A Brazilian Wind: Measuring Energy Potential

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With the average price of a gallon of gasoline hovering somewhere around $4 in the U.S. and oil prices continuing to rise, our nation and our world are refocusing their attention on the viability of alternative energy sources. A window seems to be opening for genuine progress in lessening our dependence on fossil fuels. One source of energy that has been proposed and used effectively on a limited scale is wind power. In light of this, ***The Earth Observer*** *reprints this article that was prepared for the 2008 edition of* ***Sensing Our Planet: NASA Earth Science Research Features****, which will be in print sometime in late 2008. The article reports on interesting research to try and expand the use of wind power in Brazil and how NASA satellite data has aided the effort.*

People often picture wind turbines rooted in waving fields of golden grass in rural landscapes, but wind turbines can also stand in the waves of coastal waters. Offshore wind energy is more than just clean and economical; like land-based wind energy, winds over the ocean can often be faster and fluctuate less, leading to higher and more sustained output. Offshore wind sites tend to be naturally close to the large coastal population centers that need their power, and they do not have to compete with real estate for valuable land. Plus, offshore wind technology is a proven renewable energy source. **Willette Kempton**, a professor at the University of Delaware, said, "Offshore wind power is particularly attractive because the resource is large and current technology is ready for implementation now."

So if wind energy is poised to provide the world with clean power, why are turbines not up and spinning along every coastline? Developers need solid assessments of coastal wind energy potential before they can consider a new wind project, and that information can be hard to get using traditional ground-based tools. In an effort to help assess wind energy potential, Kempton and his colleagues are using an unexpected tool—satellite data. Their latest project focuses on the undulating coastline of Brazil.

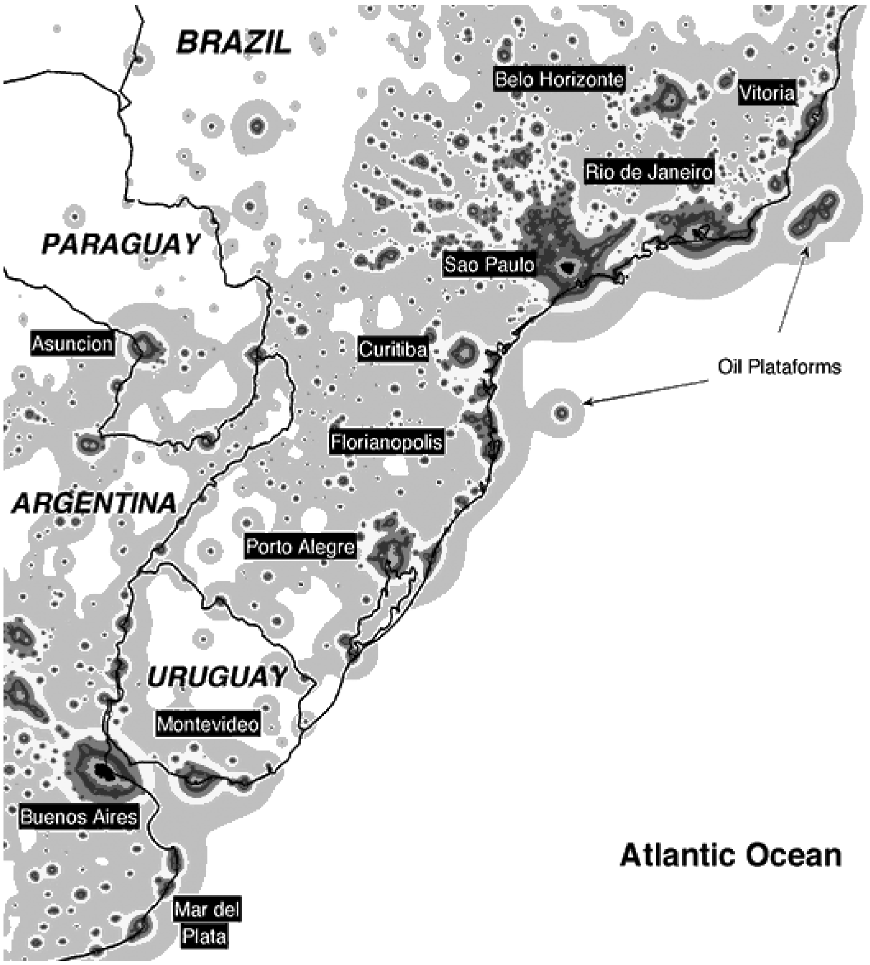
Location, Location, Location

Whether along the coast of northern Europe, the United States, or Brazil, to produce cost-effective electricity, wind turbines need to be sited in an area with a few specific requirements.

