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Pacific Northwest National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Deployment Notes for Sodars at the Stevens Institute of Technology during the March 2005 Urban Dispersion Program Field Campaign (MSG05)

Larry K. Berg
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August 2006

Prepared for the U.S. Department of Homeland Security and the Urban Dispersion Program under Related Services Agreement with the U.S. Department of Energy under Contract DE-AC05-76RL01830

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Abstract

This report documents the deployment of two sodars at the Stevens Institute of Technology (SIT) in Hoboken, New Jersey, during the March 2005 Madison Square Garden Urban Dispersion Field Campaign (MSG05) conducted in the Madison Square Garden vicinity in Midtown Manhattan. These sodars were deployed to quantify inflow conditions for the campaign. One sodar was a Scintec MFAS sodar that was operated on a dock along the Hudson River. This sodar was only operated during the two intensive observation periods (IOPs) that took place during MSG05. The other sodar was an AeroVironment (AV) Model 3000 miniSodar that was located on top of the Howe Center at SIT. This sodar was operated continuously, but there were quality issues associated with data from the lowest three and highest seven to ten range gates. Data collected by the AV miniSodar during IOPs were reprocessed to recover some data, so that only data from the three lowest and seven highest range gates were removed from the specific IOP data files. Measurements from both sodars were compared to measurements made using a propeller and vane anemometer that was also located on top of the Howe Center. The agreement between the sodars is generally good, and we recommend using either the AV miniSodar data or the Scintec data during the two IOPs, bearing in mind that there are some differences in the measured wind direction above 150 m mean sea level. This report also describes the quality control methods applied to data from each sodar and the structure and content of the data files available.

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1.0 Instrument Deployed

As part of the U.S. Department of Homeland Security's Urban Dispersion Program (UDP), scientists from Pacific Northwest National Laboratory (PNNL), with assistance from individuals from the Stevens Institute of Technology (SIT) and Brookhaven National Laboratory (BNL), deployed two sodars at SIT during the March 2005 Madison Square Garden Urban Dispersion Field Campaign (MSG05). This campaign was conducted in the Madison Square Garden vicinity in Midtown Manhattan between 7 and 21 March 2005 and included two intensive observation periods (IOPs) on 10 and 14 March. The goal of the sodar deployment was to quantify inflow conditions for the experiment centered at Madison Square Garden. One sodar was a Scintec MFAS sodar, which was only operated during the two IOPs. This sodar was located at the base of Big John, a seven-story structure located on the Hudson River (Latitude 40.74242° N, Longitude 74.02504° W; Figures 1-1 and 1-2). The dock on which the sodar was located was approximately 1.5 m above sea level. Only three acoustic beams were used: one beam was projected out over the river, one beam was projected towards the Howe Center, and one beam projected vertically. The second sodar was an AeroVironment (AV) Model 3000 miniSodar that was operated on the roof of the Howe Center, a 17-story building located on a bluff above the Hudson River (Latitude 40.74486° N, Longitude 74.02383° W). This sodar was operated continuously during the duration of the field campaign.

The original experimental plan called for the Scintec sodar to operate on top of the Howe Center, but ambient noise greatly degraded the sodar's performance. Every attempt was made to get the Scintec sodar working, which included experimenting with different frequencies. Before the MSG05 study, an AV miniSodar was operated for 15 months on the Environmental Measurements Laboratory building in New York City's West Village area. An AV miniSodar was also operated for several months on the Farley Post Office Building, located across the street from Madison Square Garden where the miniSodar routinely recorded 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 top of the Howe Center and moved the Scintec sodar to a dock near Big John. Unfortunately, this location was close to student dormitories, and the noise from the Scintec MFAS sodar resulted in several complaints from SIT students. A compromise solution was to operate the Scintec sodar only during the IOPs. Although the AV miniSodar was operated continuously during the study period, data were available only for the period 10 through 17 March because of data archiving difficulties

In addition to the two sodars, SIT scientists permanently deployed a propeller and vane anemometer on top of the Howe Center, approximately 90 m above the Scintec sodar. A correction was made to the wind direction to account for a slight misalignment of the anemometer[1].

