

# National Data Buoy Center (NDBC) Support of the Integrated Ocean Observing System (IOOS)

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**Abstract-** The National Data Buoy Center (NDBC) began implementing Integrated Ocean Observing System (IOOS) principles in 2001, when they partnered with the Gulf of Maine Ocean Observing System (GoMOOS). NDBC and GoMOOS collaborated on a project to transmit meteorological and oceanographic data from the GoMOOS buoys to NDBC in real-time. NDBC's data quality control, data format, and communications services were then used to transmit the data to the NWS Telecommunications Gateway (NWSTG), which disseminated the data to the Weather Forecast Offices (WFOs) in the region.

As IOOS has matured and Regional Associations (RAs) have developed, NDBC has been a partner. NDBC shares ocean observation expertise, develops data management techniques and quality control algorithms, and keeps the RAs and IOOS informed by participating in Regional Association meetings and workshops.

Using a scalable system that is able to receive increasing numbers of observations, while maintaining quality control, NDBC has increased the number of partner data providers to more than 40 and the number of partner platforms to more than 600. Many of the providers are members of RAs and Ocean Observing Systems (OOSs). The number of observations handled by NDBC will approach 10 million a year by the end of 2010.

As NDBC and partner data are quality controlled at the gateway, any data that do not meet the stringent quality control algorithms are automatically assigned quality flags. The flagged data are transmitted to NDBC, where analysts re-examine the data.

NDBC has also been involved in the IOOS effort to establish the technical infrastructure, standards, and protocols needed to improve

delivery of ocean data through the Data Integration Format (DIF). NDBC, along with NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) provide these services. Services include the NDBC Sensor Observation Service (SOS), which provides ocean temperatures, salinities, currents, waves, and winds from NDBC Coastal Buoys, IOOS Regional Coastal Ocean Observing Systems, and TAO moorings. In addition to these data, high Frequency Radar derived coastal surface currents are available through the NDBC THREDDS Data Server.

A new partnership between NOAA's National Oceanographic Data Center (NODC) and NDBC will lead to the capability to preserve all of NDBC's marine datasets to meet the standards for climate observation requirements established by NOAA and the Global Climate Observation System (GCOS). Taking advantage of new techniques using Ocean Geospatial Consortium (OGC) Inc. standards and the SOS described above and funded by NOAA's IOOS Program, will enable a new degree of interoperability within and between NDBC and NODC and properly archive all NDBC Partner observations.

## INTRODUCTION

The National Data Buoy Center (NDBC) provides real-time, end-to-end capability beginning with the collection of marine atmospheric and oceanographic data and ending with its transmission, quality control, and distribution. The data are disseminated to warning centers, marine forecasters, the U.S. Coast Guard, ocean platform operators and the public to making sound decisions to safely operate in the marine environment. NDBC's stations are located at sites determined by the NWS forecast and warning requirements.

Additionally, NDBC receives data from forty oil and gas platforms in the Gulf of Mexico, operates the National Node for the coastal surface currents that are derived from High Frequency Radar data, and serves as a Global Data Assembly Center (GDAC) for OceanSITES. OceanSITES is a worldwide system of long-term, deepwater reference stations measuring dozens of variables and monitoring the full depth of the ocean from air-sea interface to 5000 meters.

## QUALITY CONTROL

NDBC data must pass both automated and manual quality control algorithms before they are disseminated to ensure that WFOs, surfers, boaters, and centers operating numerical weather prediction systems are using high-standard marine observations.

Data generally undergo two types of automated quality control. During the first, gross error checks identify communications errors and sensor failures. These data are failed and not allowed to pass through the system over the GTS. The second type of automated quality control check identifies data that are not grossly in error, but are suspect. These data are released to the GTS, but they undergo manual analyses during the next twenty four hours. If the data are deemed to be inferior, their release may be halted by the DAC.

