P12R.9

Estimating the Impact of a 3-dB Sensitivity Loss on WSR-88D Data

Kevin A. Scharfenberg*, Kim L. Elmore, Eddie Forren, and Valery Melnikov
Cooperative Institute for Mesoscale Meteorology Studies, The University of Oklahoma
and NOAA/OAR National Severe Storms Laboratory, Norman, Oklahoma

Dušan S. Zrnić
NOAA/OAR National Severe Storms Laboratory, Norman, OK

1. Introduction

The U.S. network of WSR-88D radars is expected to be upgraded to include polarimetric capabilities over the next several years. These "dual-pol" radars will allow better classification of scatterer types leading to better data quality control, improved estimates of rainfall rate, and the ability to identify hydrometeor types aloft with a high degree of certainty (Schuur et al. 2003a). As part of the Joint Polarization Experiment (JPOLE) (Schuur et al. 2003b), the National Severe Storms Laboratory (NSSL) recently upgraded its WSR-88D (KOUN) to include dual-pol technology (Doviak et al. 2002).

Many research 10 cm dual-pol radars employ a ferrite switch to rapidly alternate horizontally and vertically polarized pulses. The KOUN WSR-88D, however, was designed to simultaneously transmit and receive horizontally and vertically polarized waves without the use of a switch (Doviak et al. 2002). To achieve simultaneous transmission, a high voltage power splitter was inserted into KOUN, resulting in a loss of about 3 dB in sensitivity. A similar sensitivity loss can be expected in all WSR-88D radars should this engineering solution be applied, causing the loss of some weak-signal data in the base moment fields. NSSL researchers believe the equivalent of about 2 dB in sensitivity might be recovered in the velocity and spectrum width products by combining the data from the two receive channels, though recovery of reflectivity data would not be possible using this method. Other techniques under consideration at NSSL might eventually lead to an increase in WSR-88D sensitivity beyond the 3 dB lost in the dual-pol upgrade.

This report is designed to estimate the impact of a loss of 3 dB power in WSR-88D sensitivity on operational WSR-88D products and algorithms. Data collected by the KTLX WSR-88D during six different weather events were synthetically desensitized by 3 dB. The products and algorithm output from before and after the desensitization were compared to assess the effects of the data loss. Forecasters at the National Weather Service Weather Forecast Office (WFO) in Norman, OK participated in a separate field project evaluating the loss of 3 dB sensitivity in the WSR-88D in an operational environment.

2. Technical Description

The WSR-88D data selected for case study were downloaded in Level II format from the National Climate Data Center's HDSS access system. During the real-time test at the WFO, data from the operational KTLX WSR-88D were ingested via the WFO's base data distribution system (BDDS). The data were run through a standard radar product generator (RPG) (build 6) and a modified RPG designed to threshold the moment data, simulating a 3 dB loss in sensitivity. The data from the standard RPG run (hereafter referred to as the "control" data set) and the data from the modified RPG run (hereafter referred to as the "desensitized" data set) were output separately for comparison.

The moment data were modified to simulate the dual-pol 3 dB power loss by reapplying adjusted signal-to-noise ratio (SNR) thresholds to remove data with the lowest 3 dB of power return. The power used for thresholding was calculated from reflectivity moment data because the SNR thresholding process requires an expected noise level value that is not present in the moment data. The expected noise level value for each elevation was approximated from the data bin with the lowest non-noise power return. Since some data had been removed from the moment data by previous SNR thresholding and because the 250 m resolution of the original power data cannot be fully recovered, the power value used when reapplying the SNR thresholds is also an approximation.

3. Off-Line Case Studies

During the course of data evaluation and comparison, Level II reflectivity and velocity moment data were viewed using the National Severe Storms Laboratory's Warning Decision Support System – Integrated Information (WDSS-II) (Hondl 2002). The Level II data were initially viewed in a qualitative manner in order to note general characteristics of the data such as dealiasing error rates and the visibility of major features such as fine-line signatures. The Level II reflectivity moment data were used to make counts of non-missing gates for comparison between the two data sets. Algorithm outputs from the Level III data streams were viewed using the Open Systems Principal User's Processor (OPUP). Algorithm outputs from the two data sets were viewed side-by-side in OPUP to detect differences in the data sets, and some outputs were chosen for a statistical comparison.

