Technical Bulletin

National Data Buoy Center

VOL. 15 NO. 1 MARCH 1989

NEW NDBC BUOY STATIONS SUPPORT NASA SPACE SHUTTLE WEATHER FORECASTS

On August 9, 1988, NDBC deployed a 3-meter aluminum discus buoy at station 41009 (Latitude 28°30′N, Longitude 80°11′W), approximately 32 kilometers east of Cape Canaveral, Florida, on behalf of the NASA Kennedy Space Center (Figure 1). The purpose of the buoy is to acquire surface observations in the heretofore data-void, offshore region adjacent to Cape Canaveral in support of weather forecasts for space shuttle launching and landing operations. Data from this buoy, which are comprised of the standard NDBC measurements of wind speed, gust, and direction (dual anemometers); barometric pressure; air temperature; sea surface temperature; and nondirectional waves (significant wave height, peak period, and wave energy spectrum), are being acquired and relayed via GOES at half-hour intervals. This reporting frequency, which is double NDBC's standard hourly observation rate, was implemented specifically to meet NASA requirements.

As the second element in the program, NDBC deployed another buoy at station 41010 (Latitude 28°53′N, Longitude 78°38′W), on November 9, 1988. This location is about 177 kilometers offshore, on the far side of the Gulf Stream from 41009. Due to its distance from land and its proximity

BUOY SUPPORT CONTINUED PAGE 3

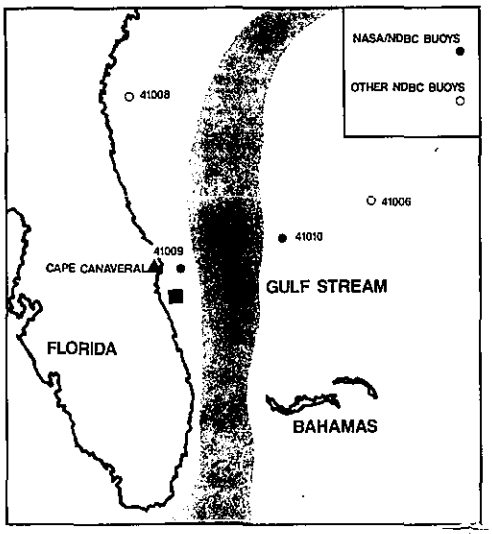

Figure 1. Buoy Locations for Shuttle Support

COASTAL-MARINE AUTOMATED NETWORK (C-MAN) IN THE WESTERN PACIFIC

In January 1987, the U.S. Air Force announced that aircraft weather reconnaissance operations in the Western Pacific (WESTPAC) would be discontinued after September 30, 1987. The last typhoon surveillance mission was flown on August 15, 1987, into Typhoon Cary in the Philippine Sea, ending 25 years of weather surveillance by WC-130 aircraft in WESTPAC. As a result of the deactivation of the 54th Weather Reconnaissance Squadron at Anderson AFB, Guam, the Navy/Air Force Joint Typhoon Warning Center (JTWC) at Guam was tasked to investigate alternative data collection capabilities and tropical cyclone forecast and warning techniques without the use of aircraft reconnaissance data.

The National Data Buoy Center's initial involvement was to make recommendations to the Commander, Naval Oceanography Command (COMNAV/OCEANCOM), at Stennis Space Center, Mississippi, in the planning and implementation of a network of Automated Meteorological Observing Stations (AMOS) for use in WESTPAC. Due to the extreme remote locations of the AMOS sites, NDBC proposed the use of a dual system which would operate with both the NOAA Geostationary Operational Environmental Satellite (GOES) and the NOAA polar-orbiting satellite (TIROS/ARGOS). The GOES system is similar to the one developed by NDBC for the Coastal-Marine Automated Network (C-MAN) and reports data synoptically at one-hour intervals. The TIROS/ARGOS system is similar to the type used on drifting buoys, has an enhanced sensor suite, and reports data an average of seven times daily at the WESTPAC latitudes; i.e., one report derived from each satellite pass.

During early discussions the Navy was concerned about the reliability of the GOES data from areas in the Western Pacific because of low site-to-satellite elevation angles with the GOES West Satellite. NDBC proposed installing a GOES system on Faraulep Island for a demonstration. The Navy accepted this proposal, and, in October 1988, NDBC installed a C-MAN type system on Faraulep. It has been providing quality data and has resolved any previous concerns relating to system performance degradation due to low satellite elevation angles.

The JTWC has identified a total of 20 islands in the South Pacific Ocean as candidates for AMOS installations. The four stations west of 144°E will be TIROS systems since they are out of range of the GOES West satellite. All of the stations east of 144°E will utilize GOES systems, and possibly will be complemented with a TIROS system as a back-up.

Implementation of the WESTPAC-AMOS network will take place over the next 5 years. It is expected that NDBC will install three additional stations in FY-89 and four stations each year thereafter through 1993.

The WESTPAC-AMOS Program involves the participation of the following departments/agencies:

- COMNAVOCEANCOM
  - — Funding for hardware procurement (operational systems and spares)

C-MAN CONTINUED PAGE 7

ENHANCED WIND MEASUREMENTS

Until recently, wind observations were limited to 8.5-minute sampling periods for buoys and 2-minute periods for land stations. In 1988, NDBC modified the on-station software for Data Acquisition Control and Telemetry (DACT) and Value Engineered Environment Payload (VEEP) payloads to continuously monitor winds. This allows measurements of consecutive 10-minute averages of wind, the hourly peak wind, and the hourly standard deviation of wind speed. The peak wind is the highest 5-second average obtained during the hour. This capability will be implemented at many of the deep-ocean buoy stations to provide concurrent comparison data for satellite-based scatterometer winds. The peak wind data should also be helpful to operational forecasters in providing them with the highest winds during thunderstorms and tropical cyclones. For these reasons, selected East and Gulf Coast Coastal-Marine Automated Network (C-MAN) stations also will report continuous winds.

