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SODAR Wind Resource Measurement Results at Long Island, Boston MA

Prepared for
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Executive Summary
SODAR data has been collected on Long Island, in Boston Harbor, to estimate the wind resource for possible wind turbines. While there is concern that some of the data has been corrupted, there is enough data to estimate the mean annual wind speeds for heights at and above 70 m. Using analysis techniques based on research at the Renewable Energy Research Laboratory (RERL), the mean wind speeds at the measurement site on Long Island for the year 2002, as an example, were estimated. The mean annual wind speed at 70 m is estimated to be 6.25 m/s with an uncertainty of +/- 0.07 m/s. The 100 m mean wind speed is estimated to be 7.04 m/s with an uncertainty of +/- 0.16 m/s.

Site Description
The UMass SODAR was installed on Long Island on April 29, 2005 (at 42-19 2.8 N latitude, 70 58 8.3 W longitude). The site location is shown in Figure 1. The site is fairly open, with low vegetation and low buildings around the SODAR site. Figure 2 shows a photograph of the area. The SODAR was first placed on the ground next to the small building in Figure 2, but was moved to the top of the small building on June 3, 2005. Figure 3 shows another view of the SODAR on top of the building. The site also includes an anemometer on the small tower in the background of Figure 2 that is operated by the MA DEP. Additionally, there are anemometers operated by RERL nearby at Thompson Island.

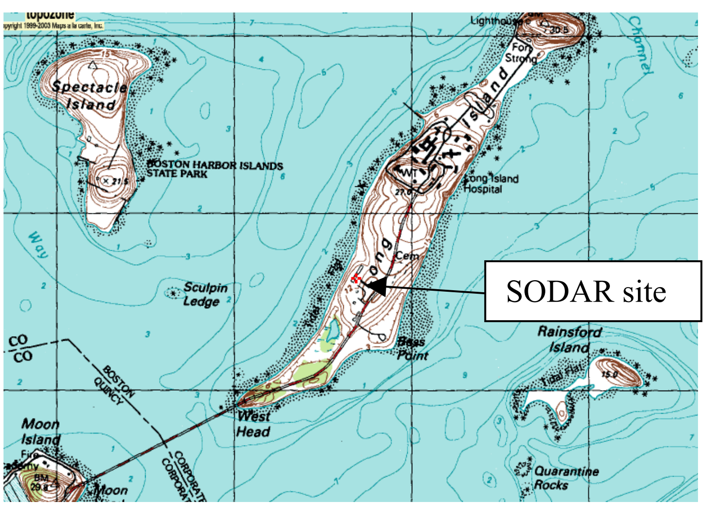

Figure 1. Map of Long Island showing SODAR site.

Figure 2. Photograph of the SODAR placement and Long Island site.

Figure 3. Close-up of the SODAR on the building.

SODAR Technology

The UMass ART VT-1 SODAR measures wind speed and direction at multiple heights using an acoustic signal. Data are collected at heights from 30 to 200 m in 10 m increments. The acoustic signals are reflected from the atmosphere and received by the SODAR and analyzed to determine wind speeds at each height.

The strength of the reflected signal decreases with height. Naturally occurring acoustic noise in the environment may overwhelm the reflected signal. When this occurs, the SODAR software does not use that sample of information. If too few samples in the 10-

minute averaging period have sufficient signal strength, the SODAR does not provide an average for that period. Thus, depending on the ambient noise levels, the SODAR may provide less data at higher elevations due to the weak signal.

Possible echoes of the SODAR signal, which are caused by high nearby objects, may also affect the reliability of the SODAR data. Potential echo problems are taken into consideration when the SODAR system is deployed and tests are conducted in order to prevent echoes from corrupting the data.

Finally, the SODAR tends to report wind speeds one or two percent below those measured with anemometers and any problem with the data collection almost always results in low measurements. Thus the SODAR provides a lower limit for the measured wind speed.