For all six cases, the velocity azimuth display (VAD) wind profile (VWP) products were examined qualitatively for comparison between the two data sets. In the two severe weather cases, the outputs from the mesocyclone, hail, and echo top algorithms

* *Corresponding author address:*
Kevin A. Scharfenberg, National Severe Storms Laboratory, 1313 Halley Circle, Norman, OK 73069;
e-mail: Kevin.Scharfenberg@noaa.gov

were also observed and compared. Other algorithms such as vertically integrated liquid (VIL) and precipitation accumulation were not observed.

Data from the KTLX WSR-88D used in this comparative study spanned 16 hours, 11 minutes, and 21 seconds over 6 case studies. 174 volume scans were processed, including volume coverage patterns (VCP) 11, 21, and 32, for a total of 1855 individual elevation angles. The cases were chosen to include a variety of different weather regimes and phenomena: A significant winter storm was examined, two other cases involved sparse coverage of light precipitation, another event contained clear-air signatures in a pre-storm environment, a fifth case included tornadic supercells at moderate to far ranges from the radar, and the final case was marked by widespread hail-producing thunderstorms.

4. Real-time Field Test

The AWIPS in the WFO was modified to ingest the products from the modified RPG. The modified RPG was given a unique radar site designation (KROC). The products from the operational WSR-88Ds, including KTLX, were not affected. The WFO established a connection from their AWIPS to the modified RPG in the standard manner, and their AWIPS automatically requested the 8-bit 0.5^o reflectivity product, 8-bit 0.5^o velocity product, 8-bit 0.5^o storm-relative velocity product, the vertically integrated liquid product, and VWP algorithm output. The AWIPS users were also able to perform one-time requests of any other standard product from the modified RPG. Forecasters were able to view the data in real-time using AWIPS via the D2D program. The Severe Weather Applications Team of the Warning Research and Development Division of NSSL was responsible for collecting feedback from WFO forecasters and for supplementing WFO staff during severe weather.

5. Results

a. Case Studies

Although the range to which clear-air returns could be detected decreased upon desensitization, important hydrometeorological features such as gust front fine-lines, hook echoes, and horizontal convective rolls could still be clearly identified. Generally, the largest hydrometeorological echo loss was from high spectrum width gates along echo edges. The simulation led to an average loss in original reflectivity data gates of near 5.5%, however the value was 8.4% in a “clear-air” event. Velocity dealiasing errors increased slightly in frequency and coverage.

In a few cases, interpretation of radar signatures in the vicinity of severe thunderstorms became slightly more difficult. For example, fig. 1 shows low-level reflectivity and velocity information in the vicinity of a supercell thunderstorm. A three-body scatter spike (TBSS) evident in the original data (top-left panel) became slightly less visible upon desensitization (bottom-left panel). In addition, some velocity information associated with low-reflectivity scatterers was lost (right-hand panels).

Because of the loss of some low reflectivity signal near the tops of convection, manual interpretation of storm-top divergence generally became more difficult. Fig. 2 shows an example of the loss of storm-top velocity information in a supercell thunderstorm. In the original data set (top panels), enough data points were available for the velocity dealiasing algorithm to correctly unfold the velocity information. Upon desensitization (bottom panels), some of the data were lost, and the dealiasing algorithm was not able to correctly unfold the velocity information.