An example showing the value of those measurements is given in the time-series plot of Figure 2. The hourly peak wind reached 31.3 meters/second (m/s) (60.7 knots) at 0829 UTC on November 5, 1988, during the passage of a cold front at Cape San Blas, FL (CSBF1). Yet, the standard wind speed obtained between 0823 and 0825 UTC was only 10.6 m/s with gusts to 11.8 m/s. Clearly, hourly peak wind information could lead to the issuance of special marine advisories.

In real-time, hourly peak wind measurements are reported in section 5, the national section, at the end of the buoy and C-MAN reports. The groups containing these measurements are 3GGgg 4ddfmfm.

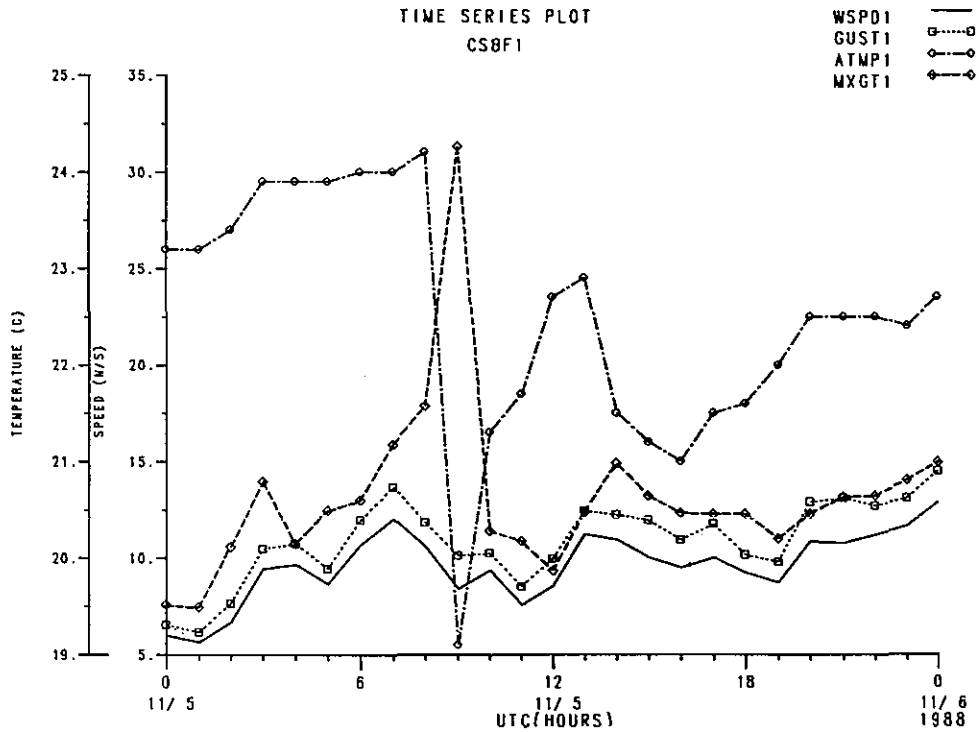

Figure 2. Times Series Plot of Wind Speed, Wind Gust, and Air Temperature for CSBF1 During November 5-6, 1988

The 3-group is the time of peak wind to the nearest minute (UTC). The 4-group is the actual peak wind. Buoys report speed in m/s and C-MAN stations report speed in knots. These groups will only be included if the peak wind is 5 m/s or higher and the peak wind is at least 3 m/s higher than the sustained wind. The 10-minute averages and standard deviation are not reported.

In archived data, all continuous wind measurements are added to the TD1138 (TDF191) and TD1171 formats at the National Climatic Data Center. These measurements will not be in TD1129 format because they are incompatible with ship observations.

David B. Gilhousen, NDBC

PRECIPITATION MEASUREMENTS AT NDBC

Precipitation is not routinely measured at all NDBC buoys and coastal stations. However, various investigations over recent years have been directed toward the identification and evaluation of rain guages that might operate reliably for 2 to 3 years at a data collection site. Different designs of commercially available precipitation sensors have been deployed for evaluation at shore stations. Also, the development of a rain gauge that can operate while installed on a moving buoy has been pursued with some success.

Ten tipping-bucket type rain gauges were purchased and installed at several Coastal-Marine Automated Network (C-MAN) sites for evaluation. A severe marine exposure for some of these instruments was realized by installing rain gauges on fixed ocean platforms located off the Atlantic Coast (Chesapeake Light, Buzzards Bay Light, and Diamond Shoal Light). Other rain gauges were installed in the more benign environments that exist at C-MAN stations located on shore sites like Grand Isle (Louisiana), Sabine, (Texas), and Newport (Oregon). All these stations have fairly rigid foundations and little motion, thus permitting the proper operation of the tipping-bucket rain-measuring mechanism inside the gauges. For the gauges tested, the rain accumulation that will cause one bucket to tip is 0.01 inch. The momentary closure of a mercury switch produces the electrical signal that indicates when a bucket full of rain tips away from under the gauge's rain-collecting funnel. This rain bucket balancing mechanism will not work on a moving platform like a buoy where the total acceleration vector at the location of the rain gauge is not constant. It is for this reason that NDBC has not installed tipping-bucket rain gauges on buoys.

