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Wind Resource Mapping for United States Offshore Areas

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D. Elliott and M. Schwartz

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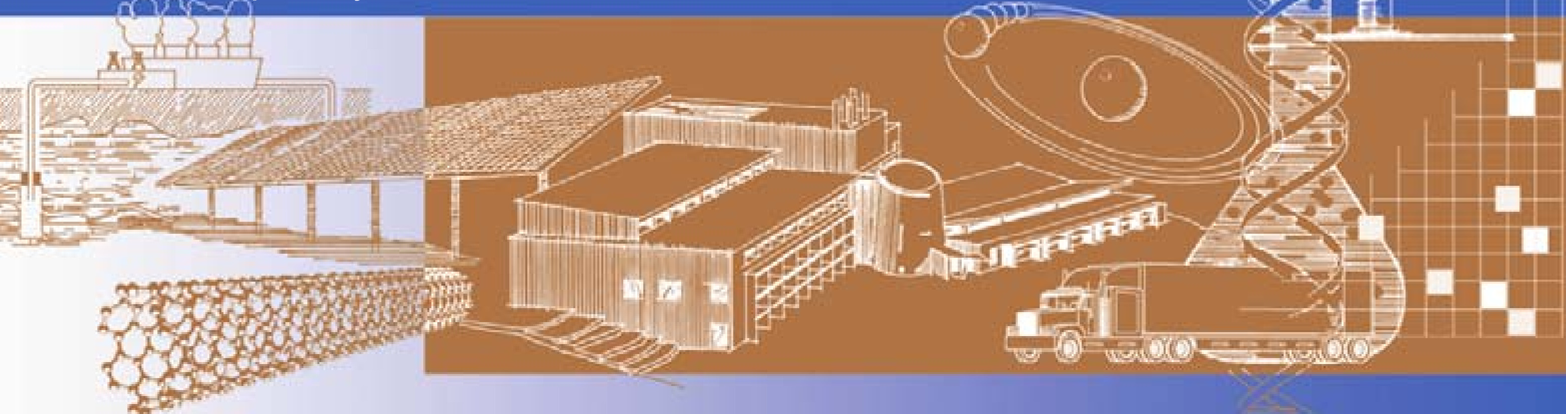

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Wind Resource Mapping for United States Offshore Areas[1]

Dennis Elliott and Marc Schwartz
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado, United States

Background

The United States appears to have vast offshore wind energy potential based on recent wind resource maps, measurement data from ocean and Great Lake buoys and automated measurement stations, plus estimates of 10-m wind speed and power derived from satellite instruments. However, the offshore wind resource areas on the maps produced by numerical models thus far have been extensions of the land-based resource estimates and not optimized for offshore areas. The U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) has started a program to produce validated wind resource maps for priority offshore regions of the United States. The maps will extend from the coastal areas to 50 nautical miles (nm) offshore and have a horizontal resolution of 0.2 km. Production of the maps is jointly funded by DOE/NREL, states, and other organizations. The maps are scheduled to be completed over a period of several years. The first set of regions to be mapped includes the Atlantic Coast from Florida to New England, the western Gulf of Mexico, and the Great Lakes. Figure 1 shows the current status of offshore mapping. The mapping of the offshore regions of Georgia, Texas, and Louisiana is underway. Mapping projects for northern New England and the Great Lakes are planned for the near future.

The methodology that NREL will use to coordinate the development and validation of the offshore resource maps is similar to that employed in the validation of the updated land-based state wind resource maps (Elliott and Schwartz 2005). The preliminary offshore maps resource will be produced by a private company, AWS Truewind (AWST) based in Albany, New York, using its proprietary MesoMap system. AWST's system uses a version of a numerical meso-scale weather prediction model as the basis for calculating the wind resource and important wind flow characteristics. An independent validation performed by NREL with assistance from regional collaborators will be the basis for modifying the preliminary model data and producing the final wind resource map. The validation effort will concentrate on producing the final maps of the wind speed and power data at 50 m above the surface. This level is considerably lower than the turbine hub-heights of modern offshore turbines (80 to 90+ m), but the paucity of