[1] This correction was reported by Brian Fullerton of Stevens Institute of Technology.

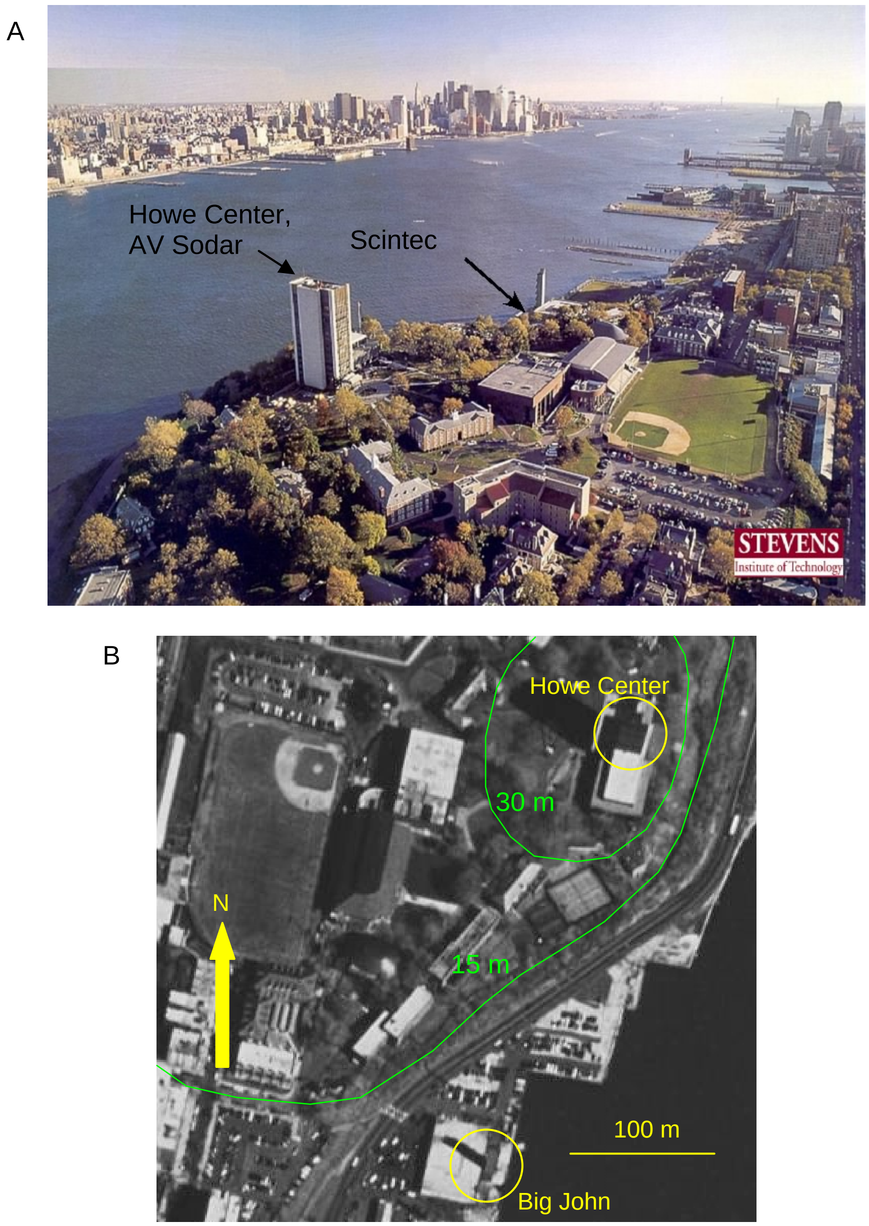

Figure 1-1. Aerial photographs of Stevens Institute of Technology, Castle Point on Hudson, looking to the southeast, with downtown Manhattan in the background (A), and from directly above (B). Circles in (B) mark the location of the Howe Center and Big John. Green lines indicate approximate terrain elevation (15-m contour interval).

Figure 1-2. Scintec sodar at the base of Big John during the MSGO5 field study (taken from the top of the Howe Center).