WSR-88D baseline echo top algorithm and Hail Detection Algorithm outputs showed no substantial change. Uncorrelated shear detections from the legacy mesocyclone algorithm were occasionally lost upon desensitization, however little change was noted in the frequency of mesocyclone and 3-D correlated shear detections. Between 1% and 2% of VWP data were lost after the simulation; the loss increased to over 12% in the “clear-air” case.

b. Field Test

WFO forecasters and NSSL scientists did not observe significant differences impacting operations when comparing the two data sets during real-time operations. With KROC data, the sampling of important weather features, such as clear-air boundaries and gust fronts, was sometimes diminished though human detection was not generally impaired. Differences in dealiasing errors were noted between the two data sets, but it could not be said these differences impacted operations. Likewise, any changes to the VIL product and products such as the mesocyclone, hail, and echo top algorithms were deemed trivial. The most noticeable changes observed were to the VAD wind profile (VWP) algorithm output. On many volume scans, the highest-altitude data point in the VWP product was “lost” due to desensitization. Occasionally, other VWP data points were lost, though the lost data points were frequently deemed by forecasters to be “incorrect” in the original KTLX data. Forecasters did not report these differences in the VWP impacted their operations. As one would expect, the losses in VWP data were most frequent in weak, clear-air echoes.

6. Discussion and Conclusions

Generally, the echoes lost upon desensitization were a result of anomalous propagation, very weak reflectivity clear-air scatterers, or weak reflectivity, high spectrum width echoes along the fringes of precipitation returns. Major meteorological features such as fine-line signatures, hook echoes, precipitation banding, etc., showed little or no change. Even very weak precipitation returns at relatively long ranges from the radar were still visible, albeit with less areal coverage. The three body scatter spike artifact could still be observed after desensitization in almost all cases. The most significant reflectivity data loss (by percentage) occurred as the radar operated in "clear-air" VCP 32, when the observed echoes were already weak and sparsely distributed. Reflectivity-related algorithms, such as the hail and SCIT algorithms, showed a slight change in detection position in only a few cases, but no other changes were observed.

The impact of the lost sensitivity was more significant on the velocity-related algorithms. Although results were unpredictable, existing dealiasing algorithm errors generally grew slightly larger, and a few more dealiasing errors could be expected in the high-shear cases. The VWP product showed a slight decrease (on the average order of 1%) in data coverage. The loss was much more significant for "clear air" cases (sometimes over 10%). Fig. 3 shows an example of VWP data loss during a period with only a few scatterers.

The RMS errors for the VWP product data points were largely unchanged as a result of the simulation (fig. 4). In 5 of the 6 cases, the RMS error for common VWP data points between the two data sets had a 0.95 or higher correlation coefficient at a confidence interval of 95%. The one exception was the "clear-air" case with very few scatterers present. This suggests the VWP output may exhibit an unpredictable change in behavior in situations with few radar echoes.

Some change in the behavior of the legacy mesocyclone algorithm was observed. Most of the observed changes involved uncorrelated shears that were false detections as a result of the interspersion of anomalous propagation and clear-air scatterers in a highly sheared environment.

Overall, the visibility and observed structures in the reflectivity and velocity data and derived products changed little as a result of the simulated desensitization. The most significant changes were in "clear air" cases, where a relatively large portion of the original non-missing data and VWP output were lost. Although the largest impacts were observed in velocity data and products, research at NSSL suggests a substantial portion of the velocity data may be recovered in dual-pol radar products by combining the backscatter information from the vertical and horizontal channels.

7. Acknowledgments

This work would not have been possible without the dedicated work of the CIMMS and NOAA/NSSL radar engineering team. The authors would like to acknowledge funding support for this work from the U.S. National Weather Service, the Federal Aviation Administration, and the Air Force Weather Agency through the NEXRAD Products Improvement Program. This extended abstract was prepared by Kevin Scharfenberg with funding provided by NOAA/Office of Oceanic and Atmospheric Research under NOAA-University of Oklahoma Cooperative Agreement #NA17RJ1227, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

8. References

Doviak, R. J., J. Carter, V. Melnikov, and D. S. Zrnić, 2002: Modification to research WSR-88D to obtain polarimetric data. Report of the National Severe Storms Laboratory, 49pp [Available from NOAA/NSSL, 1313 Halley Circle, Norman, OK, 73069].

Hondl, K., 2002: Current and planned activities for the Warning Decision Support System – Integrated Information (WDSS-II). Preprints, *21st Conf. on Severe Local Storms*, San Antonio, TX, Amer. Meteor. Soc., 146-148.

