Technical Bulletin
National Data Buoy Center

VOLUME 16, NUMBER 1 JANUARY 1990

JOINT OIL INDUSTRY METEOROLOGICAL/OCEANOGRAPHIC MEASUREMENT SYSTEM (MOMS)

On May 12, 1989, a memorandum of Agreement was signed between NWS and Chevron USA for NDBC support of the joint industry project called MOMS. The MOMS project is a 3-year Gulf of Mexico measurement program that will provide improved environmental information for hurricane evacuation, daily industry operations planning, and design criteria for future deep-water oil platforms. The project is funded by Arco Oil and Gas Company, Chevron USA, Exxon Production Research Company, Halliburton Services, and Shell Development Company. Chevron USA, is the Project Administrator.

Presently, the MOMS stations consist of two NDBC Coastal-Marine Automated Network (C-MAN) stations on Chevron's Main Pass 133C and Garden Banks 236A production platforms, and industry-maintained stations on Exxon's Lena platform and Shell's Bullwinkle platform. Figure 1 shows the locations of the MOMS stations and two standard NDBC 3-meter buoys funded by the Minerals Management Service (MMS). These buoys will be deployed prior to April 1, 1990. The buoys support efforts to improve MMS's modeling capabilities used to develop impact statements for the oil and gas lease programs. Together, these six stations greatly enhance the observation network in the Gulf of Mexico.

The MOMS stations will measure wind speed and direction, barometric pressure, air temperature, surface water temperature, and directional waves. The wave systems on the Chevron platforms are installed and maintained by Chevron. The industry participants are also measuring current speed and direction with time series current, and directional wave data recorded during significant events. The MMS buoys measure wind speed and direction, barometric pressure, air temperature, surface water temperature, and one-dimensional wave spectra.

The NDBC system on the Garden Banks platform nearly duplicates the Main Pass 133C installation described in *Technical Bul-*

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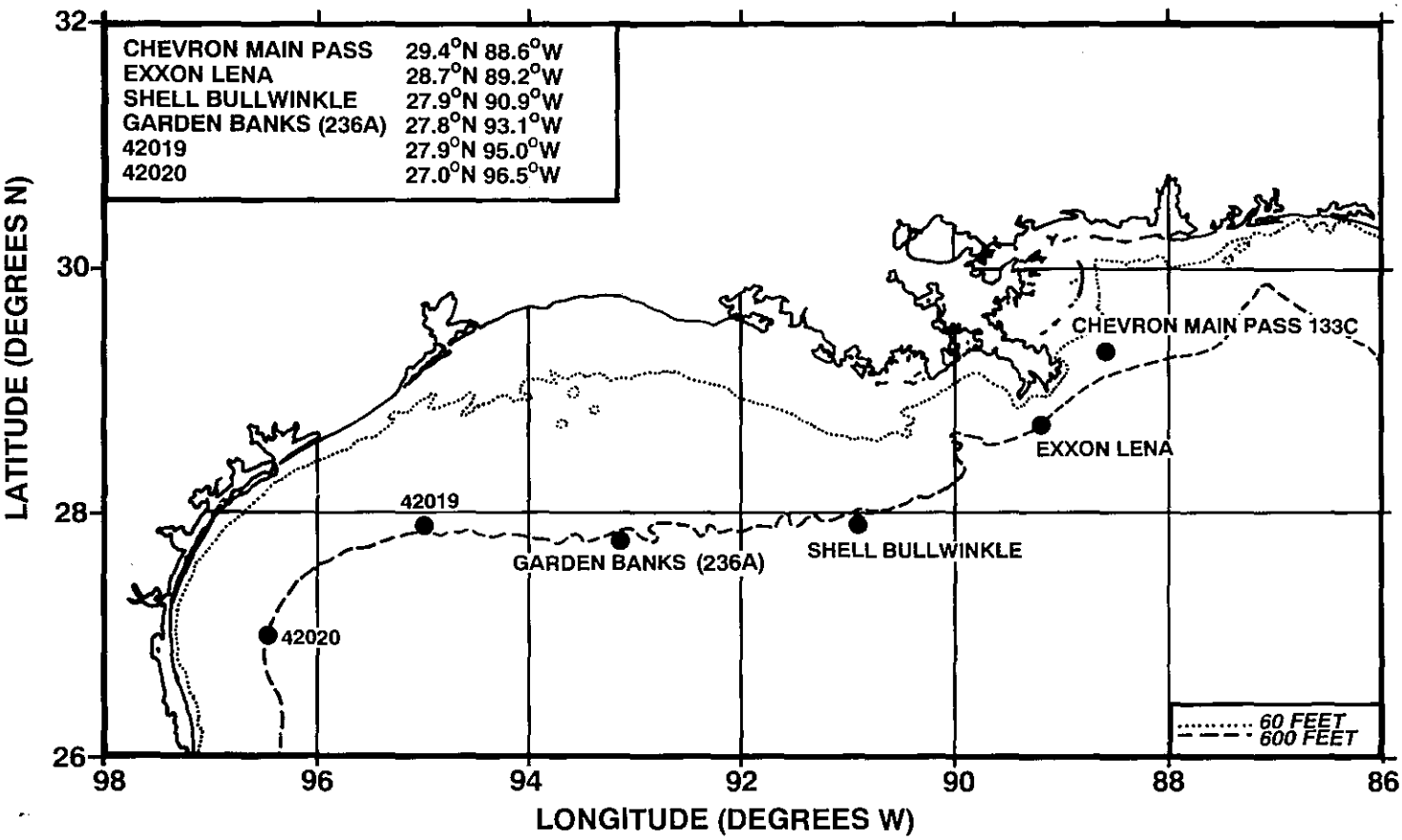

Figure 1. MOMS Stations and Two Standard 3-Meter Buoys Funded by MMS

WIND TUNNEL

In July, a new wind tunnel was placed in operation at the National Data Buoy Center (Figure 2). It is used both for routine calibrations of wind sensors and for experimentation with new anemometers and other meteorological instruments.

The tunnel has a test chamber with a 24- by 24-inch square cross section and a length of 4 feet. Clear plastic doors that swing up on both sides of the test section allow easy access for installing and observing the test objects. Maximum operating wind speed is 120 knots (60 meters per second nominal). The air speed is continuously adjustable down to a minimum of 1 knot by changing the rotation rate of the tunnel's single, motor-driven impeller.

A closed circuit (recirculating) wind tunnel design was chosen to permit a more uniform control of the test wind speed, especially during low flow rate conditions. A recirculating type tunnel is more convenient to use in a closed laboratory area because the return flow is contained inside a duct. Another good feature is that acoustic noise from the motor, impeller, and air flow is contained inside the tunnel and does not disturb the adjacent working areas.

The drive system, which is located inside the air return section, consists of a multiblade impeller directly connected to the output shaft of a 40 horsepower DC motor. Speed control of the motor is accomplished by a modern digital adjustable controller complete with silicon controlled rectifiers and a programmable microprocessor. A very accurate and stable tunnel wind speed is possible with this system. Also, the digital adjustable controller microprocessor portion is a convenient interface for automation of the tunnel's operation through use of a standard computer/controller.

A special feature of the NDBC recirculating wind tunnel is the cooling coil section. Heat must be removed from the air stream, especially during high wind speed operation, in order to maintain the internal air temperature at less than 100°F. Ambient-temperature cooling water is passed through the coils to remove the excess heat. It is also possible to bring the air temperature inside the tunnel to as low as 32°F by chilling the coil's cooling fluid. This can be accomplished only if the tunnel wind speed does not exceed 20 knots. Wind speed inside the tunnel is measured by using two static pressure orifice rings located just up-stream of the test section. One ring is around the four walls of the large cross section air settling chamber and the other ring is at the entrance of the test section. For each ring there are four pressure-sensing orifices, one through each of the four walls of the tunnel, all manifolded by a tubing loop. The difference in the static pressure sensed by the two rings is accurately measured by an electronic differential pressure sensor. The tunnel wind speed is then computed using the measured pressure difference values and the fluid dynamic relations for a venturi tube. The wind tunnel manufacturer has also calibrated this air-speed-measuring system against a reference pitot-static tube placed in the middle of the test section.

The new wind tunnel is part of NDBC's environmental test laboratory that is used to routinely monitor the operational readiness of electronic/sensor systems as well as to evaluate new developmental systems.

Ed Michelena, NDBC

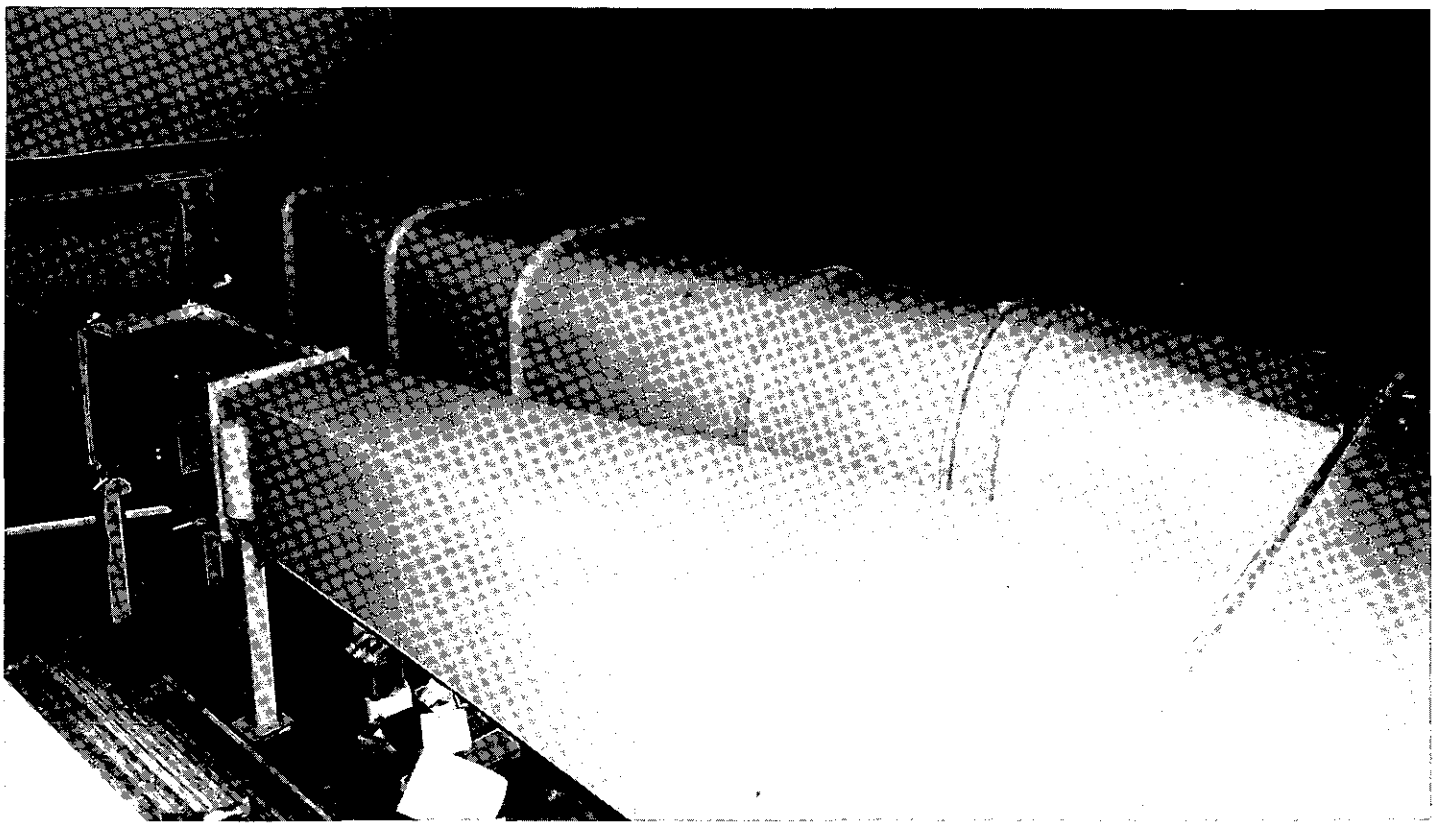

Figure 2. NDBC Wind Tunnel

NDBC DRIFTING BUOYS DEPLOYED IN THE VALDEZ OIL SPILL

On April 7, 1989, a request was received by NDBC from the NWS Alaska Regional Office in Anchorage, Alaska, to deploy drifting buoys in the Exxon Valdez oil slick. The oil slick had moved out of Prince William Sound into the Gulf of Alaska, heading in the direction of Kodiak, with the threat of entering Kamishak Bay and Cook Inlet. It had also become a threat to polluting the shores of the Kenai National Wildlife Refuge.

On April 10, 1989, NDBC shipped, via air transport, drifting buoys from their rapid response inventory to Anchorage. The buoys arrived in Anchorage on April 11, 1989. They were then shipped by truck from the airport in Anchorage to the USCG Command Post in Seward. The next day, the buoys were assembled, tested, and prepared for deployment.

The buoys were loaded on a local fishing vessel, *New Dawn*, from Seward. The *New Dawn* was contracted by VECO Corporation for the buoy deployments. VECO was the major support contractor hired by Exxon for the oil spill cleanup operation. The *New Dawn* departed late afternoon on April 12, 1989, to deploy the buoys at strategic locations in the Gulf of Alaska. The deployment locations were determined by scientists with the NOAA Hazardous Materials Response Team located at the NOAA Command Post in Valdez. On April 13-14, 1989, the buoys were deployed as indicated in Figure 3. Table 1 presents a synopsis of the buoy activity for this deployment.

The performance of the buoys was extremely valuable in supporting the efforts of the NWS in Anchorage, the NOAA Hazardous Materials Response Team in Valdez, and the U.S. Coast Guard in Seward. Buoy position data accurately tracked the movement of the oil. The buoys were especially effective in tracking the oil once the slick dissipated and the oil congealed into tarry lumps and sank just below the water surface (approximately 1 meter).

One buoy in particular (46507) circulated within an eddy for a few days (reference Figure 3). Knowledge of this eddy and its characteristics was of critical importance to everyone involved in the clean-up operations. An eddy tends to draw in the oil. Vast amounts of oil will accumulate within the

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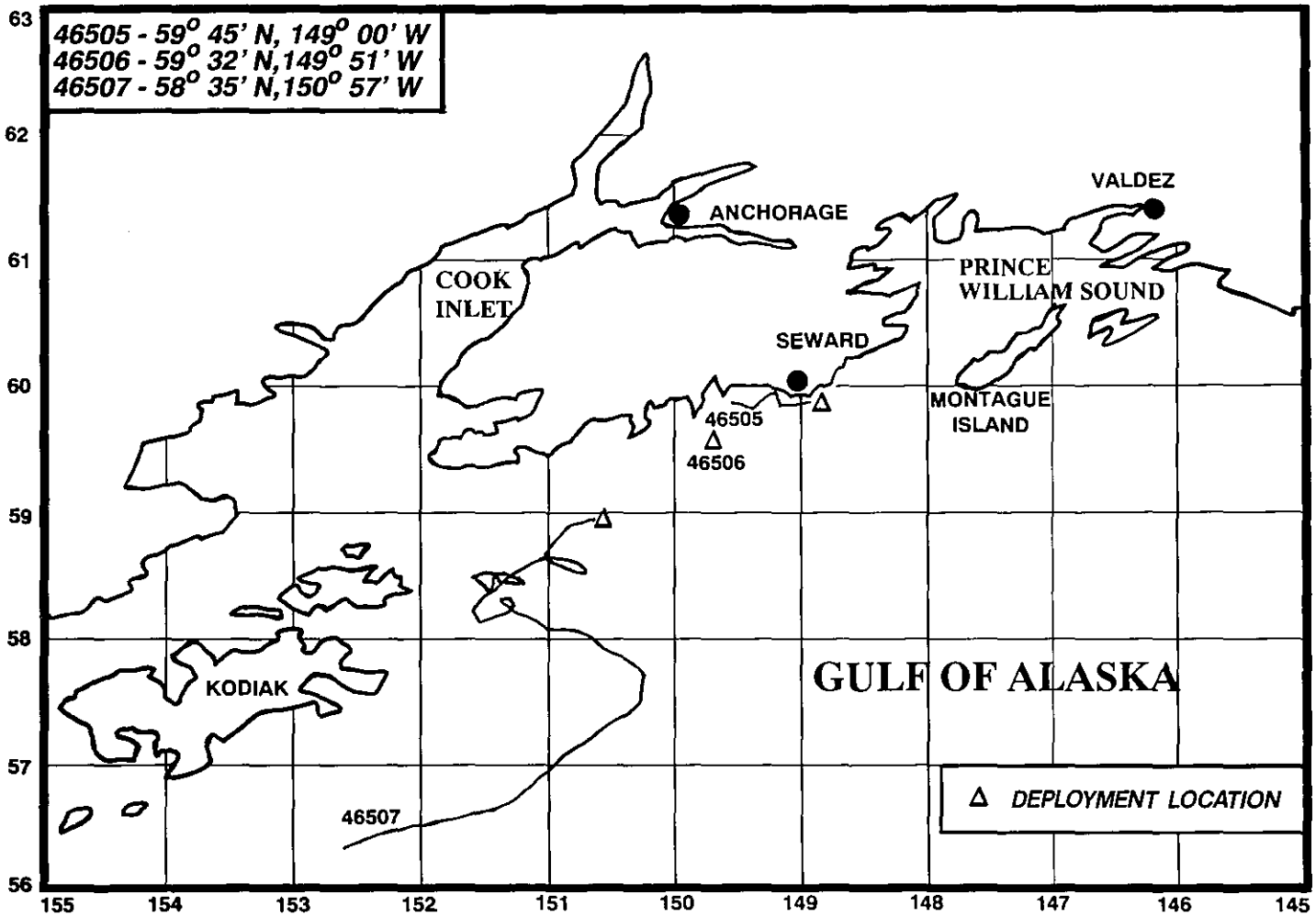

