BUOY DATA ACQUISITION, MONITORING, AND MANAGEMENT

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1. INTRODUCTION

Automated ocean stations are an important source of environmental data for numerical models. This paper presents information on station locations; acquisition systems; and data transmission, processing, and quality control.

The National Data Buoy Center (NDBC), as part of the National Weather Service (NWS), develops and operates automated data acquisition systems in deep-ocean and nearshore areas to provide real-time environmental observations in data-sparse areas (Hamilton, 1986). These include about 50 moored buoys and approximately 50 Coastal-Marine Automated Network (C-MAN) stations on navigational buoys, lighthouses, offshore platforms, and beach areas. In addition, NDBC maintains about 50 drifting buoys in the southern hemisphere for the Tropical Ocean and Global Atmosphere (TOGA) program supported by the National Ocean Service and the Office of Climate and Atmospheric Research (both of NOAA).

2. MOORED BUOY NETWORK

The buoys in the moored buoy network, shown in Figure 1, support NWS and other users. Twelve-meter-diameter buoys (Figure 2) have been replaced in severe environments by 6-meter, boat-shaped NOMAD buoys (Figure 3), except in the Bering Sea where drifting sea ice and structural ice formation are major concerns.

To reduce the cost of deploying a buoy in less severe environments, NDBC developed a small, low-cost, 3-meter-diameter discus buoy. The anemometers on board the 3-meter and 6-meter (NOMAD) hulls are located at a 5-meter height rather than the 10-meter height of the larger discus buoys. I have described these buoys in an article entitled "Small Coastal Data Buoys."[§]

Capabilities of a typical electronics payload are given in Table 1. The indicated total system accuracy is maintained through the NDBC quality control program.

[§]To be published in Preprint Volume, AMS Fourth Conference on Meteorology and Oceanography at the Coastal Zone, 1988.

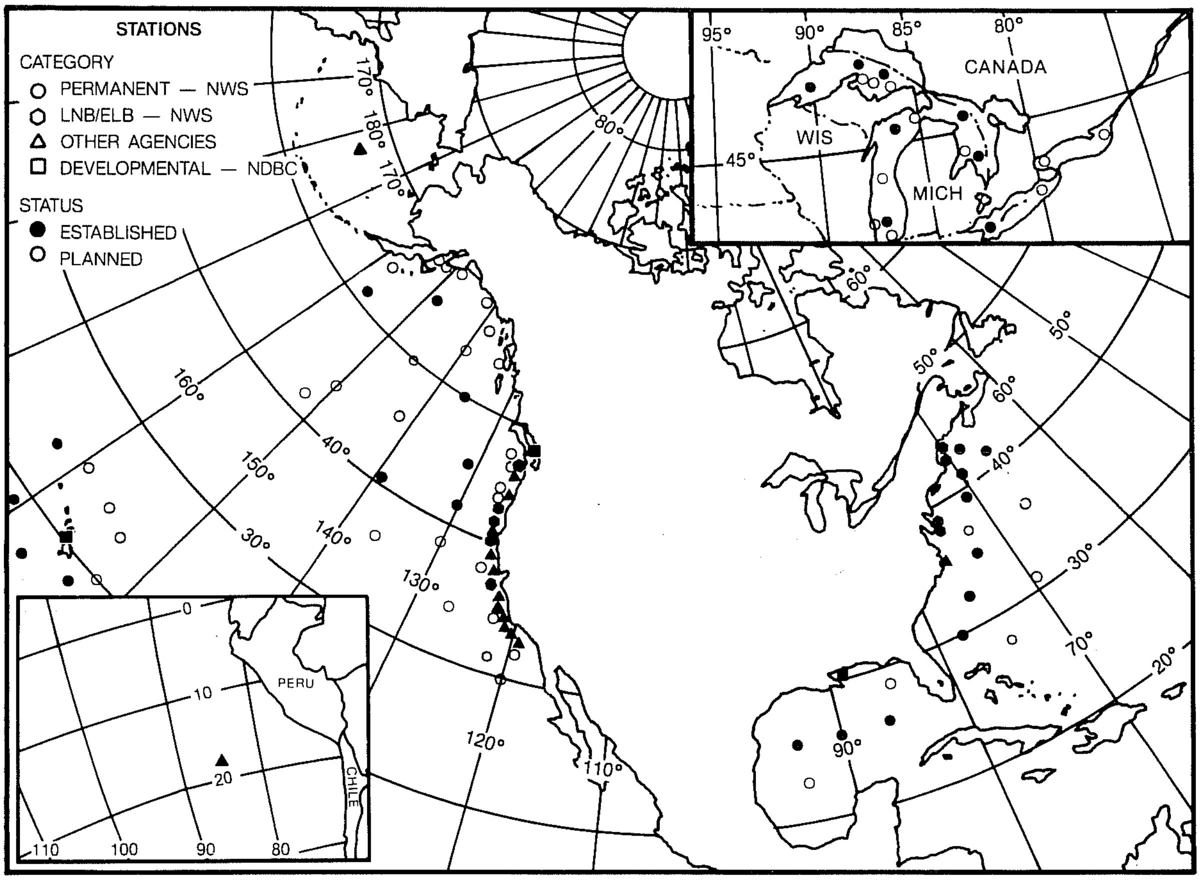

Figure 1. *NDBC Buoy Locations*

Table 1. *Typical Moored Buoy Payload Data.*

Parameter	Reporting Range	Reporting Resolution	Sample Interval	Sample Period	Total System Accuracy
Wind Speed	0 to 80 m/s	1 m/s	1 sec	8.5 min	±1 m/s or 10%
Wind Direction	0 to 360°	10°	1 sec	8.5 min	±10°
Wind Gust*	0 to 80 m/s	1 m/s	1 sec	8.5 min	±1 m/s or 10%
Air Temperature	-40° to 50° C	0.1° C	90 sec	90 sec	±1° C
Barometric Pressure	900 to 1100 hPa	0.1 hPa	4 sec	8.5 min	±1 hPa
Significant Wave Height	0 to 20 m	0.1 m	0.78 sec	20 min	±0.2 m or 5°
Wave Period	2 to 33 sec	1 sec	0.78 sec	20 min	±1 sec
Wave Spectra	0.01 to 0.5 Hz	0.01 Hz	0.78 sec	20 min	—
Surface Water Temperature	-15° to 50° C	0.1° C	90 sec	90 sec	±1° C

* Highest 8-second window average retained.