First, wind speeds must fall within a defined zone. Kempton said, "The ideal wind-speed zone has winds that are high enough to produce energy but without strong

Offshore wind turbines take advantage of predictable winds, are often close to electricity-hungry population centers, and provide carbon-free energy using proven technology. **Image credit:** phault.

storms that pose a threat to the installation." Second, offshore turbine foundations must be on relatively shallow coastal shelves; the deepest installed turbine is currently rated for 164 ft (50 m) in depth. Finally, the site must be able to accommodate the whirling blades of enough turbines to be cost-effective. Kempton said, "The idea is to fan them out and make sure they are spaced apart appropriately for effective energy production."



The offshore study area bounds 560 mi (900 km) of Brazil's coastline, shown in this night-time image. Dense population centers are labelled; the two onsite sources of wind speed data within the study area are labeled as oil platforms. To view this image in color go to: *nasadaacs.eos.nasa.gov/articles/2008/2008_wind.html*. **Image credit:** Elsevier courtesy Felipe Pimenta.

The wind industry and turbine manufacturers are concerned with all of these details; scientists are, too. "Coastal zone assessment is the piece that scientists, like our team, can provide," Kempton said. "Think of it like petroleum or coal: you need a resource assessment so that you have a sense of how much resource is located where, and how you'll need to extract it. That's what we need to do with offshore wind."

One of the most recent and promising wind assessment studies that Kempton and his University of Delaware colleagues **Richard Garvine** and **Felipe Pimenta** developed was to determine wind energy potential off the coast of southeastern Brazil. Pimenta, a native of Brazil, said, "My goal is to search for renewable energy solutions that can help diversify the Brazilian electric grid."

Assessing a Brazilian Wind

At present, most of Brazil's electricity comes from hydroelectric dams, with a sizable portion from traditional fossil-based resources and only a small percent coming from renewable resources like wind. Now, Brazil seeks to increase its share of renewable energy. Pimenta said, "A new government program, *ProInfra*, seeks to increase the use of new renewables to 10% of our annual electricity consumption. Our study is important because it is the first to evaluate Brazil's offshore wind potential."

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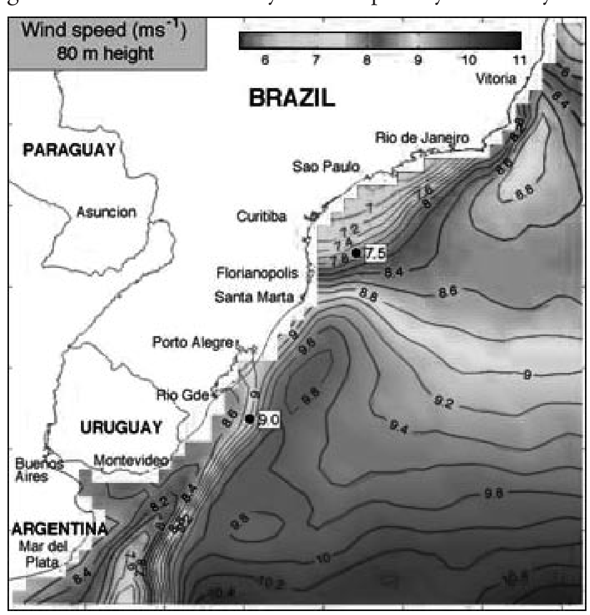
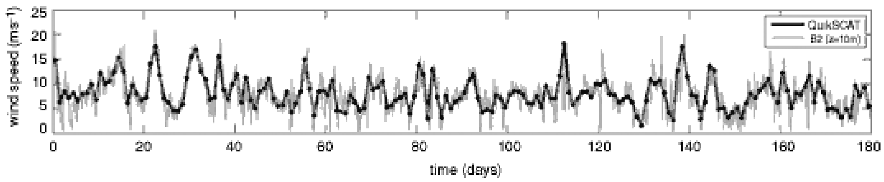
Typically, wind energy assessments begin by analyzing data from continuously operating meteorological stations or buoys that float offshore near the potential site. These stations measure wind speed up to 66 ft (20 m) above the sea surface. From these measurements, scientists extrapolate the wind speed at the turbine's hub height, approximately 262 ft (80 m), to get an idea of the wind available to turn a turbine's blades. Researchers also use station data to analyze wind-speed fluctuations from one minute to the next. However, meteorological data from buoys and fixed platforms can be hard to get. Kempton said, "Many countries simply lack historical meteorological buoy information over the ocean." The chosen study area turned out to be a good example of the sparseness of meteorological station data. Kempton said, "For the entire study area, we only had two offshore buoys available."

