The National Weather Service (NWS) United States Integrated Sustained Ocean Observing System and the Federal Backbone - The Next Steps, What Can the Federal Backbone Do for You?

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Cross Cutting Issues, Track D

***Abstract* - The U. S. Commission on Ocean Policy will make its recommendations during the summer of 2003. These recommendations are expected to fully endorse the development of a U. S. Integrated Ocean Observing System (IOOS). The form of the U.S. IOOS is emerging. Requirements have been identified, and a blueprint for the U.S. IOOS has been developed. The system would address national coastal issues as well as make a significant contribution to the larger Global Ocean Observing System (GOOS). The federal backbone components are central to the IOOS blueprint. The observing system foundation formed by the federal backbone and the services the backbone provides are critical to developing and sustaining the IOOS.**

The National Data Buoy Center (NDBC), a part the National Oceanic and Atmospheric Administration's (NOAA), National Weather Service (NWS), manages the Marine Observation Program (MOP) and operates the NWS Marine Observation Network (MON). The MON is a core element of the U.S. IOOS federal backbone. The NWS MON is an integrated, sustained ocean observation, information and product delivery system that operates in all U. S. coastal waters, as well as the off-shore waters of the Pacific and Atlantic Oceans and the Gulf of Mexico. The system consists of headland and moored buoy data acquisition platforms and real-time processing and information delivery systems, as well as drifters, floats, and voluntary observing ships. The MON produces quality controlled real-time data and products that serve the NOAA storm warning and forecast mission and support research and operational requirements of other federal, state, regional, local, academic and private sponsors. Within the context of the IOOS blueprint, NOAA's NDBC has established strategic alliances with several Regional Observation Networks. This paper presents an overview of these alliances and discusses how they are evolving into full-fledged partnerships. Partnerships that will realize the goals of the U.S. IOOS.

I. INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) has just published its Strategic Vision. This Strategic Plan “New Priorities for the 21st Century,” was developed through a broad inclusive process that involved in-depth nationwide discussions with stakeholders and employees. This process focused on NOAA’s commitment to present and future environmental, economic, and public safety issues. In its plan, NOAA identified four mission goals and common strategies to achieve them. These goals are:

NOAA MISSION GOALS

▪ ECOSYSTEMS	Mission Goal #1: Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management.
▪ CLIMATE	Mission Goal #2: Understand climate variability and change to enhance society’s ability to plan and respond.
▪ WEATHER AND WATER	Mission Goal #3: Serve society’s needs for weather and water information.
▪ COMMERCE AND TRANSPOR-TATION	Mission Goal #4: Support the Nation’s commerce with information for safe, efficient, and environmentally sound transportation.

As these goals were developed, four common strategies emerged. The four common strategies are: Monitor and Observe, Understand and Describe, Assess and Predict, and Engage, Advise and Inform. Starting with Monitor and Observe, each strategy builds on the outputs of the preceding, and each provides stakeholders and customers a variety of outputs and products.

As NOAA met with stakeholders and employees, the consensus emerged that NOAA should give its core capabilities the same priority as the four mission goals. NOAA’s core capabilities provide the critical support, infrastructure, and ability to achieve its goals and deliver timely products and services to the Nation. The first cross-cutting priority NOAA identified was the “Integrated Global Environmental Observation and Data Management System”.

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- Integrated Global Environmental Observation and Data Management System — “NOAA will work with our partners to develop global-to-local environmental observation and data managements for comprehensive, continuous monitoring of coupled ocean/ atmospheric/ land systems. This network will enhance NOAA’s ability to protect lives and property, expand economic opportunities, understand climate variability and change, and promote healthy ecosystems.”

This cross-cutting priority contains within it NOAA’s inclusive leadership to an IOOS. A review of NOAA observing systems and published budgets shows a significant investment in ocean observing and related research.

All of these efforts are candidates for inclusion in the IOOS. When one first imagines an IOOS, it is the automated observing systems that come to mind, automated systems delivering time-tested, regular quality controlled observations to decision makers and stakeholders throughout the nation. From a review, these automated in situ observing systems can be identified within NOAA’s total ocean investment. An estimate of these automated systems can be seen in Fig. 1.