Figure 3. Drifting Buoy Tracks Valdez Oil Spill April 13 to May 31, 1989

OIL SPILL CONTINUED

Table 1. Synopsis of Buoy Activity for this Deployment

BUOY ID	TYPE	DEPLOYMENT DATE/TIME	DEPLOYMENT POSITION	SENSOR PARAMETERS	REMARKS
46505/8967	TOGA	4/13/89 06:15 A.M.	59°45'N 149°07'W	AIR PRESSURE WATER TEMPERATURE AIR TEMPERATURE	BUOY RAN AGROUND 4/28/89, POSITION 59°47'56"N —149°31'37"W. ALL SENSORS WERE OPERATIONAL PRIOR TO GROUNDING.
46506/8968	TOGA	4/14/89 12:23 P.M.	59°35'N 149°39'W	AIR PRESSURE WATER TEMPERATURE AIR TEMPERATURE	(1) WATER TEMPERATURE SENSOR FAILED 4/18/89. (2) BUOY RAN AGROUND 4/21/89, POSITION 59°36'50"N — 149°37'44"W. ALL SENSORS WERE OPERATIONAL PRIOR TO GROUNDING, EXCEPT WATER TEMPERATURE.
46507/5567	WSD	4/13/89 11:16 P.M.	58°36'N 150°57'W	AIR PRESSURE WATER TEMPERATURE AIR TEMPERATURE WIND GUST DROGUE ON/OFF INDICATION	BUOY RAN AGROUND ON 9/17/89, RECOVERED RECOVERED BY USCG ON 10/3/89 AND RETURNED TO NDBC FOR REFURBISHMENT

eddy and remain within the eddy until the eddy dissipates. The buoy's data not only made it possible to identify the eddy, but when the eddy dissipated, the buoy broke loose and headed in a southwesterly direction, just as did the large accumulated mass of oil.

In addition to the effectiveness of the buoy position information, the meteorological data provided by the three buoys allowed the NOAA Hazardous Materials Response Team to make major improvements in their oil-spill computer models. Even though buoys 46505 and 46506 ran aground within a short time after deployment, the data provided prior to their running aground were very valuable. Ocean currents and water circulation patterns are continually changing and difficult to predict in ocean areas adjacent to the coastal shoreline, especially around particular points and peninsulas. The buoy tracks identified these unknown currents and circulation patterns, and the meteorological data allowed realistic conclusions to be made in determining the causal relationship that exists between changes in meteorological parameters and their effect on near-shore ocean currents and water circulation, and, in turn, oil-slick movement.

Ron Kozak, NDBC

NDBC TO PUBLISH WAVE USER GUIDE FOR NWS

NDBC recently funded development of a user's guide intended to make wave information more understandable to marine forecasters and other real-time users. The 30-page booklet, User's Guide for NDBC Real-Time Directional Wave Information, was authored by Dr. Marshall D. Earle of MEC Systems Corporation, Manassas, Virginia, under subcontract from Computer Sciences Corporation, the Data Buoy Support Contractor.

The guide is intended for National Weather Service (NWS) operational forecasters, rather than oceanographers or modelers who specialize in ocean waves. It begins with simplified explanations of most-used wave terminology, and a breakdown of the wave code as it appears on the Automation of Field Operations and Services (AFOS) communications system. It also tells how AFOS wave information is presented and properly interpreted. For example, the analysis of wave energy in two different frequency bands can be used to estimate the distance of the swell source from the measurement location. Other uses might be modification of wave height forecasts due to fetch limitation, and assessment of wave refraction near coastal locations.

Finally, the guide explains how waves are measured by buoys, how the data are processed, and the limitations of the wave data. Detailed mathematics are not used in the text, but are limited to an appendix. Another appendix provides rigorous definitions of important wave terms. Finally, a third appendix shows examples of ways that directional wave spectra can be presented for practical interpretation.

Dr. Earle travelled to the National Weather Service Forecast Offices (NWSFO's) in Los Angeles and San Francisco to talk to the meteorologists to see how they use wave data and to gain an insight into how NWS forecasters provide marine forecasts. A draft of the guide has been sent to selected NWSFO's, Regional Offices, and NWS Headquarters for review and comments. Their comments will be incorporated, and the final version of the guide will be distributed in early 1990 to all NWSFO's with marine forecast responsibilities. It is intended to be a "living" document, and will be periodically revised. Forecasters are encouraged to read the guide and, if they have any constructive changes, to pass them on to the NDBC Data Systems Division, Building 1100, Stennis Space Center, Mississippi 39529-6000.

Eric Meindl, NDBC

PROFILER SURFACE OBSERVING SYSTEMS

NDBC has been supporting NOAA's Environmental Research Laboratories (ERL) Profiler Program since 1984 (August 1987 issue, Vol. 13, No. 2 and December 1985 issue, Vol. 11, No. 2). The primary area of NDBC support has been in the systems engineering and procurement of the 404.37 MHz Doppler radar wind profiler systems scheduled to be installed at some 30 sites in a demonstration network across the central United States. This procurement, which was competitively awarded to the Unisys Corporation, is now in the production phase, with unit deliveries to begin in early 1990.

ERL has a requirement to obtain surface meteorological observations at selected profiler sites for network assessment purposes and other uses. Based on NDBC's nearly 20 years of experience in the development and operation of automated environmental monitoring equipment, ERL approached NDBC regarding the implementation of Profiler Surface Observing Systems (PSOS). In April 1989, a prototype PSOS system, measuring wind speed and direction (dual sensors), barometric pressure, air temperature, dewpoint, and rainfall amount, was installed at the Number 1 profiler prototype site in Platteville, Colorado. An additional eight PSOS systems are scheduled to be installed at the production profiler sites shown in Figure 4. These "operational" PSOS units will measure the same parameters as the Platteville prototype with the exception of barometric pressure.

At the heart of a PSOS installation is the Value Engineered Environmental Payload (VEEP) controller module, which contains the electronics system that acquires raw data from the sensors, filters and scales those data, formats the data, and relays the most recent message to the profiler. All data except for rainfall (which is a continuous, tipping-bucket count reset every 6 minutes), are sampled and averaged over a 2-minute period for each profiler polling cycle, which is 6 minutes in length. Thus, the PSOS VEEP produces 6-minute, updated messages corresponding to the 6-minute wind profile report. The PSOS is not equipped with a separate data relay system, such as a GOES transmitter; instead, all data are passed directly to the profiler for incorporation into the profiler message to the ERL-operated Hub in Boulder, Colorado.

NDBC is procuring all basic and spare equipment for PSOS and will be installing the systems with its support contractor in conjunction with the Unisys profiler installations. Subsequently, PSOS field maintenance will be performed by NWS electronics tech-

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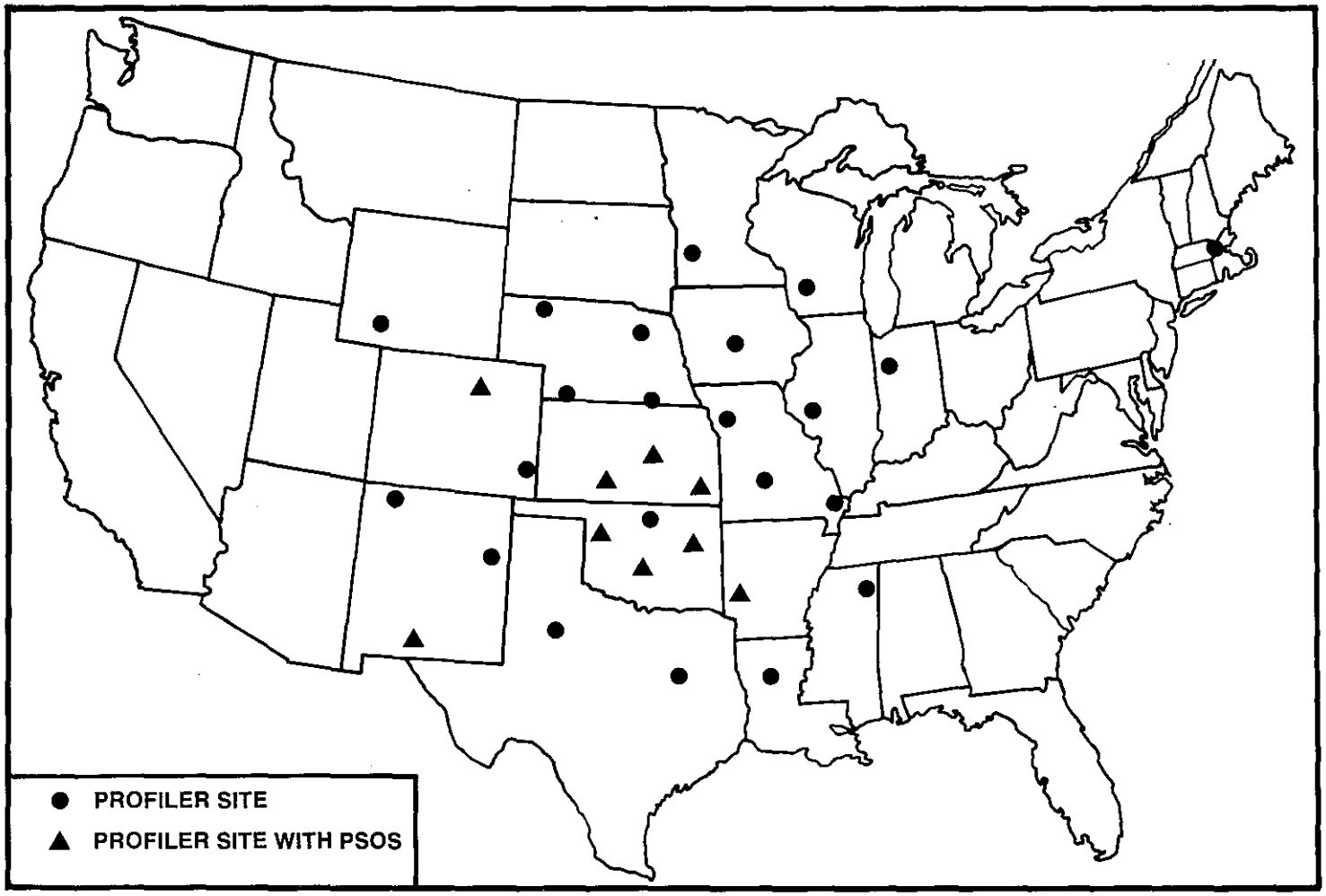

Figure 4. PSOS Sites

WSD BUOYS IN GULF OF MEXICO

Over the past 2 years, NDBC has been evaluating the capability of a drifting buoy to measure wind speed and direction. Such measurements would be particularly valuable for tropical applications, where atmospheric pressure gradients can give a poor approximation of wind speed and direction. An initial evaluation of a Wind Speed Direction (WSD) drifting buoy was conducted by NDBC in 1988 (see "An Evaluation of Wind Speed and Direction Measurements from a Drifting Buoy" by Eric Meindl, National Data Buoy Center, and Bruce Hundermark, Computer Sciences Corporation, Proceedings of MDS '89 Conference). In this study, a WSD drifting buoy was moored adjacent to a 12-meter discus buoy, and a comparison was made. Results showed that in moderate to high wind speeds (4-15 m/s), the wind speeds reported by the drifting buoy compared favorably with the moored buoy data. However, the WSD buoy exhibited a starting threshold of approximately 4 m/s. In other words, in a wind flow of 4 m/s or less, the drifting buoy tended to report calm. Drifting buoy wind directions showed good agreement with the moored buoy data.

As a further field evaluation, two WSD drifting buoys (WMO ID's 42524 and 42525) were deployed in the central Gulf of Mexico at 27°04'N, 88°03'W (approximately 200 miles south of Mobile, Alabama) on April 28, 1989. The buoys were deployed in the center of an eddy that had recently detached from the loop current. It was anticipated that the buoys would circulate in this eddy for at least a few weeks, and thus remain in the vicinity of some of NDBC's moored buoys. This would allow for a reliable assessment of the drifting buoys' performance.

The WSD buoys used in the experiment were the standard hulls used in the First GARP Global Experiment (FGGE) and the Tropical Ocean and Global Atmosphere (TOGA) projects, except modified with a rectangular wind vane attached to the antenna to align the buoy into the wind (Figure 5). The wind module included a Digicourse compass and a Savonius rotor. Two buoy configurations were deployed, one buoy was equipped with a drogue and one buoy did not have a drogue. Buoy 42524 was equipped with 100 meters of 1-inch, braided nylon line terminated with a 45-kg weight, while buoy 42525 was free floating. The two buoys were manually deployed from the research vessel *Mañana*. Several checks of the drifting buoys were made prior to departure and during the deployment operation. The transmitted data from the drifting buoys were verified before departure using the standard buoy test set, and, in addition, the drifting buoy data were compared with ground truth collected during the deployment.

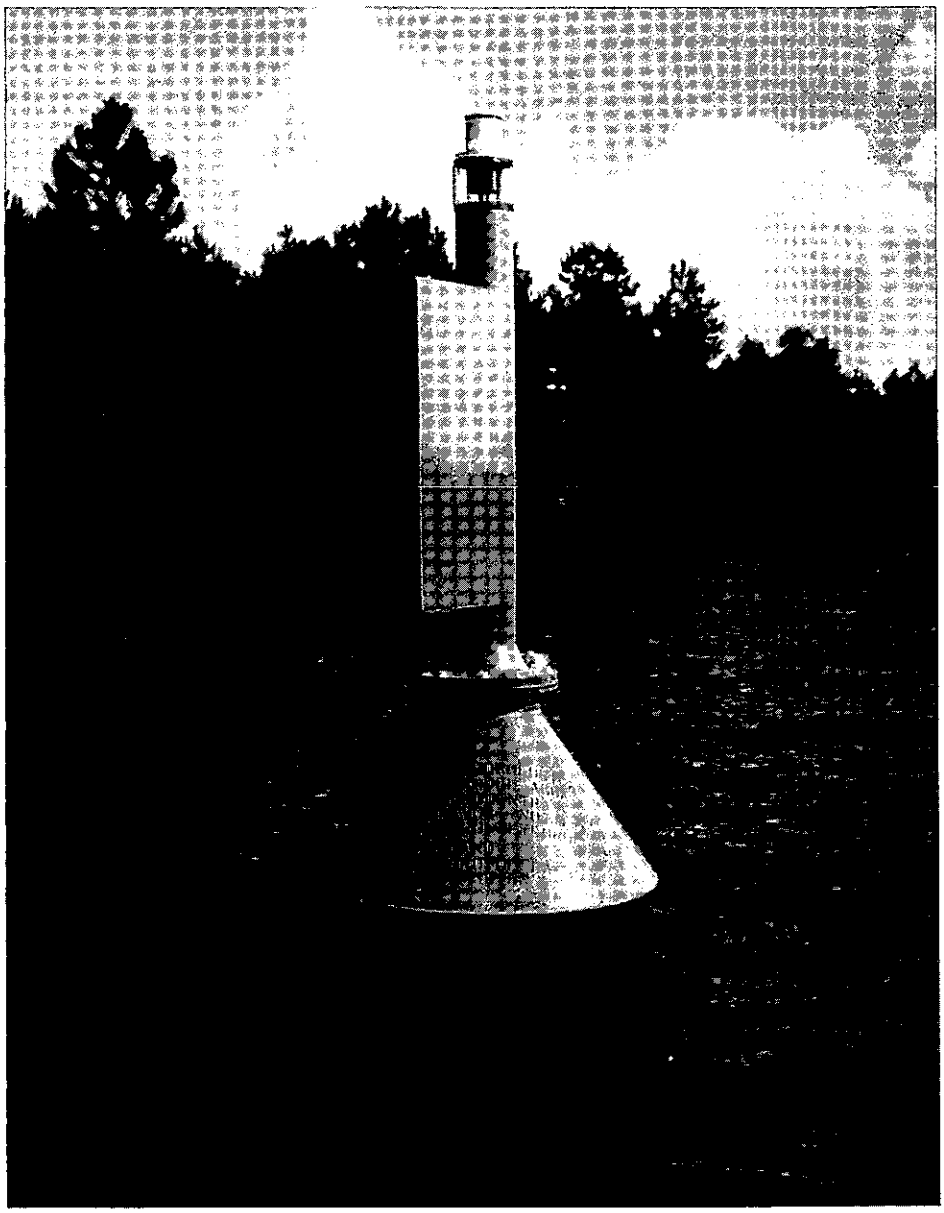

Figure 5. Wind Direction Drifting Buoy

Figure 6 and 7, respectively, display the drift tracks of buoys 42524 and 42525 from May 1 on. Generally, both of the buoys circulated in the central Gulf of Mexico under the influence of an eddy that had detached from the loop current. Eventually, however, both buoys drifted out of the influence of the eddy. Buoy 42525 became influenced by the loop current and drifted east into the Florida Straits, where it was eventually recovered by NDBC. The other buoy, 42524, surprisingly, became caught in a feature to the northwest of Cuba and drifted south through the Yucatan Channel and into the Caribbean where it entered an eddy. It finally went aground on the Isle of Pines.

