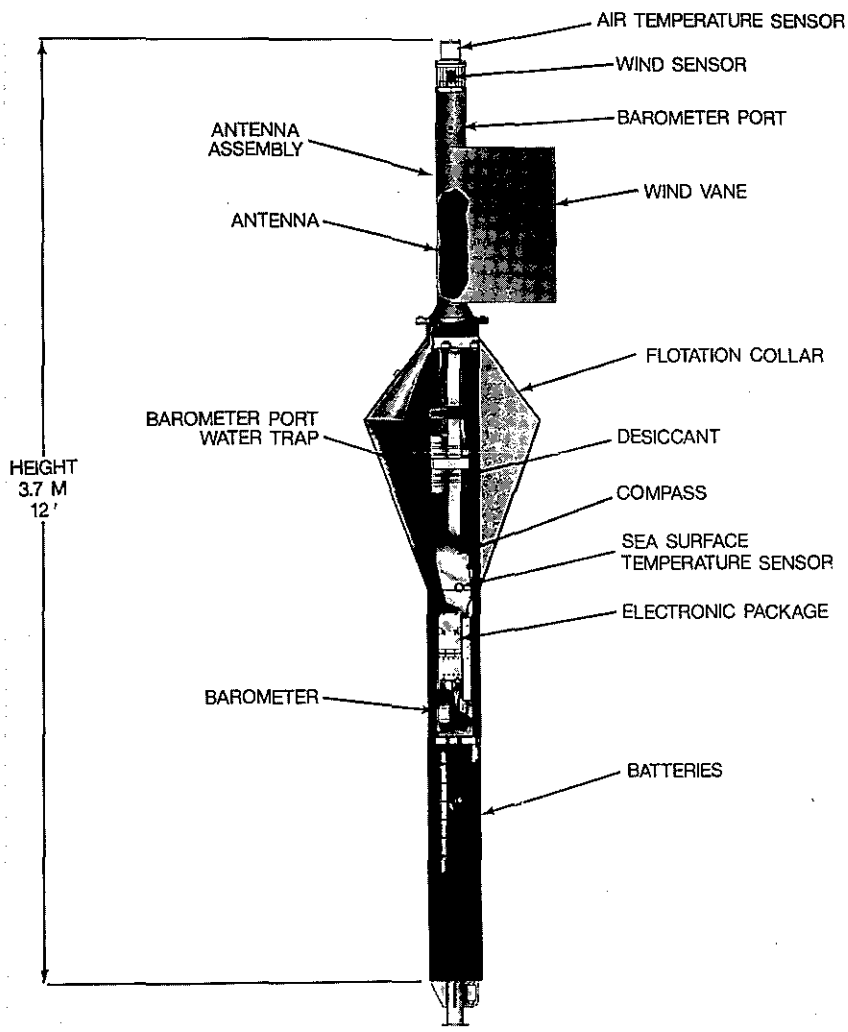

Figure 5. WSD Drifting Buoy

trend to high wind gusts with lower average wind speeds. This makes sense in light of the large swells caused by the storm and a lesser amount of spray. When in the trough of the wave, the buoy is somewhat sheltered, resulting in lower average wind speeds. At the crest of the wave, the buoy reads the true force of the hurricane winds as the wind gust.

The 1995 rapid response deployments were instantly valuable to hurricane forecasters and have remained valuable to researchers and NDBC engineers who work to constantly improve and refine drifting buoy technology to meet the extreme demands placed on these systems in severe storm environments. These deployments have proven the rapid response concept viable, and show great value to the forecast community contributing to the NWS's basic warning mission and the protection of life and property.

References:
Black, P.G., Eisberry, R.L., Shay, L.K., Partridge, R.P., and Hawkins, J.D., 1988: Atmospheric boundary layer and oceanic mixed layer observations in Hurricane Josephine obtained from air-deployed drifting buoys and research aircraft. *J. of Atmos. Oceanic Tech.*, 5, 683-693.

LTJG Todd Newman, USCG
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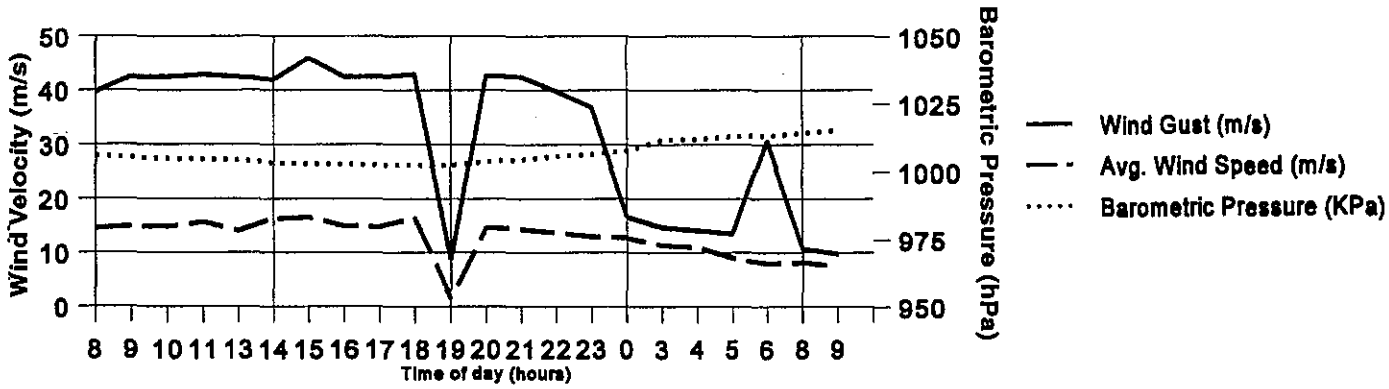