NOAA’s Marine Observation System operated by the National Weather Service’s National Data Buoy Center, accounts for over 30% of NOAA’s quality controlled, automated, in situ observing investment. This significant percentage of NOAA’s in situ observing investment presents NDBC with an opportunity of operational ocean observing leadership. NDBC is attempting to exercise that leadership role in an inclusive collaborative way. NOAA’s NDBC is committed to the establishment of a successful IOOS and is currently working collaboratively with many partners to realize this endeavor. NDBC is seeking to expand efforts with our current partners and to establish relationships with new partners.

Participants that would establish a successful IOOS would be responsible for adhering to the current IOOS design principles. These principles, as expressed by Ocean.US [1] are:

(1) Development and operation of the system will be guided by coalitions of data providers and users and by a long term strategy that enables government agencies (state and federal) to achieve their missions and goals more effectively.

(2) The IOOS will be a multiple use system that focuses on those aspects of the seven goals that can most effectively be achieved by integrating existing elements across agencies and programs. The IOOS will provide social and economic benefits to the nation through the sustained provision of data and information on the oceans that will benefit a broad spectrum of user groups from government agencies and private enterprise to NGOs and the science and education communities that use or benefit from the oceans or are responsible for their stewardship.

(3) Design and implementation will be based on high level, vetted requirements and sound science. The IOOS will enable constructive and timely synergy among research, modeling, and monitoring activities.

NOAA Ocean Observations and Related Research Activities

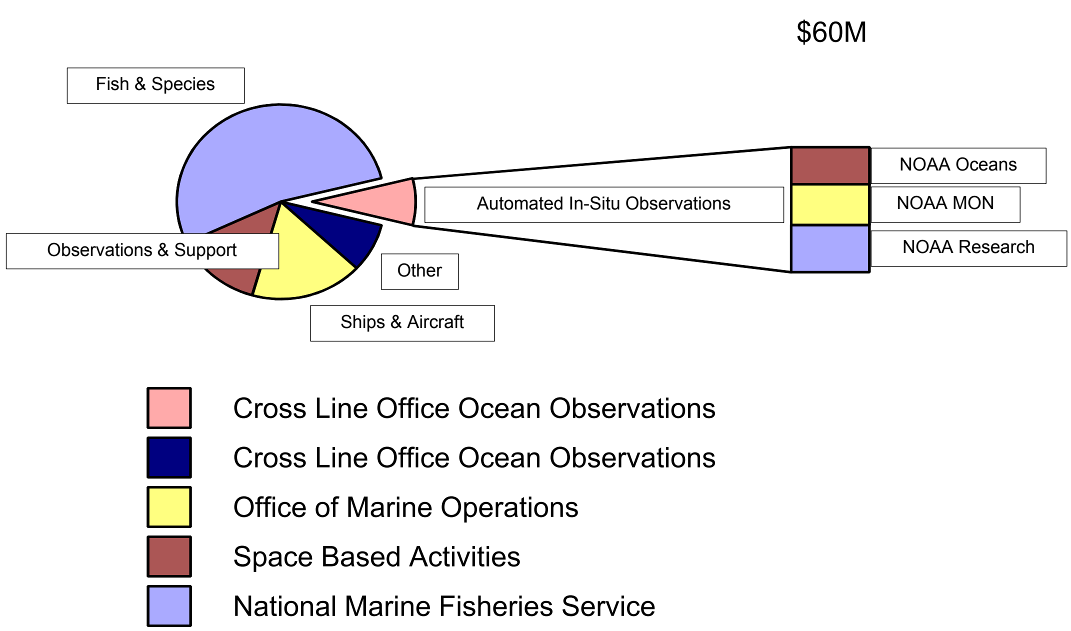

Fig. 1 NOAA Ocean Observations and Related Research Activities

(4) Both non-commercial and commercial data and products may be served. With the exception of sensitive data for the purposes of national defense and homeland security, non-commercial data and information will be produced at public expense and will be fully and openly shared in a timely manner. Commercial data and information will be produced at private expense and most likely will be proprietary. The public sector will not usurp the right of the private sector to produce such information.

