Technical Bulletin
National Data Buoy Center

Volume 20, Number 1 January 1994

NDBC Setra Barometer Development

The National Data Buoy Center (NDBC) and others have previously published on the quest for a smarter, cheaper barometer. This search for a technological breakthrough and a significant reduction in cost continues, but unfortunately it is still somewhat of a distant goal. However, NDBC has achieved some notable success in reducing the cost of barometric pressure sensors through second source competition.

Since NDBC was chartered in 1972, barometric pressure sensors have been used on most of the buoys and fixed platforms in the NDBC operational network. Until recently, the meteorological sensors were normally acquired as part of the electronic data acquisition system (payload). A system vendor could either fabricate the sensors or obtain them from a subcontractor, so long as the sensor met system performance specifications and contract deliverable requirements. Early on, all system vendors chose to use the Rosemount 1201F-series pressure transducer as the barometric pressure sensor. This sensor has had a long history of reliable and accurate service. However, procurement of replacement sensors has been somewhat costly and requires lead times of about 9 months.

After reviewing associated costs and future sensor requirements, a decision was made by NDBC to identify a barometric pressure sensor that would be directly interchangeable with the Rosemount 1201F unit in form, fit, and function. With this action, NDBC also established any future procurement of this sensor as a competitive process. That alternative unit was found when Setra, Inc., re-engineered a basic Model 270 unit.

At the time, NDBC had had 2 years of successful preliminary operational experience with the 270W1 units; the basic Model 270 was a very successful sensor that was already on the GSA schedule, making the acquisition process simpler. Most of the required redesign efforts were mechanical. All re-engineering costs could be recouped from the first procurement of modified production units.

Along with some standard general performance specifications, a sensor had to meet the following basic electromechanical requirements to be compatible with the NDBC payload system pressure sensor (1201F-type) interface:

- **Output** — 900-1100 mb reported pressure range, at 0-5 VDC or 0-10 VDC
- **Electrical connector type** — MS3112E12-10P, or equivalent
- **Power (excitation)** — + and/or - 15 VDC (2 MA each supply)
- **Pressure port** — 7/16-20 UNF 3A fitting or adapter

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Coastal Buoy Update

The development of the Coastal Buoy was initiated by NDBC in 1989. It was designed to be a lightweight, low-cost buoy suitable for meteorological, oceanographic, and directional wave measurements in coastal and protected areas (Colburn, 1990).

The prototype buoy hull consisted of an ionomer foam flotation collar 2.3 m in diameter closely fitted around a cylindrical aluminum center compartment 0.92 m in diameter and 0.83 m high. Two of these prototype 2.3-m Coastal Buoys were constructed. These buoys had the option of being outfitted with either a pendulum arm with counterweighted ring or a counterweighted center tube mooring attachment structure (Colburn, 1990; Colburn and Tagge, 1990).

Several field tests of the prototype Coastal Buoys were conducted. The first field test was with the buoy in the counterweighted center tube configuration. This was conducted for two weeks in May 1990 in the Gulf of Mexico, in 8.8 m of water. The second field test was conducted from August to November 1990, west of the Columbia River Bar, in 33 m of water. One prototype Coastal Buoy in the counterweighted center tube configuration was also used from January to April 1991 to temporarily support the Surface Waves Dynamics Experiment (SWADE). It was deployed off the Virginia coast in a water depth of 49 m. In its final field test, a 2.3-m Coastal Buoy equipped with a pendulum arm and counterweighted ring mooring attachment structure was deployed from August 1991 to March 1992 west of Monterey Bay, California, in 2,103 m of water.

During these field tests, the Coastal Buoy was exposed to a variety of environmental conditions, surviving wind speeds up to about 19 m/s and significant wave heights of approximately 6 m. The tests showed that the Coastal Buoy was a suitable platform for both meteorological data and directional wave measurements (Teng, et al., 1992; Mettlach et al., 1991; Colburn and Tagge, 1990).

In addition to the measured data, some observations of the Coastal Buoy during the field tests also provided important information used to evaluate the performance of the prototype buoys. It was observed that the Coastal Buoy generally followed the wave slope with more active pitch and roll motions (e.g., snap-jerk motions) than those of the 3-m buoy. It was felt that this lively response was caused by the buoy's smaller size and by its relatively large (5 m) mast height. Although the mast was lightweight, the aerodynamic drag, drag

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Coastal Buoy ...

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arm, and moment of inertia still contributed significantly to the buoy's dynamics. In addition, according to the deployment and retrieval crews, the high mast was difficult to handle and easily damaged at sea. Following completion of the final test and retrieval of the prototype Coastal Buoy, it was observed that the average water line, estimated from long-term water marks on the foam, was approximately 0.18 m below the deck edge. This left the buoy with only 550 kg of reserve buoyancy, which was significantly less than desired. The pendulum-arm configuration mooring attachment structure was designed such that the arm would not contact the counter-weighted ring, except under very severe conditions. Examination of the pendulum-arm and ring after the prototype Coastal Buoy was retrieved from the final field test showed that only a limited amount of light contact was made. In addition, there was no significant wear on the mooring attachments and no damage of the articulated pendulum mechanism. After each test deployment, the foam exterior of the hull was visually inspected. There were several areas of minor damage to the foam (gouges, cuts, and surface scratches). However, since the ionomer foam is closed-cell, this damage did not degrade the buoy's reserve buoyancy. After over 1 year of cumulative deployments, no significant amount of water was absorbed by the foam, and the foam material showed no sign of deterioration.

The field tests showed that the prototype 2.3-m Coastal Buoy was a good design and performed well. However, it also pointed out several areas where the design could be improved. Based on the field test results, observations, and further analysis, it was concluded that certain modifications could be made to the design which would improve the buoy's performance and survivability without degrading its existing characteristics. These were:

(1) Increase the diameter of the foam flotation collar from 2.3 m to 2.4 m. This would increase the reserve buoyancy and also smooth out the snap-jerk motion of the buoy. This size still satisfies the initial design requirements for the Coastal Buoy:
   - That a truck be able to transport the buoy without special routing or permits.
   - That the buoy be easily and safely handled without special equipment or procedures.

(2) Increase the heights of both the flotation collar and buoy center payload compartment by 0.15 m. This increases the buoy's reserve buoyancy, and it makes the center compartment the same size as that of the 3-m buoy.

(3) Decrease the anemometer height from 5 m to 3 m, to reduce the likelihood of sensor damage during the buoy's deployment/retrieval and to improve the buoy's response.

Two 2.4-m-diameter ionomer foam flotation collars were procured in late 1992. In the spring of 1993, the aluminum structure of the two prototype Coastal Buoys was modified and the enlarged foam collars installed. Figure 1 shows the modified 2.4-m Coastal Buoy.

In June 1993, one 2.4-m Coastal Buoy equipped with a standard NDBC directional wave measurement system was moored in Lake Michigan off Milwaukee, Wisconsin, in 19 m of water (station 45010). It was deployed to support the NOAA Great Lakes Environmental Research Laboratory Near Shore Hydrodynamics Project. Since its deployment, analysis has shown that the buoy has collected high-quality directional wave measurements. The buoy remained on station as planned until November 1992, at which time it was recovered prior to the winter ice season.

The second 2.4-m Coastal Buoy, equipped with a magnetometer-only directional wave measurement system, is being used in support of the University of Miami's Oil Pollution Response Center activities. The buoy provides both meteorological and directional wave information.

The 2.4-m Coastal Buoy has a bare-hull weight of 862 kg and a deployed weight of 1,315 kg. Its small weight and size (compared to that of the 3-m discus buoy) reduces its lifecycle cost and makes the buoy easier to deploy. It can also be serviced by a wider range of supporting tenders than other larger NDBC platforms. Because of its low cost and ease of deployment, the Coastal Buoy is ideally suited for supporting both short-term scientific projects and long-term environmental monitoring. NDBC has tentative plans to construct two additional 2.4-m Coastal Buoys in 1994.

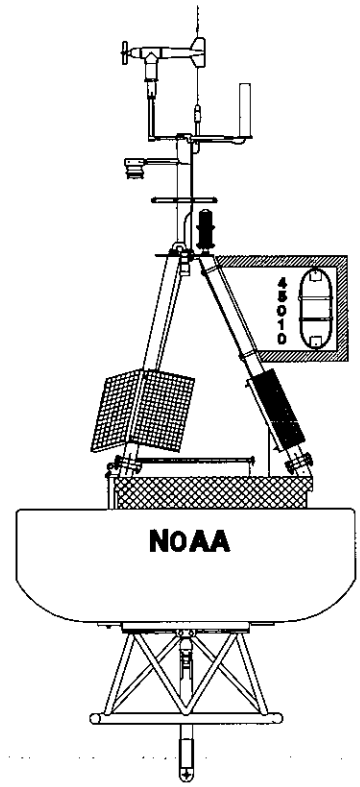

Figure 1. 2.4-Meter Coastal Buoy

References:

(1) Colburn, W.E., 1990, "Coastal Buoy Testing Begins," National Data Buoy Center, Technical Bulletin, Volume 16 Number 2.

(2) Colburn, W.E., and Tagge, L.F., 1990, "NDBC's Coastal Buoy Development Proceedings of MTS'90, pp. 358-369.

(3) Mettlach, T., Gilhousen, D., and Wang, D., 1991, "Evaluation of the National Data Buoy Center Coastal Buoy," Proceedings of MTS'91, pp.1208-1215.

(4) Teng, C.C., Timpe, G.L. and Dagnall, R.J., 1992, "Field Test and Evaluation of NDBC's Coastal Buoy," Proceedings of MTS '92, pp. 943-948.

Dr. Chung-Chu Teng, NDBC Engineering

NDBC Operational Stations Deliver 2.8 Million Data Observations For 1993

The trend of steady growth in NDBC's network of automated weather stations continued. The 1993 NDBC network, consisting of 172 operational stations and 14 Profiler Surface Observing Stations (PSOS) that were active during the year, delivered 2,803,243 real-time data messages to the National Weather Service (NWS) and other users. The total message count includes 2,371,938 meteorological messages and 436,305 wave messages. These were made up of 890,366 hourly meteorological messages from 61 moored buoys and 57 C-MAN stations; 436,305 wave messages from buoy and C-MAN stations; 82,657 asynoptic meteorological measurements from 47 drifting buoys; and 962,610 6-minute messages from PSOS. Moored buoys and C-MAN stations combined delivered 1,326,671 messages (see Figure 2).

As a measure of NDBC's success rate, a system performance figure is computed for all stations providing synoptic reports. The system performance percentage represents the usable number of synoptic observations reported, compared to the number of observations expected while the station was properly configured.

The message distribution noted above represents a success rate of 88.8 percent for buoy meteorological messages; 87.3 percent for buoy wave messages; 92.0 percent for C-MAN meteorological messages; and 94.4 percent for PSOS meteorological messages. Combined station performance for buoys and C-MAN stations was 90.3 percent for meteorological and 85.1 percent for oceanographic data (see Figure 3).

Over the past 20 years, NDBC has increasingly supported the critical NWS operational forecasting and warning mission. During 1993, NDBC buoy and C-MAN stations provided many high-quality, real-time observations from the Gulf of Mexico that helped to characterize the March '93 "Storm of the Century," and from nine east coast stations along its track that provided hourly updates for forecasters. Hurricane Emily's encounter with the Atlantic coastal states was intercepted by six NDBC buoy and C-MAN stations. The Diamond Shoals C-MAN station reported maximum sustained winds of 53 meters per second, maximum 5-second peak wind to 65.9 meters per second, and a minimum barometric pressure of 964.5 millibars during Emily.

