REPORT DOCUMENTATION PAGE

AD-A268 063

Form Approved
OBM No. 0704-0188

average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and of information. Send comments regarding this burden or any other aspect of this collection of information, including suggestions rate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to 0704-0188), Washington, DC 20503.

| | | |
|---|---|---|
| 1. Agency Use Only (Leave blank). | 2. Report Date. 1993 | 3. Report Type and Dates Covered. Final - Proceedings |

**4. Title and Subtitle.**
An Overview of the U.S. Navy's AN/WSQ-6 (Series) Drifting Buoy Program

**5. Funding Numbers.**
*Contract*
*Program Element No.* 0604704N
*Project No.* R1740
*Task No.*
*Accession No.*
*Work Unit No.* 574513803

**6. Author(s).**
Harry D. Selsor

**7. Performing Organization Name(s) and Address(es).**
Naval Research Laboratory
Tactical Oceanographic Warfare Support Office
Stennis Space Center, MS 39529-5004

**8. Performing Organization Report Number.**
NRL/PP/7410--93-0016

**9. Sponsoring/Monitoring Agency Name(s) and Address(es).**
Office of Naval Reserach
Code 0123, Ballston Tower One
800 N. Quincy Street
Arlington, VA 22217-5860

**10. Sponsoring/Monitoring Agency Report Number.**
NRL/PP/7410--93-0016

DTIC ELECTE AUG 0 6 1993 S A D

**11. Supplementary Notes.**
~~Published in International Maritime Defence 1993.~~

**12a. Distribution/Availability Statement.**
Approved for public release; distribution is unlimited.

**12b. Distribution Code.**

**13. Abstract** *(Maximum 200 words).*

The importance of a global ocean observing system capability has been wholly endorsed by the world oceanographic community. However, changing observations available in the future to support such an observing system. Ever increasing reliance is being made on moored/drifting buoys and other remote sensing capabilities. Single profile expendable instruments such as the expendable bathythermograph, though at one time cost effective, are being enhanced by a new generation of multi-parameter measuring expendable devices. The U.S. Navy under the support of the Oceanographer of the Navy, has been investigating methods to reduce reliance on single profile expendables and ship observations by development of a series of sonobuoy sized, satellite reporting expendable drifting buoys. These buoys will be capable of measuring air temperature, sea surface temperature, barometric pressure, subsurface ocean temperature with depth, ambient noise, wind speed, wind direction, and directional wave spectra. These developmental buoys have been designated by the Navy as the AN/WSQ-6 (series) mini drifting data buoys. This paper updates some of the Navy's recent testing of these buoys and provides insight into other potential applications of these sensor types.

**14. Subject Terms.**
Ambient noise, wave spectra, drifting buoy

**15. Number of Pages.** 12

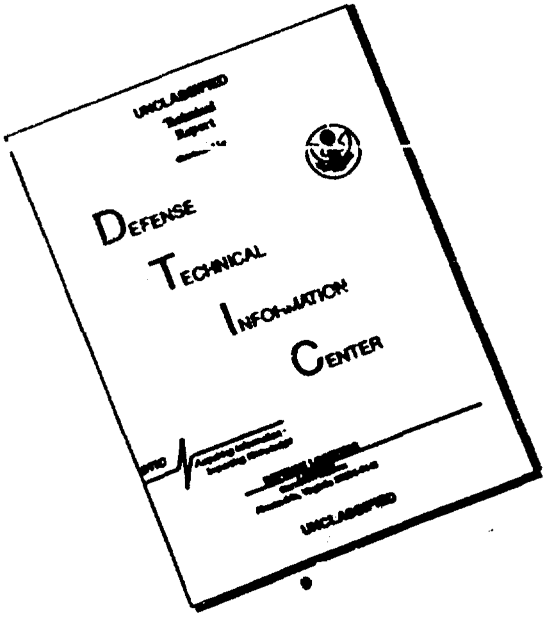
**16. Price Code.**

| 17. Security Classification of Report. | 18. Security Classification of This Page. | 19. Security Classification of Abstract. | 20. Limitation of Abstract. |
|---|---|---|---|
| Unclassified | Unclassified | Unclassified | SAR |

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

# DISCLAIMER NOTICE




**THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.**

# International MARITIME DEFENCE 1993

Dist

A-1

DTIC QUALITY INSPECTED 3

# CONFERENCE PRE-PRINTS

## VOLUME TWO

93-17932

93 8 4 190

Supported by

Sponsored by

Supported by

Vanguard Class Combat System Integration
Christopher Michael Brown, Project Manager, Vickers Shipbuilding & Engineering Ltd, Commander J Hart RN, Ministry of Defence, UK

Merlin System Integration
John Feavearyear, Engineering Director, IBM-Aerospace Systems Integration Corporation, UK

## Operating Environments

An Overview of the US Navy's AN/WSQ-6 (Series) Drifting Buoy Program
Harry D Selsor, Deputy Director, Tactical Oceanographic Warfare Support (TOWS) Program Office, Naval Research Laboratory, Stennis Space Center, USA

Toward Operation Acoustic Tomography for ASW
Michel Bouvet, Ingénieur Principal de l'Armement, Régis Martin-Lauzer, Ingénieur Principal de l'Armement, Centre Militaire d'Océanographie, EPSHOM; Michel Cresp, Prèsident-Directeur Général, SYSTEMIQUE, France

Oceanographic Forecast Aids for the Royal Navy
Dr S J Foreman, Head of Ocean Forecast Modelling, Meteorological Office; Dr A D Heathershaw, Head of Ocean Modelling, Defence Research Agency, UK

