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WSR-88D ALGORITHM COMPARISONS OF VCP 11 AND NEW VCP 12

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1. INTRODUCTION

A new volume coverage pattern (VCP) 12, planned for deployment in Spring 2004, significantly improves performance of Weather Surveillance Radar - 1988 Doppler (WSR-88D) storm algorithms. New VCP 12 collects data on 14 tilts in 4.1 minutes. Legacy VCP 11 collects data on 14 tilts in 5.0 minutes. Additionally, VCP 12 provides greater vertical resolution at lower elevation angles than VCP 11. Lower elevation angles of VCP 11 are separated by about 1 degree; but lower elevation angles of VCP 12 are separated by about 0.5 degree. Low-level, high-density sampling will allow the VCP 12 radar beam to intercept storms more frequently than the VCP 11 radar beam. National Severe Storms Laboratory (NSSL) and Radar Operations Center (ROC) personnel developed VCP 12 (Brown et al. 2000a; Brown et al. 2000b; Scott et al. 2002; Steadham et al. 2002).

Brown et al. 2003 showed that output from WSR-88D algorithms running in VCP 12 has operational advantages over algorithms running in VCP 11. The primary goal of this study was to independently verify some of the operational advantages identified by Brown et al. 2003. A secondary goal was to show that algorithm output from VCP 12 compared favorably with VCP 11 output.

2. DATA

This VCP comparison study processed archive level II data collected between 2136 UTC on 19 April 2003 and 0410 UTC on 20 April 2003. The Storm Prediction Center (SPC) preliminary severe weather report for 19 April 2003 lists 15 tornadoes: 11 in Oklahoma, two in Kansas, one in Arkansas, and one in Missouri. During the study time period, storm spotters reported six tornadoes within range of the KTLX radar, southeast of Oklahoma City using VCP 11, and the KCRI radar, in Norman using VCP 12. Of the six tornadoes, two were rated F1; two were rated F0; and two were not investigated nor rated. The KTLX radar produced 81 volume scans of data. The KCRI radar produced 93 volume scans of data. The two Oklahoma radars are separated by 19.6 km (10.6 nmi).

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3. METHODOLOGY

Because VCP 11 and VCP 12 have different volume scan update times, a time-matching process paired volume scans so that the time difference was no more than two minutes. As a result, the VCP 12 dataset shrank by 12 volume scans. Time matching produced 81 volume scan pairs.

Archive Level II playback on an ORPG (Open Radar Product Generator) produced output from the storm cell identification and tracking (SCIT) algorithm, the mesocyclone (MESO) algorithm, and the gridded vertically integrated liquid (VIL) algorithm. Matching criteria, azimuth difference less than five degrees and range difference less than five nautical miles, defined a cell or circulation pair. The SCIT algorithm computed storm tracks. If a cell within a SCIT storm track was associated with mesocyclone detection, then the SCIT storm track served as the mesocyclone track.

In order to efficiently reference algorithms running in each VCP, shorthand references are used in this paper. For example, the SCIT algorithm running in VCP 12 will be referred to as SCIT12 and the mesocyclone algorithm running in VCP 11 will be referred to as MESO11.

4. RESULTS

4.1 VCP 12 LOW-LEVEL, HIGH-DENSITY SAMPLING

Of the lower elevation slices, VCP 12 collects data at 0.5, 0.9, 1.3, 1.8, 2.4, and 3.2 degrees. Legacy VCP 11 has elevation slices at angles of 0.5, 1.5, 2.4, and 3.4 degrees. Both SCIT11 and SCIT12 algorithms detected each of the six tornadic storms that were between 156 km and 205 km in range. The SCIT12 algorithm, on average, sampled 5 layers within each storm. The SCIT 11 algorithm, on average, sampled 3 layers within each storm. Forecasters, trying to issue tornado warnings with VCP 12, would have had velocity and reflectivity data at two additional elevation angles to support their decision.

4.2 STORM CELL IDENTIFICATION

Table 1 shows a summary of the storm cell comparison. The SCIT12 algorithm identified some storm cells not found by SCIT11 and vice versa. In total, the SCIT algorithms identified 1851 storm. The 738 cell pairs, found by both VCP SCIT algorithms, represented 80% of the total number.

	KCRI Only (VCP 12)	Both	KTLX Only (VCP 11)	Total
Cell Detections	309	1476	66	1851
Percent of Total	17%	80%	3%	

Table 1. Storm cell identification comparison

Twenty-five times, two storm cells from SCIT11 matched with one storm cell from SCIT12. Experience with SCIT suggests that the algorithm does a better job vertically associating 2-dimensional features when it uses additional elevation data. VCP 12 more accurately samples storm cells because of low-level, high density sampling. When matching criteria provided more than one candidate, a subsequent rule specified that the closest VCP 11 / VCP 12 cells should match.