Michael K. Burdette, NDBC Data Systems

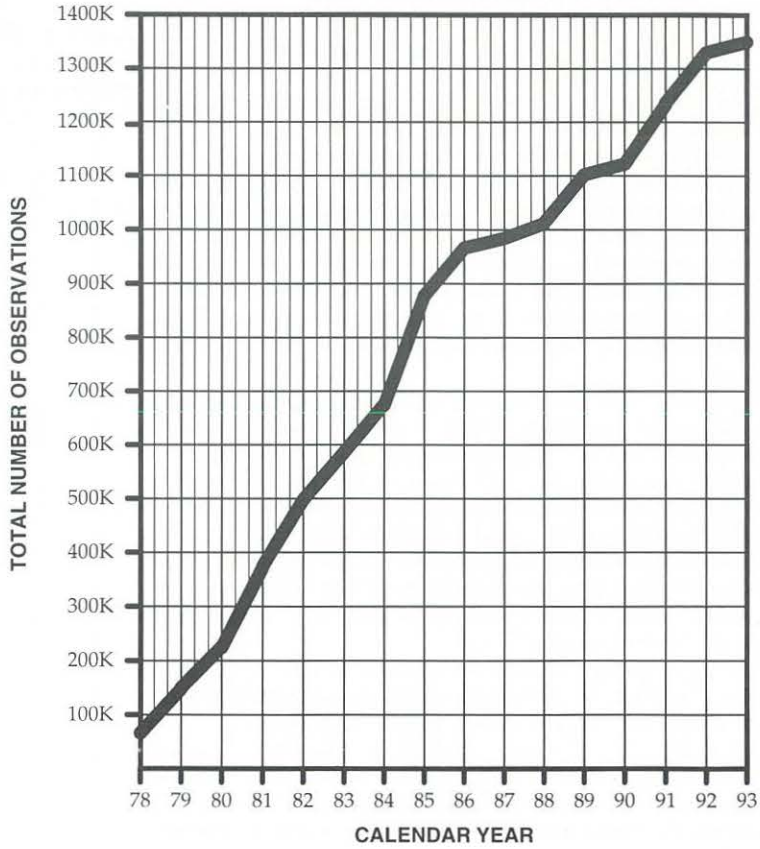

Figure 2. Total number of messages per year delivered by NDBC moored buoys and C-MAN stations

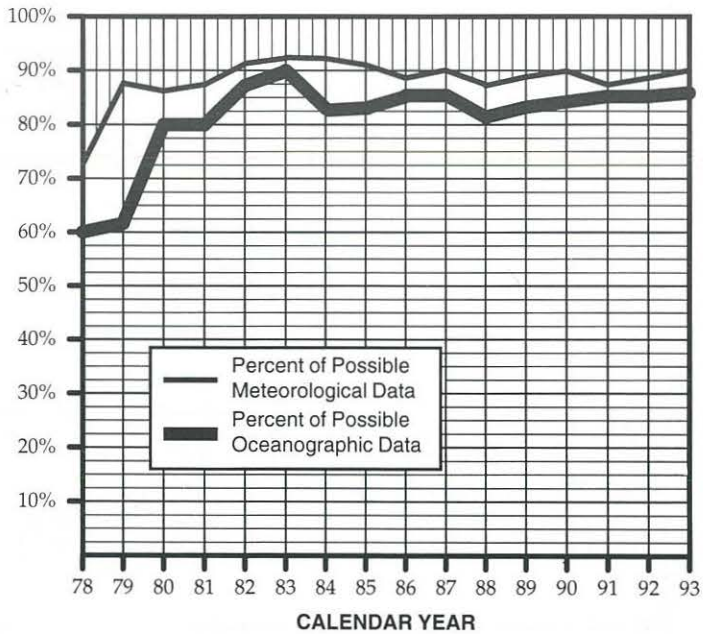

Figure 3. Station performance for moored buoy and C-MAN meteorological and oceanographic data

Setra Barometer ...

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- **Mounting** — sensor mounted and operated in a vertical position, pressure port down
- **Mounting provisions** — mounting feet or plate with four holes in a 3-inch square pattern to accommodate #8 mounting hardware.

Two 5-VDC and two 10-VDC prototype test units were delivered to NDBC in March 1992. Environmental and functional testing revealed only three minor problems associated with these units — one functional, one temperature-related, and one mechanical. Figure 4 depicts a graph of the error curve from one of the prototype units tested. The prototype test results were evaluated and reviewed by NDBC and Setra engineers, and minor design revisions were initiated to eliminate the problems. In an unrelated action, the NDBC pressure reporting range was expanded to 800-1100 mb for all systems.

In August 1993, the first five production units were received for final acceptance testing. Figure 5 shows an outline drawing of the production unit. Figure 6 is a graph of the calibration data from one production unit. It shows that the units have a very tight calibration error band at all temperatures. The small residual factory positive offset was taken out, and the calibration test was rerun. Figure 7 shows the curves for the same production unit after recalibration. The largest error range is 0.13 mb, which is well within the NDBC allowable calibration tolerance of 0.75 mb.

The development of the Setra Model 270 NDBC-5 (5-V) and Model 270 NDBC-10 (10-V) barometric pressure sensors has been completed. The units are now fully qualified for operational use in all systems and are directly interchangeable with the Rosemount barometers without any special interface requirements. As a result of this development, NDBC expects to reduce the annual barometric sensor replacement cost by 25% or more.

Dennis Mahar, NDBC Engineering

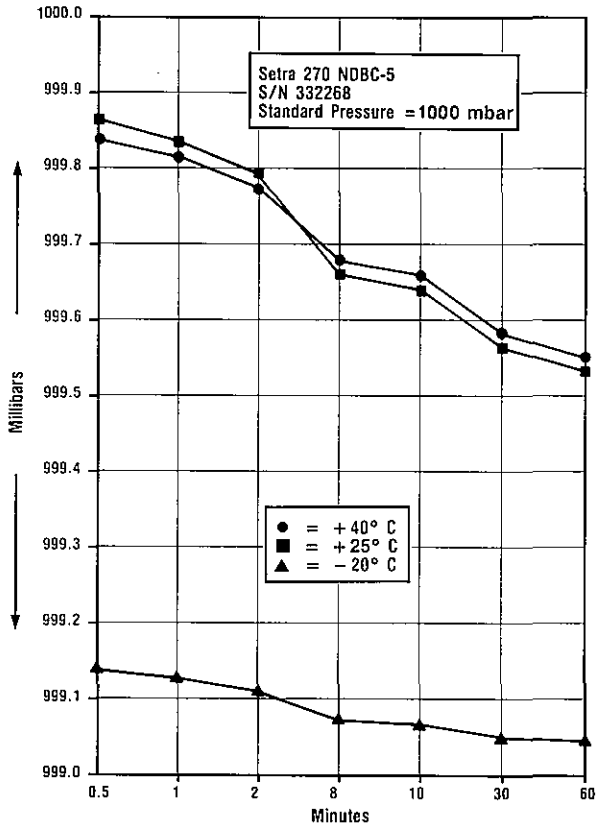

Figure 4. Typical error curve of prototype Setra 270 NDBC sensor

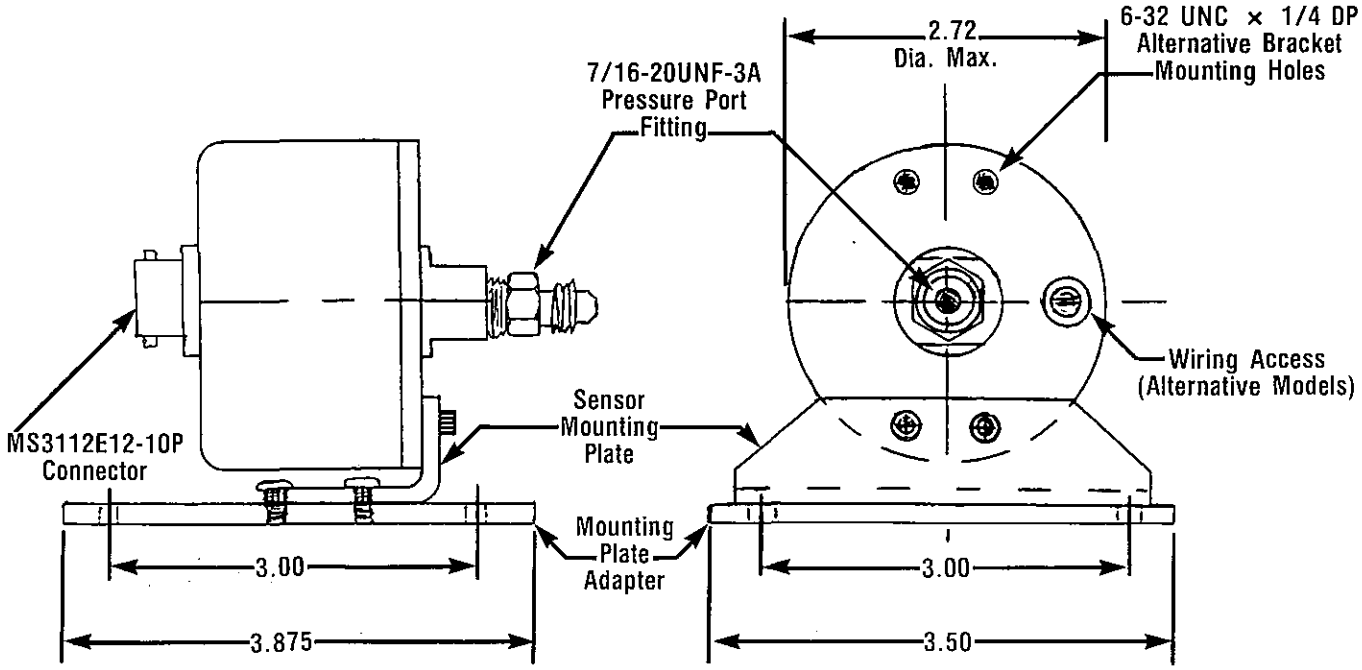

Figure 5. Setra 270 NDBC-5/10 sensor outline drawings

The Use Of NDBC Platforms For Oceanographic Monitoring

Mission

The National Data Buoy Center (NDBC) of NOAA's National Weather Service (NWS) is proposing to establish a cooperative working group interested in developing a long-term, oceanographic monitoring network using NOAA's existing weather buoys and fixed site Coastal-Marine Automated Network (C-MAN) installations. Such a group might consist of Federal and state governments, private industry, including fisheries and offshore oil production, and academia. The oceanographic data collected through the NDBC network will supplement ship data; provide longterm oceanographic data; and provide subsurface ocean data, surface calibration data, and algorithm development for satellite imagery.

Justification

While seemingly organized, present sampling strategies in the ocean environment are "hit or miss." Oceanographers certainly have the capability of studying and understanding average seasonal and annual variations, but rarely have ocean scientists had the advantage of making continuous measurements to sample episodic or short-time-scale events which may occur periodically or quasi-periodically.

A growing concern with our environmental sampling is distinguishing the natural variability from anthropogenic input. This cannot be done with short-time-scale studies. There is a conspicuous absence of quantitative and standardized long-term monitoring programs with time series on the scale of pollution events and natural climatological cycles. No clear baselines have been established in advance of human impact. This applies to the entire marine environment, whether it be with tracking coastal eutrophication or CO_2 uptake in the global ocean. To study variability in the ocean, we must look at time scales of decades, as we do in atmospheric studies.

