6.10 DETERMINING THE ACCURACY AND REPRESENTATIVENESS OF WIND PROFILER DATA

Ralph Petersen, and Kristopher Bedka
Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin – Madison
E-mail: Ralph.Petersen@SSEC.WISC.EDU

1, INTRODUCTION

CIMSS has begun to use data from the National Wind Profiler Network (NWPN) to determine the quality of mesoscale cloud motion wind derived from GOES data, as well as other wind data sets. The NWPN data have the potential advantage over all other comparison wind data sets available over the U.S. in that there are many more opportunities for matching the GOES wind data with the frequent wind profiler reports – ***especially when the 6-minute data are used for validation.*** However, before the 6-minute data could be used as a validation standard, a comprehensive analysis of both the quality and spatial/temporal representativeness of NWPN data was needed.

As series of evaluation studies were conducted using a nearly one year long archives of Wind Profiler and high-resolution radiosonde data observed taken at the Lamont, Oklahoma ARM-CART site. The objective of these studies is to determine: 1) additional quality control needed for the 6-minute profile data, 2) spatial variability of wind reports, 3) temporal variability of wind reports, and 4) accuracy of Wind Profiler observations relative to the Radiosonde data. All of these pieces of information will be essential for the optimal use of any types of wind observations in future mesoscale data assimilation systems and in designing observing systems strategies.

2. QUALITY CONTROL OF 6-MIN NWPN REPORTS

Operational ***hourly*** data from the NWPN are derived as a 'consensus averaging' of at least 4 observations from each "off-vertical" profiler beam which agree most closely during the past hour. Although data are corrected for vertical motion detected by the vertical beam and eliminated if the vertical motion exceeds certain limits, different data can be used in obtaining the averages for each of the two off vertical beams. Little Q/C information is included in the report transmitted to AWIPS or GTS. While the data used may have been observed at any time during the past hour, all ***observations are labeled for the beginning of the next hour***, which can result in 'gaps' of as much as 45 minute between actual data averaging and reported observations time and can delay the time the data are delivered to the user by up to an hour after the component observations were made..

By contrast, 6-minute data are available immediately on the web with proper time labels. However, only rudimentary quality control (QC) is currently used, which compares the most recent report with the previous 10 reports and excluded gross outliers. Detailed investigation of reports taken over individual days showed that while most of the reports showed good temporal consistency, in numerous occasions the wind direction changed scientifically between successive individual reports, then returning to values that were much more consistent with previous observations (see Fig 1).

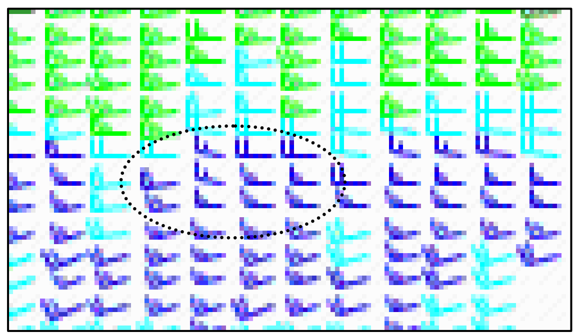

Fig. 1 – Sample of time series of lower-tropospheric 6-minute NWPN data highlighting short-duration wind direction fluctuations

To address this problem, a two-sided QC procedure was developed which rejects reports which exceeded limits based on two standard deviations of the ratio for previous reporting periods of the ratio:

$$\frac{\left(\,|\Delta \mathbf{V}_{(T-(T-6))}| + |\Delta \mathbf{V}_{((T+6)-T)}|\,\right)}{\sqrt[2]{|\,(V_{(T-6)} + 2V_T + V_{(T+6)}\,|}} =$$

Magn of vector change before/after the ob time
Square root of mean wind for 3 successive reports

Using the new Q/C approach, the Vector RMS (VRMS) difference between individual 6 NWPD observation and those 6 minutes earlier and later was reduced by nearly 1 ms^{-1} at low levels, with ~95% of the data falling within 2 Standard Deviations at all levels. Fits between profilers and radiosondes (to be discussed later) were also improved by ~8%. VRMS fits between each observation and those 6 minutes earlier and later were

* *Corresponding author address:* Dr. Ralph A. Petersen, University of Wisconsin-Madison, Cooperative Institute for Meteorological Satellite Studies (CIMSS), 1225 West Dayton Street, Madison, WI 53706;
Email Ralph.Petersen@SSEC.WISC.EDU;
Phone (608) 262-5152; Fax (608)-262-5974.

improved by nearly 1 ms-1 at low levels, with ~95% of the data falling within 2 Standard Deviations (SDs) at all levels. Fits between profilers and radiosondes (to be discussed later) were also improved by ~8%.

