P8R.8 WSR-88D OPEN RADAR DATA ACQUISITION (ORDA) ALGORITHM EVALUATIONS

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1. INTRODUCTION

The ORDA will replace the current WSR-88D Radar Data Acquisition (RDA) subsystem in 2005-2006 to improve: 1) receiver and signal processing hardware; 2) user interface; 3) signal processing and diagnostic software; 4) system reliability, maintainability, availability; and 5) data quality. Previous publications describe many aspects of the ORDA project: Belville et.al. (1997), Cate and Hall (2005); Cate et al. (2003); Crum and Reed (1998); Free et al. (2005); Ice et al. (2004); Ice et al. (2005); Patel et al. (2005); Patel and Macemon (2004); Reed and Cate (1999); Saffel et al. (2002); Zahrai et al. (2002).

One goal of the ORDA project is to replace the Legacy signal processor without affecting the data that forecasters and others use. Base data and algorithm products from ORDA should be as good as or better than Legacy data and products. Because the two radars used for algorithm evaluation were not collocated and their viewing geometry to storms and other meteorological phenomena were different, the ORDA data quality team, Lee (2005), determined that algorithm output from Legacy and ORDA systems should have a correlation coefficient of 0.7 or greater. If the correlation coefficient was less than the 0.7 criterion, then an acceptable explanation for the discrepancy was needed.

As part of the ORDA data quality evaluation, ROC Applications Branch personnel compared products from 15 algorithms both qualitatively and quantitatively from Legacy and ORDA systems. Qualitative and quantitative analyses, scatter diagrams, and correlation coefficients demonstrated that ORDA and Legacy algorithm products are similar.

2. ALGORITHM EVALUATION PROCEDURES

Two sets of Level II data were played back through RPG (Radar Product Generator) Build 7 software. One data set was collected by an ORDA RVP8 processor on the KCRI WSR-88D/RPG and a second data set was collected by KTLX, a legacy WSR-88D/RDA processor located approximately 20 km northeast of the ORDA system. Volume scan times from the two data sets were matched so that they were no more than 4 minutes apart.

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Storms and circulations were selected for comparison by requiring that their locations were within 5 nautical miles (nmi) and 5º azimuth of each other. Products and storm features that did not match in time or space were not used in the evaluation.

The Max Gridded Vertically Integrated Liquid (VIL) product gives the maximum VIL value observed anywhere within 124 nmi of the radar. Wind speed and direction values in the Velocity Azimuth Display Wind Profile (VWP) product are also derived from the same 124 nmi radar coverage area. These comparisons pose a problem because the two radars are not collocated. Their respective beams do not cover the same locations to the same degree. The comparisons of the Max Gridded VIL and VWP values were expected to be affected.

To mitigate geometry and beam differences (potentially detrimental to algorithm comparisons) storms and precipitation regions located at approximately the same distance from both KTLX and the ORDA radar, were compared. The equal-distance criteria attempts to use data with similar-sized antenna beam widths to measure similar resolution scales at storm and precipitation locations. Figure 1, from Brown et al., 2003, depicts a distribution of differences in distance from both radars. The brightest shaded area, close to both radars, encompasses the combined “cone of silence”. An attempt was made to avoid comparing algorithm detections that fell in the brightest shaded area. The area in the figure having the darkest shading represents places where the distances from the pair of radars are within 10% of each other. This region is the region of best comparison. An effort was made to compare storms that were located in the region of best comparison.

Cases were selected for the algorithm evaluation from data collected between 6 September 2004 and 30 June 2005. Nine stratiform precipitation cases, seven convective cases, and one snow case were evaluated.

Three velocity based algorithms were compared: 1) Mesocyclone Detection Algorithm (MDA), 2) Velocity Azimuth Display (VAD) Wind Profile (VWP); and 3) Radar Echo Classifier Clutter Likelihood Doppler (REC CLD). Twelve reflectivity based algorithms were compared: 1) Max Gridded VIL; 2) cell based VIL; 3) Probability Of Hail (POH); 4) Probability Of Severe Hail (POSH); 5) hail size; 6) Storm Total Precipitation (STP); 7) One Hour Precipitation (OHP); 8) Three Hour Precipitation (THP); 9) Snow Depth; 10) Snow Liquid Water Equivalent; 11) REC Clutter Likelihood Reflectivity (REC CLR); and 12) Echo Top (ET).