(5) Observing systems or elements thereof will meet national standards and protocols for measurements to ensure data quality and for data communications and management (including metadata) to ensure rapid access to data and information of known quality regardless of the source of the data or where the data reside.

(6) Procedures will be established for user groups to routinely evaluate the performance of the IOOS and assess the value of the information produced. Procedures will also be established to ensure sustained data streams and to improve the system as new capabilities become available and user requirements evolve.

(7) Federal investments in capacity building (training, infrastructure development) at state and regional levels will be needed to enable all states and regions to contribute to and benefit from the development of the IOOS.

(8) The initial IOOS will be established by selectively linking existing assets based on national and regional priorities. It will be improved by selectively enhancing and supplementing the initial system over time. Operational ocean observing systems that may be incorporated into the IOOS are those that meet IOOS design principles as described above. It is unlikely that all observing systems will meet these criteria.

Now let's examine these eight design principles and NDBC's relationship with our IOOS partners.

II. NOAA's MARINE OBSERVATION NETWORK (MON), THE REGIONAL ASSOCIATIONS, AND THEIR REGIONAL NETWORKS

NDBC manages and operates NOAA's MON, one of the IOOS "backbones," a principal NOAA coastal and deep ocean observation system. The NOAA MON supplies real-time, quality controlled measurements and products that support NOAA's missions of protecting life and property, promoting safe navigation, understanding climate, water, and weather issues, and husbanding our nation's protected species and natural resources. The MON serves as one of NOAA's fundamental observing systems providing measurements that include in situ: wave height, period, steepness, power spectral density, and direction; surface currents; ocean currents and temperature profiles; salinity and sea surface temperature; wind speed, direction, and gusts; barometric pressure; air temperature and relative humidity. The details of these measurements can be found in Table 1.

The network provides observations from a variety of data acquisition platforms that include moored buoys, drifting buoys and floats; fixed Coastal-Marine Automated Network (C-MAN) stations; and over 800 Voluntary Observing Ships. Furthermore, the MON provides reference datum stations for

