JP2.9 COMPARISONS OF MEASUREMENTS MADE USING TWO SODARS IN AN URBAN ENVIRONMENT

Larry K. Berg*[,1], R. Michael Reynolds[2], K. Jerry Allwine[1], and Alan Blumberg[3]
[1]Pacific Northwest National Laboratory, Richland, Washington
[2]Brookhaven National Laboratory, Upton, New York
[3]Stevens Institute of Technology, Hoboken, New Jersey

1. INTRODUCTION

Acoustic sounders or sodars are used in many different applications in which profiles of wind speed and wind direction in the lower atmosphere are required. During the Urban Dispersion Program's (UDP) Spring 2005 field campaign two sodars: a Scintec MFAS sodar and an AeroVironment (AV) Model 3000 MiniSodar were deployed very close to each other at Stevens Institute of Technology in Hoboken NJ. This study provides a unique opportunity to compare measurements from two sodars and a propeller anemometer in an urban environment.

2. UDP SPRING 2005 FIELD CAMPAIGN

The Urban Dispersion Program's Spring 2005 campaign was conducted between 7 and 21 March 2005, and included Intensive Operations Periods (IOPs) on 10 and 14 March. The majority of the instrumentation associated with the field campaign was located close to the tracer releases near Madison Square Garden in Manhattan. However, two sodars were deployed at the Stevens Institute of Technology in Hoboken, New Jersey (Latitude 40.7448° N, Longitude 74.0238° W) to provide inflow profiles of wind speed and direction. Stevens Institute of Technology (SIT) is located on a bluff 30 m high on the western bank of the Hudson River. There is a steep slope down to the river on the eastern edge of the SIT campus. The site is approximately 2.5 km west-southwest of Madison Square Garden. Hoboken and the surrounding communities primarily consist of low-rise apartments and row houses two to three stories in height.

The AeroVironment (AV) miniSodar was located on the roof of the Howe Center, an isolated 17 story building located near the Hudson River, while the Scintec MFAS sodar was located on a dock 3 m above the river near Big John, a seven story structure along the edge of the Hudson River (Figure 1). The AV miniSodar was approximately 90 m above the Scintec, and the horizontal separation of the two units was approximately 300 m. The AV miniSodar operates at a much higher frequency than the Scintec MFAS sodar (Table 1). Because of these differences, different range gate spacing was selected for each instrument. The 50 m range gate spacing used with the Scintec MFAS sodar was particularly coarse intending to probe deeper into the boundary layer. In addition to these two sodars, a 10 m meteorological tower maintained by SIT was located near the center of the roof of the Howe Center. This station includes a propeller and vane anemometer, which we will use as reference measure of winds for the two sodars.

The original experimental plan called for us to operate the Scintec MFAS sodar on top of the Howe Center, but there was ambient noise that significantly degraded the performance of the sodar. Every attempt was made to get the Scintec MFAS sodar working, including experimenting with different frequencies. Prior to the UDP IOPs, an AV miniSodar was operated for 15 months on the Environmental Measurements Laboratory (EML) building in the West Village area and for several months on the Farley Post Office Building across the street from Madison Square Garden, where the miniSodar routinely recording winds to heights of 120 m even with high levels of urban background noise (Reynolds and Smith 2006). Therefore, we placed an additional high frequency AV miniSodar on the Howe Center and moved the Scintec MFAS sodar to a dock near Big John. Unfortunately, this location was close to a number of student dormitories. The noise from the Scintec MFAS sodar resulted in a number of complaints from SIT students. A compromise solution was to only operate the Scintec MFAS sodar during the IOPs.

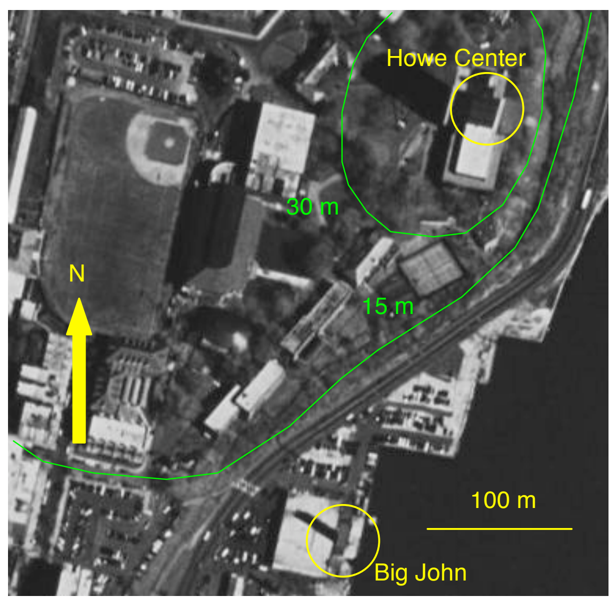

Figure 1. Aerial photograph of Stevens Institute of Technology, Castle Point on Hudson. Circles mark the location of the Howe Center and Big John. Green lines indicate approximate terrain elevation.