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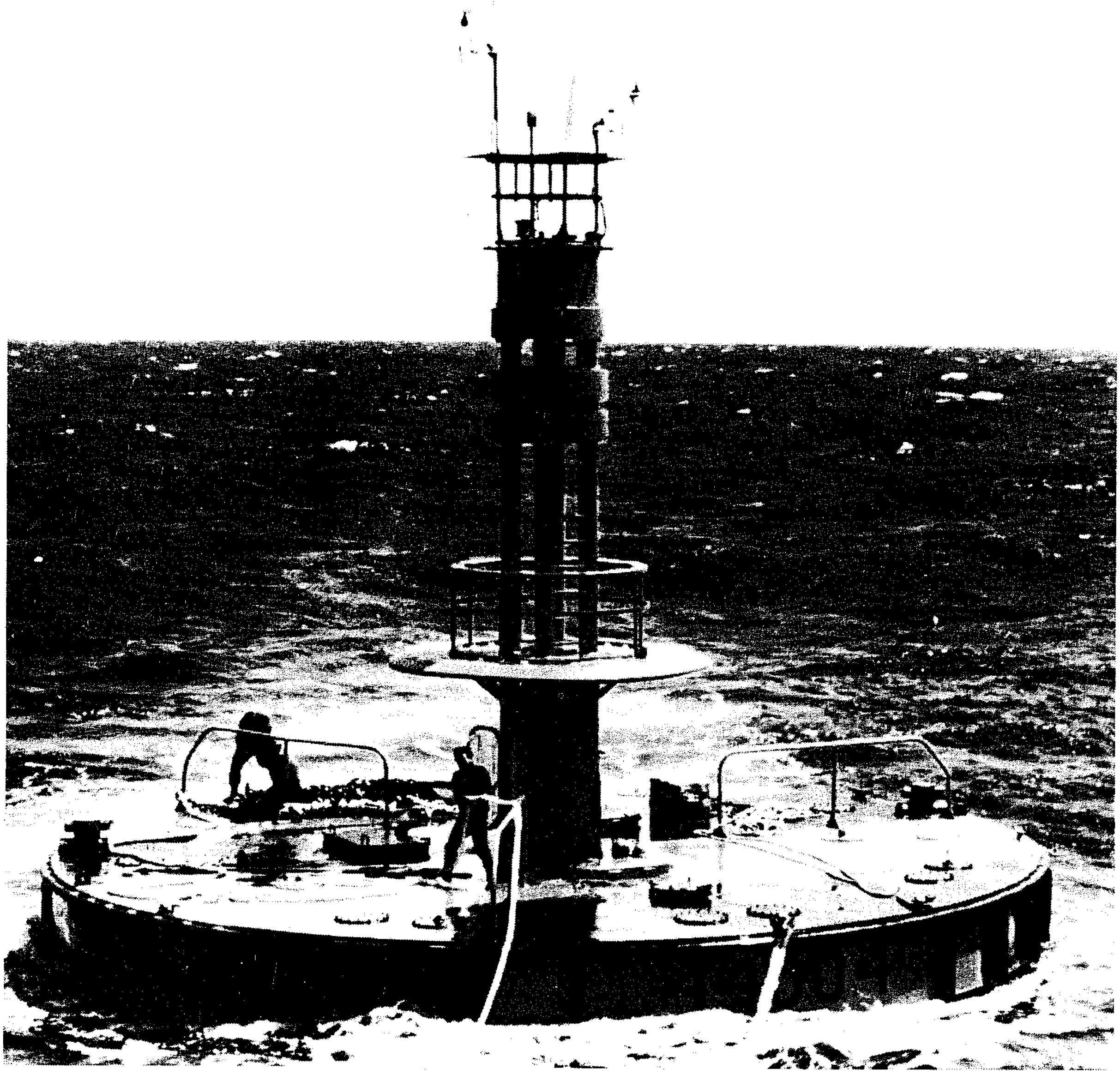

Figure 2. *12-Meter Discus Buoy*

3. DRIFTING BUOYS

The First GARP Global Experiment (FGGE) demonstrated the scientific value of drifting buoys and their importance for real-time weather forecasting. Buoys presently deployed for TOGA (Figure 4) report air temperature as well as sea-surface temperature (SST) and barometric pressure, which were measured in FGGE. Additional capabilities have also been developed for drifting buoys. As a result of air-dropping drifting buoys into the path of Hurricane Josephine in October 1984 and other testing, wind speed has proven to be an operationally valid measurement as described in an article "Atmospheric Boundary Layer and Oceanic Mixed Layer Observations in Hurricane Josephine Obtained from Air-Deployed Drifting Buoys and Research Aircraft" by P.G. Black, R.L. Elsberry, L.K. Shay, R.P. Partridge, and J.D. Hawkins.† Wind direction capability is now being tested.

†To be published in AMS Journal of Atmospheric and Oceanic Technology, 1988.