The SCIT11 algorithm identified a small number of cells that SCIT12 missed. The reason that the new SCIT12 missed these cells is unknown. This study used operational software that did not provide intermediate algorithm output. A review of cell attributes did not suggest any obvious reasons for the misses. However, SCIT is known to fragment large cells into smaller elements (Johnson et al. 1998).

At ranges beyond 185 km (100 nmi), SCIT12 identified 122 more storm cells than SCIT11. Beyond 277 km (150 nmi), SCIT12 identified 13 cells that SCIT11 missed. The SCIT algorithm from both VCPs identified a storm cell very close to each of the six reported tornadoes.

New SCIT12 output compared favorably with SCIT11 output with respect to the large percentage of common cells identified by both algorithms. On the other hand, SCIT12 identified 17% more cells than SCIT11. Additional SCIT12 cells helped maintain storm tracks, avoiding cell track re-identification and preserving cell trend data. Storm cells that SCIT12 found at larger ranges, missed by SCIT11, would have provided forecasters with additional information. Based on past experience testing algorithms and examining forecaster needs, SCIT12 provides better information than SCIT11.

4.3 STORM CELL TRACKING

For purposes of this study, a cell track contains two or more cells linked in time by the SCIT tracking algorithm. The longest cell track, identified by SCIT12, lasted 44 volume scans. The SCIT11 algorithm identified the same storm feature in 39 volume scans. However, the volume scans did not form a continuous track. Legacy SCIT11 required three cell re-identifications over the detectable life of the feature resulting in four separate cell tracks. The SCIT 12 algorithm grouped an average of 6.5 cells per track. The SCIT11 algorithm grouped an average of 5.5 cells per track.

Table 2 shows that SCIT12 identified 62 cell tracks not found by SCIT11. Additionally, the SCIT12 algorithm found 97%, (62 + 88 pairs) / 154, of all storm cell tracks. The SCIT11 algorithm found 60%, (4 + 88 pairs) / 154, of all cell tracks.

	KCRI Only (VCP 12)	Both	KTLX Only (VCP 11)	Total
Cell Tracks	62	176	4	242
Percent of Total	25%	73%	2%	

Table 2. Storm cell track comparison.

When SCIT11 fails to maintain a cell track because of a time association error that results in a cell track re-identification, cell trend data is "chopped up". Rather than representing the entire storm history, cell trend data is contained in smaller, separate tracks. Longer storm tracks that are temporally consistent cell identifications, as computed by SCIT12, provide forecasters with more accurate cell trend data.

4.4 MESOCYCLONE ALGORITHM

Table 3 shows a summary of the mesocyclone detection comparison. The MESO12 algorithm found 49 circulations and the MESO11 algorithm found 21 circulations. Therefore, the MESO12 algorithm identified more than twice as many circulations as MESO11. Additional MESO12 detections help fill in Mesocyclone tracks, identify more circulations associated with reported tornadoes, and detect circulations at greater range than the MESO11 algorithm. Note that the mesocyclone analysis is based on a relatively small sample size compared to the SCIT analysis.

	KCRI Only (VCP 12)	Both	KTLX Only (VCP 11)	Total
Meso Detections	31	36	3	70
Percent of Total	44%	52%	4%	

Table 3. Mesocyclone comparison.

Mesocyclone tracking results mimicked SCIT tracking results. On average, VCP 12 output contained 4.8 mesocyclone detections per track. Legacy VCP 11 output contained 2.3 mesocyclone detections per track. The MESO12 algorithm detected circulations near three of the six tornadoes and found a total of 17 detections associated with the reported tornadoes. Output from the MESO11 algorithm identified circulations near two of the six tornadoes and identified a total of 11 detections associated with the reported tornadoes. New VCP 12 provided the same advantage to the mesocyclone algorithm as provided to the SCIT algorithm. Beyond 185 km (100 nmi), the MESO12 algorithm identified 12 circulations that the MESO11 algorithm missed.

The MESO12 algorithm detected more circulations associated with tornadoes, more circulations at farther ranges that MESO11 missed, and more mesocyclone detections per track by virtue of improved SCIT12 tracking. Forecasters will greatly benefit from these operational advantages provided by VCP 12.