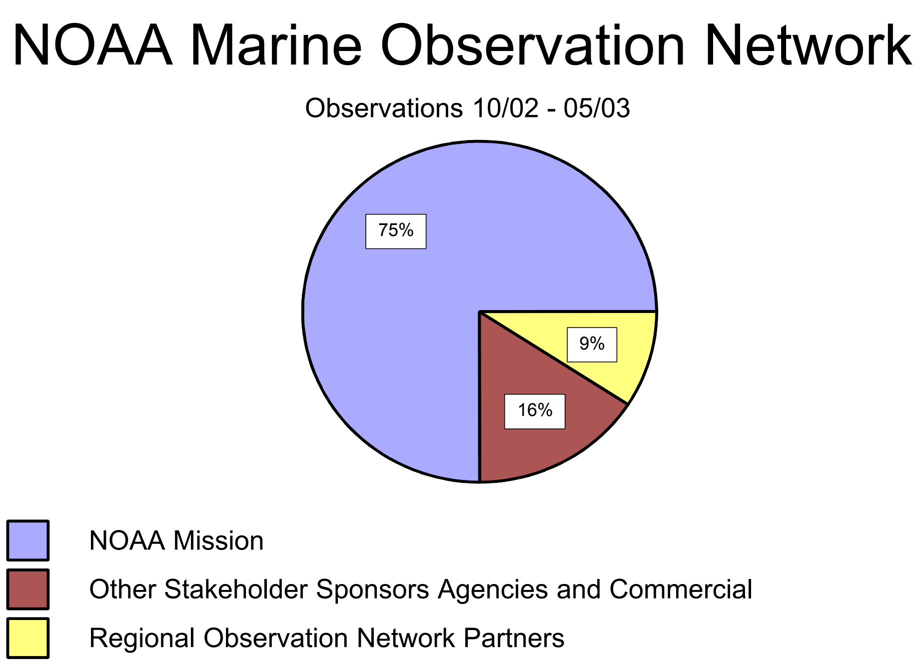

Fig. 2 NOAA's Marine Observation Network Observations 10/02 – 05/03

regional coastal ocean-observing systems. The MON is a 24X7 real-time, quality controlled system disseminating observations and products to NOAA's operational decision support systems. From NOAA's Telecommunications Operations Center (TOC) in Silver Spring, Maryland, the MON releases data to: NOAA's Advanced Weather Interactive Prediction System (AWIPS); NOAA Weather Radio; NOAA's Emergency Managers Weather Information Network (EMWIN); and the World Meteorological Organization's (WMO) Global Telecommunications System (GTS).

More than 68 individual regional observing networks currently operate in the coastal waters of the United States. These regional networks are sponsored by other federal agencies, state agencies, local governments, organizations and academia. Now Regional Associations (RA) of stakeholders are being formed to design, operate, and improve regional observing systems. NDBC has embraced the regional observing systems offering assistance and coordination on all of the eight design principle areas. NDBC hopes to embrace the RA in the same way as soon as they begin to form. To date, NDBC has significant partnerships with four regional observation networks:

1) Skidaway Institute of Oceanography (SKIO), http://skio.peacenet.edu;
2) Gulf of Maine Ocean Observing System (GoMOOS), http://www.gomoos.org;
3) Coastal Ocean Monitoring and Prediction System (COMPS), http://comps.marine.usf.edu; and
4) Texas Automated Buoy System (TABS), http://tabs.gerg.tamu.edu/Tglo.

NDBC has demonstrated successful collaborative activities in ways that further the IOOS.

(1) Development and operation of the system will be guided by coalitions of data providers and users and by a long term strategy that enables government agencies (state and federal) to achieve their missions and goals more effectively.

NDBC and its partners have created coalitions where NDBC has helped the regional data providers with information on operational standards, measurements, and sighting requirements. NDBC has supplied the data providers with an application [2] that converts data to meet the interface requirements to the Marine Observation Network. NDBC in return, through the MON interface, quality controls the data and distributes the observations in real time. The data are distributed to federal, state, and local decision makers, modelers, and first responders. Additionally, the data are released worldwide via the GTS. Finally, the observations are automatically captured by the National Archive Centers and archived. These additional regionally produced and nationally quality controlled observations enable NOAA to more effectively meet its mission goals.

From October 2002 to May 2003, the MON released 1,279,920 real time, quality controlled observations to internal and external stakeholders. Of this total, 9.0% were contributed from Regional Observation Network partners.

(2) The IOOS will be a multiple use system that focuses on those aspects of the seven goals that can most effectively be achieved by integrating existing elements across agencies and programs. The IOOS will provide social and economic benefits to the nation through the sustained provision of data and information on the oceans that will benefit a broad spectrum of user groups, from government agencies and private enterprise to NGOs, as well as the science and education communities that use or benefit from the oceans or are responsible for their stewardship.

To link regional observational networks to the national backbone and to make the complementary data from the regional observational networks available to a larger national user group, NDBC has developed a "C" language software application for encoding data into the WMO real-time codes [3]. NDBC refers to this application as the Meteorological and Oceanographic Data Exchange Module (MODEM). Once the "MODEM" encodes the data, NDBC serves as a gateway via file transfer protocol (FTP) transmission into NDBC's quality control system and dissemination via NOAA's operational infrastructure. These observations are disseminated, usually within 3 minutes, to NWS forecast offices, the National Centers for Environmental Prediction, the Weather Channel, the Federal Emergency Management Agency, and other federal, state, and local entities through EMWIN. Additionally, the observations are available to the general public via the NDBC Web site, which receives about 5 million hits each month. To date, NDBC has partnered with and is receiving complementary data from four regional observation networks:

1) Skidaway Institute of Oceanography (SKIO), http://skio.peacenet.edu;
2) Gulf of Maine Ocean Observing System (GoMOOS), http://www.gomoos.org;
3) Coastal Ocean Monitoring and Prediction System (COMPS), http://comps.marine.usf.edu; and
4) Texas Automated Buoy System (TABS), http://tabs.gerg.tamu.edu/Tglo.