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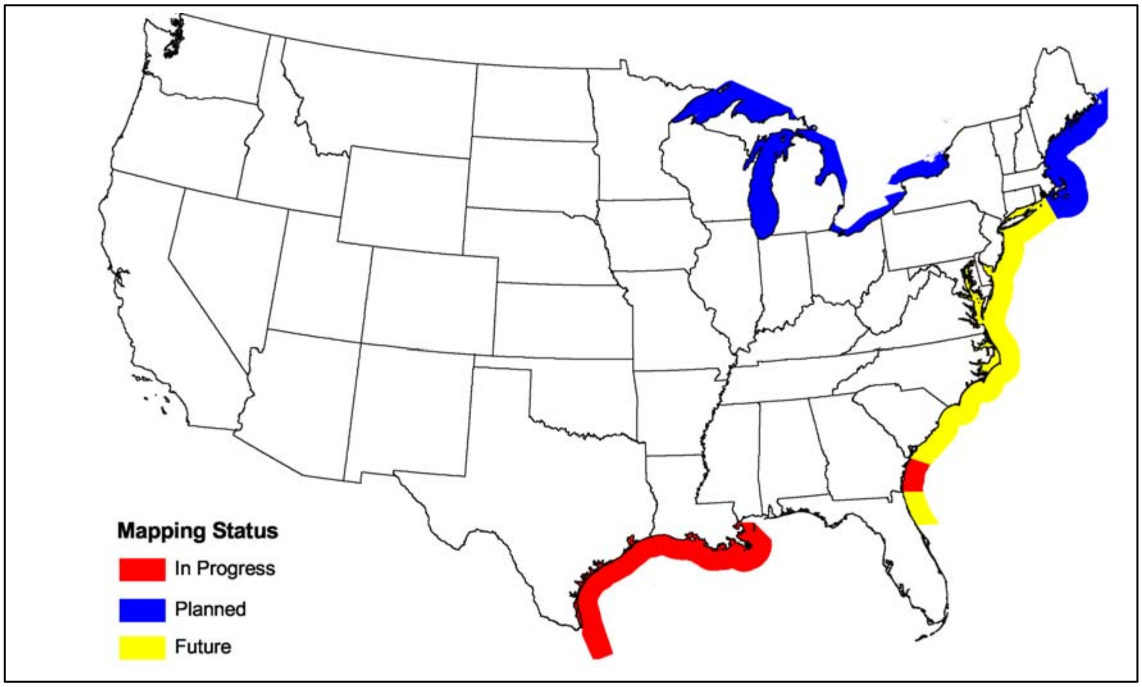

Figure 1. Status of offshore wind-mapping areas

offshore wind measurements above 10 m make extrapolation to 50 m difficult and estimation of the wind resource at turbine hub-heights problematic at best. NREL is also planning to estimate the offshore wind potential (installed capacity) in a more systematic manner than was done in the past. NREL will build a Geographic Information Systems (GIS) database to classify the offshore wind resource by state, water depth, distance from shore, and administrative unit. The wind resource data will be based on the available offshore wind resource maps. These include the updated regional offshore maps, offshore areas completed as part of land-based mapping, and estimates from the "Wind Energy Resource Atlas of the United States" (Elliott et al. 1987). The wind potential estimates will be updated as the new maps become available.

Data Sets and Validation

NREL obtains offshore and coastal meteorological station data for use in validation primarily from the National Climatic Data Center, the National Data Buoy Center, and some other sources. Coast Guard stations, lighthouses, anchored buoys, coastal marine automated network (CMAN) stations, and coastal airports are primary sources for wind measurements in coastal and offshore areas. Measurement heights are largely between 5 m (most buoys) and 20 m. Measurements higher than 20 m are generally limited to some taller offshore platforms and CMAN stations. The scarcity of measurements from tall structures in most regions causes considerable uncertainty for the offshore map validations, especially for estimating the appropriate wind shear to use when extrapolating the lower measurements to 50 m and higher.