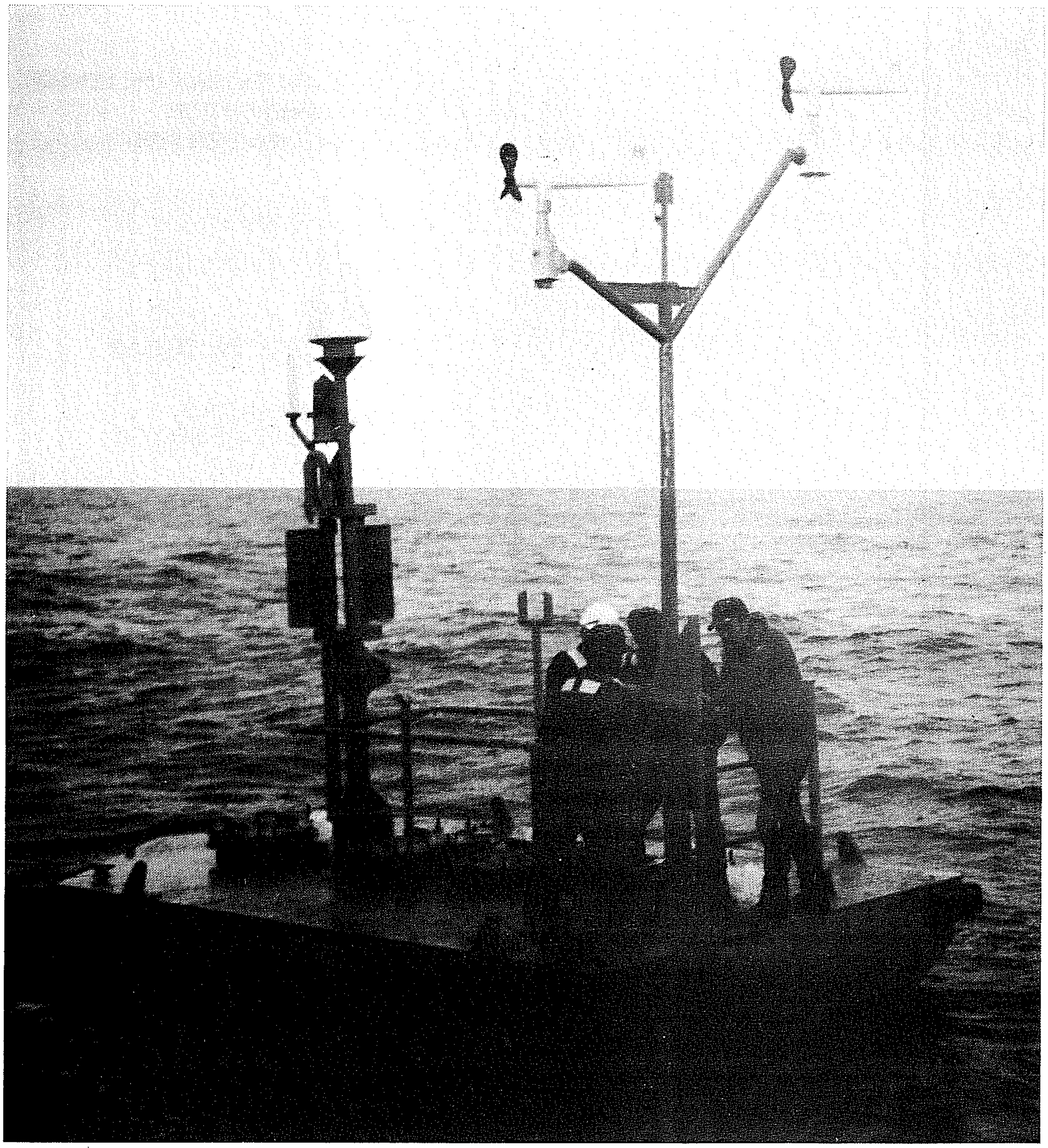

Figure 3. *6-Meter, Boat-Shaped NOMAD Buoy*

Measuring subsurface temperature is becoming more successful, as shown by the drifters in Hurricane Josephine and other experiments. The ability to measure significant wave height, period, and spectra is soon expected to be operational. Drifting buoys reporting on the Global Telecommunication System (GTS) are shown in Figure 5. There are over 400 drifting buoys reporting through Service Argos, but less than 50 percent are formatted to be processed for GTS transmission.

The development of a low-cost, miniaturized drifting buoy, or minidrifter, for deployment through sonobuoy chutes in aircraft obviates the need to open aircraft cargo hatches in flight and offers the possibility of expanding coverage into data-sparse areas.