The major problem encountered during the deployment of these ten rain gauges was corrosion of the metal parts. The external housing was very pitted after six months of exposure, and very large holes had developed after a year in the marine environment. The internal components also showed signs of excessive corrosion, and the tipping-bucket mechanism, although still able to move, had enough binding to produce a change in the

PRECIPITATION CONTINUED PAGE 5

AN EVALUATION OF WIND DATA FROM A WSD BUOY

For many years drifting buoys have been a valuable source of meteorological and oceanographic information. This has been particularly true for large scientific experiments, such as the First GARP Global Experiment (FGGE), and the Tropical Ocean and Global Atmosphere (TOGA) research program, for which large numbers of these relatively inexpensive systems could be deployed in remote, data-sparse areas. The capability of drifting buoys to measure barometric pressure, air temperature, and sea temperature has been proven. A desirable measurement for these systems is wind speed and direction, particularly in the tropics where such information can be valuable for tropical cyclone forecasting. Early attempts at developing such a wind measurement capability had mixed success (see "Wind Speed and Directional Drifter Operational Test and Evaluation" by Bruce Hundermark, Computer Sciences Corporation, NSTL Station, MS 39529, December 16, 1981). The National Data Buoy Center (NDBC) conducted an experiment last spring which seemed to indicate that most problems have been solved.

For this evaluation, an experimental Wind Speed and Direction (WSD) drifting buoy (Figure 3) was moored in the Mississippi Sound approximately 1 kilometer east of NDBC's Ocean Test Platform (OTP), a 12-meter discus buoy used by NDBC in many engineering experiments to test new technology. The mooring for the WSD buoy included a swivel and an inverse catenary, light load line so as to cause minimum influence on the behavior of the buoy to the wind.

During the experiment, data were

WSD EVAL. CONTINUED PAGE 4

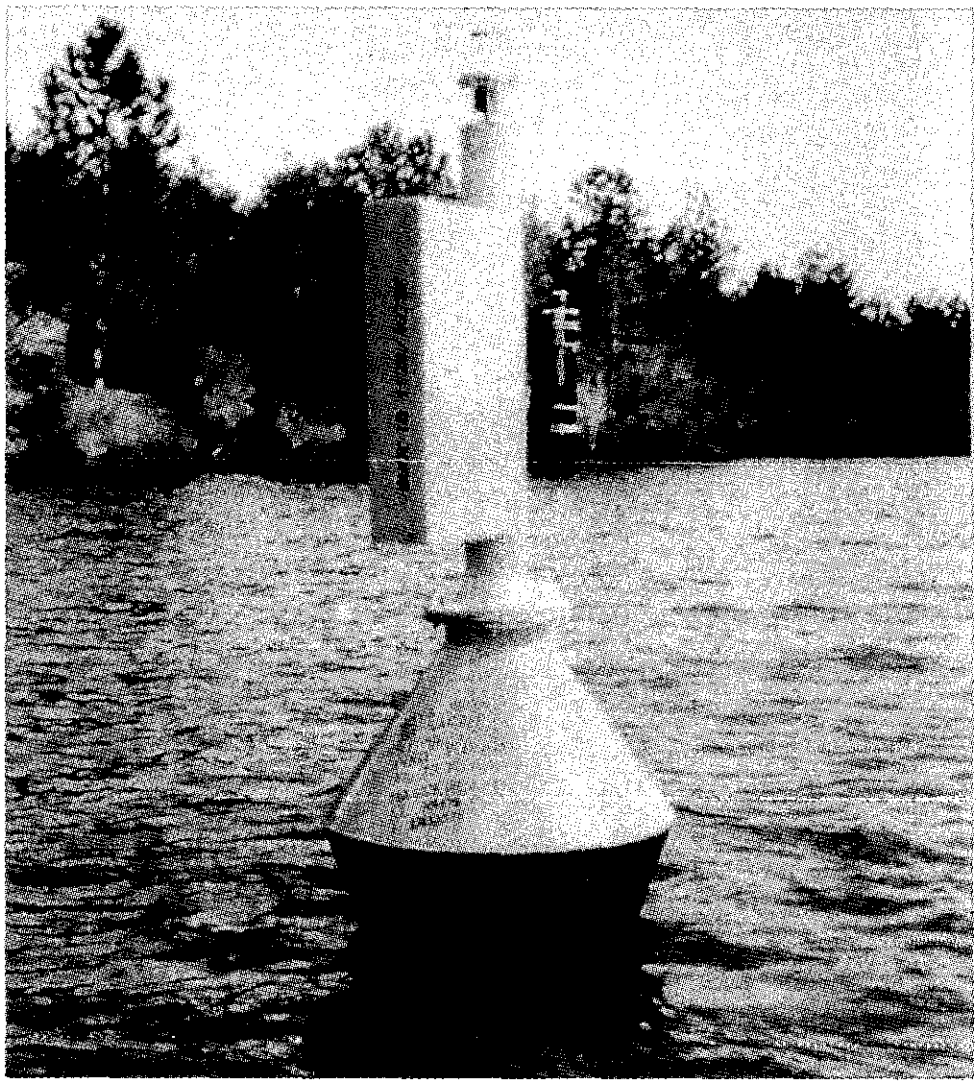

Figure 3. An Experimental Wind Speed and Direction Drifting Buoy

BUOY SUPPORT CONTINUED

to the Gulf Stream, a 10-meter discus hull was utilized. This large, steel hull, along with its inverse-catenary mooring, is specifically designed to withstand severe currents, such as could occur during a meandering of the Gulf Stream. In addition, the 10-meter buoy can be boarded and serviced at sea with relative ease, which, in view of the remote location of 41010, is critical.