Over the past 10 years, we have asked, "Is the environment getting better or worse?" This is something managers need to know if appropriate environmental regulations are to be made and enforced. Because most oceanographic studies are conducted over 1 to 3 years to address an immediate problem or a certain area, it becomes difficult for the manager or regulator to make an educated decision concerning longterm environmental problems and/or changes. At present our knowledge of the oceanic and coastal regions is inadequate to be able to predict the consequences of human-induced changes on the environment.

One answer to this problem is the use of established ocean platforms of the NWS to collect data on a continuous basis in support of those agencies, private and public, concerned with environmental conditions and long-term changes in the estuaries, coastal zones, and deep ocean environments.

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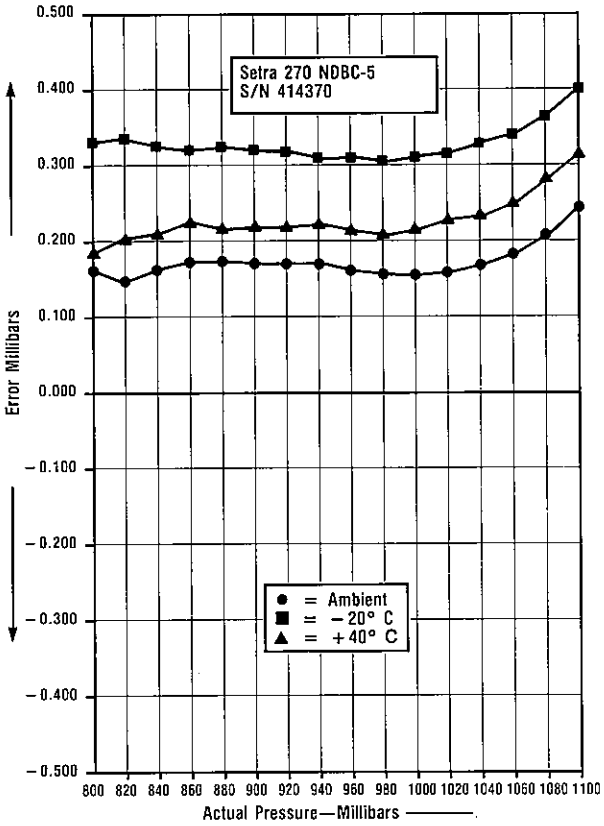

Figure 6. Calibration curve for production Setra 270 NDBC-5 (before adjustment)

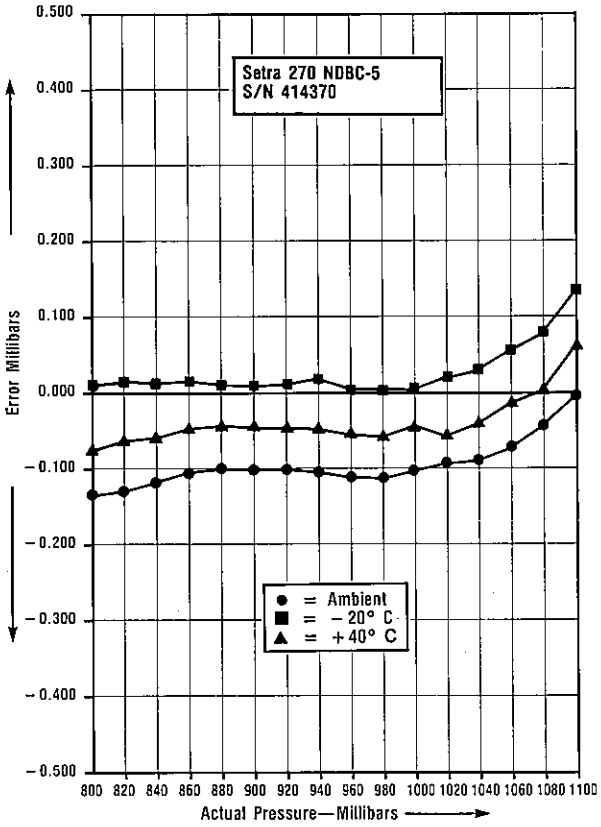

Figure 7. Calibration curve for production Setra 270 NDBC-5 (after adjustment)

Platforms ...

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NDBC is expanding its capability for installing additional sensors on its weather platforms to collect long-term oceanographic data. In addition, NDBC will work in cooperation with those organizations and individuals in research and development of reliable, low maintenance sensors that can withstand long deployments without sacrificing data integrity. NWS has achieved this for collection of marine atmospheric data, ocean temperature, and wave spectra with buoy systems that are capable of collecting these data for periods of up to 2 years without servicing. Data are monitored in real time. Erroneous data caused by serious system failures are deleted from distribution immediately; detailed analysis of the cause of failure and detection of more subtle problems occur within 24 hours. NDBC could provide this same capability for oceanographic data collection.

NDBC has been collecting marine atmospheric data since 1971. Presently, sea surface temperature and wave data are routinely collected in conjunction with atmospheric data. The atmospheric data are collected hourly and include average wind speed, direction, and peak gust, as well as "continuous" winds, air temperature, and barometric pressure. Via a cooperative agreement, the National Ocean Service (NOS) works with NDBC and funds two moored buoys, one off San Francisco and one off Los Angeles. These stations collect marine observations that support local shipping and fisheries, in addition to supporting NWS operational forecasting needs. On a few specially configured buoys, rainfall, solar radiation, and humidity are also obtained. In the past, thermistor arrays have been successfully integrated with buoy systems. During the Strategic Petroleum Reserve Program, NDBC assisted in the developing, testing, and deploying of current meters and temperature, conductivity, and depth sensors.

NDBC is already involved in two cooperative endeavors in the oceans. One is with the Florida Institute of Oceanography (FIO) to measure temperature and solar radiation in the air and temperature, salinity, and solar radiation in the water at C-MAN stations in the Florida Keys and Florida Bay (Figure 8). The second is sponsored by the Minerals Management Service. NDBC has deployed two moored buoys with Acoustic Doppler Current Profilers in the Pacific Ocean off southern California.

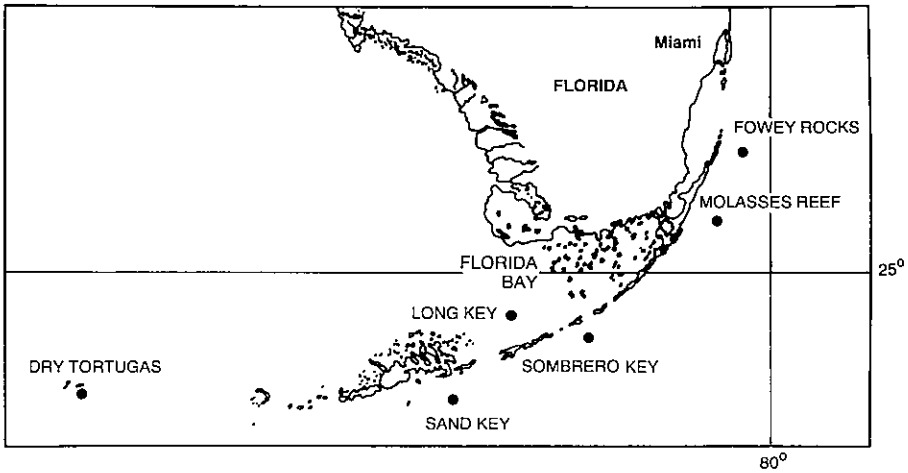

Figure 8. Enhanced NDBC C-MAN stations in the Florida Keys and Florida Bay.

Platform Availability

Several suitable station configurations are maintained by NDBC. The first group is the moored buoys. The largest are the 10- and 12-meter discus buoys. These primarily operate in deep water areas where high waves are possible, but can be used where measurements dictate a large, stable buoy. Presently, these buoys are operating in depths from 14 to 3,300 meters.

The next largest buoy is the 6-meter NOMAD. The hull is boat shaped and has very good stability in rough water. These buoys are primarily used in deep water at higher latitudes where directional wave measurements are not required. Like the 10- and 12-meter buoys, they can operate in a variety of water depths, currently ranging from 15 to 5,300 meters.

A third type hull is the 3-meter discus (Figure 9). These buoys were designed to operate in nearshore/shelf regions. However, they are presently deployed in water depths from 14 to 2,500 meters. They are small, lower cost, and perfect for coastal and estuarine monitoring.

The second group is drifting buoys (Figure 10). At this time, they are used primarily in the oceans of the Southern Hemisphere to gather meteorological data for the Tropical Ocean Global Atmosphere (TOGA) research program. They continuously transmit data for 18 to 24 months until their power supply is depleted. They would be excellent vehicles to gather basic temperature and salinity data in remote areas of our world's oceans. Modern mooring technology also enables them to be moored for some applications.

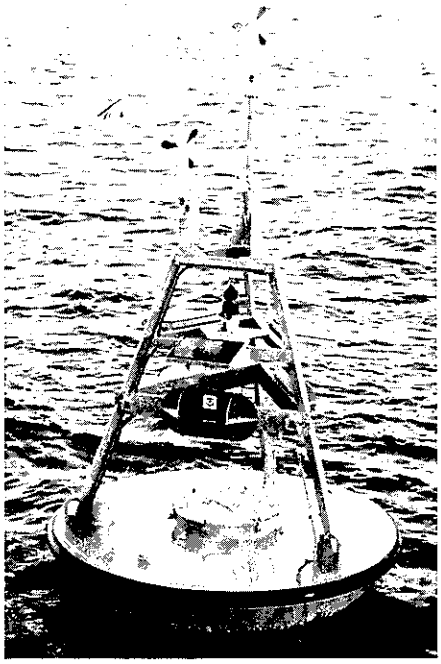

Figure 9. 3-Meter Discus Buoy

The third group of data-gathering stations is the C-MAN sites, fixed platforms located along our coasts. These stations are located on lighthouses, piers, and offshore light towers. Strategically located in the coastal zone, they provide invaluable data in an environmentally critical area, and they are relatively easy to access. Oceanographic sensors can be mounted on the light tower located at sea, or they can be deployed on a buoy with line-of-sight data transmission to land-based stations (Figure 11).

Proposed Measurements

As a first step toward using NDBC platforms for the collection of long-term oceanographic data, NDBC and NOS

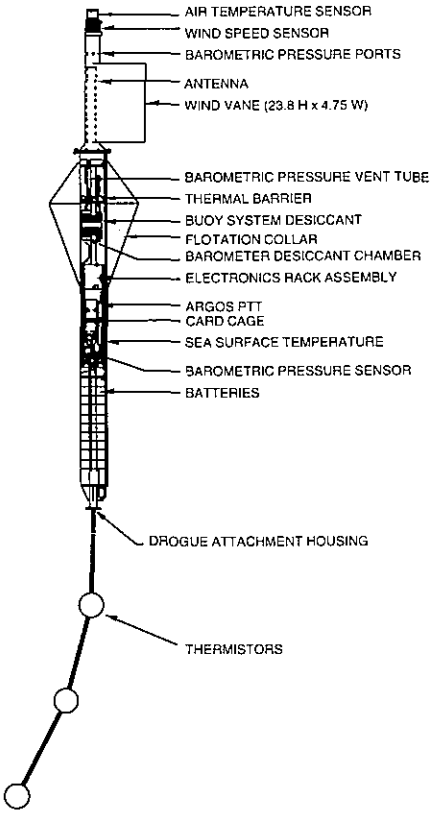

Figure 10. WSD Drifting Buoy

held a workshop in July 1993. The primary goal was to assign a high, medium, or low priority to a list of parameters defined by the Global Ocean Observing System that could be routinely measured on an operational basis to monitor the state of the ocean and oceanic ecosystems. The parameters were further divided into:

1) measurements that are now possible or require very little development to be operational (1 to 2 years); and
2) measurements that will be possible with more development (2 to 5 years).