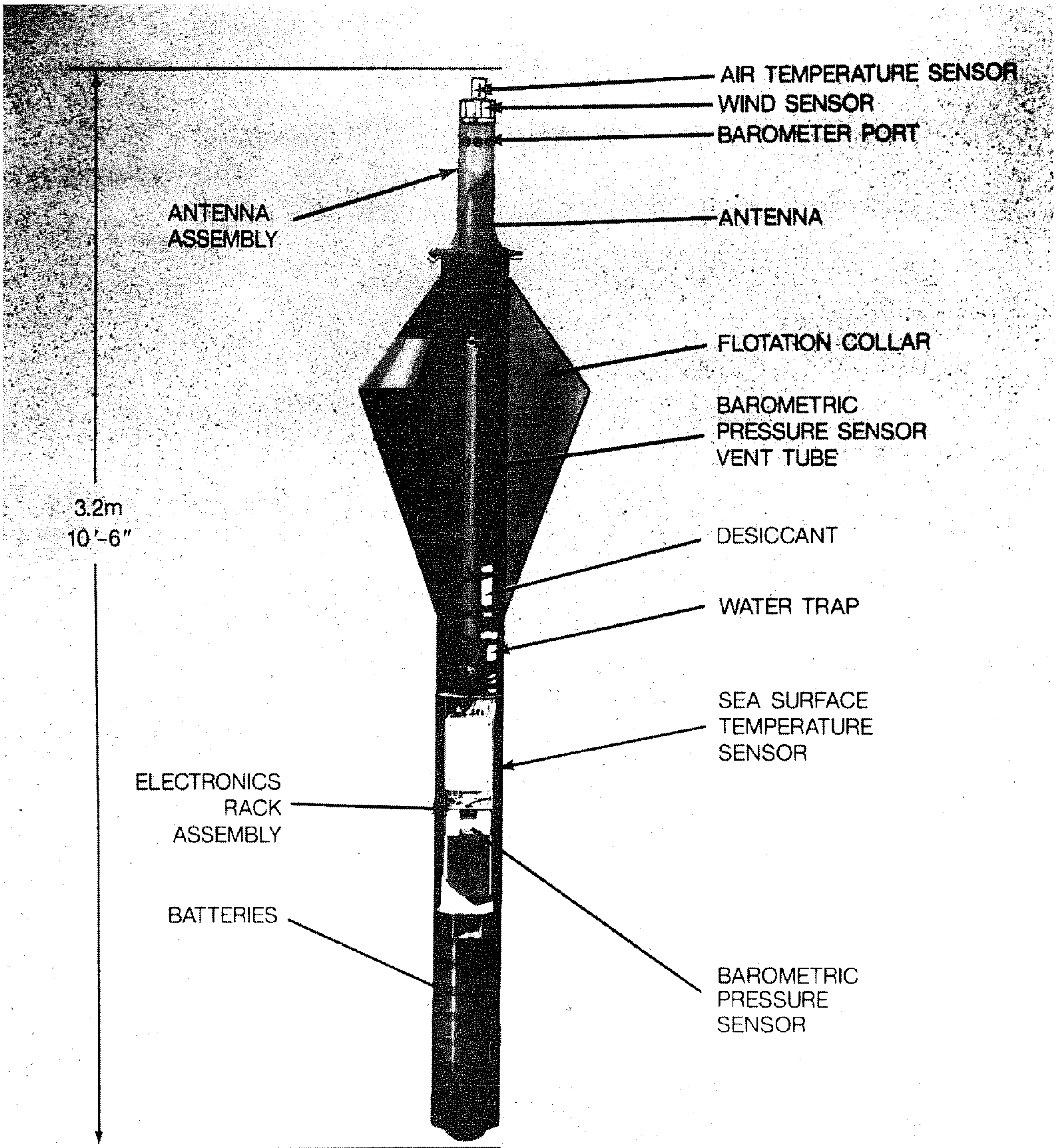

Figure 4. *Meteorological Drifting Buoy*

Starting in 1988, hundreds of drifters will be deployed in the tropical Pacific to report SST in the Pan-Pacific Experiment. Commencing in 1990, the World Ocean Circulation Experiment will employ hundreds of drifting buoys measuring SST. Drifting buoy programs of other countries are described in the IGOSS Guide to Drifting Buoys (to be published in 1988).

4. DATA QUALITY

Moored buoy and C-MAN data are transmitted hourly through the Geostationary Operational Environmental Satellite (GOES) system and processed at the National Meteorological Center (NMC). Approximately 95 percent of the data are transmitted over NWS circuits and the GTS within 30 minutes of observation time. NDBC has developed and maintained quality control programs on these data for the last 10 years.

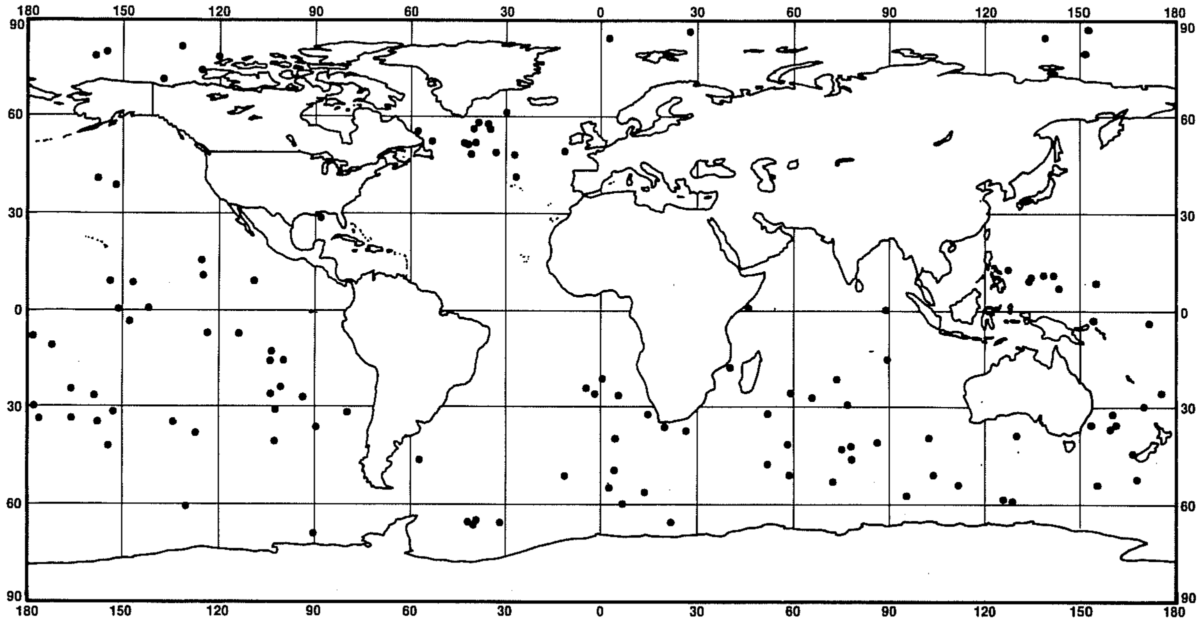

Figure 5. *Drifting Buoys Reporting on GTS*

There have been no data quality control efforts on drifting buoys in the past, and this has created problems. An example is the Fleet Numerical Oceanography Center (FNOC) 1200UTC analysis on October 22, 1986, given in Figure 6. A low-pressure report from a drifter located between New Zealand and Australia resulted in a small, intense, low-pressure area. Six hours later, when no report was received from the drifter, no low-pressure center was analyzed. This analysis is shown in Figure 7. Six months earlier, NMC reported that a similarly erroneous report from a drifter east of Tahiti produced a fictitious easterly wave. The bad data were discovered by a researcher studying how to improve the quality of the analyses, not by an operations meteorologist. Postanalysis showed that the pressures had been at least 10 hPa low for the previous 2 weeks.