Complete validations of offshore mapping areas depend on using data sets that can supplement direct observations. Ocean wind speed estimates derived from satellite instruments are the most important of the supplemental data. The state of the ocean (or lake) surface is measured by a microwave scatterometer, and that information is converted by algorithms into an estimate of the 10-m wind speed. Satellite estimates have the advantage of having uniform data points (about 25 km for most data sets) and can show details of wind speed gradients that might be present. However, satellite measurements are more inaccurate closer to land because the state of the ocean surface is affected, in these areas, by more than wind speed. Local currents and ocean/coast topography effects on the ocean surface can result in misleading wind speed estimates. Precipitation and low clouds can cause degradation to the scatterometer signal and wind speed estimates. There are several satellite data sets available for use in the offshore validation. Average wind speeds for specific locations can differ up to 0.5 m/s or more among the data sets, so no one satellite data set will be relied on for the validation. Other remote sensing data that, in theory, could be useful for offshore validation, such as sodar, lidar, and radar wind measurements, have very limited availability and have not been evaluated for this purpose. The future integration of these data sets into NREL's offshore validation remains an open question. Two other data sets – upper-air observations made by weather-balloon instruments and reanalysis upper-air data (derived by numerical models) – will be used in the offshore validation. The upper-air data sets will be used to identify large-scale wind characteristics in the mapped offshore areas and to evaluate the quality of the measurement data and satellite estimates.

Georgia Offshore Wind Mapping

The Georgia offshore area is the first region to be mapped under this program. This effort is jointly funded by the Georgia Environmental Facilities Authority and DOE/NREL. Figure 2 shows the preliminary estimates of the 90-m wind speed as produced by AWST's MesoMap system.

NREL, in collaboration with the Georgia Institute of Technology and the Skidaway Institute of Oceanography, is analyzing the available measurement data for the validation of the preliminary map estimates.

Figure 3 shows the locations of the towers, buoys, Coast Guard stations, and coastal airports that will be part of the validation effort. Anemometer heights at the buoys are only 5 m, but several offshore stations in this region have anemometer heights above 30 m: the Savannah Light Station (a CMAN station) and the four Navy Towers (part of the South Atlantic Bight Synoptic Offshore Observational Network – SABSOON). The anemometer height at Savannah Light is 33 m above the ocean, and the anemometer heights at the Navy Towers range from 34 m to 50 m. Pictures of two measurement stations – Savannah Light and Navy Tower R4 (50-m anemometer height) – are shown in Figure 4.

NREL has started to analyze data from the measurement sites. Monthly and directional wind characteristic data from Savannah Light are presented in Figures 5 and 6, and the diurnal pattern is shown in Figure 7. The data indicate that Class 4 resource is present at the anemometer height level. Wind power peaks between October and March, with

October and February having slightly higher speeds and power than does the mid-winter period. Summer is the lowest wind resource season, though the average wind speeds are still greater than 6 m/s. The strongest winds at Savannah Light blow from the northeast at around 9 m/s. The overall frequency of northeast and south winds is about the same, but the speeds of the south winds are about 2 m/s lower than the northeast winds.