Schuur, T., P. Heinselman, K. Scharfenberg, A. Ryzhkov, D. Zrnić, 2003a: Overview of the Joint Polarization Experiment (JPOLE). Report of the National Severe Storms Laboratory, 38 pp. [Available from NOAA/NSSL, 1313 Halley Circle, Norman, OK, 73069; http://cimms.ou.edu/~schuur/jpole/JPOLE_Overview_Report.pdf].

Schuur, T., A. Ryzhkov, P. Heinselman, D. Zrnić, D. Burgess, and K. Scharfenberg, 2003b: Observation and classification of echoes with the polarimetric WSR-88D radar. Report of the National Severe Storms Laboratory, 45 pp. [Available from NOAA/NSSL, 1313 Halley Circle, Norman, OK, 73069; http://cimms.ou.edu/~schuur/jpole/JPOLE_Obs_and_Classification_of_Echoes_Report.pdf].

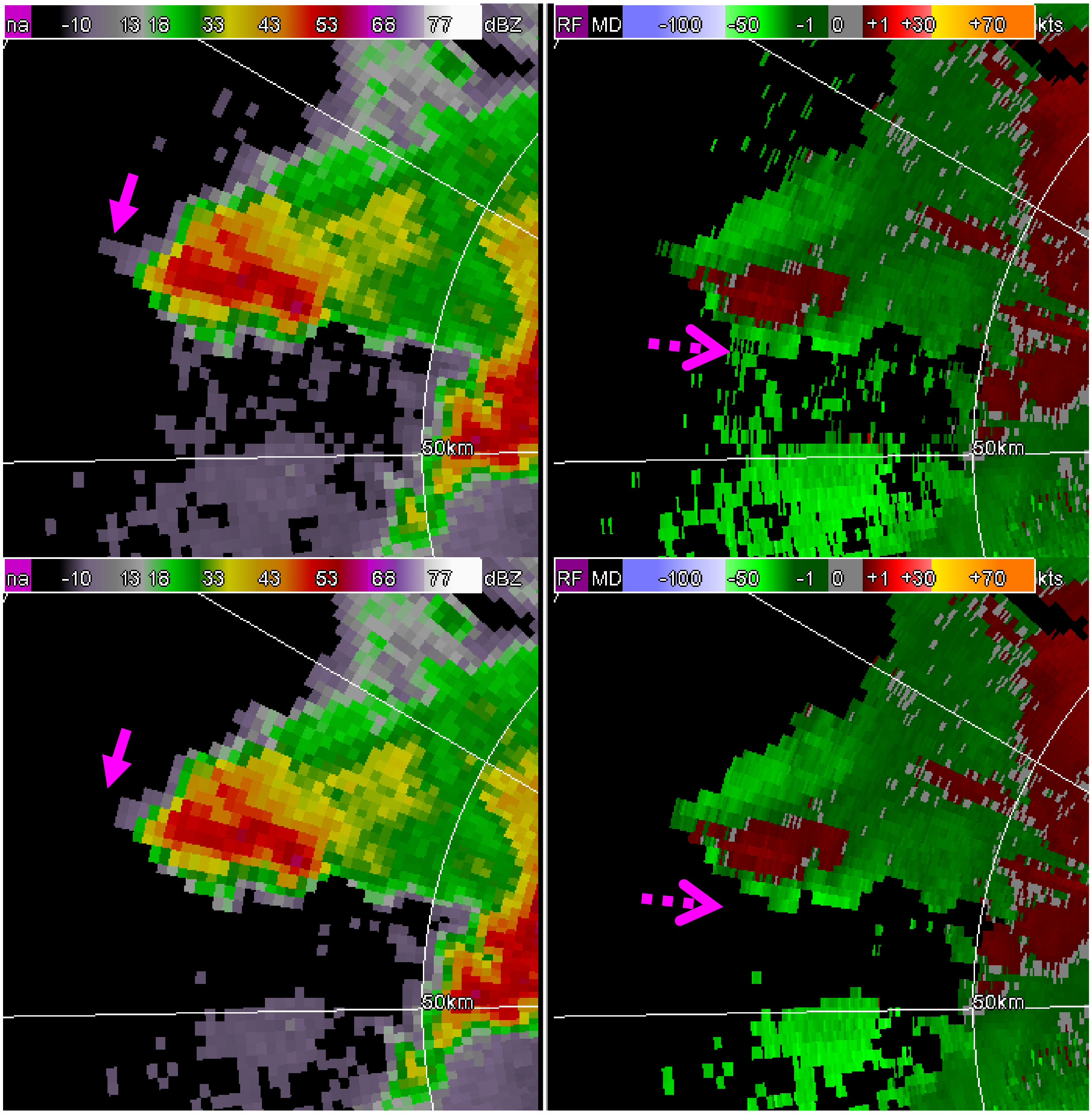

Figure 1. Control (top) and desensitized (bottom) KTLX Level II reflectivity data, 2.4° elevation angle, 0701 UTC, 8 May 2003. Solid arrows indicate location of three body scatter spike (TBSS). Dashed arrows represent lost clear-air velocities.