The U.S. Argos Processing Center (USAPC) in Landover, Maryland, became operational in November 1987 and began transmitting DRIBU messages (WMO code form FM14-VIII for drifting buoy data) from approximately 100 U.S. drifting buoys to NMC for quality control and insertion on the GTS. NDBC now routinely quality controls these data in a manner similar to that maintained on moored buoy and C-MAN data.

NDBC maintains an extensive data quality effort on all U.S. moored buoy, C-MAN, and drifting buoy data. This effort is described by David Gilhousen in an article entitled "Data Quality at the National Data Buoy Center."‡ Figure 8 shows the flow of data for transmission and processing. At NMC, NDBC-developed software performs gross range and time-continuity checks, and wind gust-to-speed ratios are also examined for fixed stations. Furthermore, an NDBC-maintained status file is read to determine sensor calibration coefficients, permanent sensor failures, and the primary sensor when duplicate sensors exist.

‡To be published in Preprint Volume, AMS Fourth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography and Hydrology, 1988.

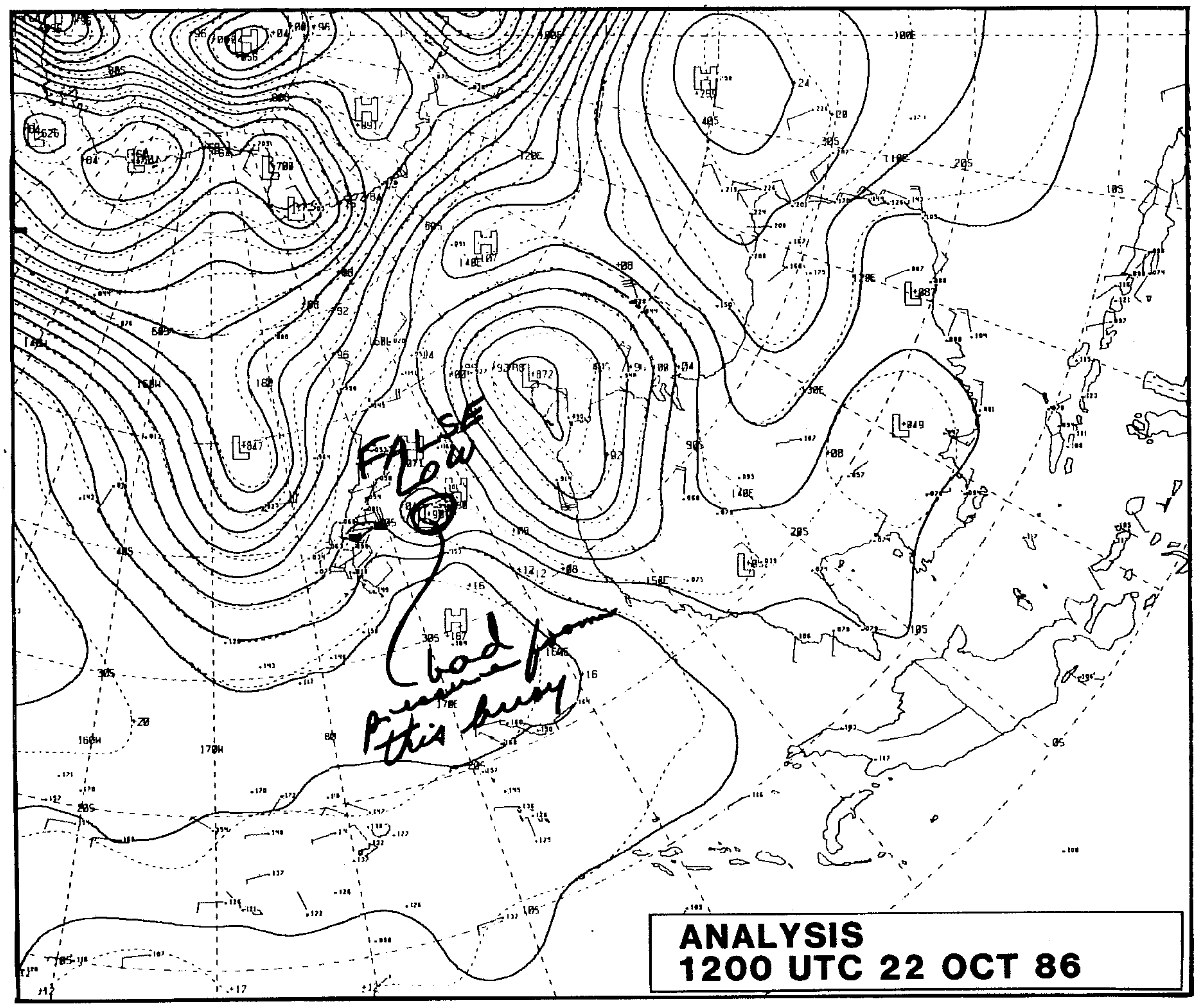

Figure 6. *FNOC Initial Analysis of Sea Level Pressure at 1200 UTC on October 22, 1986*

When tropical cyclones threaten a buoy, range limits and time-continuity checks are removed. The sudden and dramatic changes these storms can create would cause these automatic checks to delete all the buoy's data, which would eliminate some data that, otherwise, would be good.

More stringent quality control is performed at NDBC within 24 hours by a man-machine mix. Data validation checks are tighter, and limits are station-specific for each month. An additional algorithm tests the consistency between wind speeds and the energy in the wind-wave part of the spectrum. Another procedure checks to ensure that a sensor's output is not stuck.

All of the validation tests detect sensor failures, but several are of significant value. The duplicate sensor check is often the first to detect problems with anemometers and barometers. All NDBC moored buoy and C-MAN stations have duplicate anemometers, and many have duplicate barometers and air temperature sensors. The wind-wave algorithm can detect anemometer problems at stations having a single working anemometer. Also, it can spot low significant wave heights, usually caused by processing with the wrong set of coefficients.