The results are shown in Table 1.

The advantage of the NDBC network is that data acquisition and processing electronics suitable for *in situ* use are already in place, and the data acquisition system could be adopted to include oceanographic sensors.

Geographic areas that NDBC will pursue for oceanographic measurements include Florida Bay, Cape Hatteras, the coastal Middle Atlantic Bight, and the Hawaiian Ocean Time Series station. These locations have been identified by NOAA and other government agencies as scientifically and environmentally important. In some of the areas, NDBC already has C-MAN stations or moored buoys in place. Together with investigators from government agencies and academic institutions, proposals are being developed to establish enhanced monitoring stations in several of these areas.

These projects are the beginning. By coordinating the efforts of diverse organizations, NDBC is working to make more marine data available to the user. A network of enhanced stations will hopefully take root and grow steadily during the next few years.

Catherine E. Woody,
NDBC Program Management

Table 1. Results of NDBC buoy workshop

CAN MEASURE	HIGH PRIORITY	MEDIUM PRIORITY
NOW	VELOCITY, TEMPERATURE, SALINITY	FLUOROMETRY, SOLAR RADIATION, PHOTOSYNTHETIC, AVAILABLE RADIATION, TRANSMISSIVITY, PRECIPITATION
WITH REASONABLE DEVELOPMENT	CO_2	NUTRIENTS, ZOOPLANKTON, DISSOLVED OXYGEN, TOMOGRAPHY

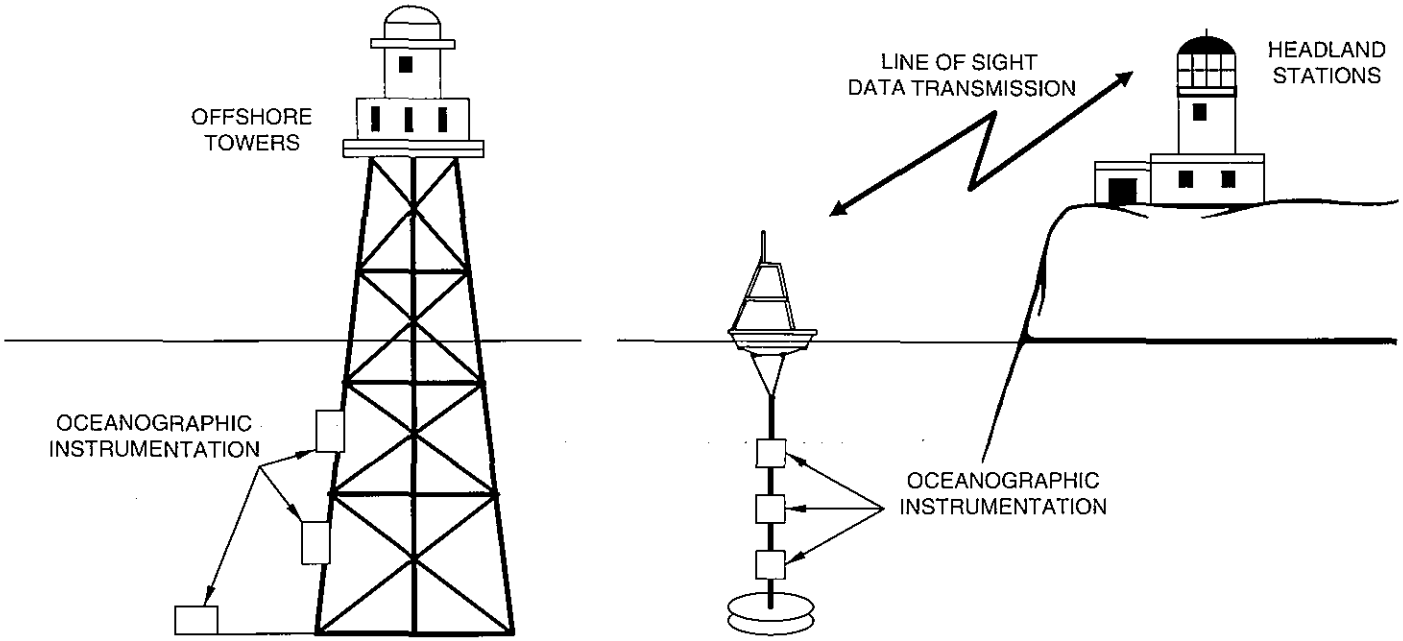

Figure 11. Oceanographic sensors mounted on NDBC C-MAN station and moored buoy.

Materials, Equipment, and Resources Lifecycle Network (MERLIN)

The demands on logistics and equipment resources to support its growing network of automated weather stations led NDBC to automate the logistics equipment management functions. Performing like a magician by pulling the pieces together into a system which supports all elements of NDBC, the Materials, Equipment, and Resources Lifecycle Network (MERLIN) integrates the parts of the automated Equipment Management System—property tracking, equipment reliability, consumable inventory, electronic component handling, and other capabilities. By entering one word, users gain access to all features of MERLIN, easily transversing through the many functions with information now shared by the different modules through data bases and tables. Responsibility for maintenance is shared by various work functions, greatly improving work flow through the automation of information between groups.

Using a Fourth Generation Language, CQCS, NDBC's support contractor originally built individual modules (PROTEUS, IRIS, COMUS, and ECHO), performing the functions described above. As the modules were implemented and became more stable, they were integrated into one system, MERLIN. New modules have been added as they became available; e.g., Internal Work Request (IWR) Tracking; status information on drawings, Engineering Change Orders (ECO's), and Engineering Change Requests (ECR's); and the first phase of Shipping and Receiving. Figure 12 illustrates the current MERLIN system. Figure 13 illustrates the current and planned MERLIN system, showing considerable increase in the interaction between modules, and the addition of the following:

- Work Control, absorbing the current IWR Tracking
- Expanded property module, tracking at the subassembly level
- Expanded reliability tracking, calculating statistics at the subassembly level
- Payload parameter tracking and control
- Expanded shipping and receiving
- Automated procurement
- Configuration management

The goal of the MERLIN system is to be responsive and flexible and to meet the needs of all NDBC functions. While new modules are being added, enhancements continue to be made to the existing system to improve its use and capabilities. As more interaction between modules causes more sharing of information to take place, the overall maintenance of the system is reduced. MERLIN is scheduled to be moved from the Data General MV/20000 super-minicomputer to the PC (Novell Netware) network after the first of the year to provide easy access for all personnel. A disk array containing more than 50 GB of storage will be added to the network server. This move is in preparation for NDBC's plan to "rightsize" the current scientific and business processing systems.