The positive effects on the U. S. IOOS distance between stations are striking. In the Gulf of Maine region, the MON backbone observational spacing is 79 nmi. With the addition of the GoMOOS stations, the observational spacing of real-time reporting systems is improved to 59 nmi. Including the GoMOOS stations reduces the station spacing along the entire East Coast from 135 nmi. to 103 nmi. Similar improvements can be seen along Florida's west coast with the inclusion of the Coastal Ocean Monitoring and Prediction System (COMPS) data. The COMPS is operated and maintained by the University of South Florida. The national backbone average observational distance in the Gulf of Mexico is 112 nmi. This is improved to 85 nmi with the inclusion of the COMPS stations. The TABS buoys provided data during a recent hurricane that made landfall on the Texas coast.

(3) Design and implementation will be based on high level, vetted requirements and sound science. The IOOS will enable constructive and timely synergy among research, modeling, and monitoring activities.

An important function of the MON as a backbone element of the coastal component of the U.S. IOOS is development and cross-compatibility of regional observing systems. This gives the opportunity to obtain leverage from "MON Platforms of Opportunity." NOAA's Office of Atmospheric and Oceanic Research (OAR) and the State of Florida support monitoring of conditions which determine the health of coral reefs in the Florida Keys. The NDBC C-MAN station at Long Key, Florida, serves as a communication platform for expanded physical and biological observations made by the Florida Institute of Oceanography.

Partnering with other federal agencies is important to fulfill the intent of the U. S. IOOS. Increasing ocean observations, environmental stewardship, and promoting commerce are an important function of a U.S. IOOS. In addition to the mission-funded stations, there are another nine stations funded by organizations other than NWS to support their specific ocean missions. These stations are outfitted with the real-time oceanographic and meteorological packages that support NOAA's operational missions. For example, NDBC has partnered with the Minerals Management Service (MMS) for over 12 years. This collaboration has produced the longest time series record of ocean currents to date. The station in the Santa Barbara channel has operated for over nine years. Additional MMS stations on the West Coast make long term current profile measurements.

In addition to the base funded C-MAN stations, NDBC operates seven C-MAN stations that are either fully or partially supported by organizations other than the NWS. For example, the U. S. Department of Transportation's St. Lawrence Seaway Development Corporation (SLSDC) funds NDBC stations to monitor conditions along the St. Lawrence Seaway and control vessel traffic. The SDLC Vessel Traffic Service Center closes the waterway when conditions deteriorate. Those portions of NOAA's operational information delivery systems that deliver NOAA MON data now interface with the SLSDC Vessel Management System (VTMS). This VMTS uses the international standard for marine Automated Information System (AIS) to retransmit NOAA quality controlled observations to commercial vessel traffic equipped with an AIS transceiver. The AIS protocol is compatible with all maritime industry standards such as Electronic Chart and Display Information System (ECDIS) and Collision Avoidance Program System Protocol (CASP). All NDBC data in the SLSDC area of operations are automatically captured by these shipboard applications and automatically displayed on the vessel's electronic chart display and radar information displays.

For over a year, NDBC's partnership with the NOAA's Gray's Reef National Marine Sanctuary has released real-time physical ocean measurements of salinity and ocean currents to the National Centers of Environmental Prediction (NCEP) where they are used to validate a variety of ocean-model guidance products. These observations are also consumed by a variety of other stakeholders in coastal management and academia.

NDBC's collaboration with our East Coast partners, GoMOOS and Skidaway Institute, has released real-time, quality controlled observations that are directly assimilated to initialize NCEP models. Additionally these observations are used to validate a variety of ocean model guidance products. The increased ocean observations spatial density in the Gulf of Maine area has directly benefited NOAA's Weather Service in increasing the "skill" of its marine forecasts and has also assisted the U. S. Coast Guard in their Search and Rescue Mission.