The Scintec sodar and the AV miniSodar operate at different frequencies, with the AV miniSodar operating at a much higher frequency (Table 1-1). Because of these differences, the range gate spacing selected for each instrument was different (Figure 1-3). The range gate spacing used with the Scintec sodar was particularly coarse for potentially probing deeper into the boundary layer. Specification of the range gates is frequently a source of some confusion. In this report, the height of the range gate is defined as the height of the top of the range gate. For example, the 150-m range gate of the Scintec MFAS corresponds to the range gate that extends from 100 m to 150 m (Figure 3).

Table 1-1. Operating Characteristics of the Sodars used during MSG05.

Measurement	Scintec MFAS	AeroVironment Model 3000 miniSodar
Range Gate Spacing (m)	50	10
Averaging Period (min)	30	1
Frequencies (Hz)	2056.3, 2296.2	4500
Maximum Range Gate (m)	550	200

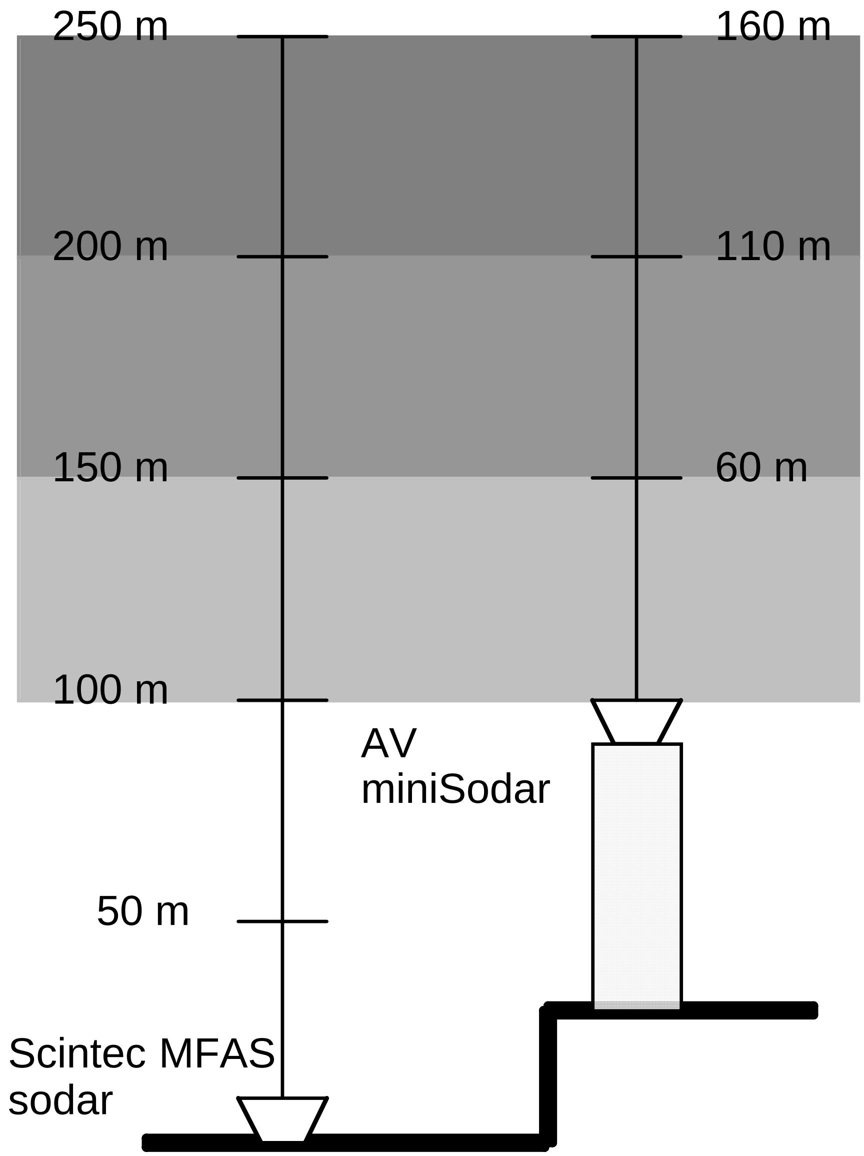

Figure 1-3. Sketch showing overlap of the Scintec sodar and AV miniSodar range gates used in this analysis. Heights indicate the top of the range gates.