When applied to the total 10 month observing period, the Q/C technique eliminated a larger percentage of data at all levels when compared with 1-sided QC approach. It is noteworthy that ~60-70% of data were retained between 800 and 550hPa for the 'low-mode' profiler data (see Fig 2) and between 400 and 250 hPa for the 'high-mode' data – leaving a gap in good quality data between 550 and 400 hPa. Errors for the 6-minute

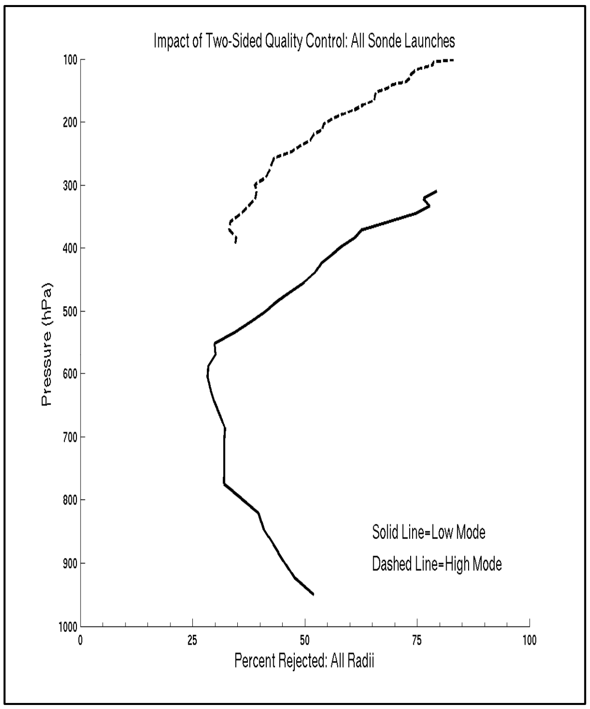

Fig. 2 – Percentage of 6-minute NWPD data rejected by 2-side QC by level.

low-mode data increase rapidly above 550 hPa and for high-mode above 250 hPa. On average, more 6-minute data are retained at all levels below 200 hPa than are used in hourly "consensus averaging".

The QC results showed diurnal variability, especially at low levels. At night, more data a rejected by the 2-sided QC than by the standard 1-sided method, while during the day, the number of report rejected by the 2-sided system data increased. Although the standard 1-sided QC rejects fewer daytime data in the boundary layer, the 2-sided method rejects more at almost all levels. The largest increase in rejections between night and day are in the upper portion of the low-mode and lower portion of the high-mode data ranges. Explanations of this diurnal behavior are being investigated.

3. WIND DATA VARIABILITY ASSESSMENT

For the wind variability/accuracy tests, six-minute frequency Profiler observations are matched in time and space with data from the radiosonde reports taken four times daily. Spatial variability was determined by creating a series of 10-25 km thick cylindrical 'tubes' around the Wind Profiler site and determining how the wind differences change with distance. The tests were made using data taken within +/- 3 minutes. The results in figure 3 show that the VRMS between reports

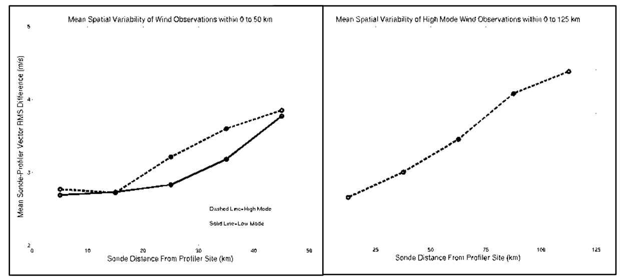

Fig. 3 – Variability of contemporaneous Profiler and GPS rawinsonde data for various observation separations

increases with distance from 2.7 ms^{-1} at 5 km to 3.7 ms^{-} at 45km for low-mode data and slightly larger values for high mode data within the first 50 km. Continuing to larger distances (higher levels), the VRMS differences increase nearly linearly from 3ms^{-1} at 12km to 6ms^{-1} at 112km.

Level-by-level comparisons show that the variability within the first 25 km is larger in the planetary boundary layer, but then decreases aloft and remains fairly constant. Above 600 hPa, where radiosonde balloon drift allows comparisons over greater distances in these tests, the differences in both the low-mode and high-

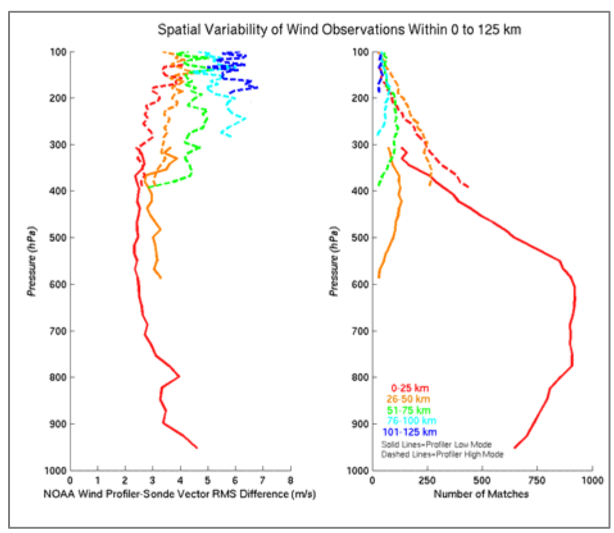

Fig. 4 – Level-by-level details of variability of contemporaneous Profiler and GPS rawinsonde data for various observation separations

mode data show systematic increases in variability with distance at all levels. The increases in spatial variability are consistent between the low- and high-mode data sets.