Unlike its smaller, 3-meter cousin, the 10-meter discus cannot be transported over land. Consequently, after it had been refurbished at the NDBC facility at Stennis Space Center, Mississippi, it had to be towed around the Florida peninsula to its new location. The Coast Guard provided the ship support for this deployment, using three different vessels to complete the towing operations. This extraordinary undertaking is indicative of Coast Guard efforts and contributions to NDBC's mission — efforts that include not only ship support, but encompass a broad spectrum of essential engineering, managerial, and other functions as well.

NDBC is continuing to work with NASA program management to pursue new opportunities in other relevant meteorological areas. One project now under way is an investigation of the feasibility of installing an electric field mill sensor on an NDBC buoy. NASA operates a network of some 30 electric field mills in the Cape Canaveral/Kennedy Space Center area to measure surface potential fields as an indicator of lightning. All of these sensors are on land. If feasible, a buoy-based electric field mill system would enable this important data acquisition network to be extended offshore.

W. Brett Wilson, NDBC

WSD BUOY EVALUATION CONTINUED

transmitted to NDBC for evaluation in exactly the same manner as operational moored and drifting buoys deployed by NDBC; that is, OTP data were transmitted via GOES while measurements from the WSD buoy were received at NDBC through the NOAA polar-orbiting satellite — Service Argos communications system.

In order to accurately compare data between the OTP and WSD buoy, a correction had to be made for sensor height. Wind speed reported from the OTP, measured at 10 meters above the sea surface had to be reduced to 1 meter, which is the height of the Savonius rotor used by the WSD buoy to measure speed. This correction was accomplished by using an algorithm that used the air-sea surface temperature difference to correct for atmospheric stability. No attempt was made to further correct for the difference in sampling period length — 8 minutes at the OTP versus 1 minute for the WSD buoy.

The initial evaluation was conducted over a rather short period of time—approximately 6 weeks in late April and May 1988. It showed that when wind speeds at the OTP were greater than 4 meters per second (m/s), speeds from the WSD buoy showed good agreement. However, the WSD buoy appeared to display a wind speed threshold of approximately 4 m/s. In other words, when wind speeds were 4 m/s or less, the WSD buoy tended to record 0 m/s (Figure 4). Wind direction from both the OTP and the WSD buoy tended to remain within 20 degrees of each other, particularly at moderate or greater wind speeds (Figure 5).

A more thorough study of this experiment is under way; however, NDBC is optimistic with the preliminary results. The most valuable improvement will be to find a way to lower the response threshold so that the WSD buoy reports winds lower than 4 m/s (approximately 8 knots). Once operational, these systems will provide valuable information to operational forecasters and researchers world-wide.