Sallie Nolan, NDBC Data Systems

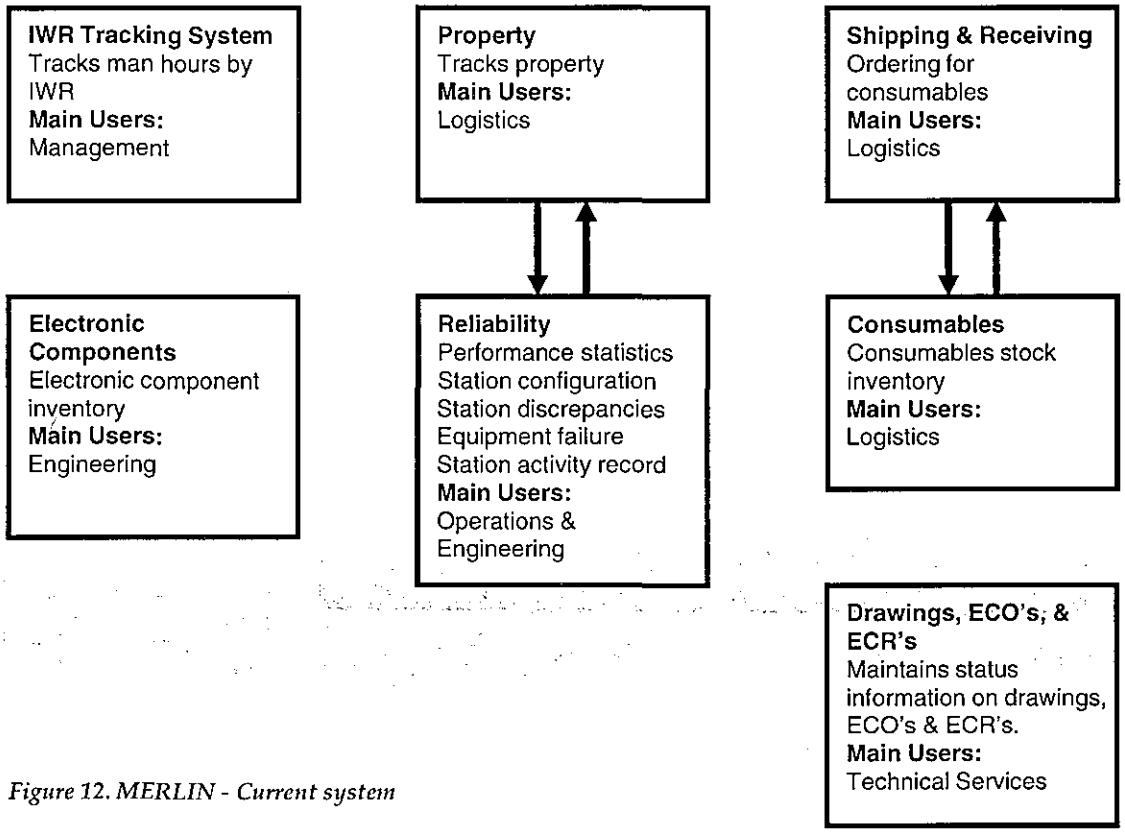

Figure 12. MERLIN - Current system

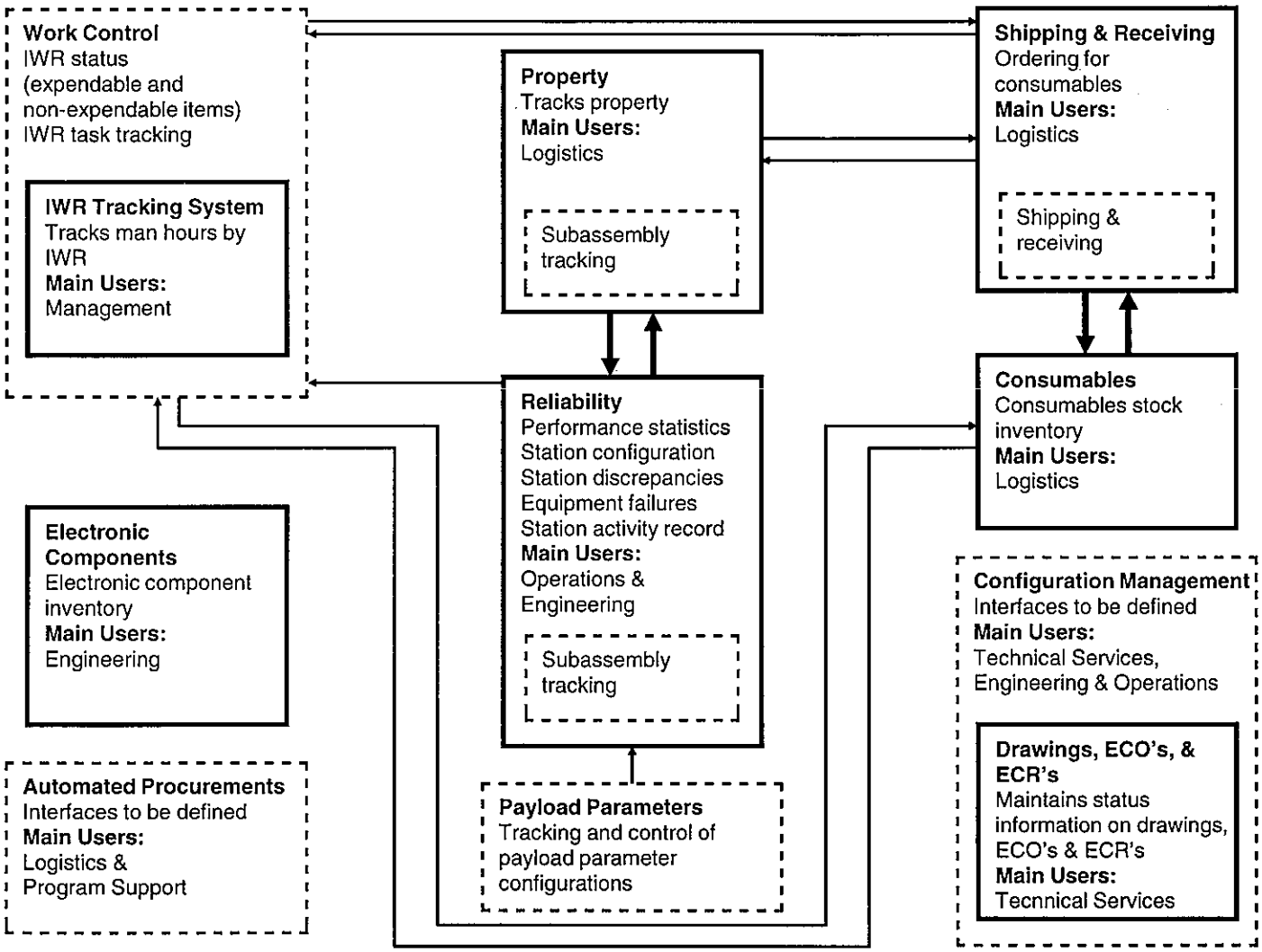

Figure 13. MERLIN - Current and planned system. Dashed boxes represent future modules.

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

National Data Buoy Center
Building 1100
Stennis Space Center, Mississsippi 39529-6000
Phone (601)688-2800

Cape Hatteras-to-Gulf Stream Remote Sensing Experiment

An experiment was performed during June 1993 to better understand radar imaging of ocean surface sub-mesoscale features. The experiment area extended from near Cape Hatteras, North Carolina, to the Gulf Stream (see Figure 14). This was the second and final experiment of the High-Resolution Remote Sensing Program (HIRES), an accelerated research initiative sponsored by the Office of Naval Research (ONR) and the Naval Research Laboratory (NRL). NDBC operated two buoys in support of each of these two experiments.

The HIRES program included the disciplines of remote sensing, oceanography, meteorology, and microlayer physics. The approach was to acquire simultaneous radar and *in situ* measurements and to conduct theoretical and modeling analyses. These analyses were to investigate the generation and variability of features having lengthscales of 10 km and less, to understand how these features modulate the surface roughness, and to use scattering theory and imaging physics to predict how the ocean's surface would look to real- and synthetic-aperture radars (RAR and SAR).

The first experiment was conducted in September 1991. Over 100 ship-crossings of the inshore edge of the Gulf Stream were made in winds ranging from 2.6 to 20.6 ms^{-1}. Aircraft overflights imaged the Stream, slicks, internal waves, surface swell, a high-backscatter feature, and a more persistent, long, narrow, cusped feature. *In situ* measurements suggested that these features were current rips lying along the edge of a Gulf Stream shingle and other water-mass boundaries. Sampling done over the shelf lay within range of a shore-based HF radar, which made synoptic maps of the surface currents. Results from this first experiment and related efforts were presented in the Special Session, "Remote sensing of submesoscale features associated with the Gulf Stream," at the Fall 1992 American Geophysical Union (AGU) Meeting.

The June 1993 experiment was designed to explore further the generation, time variability, and imaging of submesoscale features. Improvements in instrumentation, platform availability, and sampling strategy added to the existing valuable data set. Measurements were available from Minerals Management Service (MMS) current meters located along four lines (A, B, C, D), as shown in Figures 14 and 15. Research platforms (see Table 2) included two ships (the R/V *Iselin* from Woods Hole Oceanographic Institution and the Navy oceanographic research ship *Bartlett*), an NRL P-3 airplane, a Naval Air Warfare Center (NAWC) P-3, a National Aeronautics and Space Administration (NASA) T-39, and a Jet Propulsion Laboratory (JPL) DC-8. The *Iselin* towed a catamaran carrying a laser wave-slope gauge, an acoustic Doppler current profiler (ADCP), an anemometry package, an atmospheric acoustic sounder, and a video camera. The *Bartlett* had a video-based wave imaging system and towed a surface-layer temperature-salinity array, an ADCP, and a sled for measuring surface tension. Both ships had standard ADCP's and various radars.

The NRL P-3 had an X-band RAR, Ku-band scatterometer, laser profilometer, radiometer, and video multi-spectral camera. The NAWC P-3 had an SAR, and the NASA T-39 had a radar ocean wave spectrometer. The JPL DC-8 was equipped with a multi-frequency SAR (P- (441 MHz), L- (1.25 GHz), and C-band (5.3 GHz)) as well as an L-band interferrometric SAR.

As part of the experiment, two NDBC 3-m discus buoys were moored on the shelf at stations 41015 and 41017 in water depths ≅ 29 m, as shown in Figures 14 and 15. A third NDBC buoy, supported by the COE Coastal Engineering Research Center (CERC), provided data at station 44014, as shown in Figure 14. Standard instrumentation for these buoys provided air temperature, water temperature, barometric pressure, average wind speed, 5-second peak wind speed, wind direction, and directional wave data. Additional nonstandard sensors were added to each buoy to provide time series data from which wind stress, humidity, current speed and direction at 10-m depth, rain rate, and salinity could be measured. Data from NDBC Coastal Marine Automated Network (C-MAN) stations at Chesapeake Light (CHLV2), Diamond Shoals Light (DSLN7), and Cape Lookout Light (CLKN7), all fixed platforms, were also available for support of the experiment (see Figures 14 and 15).

Surface current measurements were obtained using an Ocean Surface Current Radar (OSCR) (HF, 25.4 MHz) over the full experimental time using "master" and "slave" land stations as shown in Figures 14 and 15. The measurements were made at 700 grid points, spaced 1 km apart, every 20 minutes over an approximately octagonal region (Figure 15) extending 45 km seaward from the shoreline. The illuminated area (about 1000 km^2) of the HF radar system encompassed both buoys, 41015 and 41017, and several stations along the MMS's Salvo ("B") line of current meters.

In this experiment, a "spotter plane" was used in conjunction with the HF radar surface current maps and Advanced Very High Resolution Radiometer (AVHRR) imagery to provide guidance to the ships for sampling. Sea surface temperature images with overlaid current vectors were downloaded daily to the ships. Additional surface current maps were transmitted by facsimile to the ships to direct them toward interesting surface features. In addition, data collection was coordinated with overflights of the ERS-1 satellite, which provided synoptic SAR imagery after the experiment.

Data from the second experiment are now being evaluated, and results will be published soon.