For this latest evaluation, almost three months (April 28 - July 20, 1989) of data were collected for analysis. Preliminary results showed that the drifting buoys performed well during the field test. Wind speeds reported by the drifting buoys, adjusted to the 10-meter level, while generally lower, remained within 2 m/s of the wind speeds reported by the moored buoys. Wind direction differences were mostly less than 30 degrees. For example, the time series plot in Figure 8 displays the wind speed reported by the drifting buoy 42524, adjusted to 10 meters, and the wind speeds measured by the 10-meter discus buoy 42003 for the time

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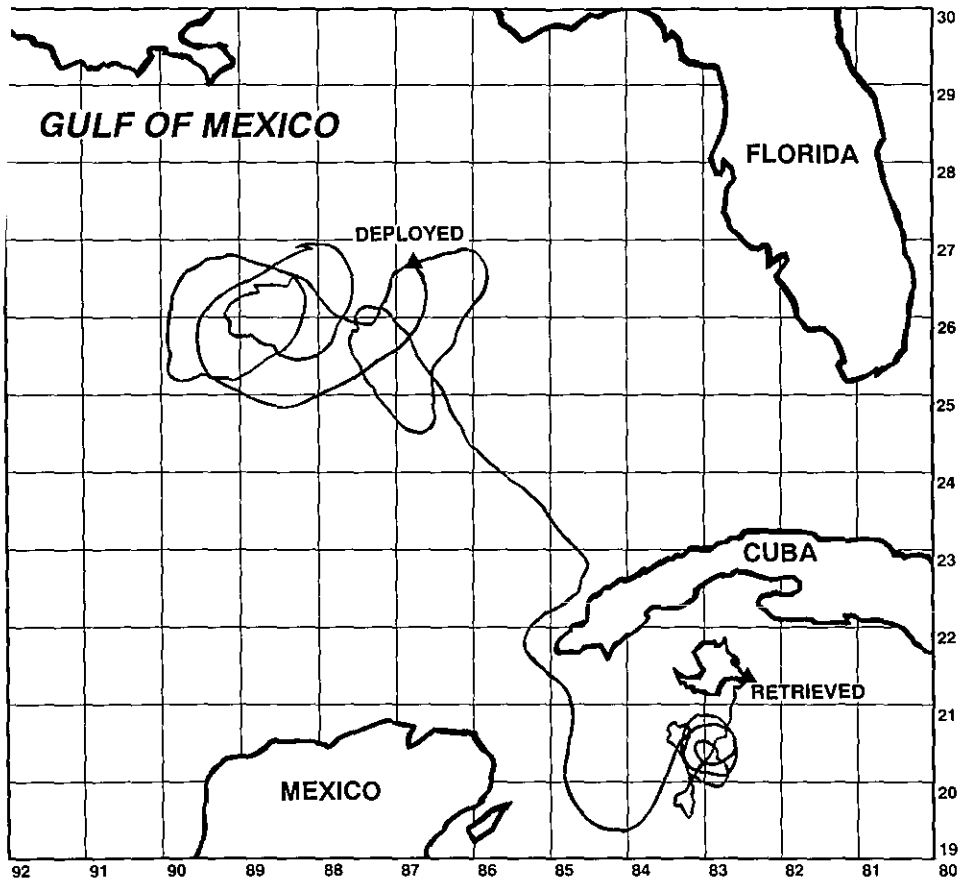

Figure 6 . Drift Tracks of Buoy 42524 , May 1-October 2, 1989

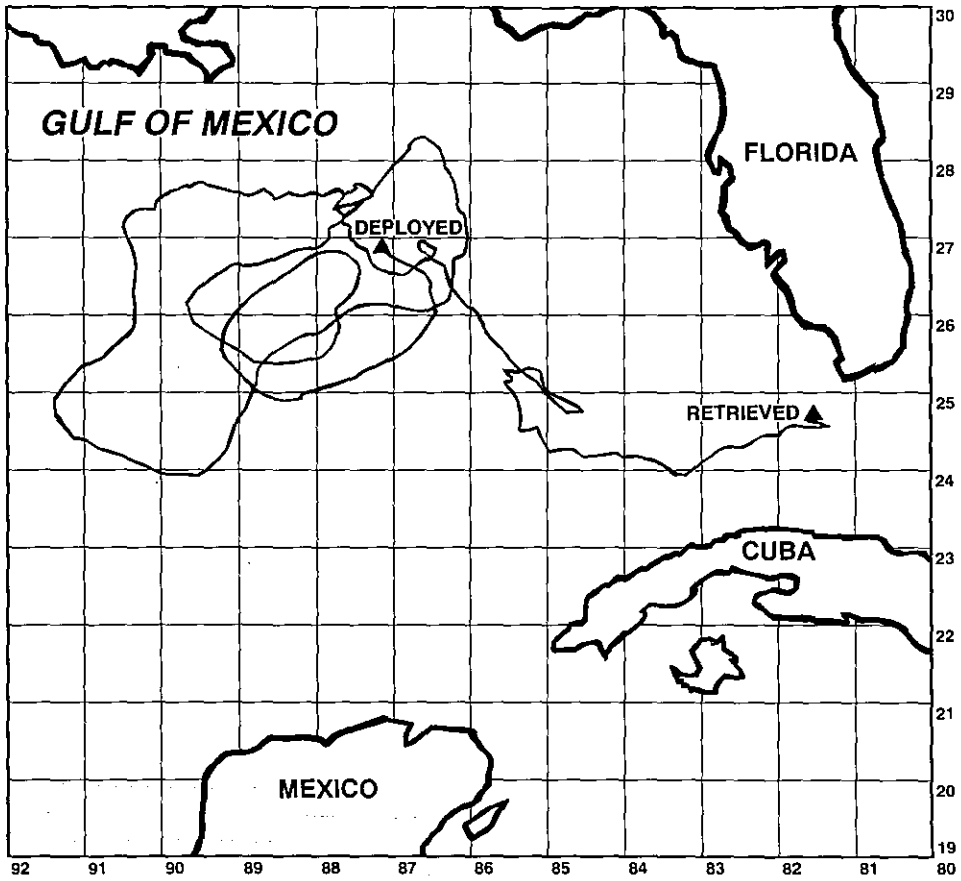

Figure 7. Drift Tracks of Buoy 42525, May 1 -July 21, 1989

PROFILER CONTINUED

nicians, with depot level support and equipment refurbishment provided by NDBC at Stennis Space Center, Mississippi. At present, NDBC is developing PSOS field maintenance training briefings and procedures for NWS personnel.

As with all NDBC-operated networks, NDBC will institute rigorous data quality control for PSOS. Real-time, automated gross range and time continuity checks will be installed at the profiler data Hub in Boulder. Further data quality checks will take place at NDBC on a next-day basis using NDBC's standard man-machine techniques. In cooperation with the profiler Hub, unacceptable data will be deleted from profiler messages prior to dissemination from the Hub. PSOS reports will only be available in the binary ("BUFR") messages containing profiler data.

In the next year or two, PSOS requirements could grow to include all of the 30 sites in the profiler demonstration network. NDBC is prepared to implement reliable, cost-effective systems to support this expansion, should it occur. Concurrently, NDBC's objective is to ensure that all installed PSOS units provide the timely and high-quality observations necessary to achieve Profiler Program goals.

W. B. Wilson, NDBC

CORRIGENDA

The following corrections should be noted to VOL. 15, NO. 1 of the *Technical Bulletin*:

Page 3, first paragraph of article entitled "An Evaluation of Wind Data from a WSD Buoy, lines 20-22 should read "speed and Direction Drifter Operational Test and Evaluation," Computer Sciences Corporation,..."

Page 7, the first line of the second paragraph of Article entitled Evaluation of Humidity and Visibility Sensors, should read "The humidity sensor used on NDBC sta-..."; it was inadvertently left off.

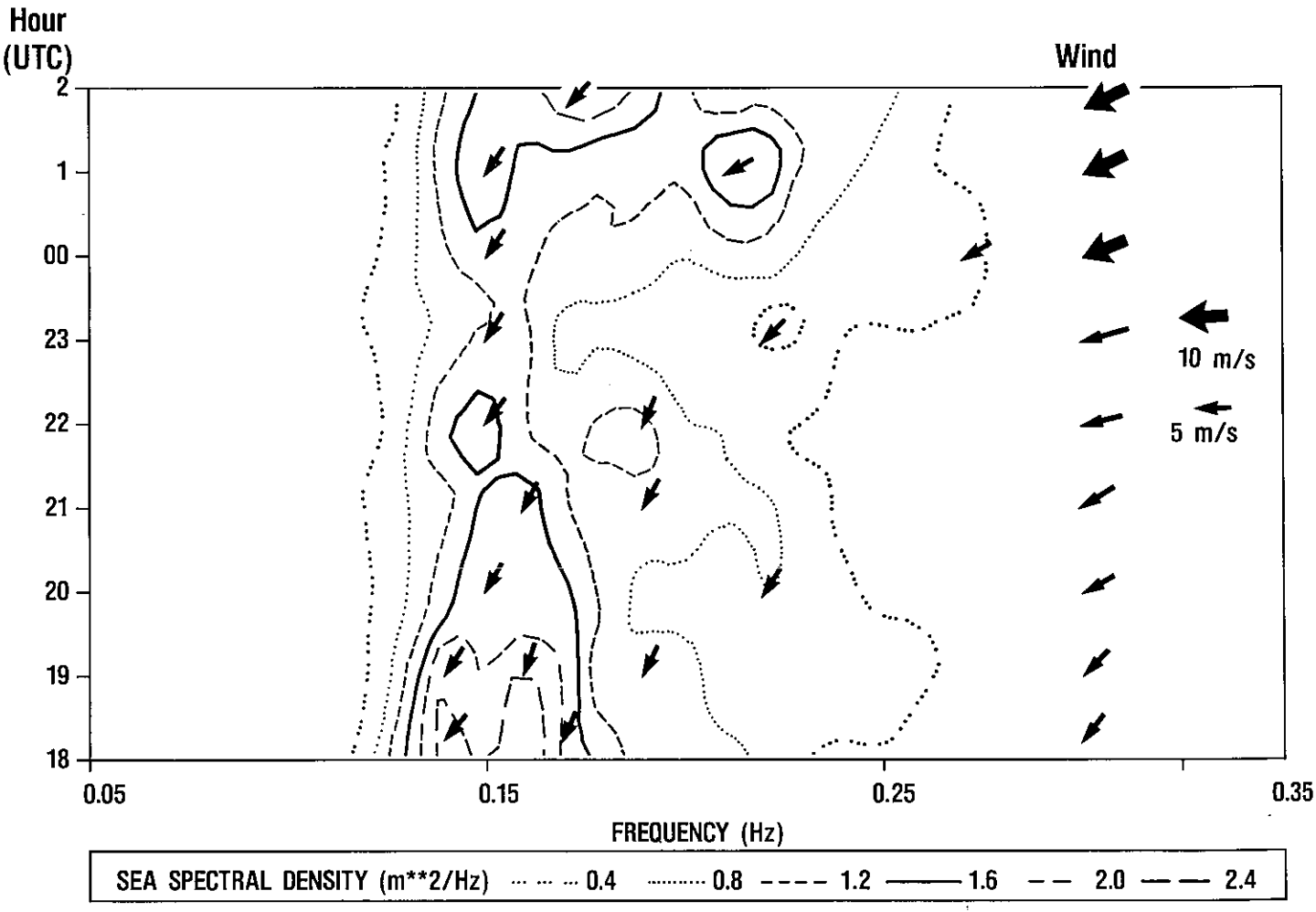

Figure 11. Contours of Spectral Density During a Wind Shift of 40°

NDBC PUBLICATIONS

The following is a compilation of articles written or co-authored by NDBC or NDBC Support Contractor Personnel since June 1988. Copies of Articles are available upon request.

1. Wilson, Brett, 1988, "A Method for Optimizing Environmental Observing Networks," Proceedings OCEANS '88.
2. Meindl, Eric, 1988, "Drifting Buoy Data Quality and Performance Assessment at NDBC," Proceedings OCEANS '88.
3. Gilhousen, Dave, 1988, "Methods of Obtaining Weather Data in Real Time," Proceedings OCEANS '88.
4. .Brown, Hal, 1988, "Infrared Laser Wave Height Sensor," Proceedings OCEANS '88.
5. Ladner, Lloyd, 1988, "Lake Superior Winter Weather Station," Proceedings OCEANS '88.
6. Gilhousen, Dave, 1988, "An Evaluation of Non-NDBC Automatic Weather Station Data," NDBC Blue Book 1801-24-03.
7. May, LT Daniel, 1988, "Mooring Performance Evaluation CY-1987," NDBC Blue Book 1804-03-01.
8. Meindl, Eric, 1988, "NDBC Data Availability Summary," NDBC Blue Book 1801-24-02 Rev. C.
9. Sharp, James, 1989, "NDBC 1988 Annual Report," NDBC Blue Book 203-01-06.
10. Gilhousen, Dave, 1989, "Field Evaluation of NDBC Directional Wave Data," Workshop for Wave Hindcasting and Forecasting.
11. Chung-Chu, David Wang, and Kenneth Steele, 1989, "Mathematical Simulations and Physical Model Tests on Hull Development of a Coastal Data Buoy," Proceedings Marine Data Systems Conference (MDS '89).
12. Meindl, Eric, 1989, "An Evaluation of Wind Speed and Direction Measurements from a Drifting Buoy," Proceedings MDS '89.
13. Hundermark, Bruce, 1989, "Field Evaluation of the Rotronic Humidity Sensor and Impulsphysik Visibility Sensor," Proceedings MDS '89.
14. Abell, Fred, 1989, "The Quality of Drifting Buoy Data -- A Status Report," Argos User's Conference.
15. Gilhousen, Dave, 1989, "How To Acquire NDBC Data," Brochure.
16. Wang, David, Chung-Chu Teng, and Kenneth Steele, 1989, "Buoy Directional Wave Observations in High Seas," Proceedings OCEANS '89.
17. Colburn, CDR Ted, 1989, "NDBC's Coastal Buoy," Proceedings OCEANS '89.
18. McCall, Jerry, 1989, "New Programs at the National Data Buoy Center," Presented at U.S. Marine Facilities Panel Meeting.

DIRECTIONAL WAVE DATA FROM LAKE ERIE

NDBC has operated an environmental data buoy at station 45005 in Lake Erie during the ice-free part of each year since 1980 (See Figure 12). This buoy has routinely measured and reported meteorological data and non-directional spectra each hour. Through support received from the Corps of Engineers (COE) Coastal Engineering Research Center (CERC) at Vicksburg, Mississippi, NDBC recently upgraded this buoy to report directional wave data. It was deployed at (41 40'05 N, 82 23'03 W) in 15 meters water depth on May 12, 1989. Directional wave data from 45005 are characterized by a minimum of swell, and thus are ideal for a study of wind-driven seas without much interference from swell.