Data Issues on Long Island

After installing the SODAR on the island, unexpected problems with possible corruption of the data due to echoes from ground clutter (low nearby trees and buildings) were identified at another site. A quick analysis of the data collected so far suggested that the same problem might be occurring at Long Island. To try to avoid these problems, the SODAR was moved to the top of a nearby building. This report covers only the data collected on the top of the building. The data from the first site does appear to be affected by this problem and is not considered here. At the moment RERL is working to resolve these problems.

Data Overview

The data from the top of the building is fairly complete. More than 90 percent of the possible data samples were received from heights as high as 100 meters (about 330 feet), as detailed in Table 1 and Figure 4. Graphs of the wind the 30 m and 100 m wind speeds are shown in Figures 5 and 6.

Table 1. Percent of possible data that was collected.

Height	Percent Good Data
30	97%
40	96%
50	96%
60	97%
70	97%
80	96%
90	94%
100	90%
110	85%

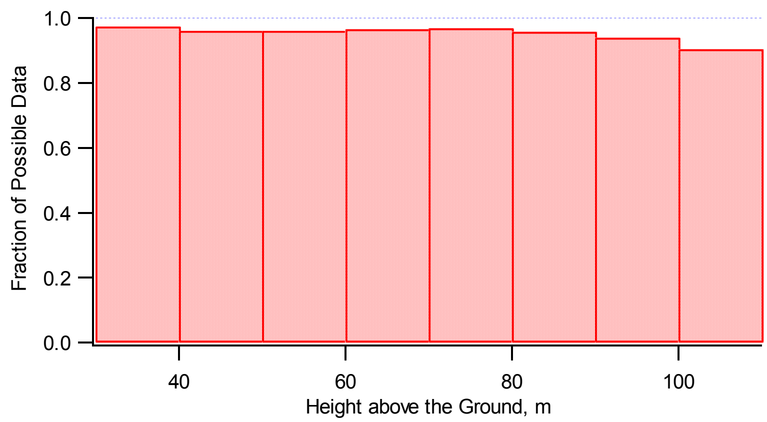

Figure 4. Fraction of possible data that was good.

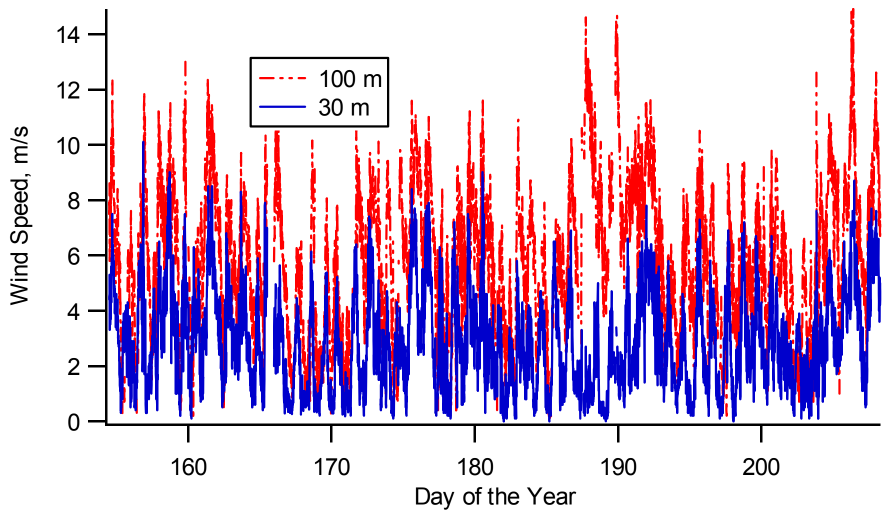

Figure 5. Graph of 10-minute averages of SODAR wind speed at 30 m and 100 m.