Eric Meindl, NDBC

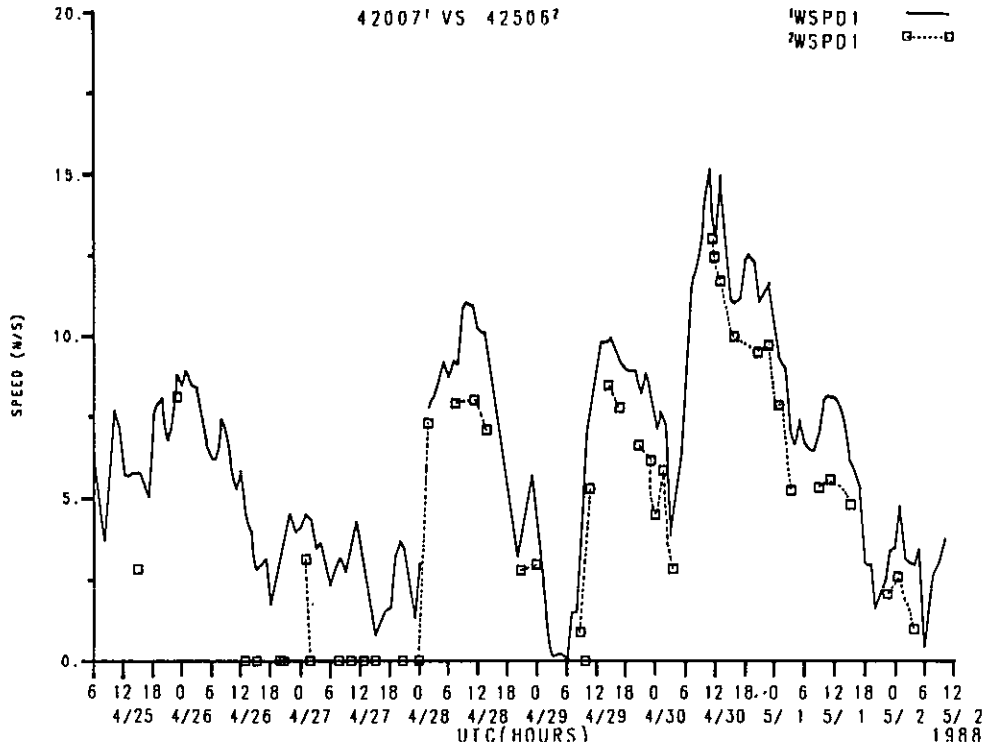

Figure 4. Wind Speed Plot for 42007 vs 42506 from April 25 through May 2, 1988

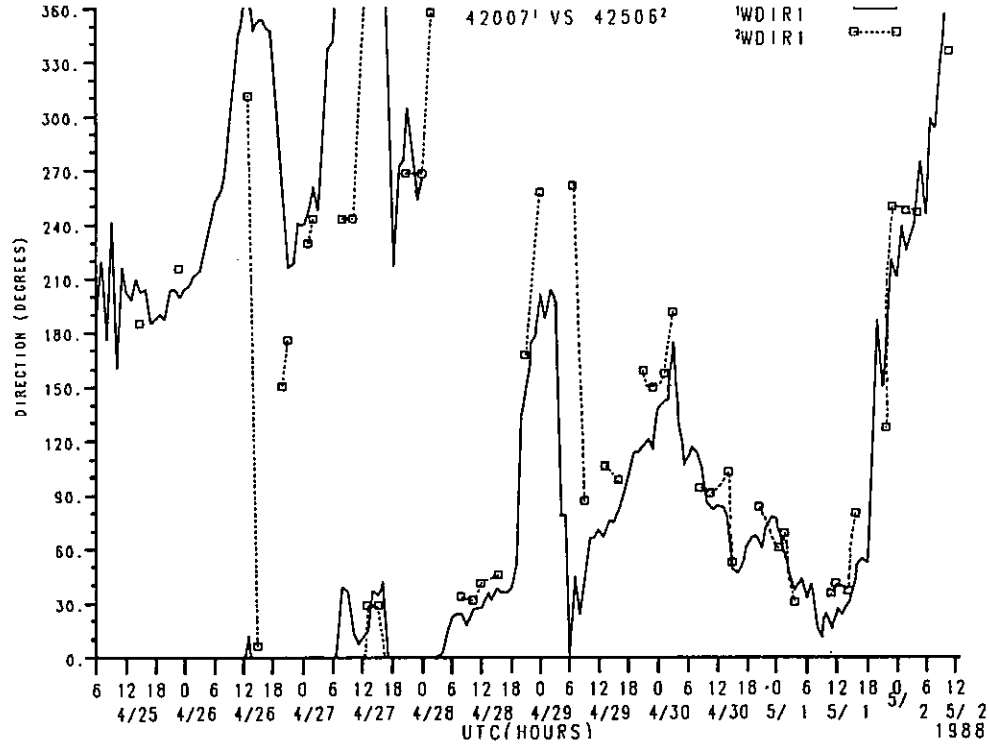

Figure 5. Wind Direction Plot for 42007 vs 42506 from April 25 through May 2, 1988

PRECIPITATION CONTINUED

instrument's calibration. Figure 6 shows how this type of rain gauge looked when removed from service.

Another type of tipping-bucket rain gauge has also been deployed on C-MAN stations for evaluation (Figure 7). This gauge is much larger in overall size and is constructed mainly with brass and stainless steel. Corrosion, while exposed in the marine environment, has not been a problem with this design. However, much larger than expected rainfall amounts were reported by this instrument at different measuring stations. It was found that the mercury switch used to signal the tipping of the buckets is quite sensitive to vibration. Although these rain gauges were installed on large, fixed, ocean platforms, the oscillations of these structures during periods of high winds and large waves were of great enough amplitude to trigger the mercury switch repeatedly. This problem resulted in many reports of high precipitation amounts even when no rain occurred in the general area, as evidenced by meteorological data from other stations in the vicinity.

Field experience with both designs of tipping-bucket rain gauges indicates that the smaller gauges are unacceptable for use in a marine environment and that the larger gauges can only be used at stations were the supporting structure is very rigid.

The effort at NDBC to obtain a rain gauge that will accurately measure precipitation while installed on a moored buoy followed a different path. For this application, commercially available rain gauges were not readily found. A development program was undertaken at NDBC to arrive at a suitable design. A few pre-prototype instrumentation experiments were conducted to determine what particular design features were most promising for further development. It was soon decided that a rain gauge that can operate on a moving platform like a buoy should directly measure the volume and not the weight of the precipitation as is done by the tipping-bucket design. Several methods to accomplish this were investigated. In all cases the precipitation was collected by a funnel device that dumped the rain into a storage tube. The water level in this rain accumulation container was then measured by an electronic transducer to obtain an electrical analog of the height of the fluid column. The general arrangement of this design is shown in Figure 8. Optical, resistive, hydrostatic pressure, and capacitive transducers were tested. Acoustical methods were not tried. The test stand where these devices were first evaluated is presented in Figure 9.

The capacitance-type, water-level-measuring transducer proved to be the easiest to implement. It is a long stainless steel rod covered with a teflon sheath that serves as the dielectric. The water mass that surrounds the probe forms the outer "plate" of a coaxial-type capacitor, and the central metallic rod is the inner "plate." As more rain is accumulated, the water level in the rain accumulation tube rises, thereby increas-