From 1800 Z on August 6, 1989, through 1200 Z on August 7, 1989, was a period when wind speeds, at times, were significantly above average. Figure 13 shows the nondirectional spectrum from heave (C11) and slope (C11S) sensors, as well as mean (ALPH1) and principal (ALPH2) wave directions at the hour of strongest winds, 0000 Z on August 7, 1989. Parameters in Figure 14 are in units of degrees, meters, seconds, and meters/second (m/s). At this hour, both mean and principal wave directions were very well aligned with the wind in those portions of the spectrum where energy density was comparable to that at the peak of the spectrum.

Shown in Figures 14 and 15, among other data, are wind speed (WSPD1) and wind direction (WDIR1) measured by the #1 wind sensor aboard the buoy during the specified period. Wind speed ranged between approximately 3.6 and 10.2 m/s. Wind direction was very steady from 2100 Z on August 6, 1989, through 1100 Z on August 7, 1989. Winds were essentially from the north and varied in direction approximately ±10 degrees. Shown also in Figures 14 and 15 are the mean and principal wave directions at 0.35 Hz and 0.25 Hz.

Although wind direction after 2000 Z on August 6, 1989, was steady, wind speed was not, so stationarity may not be assumed. Under these circumstances, one might wonder how well the mean and principal wave directions at various frequencies would track the wind direction. Figure 14 shows directional wave data for the shortest period reported (f = 0.35 Hz, period=3 sec.). At 1800 Z, both mean and principal wave directions were at about 285 degrees and coincided with the wind direction. As wind direction shifted clockwise by 75 degrees to a generally north direction, both wave directions together slowly began to change towards north, but lagged behind wind direction, as one might expect. The wave directions caught up with wind direction at 2300 Z, 2 hours after the wind direction had stabilized. It is interesting that the two wave directions agreed with each other throughout the period when the wind was changing direction, and for about 3 hours after it stabilized. During this latter 3 hours, the wind was increasing.

After 0000 Z on August 7, 1989, the wind speed decreased for several hours, although its direction remained steady. Coincident with this decrease, the principal wave direction deviated from wind direction by from 20 to 60 degrees, while the mean wave direction continued to track the wind direction for the most part.

Figure 15 shows the same type data for a wave period of 4 seconds (f = 0.25 Hz). During the wind direction-change period, the pattern of behavior for wave directions is similar to that for 3 seconds, except that mean wave direction lags behind principal wave direction in the process of each getting aligned with the new wind direction. After the wind becomes steady in direction, both wave directions track wind direction very well, even during the falling-wind-speed period.

The behavior of mean and principal wave directions at 0.25 and 0.35 Hz raises some interesting questions. Energy densities usually build up from high frequencies to low, so why did the 0.25 Hz waves align themselves with the wind more quickly than did those at 0.35 Hz? And why did the principal wave direction at 0.25 Hz remain aligned with the wind, which was unchanging in direction as it decreased, whereas the principal wave direction at 0.35 Hz did not? We have no immediate answers to these questions. We hope that researchers may use the large quantities of directional wave data already archived by NDBC to answer such questions.

Ken Steele, NDBC

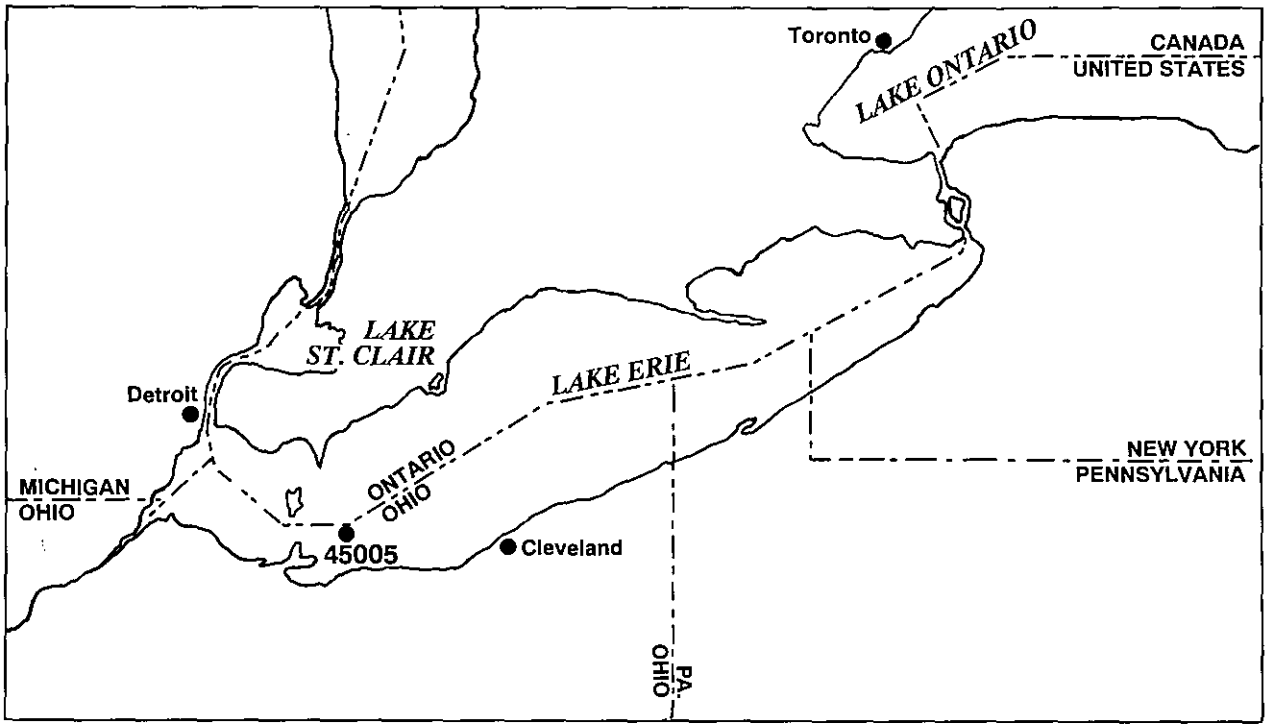

Figure 12. NDBC Enviromental Data Buoy at Station 45005 in Lake Erie

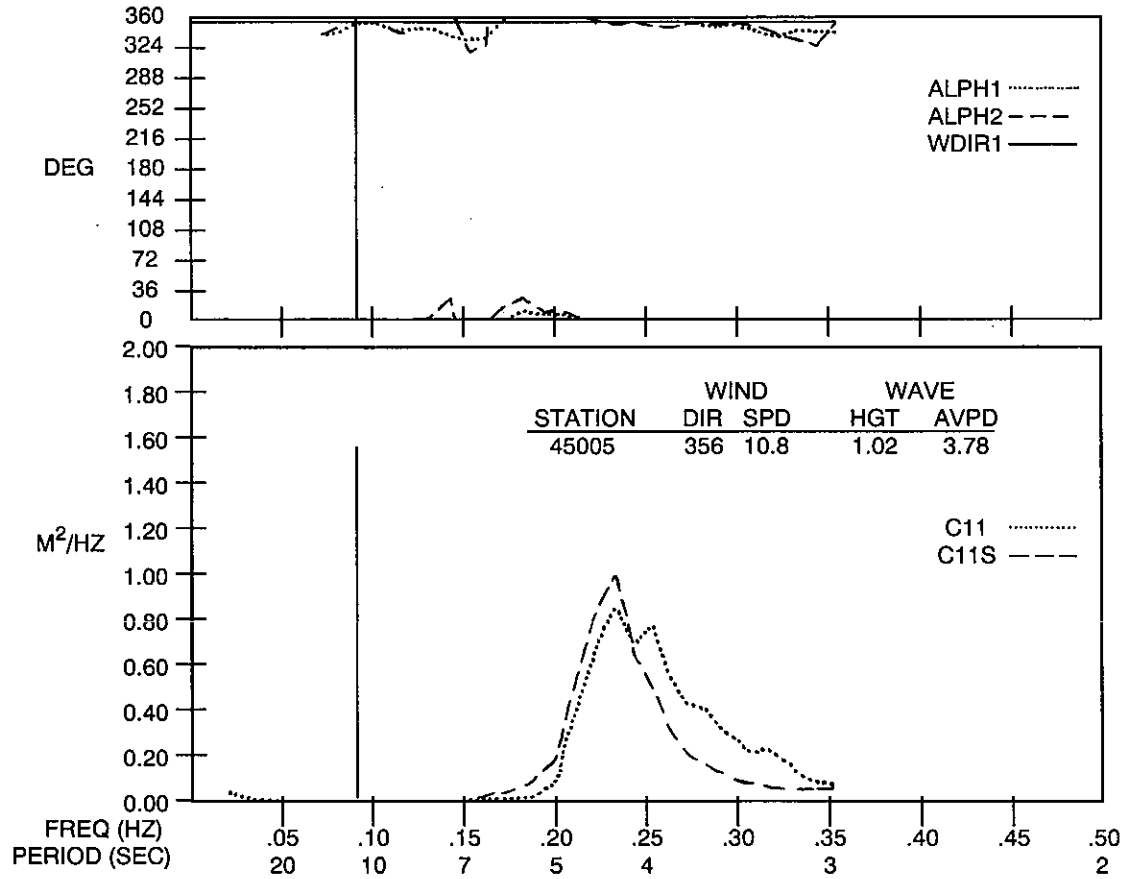

Figure 13. Nondirectonal Spectrum from Heave (C11) and Slope (C11S) Sensors, as well as Mean (ALPH1) and Principal (ALPH2)Wave Directions at the Hour of Strongest Winds, 0000 Z on August 7, 1989

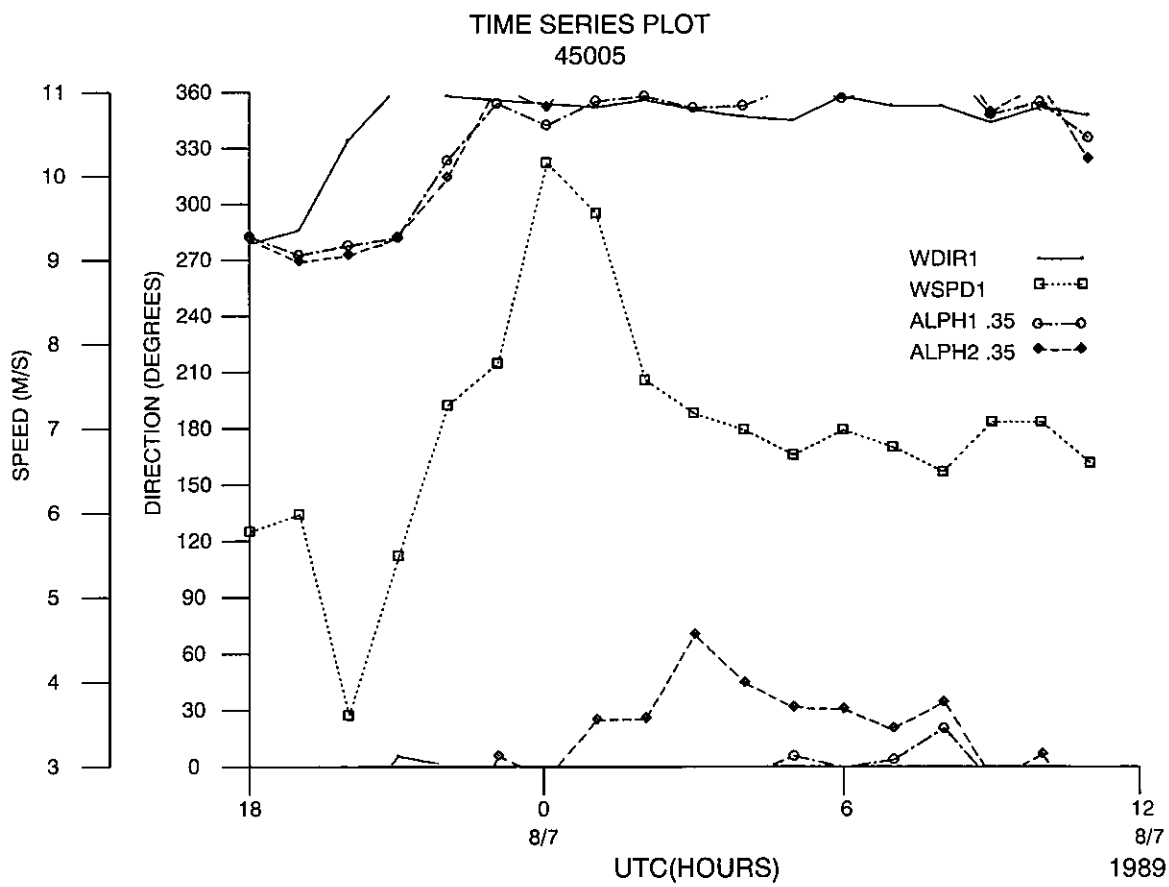

Figure 14. Mean and Principal Wave Directions (deg.) for the Shortest Period Reported (f=0.35 Hz,period 3 sec.)

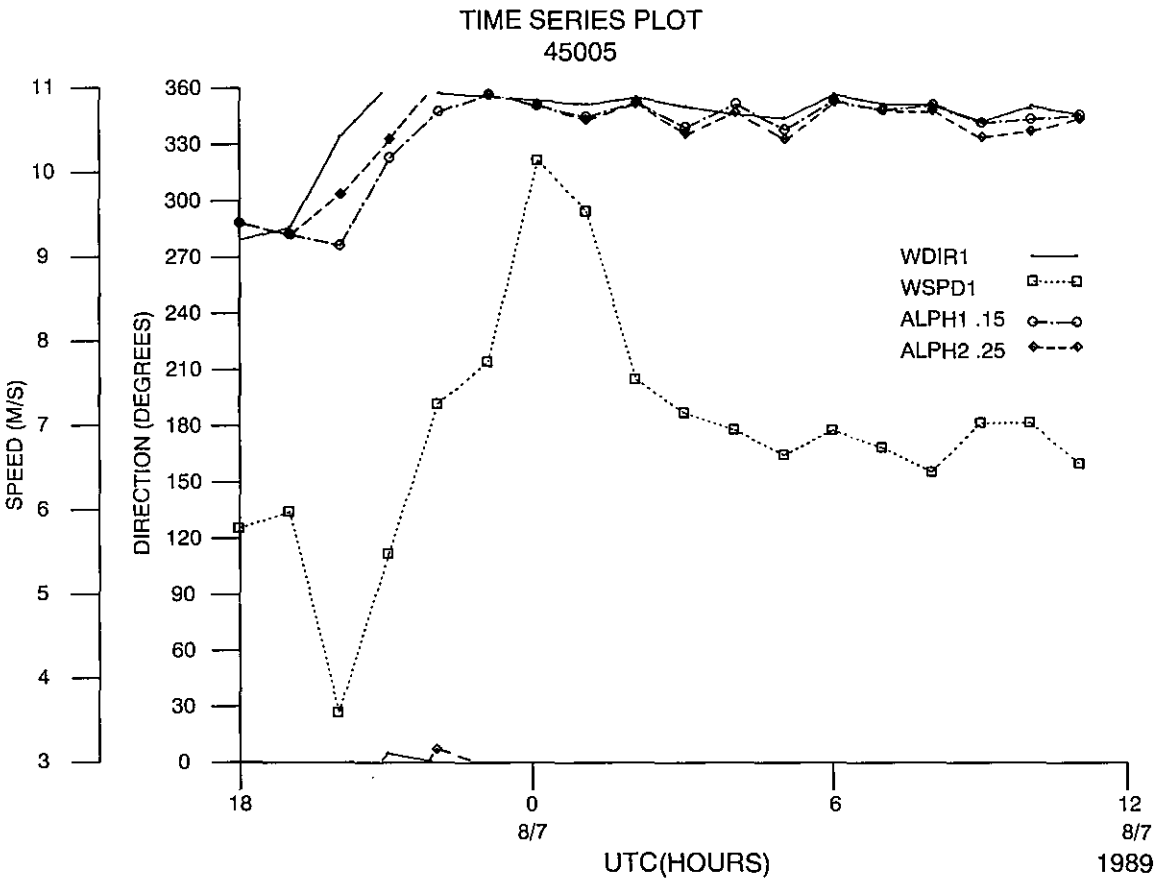

Figure 15. Mean and Principal Wave Directions (deg.) for period of 4 seconds (f=0..25 Hz)

NDBC STATION MESSAGES TOP ONE MILLION FOR 1988

NDBC stations delivered over 1 million observations in real time during 1988. This is the first time that the annual message count exceeded 1 million. The total number of observations, 1,014,991, was composed of 676,639 meteorological and 338,352 oceanographic (wave spectra) messages, and was a 6% increase over 1987. The data were delivered by a network of 53 operational moored buoys, 43 Coastal-Marine Automated Network (C-MAN) stations, and 5 experimental buoys.