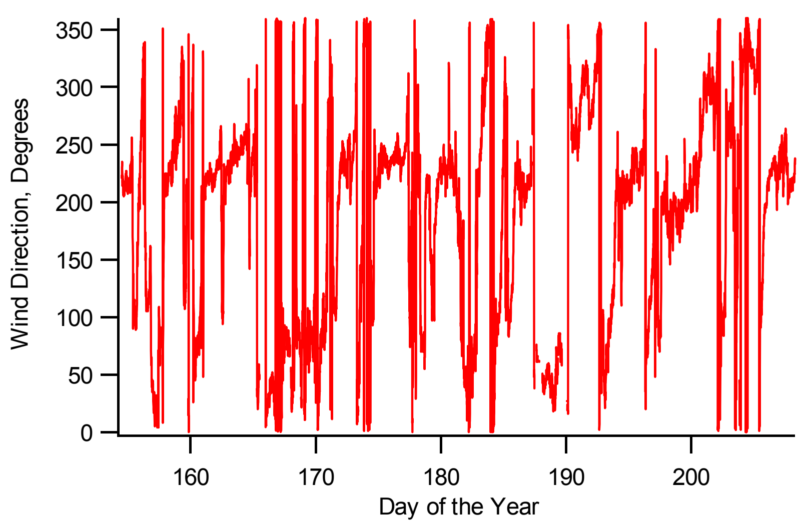

Figure 6. Graph of wind direction at the Long Island site.

Data Validation

The SODAR data were compared with anemometer data from both the nearby tower and from Thompson Island to confirm that the data is of high quality. Comparisons with the nearby anemometer and Thompson Island show that there may be ground clutter problems that also affect data from the lower measurement levels when the SODAR is on top of the building. Using tests developed at RERL, it appears that the data from 70 m and above is good data. The remaining analysis will focus on the data at and above 70 m. Examples of graphs of good data are shown in Figures 7 and 8. In these graphs, the SODAR data are plotted against data from Thompson Island. In this type of graph, good data are bunched along a line. Data that show the effects of ground clutter look like the graph in Figure 9, in which the points form a cloud with a straight upper boundary, but no clear lower boundary and numerous points well below others.

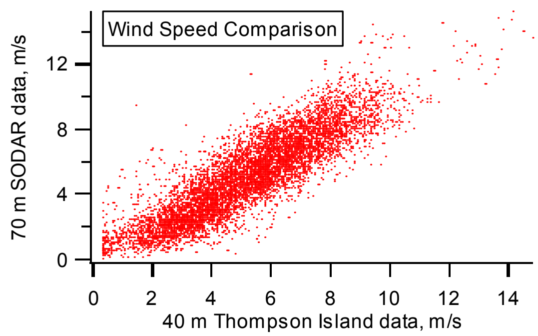

Figure 7. Graph of 70 m SODAR data vs. Thompson Island data.

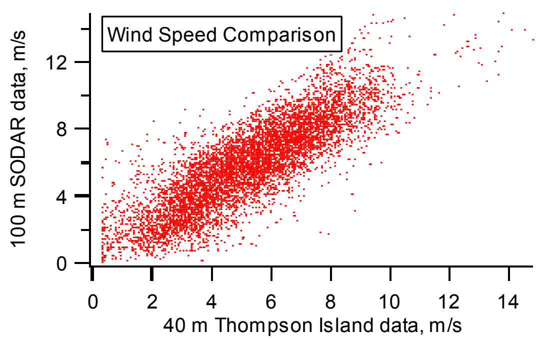

Figure 8. Graph of 100 m SODAR data vs. Thompson Island data.

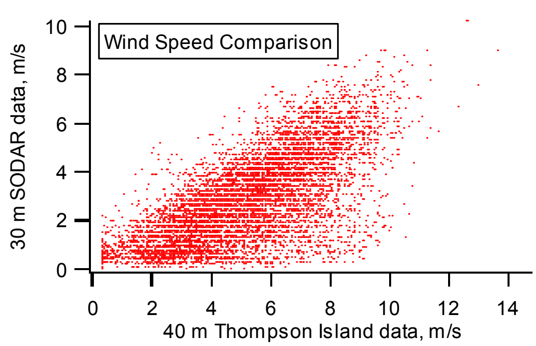

Figure 9. Graph of 30 m SODAR data vs. Thompson Island data.