Measurements & Modelling of Internal Waves
Lt Col Hans Dahlquist, National Defence Research Establishment, Erland Källen, Department of Meteorology, Stockholm University, Sweden

Development of Oceanographic Instrumentation for Military Applications
Richard Burt, Marketing Director, Chelsea Instruments Ltd, Nichola Lane, Section Leader - Tactical Exploitation, Defence Research Agency, UK

Hydroacoustic Modelling of the Baltic Sea
Lennart Berghult, Research Officer, Per Moren, Senior Research Officer, Swedish Defence Research Establishment (FOA), Sweden

Title: AN OVERVIEW OF THE U.S. NAVY'S AN/WSQ-6 (SERIES) DRIFTING BUOY PROGRAM

AUTHOR: HARRY D. SELSOR, NAVAL RESEARCH LABORATORY, CODE 7410, STENNIS SPACE CENTER, MS 39529-5004

COUNTRY: UNITED STATES OF AMERICA

ABSTRACT: *The importance of a global ocean observing system capability has been wholly endorsed by the world oceanographic community. However, changing world politics and economics will undoubtedly reduce the number of maritime observations available in the future to support such an observing system. Ever increasing reliance is being made on moored/drifting buoys and other remote sensing capabilities. Single profile expendable instruments such as the expendable bathythermograph, though at one time cost effective, are being enhanced by a new generation of multi-parameter measuring, expendable devices. The U.S. Navy under the support of the Oceanographer of the Navy, has been investigating methods to reduce reliance on single profile expendables and ship observations by development of a series of sonobuoy sized, satellite reporting expendable drifting buoys. These buoys will be capable of measuring air temperature, sea surface temperature, barometric pressure, subsurface ocean temperature with depth, ambient noise, wind speed, wind direction, and directional wave spectra. These developmental buoys have been designated by the Navy as the AN/WSQ-6 (series) mini drifting data buoys. This paper updates some of the Navy's recent testing of these buoys and provides insight into other potential applications of these sensor types.*

In January 1991, the U.S. Navy endorsed an Operational Requirement (OR) for development of a series of A-sized sonobuoy style, satellite reporting, long life (90 day), mini drifting data buoys (MDDBs). The requirement specification calls for development of three variations of the buoy that will have the capability to measure and report various near surface meteorological and oceanographic environmental parameters. These include measurements such as air temperature (AT), sea surface temperature (SST), barometric pressure (BP), directional wind speed (WS/WD), omni directional ambient noise (AN), and subsurface temperature with depth (TZ) at various intervals down to 600 meters. These three buoy configurations and sensor specifications are summarized in Table I.

The Oceanographer of the Navy (N096) provided funding support and tasking to the Naval Research Laboratory's (NRL's) Tactical Oceanographic Warfare Support (TOWS) Program Office to manage technical development of these buoys to meet the OR specifications. The TOWS program had previously evaluated a commercially available buoy manufactured by a Canadian firm called the Compact Meteorological and Oceanographic Drifter (CMOD). The CMOD buoy comes in an A-sized sonobuoy style package and measures air temperature, sea surface temperature and barometric pressure. Data are sampled hourly and transmitted via the NOAA polar orbiting satellites using Service ARGOS reporting formats. The CMOD buoy was tested and modified to allow it to be safely deployed by Navy P-3 Orion aircraft. Sensor evaluation and testing resulted in further refinements to the buoy's sampling technique and addition of a 100 meter prototype thermistor string on 60 buoys. This design effort projected that it would be feasible to use a very thin wire, free flooding cable with potted thermistors for long term (90 day) ocean thermal structure measurements using expendable drifting buoy technology. However, the sea is an unforgiving environment; and thermistor string reliability proved to be poor due to salt water leakage into the thermistors, a problem still prevalent in thermistor strings with much larger diameters and better water permeability protection. Improved manufacturing techniques for this cable design have been identified, and subsequent testing of a 100 m TZ buoy showed no thermistor failures over a 102 day life span in an open ocean test. This design experience has led to other improvements that will be discussed further.

Figure 1 is an analysis of environmental observation sources compiled from statistics at the Fleet Numerical Oceanography Center (FNOC). The number of drifting buoy observations over the ocean is fast approaching the number of rawinsonde observations (RAOBS) available over land. However, there is still three times as much ocean area compared to land that needs observation coverage. Of note is the overall number of reports from satellites. Most of the satellite derived measurements are area estimates based on a variety of assumptions. Over the open ocean, data from drifting buoys, ships and bathythermograph (BT) observations provide the "sea truth" data for most remote sensed oceanic parameters. If the number of manually observed ship and BT reports decrease as projected, a growing reliance will be made on automated reporting such as the drifting buoys.

The U.S. Navy is committed to using expendable drifting buoys and routinely deploys them world wide as part of the Naval Oceanography Command's Integrated Drifting Buoy program. These buoys have been used to "tag" certain frontal and oceanographic features and at times provided the only available data for location and movement of these features. Initial evaluations indicated the basic CMOD buoy design is sometimes wind driven and does not act as a Lagrangian current follower. However, the Navy did not specify design requirements for buoy current following. Subsequently, specially configured drogued mini drifting data buoys have been utilized to evaluate shallow water circulation models and current drift trajectory predictions. The National Oceanic and Atmospheric Administration (NOAA) has done a side by side comparison of a drogued mini drifting data buoy with current following shapes and found no substantial difference in its current following ability. A comparative test of the mini drifting data buoy's current following ability with a World Ocean Circulation Experiment (WOCE) "standard" buoy is envisioned in the near future.