The record message count was achieved in spite of a batch of defective batteries received in 1987. The buoy battery problem caused the percentage of all possible buoy observations received to fall slightly from 1987 levels to 83.5% (meteorological) and 81.6% (oceanographic). Delivery of data from C-MAN stations was 94.1%, which was almost no change from the previous year. The average of meteorological messages received from all NDBC operational stations was 88.3% of the total possible, slightly lower than the 89.8% in 1987. The performance percentages and total number of messages delivered since 1978 are shown in Figure 16.

Another method of evaluating data delivery to users is through total station days and percent of total station days operating. A station day is defined as a day in which both barometric pressure and winds are available from an operational (non-experimental) station. While message count gives an indication of data available to users in real time, total station days provides a better assessment of data available for archival.

Table 2 provides an overall analysis of station days operating and causes of data loss from NDBC systems (moored buoys and C-MAN stations) since 1975. Tables 3 and 4 provide a similar analysis, but separate moored buoy and C-MAN performance since 1983, after C-MAN became a separate NDBC program. In Tables 2 and 3, the battery problem mentioned earlier is reflected in the column labelled "Payload/Sensor Failures," and was the cause of the relatively lower percentage of station days operating.

Based on the first 8 months of 1989, the total number of messages from NDBC stations in 1989 is projected to increase by 8% to approximately 1,110,000.

Eric Meindl, NDBC

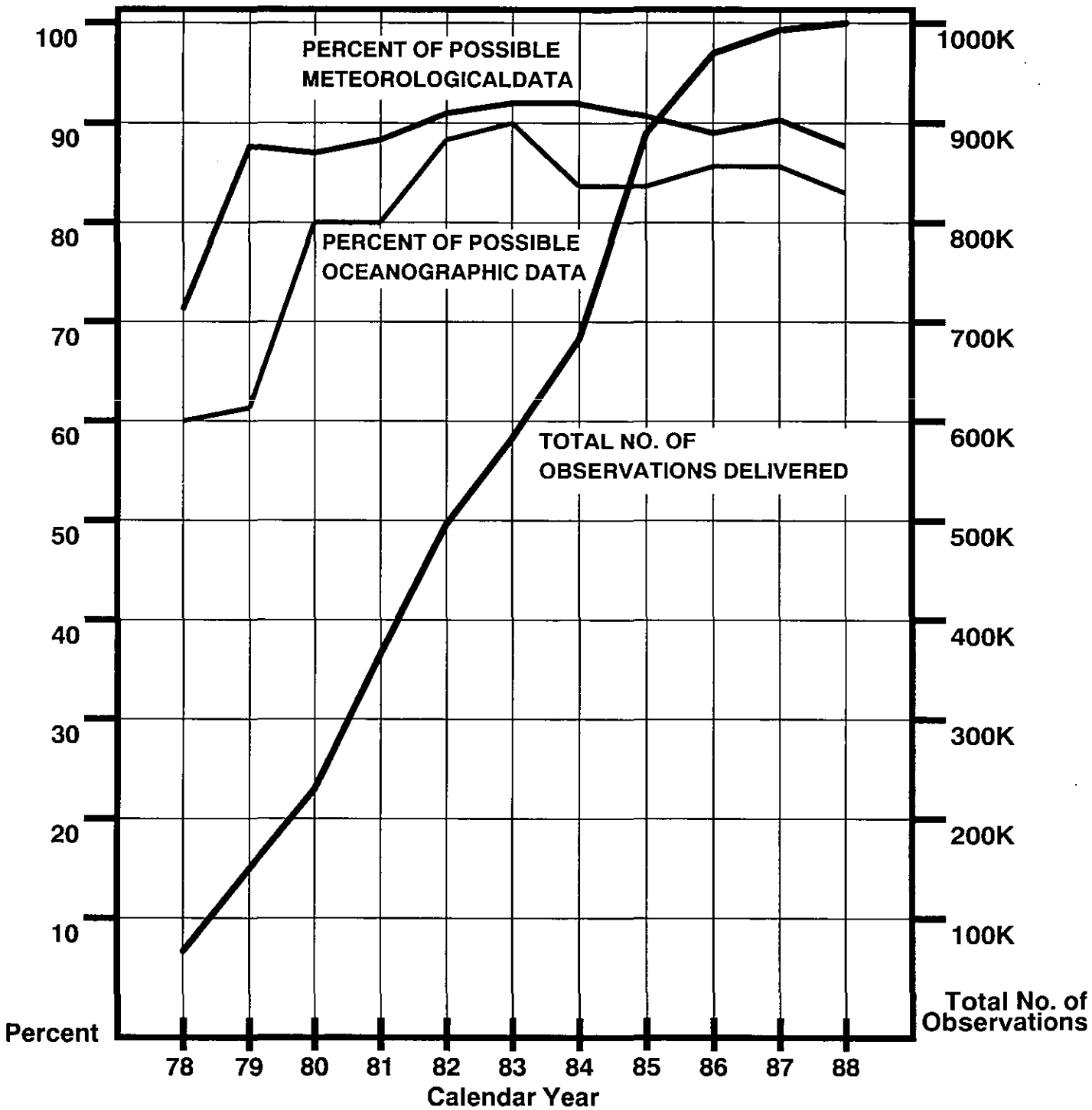

Figure 16. Performance Percentage and Total Number of Messages Delivered Since 1978

Table 2. Overall Analysis of Station Days Operating and Causes of Data Loss

CY	TOTAL STATION DAYS	% STATION DAYS OPERATING	PERCENT STATION DAYS LOST DUE TO: PAYLOAD/ SENSOR FAILURES	SCHEDULED REFURBISHMENT	VANDALISM OR COLLISION	SAT AND COMMS	MOORING FAILURES	CAPSIZINGS
1975	2,182	76.2	18.8	0.0			5.0	0.0
1976	3,520	79.5	12.8	1.9			5.8	0.0
1977	6,023	77.8	7.6	5.0			3.8	5.8
1978	6,794	77.0	7.3	4.0			7.9	3.8
1979	7,792	88.8	3.7	1.0			6.5	0.0
1980	8,549	79.5	13.1	0.7			4.6	2.1
1981	10,729	88.5	3.7	5.8			0.7	1.3
1982	10,940	91.0	4.0	3.8			1.2	0.0
1983	14,519	91.0	2.2	0.8	0.1		0.7	0.0
1984	22,258	96.0	1.6	3.6	0.4		0.9	0.4
1985	28,458	94.5	4.3	2.6	0.3		0.5	0.0
1986	30,411	93.7	6.1	3.0	0.5		3.6	0.0
1987	30,814	93.4	3.7	1.6	0.4	0.4	0.5	0.0
1988	34,067	91.0	7.6	0.8	0.0	0.0	0.6	0.0

Table 3. NDBC Buoy Performance Analysis

CY	TOTAL STATION DAYS	% STATION DAYS OPERATING	PERCENT STATION DAYS LOST DUE TO: PAYLOAD/ SENSOR FAILURES	SCHEDULED REFURBISHMENT	VANDALISM OR COLLISION	COMMS	MOORING FAILURES	CAPSIZINGS
1975	2,182	76.2	18.8	0.0			5.0	0.0
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1980	8,549	79.5	13.1	0.7			4.6	2.1
1981	10,729	88.5	3.7	5.8			0.7	1.3
1982	10,940	91.0	4.0	3.8			1.2	0.0
1983	13,516	96.2	2.2	0.8	0.1		0.7	0.0
1984	15,132	92.9	1.6	3.6	1.0		0.9	0.0
1985	15,508	91.9	4.3	2.6	0.7		0.5	0.0
1986	16,356	86.4	6.1	3.0	0.9		3.6	0.0
1987	16,578	89.6	5.5	2.9	0.7	0.4	0.9	0.0
1988	18,710	85.4	12.0	1.5	0.0	0.0	1.1	0.0

Table 4. C-Man Performance Analysis

CY	TOTAL STATION DAYS	% STATION DAYS OPERATING	PERCENT STATION DAYS LOST DUE TO: PAYLOAD/ SENSOR FAILURES	SCHEDULED REFURBISHMENT	VANDALISM OR COLLISION	COMMS
1983	1,003	93.5	5.4	1.1	0.0	
1984	7,126	98.1	1.8	0.1	0.0	
1985	12,950	95.8	4.1	0.1	0.0	
1986	14,055	97.5	2.5	0.0	0.0	
1987	14,236	97.8	1.7	0.1	0.0	0.4
1988	15,357	97.7	2.2	0.1	0.0	0.0

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Technical Bulletin
National Data Buoy Center

VOLUME 16, NUMBER 2 AUGUST 1990

Florida Institute of Oceanography and NDBC Joint Program Monitoring in the Florida Keys

The Florida Keys "Seascape," an area southeast of the Florida Peninsula stretching from Soldiers Key to the Dry Tortugas, is the only tropical coastline in the continental United States. Coral reefs, mangrove forests, and seagrass beds are all a part of the natural beauty of this area. The Keys provide habitats for the prolific marine life important to the fishing industries and is an important tourist attraction. The preservation of this water wilderness is important to Florida and to the nation as a unique national treasure. Evidence collected in the last decade confirms a precipitous decline in the environmental health of marine plants and animals comprising this area. In the past 10 years, the massive seagrass die-back in Florida Bay and the unexplained decrease in live coral emphasizes the need to understand the dynamics of the interacting ecosystems, their relationship to the natural processes, and the changes to the environment caused by man. A group consisting of government and private organizations has been formed to gather data, to define the causes of this decline, and to initiate policies to prevent the decay and erosion of this natural wonder. The Florida Institute of Oceanography (FIO) will lead this project for the acquisition of the information required to research the causes of the threat.

At least four hypotheses have been advanced to explain the decline in coral reef health.

1. Nutrients from sewage and agricultural runoff are poisoning the coral and favoring the growth of nutrient-tolerant algae.
2. Trace metals and pesticides from the same sources induce lethal and sublethal stresses in the coral reefs.
3. The coral bleaching events of 1983 and 1987, associated with the El Nino/Southern Oscillation atmospheric-oceanographic disturbances and the associated high temperature and other natural disturbances such as storms and disease, are causing the decline.
4. Lastly, a combination of all three may be involved.

The National Data Buoy Center (NDBC) has been requested by FIO to support the acquisition of the data necessary to determine the causes of the recent changes and to provide an information data base to evaluate further changes. NDBC will apply the technology developed for the Coastal-Marine Automated Network (C-MAN) stations to provide the remote data acquisition and telemetry capability required for collection of the specified meteorological and oceanographic data. The Value Engineered Environmental Payload (VEEP), NDBC's most recent operational payload, will obtain and transmit the meteorological data. An addition-

Continued on page 2

Coastal Buoy Testing Begins

The Coastal Buoy project was initiated to develop a low-cost, lightweight, reliable, moored buoy for use in the coastal environment.

Two prototype Coastal Buoys have been fabricated for test and evaluation. The first prototype, Coastal Buoy I, has completed a limited deployment field test and is scheduled for deployment off the Columbia River Bar in the fall of 1990. A photograph of the Coastal Buoy is shown in Figure 1.

The Coastal Buoy is suitable for meteorological, oceanographic, and directional wave measurements. The meteorological package includes two barometers, two anemometers (for wind speed and direction), an air temperature sensor, and an ocean temperature sensor. The anemometers and air temperature sensor are mounted on the mast at 5.0 and 4.5 meters, respectively. Since NDBC's 6-meter and 3-meter buoys measure wind and air temperature at the 5-meter level, this is the preferred height, allowing direct correlation of the data collected on the various hull types. The Coastal Buoy has a fin to orient the hull into the wind so that there is no obstruction to the anemometers.

Continued on page 3

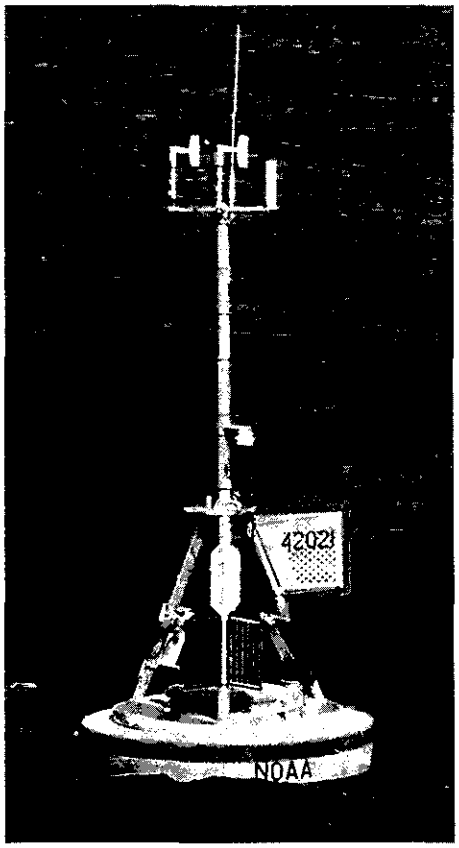

Figure 1. Coastal Buoy Deployed

A New Approach for Measuring Wind Speed and Direction From a Moored Buoy

A key observation made by NDBC buoys is ocean surface wind. On each buoy, wind speed and direction are measured by two duplicate anemometers. In this way two objectives are achieved: 1) reliability is improved through the installation of redundant wind sensors; and 2) data quality is enhanced, since the winds from the two sensors may be intercompared. These objectives are important because the anemometers are the only buoy sensors with moving parts that are exposed to the marine environment.

In the last year, NDBC has demonstrated the feasibility of measuring ocean surface wind speed and direction from by-products of the NDBC directional wave measurement system. The technique to perform this measurement requires no additional sensors and, consequently, is very cost effective. Field tests have proven the accuracy and reliability of the technique. As a result, NDBC now has a method, independent of the standard anemometer wind sensors, to obtain ocean surface winds. The resulting data may be employed routinely for wind sensor data quality assurance.

Recently, a vertical, flat fin was attached to one leg of the mast of a 3-meter discus buoy used for directional wave measurements. The fin provides the restoring torque to force the designated bow of the buoy hull to face the wind and to dampen yawing oscillations of the buoy. As a result, a rather stationary buoy hull condition can be provided during data acquisition. Therefore, the wind direction can be estimated from the direction of the buoy bow, which is expressed by buoy magnetic azimuth produced from an onboard magnetometer that is a part of the directional wave measurement system. Furthermore, the wind will generate drag on the buoy mast, which, in conjunction with the mooring force holding the buoy on station, will cause the buoy to tilt in the fore and aft direction (pitch). Ocean waves and other environmental forces also affect buoy dynamics, causing pitch (and other buoy motions) to continuously vary. However, over the period of wave measurement sampling (20 minutes), wave-induced pitch will theoretically have a mean of zero. If the wind is relatively steady over the 20-minute period, then the azimuth (mean of maximum and minimum value) and the mean pitch that are produced by the directional wave measurement system can be used to estimate wind direction and speed, respectively.

Three months of data collected at several NDBC directional wave buoy stations were used to verify the technique. Scatterplots were made between the measured wind directions and the estimated wind directions from the buoy azimuths. For wind speed, an empirical equation relating wind speed to mean pitch angle was derived for each station. The form of this relationship was based on a theoretical analysis of the aerodynamic drag on the buoy superstructure. Using empirical formulae, wind speeds from buoy pitch were estimated and compared to anemometer-produced wind speeds. The effects of the steadiness of the wind on the difference between the winds from the wind sensors and the winds estimated from buoy pitch and azimuth were studied. For wind speed, variations in the length of the upper mooring chain, which affects the restoring moment of the buoy, were also analyzed.

For the wind direction study, field data were obtained from two directional wave buoy stations (stations 45005 and 46042). Station 45005 was the first NDBC directional wave buoy station deployed in the Great Lakes area. The station is located at the southwest end of Lake Erie. The water depth at the deployment site is about 15 meters. Station 46042 is located outside of Monterey Bay, California, at a water depth of 2103 meters. For the wind speed analysis, data were used from station 46042 and from station 41008 located in 18 meters of water off St. Mary's Entrance, Florida.

Based on the results of these studies, about 85 percent of the estimated wind directions (from mean buoy azimuth over a 20-minute data acquisition period), differed no more than 20 degrees from the wind sensor wind directions. Under steady conditions in both wind speed and direction, 96 percent of estimated mean buoy azimuths were less than 20 degrees from the measured wind directions. Using the mean pitch technique, more than 94 percent of estimated wind speeds were within 2 m/s of the wind sensor measured wind speeds, irrespective of wind steadiness. Therefore, both the wind speed and direction estimating techniques have been demonstrated to work quite well.