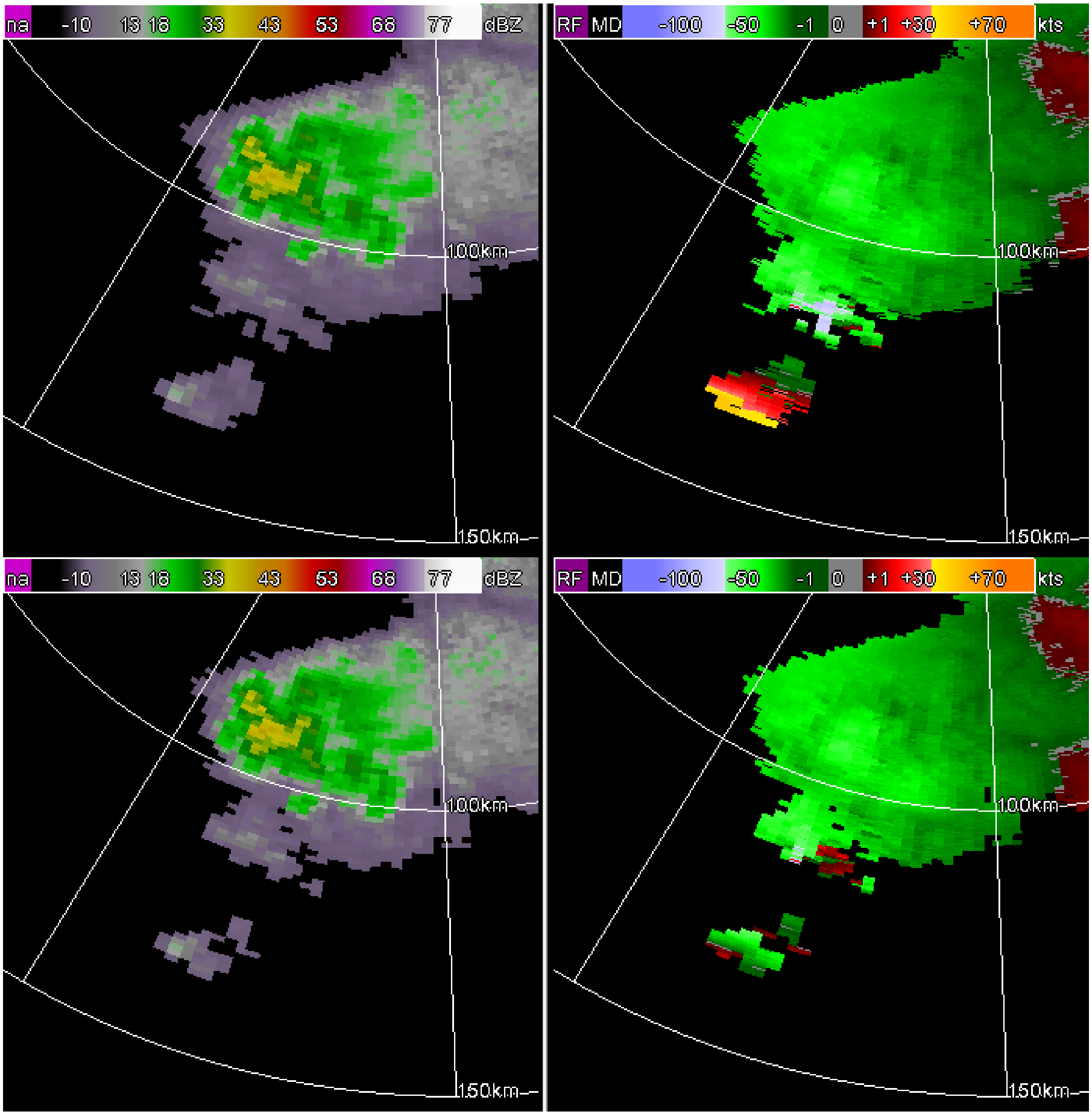

Figure 2. Control (top) and desensitized (bottom) KTLX Level II reflectivity data, 7.5° elevation angle, 0632 UTC, 8 May 2003.