2.0 Site Description

Both sodars were well located for measuring the inflow winds to Midtown Manhattan for cases with westerly winds (Figure 2-1). The SIT is located in Hoboken, New Jersey, which consists of many densely packed low-rise buildings and some taller buildings along the Hudson River (Figures 2-2 and 2-3). As shown from the figures, the Scintec sodar was tucked in along the base of a bluff.

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,

$$z_d = f_d z_{H,ave}, \tag{1}$$

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,

$$z_0 = f_0 z_{H,ave}, \tag{2}$$

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 (1980) suggested that $z^*=4.5z_{H,ave}$ during neutral conditions. The average building height near the sodars, as determined visually during site visits, is on the order 10 m. Following Eqs. (1) and (2), z_d is 5 m and z_0 is 1 m. This result 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^*. The lowest range gate or two of the Scintec sodar was likely within the roughness sub-layer. The AV miniSodar was located on top of the Howe Center, approximately 60 m above the local surface. Depending on the stability, the lowest range gates may also be in the roughness sub-layer.

Figure 2-1. Views looking to the east of the Scintec sodar (A) and from the AV sodar at the top of the Howe Center (B).

Figure 2-2. Views looking to the northeast (A), north (B), northwest (C), and south (D) near the Scintec sodar.

Figure 2-3. Views looking to the north (A), northwest (B), southwest (C), and south (D) from the AV miniSodar located on top of the Howe Center.

3.0 Data Processing and Quality Control

The goal of the quality control process is to identify and remove observations that contain errors. The averaging time used by the Scintec sodar was 30 minutes, while the AV miniSodar used an averaging time of 1 minute. The AV miniSodar data and data from the propeller and vane anemometer on top of the Howe Center have been averaged using 30-minute block averaging to match the time resolution of the Scintec sodar. The purpose of the time averaging was to reduce the noise in the data sets. In addition to the time averaging, five different quality control checks were applied to data from both sodars. The processes we applied were designed to be conservative, meaning that if data were at all questionable they were removed and not included in the archived data files. The five quality control checks were as follows:

1. All wind speeds greater than 20 ms^{-1} were excluded from the time series. The data from the upper range gates of the AV miniSodar were contaminated by some ambient noise source, which yielded measured wind speeds that approached 30 ms^{-1}. The IOP data from the AV miniSodar have been preprocessed and some data from the upper range gates have been recovered.

2. One-minute time averages of the AV miniSodar data with standard deviation greater than 1.5 ms^{-1} were excluded from the final data set.

3. Thirty-minute time averages of the Scintec sodar or AV miniSodar data with standard deviation greater than 5.0 ms^{-1} were excluded from the final data set. This value is larger than the 1.5 ms^{-1} value used for the 1-minute average because we anticipate a larger standard deviation over a longer time interval.

4. A consistency check (in time) was applied to the wind direction measured by both sodars. The entire time series was broken into sets of three sequential 30-minute average values of wind direction. If the wind direction difference between the first and second average was greater than 60°, and the wind direction difference between the first and third average was less than 45°, then the middle value was discarded and replaced with the missing data flag. In cases with significant amounts of missing data, this check was applied visually.

5. AV miniSodar measurements of wind speed and direction above 230 m mean sea level (MSL) were ignored and were not included in the archived files. Above this altitude, the measured wind speed and direction show great variability from one averaging period to the next, even after the reprocessing. Likewise, the quality of the Scintec sodar data above 300 m MSL is also questionable, and that data is not included in the data archive[1].

To facilitate comparisons of data from the AV miniSodar and from the Scintec sodar, data from the AV miniSodar have been averaged in height to match the height resolution of the Scintec sodar. Because the AV miniSodar was located on a building top well above the Scintec sodar, its

[1] Although the data have been submitted to the UDP data archive, it will be permanently saved at PNNL.