Estimates of Long Term Wind Speed

The long-term mean wind speeds at a variety of heights were estimated using the Measure-Correlate-Predict (MCP) technique. The SODAR data from 70 to 110 m and the Thompson Island 40 m data from 2002 were used to estimate the mean wind speeds at Long Island. The year 2002 was chosen because the Thompson Island had no gaps in it that year due to sensor maintenance. Using these data sets, the MCP approach provides estimates of the Long Island wind speeds at 70 to 110 m for the 2002. The form of the MCP relationship used was the "Variance" method developed at RERL[1]. The uncertainty of the results is determined using the Jackknife estimate of variance[2]. While this approach works well in many circumstances, its validity for MCP analyses is still being investigated at RERL.

The analysis used data from Thompson Island and from the SODAR on Long from June 3, 2005 until July 27, 2005. During this time the average wind speeds were 5.25 m/s at 40 m on Thompson Island and varied from 5.17 m/s at 70 m to 6.12 m/s at 110 m above the ground as measured by the SODAR on Long Island. The relationship between the Thompson Island and Long Island data sets was used with a year of Thompson Island data (see figure 10) to estimate the 2002 average wind speeds at Long Island from 70 m to 110 m.

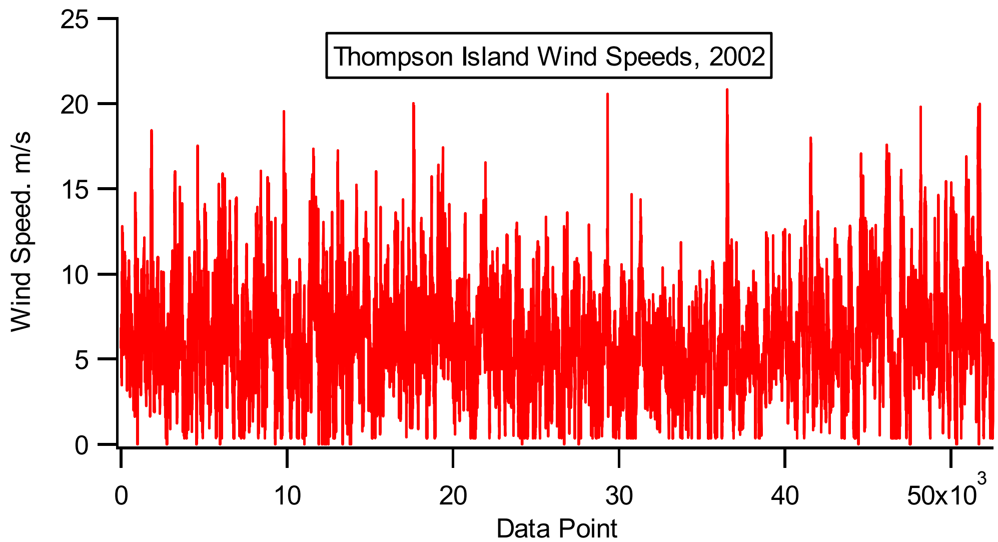

Figure 10. Thompson Island wind speeds for 2002.

The results are shown in Table 2 and in Figure 11. The estimated mean annual wind speeds increase from 6.25 m/s at 70 m to 7.24 m/s at 110 m. Any analysis has some uncertainty associated with it. It is estimated that there is a 63% confidence that the mean speed lies between the upper limit and the lower limits listed in Table 2. Thus, there is a 63% chance that the mean 70 m wind speed at the Long Island site for the year 2002 was between 6.18 and 6.32 m/s.

Table 2. Estimated mean annual wind speed at the Long Island site

Height, m	Estimated Mean Annual Wind speed	Confidence Interval Upper Limit	Confidence Interval Lower Limit
70	6.25	6.32	6.18
80	6.57	6.68	6.46
90	6.80	6.94	6.67
100	7.04	7.19	6.88
110	7.24	7.40	7.08

Figure 11 shows a graph of the estimated annual wind speeds and includes the 63% confidence interval limits. It also includes an exponential fit to the data that allows one to estimate the mean wind speeds at lower heights, using the data from 70 m and above. Thus, one can see that the mean wind speed at 50 m is about 5.6 m/s. The estimated shear exponential coefficient is 0.32. This is fairly high for an offshore site, but this might be explained by the fact that the winds during the measurement period were coming almost exclusively from the SW over the island. Another cause of the high shear could be yet-unidentified effects of ground clutter, although there are no other indications that the data from 70 m and higher might be corrupted. In any case, these wind speeds should be conservative estimates.