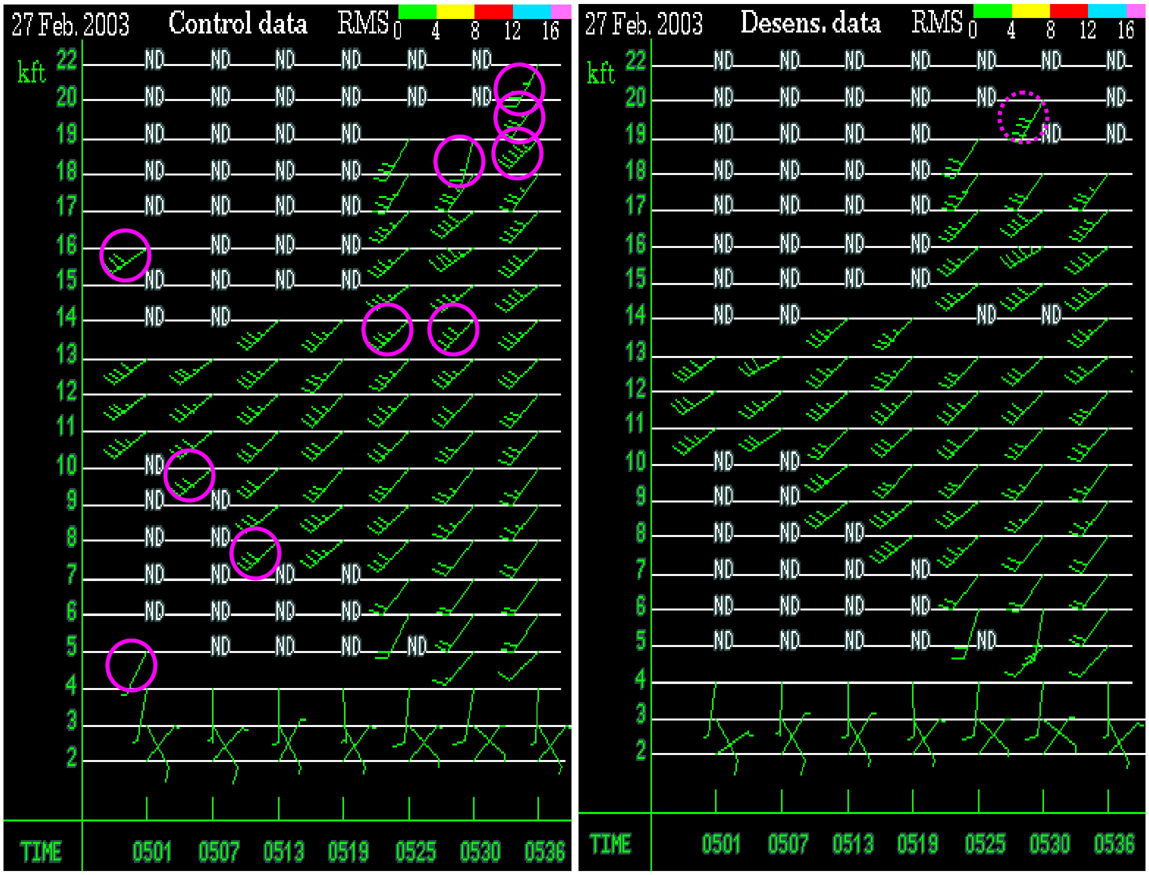

Figure 3. VAD wind profile (VWP) products, 27 February 2003 at 0536 UTC, from control data set (left) and desensitized data set (right). Solid-circled barbs indicate data points lost after desensitization, while