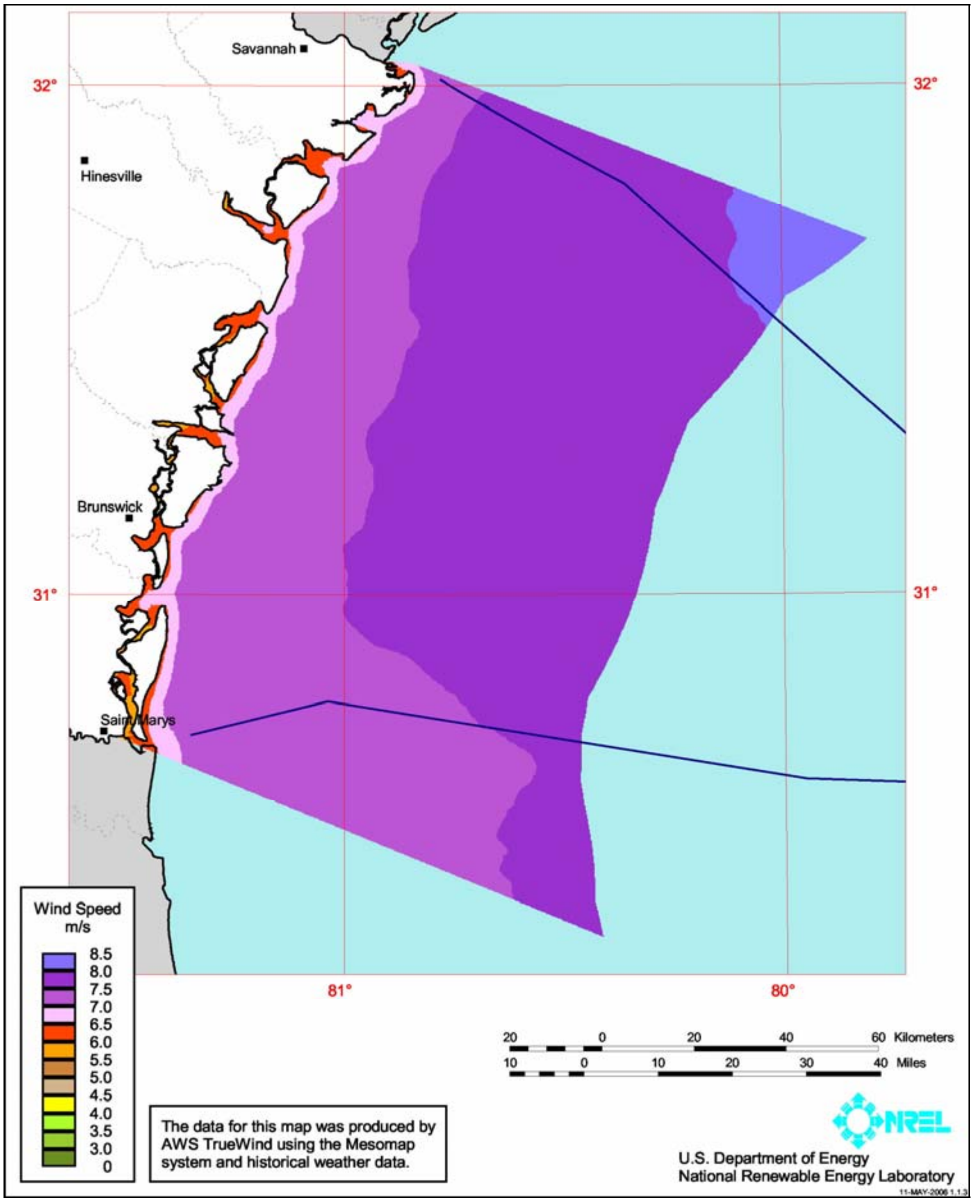

Figure 2. Preliminary 90-m wind-speed map for Georgia offshore region. The solid dark lines are the current proposed boundaries for the Georgia offshore administrative area. The boundaries were developed by the Mineral Management Service of the U.S. Department of the Interior.