4.5 VIL AND CELL AZIMUTH / RANGE

The VIL algorithm computed gridded VIL values within the VCP 11 and VCP 12 radar domains for each of the 81 time-matched volume scans. Because of low-level, high-density sampling, the VIL12 algorithm assumes less about the vertical structure than the VIL11 algorithm. The VIL12 algorithm is inherently more accurate than the VCP11 algorithm.

An analysis of the 81 common volume scans computed a correlation coefficient of 0.91 between VCP 11 maximum values of gridded VIL and VCP 12 maximum values of gridded VIL. A scatter diagram was created and is shown in Fig 1. A separate analysis of the 738 common storm cells, not shown, computed a correlation coefficient of 0.90 between VCP 11 cell-based VIL values and VCP 12 cell-based VIL values.

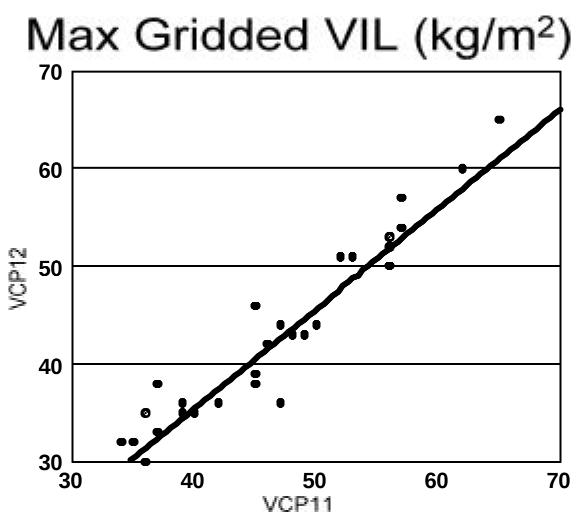

Figure 1. Max Gridded VIL comparison.

To study SCIT's ability to identify storm cell location, a translation algorithm re-computed KCRI (VCP 12) azimuth and range values of the 738 common storm cells. This translation simulated KCRI storm cell positions from the KTLX (VCP 11) location. After the translation, a statistical analysis compared the azimuth and range of each matched storm cell. Table 4 shows the result of the comparison.

	Azimuth	Range
Mean Difference	-0.05 deg	1.9 km (1.03 nmi)
STD	0.86 deg	2.8 km (1.51 nmi)
Corr. Coeff.	0.97	0.99

Table 4. Azimuth and range comparison.

The VIL12 calculations are inherently more accurate and highly correlate with VIL11 calculations. Storm cell azimuths and ranges, computed from SCIT12 output, correspond to a high degree with SCIT11 storm cell locations. These results suggest that VIL and storm cell location output from SCIT12 is highly correlated with output from SCIT11.

5. SUMMARY

This study examined 81 volume scans from a tornado outbreak that lasted approximately seven hours. Based on this independent investigation, storm algorithm output studied from VCP 12 compares favorably with output from VCP 11. When differences were observed between storm algorithm products from VCP 11 and VCP 12, VCP 12 products were judged to be superior. This independent study confirmed the operational advantages of VCP 12 identified by Brown et al. 2003.

This study confirmed that values of gridded VIL and cell-based VIL are highly correlated between the new and legacy VCPs. This study also computed small mean difference and standard deviation values of storm cell azimuths and ranges between the two VCPs. Additionally, algorithms investigated from VCP 11 and VCP 12 generated similar output, as evidenced by the large percentage of common cells, common cell tracks, and common mesocyclone detections.

Storm cell tracking benefited greatly from VCP 12. The SCIT12 algorithm identified many, less fragmented cell tracks that legacy SCIT11 missed. New VCP 12 also minimized cell re-identification, which resulted in more storm cells per track. Longer, more consistent storm tracks help forecasters better predict future cell locations and provide better cell trend data.

Algorithms using VCP 12 detected storm cells and mesocyclonic circulations at longer ranges than the algorithms using VCP 11. The MESO12 algorithm identified more circulations associated with reported tornadoes. On average, VCP 12 allowed algorithms to identify circulations and cells six minutes earlier. With a higher temporal resolution, VCP 12 offers forecasters the ability to identify dangerous storms at a greater range with a greater lead-time. Severe storm algorithms, operating in VCP 12, performed as well or better than algorithms operating in legacy VCP 11. Forecasters, using VCP 12, will be able to: investigate distant storms with more elevation scans; estimate VIL values more accurately; receive faster VCP updates; detect storms and tornadic circulations sooner; track storms and tornadic circulations longer; and consistently identify cells that belong to the same storm track.

6. REFERENCES

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7. ACKNOWLEDGMENT

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