Drifting buoys represent a special data quality problem because they have a single set of sensors and are usually deployed in extremely data-sparse areas like the southern hemisphere. Since drifting buoys report through NOAA/TIROS polar-orbiting satellites, the reports are largely at off-synoptic times, and the

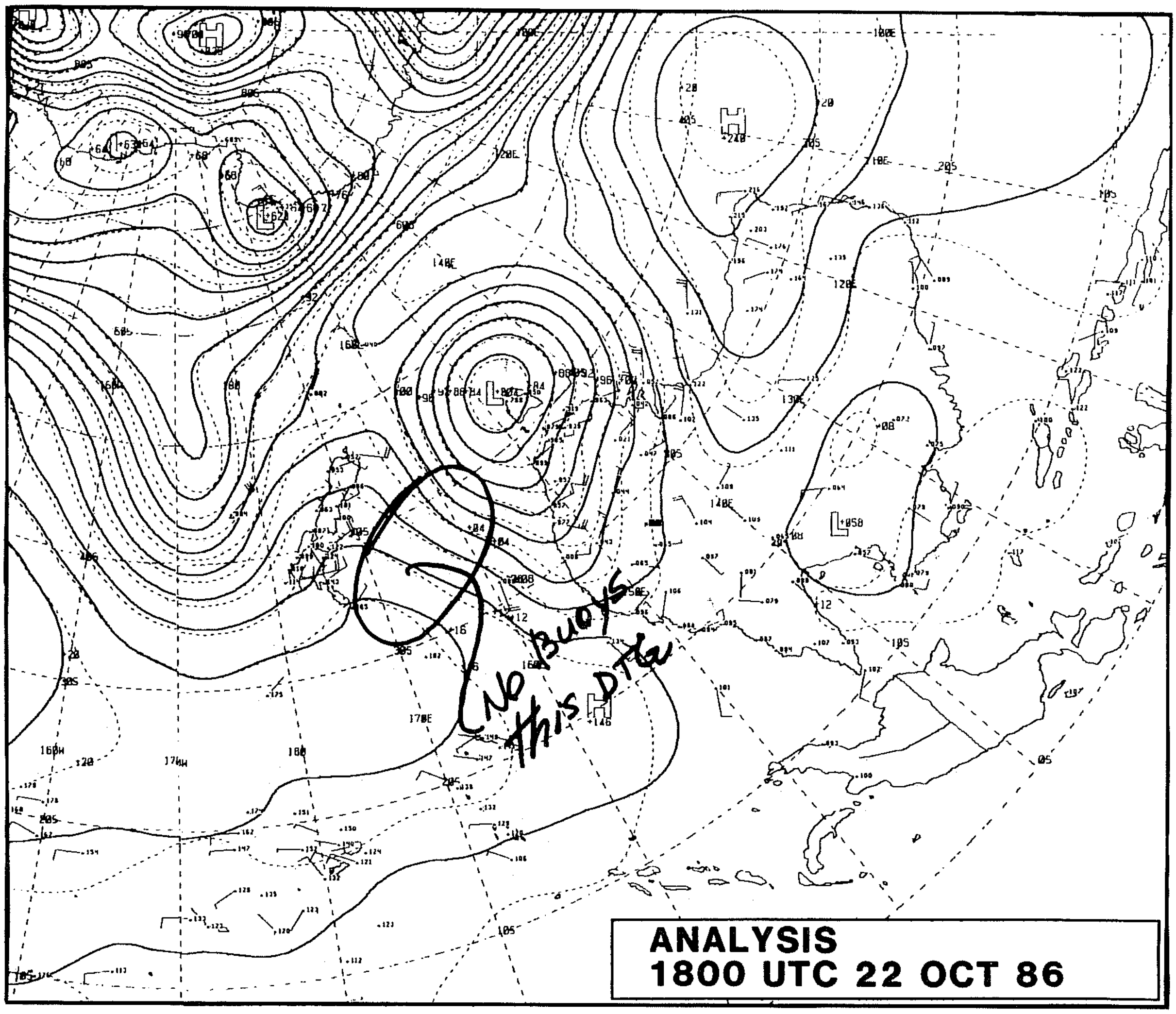

Figure 7. *FNOC Initial Analysis 6 Hours Later Showing Removal of Spurious Low*

number of reports varies as a function of the buoy's latitude, with an average ranging from 7 at the equator to 28 at the poles. NMC analysis and "first guess" fields of sea level pressure and air and water temperatures are used for comparison with drifting buoy observations. European Centre for Medium Range Weather Forecasts statistics, comparing biases between "first guess" fields and drifting buoy reports, have proven valuable.

All of the validation procedures flag suspicious data. After data analysts review flagged data, they can produce a variety of computer graphics to help them distinguish between true sensor or system failure and legitimate data. Time-series plots of measurements from dual sensors, adjacent stations, and analysis fields have proven to be valuable tools. Scatterplots can give a clear indication of sensor problems. Figure 9 shows an example of a wind direction discrepancy caused by a compass problem on a moored buoy. Failure of a drifting buoy sea-level pressure sensor is indicated in Figure 10. When sensor deficiencies are detected, the status file at NMC is either updated to withhold release of that sensor's data, or the values are modified to correct for sensor drift.

A problem with drifting buoy data has been noted with respect to position fixes and reports transmitted on the GTS from Local User Terminals (LUTs). These positions are less accurate than those obtained by the French and U.S. Argos Processing Centers. Table 2 contains an example of reports received at the FNOC from the same drifting buoy from duplicate sources on the GTS. The observation times are