Dr. Hans Graber,
University of Miami

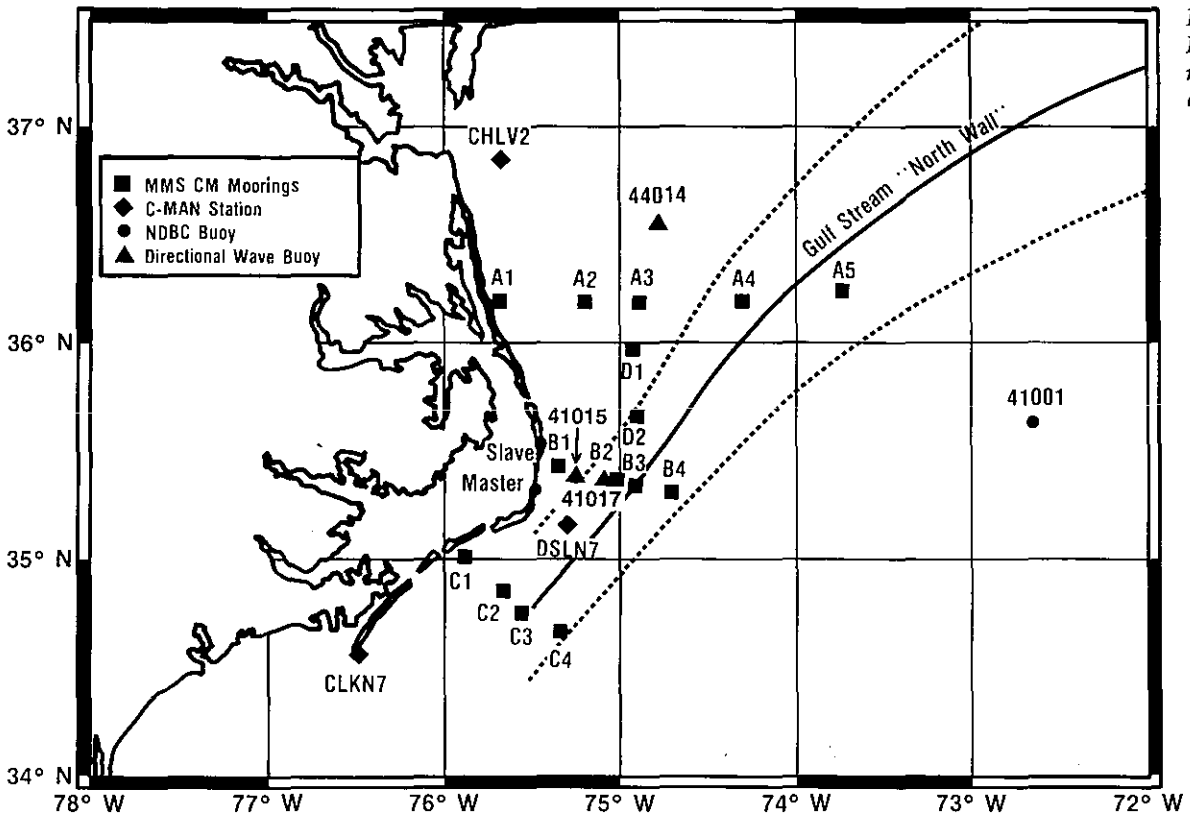

Figure 14. High-resolution remote sensing experiment

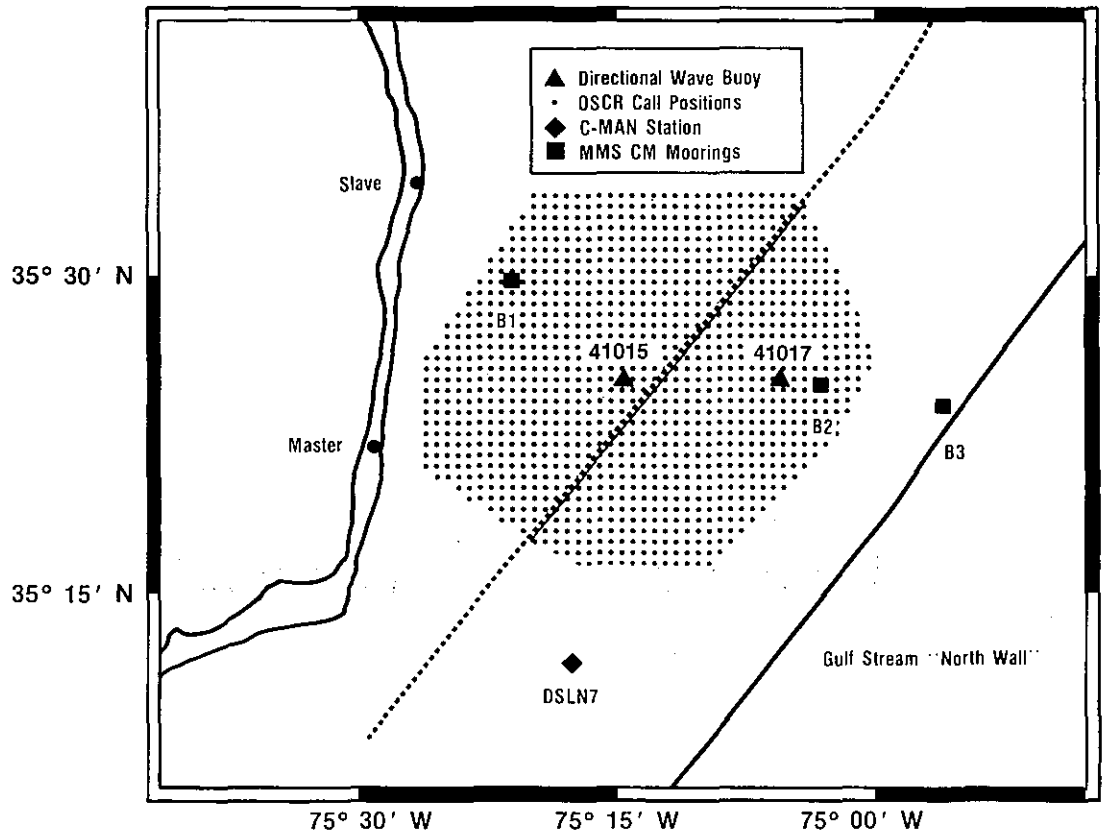

Figure 15. HIRES and MMS field program

Table 2. High-Resolution 2 experiment resources

PLATFORM	PI	SYSTEM/TASKS
NRL-Wash DC		
	Mied/Valenzuaela	Communications & Control
	Trizna	
USNS Bartlett		
	Marmorino	Chief scientist
	Donato(Askari)/ Kaiser	Ku-band, C-band, PRT-5, ship motion & wind
	Donato	Monitor Edson's wind stress system, Help CTD
	Kaiser/Andrews	STEMS, video wave imaging
	Marmorino/Greenewalt	STAR, towed CTD
	McLaughlin/Allan/ Martin/Gordon	Coherent Doppler radar
	Trizna/Martin/Sletten	Marine radar (RAR)
	Trump	Ship-mounted ADCP, Towed ADCP and CTD (TOAD)
R/V Iselin		
	Bock	Chief scientist
	Edson/Young	Wind stress, ship-mounted ADCP
	Gotwols/Chapman	Short-pulse coherent X-band radar
	Hwang	Scanning laser slope buoy
	Hara/Hare(Lyzenga)	Doppler radar & IR,
	Smith	Wire-gauge wave buoy, Passive microwave
	Blanco(Trizna)	Marine radar (RAR)
	Meadows	Radar-tracked drifters
R/P LADAS		
	Bock/Hara	Scanning laser slope gauge
	Chapman	Ultrasonic current meter
	Edson/Young	Iner-diss & eddy correlation wind stress, ADCP
NAWC P-3 *(6 flights)*		
	Lyden/Verdi	Chief scientists, NAWC SAR
NRL P-3		
	Askari	Chief scientist, X-band imaging RAR, PRT-5, GPS & inertial navigation, Multi-spectral camera
	Lin	W-band (95 GHz) radar
NASA T-39 *(5 flights)*		
	Vandemark	ROWS, GPS & inertial navigation, Hi-Res observer on flight 4 & 5
JPL DC-8		
	Graber	Chief scientist, interferometric SAR
Spotter *(Billy Mitchell Field, South Cape Hatteras, NC)*		
	Luther/Trizna	Feature detection/confirmation
Cape Hatteras area *(cities of Avon & Waves)*		
	Graber/Shay/Ross	OSCR (45-km range)
Discus buoys (2)		
	Graber	Standard NDBC met package, wave spectra, humidity flux, sonic anemomete WOTAN passive acoustics, 2-25kHz
	Donelan	K-Gill anemometer
	Chapman	6-m currents
WOCE Drifters *(with GPS navigation)*		
	Graber	Accelerometer for 1-D spectrum, NOAA-12 satellite, AVHRR imagery
ERS-1		
	Beal	SAR imagery
	Graber	Scatterometer/altimeter
DMSP		
	Sandlin	SSM/I
MMS Program		
	Johnson	Moorings, drifters (ARGOS tracked)

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Technical Bulletin
National Data Buoy Center

Volume 20, Number 2 August 1994

Time Series Data Recorder

The National Data Buoy Center (NDBC) maintains and operates approximately 150 moored buoys and coastal installations which collect, process, and report surface meteorological and oceanographic data. These stations are equipped with one of several configurations of NDBC custom payloads, including a meteorological/oceanographic sensor suite, data acquisition and control unit, and GOES transmitter unit. Typically, these stations are set up, via operator-selectable parameters, to acquire data during a 2-minute (land station) or 8-minute (moored buoy) sampling period once per hour. These data are then processed and sent to the users via the GOES Data Collection System.

The data collected by the NDBC payloads are sampled typically at a 1-Hz rate, converted to physical units, and averaged over the entire data acquisition interval. In this way, only one data value for a measured parameter is reported each hour. This is sufficient to meet the needs of our basic mission requirements, but there have been a number of instances in the past when this has not been adequate to meet the needs of scientific investigators. There have been occasions when extremely interesting or exceptional weather events have been recorded by one or more stations. Following these events, there have been a number of requests for raw, unprocessed time history data. Unfortunately, due to payload operation, the individual data values are discarded after the hourly GOES message has been reported.

To meet the needs of the rigorous scientific investigator, NDBC has developed the Time Series Data Recorder (TSDR). This device will accept the outputs from any or all NDBC sensors, or any other sensor with a reasonably standard output signal, in parallel with the NDBC GOES payload. The TSDR samples and stores a continuous block of time-correlated raw data on a 540-megabyte magnetic disk. As the software is presently configured, the TSDR will sample and record data until its hard disk is filled, then it will go to an inactive state. Data are subsequently retrieved by physically removing the TSDR assembly and downloading the data in the lab via a specially programmed PC.

The TSDR was initially designed to record raw data values from standard NDBC wave sensors. It was later modified to accept other standard

continued on page 2

MARS Project Status

Development of NDBC's new payload, the Multifunction Acquisition and Reporting System (MARS), is now in its final stages. Four prototype systems have been fabricated and are undergoing tests. Results have been excellent, and all the goals to date have been met. It is anticipated that the MARS will be certified for production and deployment before the end of calendar year 1994.

Since its inception in 1971, NDBC has used five environmental data acquisition and reporting systems. Three of these systems, the General Service Buoy Payload (GSBP), the Data Acquisition and Control Telemetry (DACT) system, and the Value Engineered Environmental Payload (VEEP), are still in service.

The GSBP, DACT, and VEEP projects were all highly successful. Each of these three systems showed significant improvements in performance, reliability, endurance, and survivability, while reducing costs with respect to earlier systems. However, the GSBP is used on just a few platforms and is in the process of being phased out. The DACT is in widespread use but is very limited in expansion capability, and it has already significantly exceeded its expected useful life. Production of the VEEP, the primary NDBC payload, has been completed. Rather than issue a new contract for the production of additional VEEPs, which now represent old technology, NDBC began development of a new payload.

Key NDBC and NDBC Technical Services Contractor (NTSC) personnel submitted their recommendations concerning both present and projected requirements for the new payload. Based on these inputs, NDBC requirements and specifications for a sixth generation payload were derived.

Basic requirements for the new payload were that it should:

1. be a transparent substitute for existing payloads, both physically and functionally, and satisfy all requirements presently fulfilled by existing payloads;
2. be capable of processing data from all standard environmental sensors, including the new generation of smart sensors;
3. use standard, off-the-shelf hardware and a widely used software language;
4. use a PC-compatible computer as a test set instead of a specially designed unit;

continued on page 5

TSDR ...

(continued from page 1)

sensors as well. In its present configuration, the TSDR will accept sensors with output signals which include ±10 volt, ±2.5 volt, 0-5 volt, and 0-20 millivolt analog channels, pulse-type (counter input) channels, and serial digital RS-232 compatible channels. In addition to sampling and storing data values from these active sensors, the TSDR periodically samples and stores data values from its internal calibration source.

The TSDR allows a choice of several operator setup parameters to be used to configure the device for a particular installation. These include:

- Enable/disable a sensor
- Assign a sensor to a particular channel
- Select a sample rate (1 Hz, 1.7067 Hz, and 2.56 Hz)
- Enable and set interval for calibration
- Set the real-time clock
- Assign identifying number to data
- Reset data recording file number.

These setup data are stored on hard disk.

The quantity of data that can be stored on the TSDR is dependent upon the number and type of sensors enabled as well as the sample rate selected. For a typical sensor configuration sampled at 1 Hz, the storage capacity will accommodate 156 days of data.

Ten TSDR units have been produced. They have been operationally deployed in several experiments, including 3-m buoy deployments off Galveston, TX, in late 1993, and Pt. Conception, CA, in early 1994. The TSDR was also deployed in a NOMAD buoy hull without a GOES payload in a U.S. Coast Guard experiment in the Boston area. Three TSDRs will be important components of the Duck '94 summer experiment off the North Carolina coast. They will be recording time-series data from the standard wave sensors as well as an experimental triaxial wave sensor. Details of the results of this experiment will be reported in a future issue of the Technical Bulletin.

Robert Timko,
NDBC Engineering

Measurements to Appear on CD-ROM and BBS

Data Systems Division received funding in FY 1994 for two projects designed to improve access to NDBC moored buoy and Coastal-Marine Automated Network (C-MAN) observations. One project is structured to update the *Climatic Summaries for NDBC Stations* and place them on CD-ROM. The other project involves placing recent observations on-line on a bulletin board system (BBS). Both projects are funded as part of NOAA's Earth System Data and Information Management program and should be completed by February 1995.

The need to update the climatic summaries is great. Several recent hurricanes and winter storms have dramatically changed the extreme wind and wave frequencies from the last summarization. The update will contain data from 65 new stations, most of them C-MAN. The inclusion of several new buoy stations will provide a climatology of wave measurements where no previous summaries existed. These areas include coastal Florida, Georgia, Texas, North Carolina, Washington, and Oregon. Hourly peak wind will be summarized at stations that measure continuous winds.

The large space available on a CD-ROM allows us to provide additional features. Tables of significant wave height versus period will have better resolution, and separate tables will be created for average and dominant wave periods. A new table will summarize the means and extremes observed during an individual month. This will help users studying interannual variability. In addition to the summary tables, the entire data record will also be placed on the CD-ROM. This will provide a convenient means for PC users to obtain the hourly observations.