As an example, Figure 2 is a time series plot showing wind speed for station 46042 as measured by the wind sensor and as estimated from buoy mean pitch. The agreement is quite good. Figure 3 shows a similar time series for wind direction for station 45005. In this figure, the estimated wind direction is labeled BUOYAZ. Note that the directions of the two anemometers (WDIR1 and WDIR2) disagreed, but that the BUOYAZ showed WDIR2 to be correct.

David Wang
Computer Sciences Corporation

Florida Keys Continued

al system, a stand-alone microprocessor interfaced to the VEEP, will be used to gather data from the oceanographic sensor systems and pass them to the VEEP for transmission via satellite and/or telephone modem.

The VEEP will collect the standard C-MAN meteorological data, such as winds, barometric pressure, air temperature, rainfall, and solar radiation, on an hourly basis. Oceanographic data will also be collected by the microprocessor on an hourly basis. The initial suite of oceanographic parameters will include salinity, water temperature, and an underwater solar sensor to measure light penetration into the water. The microprocessor system will be designed to accept additional oceanographic sensors as required.

Continued on page 8

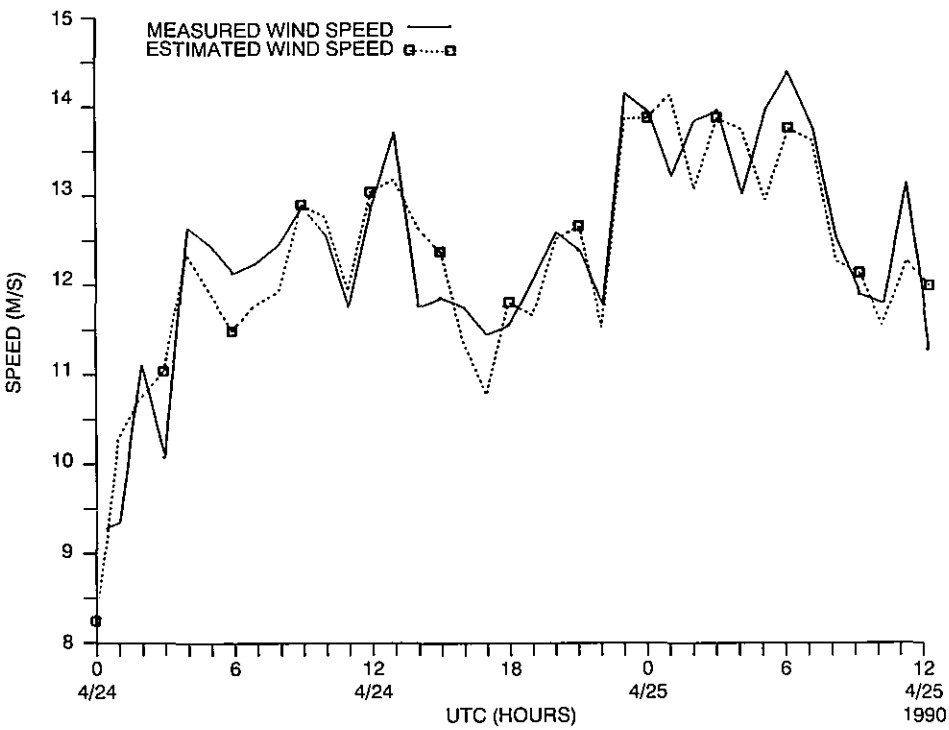

Figure 2. Time Series Plot Showing Wind Speed for Station 46042 as Measured by an Anemometer and as Estimated from Buoy Mean Pitch.

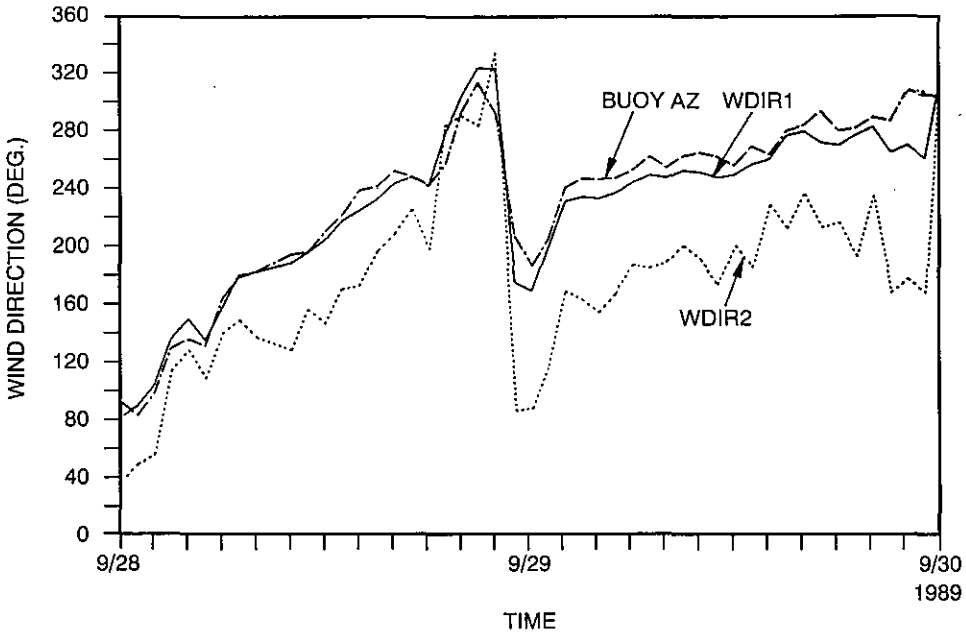

Figure 3. Time Series Plot Showing Wind Direction for Station 45005 as Measured by the Wind Sensors and as Estimated from Buoy Mean Azimuth Angle.

Coastal Buoy Continued

Any of NDBC's operational payload configurations will fit into the payload compartment, which is a cylinder 0.91 meter in diameter and 0.82 meter tall. Because magnetometers and magnetic compasses will be part of the payloads, the Coastal Buoy is being fabricated of nonmagnetic materials. The Coastal Buoy can be serviced at sea in calm weather. Servicing can be expected to call for meteorological sensor change-out and access into the top of the electronic payload compartment. While at sea, the normal servicing procedure will be on board the servicing vessel or along side.

Other design features are: (1) a truck can transport the buoy without special routing or permits; (2) the buoy can be easily and safely handled without special equipment or procedures; (3) completely outfitted, the buoy weighs less than 820 kg; and (4) buoy hull life is in excess of 6 years.

Since these Coastal Buoys will be used in coastal waters, they will be more exposed to vandalism than deep-ocean buoys. The most frequent form of vandalism has been from small arms fire. The Coastal Buoy hull is composed of closed-cell foam that decreases the possibility of catastrophic damage from gunfire.

In the NDBC standard Meteorological Monitoring Configuration, the Coastal Buoy is designed to have at least a 1-year unattended life. It will operate in wind speeds up to 50 knots, significant wave heights up to 5 meters, and surface currents up to 2 knots. It is designed to survive wind speeds up to 75 knots, significant wave heights up to 8 meters, and surface currents up to 4 knots.

The hull form was selected to provide sufficient buoyancy and stability, acceptable wave motion response, and good performance in moderate ocean current regimes. Mathematical simulation analyses and scale model testing of foam discus hull buoys at NDBC indicated that a hull 2.3 meters in diameter would provide appropriate wave motion response for the range of wave conditions expected. A study conducted by the Coast Guard in the late 1970's had indicated that the curved hull chine would have the best

Continued on 9

Discus Buoy Hydrostatics Computer Program

In an ongoing effort to improve the cost-effectiveness of marine monitoring systems, NDBC began, in the 1980's, to investigate the feasibility of small, low-cost data buoys. This effort led to the highly successful 3-meter discus (NDBC Technical Bulletin, Volume 9, No. 1, May 1983). As new requirements have arisen for observations in coastal regions, NDBC has continued small buoy development activities via the Coastal Buoy project (see article this issue).

An essential aspect of buoy design is hydrostatic naval architecture (i.e., how the buoy will float). Typically, a vessel's hydrostatic properties are determined using one of several standard naval architecture computer programs. However, these programs were originally written for ship shapes and are not easily adapted for round hulls such as discus buoys. As a result, an easy-to-use computer program has been developed to calculate the Curves of Form and Cross Curves of Stability for axisymmetric discus buoy hulls. The program, entitled AXISTAB2, has been designed to run interactively on IBM-compatible Personal Computers.

AXISTAB2 is based on the vertical numerical (trapezoidal rule) integration of water planes. Inputs to the program are merely waterline heights and radii, and the volumes and centroids of discrete appendages, if any. Two categories of output are produced - Curves of Form (versus draft) and Cross Curves of Stability - as described below:

Curves of Form (versus draft)

WPAREA - water plane area, square feet
VOLUME - displaced volume, cubic feet
DISP SW - displacement in seawater, pounds
DISP FW - displacement in fresh water, pounds
KB - height of the center of buoyancy above the keel, feet
BM - distance from the center of buoyancy to the metacenter, feet
KM - distance from the keel to the metacenter, feet
MCT - moment to change trim one inch, foot-pounds (based on trim measured at the maximum buoy diameter)
PPI - pounds per inch of draft
CB - block coefficient -- the ratio of the displaced volume to the volume of a circumscribing block of size diameter long by diameter wide by draft deep. The diameter is that at the specific draft
CVP - vertical prismatic coefficient -- the ratio of displaced volume to the volume of a circumscribing cylinder of size diameter and depth draft
CSURFOLLOW - a parameter indicative of the surface-following ability of a hull, = water plane area/ $(\text{volume})^{2/3}$. High numbers are discus shapes, low numbers are spars.

Cross Curves of Stability

For each of six angles of heel (15°, 30°, 45°, 60°, 75°, and 90°), hull displacement and righting arm (GZ) values are determined for both the "bare hull" and "hull with appendages" cases. The righting arm is equal to the righting moment divided by the displacement. The assumed center of gravity is at the buoy baseline (height = 0.0). A righting arm curve may be obtained from the cross curves by entering at a given displacement and noting the value of GZ at each heel angle. The resulting righting arm curve must be corrected for the actual KG by the formula:

GZ act = GZ cross curves - KG sin (heeling angle)

As an example, several of the AXISTAB2-computed curves of form properties for NDBC's Coastal Buoy are plotted in Figure 4. AXISTAB2 has been verified by hand calculation and by comparison with hydrostatics previously computed for NDBC's 3-meter discus buoy using the Navy's Ship's Hull Characteristics Program (SHCP). Results from these checks have been excellent, with nearly exact agreement between SHCP and AXISTAB2 output.

W. Brett Wilson
NDBC Program Management

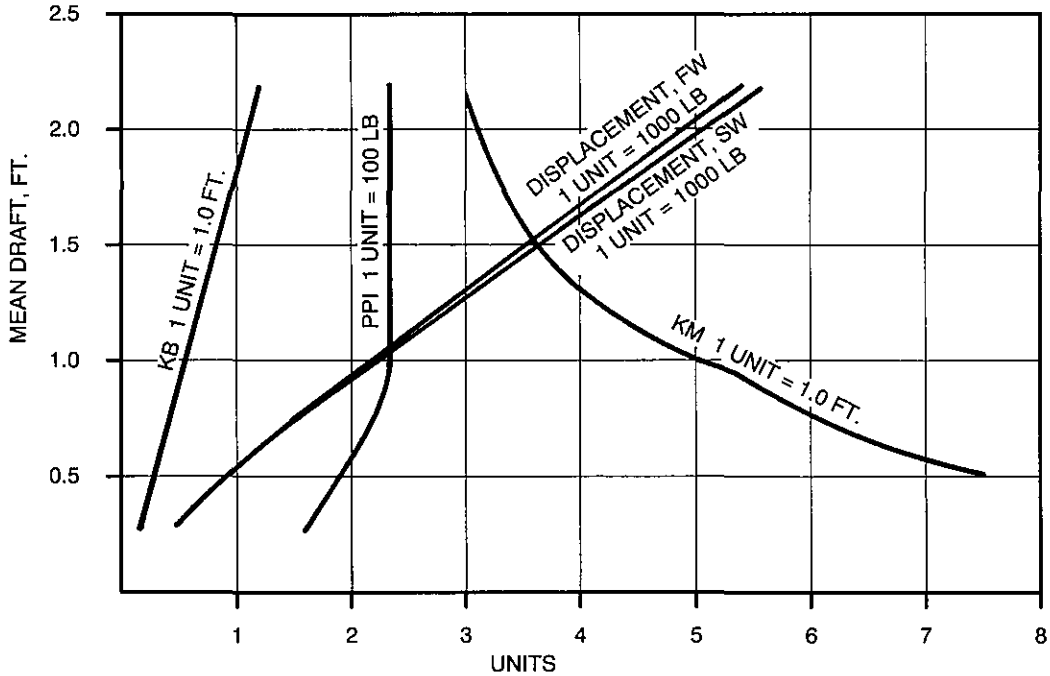

Figure 4. Coastal Buoy (Bare Hull) Curves of Form

NDBC Station Performance Statistics, Number of Messages Up in 1989

NDBC station performance last year improved over 1988 figures, and the number of data messages from NDBC stations approached 1.1 million during 1989 (Figure 5). The percentage of all possible hourly meteorological messages, successfully received from stations equipped with NDBC systems, was 89.3 percent, while the percentage for oceanographic messages was 83.0 percent. This compares to the 1988 results of 88.3 percent and 81.0 percent, respectively. After general improvement in the mid-1970's and early 1980's, station performance percentages since 1984 have remained excellent and relatively constant (Figure 6).

Station performance, represented above, includes failure of NDBC hardware, as well as data lost during scheduled maintenance, communications problems, and shoreside computer outages. It is a measure, from an end user's perspective, of how successfully NDBC data are delivered to field users. If system performance is considered, in which only the failure of NDBC sensors or payloads is computed, the percentage of meteorological and oceanographic data successfully delivered rises to 90.5 percent and 84.8 percent, respectively.

A slightly different method of evaluating performance, that of total station days, helps NDBC identify reasons for data loss. A "station day" is defined as any day in which at least one observation, which includes both winds and barometric pressure, was successfully received from a station. Tables 1 and 2 show the causes of data loss since 1975 for NDBC moored buoy and C-MAN stations.

The actual number of messages delivered by NDBC stations last year totalled 1,094,173. There were 724,113 meteorological messages (a 7.0 percent increase over 1988) and 370,060 oceanographic messages (a 9.4 percent increase).

The NDBC network in 1989 was composed of 56 moored buoys, which included 9 U.S. Coast Guard Navigational Buoys, and 46 fixed Coastal-Marine Automated Network stations located on lighthouses, coastal headlands, and offshore platforms.