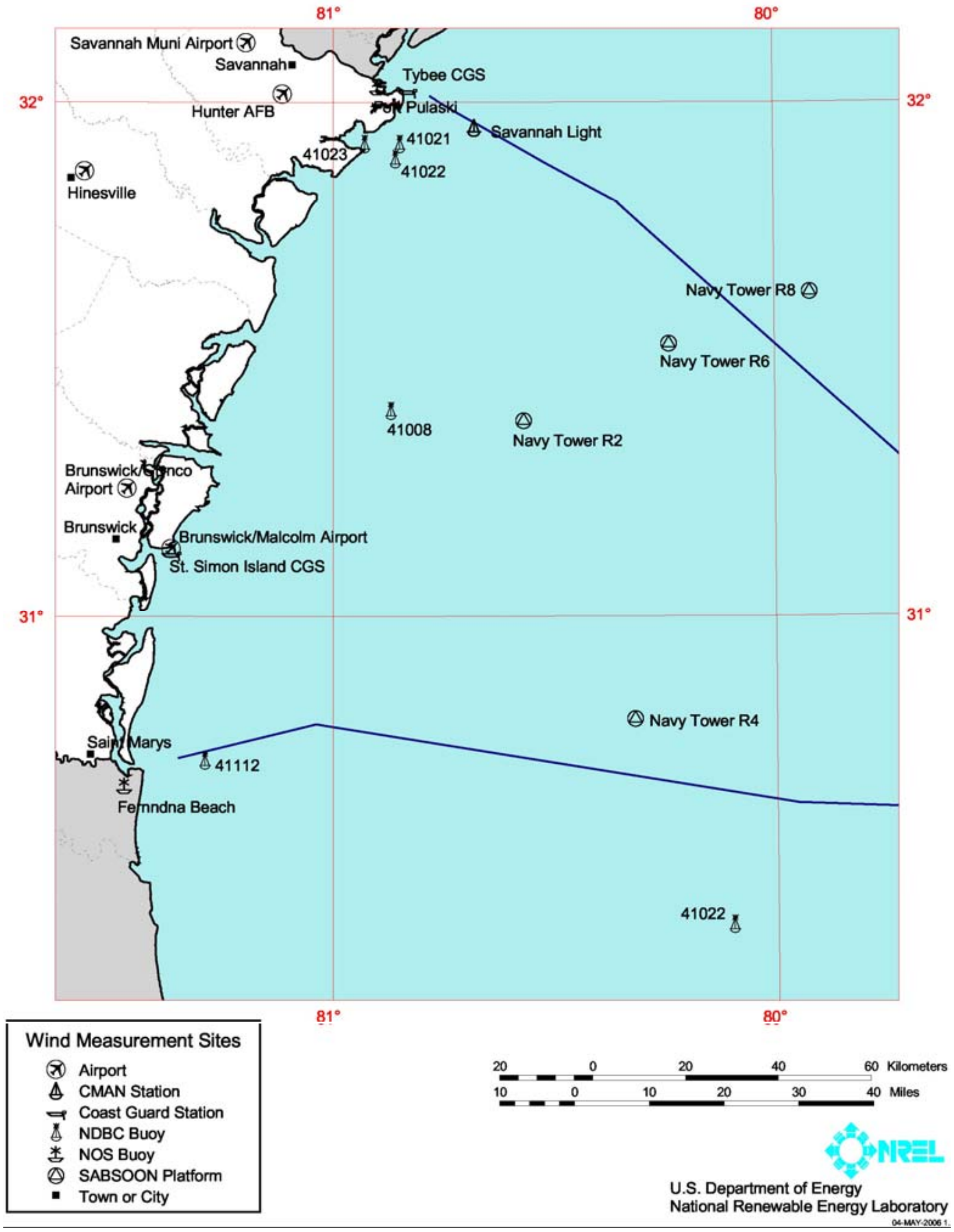

Figure 3. Wind-measurement locations in the Georgia offshore region. The solid dark lines are as described in Figure 2.

Figure 4. Pictures of the Savannah Light Station (left) and U.S. Navy R2 Tower (right)

