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Atmospheric Profiling And Modeling For Offshore Sites

Ongoing research at sites off the coast of the northeastern U.S. is aiding resource assessment.

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Recently proposed offshore wind generating facilities in the U.S. have attracted considerable attention, with projects now in various stages of development in Nantucket Sound (Cape Wind Associates) and south of Long Island (the Long Island Power Authority's [LIPA] Offshore Wind Initiative).

Other serious projects are likely to be proposed in the foreseeable future in light of the country's vast offshore development potential and its growing appetite for wind-based electric generation. The heavily populated mid-Atlantic and New England region is the nation's major center of electric demand and demand growth, and it is blessed with strong marine winds close to shore. This region, therefore, is a logical candidate for near-term offshore wind energy development.

One of the barriers to offshore development in this region and others is the lack of quantitative wind, wave and other geophysical data needed to optimally design wind facilities to survive the elements. Until now, no field studies have focused exclusively on the U.S. offshore physical marine environment as it relates to wind energy.

Technical demands studied

During the past year, a team of leading atmospheric measurement /modeling and marine science organizations has been assembled to address the technical demands of measuring and modeling the marine wind and wave environment.

This multi-disciplinary team consists of AWS Truewind LLC (project manager), Atmospheric Information Services (project science), and the Woods Hole Oceanographic Institution (project participant).

The team is working on a project titled "Development of Atmospheric Profiling and Modeling Techniques to Evaluate the Design and Operating Environment of Offshore Wind Turbines." The project is funded by the National Renewable Energy Laboratory, the Long Island Power Authority, and the New York State Energy Research and Development Authority as part of the U.S. Department of Energy's Low Wind Speed Turbine Program (Phase II).

Through its advisory committee, the project will incorporate the input and advice from the intended users and "customers" of the results of this project. Committee members include GE Wind Energy, Vestas, FPL Energy and Erie County, N.Y., which contains the city of Buffalo on Lake Erie.

The main focus of the project is the establishment of an offshore monitoring facility that measures wind, wave and current conditions at a fixed structure in the Atlantic Ocean off the coasts of New York City and New Jersey. The research results are aimed at providing wind system designers with new data sets and tools to obtain site-specific design criteria and loading data necessary to cost-effectively engineer and optimize offshore wind facilities in the Atlantic region. If future funding becomes available, it is hoped that field efforts expand into the lower Great Lakes region as well.

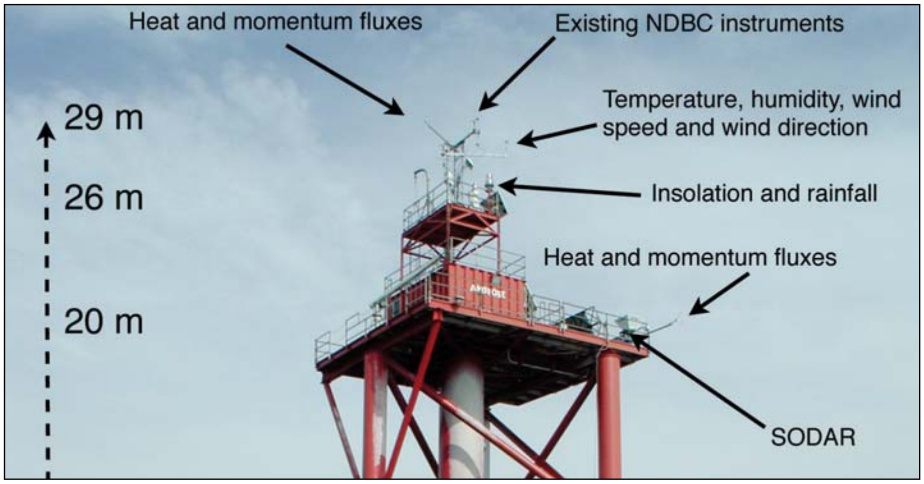
Project components

The project has four principal components:

• The assessment of existing monitoring and observation network data;

• A six-month or longer intensive field measurement campaign;

• A modeling analysis and verifica-



The Ambrose Light Field Station off the New Jersey coast has been equipped with additional instrumentation to study the meteorological and oceanic environments. Photo courtesy of AWS Truewind and Atmospheric Information Services

tion study of the coastal wave and meteorological regime; and

• The conceptual development of a buoy-adapted atmospheric profiling system.

A brief summary of the project objectives follows.

Integration of existing observation networks and historical data sets were considered. Within and adjacent to the project domain, several different agencies and other entities operate meteorological surface and tidal observation networks. In addition to the surface observation networks, satellite remote sensing platforms are also making daily or more frequent estimates of surface winds over the Great Lakes and the oceans.

These data sources are being compiled and assessed for their effectiveness (accuracy, coverage, resolution) at defining the coastal and offshore wind regime in the Long Island, New England and the lower Great Lakes regions. Gaps in the quality or applicability of these data sources for offshore wind plant applications will be characterized in the context of engineering and financing requirements.