The National Climatic Data Center will produce the summaries and place them on CD-ROM. Users will be greeted by a map showing NDBC station locations where they can make selections via a mouse or keyboard. The CD-ROM will be priced at about $100, but will be free to NOAA users.

The BBS will meet another critical need by providing an easy way for users to obtain recent, quality controlled data that have not yet been archived. This should be a boon to post-storm or accident investigators and scientists conducting remote sensing experiments who frequently request NDBC data. It will benefit NDBC as well because it will virtually eliminate time-consuming production and mailing of printouts and diskettes.

Data will typically be quality controlled and posted within a few days of collection. Data will remain on line for the last 3 months. The collection should also be more complete and offer better resolution than what is transmitted in real time.

In addition to data, the BBS will contain an inventory listing all measurements that have been archived. Status reports will show what platforms and sensors are functioning. Climatic summary tables produced for the CD-ROM will be available for the user who needs a few tables. Similarly, we plan to make available the archived observations from the CD-ROM.

The BBS will feature a graphical user interface based on the Remote Imaging Protocol (RIP). RIP allows PC users with a mouse to interact with the BBS in a manner similar to Windows. Like the CD-ROM, buttons will appear on maps showing current and previous station locations.

A Pentium PC networked to NDBC's Data General minicomputers will host the BBS. This PC will contain two Hayes V.Fast modems that can transmit data at up to 28,800 bps. Though users can dial in anytime, NDBC's Technical Support Contractor will run the system and be available to assist callers Monday through Friday during normal working hours.

Table 1 is a list of NDBC measurements that will be available through the BBS and/or the CD-ROM. Core measurements are made at almost all NDBC stations. Additionally, those listed as buoy measurements are made at almost all buoy stations. Optional measurements are made only at selected stations. The CD-ROM will not include frequency distribution tables unless 3 years of a measurement have been archived. However, if less than 3 years

Table 1. List of NDBC measurements available through the BBS and/or CD-ROM.

MEASUREMENT	BBS	CD-ROM		
		Frequency Distribution Tables	Individual Monthly Summary Tables	Observations
CORE MEASUREMENTS				
Hourly winds including gust	Y	Y	Y	Y
Air temperature	Y	Y	Y	Y
Sea level pressure	Y	Y	Y	Y
BUOY MEASUREMENTS				
Sea surface temperature	Y	Y	Y	Y
Significant wave height	Y	Y	Y	Y
Dominant & average wave periods	Y	Y	Y	Y
Spectral densities	Y	N	N	N[1]
OPTIONAL MEASUREMENTS				
Continuous winds	Y	Y[2]	Y[2]	Y
Wave direction at dominant period	Y	N	Y[3]	Y[3]
Mean wave directions	Y	N	N	N[1]
Dew point	Y	N	Y	Y
Visibility	Y	N	Y	Y
Precipitation	N	N	Y	Y
Water level	Y[4]	N	N	Y[5]
Ocean currents (ADCP)	Y	N	N	N

[1] Available on other CD-ROMs from the National Oceanographic Data Center
[2] Maximum Hourly Peak (5-s) Wind
[3] Available since July 1991
[4] Available upon request
[5] Available since October 1992

are available, the archived observations and individual monthly means and extremes will be on the CD-ROM.

If you are interested in purchasing the CD-ROM or using BBS, please mail or fax the attached coupon to:

Mr. David Gilhousen, W/DB3
National Data Buoy Center
Stennis Space Center, MS 39529-6000

Phone: 601-688-2840,
Fax: 601-688-3153

Information will be sent to you when the products become available.

David B. Gilhousen,
NDBC Data Systems

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Update on ADCP Operations and Performance

A third buoy equipped with a 75-KHz Acoustic Doppler Current Profiler (ADCP) will be deployed off the coast of Southern California this fall. The buoy, to be deployed at station 46023 (about 3 km southwest of Point Arguello, CA), will join two existing ADCP-equipped buoys deployed at stations 46053 (8 km southwest of Santa Barbara, CA) and 46054 (5 km south of Point Conception, CA). Previous Technical Bulletin articles described ADCP hardware and performance (O'Neil, 1992) and the current profile data received from the stations (O'Neil and Mettlach, 1993).

The first two 10-m discus buoys equipped with the ADCP system were originally deployed at stations 46047 and 46048 (75 km and 25 km, respectively, west of San Diego, CA). The mission was to acquire long-term records of ocean current data to aid in the assessment of the potential impact of offshore oil, gas, or mineral exploration. Current profiles at station 46047, where the water depth is 172 m, were measured in 8-m increments to a depth of 144 m. At station 46048, where the water depth is 405 m, current profiles were measured in 16-m increments to a depth of 328 m. Data were transmitted hourly via the Geostationary Operating Environmental Satellite system.

The ADCP systems performed well. Ninety-eight percent of the scheduled current profile reports were received correctly from the stations. Following comprehensive analysis by NDBC, some data were discarded. The amount of data which met NDBC quality standards was 85 percent for station 46047 and 95 percent for station 46048. The difference in the quantity of acceptable data from the two stations is attributed to different environmental conditions at the two locations, with station 46047 experiencing more severe sea conditions which caused microbubbles that adversely affected the ADCP performance (Winant *et al.*, 1994). The two buoys remained on station until August 1993.

The two buoys were subsequently redeployed at station 46053, in a water depth of 459 m, and station 46054, in a water depth of 477 m. Current profiles at both stations are measured in 16-m increments to a depth of 328 m. The acceptable data rates are 90 percent at station 46053 and 53 percent at station 46054. As for the previous stations, the difference in the quantity of acceptable data from the two stations is attributed to different environmental conditions at the two locations, with more severe sea conditions (and more microbubbles) encountered off Point Conception.

The ADCP, manufactured by RD Instruments, has experienced no problems during these deployments. The NDBC-developed interface between the ADCP and the buoy electronics systems has also performed well. An error in timing between the ADCP and NDBC hardware was resolved early in the initial deployments, and since that time no changes in hardware or system software have been required. It was originally thought that frequent service visits to the buoys would be required to keep the ADCP transducer transmitting and receiving heads free of marine growth. However, the use of an anti-fouling coating has resulted in little or no marine growth on the heads.

The ADCP-equipped buoys have accomplished all the original design goals and have proven to be reliable and maintainable systems for long-term deployments.

References:

O'Neil, K.C., 1992, Acoustic Doppler Current Profiler systems deployed on 10-meter discus buoys: NDBC Technical Bulletin, vol. 18, no. 1, p. 1.

O'Neil, K.C., and Mettlach, T.R., 1993, ADCP design and performance: NDBC Technical Bulletin, vol. 19, no. 1, p. 1.

Winant, C., Mettlach, T., and Larson, S., 1994, Comparison of buoy-mounted 75-KHz Acoustic Doppler Current Profiler with vector measuring current meters: J. Atmos. Ocean. Tech., In press.

Ray Canada,
NDBC Program Management

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

National Data Buoy Center
Building 1100
Stennis Space Center, Mississsippi 39529-6000
Phone (601)688-2800

MARS ...

(continued from page 1)

5. be designed so that the hardware and software maintenance, modification, and repair can be done by the NTSC; and
6. be designed so that change and expansion do not require a major redesign.

Previous payloads were designed by the manufacturers based on NDBC requirements and specifications. Given the state of the technology in those areas, it was difficult to forecast several years ahead as to what expansion capability would be required, so the growth capability requirements were not well defined. To ensure realization of the needed flexibility, it was decided that the best solution would be to design the new payload in-house. Once this decision was made, one more requirement was added: the new payload must have capabilities exceeding the GSBP, DACT, and VEEP, and must cost less.

The payload was designed by the NTSC and named MARS. It acquires data at preselected intervals, processes these data into geophysical units, and transmits the information to users via one or more communications systems. The system was designed using modularity and standard interface features of hardware and software for easy conversion of the MARS from buoy to shore-based installations, for expanded applications, and to simplify operation and maintenance. The four prototype systems now undergoing tests were fabricated at NDBC by the NTSC, who also wrote all payload, test set, and test software.

A block diagram of the MARS is shown in Figure 1. General MARS specifications are given in Table 2. Measurements presently included in the payload baseline configuration, as well as housekeeping and projected future measurements, are listed in Table 3.

The payload will accept wave data in serial format from the Waves Processing Module now in use at NDBC, and is capable of processing wave data internally.

Following the successful completion of all tests on the prototypes, a production specifications package will be finalized and bids solicited for production of the system. Once the system is in operation, all hardware and software maintenance, modifications, and repairs will be done in-house by the NTSC.

The five previous payloads were supported for many years by the manufacturers, based on task order support contracts. Software changes were made by the manufacturers at their facilities, and hardware modifications required that the units be shipped to and from the manufacturers' facilities. In addition to pipeline delays in the cycling of aged payloads to and from the manufacturers' facilities, it also became of less interest to the manufacturers and more costly to NDBC to continue the arrangement for equipment modification, maintenance, and repair functions. Performing such functions at NDBC has significantly reduced costs, and will save time and money in the future.

The MARS will initially be deployed at nearby shore-based sites. Once the system performs reliably in the field, it will be deployed at all NDBC buoy, platform, and land-based sites. First, the phase-out of the GSBP will be completed, then the DACT, and over time, the MARS will replace the VEEP as the primary NDBC payload.

Hal Brown,
NDBC Engineering

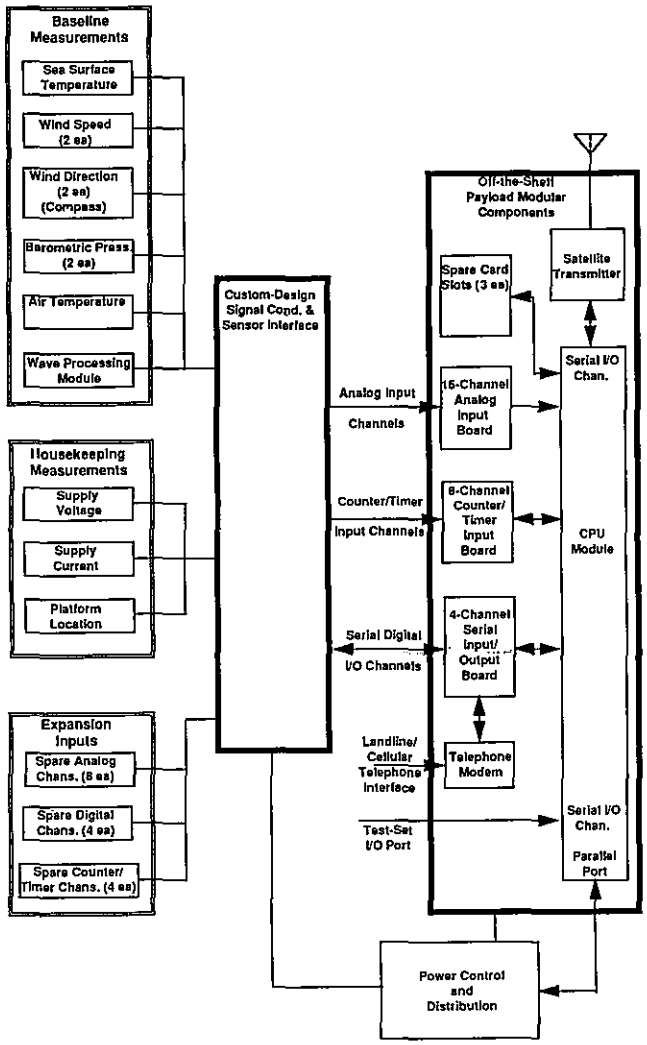

Figure 1. Next generation MARS payload.