(4) Both non-commercial and commercial data and products may be served. With the exception of sensitive data for the purposes of national defense and homeland security, non-commercial data and information will be produced at public expense and will be fully and openly shared in a timely manner. Commercial data and information will be produced at private expense and most likely will be proprietary. The public sector will not usurp the right of the private sector to produce such information.

NOAA's MON produces mission funded observations and ingests complementary data from various data producers. These data all undergo automatic quality control processing and are released as "NOAA quality controlled original data." These are distributed across various networks. Like all Other NOAA NWS observations, these data are available to value-added third parties for processing and possible sale.

(5) Observing systems or elements thereof will meet national standards and protocols for measurements to ensure data quality and for data communications and management (including metadata) to ensure rapid access to data and information of known quality regardless of the source of the data or where the data reside.

The MON releases real-time data using the international data exchange and communications formats and protocols sanctioned by the WMO. Currently the MON releases information in the FM-13 SHIP code for average wind speed, wind direction, wind gust, air temperature, sea surface temperature, station pressure, sea level pressure, visibility, significant wave height, and dominate period. NDBC uses WMO FM 65-TESAC code to disseminate temperature, salinity and ocean currents at the surface and at multiple depths, and the WMO-allowed, standard national C-MAN code, a variant of FM12 SYNOP, for the same variables as FM-13 with the addition of water level. Using these standard forms, NDBC implements a system of real-time data quality control processing. These standard forms facilitate the link between NDBC and the regional observation systems and allow them access to the real-time data quality control processing.

The objective behind the NDBC quality control procedures and techniques is that all sensors should perform within stated accuracies. The quality control procedures used by NDBC fall into two categories: completely automated and those that involve a man-machine mix. The completely automated procedures are performed at National Weather Service Telecommunications Gateway (NWSTG) / TOC for real-time messages used for operational forecasts and warnings. The other procedures are performed at NDBC for data that is submitted for archival.

The real-time automated procedures, performed at NWSTG, check to eliminate gross errors. Transmission parity error, range limit, and time continuity checks are performed. Relational checks, such as examining the wind gust to wind speed ratio, are performed to check the quality of both measurements. Another check ensures that the battery voltage is adequate for barometric pressure measurements.

At NDBC, stricter range and time continuity limits are performed. Measurements from duplicate sensors are compared to ensure that they track together. NDBC also uses a man-machine mix of quality checks, such as graphical procedures which relate wind speed and spectral wave energy. Other man-machine procedures involve time series plots, spectral wave curves, and computerized weather maps. When sensor or system degradation is detected, the affected data are removed before posting on the NDBC Web site or archival at one of the national archive centers. The real-time processing at NWSTG is instructed to not release data from the degraded sensor.

(6) Procedures will be established for user groups to routinely evaluate the performance of the IOOS and assess the value of the information produced. Procedures will also be established to ensure sustained data streams and to improve the system as new capabilities become available and user requirements evolve.

In its structure and governance document, Ocean.US [1] outlines criteria for migrating from research to operations. NDBC is open to assist the Regional Observations Networks and the emerging RA's as they face these issues. NDBC has, at least on the federal level, just completed the transition of the Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoys from NOAA Research to NOAA Weather at NDBC. This represents one of the first successful complete NOAA system transfers from research to operations. The NDBC DART transition effort was accomplished in close coordination with the DART research team at NOAA Research's Pacific Marine Environmental Laboratory. Teamwork and dedication accomplished the transition with no loss of data or service the program stakeholders.

Ocean.US specifically identifies stages for transfer from research to operations. The stages are:

- Research that is likely to contribute to the development of the IOOS may be specifically funded to address IOOS priorities (mission driven research) or may emerge through research designed to achieve goals established by the scientific community (hypothesis-driven research). Research priorities are established under the auspices of the National Ocean Research Leadership Council (NORLC [Ocean.US]). Research projects may be selected for funding through the National Ocean Partnership Program (NOPP) competition process or through mechanisms established by individual participating agencies;
- Proof-of-concept pilot projects fall into one of two categories, those that target specific elements of the system (sensors, models, etc.), and those that constitute an "end-to-end" system (e.g., regional observing systems). Although pilot projects are expected to be conducted by researchers, collaboration with and/or endorsement by operational groups and potential users must be documented;
- Candidates for Pre-Operational Projects; and finally,
- System/sensor established as part of the operational system.