3. QUALITATIVE EVALUATIONS

The following algorithms were compared qualitatively: VIL, ET, OHP, THP, STP, REC CLR, REC CLD, Snow Liquid Water Equivalent, and Snow Depth. Products from ORDA and Legacy systems were compared side by side to make sure that ORDA products were similar to Legacy products. When differences were noticed, an explanation was provided or the cause of the discrepancy was identified and corrected. For example, in 2004 the ORDA radar (KCRI), had a low reflectivity bias compared to the Legacy radar (KTLX) which accounted for some minor differences. The calibration difference decreased in 2005 as engineers were able to fine tune the ORDA system and qualitative algorithm comparisons improved.

4. MDA QUANTITATIVE EVALUATION

Six cases contained thunderstorms which provided a possibility to detect atmospheric vortices. The MDA is capable of identifying a wide range of circulations and weaker circulations tend to be associated with features not related to storms. For this study, only the stronger, operationally significant circulations with strength rank value 5 or greater were compared. Strength rank is a non-dimensional number related to rotational velocity.

Unfortunately, only a few operationally significant mesocyclones fell within the region of best comparison, shown in Figure 1. Thunderstorms that occurred on 18 April, 1 May, and 8 May 2005 had no operationally significant circulations at all. In order to include tornadic circulations in the analysis, some algorithm detections **outside** the region of good comparison were included in the evaluation. The strength rank values of 89 circulation pairs had a correlation coefficient of 0.81.

5. VWP QUANTITATIVE EVALUATION

Velocity Azimuth Display Wind Profile products were requested from time matched volume scans from ORDA and Legacy. The VWP products list wind components, u and v, at various heights. The u and v wind components from the 2 kft, 5 kft, 10 kft, and 18 kft levels were recorded and compared. The u wind component value pairs from 8 cases collected in 2004 were combined and u wind component value pairs from 6 cases collected in 2005 were combined. A similar procedure was followed for the v wind component pairs. Correlation coefficients for the various u, v height combinations ranged from 0.83 to 0.99. Only two of the 16 correlation coefficients were less than 0.90. This analysis contained over 13,000 data pairs.

6. MAXIMUM GRIDDED VIL QUANTITATIVE EVALUATION

The VIL quantitative analysis was expected to show poor correlation because maximum VIL values from ORDA and Legacy systems were not guaranteed to come from the same precipitation area. Over 2200 volume scans were matched in time, maximum VIL values within each radar umbrella were recorded, and correlation coefficients were computed. Correlation coefficients from a diverse set of meteorological events met the preset threshold of 0.7, ranging from 0.77 to 0.99.

7. QUANTITATIVE EVALUATION OF CELL BASED VIL, POH, POSH, AND HAIL SIZE

More than 1300 storms cells from 5 cases, detected by both radars, were evaluated after the cells had been time matched and filtered to eliminate cells outside the good comparison region, shown in Figure 1.

Results are shown in Table 1. All the correlation coefficients meet the prescribed threshold of 0.7 except for the POSH and hail size correlation coefficient values shown for the 6 September 2004 case. A low reflectivity bias in the ORDA radar system during 2004 was identified as the cause.

The computation of VIL and POH are simple functions that are not very sensitive to reflectivity and their correlations are quite high in both 2004 and 2005 as shown in Table 1. Values of POSH and hail size are highly dependent on reflectivity because reflectivity is used as an exponent in the calculation of these two parameters. Therefore, ORDA POSH and hail size values were strongly affected by the low reflectivity bias present in the 2004 data. It's not unexpected that the correlations for POSH and hail size were worse than the correlations for POH and VIL. During 2005, the calibration difference between ORDA (KCRI) and Legacy (KTLX) decreased and correlations between POSH and Hail Size met the prescribed threshold. The reflectivity bias decrease in 2005 was attributed to increased practice and additional experience calibrating the ORDA system.

8. STP QUANTITATIVE EVALUATION

Eight cases were evaluated. Other than a weak squall line on 6 September 2004, no severe weather occurred during these precipitation cases.

Storm total precipitation values were obtained by playing back each case study and capturing the digital data from the WSR-88D precipitation processing algorithm. Separate files were created for each case and each radar. Each file consisted of accumulation values with 1 degree by 115 bins where each bin was 2 km in length.

Unique software to map Legacy accumulation bins to ORDA accumulation bins was also written. The mapping required knowing the latitude and longitude of each radar. Software calculated the latitude and longitude of each ORDA accumulation bin and then computed the range and azimuth from the Legacy radar to the ORDA accumulation bin. The range and azimuth, when converted to integers, pointed to the correct Legacy bin to compare to the ORDA bin. The corresponding pairs of bins were then written to a text file. The text file was transferred to a PC, read in by a spreadsheet, and graphed.

Precipitation values, in 100th inch increments, were saved for each radial from 1 to 360 and for each 2 km bin from 0 km to 230 km. Precipitation data within the red area shown in Figure 2; 100km to 200km, 300º to 360º, 120 º to 180 º; were retained. Precipitation values from both radars were matched by mapping the 2km radar bins so that each radar measurement correlated in time and space.

