

## On the Application of miniSoDAR technology to Wind Energy

By

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### Introduction

In the late 1990's wind turbines with nacelle heights exceeding 60 meters were introduced to the wind energy community. Initially, wind prospecting and siting studies continued to use 50-meter wind towers and extrapolate the measurement to the nacelle heights. It was quickly determined that this approach was not sufficient for the placement of these tall turbines. The next approach was to increase the wind tower heights to between 80 meters and 100 meters. In this case the initial financial investment (100 meter towers, installation, etc.), the required FAA permits and tower safety equipment, the increased need for larger land areas coupled with the visibility of these towers in the local community area are reasons to seek alternative measurement methods.

In the mid-1990's, Atmospheric Systems Corporation (ASC) independently developed an acoustic remote sensing unit called a Doppler miniSoDAR (or miniSoDAR for short) for high-resolution wind profiling in the lowest 200 meters of the atmosphere. Initially the miniSoDAR was developed under a NAVY SBIR (Small Business Innovative Research) grant to provide wind measurements with NAVY helicopters hovering at a height of 100 feet (AGL) at a distance of 150 feet away from the miniSoDAR system. The miniSoDAR systems were designed to be autonomous and telemeter their data continuously to a central Control and Display PC near the helicopter Field Operations Director. The miniSoDAR was specifically designed for providing high spatial resolution measurements in high background noise environments. SODAR technology was originally designed and employed in high altitude wind measurements (600 meters or higher) and low background noise environments (characteristic of the Air Quality and Atmospheric Research monitoring sites). The miniSoDAR was (and remains) a significant technical advance to SODAR technology. In contrast to those commercial systems designed for Air Quality applications the miniSoDAR can produce wind profile measurements (from 15 meters to 200 meters in 5 meter increments) in time intervals as short as 30 seconds to hour averages or longer.



Since its introduction the miniSoDAR has been successfully used in a wide range of observational and operational activities. For example, NASA together with the USAF has purchased thirteen miniSoDAR systems to support their rocket launch and Space Shuttle landing activities at Cape Canaveral and Vandenberg Air Force Base. These

units have been operational for over four years and are networked (via an ethernet link) to their respective base weather operations office. In effect the miniSoDAR systems are in the process of replacing the local wind tower network. The FAA has recently realized the potential for the miniSoDAR to detect and monitor airplane wing tip wake vortices. ASC is currently contracted to provide the instrumentation and data processing expertise to rapidly advance the wing tip wake detection program.

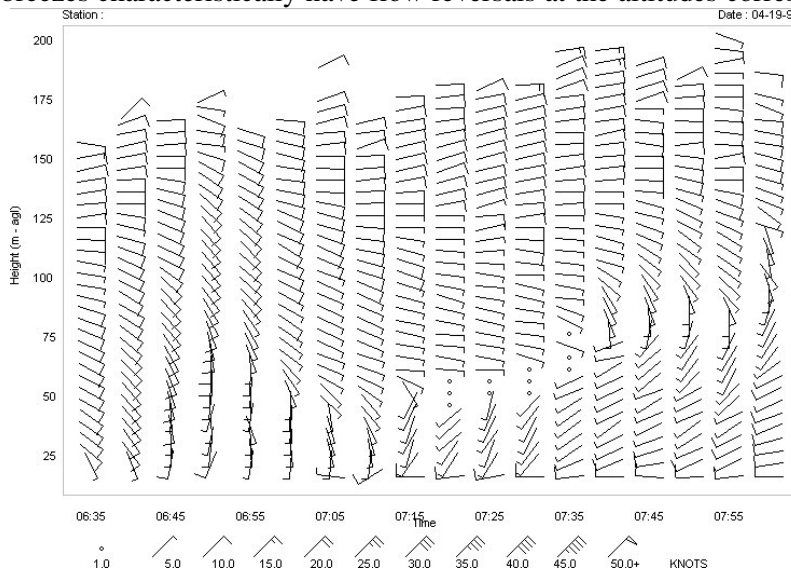
In addition to developing and manufacturing the miniSoDAR hardware, ASC also has developed user friendly Windows based programs to manipulate and visualize the miniSoDAR data. These programs provide our customer's with the ability to cost effectively use miniSoDAR measurements.