the dotted-circled barb indicates a data point gained after desensitization.

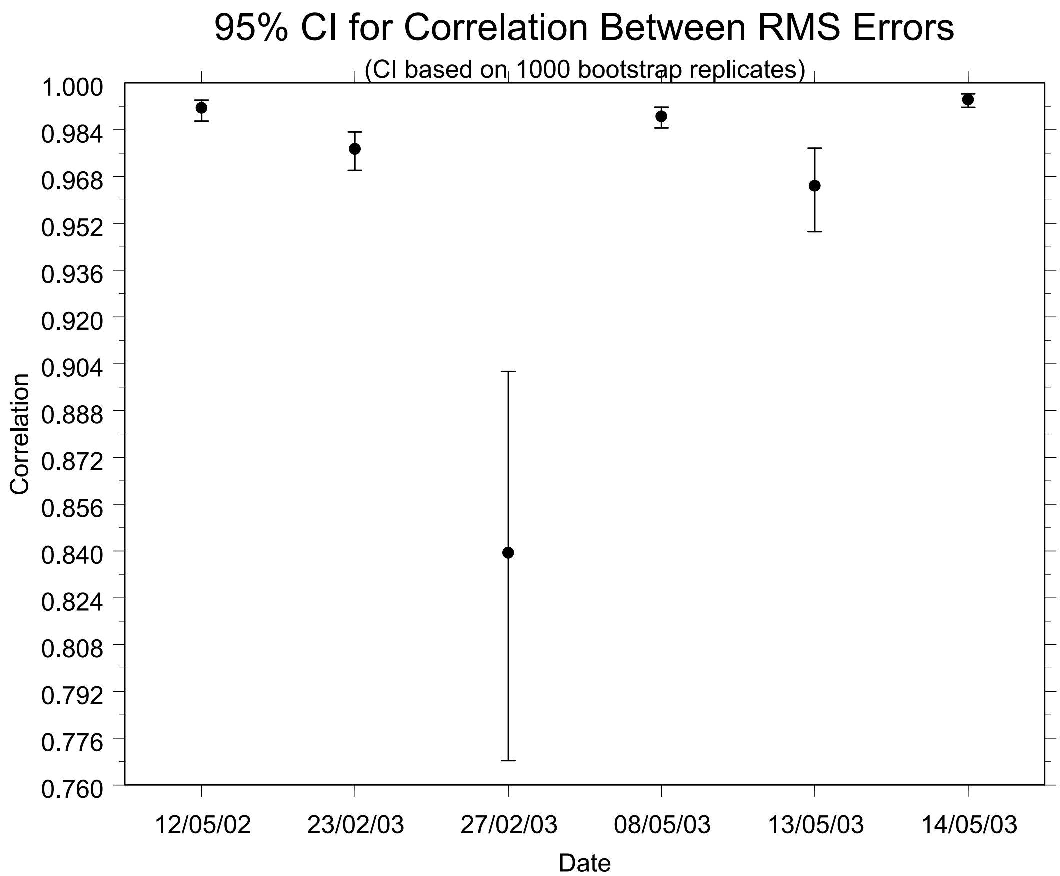

Figure 4. Estimates of correlation coefficient between VWP wind data point RMS errors and associated 95% confidence intervals.