Given the lack of wind speed data from meteorological stations, the team needed a different source. "In a new offshore wind power seminar we teach at the University of Delaware, student **Oleksiy Kalynychenko** suggested using NASA Quick Scatterometer (QuikSCAT) data—and Felipe decided to try it. To our knowledge, this study is the first to use QuikSCAT to assess wind power resources over a large ocean area," Kempton said. The SeaWinds instrument, on board the QuickSCAT satellite, provides scatterometer data that is hosted by the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC). The instrument measures ocean roughness and relates it to wind speed at the ocean surface. "QuikSCAT has exceptional global geographic coverage at a very reasonable spatial resolution—from just over 8–31 mi (12–50 km)," Kempton said. "The satellite data filled in the gaps in the vast areas around the two buoys."

Before settling on QuikSCAT, the scientists first wanted to confirm that the satellite data correlated well to existing buoy data. "We crosschecked meteorological data from several places against QuikSCAT to ensure that we could use the satellite data for assessing the Brazilian power resource," said Kempton. By combining the meteorological and QuikSCAT data, the team could also address a limitation of the satellite data. Wind speeds can fluctuate from minute to minute and from hour to hour, so unless data is taken continuously—as meteorological stations are able to do—those fluctuations will not be captured. Kempton said, "When the satellite passes over the study region, that's when you get the data—once or maybe twice per day. The buoys are running continuously, but in only a few places. The two together provide both spatial and temporal coverage." One of the two buoys within the study area was particularly helpful for this purpose because it took measurements during the same months that QuikSCAT passed overhead. "We could confirm that the satellite data was within acceptable margins of error for a first-cut evaluation of power resources," he said. "QuikSCAT can



Wind speeds at a height of 262 ft (80 m)—approximately the hub height of a turbine—show a viable wind resource in the study area. If the area were to become a fully developed offshore wind project, it could supply more than the country's current electricity needs. To view this image in color go to: *nasadaacs.eos.nasa.gov/articles/2008/2008_wind.html*. **Image credit:** Elsevier courtesy Felipe Pimenta.



QuikSCAT satellite wind speed data correlated well with wind speed data taken from an onsite meteorological station. In this sample data, the thick black line shows QuikSCAT and the thin gray line shows the station data. To view this image in color go to: *nasadaacs.eos.nasa.gov/articles/2008/2008_wind.html*. **Credit:** Elsevier courtesy Felipe Pimenta.

indeed provide practical measures of wind power, especially when looking for monthly or yearly estimates."

Where the Wind Blows

Having cross-referenced the buoy and satellite data, the scientists' next step was to explore the "footing" on which turbines could stand in the study area. "Felipe got bathymetric information by digitizing Brazilian Navy nautical charts," Kempton said. "This helped us estimate the shelf areas that are within the practical limits of exploration, in terms of depth."

Kempton and his team now had the information they needed to assess the practical wind-turbine-worthy wind resource: the wind speed at hub height over a large area from the satellite data; an idea of the fluctuations of wind speed based on the hour and season from both buoy and satellite data; and the depth of the continental shelf, where the turbines would be planted, from the bathymetric data.

Using all of this information, Kempton, Garvine, and Pimenta calculated the potential power production for two different wind turbine models. Kempton said, "The total average electricity use of Brazil is near 100 gigawatts, and the offshore wind resource of this one section of coast, to only 164 ft (50 m) of water, is 102 gigawatts." **That means that if the study area were to become a fully built wind energy project, it could supply enough electricity for the entire country's electricity needs.**

"However," Kempton said, "there would certainly be areas that would be excluded from development, and we didn't attempt to consider those in our calculation. According to previous studies, exclusions for shipping lanes, marine conservation sites, and commercial fishing, could reduce the site's capacity by 10–46%." Even with areas

That means that if the study area were to become a fully built wind energy project, it could supply enough electricity for the entire country's electricity needs. ... Even with areas excluded from development, an offshore wind project in the study region could still meet ProInfra's efforts to increase Brazil's renewable energy output.

Scientists Willett Kempton, Felipe Pimenta, and Richard Garvine worked together on the research featured in this article. Richard Garvine was widely considered a pioneer and international authority in the field of coastal physical oceanography; more recently, he was dedicated to the study of renewable energy solutions. He served as close mentor to Felipe Pimenta, as well as many other young oceanographers, during his thirty-eight-year career. Garvine passed away last fall. **Photo credit:** Felipe Pimenta.