PRECIPITATION CONTINUED PAGE 6

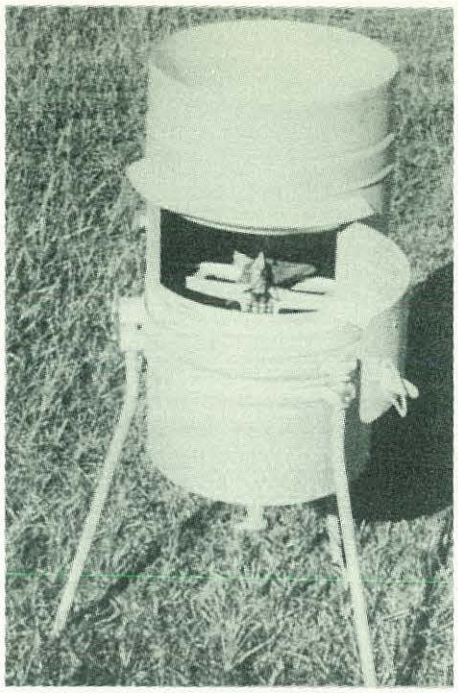

Figure 7. A Tipping Bucket-Type Rain Gauge Also Deployed on C-MAN Stations

Figure 6. A Tipping Bucket-Type Rain Gauge After 6 Months of Service

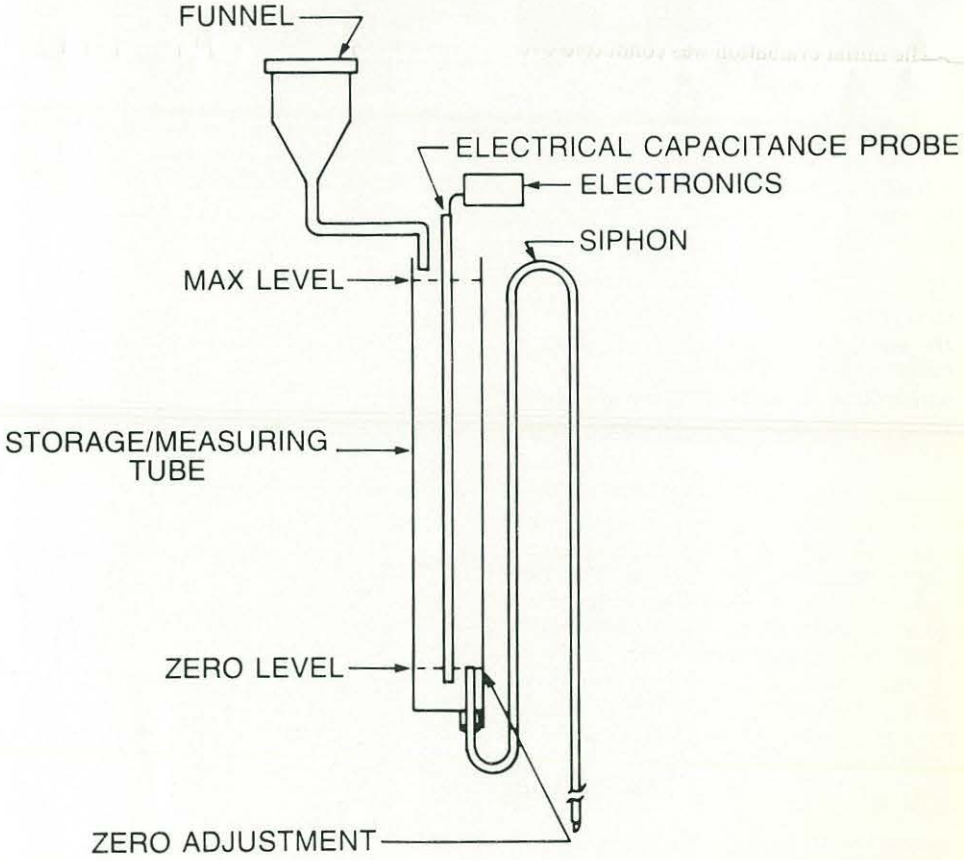

Figure 8. A Prototype Rain Gauge Designed by NDBC

PRECIPITATION CONTINUED

ing the total capacitance. Additional electronics are used to measure the value of the total capacitance and to output an analog voltage that is directly proportional to the amount of precipitation intercepted and accumulated by the rain gauge. Dumping of the accumulated rain when the rain storage tube is full is done by a self-initiating siphon that trips when the water level reaches the upper limit of the container. This resets the gauge for a new rain collection cycle. The construction and testing of these prototype rain gauges were discussed in the papers "Rain Gauge for NOAA Data Buoys," presented at the IEEE/MTS Symposium Oceans '81 and "Design and Testing of a New Rain Gauge for NDBC Meteorological Data Buoys," presented at the American Meteorological Society Fifth Symposium, Meteorological Observations and Instrumentation, April 1983.

Three siphon-dump type rain gauges were built for NDBC by an instrument manufacturer to continue the development effort. One of these instruments is shown in Figure 10. These particular units proved not to be very precise and were of poor mechanical design and construction. Laboratory testing demonstrated that field evaluation of these instruments should not be undertaken and all further development of these units was cancelled.

Presently, NDBC has purchased 13 commercially available volume-measuring/siphon-dump type rain gauges. Their construction and operation is based on the development efforts previously performed at NDBC. Total accumulation of precipitation before siphon-dump is 5 centimeters and the output analog signal ranges from 0 to 5 VDC. A side view of this rain gauge is shown in Figure 11. Both laboratory and field evaluation of this new instrument are under way, and results of these efforts will be reported in a future article.