**NDCB Partner Status - Western States**

**Sunday, 8/8/2010**

| Partner Name | Status   | Day      | Time     | Notes |
|--------------|----------|----------|----------|-------|
| ABC          | Good     | 8/8/2010 | 10:00 AM |       |
| DEF          | Warning  | 8/8/2010 | 10:00 AM |       |
| GHI          | Critical | 8/8/2010 | 10:00 AM |       |
| JKL          | Good     | 8/8/2010 | 10:00 AM |       |
| MNO          | Warning  | 8/8/2010 | 10:00 AM |       |
| PQR          | Critical | 8/8/2010 | 10:00 AM |       |
| STU          | Good     | 8/8/2010 | 10:00 AM |       |
| VWX          | Warning  | 8/8/2010 | 10:00 AM |       |
| YZA          | Critical | 8/8/2010 | 10:00 AM |       |
| BCD          | Good     | 8/8/2010 | 10:00 AM |       |
| EFG          | Warning  | 8/8/2010 | 10:00 AM |       |
| HIJ          | Critical | 8/8/2010 | 10:00 AM |       |
| KLM          | Good     | 8/8/2010 | 10:00 AM |       |
| NOP          | Warning  | 8/8/2010 | 10:00 AM |       |
| QRS          | Critical | 8/8/2010 | 10:00 AM |       |
| TUV          | Good     | 8/8/2010 | 10:00 AM |       |
| WXY          | Warning  | 8/8/2010 | 10:00 AM |       |
| ZAB          | Critical | 8/8/2010 | 10:00 AM |       |
| ACD          | Good     | 8/8/2010 | 10:00 AM |       |
| EFG          | Warning  | 8/8/2010 | 10:00 AM |       |
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| EFG          | Warning  | 8/8/2010 | 10:00 AM |       |
| HIJ          | C        |          |          |       |

In addition to quality controlling partner data, NDBC also informs partners of the status of their data. If expected data are not received from a station, DAC analysts check the partner website and then transmit an email to the station contact. Additionally, the status of all partner data is kept in a table on the NDBC website, accessible to all. The status codes are provided in Table 1.

The Quality Assurance of Real-Time Oceanographic Data (QARTOD) working group is committed to addressing quality assurance and quality control issues of the IOOS community. QARTOD is a multi-agency effort that has addressed minimum standards for calibration, metadata, and quality control needs for HF Radar, ocean currents, ocean waves, and CTD measurements.

Table 1.  
Description of Codes contained in the NDBC Partner Platform Spreadsheet

| Code           | Meaning                     |
|----------------|-----------------------------|
| Exp            | Expected                    |
| Sta            | Station Name                |
| Pgm            | Associated Program          |
| Date of Eval   | Evaluation Date             |
| Met Status     | Released/Not Released       |
| NWS Met Status | Release to GTS              |
| Ob Freq        | Observation Frequency       |
| BA             | Barometric Pressure         |
| AT             | Air Temperature             |
| DP             | Dew Point                   |
| WD             | Wind Direction              |
| WS             | Wind Speed                  |
| GT             | Wind Gust                   |
| WV             | Wave Height                 |
| PD             | Dominant Wave Period        |
| WT             | Water Temperature           |
| TD             | Tide Level                  |
| VS             | Visibility                  |
| RD             | Radiation                   |
| OC             | Ocean Data (see ocean page) |
| Date Expected  | Date Expected               |
| Flags          | QC Flags Set                |
| Email Data     | Notification Date           |
| Comments       | Description of Issues       |

#### PARTNER INTERACTION

Today the NDBC IOOS DAC provides services to more than 700 platforms from more than 40 different partners. These partners include academic, industry, and federal partners. Many are members of the eleven Regional Associations that represent the many Ocean Observing Systems in existence around the United States. In addition to quality control of partner data, the IOOS DAC reports station failures to data providers within three hours of determination and assigns WMO identifiers to enable the release of partner data to the GTS in real-time.

NDBC stays engaged with Regional Associations and their Ocean Observing Systems throughout the year. NDBC personnel are assigned as liaisons to each of the RAs. NDBC liaisons participate in meetings and keep up with ongoing activities. Interactions include providing updates on NDBC activities and encouraging access to new stations as they are established by RAs and the Ocean Observing Systems.

Each of the Regional Associations consists of academic, industry, and government partners.

Table 2.  
IOOS Regional Associations and their areas of responsibility.

| Regional Association  | Area of Interest   |
|---|--|
| Northeastern RA of Coastal Ocean Observing Systems (NERACOOS)       | Canadian Maritime Provinces to New York Bight                                      |
| Mid-Atlantic Coastal Ocean Observing RA (MACOORA)                   | Cape Hatteras to Cape Cod  |
| Southeast Coastal Ocean Observing RA (SECOORA)                      | Southeast United States  |
| Gulf of Mexico Coastal Ocean Observing System (GCOOS)               | Gulf of Mexico   |
| Caribbean RA (CaRA)   | Northeastern Caribbean Region  |
| Great Lakes Observing System (GLOS)                                 | Great Lakes, connecting waterways, and St. Lawrence Seaway                         |
| Southern California Coastal Ocean Observing System (SCCOOS)         | Southern California Bight  |
| Central and Northern California Ocean Observing System (CENCOOS)    | Point Conception north to the California-Oregon border                             |
| Northwest Association of Networked Ocean Observing Systems (NANOOS) | Pacific Northwest  |
| Alaska Ocean Observing System (AOOS)                                | Alaska's Coasts and Oceans   |
| Pacific Islands Ocean Observing System (PACIOOS)                    | Commonwealth and Territories of the US and Freely Associated States of the Pacific |

#### Academic Partners

NDBC works with many universities. Many are members of regional associations. Universities maintain ocean observing systems, provide data management expertise, repair and exchange equipment, etc. NDBC works with Universities to accomplish common goals.