In response to the OR for the mini drifting data buoys, the TOWS program initiated a cost shared (50/50) development program with the government of Canada under the auspices of a 1963 U.S./ Canadian Defense Development Sharing Agreement. This multi year, multi million dollar contract called for a phased development of four additional sensors using the basic CMOD package concept. Four buoy configurations were proposed with an option for a fifth. These buoy configurations have been given the designation as AN/WSQ-6 (series) buoys (see Table II). In each phase of the development, the contractor is to build at least six prototype buoys for proof of concept and in-house testing and then, upon demonstration of successful sensor performance capability, deliver 25 of each prototype to the Navy for additional testing. Prior to Navy testing, "dummy buoys" of the same size, weight and center of gravity characteristics and external configuration were air deployed from test aircraft to ensure the buoys met Air Safety certification requirements for deployment from P-3 and S-3 aircraft sonobuoy launchers.

Figure 2 shows the planned configuration of the AN/WSQ-6 series buoys. The first configuration, the XAN-1, is similar to the standard CMOD. The second configuration calls for the addition of an ambient noise sensor hydrophone, located at 100 meters, onto a basic CMOD buoy (AN/WSQ-6 XAN-2). The hydrophone sensor will collect broad band, omni directional ambient noise at 16 frequencies between 5 Hz and 25 kHz in one third octave band filters using a time bandwidth product of 100. Data are sampled and updated hourly. The hydrophone assembly is attached to a membrane suspended in the center of the lower drogue. The hydrophone contains an integral preamplifier which is powered by and transmits signal over a simple two wire link with the surface unit over the frequency band of 5 Hz to 25 kHz. It has a sensitivity of -163 dBV, +/-2 dB at the output of the line receiver in the surface electronics. Figure 3 shows data from two prototype test buoys deployed to the northeast and south of Iceland. Note the variability in the ambient noise (wind and weather vs shipping) in the two regional areas. Figure 4 is a 30 day time series of 6 of the 16 frequencies from one of these buoys. Acoustic variability of 20 or more decibels can be seen on time scales of less than 12 hours. Wind and weather related noise events from passing storms have been correlated.

The Navy has taken delivery of the 25 AN/WSQ-6 XAN-2 prototype units and "MIL SPEC" testing of this configuration is near completion. The majority of the testing is being done through the Naval Air Warfare Center (NAWC), Indianapolis, Indiana. These include air safety certification, examination of Hazards of Electromagnetic Radiation to Ordinance (HERO), survivability to shock and vibration extremes, temperature and humidity extremes, accelerated aging, hydrophone acoustic response, antennae beam pattern verification, verification of the ARGOS communications format, open ocean deployment at the sonobuoy test range in San Clemente, full operational air deployment evaluation including underwater photography of buoy water entry and deployment of buoys in operational scenarios by fleet aircraft. Test units have shown the ability to meet nearly all the minimum military specifications required of the sensor performance specified in the OR with the exception of 90 day life on subsurface sensors. Preliminary analysis of available data indicates premature failure of one or both of the copper conductors and possible fatigue failure in the suspension system rubber compliance members after about 8 days of constant wave action. The result is either a total loss of subsurface data or contamination of the acoustic data due to flow induced and mechanical noise. A cable design improvement is being implemented for testing in future configurations.

The XAN-3 is equipped with a 300 meter thermistor (TZ) string and is identical to the XAN-2 in size, weight and center of gravity. In lieu of the hydrophone, the buoy has a prototype 300 meter thermistor string with 10 thermistors at depths of 7.5, 17.5, 25, 32.5, 50, 75, 100, 150, 200 and 300 meters. These thermistor depths correspond to Navy standard Optimum Thermal Interpolation Scheme (OTIS) model depths and will be used to sea truth model output. A pressure sensor is attached to allow correction for thermistor string catenary depth differences. Experience with the 100 meter TZ buoy prototype indicated that the most notable failure mode of the thermistor string was a slow short to seawater and potential copper conductor stress fatigue. A new torque balanced cable design was prepared that incorporated the thermistors "in line" with an extruded water blocked organic polymer (polyurethane) jacket. The design specifications allow for commonality of other configurations by the addition of two internal wire leads to add a hydrophone or other sensor at the bottom of the cable. The cable specifications have been given to two independent manufacturers and delivery of ten prototype cables is expected to be complete by the end of March 1993. Manufacturer testing of the 300 meter thermistor string prototypes will be completed by late summer 1993 followed by Navy tests of 25 prototypes in tests similar to those performed on the hydrophone configuration (AN/WSQ-6 XAN-2).

The AN/WSQ-6 XAN-4 prototype will combine the thermistor string and hydrophone on one buoy. This configuration will have a redesigned antennae and mast assembly, increased sensor payload capacity and incorporation of a UHF command active receiver for buoy scuttling from suitably equipped aircraft. Due to ARGOS transmitting limitations of only 256 bits per identification number, only 11 frequencies (vice 16) from 5 Hz to 8 kHz will be reported in addition to the meteorological and thermistor sensor data. Packaging constraints due to cable diameter and space available may limit the actual length of the TZ cable to only 200 meters with the 300 meter thermistor attached near the hydrophone at the base. If subsurface sensor longevity can reliably exceed 40-60 days, this buoy will prove to be a tremendous multi-parameter open ocean expendable data gathering instrument. It can be used to gather time series correlated sea truth data for a variety of remote sensing instruments and parameters.

