

Atmospheric Modeling For Mapping And Forecasting

An increasingly important part in promoting the development and use of wind energy is being played.

BY MICHAEL C. BROWER

Wind project developers need to know where the wind blows strongest to site their projects most profitably. Once a project is in operation, the owners or power purchasers need to know when the wind will blow – in the next few hours or the next few days – to manage their generation assets most productively. What do these different needs have in common? Atmospheric modeling.

Atmospheric modeling plays an increasingly important part in promoting the development and use of wind energy. Using atmospheric models, firms produce maps of the wind resource in numerous states and countries around the globe. These firms, both European and American, also provide wind forecasts. These services help accelerate the development process and increase the value of wind energy in the power market.

Atmospheric modeling has not always played such a big part in the wind industry as a whole. In the 1980s, atmospheric models for wind energy applications were in their infancy. There was WASP, from Europe, but it had been shown to have problems predicting wind speeds accurately in the complex terrain and wind climates found in the U.S. A Califor-

nia mountain pass is nothing like the plains of northern Europe! Most American wind meteorologists consequently avoided WASP and other, similar models in favor of measuring the wind in as many locations as possible.

As for wind forecasting, there was not much need for it before the second boom of wind energy in the mid-1990s. As long as utility companies got only a tiny fraction of their energy from wind, the fluctuations of wind output were simply in the “noise” of normal variations in power demand.

True, this was not the case in California, where the fraction of power supplied by wind was pretty high – close to 10% – in certain areas and at certain times. But even there, power companies managed to get by with little or no forecasting, in part because fixed-price, take-all contracts gave wind producers no incentive to provide forecasts, and also because the utilities purchasing the power could pass any costs created by wind fluctuations on to the consumer.

This situation was bound to change as the wind industry grew, models improved and the electric power industry deregulated. Today, atmospheric modeling is a key to enabling wind companies to maximize their profits and reduce their risks.

The financial costs of inadequate models is greater now than at any time in the brief history of utility-scale wind generation.

Where does atmospheric modeling stand today? And what are its hopes for the future?

Wind mapping is key

It is appropriate to start at the beginning of the development process. Many developers want to find project sites in regions that have not already been picked over by others. That means that there is usually little or no reliable data from tall towers to indicate how much wind is available and where the best locations are.

Atmospheric modeling using a combination of mesoscale and microscale models can overcome this hurdle. One approach is to create high-resolution wind resource maps of large regions, such as a state or country, without the need for surface wind data. Naturally, most of the maps are proprietary. But the same technique can be used to create public maps of the U.S. for the U.S. Department of Energy’s Wind Powering America program

This approach is based on two models: A mesoscale weather model, which develops a picture of the historical wind climate in the region at a

scale of about 2 km, and a mass-conserving microscale wind flow model, which accounts for local terrain and surface roughness changes at a scale of 100 m or 200 m.

Mesoscale models are useful for simulating complex wind climates featuring time-varying temperature gradients, stability effects, temperature inversions and other phenomena, like the California mountain passes mentioned earlier. But they require a lot of computer power, making them impractical for dealing with very fine-scale features, where microscale models can excel.

The usefulness of wind maps depends a lot on their accuracy, of course. Our philosophy is to never trust a model unless you can demonstrate its effectiveness against data – and not just from one or two stations, where you might get lucky, but from hundreds.

Naturally, developers should not make big investments or try to get financing for their projects on the basis of the maps alone: On-site measurements are always needed to confirm the resource. Whatever the type, atmospheric models are a tool to assist conventional wind resource assessment, not to replace it.

Managing wind risk

Atmospheric models have another use – predicting the future up to a few days ahead. How does that work?

Like everything else in the universe, the atmosphere obeys the fundamental laws of physics. Those laws – such as conservation of mass, momentum and energy – are embodied in mesoscale weather models. Knowing the state of the atmosphere at a given moment in time – including the temperature, pressure, wind, cloud cover and other variables – the models predict how the atmosphere will evolve in the future.

Neither the data used to initialize the models, nor the models them-

selves, are perfect, however. Probably the biggest problem is the data. Weather models are driven by data from a wide variety of sources.

The most important of these – including weather balloons, surface met stations and radar profilers – are spaced widely apart and provide poor coverage over the poles and oceans. As a result, the location of a cold front, or the precise depth and extent of a low-pressure trough, cannot be determined with high precision. Starting from such an imperfect picture, the models inevitably diverge from reality over time.

Even so, they do a surprisingly good job. When forecasting the wind one to three days in advance, models can reduce errors in the predicted wind plant output for any hour by up to 60%. (The standard of comparison is a climatological forecast, in which the energy output in the future is assumed to be the same as that in the last month or year.) Typically, the mean absolute error in day-ahead plant output forecasts is about 15% to 20% of plant capacity.

When forecasting just a few hours ahead, recent information from the site (wind, plant output) can be added to the mix to reduce the errors. This is done through a statistical model of some kind, such as a multiple linear regression, an artificial neural net (ANN) or a support vector machine (SVM). With such techniques, the mean absolute error can be reduced, to around 5% to 7% for one-hour-ahead forecasts.

Over the next several years, virtually all plants in North America are expected to receive wind forecasts from one provider or another.

Trends in forecasting

While we think wind forecast accuracy is pretty good, there is certainly room for improvement. Wind forecasting firms are involved in several research projects to advance the

science of wind forecasting.

For example, AWS Truewind is in the middle of a research grant funded by the California Energy Commission (under a project managed by the Electric Power Research Institute) to reduce errors in very short-term forecasts of a few minutes to a few hours ahead. This research involves new weather and wind data sources, such as radar profilers and off-site met masts; new geophysical data sources, such as high-resolution, sea-surface temperatures; and new modeling techniques, such as conducting more frequent mesoscale model runs over shorter periods to take advantage of the latest available data.

Advanced statistical techniques also are being explored, including the support vector machine (SVM). We expect this research to yield substantial improvements in forecasting accuracy in the near future.

Looking farther ahead, there is great promise in new satellites that will be launched in the next several years. These satellites will carry sensors, such as NASA's GIFTS (geosynchronous imaging fourier transform spectrometer) instrument, which will provide a far more detailed and complete picture of the earth's atmosphere in near real-time, thus helping to solve the problem of accurate initialization of weather models.

In just a few short years, atmospheric models have surged to the forefront of the wind energy industry. Whether it is in mapping, micrositing or forecasting, atmospheric models are becoming increasingly important to the successful development and operation of wind projects. **SWP**

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