The degree of further reduction in uncertainty needed to meet the requirements of these stakeholders will define the requirements of subsequent on-site measurement equipment.

A field-measurement campaign is also being done. The nexus of this study is the establishment of an offshore research observatory with a focal point of Ambrose Light, a coastal-marine automated network (C-MAN) station operated and maintained by the U.S. Coast Guard.

Ambrose Light is situated in 25 meters of water 12 km south of Rockaway, N.Y., and 13 km east of Sandy Hook, N.J. This location is approximately 32 km west of and in similar depths to the proposed LIPA offshore wind energy facility. The National Data Buoy Center (NDBC) maintains a suite of instruments on Ambrose, including air temperature, wind speed and direction (29 meters above mean sea level [AMSL]), and pressure (21 meters AMSL).

To develop a more comprehensive description of the meteorological and oceanographic environment, and to support modeling studies, we have installed additional instrumentation on the facility to measure the stress and buoyancy fluxes, precipitation, net radiation and profiles of wind speed, wind direction and temperature (Figure 1).

For surface and sub-surface measurements, a 3-meter discus buoy is now deployed 300 meters east of Ambrose Light making standard meteorological and sea state observations. These include: barometric pressure; wind direction, speed and gust; air and sea temperature; and directional current, wave and wave energy spectra from which significant wave height, dominant wave period, average wave period and wave direction are derived.

Wind variability

Understanding the variability of the wind profile in the offshore environment is one of the objectives of the field program. To complete our characterization of the wind environment from the ocean surface up through anticipated rotor heights (150 meters or more), a sound detecting and ranging (SODAR) is now operating near the top (26 meters) of Ambrose Light. (This is the first field project in the U.S. to deploy a SODAR in such an offshore environment.)

Unlike classical in-situ instruments that only yield information for one height, the SODAR yields nearly simultaneous information from a height range (at Ambrose, from about 40 meters AMSL up to 240 meters AMSL).

Thus, a measurement directly at hub height and throughout the rotor plane is possible, and no extrapolation from a point measurement is necessary. Since speed and directional shear (change of wind speed and direction with height) over the rotor plane can vary considerably in the marine environment, characteristic profile measurements could lead project developers to consider additional and/or more site-specific turbine design and siting factors.

Finally, to complement the offshore measurements, an onshore meteorological station is now deployed at Fort Tilden, in Gateway National Recreation Area, Rockaway, N.Y. This station features a 20 m instrumented tower, with profiles of temperature, humidity, wind direction and wind speed used to characterize the near-shore environment. Periodically, a "roving" SODAR will operate near this tower, to complement wind profile measurements.

Atmospheric and wave modeling are being studied. A model's ability to reproduce accurate estimates of the wind and wave conditions for the offshore environment is crucial to identifying favorable areas for wind energy development, especially when no onsite measurement data is available. An important objective of this project is to determine how well physics-based numerical models using only standard meteorological data can reproduce the atmospheric and sea state conditions that are critical to offshore wind applications.

The data collected in the field campaign will be used to:

• Improve the understanding of the multi-scale physical processes that control the spatial and temporal variability of the wind and sea state in the vicinity of an offshore site; and

• Determine how to configure physics-based atmospheric and sea surface numerical models to produce the best possible simulations of an offshore site's horizontal and vertical wind profiles and sea state conditions.

To achieve these objects, the mesoscale atmospheric simulation system (MASS) model will be coupled with WAVEWATCH III, a third-generation wave model developed at NOAA/NCEP.

A buoy-mounted atmospheric profiler is being developed. The measurement of marine environmental conditions has traditionally been done using buoy and C-MAN wave/meteorological stations, ship observations and satellite imagery. While providing a broad overview of wave, wind and weather conditions, these data sources are not sufficient to address the needs of offshore wind turbine manufacturers and developers.

Conventional approaches to meteorological measurements use fixed towers with heights near or at the anticipated turbine hub height. However, such towers are expensive to build offshore – typically costing $1 million to $2 million – and may not be feasible in relatively deep waters. To overcome the limitations of fixed towers in offshore applications, this project will develop a conceptual design and conduct preliminary tests for a buoy-mounted atmospheric profiling system that would displace the need for a fixed meteorological tower, with the bonus of providing more extensive data.

The system will measure:

• wind profiles up to 200 meters above the surface using SODAR;

• wave frequency-direction spectra;

• surface wind stress;

• air and sea surface temperature; and

• ocean currents.

Other requirements are that the system operate in waters of virtually any depth, be self-contained with on-board power and communication systems, and that the system be durable and easy to handle and maintain.

Results from this work should assist the offshore wind industry in more precisely quantifying the design load conditions at specific sites, thereby enabling projects to be engineered and operated more cost-effectively and with lower risk. NWP

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