A crucial sensor needed for the buoy is a wind speed and direction sensor. The XAN-5 prototype will incorporate a prototype sensor for this application. From a developmental view, this sensor is viewed as the most technically challenging. Small mechanical anemometer cup and vane type devices have been added to larger moored and drifting buoy platforms where power and space were adequate. None of these devices lend themselves to the miniaturization and reliability required for these small expendable buoys. The wind sensor for this buoy should have no moving parts, lend itself to expendable low power technology and yet be accurate enough to act as a "bell ringer" for gale and storm force winds and portray wind shifts associated with passage of synoptic scale weather features. Several non-mechanical techniques to determine wind speed have been investigated. One of these is the Wind Observation Through Ambient Noise (WOTAN) technique where correlation has been shown to exist between wind speed measurements and estimates obtained by evaluation of ambient noise at selected frequencies (see Figure 5). Researchers at the Naval Postgraduate School are currently investigating these techniques and assisting in evaluation of the mini drifting data buoys. A modified WOTAN technique was applied to acoustic data from one of the ambient noise drifting buoys deployed near Bermuda in 1992 and compared to Defense Meteorological Satellite Program (DMSP) derived Special Scanning Microwave Imaging (SSM/I) wind speed estimates over the area, the results are shown in Figure 6. Although the correlation in this case was excellent, other data in different water masses from the Pacific indicate that the algorithm may not be universal. Further research in this area is needed. NOAA is currently investigating WOTAN type techniques for classification and quantification of precipitation. Although promising, this technique is still not proven enough for expendable drifting buoy applications. A technique was also investigated using differential pressure sensors but was not deemed feasible. A German company is presently designing a wind speed sensor using a differential strain gauge technique that they successfully demonstrated to a Swiss meteorological organization. This technique appears to lend itself to the miniaturization and power requirements of an expendable sensor. A phase I design effort and bread board sensor development effort was initiated in January 1993. If successful it will be integrated onto a AN/WSQ-6 prototype buoy and tested in Fiscal Year 1994 with funding obtained through a Strategic Environmental Research and Development Program (SERDP) initiative coordinated with the Office of Naval Research.

A related development to add directional wave spectra capabilities to a CMOD style buoy was also initiated this year. A three axis accelerometer and magnetometer technique will be used to extract directional wave spectra from buoy motions. Buoy/wave response function corrections and encoding of wave processing results for transmission by ARGOS will be required. Techniques similar to those used on larger buoys maintained by the National Data Buoy Center can be utilized to look at the high frequency component of the wave spectrum for estimation of wind speed and direction. This design prototype will require an integrated processor capability and additional power for processing. As more sensors are added, power budgets and data sampling strategy will have to be revised or the buoys will have much shorter life spans. Moored or drifting versions of this buoy will be used to support the Navy's new initiatives to shift emphasis to support shallow water and littoral region conflict scenarios and amphibious operations.

The TOWS office has also supported a National Aeronautics and Space Administration (NASA) initiative to add a multi-channel passive upwelling optical radiance filter to the bottom of a CMOD style buoy. This buoy prototype has seven passive optical filters that correspond to the channels of sensors on the upcoming SEAWIFS ocean color satellite. A recent successful air deployment and testing of two of these buoys was accomplished in Pacific equatorial regions this past year.

The developmental phase of the AN/WSQ-6 is expected to be completed by late 1994 with transition to an operational buoy program in 1995. Performance specifications will be written and an openly competed procurement contract will be initiated. The Navy's Commander Naval Oceanography Command and the Program Executive Office for fleet sonobuoy procurement have agreements in place to transition this buoy program to full operational status. Multi-parameter, long life, expendable instrumentation such as the AN/WSQ-6 buoys are a vital key to success of the U.S. Navy's contribution to a global ocean observing system.

Acknowledgements. Funding for the the AN/WSQ-6 Mini Drifting Data Buoy project is co-sponsored by the Chief of Naval Operations Oceanographer of the Navy through the Naval Research Laboratory's Tactical Oceanographic Warfare Support Program Office (PE 0604704) and the Defense Electronics Division, Industry Science and Technology, Canada. Sincere appreciation is also given to Dr. Jeffery Nystuen of the Naval Postgraduate School, Monterey, who provided the WOTAN and SSMI wind comparison data. Operational deployment support was provided through various organizations under the Commander Naval Oceanogaphy Command and the Naval Oceanographic Office. Special thanks is also given to Mr. Richard Myrick and Mr. William Popovich of the Naval Research Laboratory, Stennis Space Center, for their software and data collection support. Navy military specification testing support is provided through Mr. Brian Ackerman of the Naval Air Warfare Center, Aircraft Division, Indianapolis.

| PE | Sensor | Range | Accuracy |
|---|---|---|---|
| OPERATIONAL REQUIREMENT SPECIFICATIONS Mini Drifting Data Buoy (MDDB) | | | |
| *teorological* | Barometric Pressure | 850-1054 mb | +/- 1.0 mb |
| | Air Temperature | -30 to +46°C | +/- 0.2°C |
| | Sea Surface Temperature | -5 to +35°C | +/- 0.2°C |
| | Wind Speed | 0 to 63 m/s | +/- 1.0 m/s |
| | Wind Direction | 0 to 360°T | +/- 15°T |
| *IALLOW TZ-MET* | Met package as above | | |
| | TZ Tail to 300 m | Logarithmic spacing | |
| | Ten Thermistors | -5 to + 35°C | +/- 0.2°C |
| | Pressure Sensor | 0 to 330 db | +/- 3 db |
| | Omni-Hydrophone (100 m) | 5Hz - 5 kHz | +/- 1 dB |
| *EP TZ (600 m)* | Sea Surface Temperature | -5 to +35°C | +/- 0.2°C |
| | TZ Tail to 600 m | Logarithmic spacing | |
| | Fifteen Thermistors | -5 to +35°C | +/- 0.2°C |
| | Pressure Sensor | 0 to 660 db | +/- 3 db |
| | Omni Hydrophone | 5 Hz to 5 kHz | +/- 1 dB |

ole I. Operational requirement specifications.