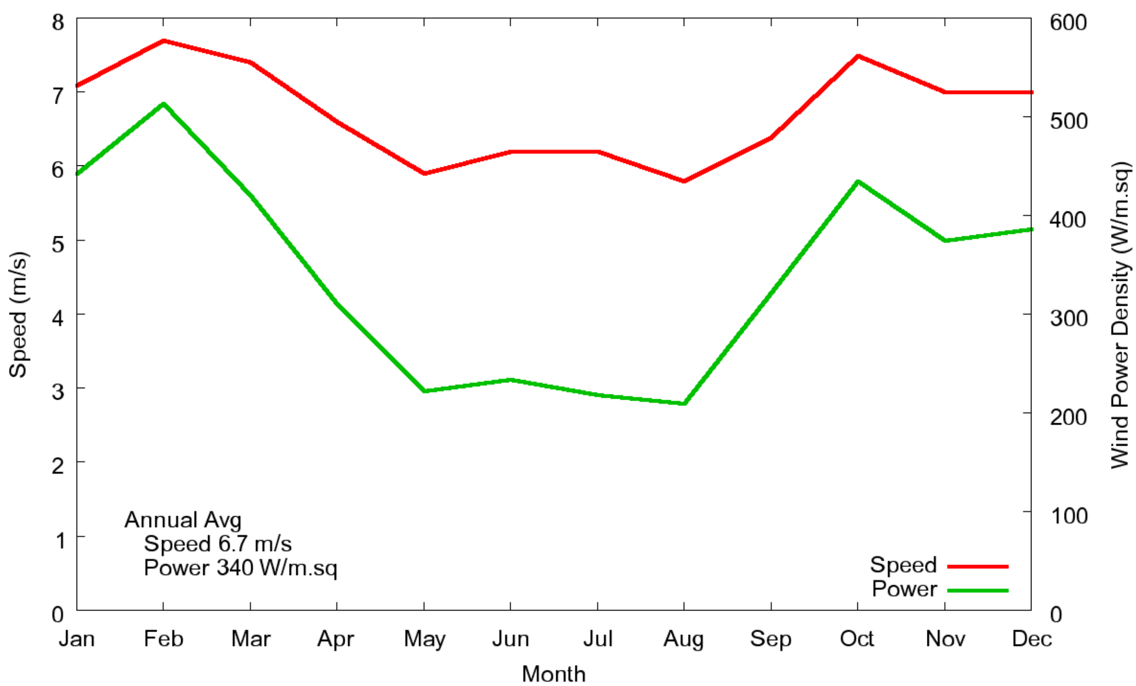

Figure 5. Wind speed and power density by month for Savannah Light Station

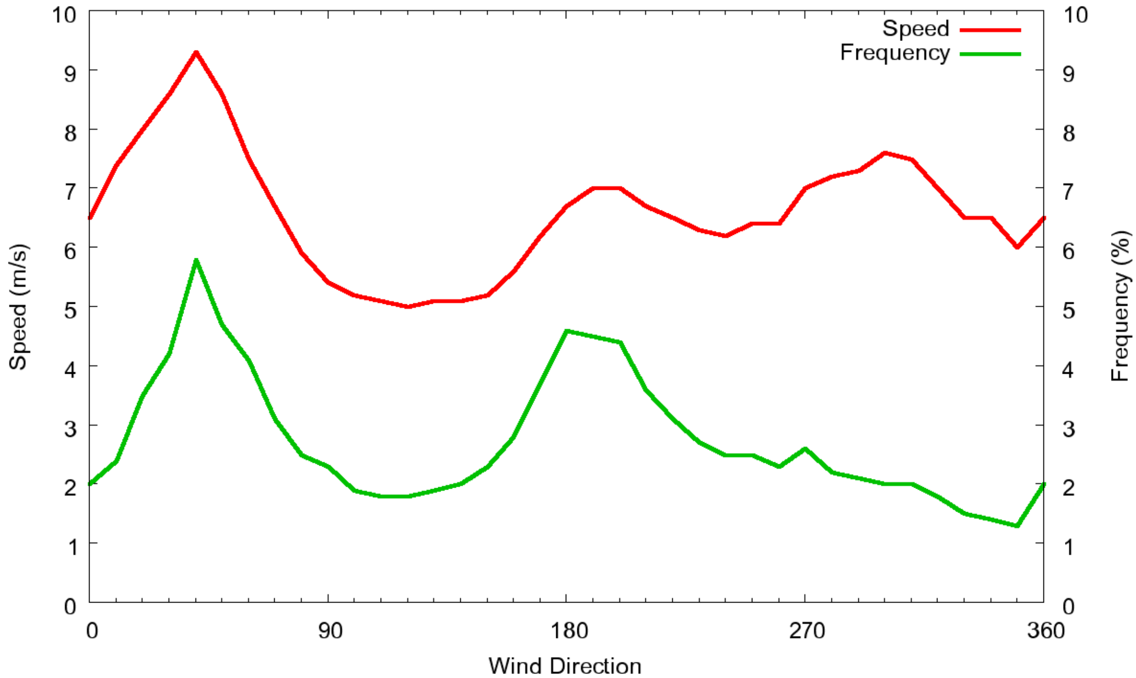

Figure 6. Wind speed and frequency by direction for Savannah Light Station

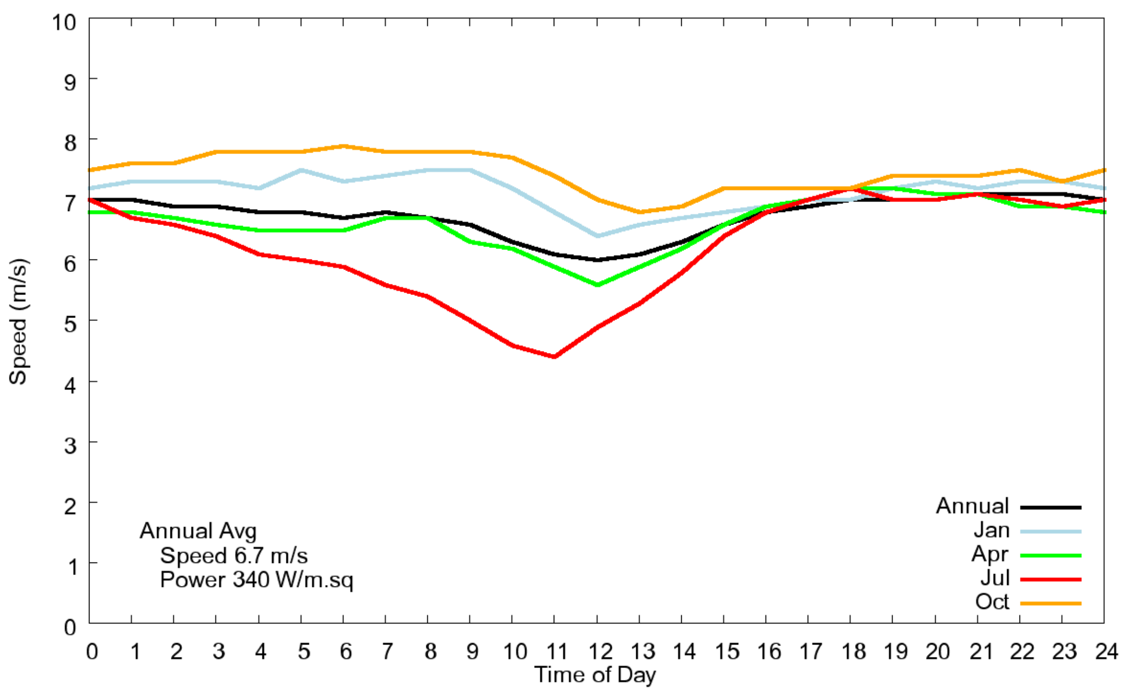

Figure 7. Wind speed by time of day for Savannah Light Station for 4 months and the annual average. Time of day is in Local Standard Time.

The highest wind speeds occur at night and the lowest at midday, a typical pattern for marine locations. The highest amplitude of the diurnal pattern is in summer because of the significant difference (2.5 m/s) between the midday and the evening-to-night wind speeds. The lower wind speeds during early morning to midday hours in summer are responsible for that season's wind resource minimum. Highest average wind speeds in summer occur from about 4 p.m. to midnight and are comparable to average wind speeds during those hours in the other seasons.

Similar analyses of data at other measurement locations and study of the satellite estimates and the upper-air data will be used to derive an appropriate wind shear to use to extrapolate measurement data to 50 m. The validation will also compare the 50-m wind speed and power from the model estimates to the extrapolated 50-m values from the measurement stations. The validation results will be used to revise the preliminary wind resource estimates and produce the final Georgia offshore map.

Offshore Wind Potential

An important parallel task to the offshore mapping activity is a systematic estimation of the offshore wind potential. NREL has developed a methodology to do this using a GIS database that will allow the offshore wind resource to be classified by a number of criteria, including wind power class, water depth, distance from shore, and offshore administrative unit. A variety of data sources will be used to construct the database. Wind power class values will be obtained from available offshore resource maps. At first, we will integrate data from offshore maps that were created by different methods and not strictly for offshore wind assessment. As the new offshore maps are completed, these data will be inserted into the database. Data produced by the National Oceanic and Atmospheric Administration (NOAA) and the Department of Interior's Mineral Management Service (MMS) will be key components the database. NOAA's information includes