Ed Michelena, NDBC

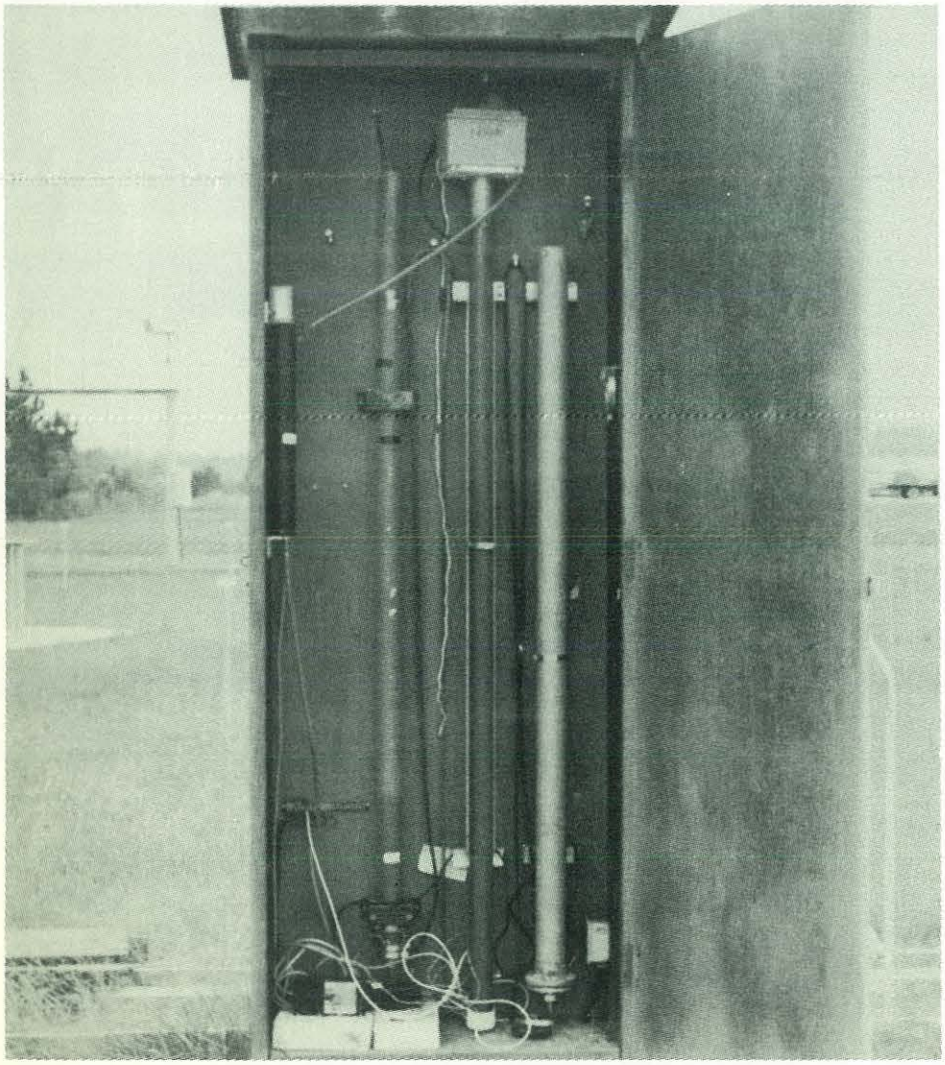

Figure 9. First Test Stand Used for the Prototype Rain Gauge

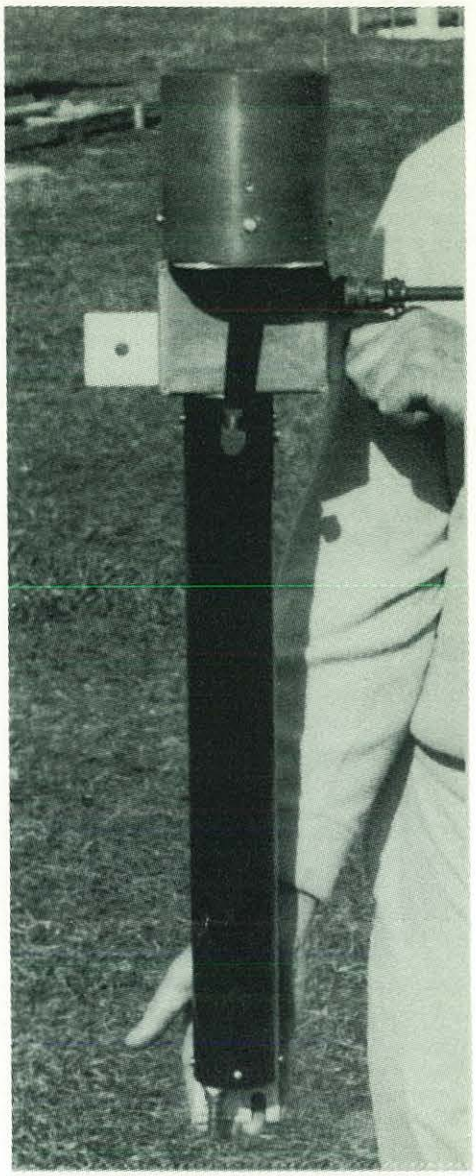

Figure 10. Siphon-Dump-Type Rain Gauge Which Was Tested But Not Used

Figure 11. Volume-Measuring/Siphon Dump-Type Rain Gauge Currently Being Tested

EVALUATION OF HUMIDITY AND VISIBILITY SENSORS

A field evaluation of a Rotronic humidity sensor and an Impulsphysik visibility sensor was conducted at the National Data Buoy Center's (NDBC) Coastal-Marine Automated Network (C-MAN) station at Pt. Arguello, CA (PTGC1). The main emphasis in the study was on the relative humidity/visibility system at PTGC1, but Rotronic humidity sensors installed on eight Minerals Management Service (MMS) buoys moored just offshore on the west coast of the United States and on three other C-MAN sites were also monitored. Table 1 on page 8 displays a list of the NDBC stations with Rotronic humidity sensors installed. A visibility sensor was installed at PTGC1 only. The primary statistical evaluation at PTGC1 used August 1988 data, while monitoring of the relative humidity data from the other stations ranged from 1 to 5 months, depending on when the sensors were installed at the stations.

tions is a Rotronic Hygromer Model MP100C. The sensor is a small hygroscopic capacitor that modifies its value as a function of both the water vapor pressure and temperature of the environment. The sensor performance is said to be excellent at high humidities and sensor hysteresis is also said to be exceptionally low. The visibility sensor installed at PTGC1 is an Impulsphysik Videograph. The Videograph measures backscattered light intensity. The measured intensity depends on the number of scatters and their backscatter characteristics.