Figure 6. Environmental Data From Hurricane Luis (WMO No. 41526) for September 9-10, 1995

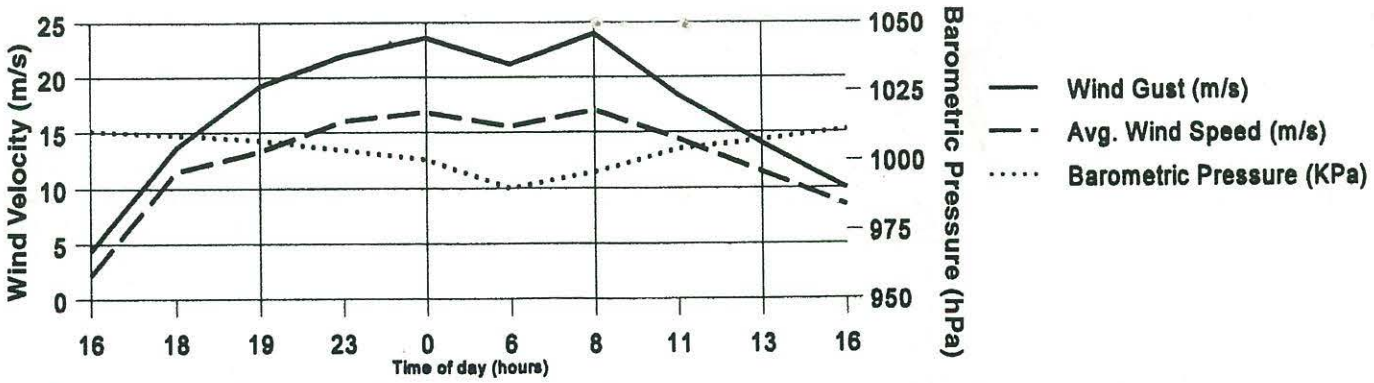

Figure 7. Environmental Data During Hurricane Marilyn (WMO No. 41585) for September 18-19, 1995

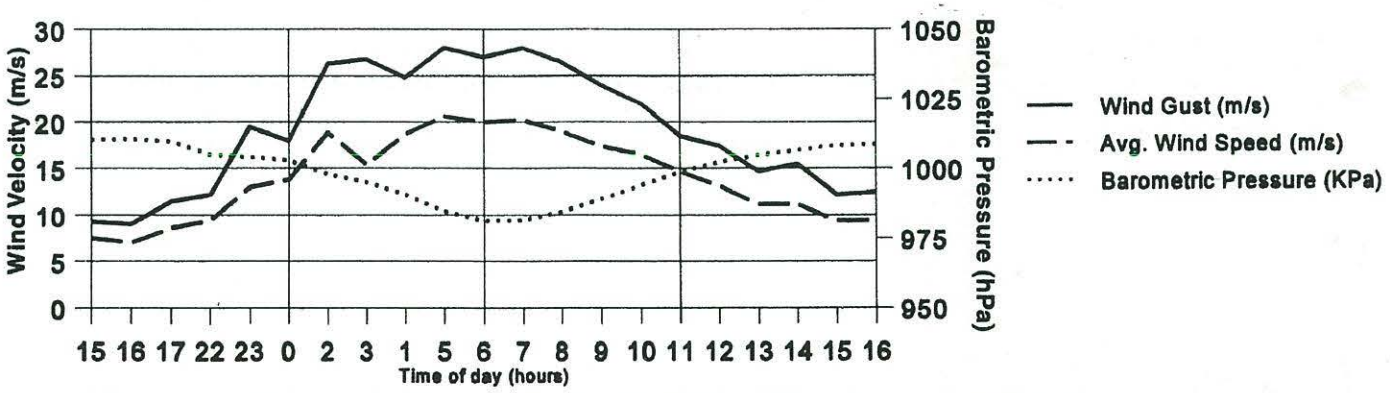

Figure 8. Environmental Data During Hurricane Marilyn (WMO No. 41527) for September 18-19, 1995

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