Eric Meindl
NDBC Data Systems

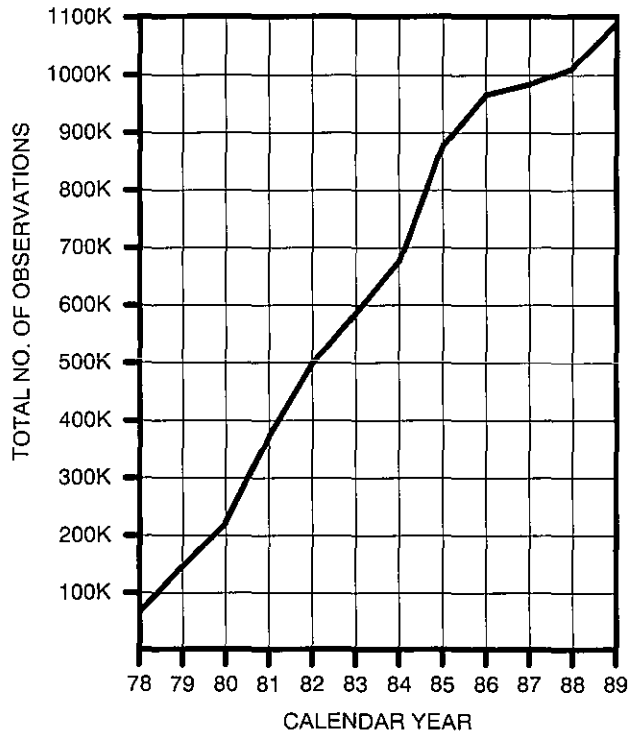

Figure 5. Total Number of Messages Per Year Delivered by NDBC Moored Buoy and C-MAN Stations Since 1978

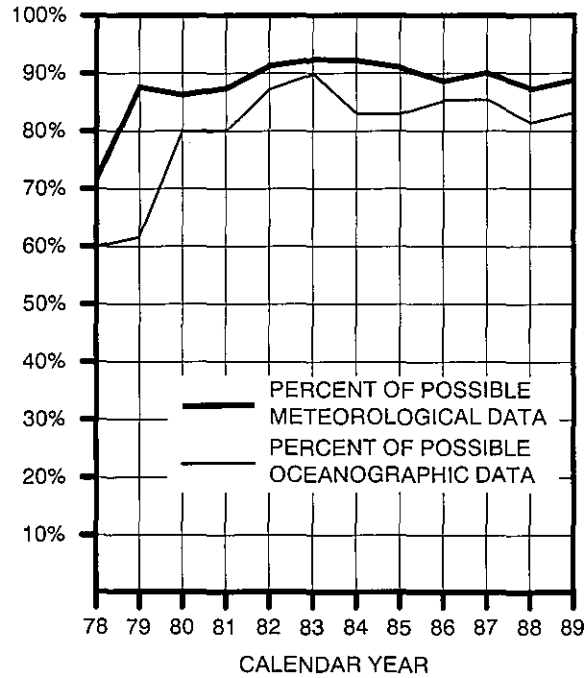

Figure 6. Station Performance for Meteorological and Oceanographic Data Since 1978

Performance Continued

Table 1. NDBC Moored Buoy Performance Analysis

			PERCENT STATIONS DAYS LOST DUE TO :					
CY	TOTAL STATION DAYS	% STATION DAYS OPERATING	PAYLOAD/ SENSOR FAILURES	SCHEDULED REFURBISHMENT	VANDALISM OR COLLISION	COMMS	MOORING FAILURES	CAPSIZINGS
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1984	15,132	92.9	1.6	3.6	1.0		0.9	0.0
1985	15,508	91.9	4.3	2.6	0.3		0.5	0.0
1986	16,356	86.4	6.1	3.0	0.9		3.6	0.0
1987	16,578	89.6	5.5	2.9	0.7	0.4	0.9	0.0
1988	18,710	85.4	12.0	1.5	0.0	0.0	1.1	0.0
1989	18,153	88.2	8.8	1.7	0.4	0.0	0.9	0.0

Table 2. NDBC C-MAN Performance Analysis

			PERCENT STATION DAYS LOST DUE TO:			
CY	TOTAL STATION DAYS	% STATION DAYS OPERATING	PAYLOAD/ SENSOR FAILURES	SCHEDULED REFURBISHMENT	VANDALISM OR COLLISION	COMMS
1983	1,003	93.5	5.4	1.1	0.0	
1984	7,126	98.1	1.8	0.1	0.0	
1985	12,950	95.8	4.1	0.1	0.0	
1986	14,055	97.5	2.5	0.0	0.0	
1987	14,236	97.8	1.7	0.1	0.0	0.4
1988	15,357	97.7	2.2	0.1	0.0	0.0
1989	15,923	98.1	1.8	0.1	0.0	0.0

NDBC Publications

The following recent articles were written or co-authored, since the last issue of the Technical Bulletin, by NDBC or NDBC Support Contractor Personnel. Copies of these Articles are available upon request.

1. Wang, David, 1990. "Estimating Wind Direction From a Small Discus Buoy," Proceedings Marine Instrumentation 90, San Diego, California.
2. Gilhousen, David, 1989. "Animate It, Contour It, or Three-Dimensionalize It," AMS Conference Paper.
3. Canada, Raymond, 1989. "Meteorological and Oceanographic Measurement System (MOMS) in the Gulf of Mexico," Gulf of Mexico Information Transfer Meetings.
4. Gilhousen, David, 1990. "NDBC Directional Wave Measurements," Proceedings Marine Instrumentation '90, San Diego, California.
5. Carolan, Robert, 1990. "An Evaluation of the R.M. Young Rain Gauge at Grand Isle, Louisiana," In-House Technical Report.
6. Brown, Hal, and Robert Gustavson, 1990. "Infrared Laser Wave Height Sensor," Proceedings Marine Instrumentation '90, San Diego, California.
7. Remond, Frank, and Chung-Chu Teng, 1990. "Automatic Determination of Buoy Hull Magnetic Constants," Proceedings Marine Instrumentation '90, San Diego, California.
8. Meindl, Eric, 1990. "Directional Wave Data Available in Lake Erie," Great Lakes Marine Weather Newsletter.
9. Gilhousen, David, 1990. "The Quality of Moored Buoy Winds," Canadian Meteorological and Oceanographic Society, Third Workshop on Operational Meteorology, Montreal, Quebec, Canada.
10. Remond, Frank, 1990. "Magnetic Direction Error Analysis," In-House Technical Paper.
11. "NDBC Integrated Logistics," NDBC Publication 701-02, May 9, 1990.
12. "Mooring Performance Evaluation CY 1989," NDBC Publication 1804-05.06, March 1990.
13. Steele, Kenneth, David Wei-Chi Wang, Chung-Chu Teng, and Norman Lang. "Directional-Wave Measurements with NDBC 3-Meter Discus Buoys," NDBC Publication 1804-01.05, April 1990.
14. "NDBC Mooring Design Manual," NDBC Publication 1804-05-07, December 1989.
15. Earle, Marshall D. "NDBC Real-Time Directional Wave Information User's Guide," NDBC Publication 1804-01-04, Prepared by MEC Systems Corporation, Manassus, Virginia, for the National Data Buoy Center, January 1990.

C-MAN Water Level Measurement for Storm Surge Observation and Warning

The Coastal-Marine Automated Network (C-MAN) program presently includes automated meteorological observation systems on 9 Coast Guard buoys and on 46 fixed sites in data-sparse coastal regions. At the program's inception in the early 1980's, the National Weather Service designated water level measurement for storm surge observation as an expansion parameter for 15 of the present fixed sites.

In 1984, NDBC installed a C-MAN station on the Lake Worth, FL, Municipal Pier, next to the National Ocean Service (NOS) Tide Station. The C-MAN payload accessed and reported data from the NOS tide gauge. In 1985 and 1986 the Lake Worth C-MAN station was operated briefly with an acoustic pulse water level sensor. In 1986, NDBC installed a C-MAN station at St. Augustine, FL, which included an acoustic pulse water level sensor.

As of January 1990, NDBC has installed water level measurement sensors at the following C-MAN sites: St. Augustine, FL; Lake Worth, FL; Grand Bahama Island; Venice, FL; Dauphin Island, AL; Grand Isle, LA; and Port Aransas, TX. Four of these C-MAN stations are collocated with NOS Tide Stations and access data from the NOS gauge via a shaft encoder interface. These stations currently use the Leupold Stephens gauge. At St. Augustine, Venice, and Port Aransas, NDBC operates Aquatrak acoustic pulse sensors.

For both sensor configurations, the NDBC payload samples twice per second for 3 minutes. A mean and standard deviation are calculated for the 360 samples. Those samples more than 3 sigma from the mean are discarded. The average of the remaining samples is recomputed and reported as water level (in feet). The computed standard deviation and number of discarded samples is also reported. This process is repeated ten times per hour, with sampling periods centered at the top of the hour and at 6-minute intervals thereafter. This sampling scheme was patterned after the one developed by NOS for the Next Generation Water Level Measurement System.

In 1989, Mean Lower Low Water (MLLW) became the standard reference for tides on the Atlantic and Gulf coasts. To facilitate operational forecasters' use of NDBC data with the NOS-published Tide Tables, water level data have been adjusted to an MLLW reference so that a value of 10.00 feet corresponds to MLLW. NOS has calculated MLLW for historic data for the sites where the C-MAN station accesses data from an established NOS gauge. At sites where NDBC has installed an Aquatrak sensor, MLLW was determined by aligning the sensor to established NOS bench marks on land.

Data are disseminated in real time, together with other C-MAN data, over the NWS AFOS and Family of Services Networks. These data are also available in the data queue at the National Environmental Satellite, Data, and Information Service. The "C-MAN Users Guide" explains the coding format for water level and other C-MAN data.

In addition to routine operational use, NDBC water level data are being used in studies of Gulf Stream transport and in verification of storm surge prediction models for the Gulf coast of Florida.

Doug Scally
NDBC Operations

NDBC Computer Systems Update

NDBC's Computer Systems serve as the nucleus for automated quality control, system and field evaluations, real-time control of the automated weather station data, and support of the NDBC engineering development programs. Daily processing and analysis, which include the evaluation of the quality and performance of operational data and the functionality of the developmental and test and evaluation data, along with the financial and equipment management requirements, are performed on these systems.

NDBC retrieves and quality checks the data from an operational network of moored buoy and coastal weather stations, which report hourly through the NOAA Geostationary Operational Environmental Satellite (GOES), and from drifting buoys which transmit data through the NOAA polar-orbiting satellites. These stations report a variety of geophysical data such as barometric pressure, air temperature, water temperature, wind speed, wind direction, wind gust, wave height, wave period, wave energy spectra, and wave direction. NDBC develops and implements all algorithms for the processing and quality control of these data; retrieves, processes, and archives all operational station data; and controls the release of these data over the worldwide weather distribution network through the National Weather Service Telecommunications Gateway (NWSTG). NDBC computer systems are interlinked by the IEEE 802.3 network, which provides resource sharing and data communications for all users.

The NDBC Computer System was procured competitively in 1983 and consisted of two Data General MV/8000 super-minicomputers. The system was upgraded in 1986 with the addition of an MV/20000 computer. In 1989, one MV/8000 was upgraded to an MV/15000 Mod 10. These upgrades increased the computing power of the original two MV/8000 systems from 1.2 million-instructions-per-second (MIPS) each, to three systems with an MV/20000 (6 MIPS), an MV/15000 Mod 10 (4 MIPS), and an MV/8000 (1.2 MIPS). Peripherals have been updated as required. New disk drives have been added to handle the increased volume

Continued on page 12

Florida Keys Continued

Existing C-MAN stations at Molasses Reef in the Key Largo National Marine Sanctuary and Sombrero Key near Looe Key National Marine Sanctuary will be augmented by two new stations at Fowey Rocks in Biscayne National Park and Sand Key Light near Key West (Figure 7). The C-MAN stations will be maintained by NDBC and the oceanographic sensors will be provided and maintained by FIO.

NDBC will collect the data and provide the necessary data quality control. The modification of two existing C-MAN stations and the establishment of two new stations enhances an NDBC commitment to long-term environmental monitoring.

This research will not only provide information to help resolve the problems of today but will help establish the basis for proper stewardship of this natural resource in the future.

Ralph Dagnall
NDBC Engineering

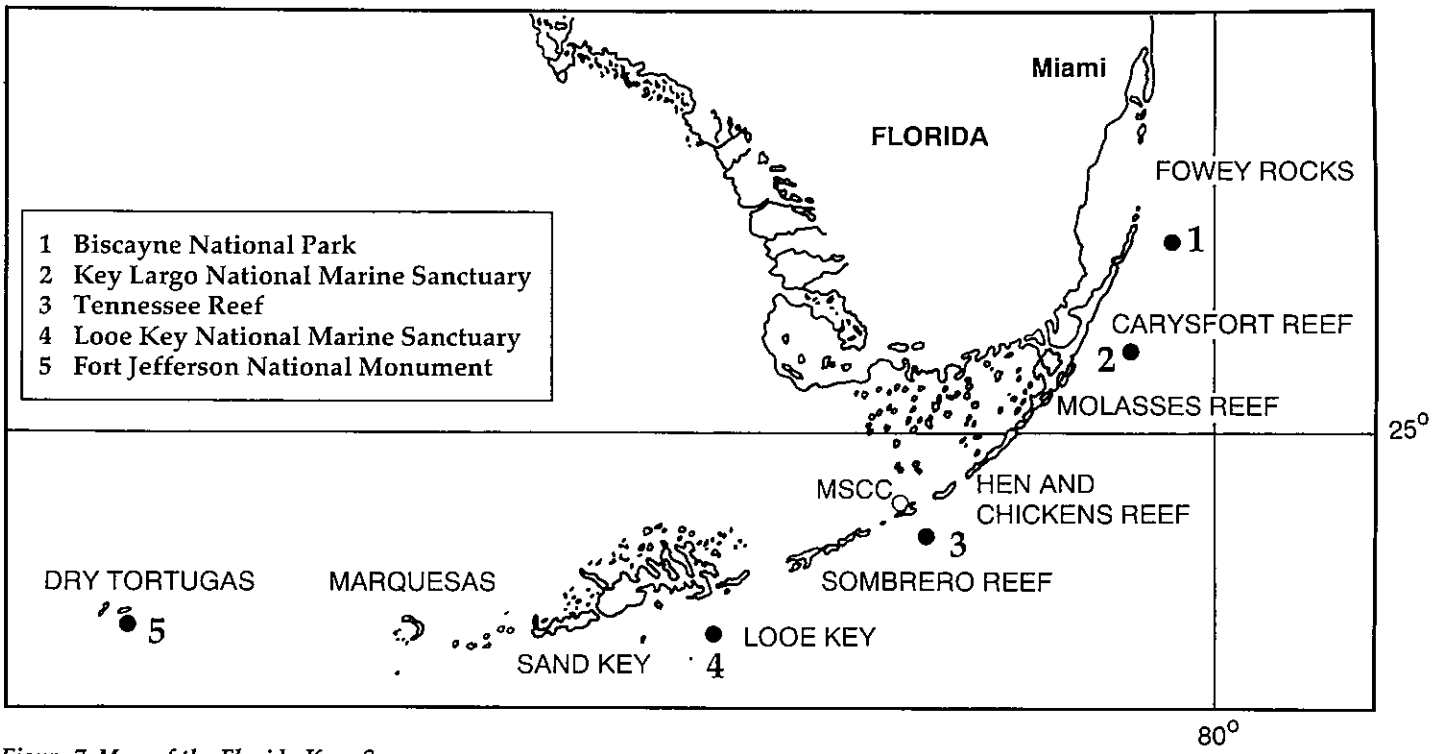

Figure 7. Map of the Florida Keys Seascape

Coastal Buoy Continued

performance in currents and thus was selected as the hull form for the Coastal Buoy. This hull form has sufficient freeboard to provide in excess of 145 percent reserve buoyancy based on a maximum expected deployed displacement of 1000 kg with 260 kg of payload and 175 kg of static mooring load.

The hull structure is marine-grade aluminum with a resilient closed cell foam flotation collar closely fitted around the payload compartment. The central hull structural component is the payload compartment shell.

The subsurface structure also has two significant variations. The first subsurface structure is designed to optimize wave-following characteristics for directional wave measurements.

Research by R.L. Boy at MIT/WHOI indicates that a fixed, counterweighted, hoop design will allow freedom of hull movement (to follow the wave slope, to reduce surface-current-induced trim, and to minimize dynamic mooring load fluctuations). Because a discus buoy moored from its base is subject to capsizing, a pendulum arm is used inside the hoop to provide restoring moment in the limiting sea conditions when the pendulum arm contacts the hoop. Figure 8 illustrates this concept. A secondary benefit of this concept is that the buoy may be secured vertically on deck or ashore when the pendulum arm is not attached.

This version of the subsurface structure will be evaluated to confirm the expected near-linear wave-following ability. Also being evaluated will be the wear on the mooring attachment to the hull, potential directional wave sensor noise if the pendulum arm contacts the hoop (with resilient fendering), and buoy pitch/roll motion effect on wind sensor data.

The second subsurface structure is designed to reduce pitch-roll motions to best support the meteorological measurements. A traditional counterweighted center pipe design with its primary mooring attachment at the base of the center pipe is shown in Figure 9. This approach uses the mooring loads to increase stability and provide increased damping in pitch and roll.

The Coastal Buoy structure incorporates several experimental designs and design variations. The hatch closure and gaskets are based on the controlled compression of a contained elastomer gasket irrespective of fastener torque. This system is a low-cost approach to the misalignment and gasket compression cutting failure syndrome common to the standard hatch on scuttle sealing systems. The tubular tripod mast legs double as hull vent pipes and support members for solar panels, wind fin, radar reflector, pole mast, and associated sensors. The tripod mast is sized to survive the failure of the pole mast at 4340 Newton-Meter torque or a 180-kg horizontal point load at the top of the mast. The pole mast is not connected to the vent system, allowing a total failure of the pole mast without affecting the survivability of the main hull.

The foam flotation collar was designed to absorb the impact energy of collisions with the service vessel during deployment and retrieval operations.

Static stability was measured using applied couples to determine the buoy's righting moments. Couples were applied to Coastal Buoy I by applying equal opposing vertical forces on opposite sides of the integrated buoy to determine the low end of the hull righting moment. The righting moment curve was expanded by applying near horizontal forces at the deck level and to the top of the mast. The results of these procedures on Coastal Buoy I are shown in Figure 10.