60-m height bin corresponds to the 150-m bin of the Scintec sodar[1]. There is generally good agreement between the observations made by the two sodars and the tower measurements during both IOPs. During both IOPs, the Scintec sodar data suggest that the winds veer some with height (Figure 3-1). The AV miniSodar data also show some veering of the wind with height, particularly during IOP 2.

Time-height cross sections of data from both sodars have been compared (Figure 3-2). In this case, data from the AV miniSodar have not been averaged in height, and the full 10-m range gate resolution is displayed. There is good agreement between the two sodars. Data from the Scintec sodar indicates that the wind speed decreases significantly with height below the top of the Howe Center (100 m). Given the relatively sheltered location of the Scintec sodar, this is not surprising. However, these observations are likely in the roughness sub layer and may not be representative of a large area.

For applications in which a continuous time series is desired, the entire AV miniSodar time series can be used. The height coverage is limited due to problems with data from both the highest and lowest range gates. Only data from the 50-, 60-, 70-, 80-, 90-, 100-, 110-, 120-, and 130-m range gates have been archived, but the data collected above 80 m is only available intermittently. Figure 3-3 shows a time series of this data along with data from the anemometer on top of the Howe Center. There is generally good agreement throughout the entire period. As expected, the AV sodar indicates that the wind speed increases as a function of height.

[1] The height used to define the range gate is the top of the range gate (see Section 1).