Wind energy

Until recently inexpensive tower based instruments were employed in most wind energy studies. The desire to expand wind energy sites and to locate the megawatt tall turbines in complex terrain and at off shore locations has created the need for cost-effective wind measurements at heights of 80 meters to 120 meters. For these measurements the ASC miniSoDAR system is uniquely qualified. Using pulsed high frequency sound energy (4500 Hz to 6500 Hz) the miniSoDAR can be quickly deployed in energy autonomous configurations such as the ocean platform site on the right. Off the coast of Northern Germany the miniSoDAR has been deployed to measure the vertical profile of the horizontal and vertical wind field for almost one year of continuous measurements. This information is being used for the design of a nearby wind energy park. Inexpensive anemometers mounted on tall towers are not suitable for these measurements.



Other potential wind energy sites such as mountain ridges, complex terrain valley and coastal regions are also not able to be characterized effectively with conventional tall towers. As an example the complex wind flow patterns in coastal regions due to the Land/Sea (or Ocean) breezes characteristically have flow reversals at the altitudes corresponding to the nacelle heights

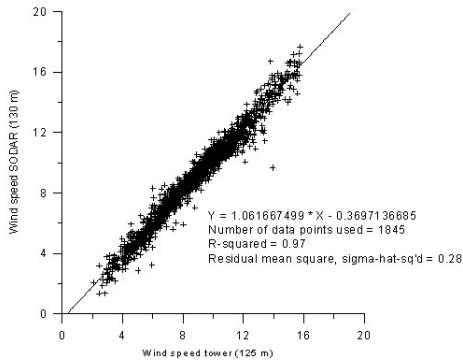


of these large wind turbines. The wind profile plot shown to the left is one example of complex wind flow patterns in coastal climates. In this case a 60-meter tower would not provide a reasonable picture of the wind flow either above or below 60 meters. In fact any attempt to extrapolate to other altitudes would not be correct. This type of flow is observed on both land and over the ocean.

Complex terrain sites (mountain – valley) show similar complex wind flow patterns. The improper location of a million-dollar megawatt tall wind turbine could cause financial stress to both developers and other wind farm investors. The price for the deployment of the miniSoDAR, its operation and data validation is small in comparison.

Accuracy

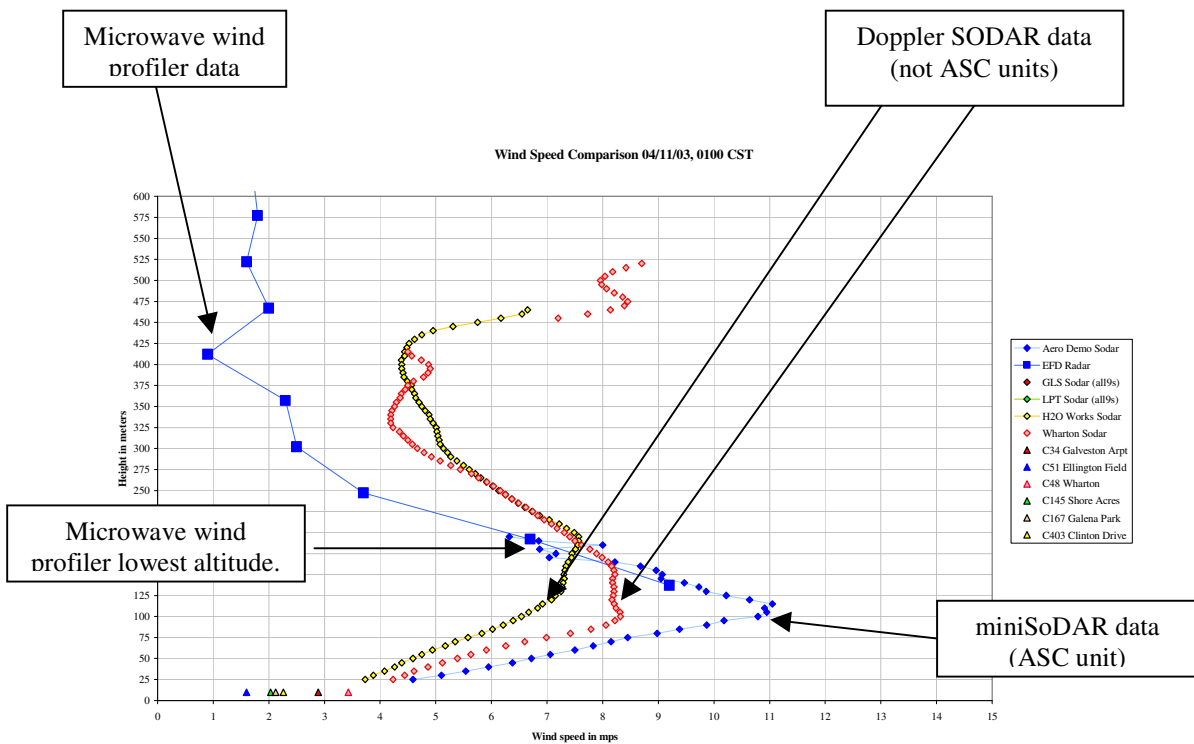
The miniSoDAR designed and manufactured by ASC is a unique instrument. It is the most accurate acoustic remote sensing system available commercially. Independent measurements show that a properly sited and attentively operated miniSoDAR produces wind measurements of the same quality and accuracy as the cup anemometers currently used for wind energy applications.