Among the academic partners are: Woods Hole Oceanographic Institution; Scripps Institution of Oceanography; Rutgers University; University of South Florida; Stevens Institute; Louisiana State

University of Southern Mississippi; University of South Carolina; and the University of North Carolina Wilmington. Academic Partners in the Gulf of Mexico and Southeastern United States Regions are shown in fig. 2.

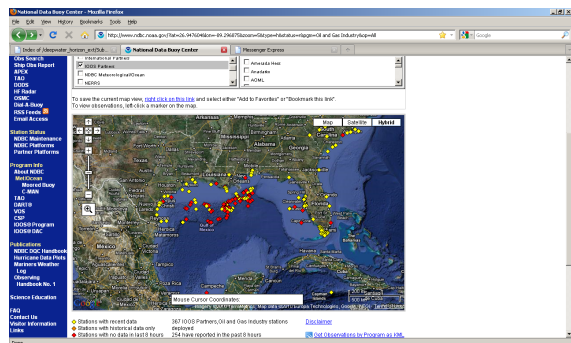


Fig. 2. Academic partners and oil and gas platforms in the Gulf of Mexico and Southeastern United States.

### Industry Partners

In the mid-1990s, MMS requested that NDBC deploy buoys in the Santa Barbara Channel and off the coast of Louisiana in the Gulf of Mexico to provide data for drilling operations. NDBC also disseminates large volumes of ocean current profile data from more than forty oil and gas platforms in the Gulf of Mexico (fig 2). Before the Minerals Management Service (MMS) Notice to Lessees required the oil and gas companies that were planning to drill in water deeper than 400 meters on the outer continental shelf of the Gulf of Mexico to equip their platforms with Acoustic Doppler Current Profilers, industry and NDBC were partners. Some of the oil and gas companies agreed to provide meteorological data even though it was not required.

A fixed platform owned by Mariner Energy and maintained by Essi Corporation has been providing meteorological and surface current data and animations from the western Gulf of Mexico as NDBC CMAN station FGBL1, since 1 January 2005.

Shell Oil and Exploration entered into an agreement with NDBC to upgrade their systems by adding battery backup power to be able to provide meteorological data in the event of evacuation during a tropical event. The National Weather Service now has access to important data from the Gulf of Mexico that is currently missing. The importance of this effort was borne out during Hurricane Ike, as winds measuring more than 100 mph were reported as the Hurricane passed nearby. Shell is in the process of making other enhancements to their platforms, also.

BP Inc. has equipped several oil and gas platforms with meteorological sensors since the Deepwater Horizon oil spill and provides those data to NDBC for quality control and dissemination.

### Federal Partners

A number of NOAA entities (Table 3 and fig. 3) transmit data to NDBC for quality control and dissemination over the GTS. National Weather Service Eastern, Central, and Alaska Regional Centers send data from rivers and lakes in their regions. The National Estuarine Research Reserves collect weather data in addition to water quality information and provides these data to NDBC.

Table 3. Federal partners providing data to NDBC.

| FEDERAL PARTNERS   |
|--|
| NWS Central Region   |
| NWS Eastern Region   |
| NWS Alaska Region  |
| NOS Center for Operational Oceanographic Products and Services |
| National Estuarine Research Reserve                            |
| Chesapeake Bay Observing System                                |
| Chesapeake Bay Interpretive Buoy System                        |
| Great Lakes Environmental Research Laboratory                  |

NDBC works closely with the NOS Coastal Ocean Operational Prediction System (CO-OPS) to provide meteorological data from tide gauge platforms around the United States. NDBC has also worked with the US Army Corps of Engineers to deploy hippy wave sensors on NDBC buoys.

