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Wave Measurement and Forecasting for Mid-Atlantic

New Buoy, Online Data Portal Support Offshore Wind Development

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Over the past five years, the Virginia Department of Mines, Minerals and Energy (DMME) has judiciously expended state funds to advance the development of offshore wind energy resources on the Outer Continental Shelf off Virginia, with a focus on activities that will lower risks and reduce costs. DMME also has successfully leveraged state funds by obtaining cost sharing from federal and industry partners to support its offshore wind projects.

This article describes two such projects, which combine to provide considerable added value to the commercial wind energy area (WEA) leased by Dominion Virginia Power, and the two DMME research leases, one executed and one pending, that are immediately adjacent to or within the commercial WEA off Virginia. The first of these projects is the deployment of a Datawell Waverider buoy just south of the DMME research lease for technology demonstration. The second DMME project is the development and implementation of a Mid-Atlantic Metocean Data Portal to enable real-time validation of various public-domain forecasts of winds, waves, water levels and surface currents.

DMME funding of the Data Portal was motivated by the need to de-risk offshore site assessment and construction activities on Virginia's research leases and the commercial lease held by Dominion Virginia Power. This is particularly important for lift boats being mobilized from the Gulf of Mexico to assist in Mid-Atlantic offshore wind activities, due to the dense sand seabed, which limits jacking up and jacking down operations to wave heights less than 5 ft. The Portal's geographic coverage domain also includes the commercial offshore WEAs off Maryland, Delaware and Kitty Hawk, North Carolina.

Wave Buoy Deployment

A Datawell DWR-MKIII directional Waverider buoy was deployed June 2014 near the Virginia offshore WEA by CoastalObsTechServices LLC. The selected wave buoy is an internationally identified standard against which other wave observations are compared, in large part because Datawell has over 50 years of experience tightly focused on wave observations from buoys. The DWR-MKIII utilizes the traditional accelerometer (versus the GPS-based systems offered by Datawell), but several key Datawell options were also purchased. The Iridium satellite data telemetry option provides for transmission of all data, including full resolution spectra and ensuring robust data communications in all weather. The hull is composed of CuNiFer-10, a material that is anti-corrosive, naturally biofouling resistant due to the high copper content, and only increases cost by 12 percent. There is no need to apply anti-fouling paint, upon recovery there is little cleanup, and throughout the duration of the deployment there's no concern about biofouling loading affecting the wave observations. Another option that was selected is the Datawell Intelligent Test Box (ITB), which draws power sequentially from each of the three battery banks. When a bank is depleted, the ITB adds the next bank, thereby ensuring that any battery rebound in the depleted banks will be used.

The DMME buoy was deployed with the assistance of Cape Henry Launch Service's *Cape Crusader* just south of the Virginia research lease on the western edge of the commercial WEA, 24 nautical miles (nm) east of Virginia Beach. It was struck by a vessel or trailing gear in October 2014 and went off station, survived, was recovered and redeployed in January 2015. It was later retrieved in December 2015 for battery replacement and redeployed in February 2016. As with all Datawell Waveriders, the buoy deployed for DMME is purpose-built to provide the highest quality wave measurements possible. It appears as "VA DMME Lighted Data Buoy" on navigational charts, as WMO ID 44093 on the National Data Buoy Center station website (http://bit.ly/2epCyYv), and as Coastal Data Information Program station 210 (http://bit.ly/2dl4HEf).

The buoy has a nominal 1-Hz sampling frequency and streams data to the Coastal Data Information Program (CDIP) at Scripps Institution of Oceanography through an Iridium satellite link every 30 min. Data are processed and quality controlled in real time in accordance with U.S. IOOS Quality Assurance/Quality Control of Real-Time Oceanographic Data (QARTOD) guidance, using QC tests developed with substantial input from CDIP, as well as others within the wave observation community. Standard products are delivered on the Web in near real time at the CDIP station website.

CDIP's rapid dissemination of quality controlled data provides the most complete, accurate and timely collection of wave and climatological data possible, routinely approaching 100 percent data delivery for their network of buoys. CDIP maintains an automated anchor watch service to provide an alert if a buoy goes off station, monitors battery voltages to assist in repower planning, and archives all raw data. Observations are also distributed globally via the Global Telecommunications Systems thanks to the support of NOAA's National Data Buoy Center and assignment of a World Meteorological Organization ID.

Wave Forecasts

Available wave forecasts for the DMME buoy station include NOAA operational WAVEWATCH III and the experimental Nearshore Wave Prediction System (NWPS). The NOAA WAVEWATCH III model is a nested global spectral wave model with an adaptive hurricane grid that follows major storms. Model output resolution in the offshore lease area is 7.5 km. The NWPS is a nested series of Simulating WAves Nearshore (SWAN) grids operated by the National Weather Service (http://polar.ncep.noaa.gov/nwps). NWPS is forced by WAVEWATCH at the boundaries and provides on-demand, less than 0.5 km resolution nearshore wave forecasts to U.S. coastal wind forecast offices using forecast wind grids prepared and submitted by the individual offices. The system was implemented on a National Centers for Environmental Prediction operational supercomputer for NWS Southern and Eastern Regions in February 2016, with the remaining regions following in October 2016.

A challenge for NWS Regional Forecast Offices (RFOs), which issues daily coastal wave forecasts out to 60 nm offshore, is to evaluate model guidance in developing a consensus forecast for any given event. Hence the DMME scope of work included development of real-time model forecast evaluation tools available in a custom online data portal and close collaboration with the NWS Wakefield RFO for feedback on portal utility.

