



NCAR

A Whirlwind of Research

Wind-energy prediction and impacts

The concept of harnessing the wind's energy is hardly new, but wind remains among the most difficult weather variables to forecast. Topography, ground cover, temperature inversions, and foliage all affect its strength and direction.

As wind energy grows in importance, this forecast problem is taking on new urgency. Several groups at NCAR are studying how wind turbines and farms interact with the atmosphere and how their output can be better predicted and managed.

Last December, NCAR finalized an agreement with Xcel Energy—one of the largest providers of electricity across the U.S. West and Midwest—to provide highly detailed, localized weather forecasts. These will enable Xcel to better integrate electricity generated from wind into the power grid, in particular by helping plant operators decide when to power down traditional coal and natural gas plants and rely on wind energy instead.

“One of the major obstacles that has prevented more widespread use of wind energy is the difficulty in predicting when and how strongly the wind will blow at wind farms,” says NCAR’s William Mahoney. “These forecasts are a critical step in using more energy from wind.”

Over the next year and a half, NCAR will develop a prototype advanced wind prediction system and begin generating test forecasts for Xcel wind farms in Colorado, Minnesota, New Mexico, Texas, and Wyoming. NCAR will eventually transfer the system over to Xcel. If the technology proves successful, other wind forecasting companies in the United States and overseas may adopt it.



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Catching the Wind

The wind-prediction system involves the Real-Time Four Dimensional Data Assimilation (RTFDDA) system, which is based on the Weather Research and Forecasting model (WRF). RTFDDA collects diverse weather observations from various platforms—upper-air and surface reports, commercial aircraft reports, mesonets, and data from radars, wind profilers, satellites, and other instruments—and assimilates these data using a technique designed to increase their impact on the analysis of the initial conditions.

The purpose of the system is to pinpoint the wind conditions in the vicinity of wind turbines, which generally stand about 60–120 meters (200–400 feet) above the ground, arrayed in tightly clustered wind farms. Winds at these heights are usually far stronger than at 10 meters (33 feet), the height used by ground-level weather stations (see sidebar).

The researchers hope that the system will immediately cut error rates for wind energy by 5 to 10% across the Xcel power grid. A long-term goal is to help make the costs of wind energy more competitive against traditional power plants.

A Series of Scale Problems

Elsewhere at NCAR, Peter Sullivan and Ned Patton are doing basic turbulence research that underlies wind energy. Using supercomputers, they create simulations of atmospheric turbulence that they use to explore problems ranging from large scale (where should wind turbines be placed?) down to very small scales (characterizing the wind field within which a turbine’s blades operate).

One of their research questions is where to site wind farms, beyond the obvious—where the wind blows. Land-surface characteristics such as hills, trees, and the turbines themselves interact with the atmosphere to influence local wind speed, direction, and turbulence characteristics.

Another consideration is how to space turbines. Because a wind turbine creates a wake behind it, when turbines are

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grouped together in wind farms, the wakes affect each other and can result in wind farms underproducing compared to expectations. "This is a really important issue, because there are aspects to optimizing turbine spacing that can lend to enhanced energy capture," Patton explains.

Another pressing issue for the wind industry is the structural fatigue that results as turbines wear down under the wind's pressure. Most turbines are built to last 20 years, but their actual lifetime is much shorter. Sullivan and Patton are collaborating with researchers outside NCAR to simulate extreme wind, wind shear, and turbulence events that stress turbines, with the goal of improving their design.

In an intriguing study, NCAR's Donald Lenschow collaborated with David Keith (University of Calgary) and former NCAR scientist Philip Rasch (Pacific Northwest National Laboratory)

to study how wind farms could affect climate. Their goal was to determine what would happen if massive wind farms blanketed portions of Earth large enough to produce a significant fraction of the world's total electrical energy.

The research, led by Keith and published in Proceedings of the National Academy of Sciences in 2004, showed that wind farms covering most of the U.S. Midwest, along with most of Europe and a large part of east Asia, did have an impact on climate in the model simulations, albeit minor. By adding drag to the atmosphere, they perturbed the model's general circulation, leading to slight cooling in northern temperate and polar regions and compensating warming in the vicinity of the wind farms.

Lenschow emphasizes that the effect is insignificant except in the case of unrealistically large wind farms. "But we do think it was an interesting result, not from the standpoint of changing our ways of incorporating wind energy, but from the standpoint of satisfying curiosity and comparing the climatic effects with other energy sources," he says. "You really can't do large projects on planet Earth without having some impacts that are global."

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NEW TALLY BUMPS UP ESTIMATE OF AVAILABLE WIND POWER

According to a team of scientists at the University of California, Irvine, more than 50% more power is available for wind energy over the globe's oceans at the typical turbine height of 80 meters (260 feet) than in previous estimates compiled for the standard observing height of 10 m (33 ft).

The study, by Scott Capps and Charles Zender, was presented at the annual meeting of the American Geophysical Union last December and will soon be published in Geophysical Research Letters. Its focus on ocean winds complements a 2005 analysis of 80-meter winds over land by Cristina Archer and colleagues at Stanford University. "To our knowledge," says Capps, "these two studies are the first global wind power assessments at typical turbine heights."

Drawing on a wide range of observations, Capps and Zender adjusted for stronger winds at turbine level, where surface-based friction is less of a factor. They also accounted for the effects of surface-layer air stability; when conditions are more stable and the air is less thoroughly mixed, 80-meter winds are able to blow more strongly relative to the 10-meter winds.

The upshot, according to Zender: "There is a lot more power out there than you might guess." All told, the average global ocean wind power during the period 2000–06 is estimated at 841 watts for every square meter swept by turbine rotors, which is more than 1.5 times previous estimates. The difference in the study between wind power at turbine height and standard observation height was especially strong—more than a sixfold difference in some areas—during stable summertime conditions off the east coasts of Asia and North America. "To provide access to this power, technology to place turbines in deeper water farther offshore is being refined," says Capps.

The boosted wind-power estimates are also of interest to those investigating potential geoengineering schemes that would harvest offshore wind energy to help mitigate climate change. One such technique, explored by Stephen Salter (University of Edinburgh) and John Latham (NCAR), would use offshore winds to drive turbines that would generate saltwater spray and potentially help brighten sun-reflecting marine stratocumulus clouds. The researchers are now working with climate modelers to simulate the plan's effects in more detail.