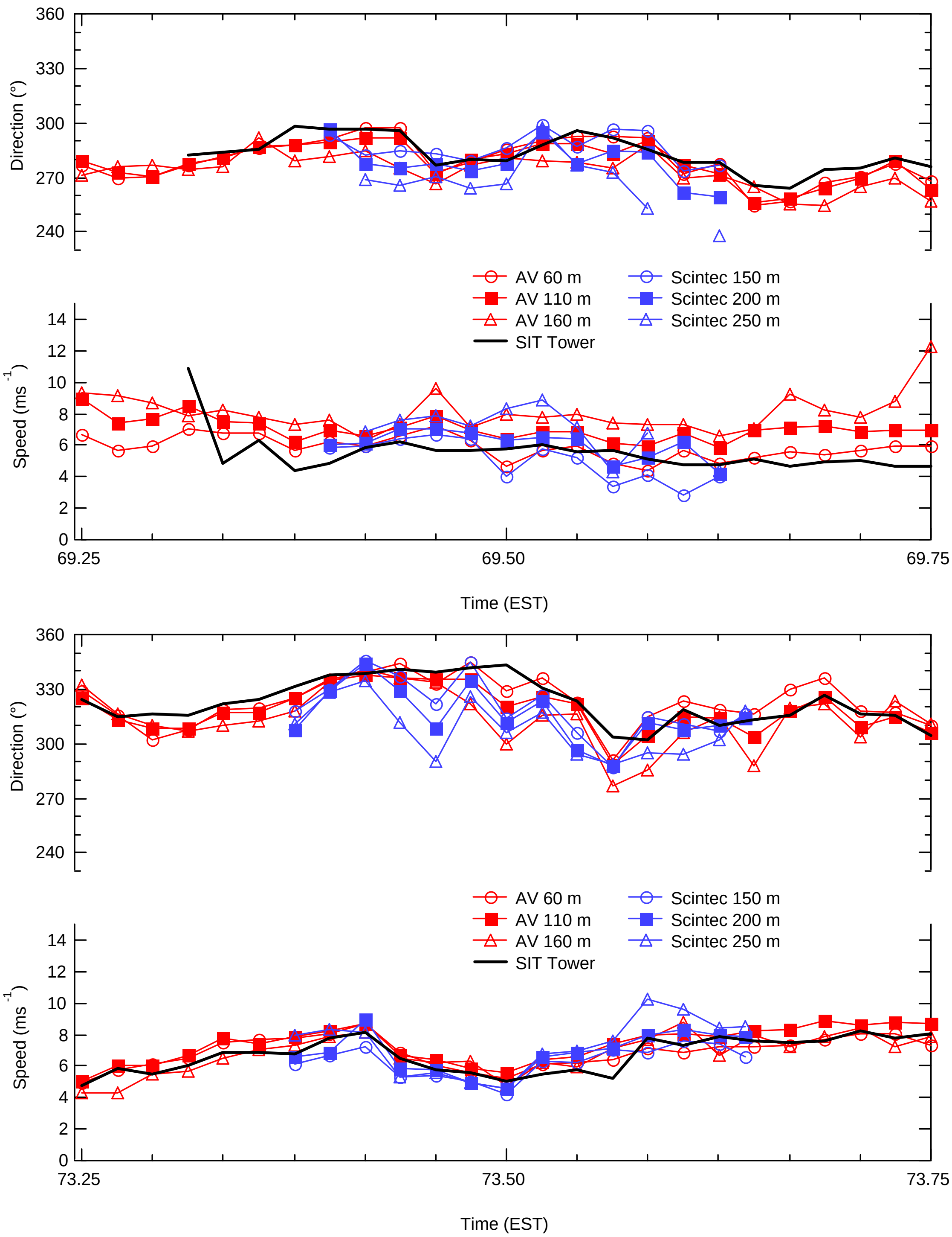

Figure 3-1. Time series of data from the AV miniSodar (red), Scintec sodar (blue), and propeller and vane anemometer (black) for IOPs 1 (A) and 2 (B). Symbols indicate the sodar range gate.