(7) Federal investments in capacity building (training, infrastructure development) at state and regional levels will be needed to enable all states and regions to contribute to and benefit from the development of the IOOS.

The NWS MON realizes all six points identified for the IOC Global Coastal System (GCS) design in the draft report, August 2002: national backbone of limited size; provides economy of scale, international standards, and the link between regional federations and global observing systems; provides for comparative analysis; and facilitates capacity building [3]. NDBC is working closely with partners on proper sensor selection and operational sensor improvements. NDBC recently joined as a associate member, the Alliance for Coastal Technologies (ACT). We expect the alliance to pay significant dividends over the next few years.

(8) The initial IOOS will be established by selectively linking existing assets based on national and regional priorities. It will be improved by selectively enhancing and supplementing the initial system over time. Operational ocean-observing systems that may be incorporated into the IOOS are those that meet IOOS design principles as described above. It is unlikely that all observing systems will meet these criteria.

III. FUTURE THOUGHTS

NDBC has embraced the IOOS spirit and current design principles. NDBC is committed to working cooperatively with the new Regional Observations Networks and the emerging RA's to bring about a successful IOOS. As the NWS Marine Observation Program manager and operator of over 30% of NOAA's automated real-time ocean observation stations, NDBC is reaching out to foster an IOOS. In doing so, NDBC is receiving invaluable help in accomplishing its mission. This is a good model for federal agencies and stakeholders to embrace. Following this path will lead to a successful IOOS.

Table 1. Measurements of NOAA's Marine Observation Network

PARAMETER	RANGE	FREQ.	AVG. PERIOD	RESOLUTION	ACCURACY
WIND DIR.	0 to 360	1.71 Hz	2/8 min	1.0 deg	+/- 10.0 deg
WIND SPEED	0 to 62 m/s	1.71 Hz	2/8 min	0.1 m/s	+/- 1.0 m/s or 10%
WIND GUST	0 to 82 m/s	1.71 Hz	3 & 5 sec	0.1 m/s	+/- 1.0 m/s or 10%
AIR TEMP.	-40 to +60 C	1.71 Hz	2/8 min	0.1 C	+/- 1.0 C
PRESSURE	800 to 1100 hPa	1.71 Hz	2/8 min	0.1 hPa	+/- 1.0 hPa
SEA SURFACE TEMP.	-5 to +40 C	1.71 Hz	2/8 min	0.1 C	+/- 1.0 C
REL. HUMIDITY	0 to 100 %	1.71 Hz	2/8 min	0.1 %	+/- 3 %
WAVE HEIGHT	0 to 35 m	2.56 Hz	20 min	0.1 m	+/- 0.2 m
WAVE PERIOD	0 to 30 SEC	2.56 Hz	20 min	1.0 sec	+/- 1 sec
WAVE SPECTRA	0 to 99 m*m/Hz	2.56 Hz	20 min	0.01 Hz[1]	NA
WAVE DIR	0 to 360	2.56 Hz	20 min	0.1 deg	+/- 10 deg
DEW POINT	-35 to +30 C	1.71 Hz	2/8 min	0.1 C	+/- 1.0 C
SOLAR RADIATION	0 to 2150 W/m*m	1.71 Hz	2/8 min	0.5 W/m*m	+/- 5 %
WATER LEVEL	0 to 99.99 ft	1.71 Hz	10 min	0.1 ft	0.01 %
VISIBILITY	0 to 8 mi	1.71 Hz	2/8 min	0.125 mi	+/- 10 %
ADCP	-10 to 10 m/s	1.71 Hz	20 min	0.1 cm/s	+/- 2 cm/sec

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