| BUOY CONFIGURATION | U.S. NAVY DESIGNATION |
|---|---|
| CMOD | AN/WSQ-6 (XAN-1) |
| CMOD/ANS | AN/WSQ-6 (XAN-2) |
| CMOD/TZ 300 m | AN/WSQ-6 (XAN-3) |
| CMOD/TZ/ANS | AN/WSQ-6 (XAN-4) |
| CMOD/WS/WD | AN/WSQ-6 (XAN-5) |

BLE II. Buoy configurations and corresponding Navy designation.
W - Water Surface & Underwater Combination
S - Special Types
Q - Special or Combination of Purposes
XAN-# - Naval Air Warfare Center Indianapolis Prototype

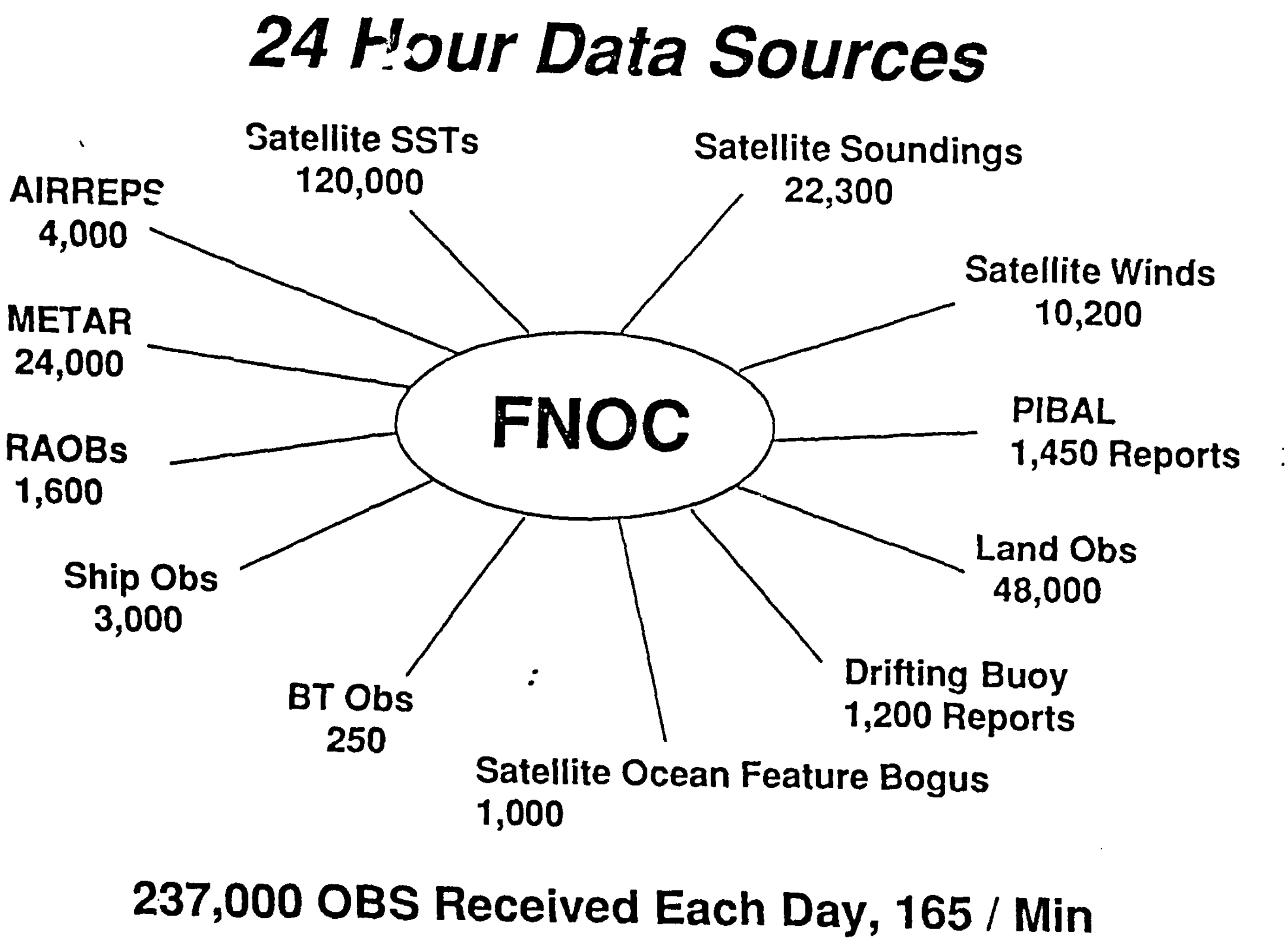



Figure 1. 24 hour data summary.