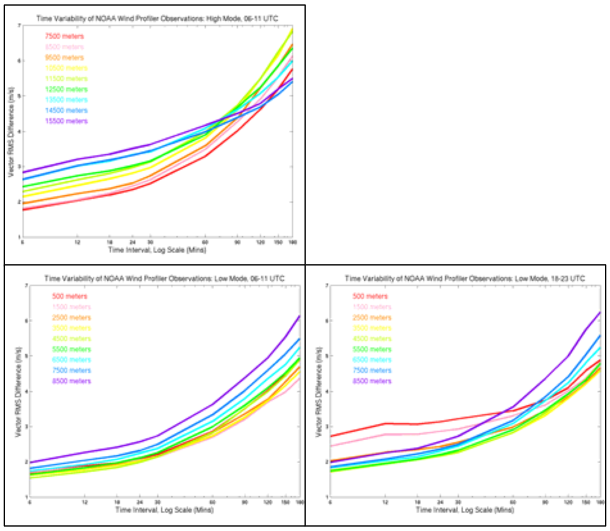

Fig. 5 – Variability by level of Profiler data versus time intervals (high-mode: top, night-time: left).

Temporal variability was determined by from the Wind Profiler data alone. In these tests, each of the high time-resolution Profiler reports was compared with data taken from 6 minutes to 6 hours from that time. The results (Fig. 4) show increases in temporal variability both with time and elevation, ranging from about 2.5 to greater than 4.5 m/s with elevation at 6-minutes and reaching over 10 m/s at some levels at 6-hours.

Significant diurnal variations were also noted, especially at low levels, where increased mixing in the boundary layer due to diurnal heating nearly doubles the temporal variability from night to day. The temporal variability of Night-time (06-11 UTC) high-mode data (bottom left panel of Fig.4), with differences increasing from 2 to 3 ms-1 at 6-minutes to 5.5 to 7 ms-1 at 3 hours and were larger than the low-mode data. These upper-level reports showed consistent patterns, with Vector RMS fits increasing from between 1.5 and 2 ms-1 (near 8 km) for 6-minute time differences to between 4.5 and 6 ms-1 for 3 hour intervals. The decrease in longer-term variability at highest (blue) levels may be due to slower frequency of wind changes typical of regions above the tropopause. While day-time (18-23UTC) data from the high-mode reports remained very similar to the night-time, increased day-time mixing in the boundary layer due to diurnal heating nearly doubles the temporal RMS differences in the lowest layers.

These results show that the time 'gap' between consensus averaging and "reported" time of standard hourly observation can add 0.5 to 1.0 ms^{-1} to the expected errors in the hourly profiler data when compared with correctly labeled 6-minute data, a 30-50% increase in error.

4. NWPN DATA ACCURACY APPROXIMATION

Accuracy tests were made using rawinsonde data located within 25 km of the profiler location and within +/-3 minutes of the profiler observations. Comparisons show mid-tropospheric VRMS differences of approximately 3 ms^{-1}, with larger differences nearer the earth's surface and farther aloft. The VRMS differences are similar for both the "Low Mode" and "High Mode" portions of the Profiler reports, even though the wind bias changes between the two reporting modes. Within the first 25 km, the variability is larger in the planetary boundary layer, but then decreases aloft and remains fairly constant. Above 600 hPa, where radiosonde balloon drift allows comparisons over greater distances, the differences in both the low-mode and high-mode data show systematic increases in variability with distance at all levels.

If the Profiler and radiosonde errors are assumed to be uncorrelated, the error in the Wind Profiler data may be able to be approximated knowing that instrument error approximations for GPS radiosondes. For example, at 600 hPa, the fits of profiler to radiosonde can be extrapolated to be about 2.0 ms-1 for perfect time and space co-locations, which includes only radiosonde and profiler instrument errors and local atmospheric variability. Using published values for GPS rawinsonde errors, this leaves the NWPN and GPS rawinsondes with comparable levels of performance.

5. SUMMARY

Six-minute data from the National Wind Profiler Network (NWPN) have been compared with precisely lo-located GPS radiosonde data. Results from nearly a year of co-locations using 2-4 matches per day show that the NWPN data:

1) Are of excellent value, ***if*** subjected to 2-sided quality control procedures before use,

2) Can be improved by removing the time 'lag' in current hourly NWPN data labeling, thereby reduce errors by 0.5 to 1 ms^{-1},

3) Show good temporal and spatial continuity, with greater variability in the boundary layer during day, and

4) Agree extremely well with precisely co-located radiosonde data.