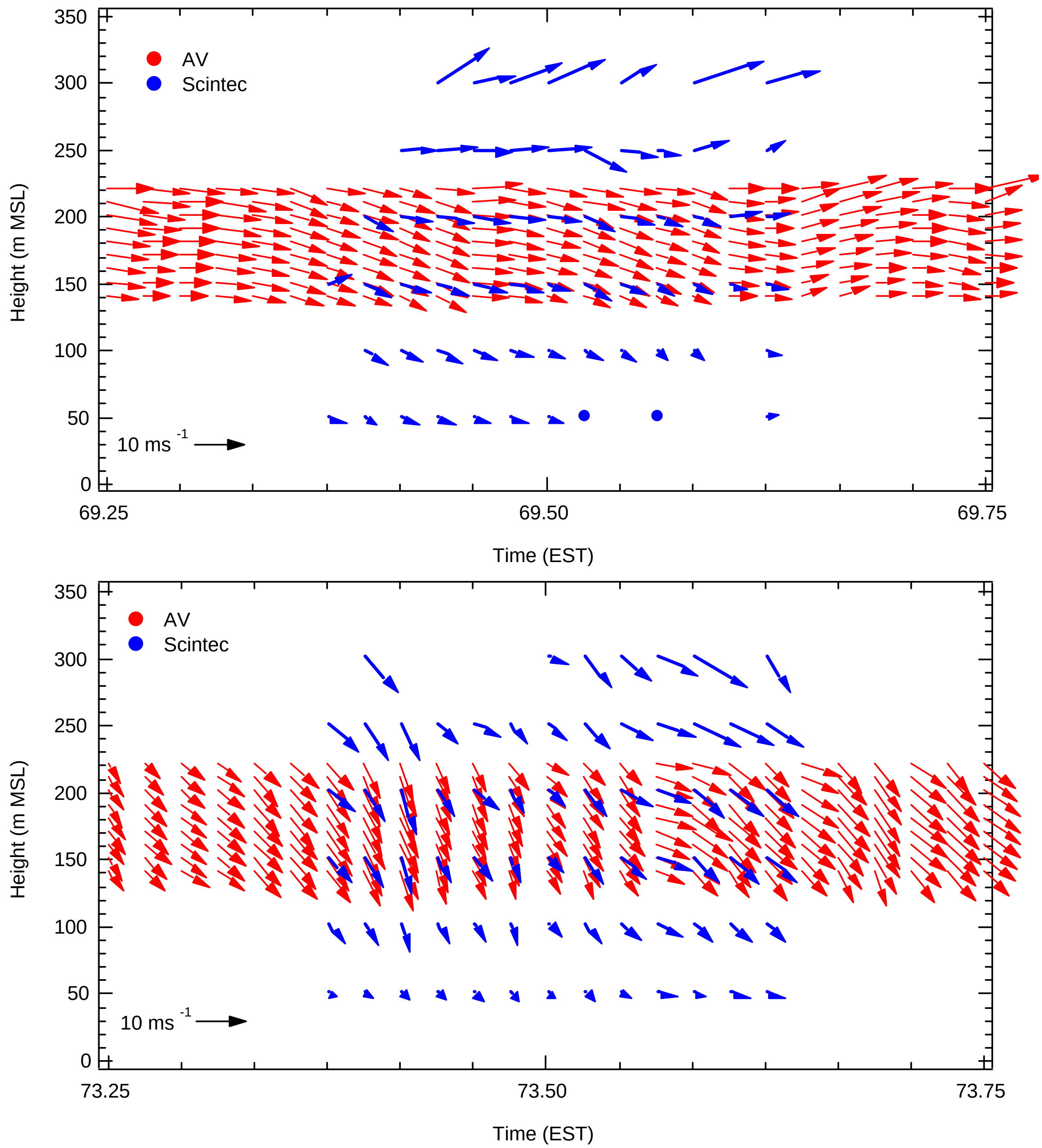

Figure 3-2. Time-height cross sections of the wind vectors from the AV miniSodar (red) and the Scintec sodar (black) for IOPs 1 (A) and 2 (B). The vector indicating 10 ms^{-1} wind speed is also plotted. Circles indicate a wind speed less than 4 ms^{-1}.

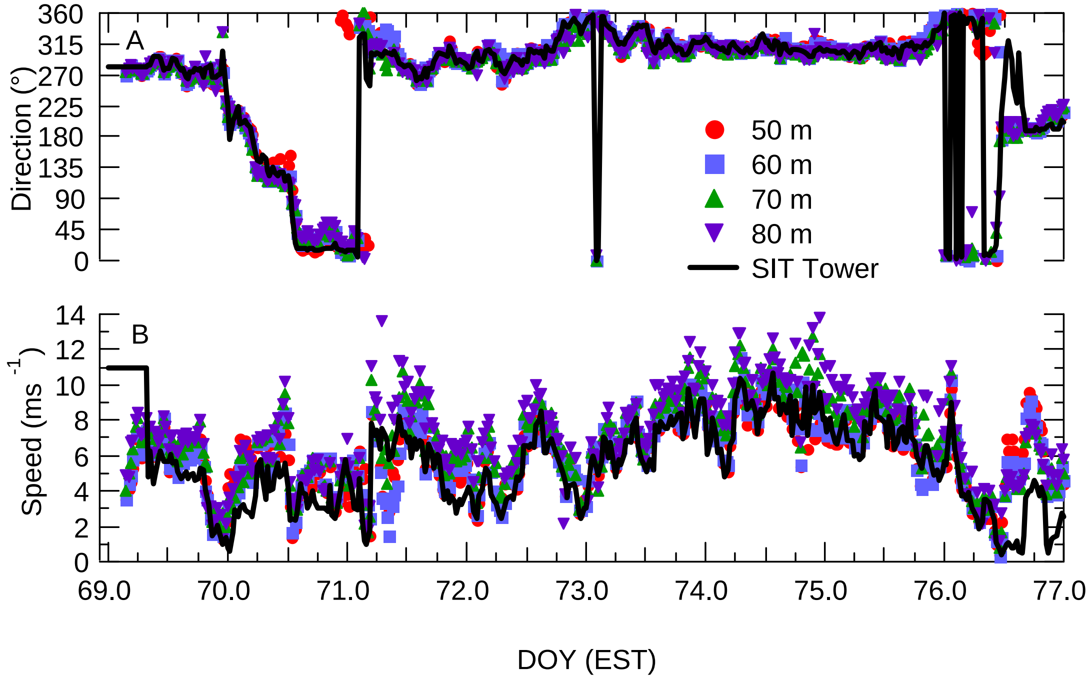

Figure 3-3. Wind direction (A) and wind speed (B) measured by the AV miniSodar and the propeller and vane anemometer mounted on top of the Howe Center for the entire period that AV miniSodar data were available (10–17 March).