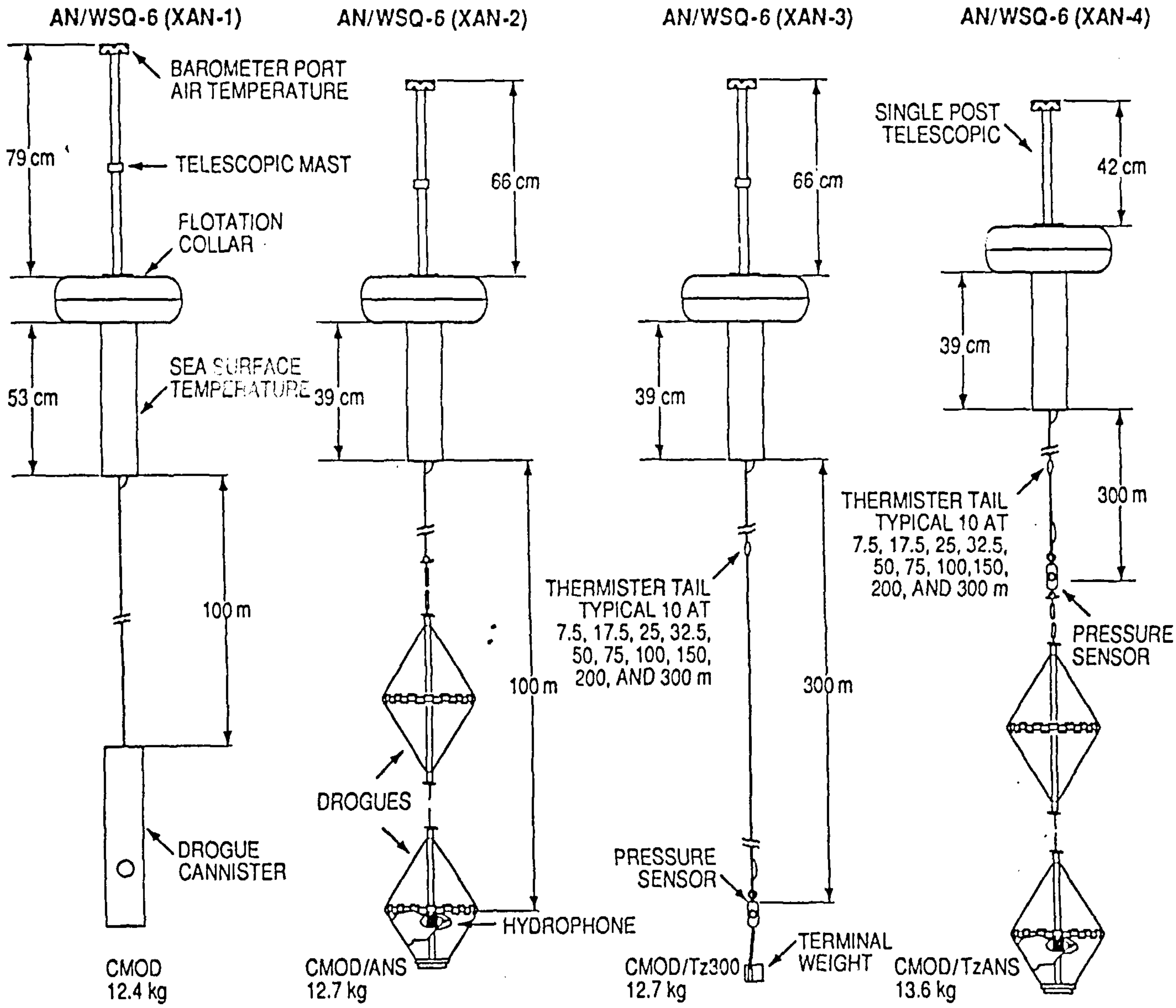
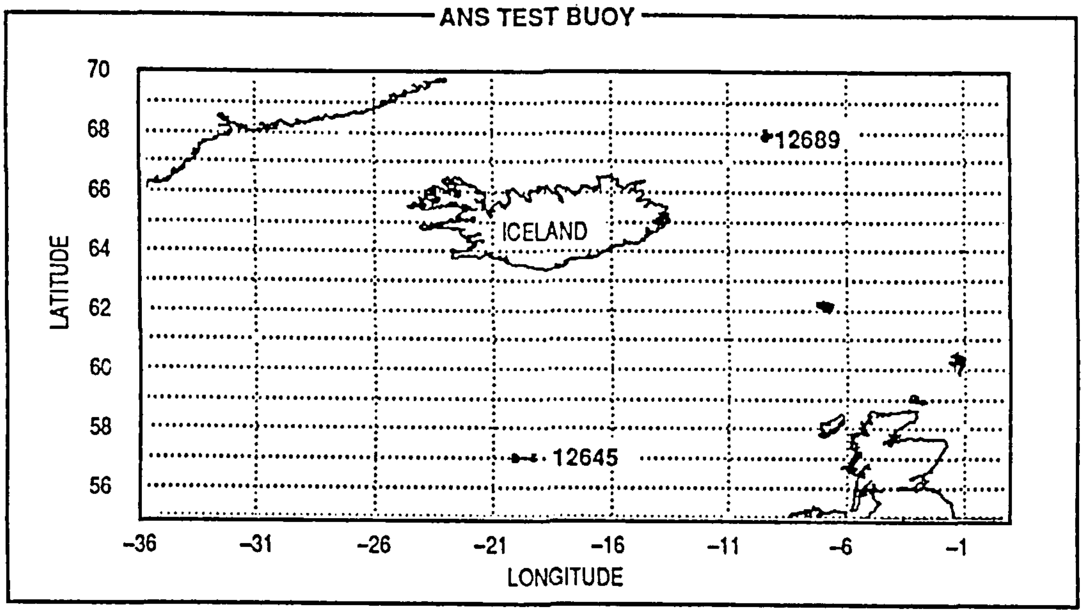



Figure 2. Mini Drifting Data Buoy configurations and nomenclature.