Table 2. MARS specifications.

Operating temperature	-40 °C to +50 °C
Storage temperature	-60 °C to +50 °C
Relative humidity	100%, condensing
Dimensions, outer	178mm H X 254mm W X 356mm L
Weights	10.25 kg
Power requirement	12 VDC +3/-2 VDC
Power consumption (hourly average)	0.280 mA
System architecture	STD bus
Operating system	Proprietary
Programming language	C
System accuracy, analog	±0.1% of full scale*
System accuracy, digital/counter-timer	100% with no bit loss*
Analog channels	16
Counter-timer channels	8
Serial I/O channels	6**
Data transmission methods	via GOES, POES, GMS, METEOSAT, or commercial telephone

* Does not include sensor accuracy
** Number includes two channels normally used for transmitter and test set

Table 3. Sensor/measurement summary.

BASELINE SENSORS	
Wind speed	2
Wind direction	2
Compass heading	2
Barometric pressure	2
Air temperature	1
Sea surface temperature	1
HOUSEKEEPING MEASUREMENTS	
Buoy position (loran, TDD, GPS)	Discrete status inputs
Battery voltage	Charger current
PROJECTED EXPANSION MEASUREMENTS	
Radiation	Precipitation
Salinity	Water level
Dissolved oxygen	pH
Sea temperature	Depth
Visibility	Relative humidity
Humidity	
Acoustic Doppler Current Profiler (ADCP)	
Photosynthetically active radiation (PAR)	

Quality Control of Wave Data

Sensors onboard NDBC buoys and at Coastal-Marine Automated Network (C-MAN) sites measure and transmit hourly meteorological and oceanographic data worldwide to NDBC's many users. The most sophisticated measurements involve ocean surface waves. NDBC is one of the few organizations which routinely measure and transmit ocean wave data. These data are vital to many diverse groups, including meteorological forecasters, the shipping industry, and ocean engineers. Because of NDBC's total commitment to release only high-quality data, all meteorological and oceanographic data are routinely checked for gross errors in real time before transmittal over the Global Telecommunications System (GTS) and are subsequently checked for accuracy and validity, using a man-machine mix of techniques and procedures, prior to archival at the national archive centers.

The quality control of wave data is particularly difficult. Some of the problems inherent in the automated quality control of wave data are due to the complex nature of ocean wave physics. The limitations of computer resources can also be a hindrance; therefore, any advancement in technique, no matter how small, is often welcome. At NDBC, a new procedure for checking the validity of wave data has been developed and is used in conjunction with existing methods. The quality control process will be presented following a brief description of how sea-state measurements are made.

Wave data are derived by using complex methods and formulas, unlike many meteorological and oceanographic parameters which are measured directly. NDBC uses accelerometers placed at the center of flotation within the buoy hull to measure the vertical acceleration or displacement of the hull, depending upon the buoy system. Statistical processing is then performed to account for hull and electronic factors that influence the acceleration or displacement data. The onboard processor then computes spectral estimates of the wave energy. In this usage, "spectral" refers to the wave energy being associated with waves of different lengths and frequencies (temporal periods). Frequencies of NDBC spectral wave estimates range from 0.03 Hz through 0.40 Hz. Waves caused by the local winds are generally associated with frequencies greater than 0.15 Hz. The sum of the spectral energies over the entire frequency range is related to the significant wave height of the wave field.

The new NDBC Wind-Wave Quality Control Procedure is used as the final check of the wave data before they are archived. NDBC still uses a wind-wave algorithm developed in 1987 for the real-time, operational check of the wave data (Lang, 1987). The new wind-wave procedure, like the 1987 algorithm, focuses on spectral wave energy corresponding to wind-generated waves. Many years ago, NDBC scientists realized that wind speed could be used in the quality control of wind-wave energy (Steele and Marks, 1979). Knowledge of the quality of the wind-wave data would provide some idea as to the overall quality of the entire wave data ensemble. When the sum of wave energy within a specified frequency range is plotted against wind speed (or wind speed raised to a power) the wind-wave relationship is visualized. It is on this visualization that the quality control of NDBC wave data is based.

The 1987 algorithm attempts to flag erroneous wave energy data by comparing the hourly energy values to predetermined upper and lower energy limits. The sum of wave energy within the frequency range 0.22-0.27 Hz and the square of the 4-hour average wind speed (the current hour and the three previous hours) for 22 months of hourly data were used to create a climatological representation of the wind and wave relationship. Three linear least squares lines were then fit through the data cloud. Next, the upper limit of wave energy was chosen so that no more than 3 percent of the data fell beyond it. The differences between the three lines and the upper limit were then used to determine the lower limit (Fig. 2). Any real-time wave energy observation falling outside the upper or lower limit is flagged as erroneous and is printed on a daily, tabular output for review by a data analyst.

After many years of use, NDBC realized that although the 1987 algorithm performs well, it has limitations. The most serious was the requirement for the data analyst to mentally integrate the information printed on the tabular output and recognize a long-term pattern of erroneous data. Therefore, NDBC initiated a study to recommend improvements to the 1987 algorithm and/or devise a new procedure. It was decided that a new procedure to complement the 1987 algorithm was in order. Since the existing algorithm did a superb job in the real-time flagging of erroneous data, only a new procedure to detect long-term, subtle errors was needed.

The new procedure differs from the 1987 algorithm in many ways. First, in developing the new procedure, a higher wave frequency range (0.30-0.35 Hz) was used in the plotting of the wind and wave relationship. The lower wave frequency range of the algorithm had allowed shallow water and fetch effects to contaminate the wind and wave relationship from which the wave energy limits were derived. Second, over 8 years of data from six NDBC buoy stations (as opposed to a total of 22 months of data) were plotted and analyzed to ascertain a true climatological representation of the wind-wave field. Third, wave energy limits were not calculated. Instead, the outer edge of the data cloud was modeled by dividing the wind speed/wave energy plot into sectors and then computing the joint probability density distribution. The density distribution

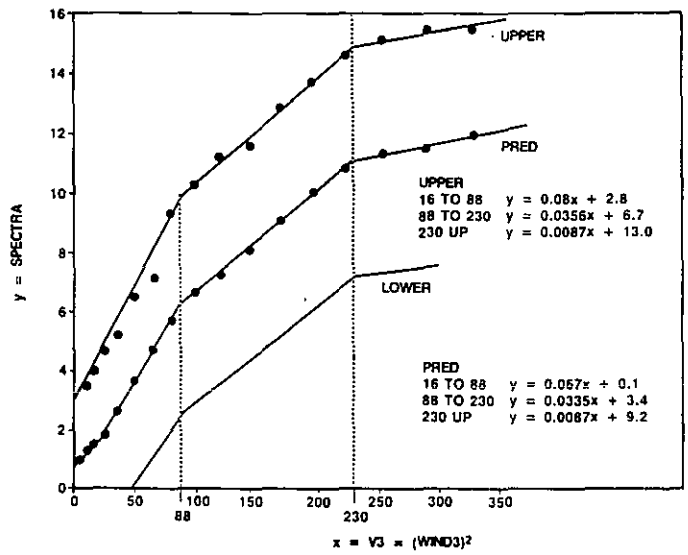

Figure 2. Visual representation of the 1987 wind-wave algorithm from Lang (1987).

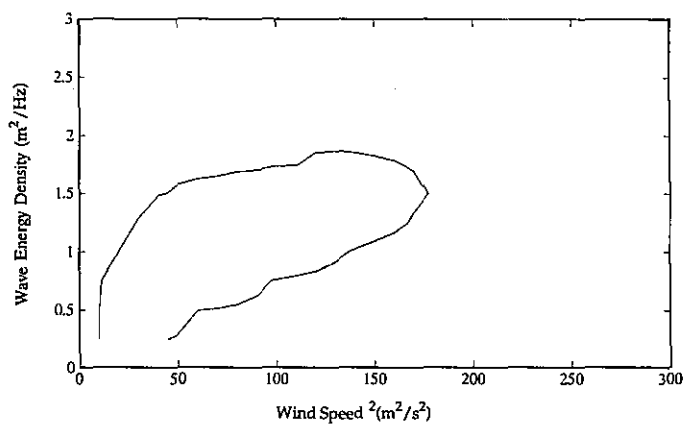

Figure 3. The outer limit of the wind speed and wave energy relationship defined by the 0.01 contour line.

was contoured and the 0.01 contour line was chosen as best representing the outer edge of the data cloud (Fig. 3). Any point falling outside of this contour line is possibly erroneous. There are instances, such as during an intense storm, when the wave energy will fall outside of the contour but may still be valid. In these cases, it is up to the discretion of the data analyst to decide whether this data should be archived. Finally, the new procedure produces a monthly graphical output consisting of the 0.01 contour line and the associated wind speed and wave energy relationship for the entire month for each station. This makes it much easier for the data analyst to determine whether the wave data from a specific station are suitable for archival. Figure 4 shows the graphical representation of the wind and wave relationship of station 44009 for February 1994. A quick study determined that the reduced wave energy was caused by a malfunctioning

accelerometer and that the data should not be submitted for archival.

In summary, the Wind-Wave Quality Control Procedure is a beneficial complement to the 1987 wind-wave algorithm. Using both quality control methods, NDBC can now detect sudden errors and long-term degradation associated with the wave measuring system. The new procedure also provides the capability of detecting the most subtle errors associated with the wave system, such as those which occur when an incorrect hull transfer function is used. Overall, the incorporation of the Wind-Wave Quality Control Procedure in the NDBC arsenal of automated quality checks allows NDBC to provide a better quality product to its users.

Ian Palao,
CSC Data Systems

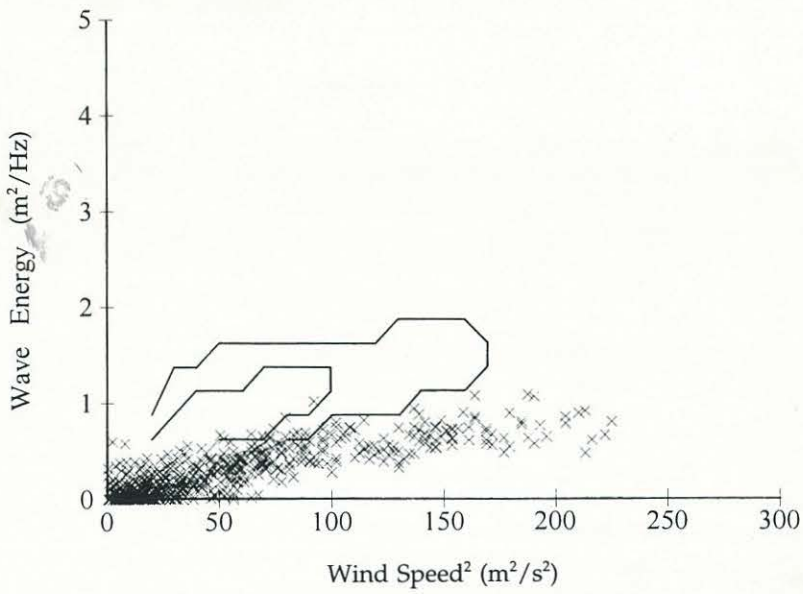

Figure 4. Data from station 44009, February 1994, showing the result of a malfunctioning accelerometer.

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