4.0 Conclusion and Recommendations

After applying the time averaging and five quality control procedures described in Section 3, there is generally good agreement between data collected during the IOPs with the Scintec sodar, AV miniSodar, and the anemometer mounted on a meteorological tower on top of the Howe Center. There were problems with ground clutter and/or ambient noise in the lowest three range gates and the range gates above 80 m in height for the AV miniSodar. Reprocessing of the data helped the data recovery rate in the upper AV miniSodar range gates. Data from the lowest two range gates of the Scintec sodar may be within the roughness sub layer and may not be representative of the larger scale winds at those levels. We recommend that either the reprocessed AV data or the Scintec data be used for applications that require the wind profile as a function of time. The continuous AV data are reliable between 50 and 80 m and can be used for applications that require data from non-IOPs. The structure and content of the quality-controlled data files are described in the Appendix.

5.0 Acknowledgments

This work was supported through a Department of Homeland Security Contract under a related services agreement with the U.S. Department of Energy under Contract DE-AC06-76RL01830. Support in the field was provided by Prof. Alan Blumberg, Brian Fullerton, Howie Goheen, Jeremy Turner, and Mike Raferty of SIT and Dr. R. Michael Reynolds and Scott Smith of BNL. Dr. Kenneth Underwood of Atmospheric Systems Inc. (formally of AeroVironment) facilitated the rapid deployment of the AV miniSodar and assisted with the post-processing of the AV miniSodar data.

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Appendix

File Descriptions

Appendix

File Descriptions

Files from the Scintec sodar, AV miniSodar and the SIT meteorological tower are comma delimitated ASCII text. The general naming convention is an instrument id (av, scintec, or sit), two-digit year, two-digit month, and two-digit day. For observations that span several days, the two-digit day is represented by a XX. The sodar observations are broken into two different files: one with the vector average wind speed (indicated with the .speed.ave suffix), and another for the vector average wind direction (indicated with the .dir.ave suffix). The following files can be found in the data archive, specific details are included in the remainder of this Appendix.

Table A-1. File names, associated instrument, and brief description of the file contents.

File Name	Instrument	Contents
av.0503XX.speed.ave	AV miniSodar	Vector average wind speed (ms-1) for the period 10 through 17 March
av.0503XX.dir.ave	AV miniSodar	Vector average wind direction (°) for the period 10 through 17 March
av.050310.speed.ave	AV miniSodar	Reprocessed vector average wind speed (ms-1) on 10 March
av.050310.dir.ave	AV miniSodar	Reprocessed vector average wind direction (°) on 10 March
av.050314.speed.ave	AV miniSodar	Reprocessed vector average wind speed (ms-1) on 14 March
av.050314.dir.ave	AV miniSodar	Reprocessed vector average wind direction (°) 14 March
scintec.050310.speed.ave	Scintec sodar	Vector average wind speed (ms-1) on 10 March
scintec.050310.dir.ave	Scintec sodar	Vector average wind direction (°) on 10 March
scintec.050314.speed.ave	Scintec sodar	Vector average wind speed (ms-1) on 14 March
scintec.050314.dir.ave	Scintec sodar	Vector average wind direction (°) on 14 March
sit.0503XX.ave	SIT Tower	U and V wind components, vector average wind speed (ms-1) and wind direction.

Sodar Data Files

The same methodology is used in each of the AV miniSodar and Scintec sodar data files. The data are arranged with separate columns for each range gate. The first line of the file is a heading the lists the top of the range gate (in m above either the AV miniSodar or Scintec sodar). The first column is the time of day expressed as Day of Year (DOY), in EST, at the end of the 30-minute averaging period. Each subsequent row contains the time, listed in terms of DOY and followed by the vector average wind speed or wind direction measured at each range gate. The flag -9999.99 indicates missing data.

SIT Tower

Data from the SIT tower are arranged a bit differently than the sodar data files because all of the observations are from the same altitude. The file consists of a header line listing the variables: for the average U, average V, vector average wind speed, and vector average wind direction. The first column is the time at the end of the averaging period expressed as DOY in EST.

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