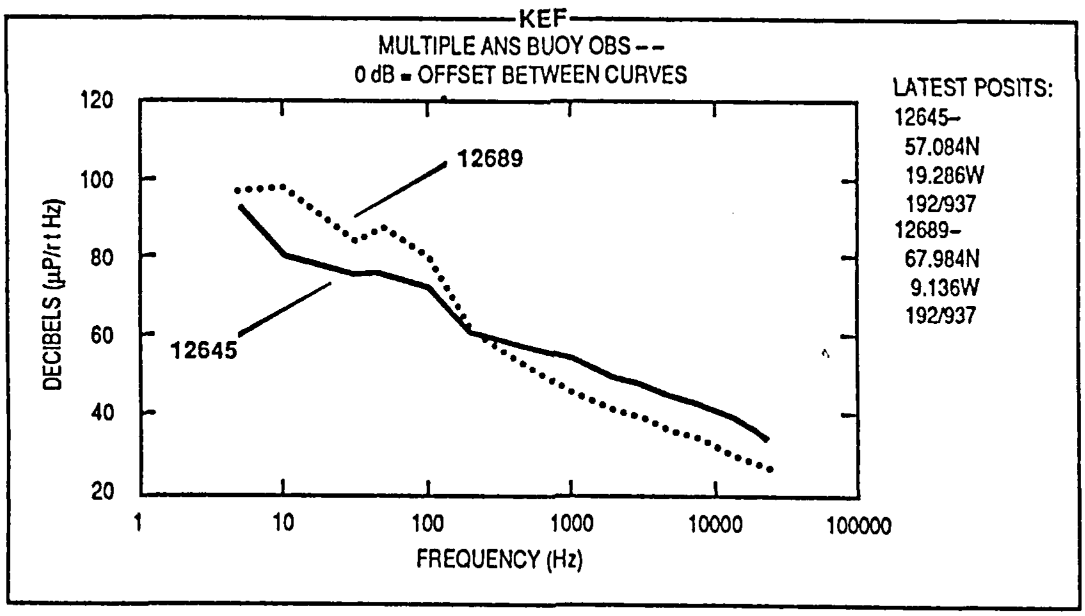




Figure 3. Ambient noise data from 2 buoys deployed near Iceland, July 1992.

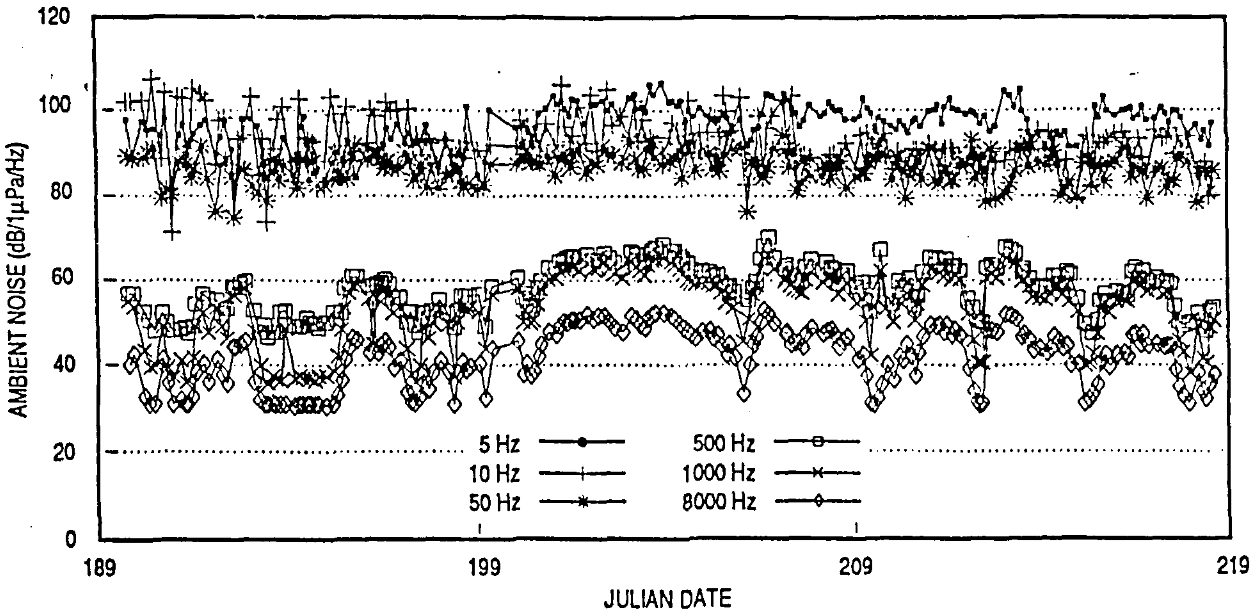



Figure 4. Thirty day ambient noise summary from buoy 12689.