A New Online Data Portal

The Mid-Atlantic Metocean Data Portal provides real-time access to observations and forecasts of winds, waves, currents and water levels to support offshore wind development and other maritime activities in the Mid-Atlantic region. Users can interactively select points of interest for detailed plotting and analysis, including customizable validation of the following forecast models: NWPS, WAVEWATCH III, National Digital Forecast Database (NDFD), Chesapeake Bay Operational Forecast System (CBOFS), and NOAA Extratropical Surge and Tide Operational Forecast System (ESTOFS).

Emphasis is on quick access to real-time data and a robust evaluation of model forecast skill. The goal is to reduce the risk of encountering hazardous weather conditions resulting in unexpected construction delays or accidents.

Measured data sources include observations from the National Data Buoy Center (NDBC) and the Center for Operational Oceanographic Products and Services (CO-OPS), satellite imagery and active tropical storm tracks. Modeled results for winds, waves, water levels and surface currents are available in map form, in which users can create a “virtual buoy” for plotting and downloading modeled time series.

Users can view map-based model fields and interactively select specific grid points (“virtual buoys”) for customized plotting of modeled time series data, including comparison with nearby measurements. A dedicated Validate Tool enables robust statistical validation of wind and wave forecasts from 00 to 96-plus hr.

The data portal is built on the RPS OceansMap front-end Web framework and a back end consisting of the Environmental Data Server (EDS). It leverages powerful Python-based Web services that accesses model forecasts and metocean observations via the EDS API. Web services provide a dynamic table of contents, advanced plotting features, analysis tools and data download all through a user-friendly, Web-based graphical user interface . The EDS comprises a central data server (with mirroring) that stores archive data and collects data from designated sources (e.g., numerical models, sensors). It is designed to be scalable and modular and utilizes a Service Oriented Architecture that provides Simple Object Access Protocol , Representational State Transfer and Web Map Service interfaces for client applications.

Example Applications

Comparison of observations and evolving forecasts during Tropical Storm Hermine in September 2016 nicely demonstrates the value of having on-site measurements to evaluate wave forecast trends during the summer offshore construction season, which also coincides with the Atlantic hurricane season. The Data Portal has an Explore Tool that can quickly plot measured time series data and over-plot the forecast data from the model of interest. These comparison data can be readily downloaded as comma-separated value (CSV) files, enabling users to perform their own custom analyses or plotting.

After making landfall in Florida as a Category 1 hurricane, Hermine transitioned to a tropical storm and tracked north to impact the Mid-Atlantic region. Observed wave heights peaked at the DMME buoy on September 3, and comparison of the evolving wave height forecasts from WAVEWATCH III and the NWPS two days before the observed peak reveals that both models forecast a higher and higher peak from issue to issue, but the trends in timing of the peak were opposite: While the WAVEWATCH III forecast peak trended to an earlier and earlier peak, the NWPS peak trended to a later and later peak.

The Data Portal also has a Validate Tool that enables users to select a specific time period to quantify forecast performance. Thus, this tool allows offshore operators to better understand the forecast skill of different wave or wind models, based on forecast performance over the past few days and during similar historical time periods. As with the Explore Tool, the Validate Tool enables users to download CSV data files for custom analysis or plotting.

Finally, the versatility of the Data Portal map view enables rapid over-plotting of selected model layers to create insightful displays of offshore and coastal processes. For example, on October 9, 2016 the Mid-Atlantic region was under the influence of Category 1 Hurricane Matthew's counterclockwise surface wind circulation converging with northerly winds associated with a cold front.

Development and implementation of the Data Portal are centered on the NWS Wakefield RFO spatial domain because it covers four offshore wind energy areas and has a large number of validation stations available, particularly in the southern part of the domain covering the two lease areas off the coastal service territory of Dominion Virginia Power and Dominion North Carolina Power. With additional funding, it can be readily extended to other RFO coastal domains as mapped at http://polar.ncep.noaa.gov/nwps. We anticipate that the Data Portal will benefit coastal engineers, commercial shipping, fisheries, emergency responders and recreational users.

Access to the portal is freely and publicly available at http://oceansmap.com/midatlanticportal.

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Fig 1
Datawell DWR-MKIII buoy deployed near Virginia offshore wind energy area, just south of DMME research lease. (Photo Credit: Mark Bushnell)

Fig 2
This screen capture of the Mid-Atlantic Metocean Data Portal map view is a composite of three different models layered in the following order from top to bottom, to illustrate the spatial extent of their different domains: CBOFS tidal water level; NWPS surface currents; NDFD surface winds. The global layer behind these three domains is the observed sea surface temperature (SST) seven-day composite from NOAA's AVHRR satellite measurements. Also shown are NDBC and CO-OPS validation stations.

Fig 3
Comparison of evolving trends in significant wave height time series forecasts between two wave models using the Explore Tool in the Data Portal. The forecast issue date-time curves are labeled in UTC, while the X-axis indicates local time (UTC-4 hr.).

Fig 4
Screen capture of Portal Validate Tool applied to the 48-hr. forecast performance of the NWPS model for significant wave height during the summer construction months of June and July 2016.

Fig 5

This cropped screen capture of the Data Portal map view shows NDFD surface wind field and the ESTOFS de-tided water level at 1700 local time (2100 UTC) during Hurricane Matthew on October 9, 2016. It shows how frontal winds from the north converge with Matthew's circulation to pile up water on the open-ocean coast off Virginia Beach. It also shows how the frontal winds draw down water levels at the north end of Chesapeake Bay and raise them at the southern end.