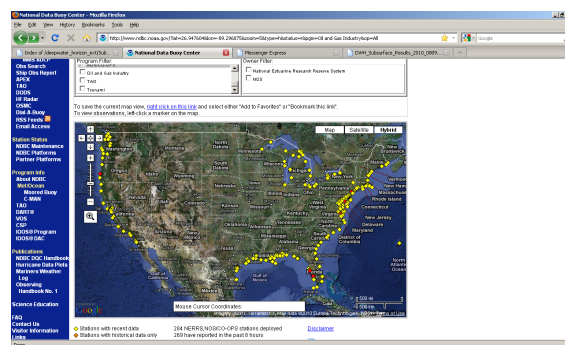


Fig. 3. The location of federal stations providing data to NDBC.

### DATA AVAILABILITY

IOOS is accomplishing the mission of integrating and standardizing data from a variety of sources. Through the IOOS Data Infrastructure Framework (DIF), IOOS is making these core ocean data

available to numerical models, registries, and data base servers.

The NDBC Sensor Observation Service (SOS) server provides in-situ temperature, salinity, currents, water level, waves and winds data from NDBC moorings, IOOS Regional Coastal Ocean Observing Systems, Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys, and Tropical Atmosphere Ocean (TAO) buoys. The server is operated by the NOAA National Weather Service (NWS) NDBC. SOS is an Open Geospatial Consortium (OGC) standard. An example of IOOS observations of ocean temperature on the west coast is provided in fig. 4.

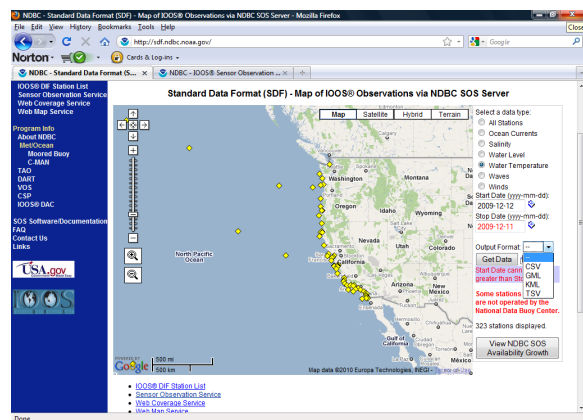


Fig. 4. Ocean stations providing temperature through the IOOS SOS server.

The NDBC Thematic Realtime Environmental Distributed Data Services (THREDDs) Data Server (TDS) provides gridded surface currents derived from high-frequency radar (HFR) installations along the coast (fig. 5). The server supports Web Coverage Service (WCS) and Open-source Project for a Network Data Access Protocol (OpenDAP) and is operated by NDBC.

## DATA ARCHIVAL

NDBC does not archive marine meteorological and oceanographic data. That service is provided by NOAA's National Climate Data Center (NCDC) and National Oceanographic Data Center (NODC). NDBC's data are currently transmitted to these two centers in an outdated 291 Format.

A new partnership between NOAA's NODC, which is aligned with the National Environmental Satellite, Data, and Information Service (NESDIS) and NDBC will lead to the capability to preserve all of NDBC's marine datasets to meet the standards for climate observation requirements established by NOAA and the Global Climate Observation System (GCOS). These standards include regularly assessing the quality of data as well as providing the details and history of local conditions, instruments, operating procedures, data processing algorithms, and other factors pertinent to interpreting data (i.e. metadata). Taking advantage of new techniques using Ocean Geospatial Consortium Inc. standards and Sensor Observation Services (funded by NOAA's IOOS Program), will enable a new degree of interoperability within and between NDBC and NODC and properly archive all NDBC Partner observations. By the end of January 2011, NDBC will end the procedure of archiving data in the outdated F291 format and begin archiving all 2011 (and beyond) observations using netCDF.

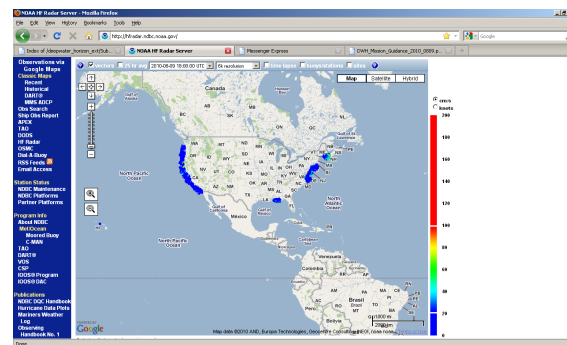


Fig. 5. High-frequency radar surface currents provided in the IOOS SOS.

## Acknowledgments

I am indebted to Rex Hervey, Bill Burnett, Richard Bouchard, and Kevin Kern of NDBC and Darrel Duncan and the SAIC IT team for their efforts.