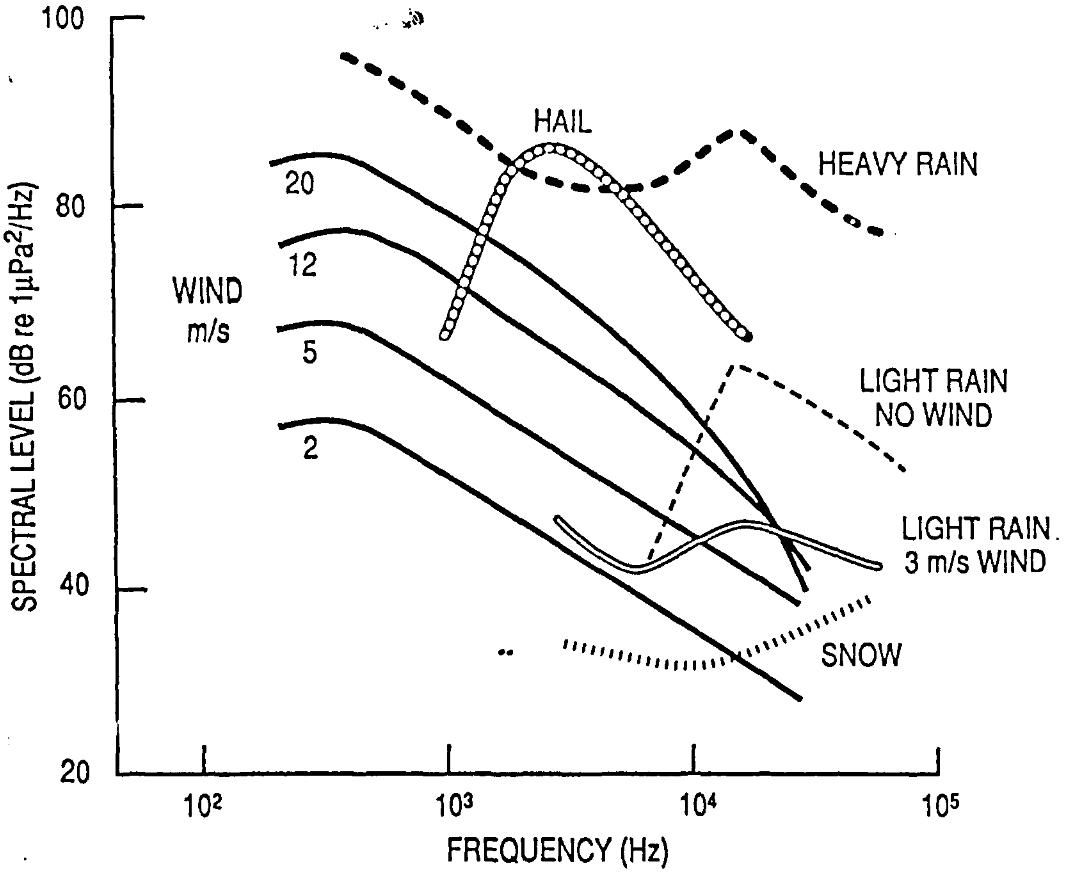



Figure 5. Acoustic spectrum of wind speed/precipitation.

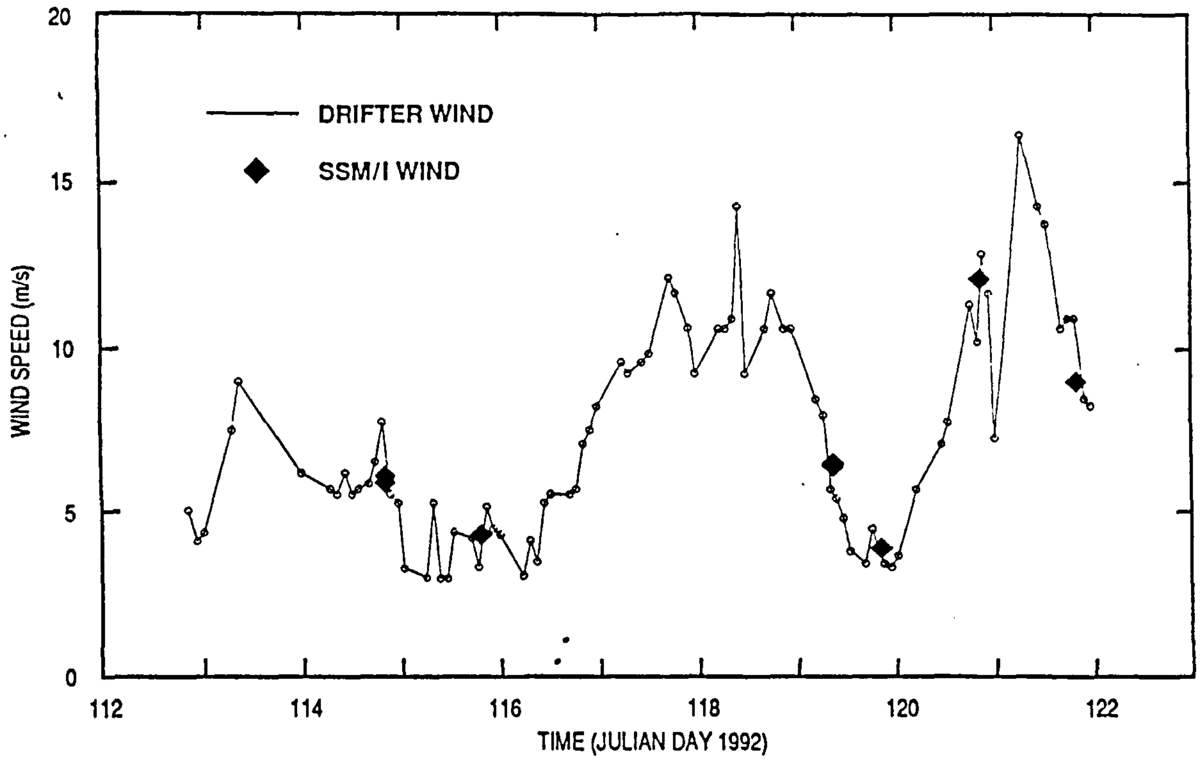



Figure 6. Comparison of WOTAN wind speed estimates to SSMI winds.