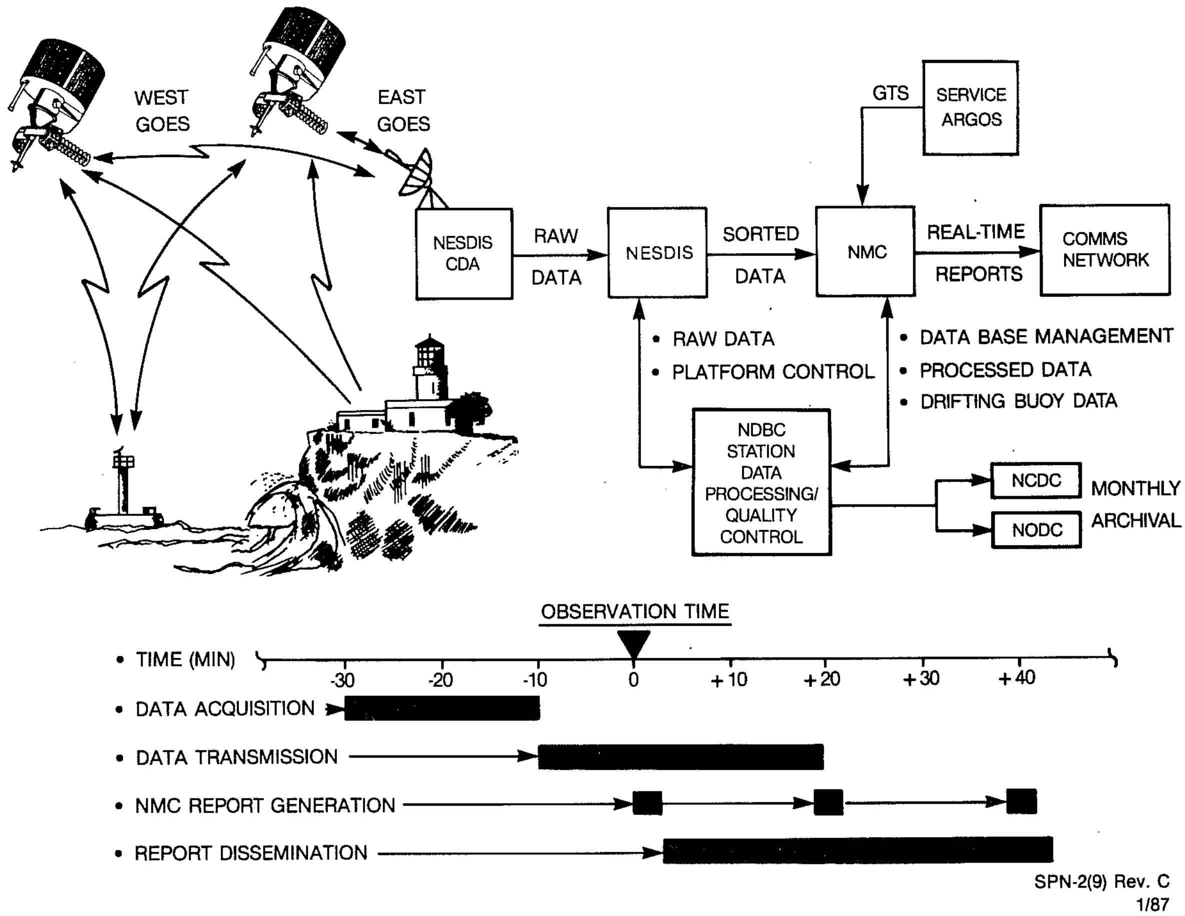

Figure 8. *Data Flow and Processing*

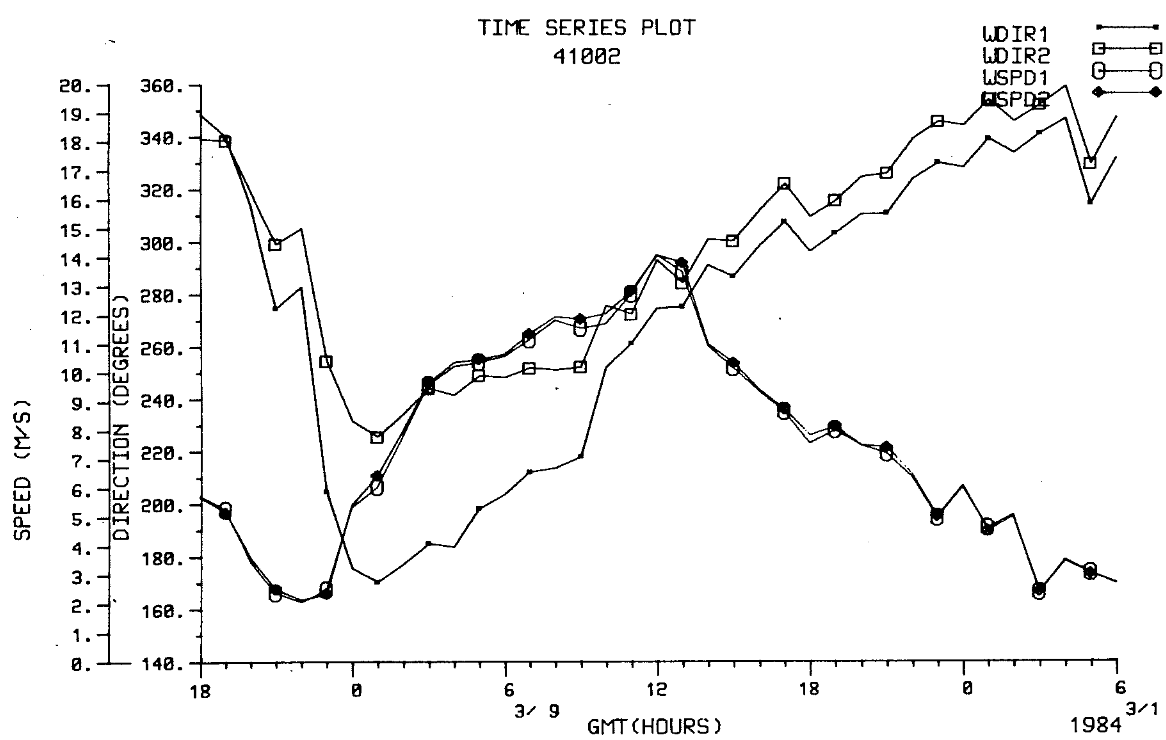

Figure 9. *Wind Direction Discrepancy for a Moored Buoy*

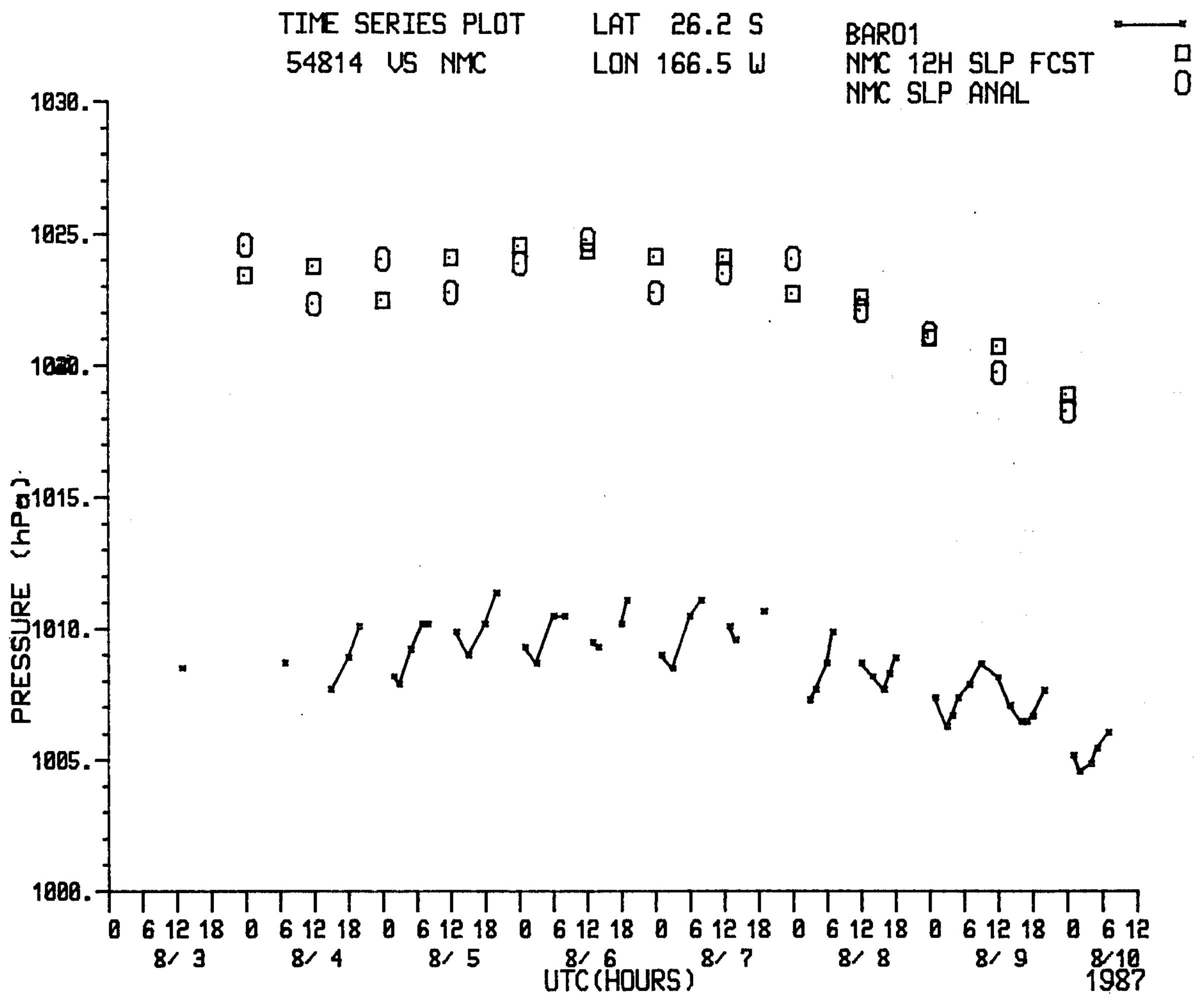

Figure 10. *Sea Level Pressures Reported by Drifter 54814 are Compared to NMC Analyses and 12-Hour Forecasts*

within 10 minutes of each other. Large position and barometric pressure discrepancies can be seen. These large errors occurred frequently enough that FNOC analysts spent considerable time in diagnosing the problem. FNOC eventually decided not to use any data transmitted by several LUTs.

In 1988, the NMC Ocean Products Center will commence a program of real-time quality control for data being ingested into numerical models. This program will include data from U.S. drifting buoys that will be checked and ready for model use and dissemination on the GTS within 60 minutes after receipt of

Table 2. *Concurrent Reports from the Same Drifting Buoy from Duplicate Sources Revealing LUT Position Errors*

DRIFTER	SOURCE	LATITUDE	LONGITUDE	PRESSURE (hPa)
17807	S. AFRICAN LUT	40°27'S	4°16'W	1019.3
	ARGOS	40°48'S	24°25'W	1019.4
25525	CANADIAN LUT	85°16'N	140°00'E	1031.4
	NORWEGIAN LUT	85°22'N	127°32'E	950.0
25523	CANADIAN LUT	84°19'N	168°23'E	1032.8
	NORWEGIAN LUT	85°31'N	161°00'E	950.0

the data at NMC from the USAPC. At the WMO/IOC Drifting Buoy Cooperation Panel Meeting in Paris in October 1987, worldwide quality control of drifting buoy data was advocated.

As a final item in data quality, winds from buoys need to be addressed. Anemometers on large buoys may be located as high as 10 meters above the surface. Other buoy anemometers can be situated at various heights, while drifting buoy anemometers can be at a 1-meter height. This can create confusion for marine data users who compare buoy winds to ships whose anemometers may be at a 20-meter height, or higher. To alleviate this problem, NDBC now extrapolates all moored buoy and C-MAN winds to 10 and 20 meters and enters the values as additional groups in the processed data messages. These procedures are discussed in Gilhousen (1987).

5. REFERENCES

Gilhousen, D.B., 1987: A Field Evaluation of NDBC Moored Buoy Winds. Journal of Atmospheric and Oceanic Technology, 4, 94-104.

Hamilton, G.D., 1986: National Data Buoy Center Programs. Bulletin of the American Meteorological Society, 67, 411-415.