*Corresponding Author Address: Dr. Larry K. Berg, Pacific Northwest National Lab, PO Box 999, Richland, WA 99352. e-mail: larry.berg@pnl.gov.

Table 1. Operating characteristics of the sodars used during the spring 2005 UDP field campaign.

Sodar Characteristics	Scintec MFAS	AV Model 3000 Mini-Sodar
Range Gate Spacing (m)	50	10
Ave. Period (min)	30	1
Highest Range Gate (m)	550	200
Frequencies (Hz)	2056, 2296	4500

The roughness sub-layer is the layer where the flow is dominated by building wakes associated with specific buildings (Roth 2000). Estimates of the displacement height (z_d) and the aerodynamic roughness length (z_0) were based on the building height as suggested by Grimmond and Oke (1999). They suggest that z_d can be approximated using,

$$z_d = f_d z_{H,ave}, \qquad (1)$$

where f_d is an empirical constant of 0.5 and $z_{H,ave}$ is the average building height, and that z_0 can be estimated using,

$$z_0 = f_0 z_{H,ave}, \qquad (2)$$

where f_o is an empirical constant of 0.1. Garratt (1980) suggested a relationship between the depth of the roughness sub-layer (z_*), z_0, and z_d, such that, $z_*=150z_0+z_d$ during unstable conditions, and Garrett (1978) suggested that z_*=4.5$z_{H,ave}$ during neutral conditions. The average building height near the sodars, as determined by eye during site visits, is on the order 10 m. Following (1) and (2) z_d is 5 m and z_0 is 1 m. This suggests that z_* ranges from 150 m for unstable conditions to 50 m for neutral conditions. Thus both sodars are able to measure winds above z_*.

3. RESULTS

As described in Section 2, the range gate spacing and time averaging used by the Scintec MFAS sodar and the AV miniSodar were different. Before comparing the measurements, data from the AV miniSodar was averaged in both space and time to match the averages generated by the Scintec. The averages were computed so that the new AV miniSodar range gates correspond directly to the Scintec MFAS sodar range gates (Figure 2), where the range gate height refers to the height of the top of the range gate.

In general, there was good agreement between the wind speed measured by the Scintec sodar, the wind speed measured in the 60 m range gate by the AV miniSodar, and that measured by the anemometer on the SIT Tower, especially if one considers that the measurements from both sodars represent an average over a finite volume, while the anemometer on the SIT Tower is a single point measurement close to the building top (Figures 3 and 4). There is a small systematic difference in the wind direction measured by both sodars when compared to the wind direction measured by the anemometer located on the SIT Tower (Table 2), but the differences are close to the stated accuracies of the sodars. As we would expect, the wind speed difference relative to the tower measurement increases with height, but the increase for the AV miniSodar was quite large and will be discussed later. Both the average wind speed and average wind direction differences increase as a function of height, indicating that there is vertical wind shear during the IOPs.

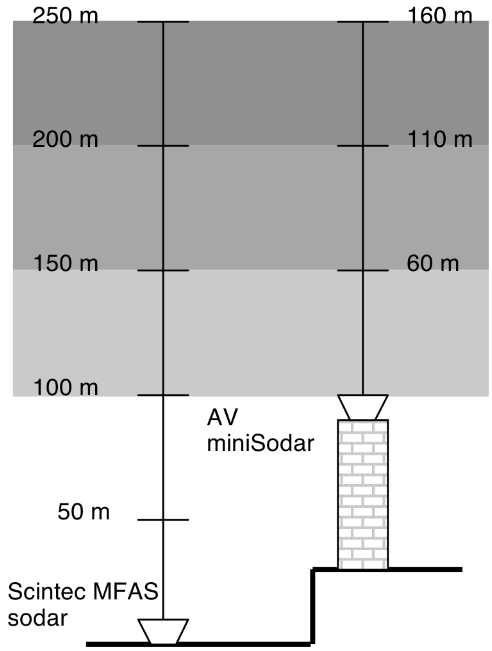

Figure 2. Sketch showing overlap of the Scintec sodar and AV miniSodar range gates used in this analysis. Heights indicate the top of the range gates.