Table 2 shows the result of the comparison. All the correlation coefficients, except for the case from 9 October, meet the 0.7 criteria. Notice that the two cases that had the smallest correlation coefficients, cells with no shading in Table 2, also had the smallest number of data points.

9. SUMMARY

Algorithm output from 17 cases was compared between ORDA and legacy KTLX radars. Both qualitative and quantitative analyses were performed on 15 algorithm products.

Qualitative analyses of Maximum VIL, OHP, THP, STP, Snow, REC CLR, and REC CLD showed that ORDA and Legacy products were similar. Quantitative analyses, scatter diagrams, and correlation coefficients of Maximum VIL, MDA, STP, SCIT Cell-based VIL, SCIT POH, SCIT POSH, and SCIT Hail Size showed that ORDA data were consistent with Legacy data within the correlation coefficient threshold set before the comparison project began.

Qualitative and quantitative evaluations have shown that ORDA and Legacy algorithm products are compatible. Radar users from the NWS, DOD, and DOT should find ORDA products well-matched with Legacy products.

10. ACKNOWLEDGMENT

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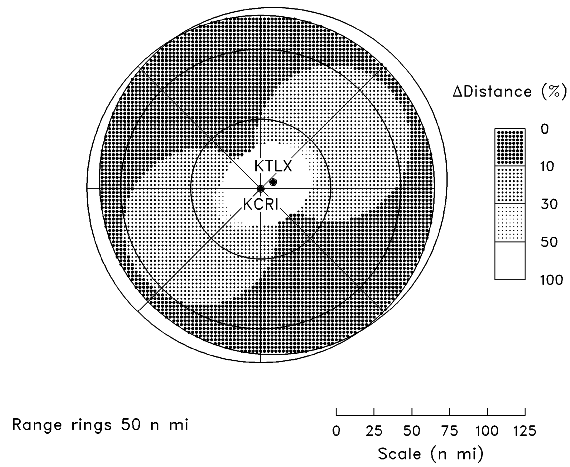

Figure 1.. Geographic distribution of percentage differences in distance from KCRI (ORDA) and KTLX (Legacy) within 230 km (125 n mi) of both radars. Darkest shading indicates locations where distances from the two radar locations are within 10% of each other, the region of good comparison.

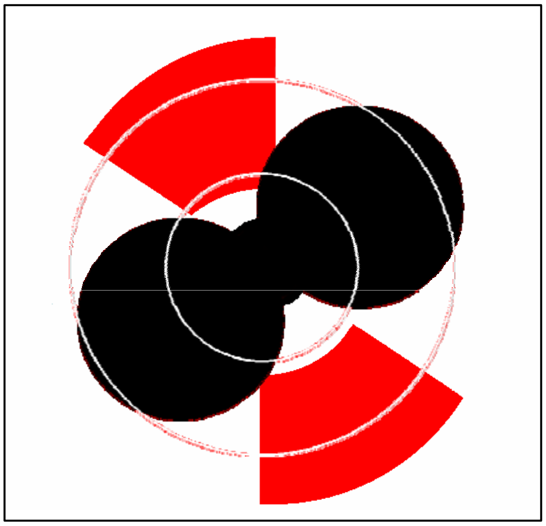

Figure 2. The red region was used to quantitatively compare storm total precipitation fields between ORDA and KTLX systems.

Table 1 – SCIT Correlation Comparison

Algorithm	6 Sep 2004	20 Mar 2005	21 Mar 2005	10 Apr 2005	8 May 2005
# of Storm Cells	694	140	123	199	202
Cell based VIL	0.85	0.96	0.94	0.88	0.94
POH	0.87	0.95	0.91	0.93	0.78
POSH	0.64	0.90	0.96	0.86	0.96
Hail Size	0.57	0.88	0.88	0.92	0.90

Table 2 – Storm Total Precipitation Comparison

Date	**Correlation Coefficient**	**Number of Precip. Measurements**	**Mean Precip. Amount**	
			ORDA (KCRI)	**Legacy (KTLX)**
6 Sep 2004	0.89	7215	0.38	0.53
6 Oct 2004	0.86	4191	0.12	0.13
7 Oct 2004	0.93	5483	0.43	0.55
9 Oct 2004	0.65	2496	0.02	0.07
10 Oct 2004	0.85	5495	0.20	0.40
30 Oct 2004	0.96	6167	1.04	1.75
1 Nov 2004	0.75	2816	0.13	0.14
2 Nov 2004	0.96	4463	0.32	0.41