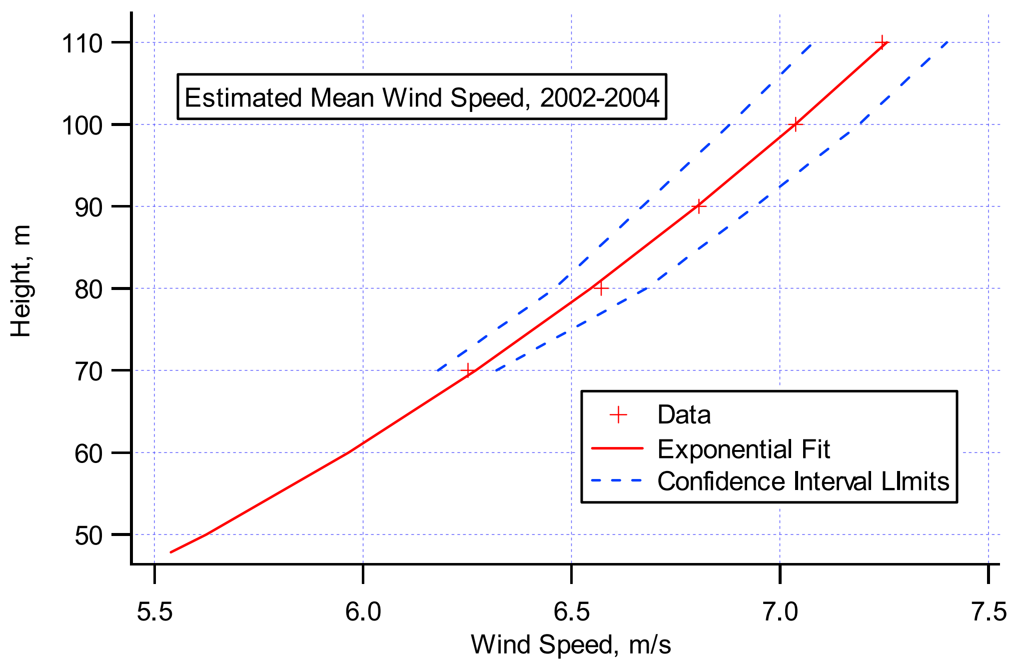

Figure 11. Estimates of average 2002 wind speed at the Long Island site.

Power Production

Using the estimates of annual mean wind speeds presented above, the energy production from a Vestas V47 wind turbine, the type located at Hull, has been estimated. At 70 m the estimated capacity factor is about 26%, not including electrical losses, and the estimated energy production would be 1500 MWh/year. At 100 m these would be 33% and 1900

MWh/year. This compares with the actual capacity factor of the Hull turbine of about 28%.

Conclusion

The SODAR data collection has so far provided wind speed data above 70 m at the Long Island site and initial estimates of annual wind speeds at the site. The data has also provided an initial estimate of wind shear, but mostly for winds from the SW. The estimates of annual wind speed, shear and capacity factor are only based on the data characteristics for the summer period and may not be representative of the wind characteristics over the whole year. A more accurate analysis will be warranted once more data has been analyzed.

The next steps are to resume SODAR data collection at the site in the fall to obtain more data during a different season and with winds from a different direction and thereby to refine estimates of annual wind speeds and the shear characteristics at the site. It is expected that the direction of the oncoming winds will have a large effect on the wind speeds and on the comparison with Thompson Island data. Work will also continue on resolving ground clutter issues that might affect the SODAR's data in order to best characterize the winds at the site.

References

1. "Comparison of the Performance of Four Measure-Correlate-Predict Algorithms," A. L. Rogers, J. W. Rogers, J. F. Manwell, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 93/3, pp. 243-264 2005

2. "Uncertainties in Results of Measure-Correlate-Predict Analyses," A. L. Rogers, J. W. Rogers, J F. Manwell, Proc. Windpower 2005 Conference and Exhibition, Denver, May 15-19, 2005, American Wind Energy Association, Washington, D.C.