bathymetry and shorelines in a GIS format. The shoreline identification is an important baseline to calculate offshore distance. The MMS has created GIS files that identify important economic zones, such as the 3-nm and 6-nm zones from shore and proposed state jurisdiction boundaries. The MMS periodically updates its data, and we will use the latest version in our GIS database.

Each offshore wind resource grid cell (0.2 km by 0.2 km) will be classified by GIS database element. The standard final products will be tables of the offshore wind resource classified by state and GIS data. The flexibility of the database will also accommodate special wind potential requests and projects. NREL will document and publish the relevant offshore potential assumptions and summaries.

Conclusions

NREL has started a program to produce and validate offshore wind-resource maps for many areas of the United States. The first mapping region is the Georgia offshore area. The western Gulf of Mexico off the coast of Texas and Louisiana is the next mapping region. NREL plans to map most of the Atlantic coast and the Great Lakes in the first phase of this project. The preliminary maps will be validated using many types of meteorological data. Offshore validation has more uncertainty than land-based validation because of the scarcity of direct wind measurements higher than 20 m above the water surface. A parallel activity to the mapping is the systematic estimation of the offshore wind potential. A GIS database will enable the offshore resource to be classified by a number of attributes. Together, the mapping and the wind potential activities will impart offshore wind resource information to the wind energy community and help develop future projects.

Acknowledgments

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14. ABSTRACT *(Maximum 200 Words)*

The U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) is producing validated wind resource maps for priority offshore regions of the United States. This report describes the methodology used to validate the maps and to build a Geographic Information Systems (GIS) database to classify the offshore wind resource by state, water depth, distance from shore, and administrative unit.

15. SUBJECT TERMS

wind energy; offshore wind development; wind resources; wind resource mapping; geopgraphic information systems

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