For the statistical evaluation, the relative humidity and visibility data from PTGC1 were compared with surface observations from Vandenberg Air Force Base (VBG). The two stations are about 15 miles apart with PTGC1 directly adjacent to the ocean and VBG inland and north of PTGC1. Results showed that the Rotronic humidity sensor accurately depicted the marine environment. The mean dewpoint difference between the two sites for August 1988 data was 1.5 degrees C, a good result, considering the distance between the sites and the fact that PTGC1 is closer to a source of water vapor. In addition, the sensor performed quite well in high humidity and fog conditions, and sensor hysteresis was not evident. Further, a good correlation existed between the relative humidity and visibility data at PTGC1. This is shown in Figure 12. When the Rotronic reported relative humidity values of 100 percent during fog, the visibility sensor, correspondingly, reported values as low as 2 miles, while when the Rotronic reported relative humidity values of 88 percent, the visibility values increased to 8 miles. The monitoring of eleven other Rotronic sensors in the field, for up to 5 months, detected three hard sensor failures. However, nine Rotronic sensors performed well and without failure in a marine environment since installation, an average time span of 3 months.

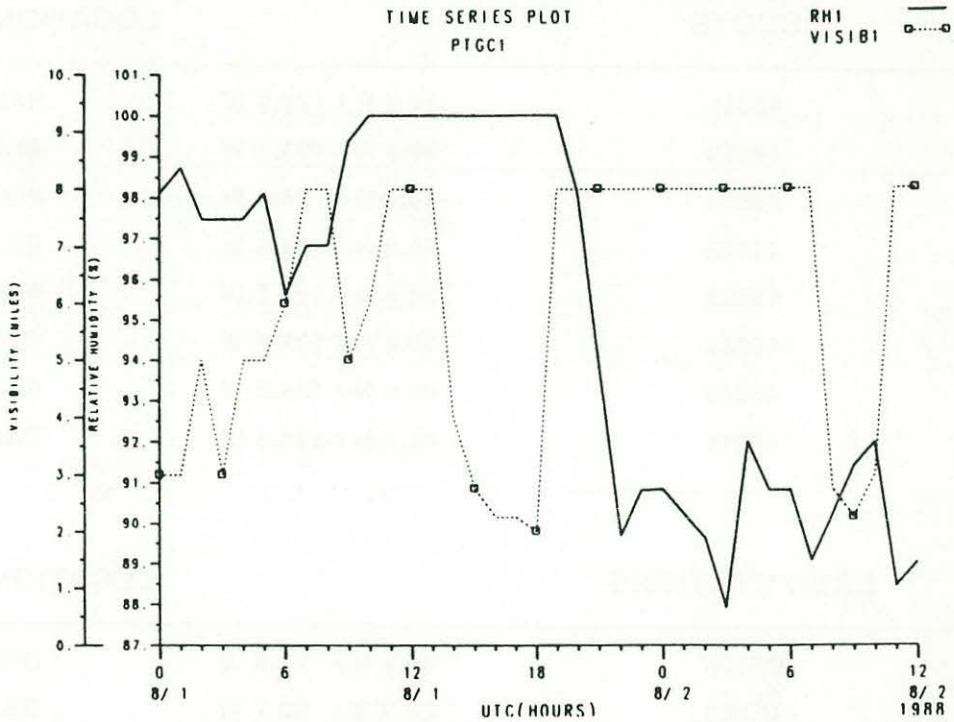

Figure 12. A Time Series Plot of Visibility and Relative Humidity for PTGC1 During August 1-2, 1988

The Impulsphysik visibility sensor showed no serious discrepancies, and importantly, the sensor responded well in fog. The visibility sensor operated in the field for 5 months without failure.

As the results of the field evaluation were favorable, NDBC has qualified the Rotronic humidity sensor for operational use, and dewpoint will be sent in real-time to the user community. The visibility values from PTGC1 are currently being released.

Bruce Hundermark, CSC

(C-MAN) CONTINUED

- JTWC—NAVWESTOCEANCEN
  - — Operational network implementation planning and management
  - — Installation logistic support
  - — Selection of AMOS locations and determining installation priorities
- NWS Pacific Region
  - — Program Management
  - — Obtain required clearances from local island governments
  - — Planning and management of fund transfers
- Department of Interior
  - — Funding for system installation, operation, and maintenance (field and depot), via NWS Pacific Region
- NDBC
  - — Identify system configuration
  - — Procure hardware
  - — Design and install systems
  - — System life cycle maintenance (field and depot)
  - — Operational data quality

The JTWC in Guam is extremely pleased with the quality of the data being received from the demonstration system on Faraulep Island. The reliable performance of this first station has demonstrated that an operational WESTPAC-AMOS network would provide a significant enhancement to tropical analyses in the Western Pacific.

Ron Kozak, NDBC

Table 1. A List of NDBC Stations with Rotronic Humidity Sensors Installed

BUOYS	LOCATION	
46011	34.9 N / 120.9 W	SANTA MARIA, CA
46013	38.2 N / 123.3 W	BODEGA BAY, CA
46014	39.2 N / 124.0 W	POINT ARENA, CA
46022	40.8 N / 124.5 W	EEL RIVER, CA
46023	34.3 N / 120.7 W	POINT CONCEPTION, CA
46028	35.8 N / 121.9 W	CAPE SAN MARTIN, CA
46040	44.8 N / 124.3 W	CAPE FOULWEATHER, OR
46041	47.4 N / 124.5 W	CAPE ELIZABETH, WA

LAND STATIONS	LOCATION	
DSLN7	35.2 N / 75.3 W	DIAMOND SHOALS LIGHT, NC
GDIL1	29.3 N / 90.7 W	GRAND ISLE, LA
PTGC1	34.6 N / 120.7 W	POINT ARGUELLO, CA
SGNW3	43.8 N / 87.7 W	SHEBOYGAN, WI

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