A 90-kg man climbed the mast and placed his center of gravity approximately 4 meters above the waterline. Using his weight, he pumped the buoy by the natural frequency to the maximum amplitude obtainable. The maximum roll obtained on the integrated Coastal Buoy I was less than 30 degrees.

Coastal Buoy I's first deployment was south of Mobile, Alabama, at latitude 30°10'N, longitude 88°07'W at station 42021 in 8.8 meters of water near two operational NDBC 3-meter buoys and one NDBC engineering test 3-meter buoy. All four buoys were instrumented with two anemometers at the 5-meter level, two barometers, one air temperature sensor, one water temperature sensor, and a directional wave measurement system. The directional wave measurement system used on Coastal Buoy I is a new system NDBC is evaluating under a separate effort and does not use the same sensors or algorithms as the systems installed in the three 3-meter buoys. As a result, the directional wave measurement comparisons are of limited validity until the new system development progresses in conjunction with a later deployment. This first deployment provided initial comparisons of meteorological and water temperature measurements, an opportunity to observe the buoy at sea, and a first look at deployment and retrieval handling procedures.

Continued on Page 10

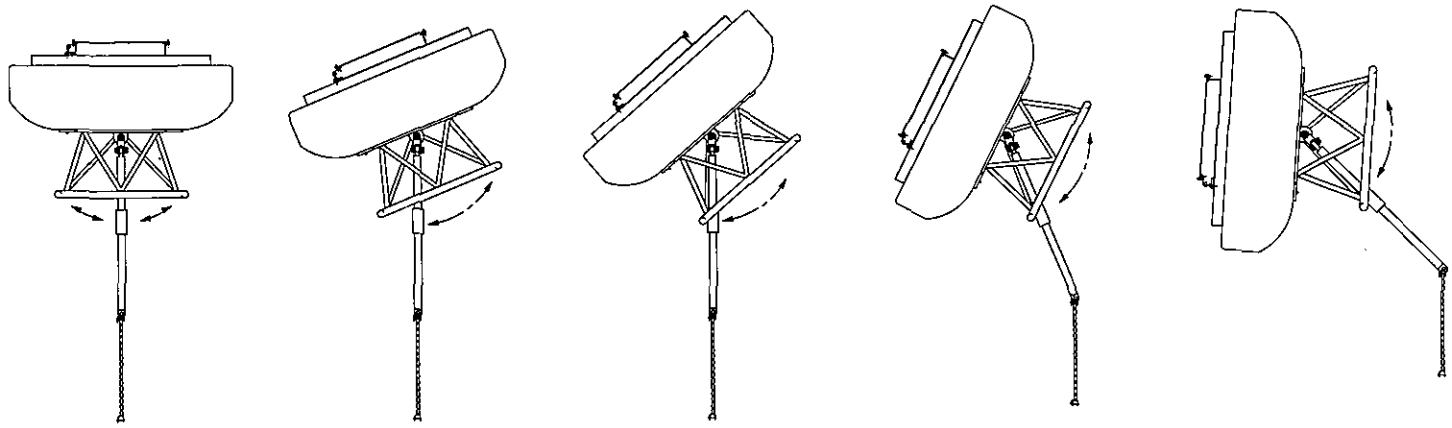

Figure 8. Pendulum Arm Mooring Attachment Restoring Moment Ability and Limited Freedom of Movement

Coastal Buoy Continued

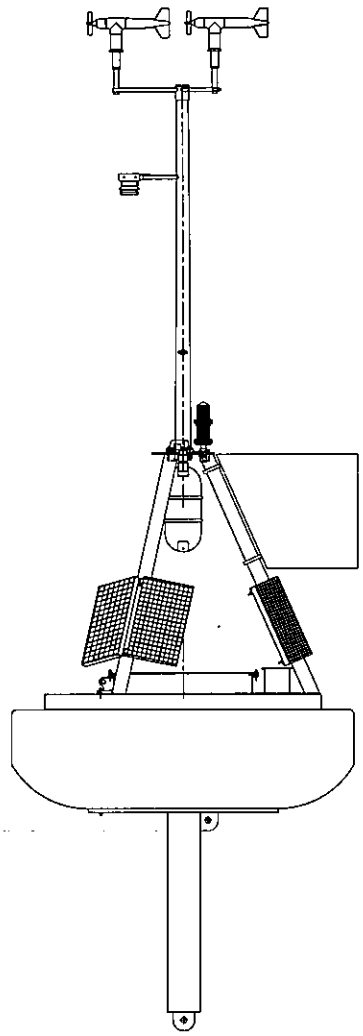

Figure 9. Counterweighted, Center Pipe Mooring Attachment Subsurface Structure

Coastal Buoy I was deployed a second time in early August of 1990 at latitude 46°20'N, longitude 124°11'W in 32 meters of water at station 46046, which is a few kilometers west of the Columbia River Bar. This location provides a potentially more diversified and severe sea environment than was experienced during the first deployment. It also allows the opportunity to receive observations of the buoy's behavior in rough weather through coordinated observations with the Coast Guard. The Coast Guard operates its Motor Lifeboat School at Cape Disappointment and looks for severe weather for training its boat crews. One of the added observations anticipated during this deployment is to evaluate the effect basking sea lions and seals will have on the measurements and survivability of the buoy. A 12-meter-diameter Coast Guard Large Navigational Buoy (LNB Station 46010) is moored approximately 10 km south of the Coastal Buoy position and is instrumented with an NDBC weather-measuring system including meteorological sensors at the 10-meter level and non-directional wave instrumentation. The LNB will provide ground truth data for evaluating Coastal Buoy I's performance. Coastal Buoy I's third deployment will be on the West Coast near another NDBC directional wave-measuring buoy station.

Coastal Buoy II's first deployment is planned for south of Mobile, Alabama, at Station 42018 at latitude 29°58'N, longitude 88°12'W. The buoy will be instrumented to measure the same parameters as Coastal Buoy I, except the wave measurement system will be a nondirectional system. This deployment will provide initial observation of Coastal Buoy II's traditional center pipe underhull structure.

Coastal Buoy II's second deployment is planned for east of Cape Lookout, North Carolina, near the NDBC Coastal-Marine Automated Network (C-MAN) station CLKN7. This deployment will test the buoy's survivability off Cape Hatteras and provide an additional test of a second instrumentation system installed for this deployment. This instrumentation system will report selected measurements directly to the C-MAN station CLKN7 for communication to the National Weather Service.

NDBC's use of the proven 3-meter buoy system as a comparison standard provides the opportunity to evaluate the two forms of the Coastal Buoy in both their anticipated deployment scenarios without requiring deployment of both buoys in each scenario.

Coastal Buoy I was deployed from the deck of the Coast Guard Cutter *White Holly*, a 133-foot Buoy Tender, on May 2, 1990, using the anchor-last technique. The initial data received from Coastal Buoy I during its first deployment can only be used as an indicator of the buoy's capability under limited conditions. A detailed data analysis will be conducted during its later deployments.

The buoy was observed to be active in pitch/roll in the wave environment and visually appeared to follow the wave slope well. The increase in pitch/roll activity, considered desirable for directional wave measurements, raises the question as to whether or not the anemometer measurement data quality is significantly reduced. The time series plot of wind speeds measured from Coastal Buoy I and

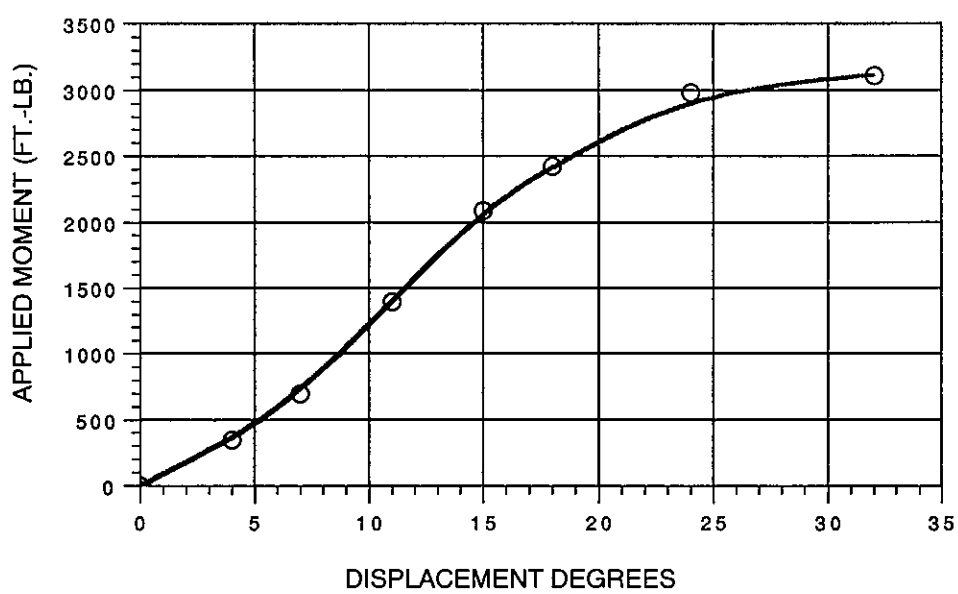

Figure 10. Righting Moment Measurements of Coastal Buoy I Without a Mooring Load Attached

the 3- meter NDBC buoy at station 42016 (Figure 11) for a 5.5-day deployment period shows good correlation between the two buoys. This portion of the deployment period was selected because it shows the passage of a weather front over the buoys. The wind speed is an 8-minute average of observations sampled at 1 Hz.

The wind direction time series plot (Figure 12) is an 8-minute average of observations sampled at 1 Hz. The consistency of differences between the two buoys as a function of wind direction may be due to compass deviations and alignments in the buoys. The Coastal Buoy uses one compass for each anemometer, and the 3-meter buoy at station 42016 uses one compass for both anemometers. Both buoys have wind fins to align each buoy with the wind.

The Coastal Buoy shows strong potential for meteorological, oceanographic, and directional wave measurements in coastal waters. The buoy is less costly and easier to handle than NDBC's open ocean moored buoys. The freedom of movement with a capsize-resistant hoop underhull structure offers an opportunity to investigate potential for improved buoy motion response for directional wave motions, decreased ocean-surface-current-induced trim, and mooring dynamic tension couplings to hull motion. The center pipe design offers a proven approach to increase stability and limit pitch and roll for wind measurements.

The buoy survived a 2-week deployment at sea and then retrieval without any damage for the limited sea (1.5-m maximum average wave height) and wind (14-m/s average, 17-m/s gust) conditions experienced to date.

Initial comparisons for meteorological, surface water temperature, and nondirectional wave measurements show good correlation. Wind speed and direction measurements did not show any anomalies from the active buoy pitch/roll motion. Qualification as an NDBC data buoy platform will require significantly more analysis from future deployments.

CDR W.E. Colburn,
USCG/NDBC

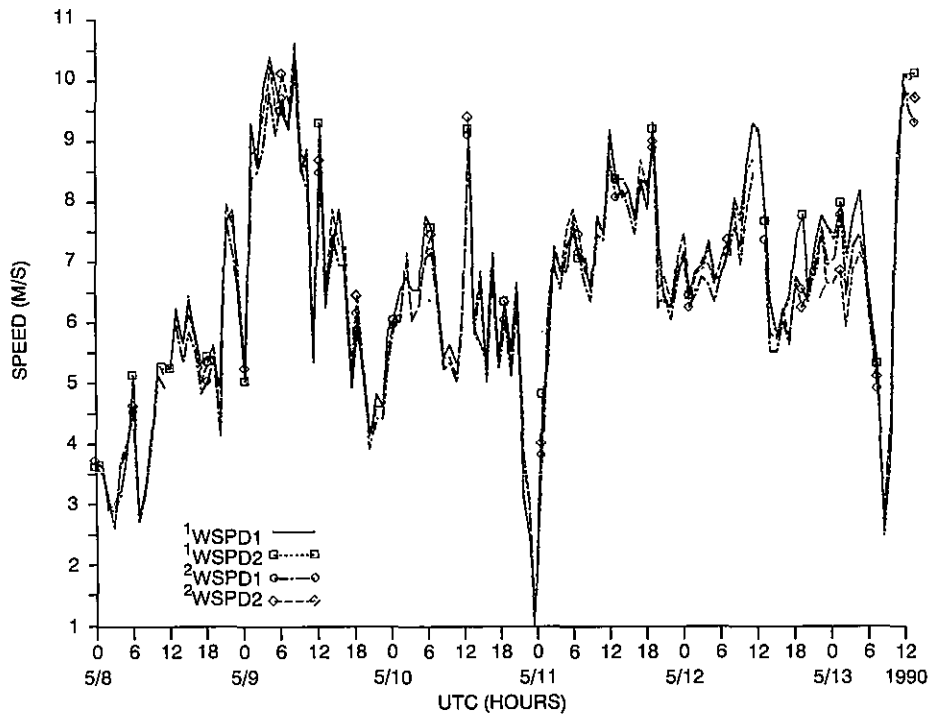

Figure 11. Wind Speed Time Series Plot for Two Anemometers on Coastal Buoy I (Station 42021, Prefix 1) and 3-Meter Buoy 3D10 (Station 42016, Prefix 2)

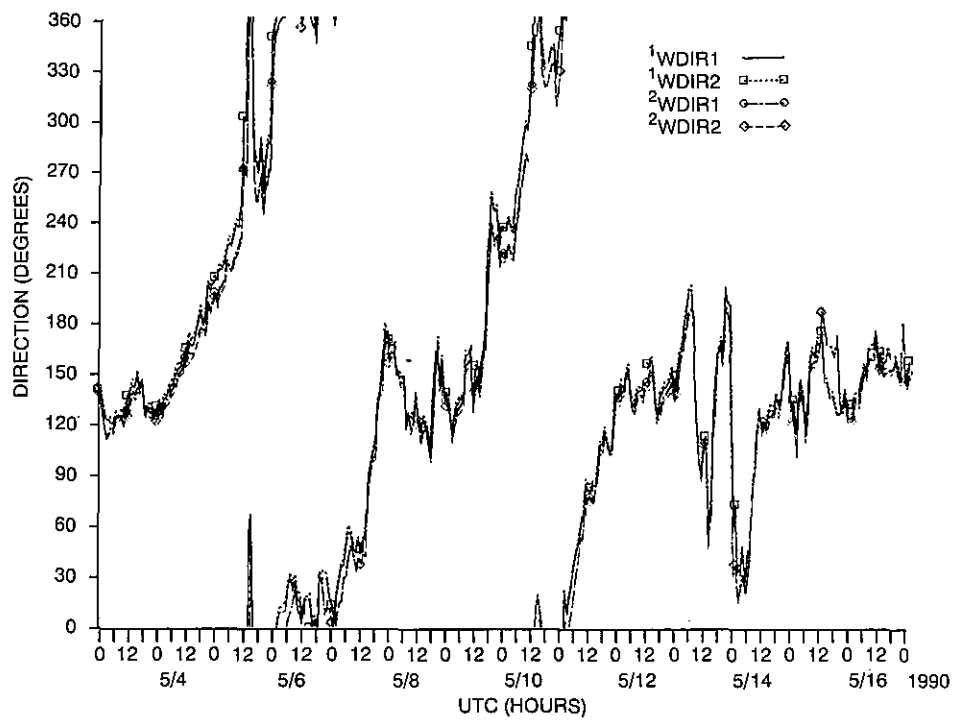

Figure 12. Wind Direction Time Series Plot for Two Anemometers on Coastal Buoy I (Station 42021, Prefix 1) and 3-Meter Buoy 3D10 (Station 42016, Prefix 2)

Update Continued

of data. Use of new technology in these peripherals has also resulted in reduced maintenance costs. Future planned upgrades include converting the MV/20000 to a dual processor by adding a central processing unit (CPU), increasing the compute power to 12 MIPS, and replacing the remaining MV/8000 with a 3-MIPS machine.

IBM PC compatible microsystems are being integrated into the NDBC computer inventory to perform specialized tasks, such as statistical and graphical analysis, weather products monitoring in support of data quality control, automation of the Engineering Test and Evaluation Laboratory, smart sensor development, payload maintenance, Mechanical Engineering analysis, and laptop computer applications in support of Field Services. This has been a cost-effective approach allowing NDBC to take advantage of off-the-shelf, commercially available software for many of these specialized tasks.

The present NDBC Computer System's projected life cycle extends through 1994, and a Feasibility Study has begun for NDBC's NEXT computer system. A thorough review of present and future data requirements, along with an analysis of all required applications, data access, and processing requirements will be studied and reviewed to anticipate the type of processing capabilities that will be needed. After this analysis, a review of current technology and its application to needs will be conducted.

Sallie P. Nolan
NDBC Data Systems

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 glossies. The right to edit all submissions is reserved. Articles ready for publication should be submitted to the:
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