Statistically the wind speed differences between the miniSoDAR and instrumented towers are less than 20 cm/sec. This is comparable to the difference expected between two anemometers at similar altitudes and separated by a distance of 100 meters. The observed wind direction differences were less than  $\pm 2$  degrees. Sometimes when a miniSoDAR is first deployed near an instrumented tower the miniSoDAR wind direction data are able to identify those wind vanes that are not properly referenced to True North. These miniSoDAR measurements are used to adjust the wind vanes to the True North reference prior to any further comparison.

Low Level Jet

One feature well known to boundary layer meteorologists but only recently of interest to the wind energy community is the phenomena called the low-level jet. This is a nocturnal event created by



the de-coupling of the upper level winds from that Earth's surface. Nocturnal jets were first discovered in the late 1940's and early 1950's as aircraft operations extended landings into the night at locations in the Midwest US. The nocturnal jet is observed at altitudes from 80 meters to 300 meters.

The ability to detect and accurately measure the low-level jet is essential when locating the large wind turbines. The miniSoDAR was designed with the ability to accurately measure wind shears. The figure above is an example of this capability. These measurements were recently (May 2003) collected and analyzed by a customer evaluating the miniSoDAR's capabilities. In this location the miniSoDAR was co-located with a microwave wind profiler (which profiles winds from 150 meters to 3000 meters). Nearby there were two Doppler SODAR available from another manufacturer. The customer is mainly concerned with the long-range transport of air pollutants. The miniSoDAR is able to measure the low-level jet and show that the maximum wind speed is observed at the altitude of 125 meters. Furthermore the miniSoDAR data matches the microwave wind profiler data where the sampling altitudes overlap. In contrast the SODAR system from another commercial manufacturer is not able to accurately measure the speeds either below or above the low-level jet.

#### Autonomous configuration

The miniSoDAR is often configured for operation independent of power and landline telephone access. In this case the miniSoDAR is DC powered using a combination of 10 to 15 batteries and 250 to 300 watts of solar panels. A battery-powered miniSoDAR consumes an average of 50 watts continuously. About 20 % of this power is used for the DC audio amplifier, 60 % for the microprocessor and data storage device and 20% to power the speaker array antenna. Optionally a diesel generator is used for periodic charging of the batteries. Communication with the miniSoDAR is supported through either a serial connection or a network connection. Normally serial connections are used for modems (preferred for system operation and system maintenance) connected to either standard telephone lines or cellular telephones. Fixed IP addresses are used in the network connection (preferred connection for data transfer). Most often in the field the network connection is used with either a DSL or a direct ethernet connection (crossover cable connected to a laptop PC ethernet interface). An example of the autonomous configuration is shown in the picture to the right. In this case the DC powered electronics are mounted in the white case, the batteries are placed in the black box at the end of the trailer and the antenna cuffs are removed and secured in the holder just behind the system electronics.



In summary, the miniSoDAR is both capable and configurable to provide timely, accurate and cost effective wind profile measurements for wind energy applications. In the autonomous configuration the miniSoDAR system can be easily moved to multiple locations in reasonable time periods when prospecting for new energy sites. The miniSoDAR provides the measurements of the horizontal wind field that is needed to secure with confidence the financial investment for the tall turbine wind energy parks.