On both days the wind speed measured by the AV miniSodar in the 110 m and 160 m range gates were much larger than that measured by the Scintec MFAS sodar. This behavior is the result of ambient noise that created a large peak in the spectra collected by the AV miniSodar (Ken Underwood, personal communication), therefore these results were not included in Figures 3 and 4 or in Table 2. The spectra collected by the AV miniSodar will be reprocessed in the near future and compared to values obtained from the Scintec MFAS sodar.

Table 2. Average Wind direction difference and wind speed difference of the AV miniSodar and Scintec MFAS sodar measurements for three range gates compared with the SIT anemometer.

	Ave. Wind Dir. Diff (°)		Ave. Wind Speed Diff. (ms^{-1})	
Height	AV	Scintec	AV	Scintec
150	-6	-4	-0.5	-0.4
200		-11		0.4
250		-20		1.0

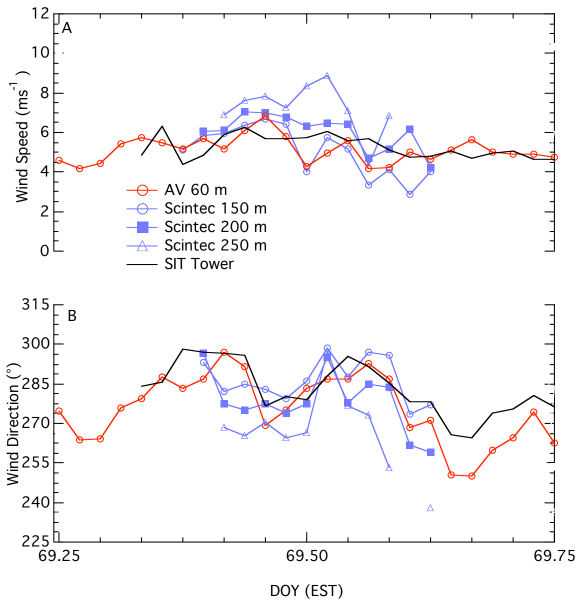

Figure 3. Thirty minute average of wind speed (A) and wind direction (B) measured by the AV miniSodar at 60 m (red lines with open circles), Scintec sodar at 150 m (blue lines with circles), 200 m (blue lines with squares), and 250 m (blue lines with triangles) above the sodar, and at the SIT Tower (black line) on 10 March 2005.

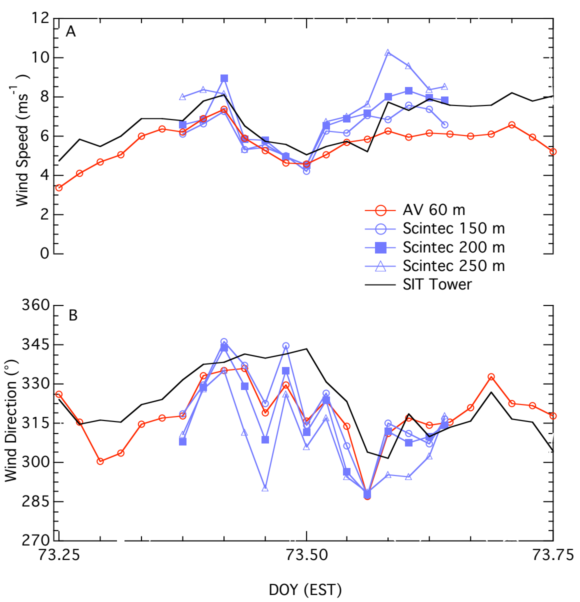

Figure 4. Thirty minute average of wind speed (A) and wind direction (B) measured by the AV miniSodar at 60 m (red lines with open circles), Scintec sodar at 150 m (blue lines with circles), 200 m (blue lines with squares), and 250 m (blue lines with triangles) above the sodar, and at the SIT Tower (black line) on 14 March 2005. Table 2. Note the different ranges of the wind direction plotted in figure 3 and 4.

4. CONCLUSIONS

Two sodars, an AV Model 3000 miniSodar, and Scintec MFAS sodar, were operated in Hoboken NJ during the UDP Spring 2005 field campaign. Our results suggest:

- A lower frequency sodar, such as the Scintec MFAS that uses frequencies near 2000 Hz, does not perform well on building tops with large amounts ambient noise.
- Differences in wind speed and wind direction measured by the Scintec sodar and AV Model 3000 miniSodar were small in the lowest range gates of both instruments.
- The agreement between the wind speed measured in the lowest range gate of each sodar was generally in good agreement with that measured by the anemometer on the SIT Tower.

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