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P13.15 OPTIMIZING THE ITWS ALGORITHM DESIGNED TO REMOVE ANOMALOUS PROPAGATION GROUND CLUTTER FROM THE ASR–9 PRECIPITATION PRODUCT*#

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1. INTRODUCTION

A key product within the Integrated Terminal Weather System (ITWS) Initial Operating Capability (IOC) product suite removes anomalous propagation (AP) ground clutter from the ASR–9 precipitation product. This has been identified as a critical component of ITWS due to the frequent occurrence of AP when storms or outflows move over an ASR–9. Editing is accomplished by comparing the raw ASR–9 weather data to composite maps generated by the Next Generation Weather Radar (NEXRAD) and the Terminal Doppler Weather Radar (TDWR). An editing template, containing regions of AP, is created based on the ASR–9 data collected at the middle of the composite volume scan to minimize the difference in update rates. The template is used to edit the ASR–9 scan immediately after the composite map and all subsequent scans until a new composite map is received.

This algorithm has been shown to perform quite well, especially if the weather and AP returns are not co–located. During the 1994 Demonstration and Validation Operational Test and Evaluation in Memphis (MEM) and Orlando (MCO), the probability of editing AP (PEAP) in the absence of weather was 0.97 for level 2 and greater returns (Klingle–Wilson, 1995). The probability of editing weather (PEW) for those cases with weather only was quite low, i.e., 0.01. In order to minimize the removal of weather returns in those cases where the AP and weather are located in close proximity, the editing thresholds are quite conservative. This is reflected by the 1994 results which show a PEAP of 0.81 and a PEW of 0.02 for this class of event. Besides the conservative thresholds, another area of concern is the fact that the AP regions can expand or increase in intensity after the AP editing template is created. This rapid variation frequently occurs with convectively generated AP and can cause the performance of the algorithm to decrease with time until a new template is created.

In this study, we will examine the algorithm failure mechanisms in detail to identify possible site–adaptable parameter changes that can be used to improve the performance for the mixed weather/AP events. This is especially germane since the parameter set was not re–evaluated after the TDWR composite map was incorporated in 1995. In the critical region over the airport during hazardous weather conditions, this radar updates more frequently than the NEXRAD. Since the parameters were designed to account for the NEXRAD volume update rate, they are probably too conservative for the current algorithm (which uses both composite maps).

2. ALGORITHM DESCRIPTION

The ASR–9 AP editing algorithm uses a combination of composite reflectivity data collected by the TDWR and NEXRAD. An editing template is created based upon the intensity and location of echoes in the ASR–9 image located in the middle of the composite volume scan. This scan is chosen to mitigate the effects of both AP expansion and rapid storm growth (Klingle–Wilson, et al., 1995). A look–up table (Klingle–Wilson, et al., 1995) is used to determine the maximum acceptable valid weather level in all bins of the editing template based on the corresponding composite values. In order to determine the maximum acceptable weather level, a 7 by 7 km area centered on the ASR–9 pixel is searched. If the NEXRAD search area does not contain at least 10 pixels above the corresponding threshold in the look–up table, the ASR–9 data are flagged as AP. The TDWR reflectivity map is used to provide a more rapid update rate in the vicinity of the airport. At favorable geometry sites like MEM, the TDWR data are also employed to edit AP within the NEXRAD "cone of silence." A correlation tracking technique (Chornoboy, 1992) is used to ensure that weather returns which move into a region previously flagged as AP are not inadvertently removed. For a more detailed description of the algorithm, refer to Klingle–Wilson, et al., 1995.

3. TRUTHING/SCORING METHODOLOGY

The AP editing algorithm performance was scored by objectively comparing regions of AP identified by experienced radar meteorologists with the AP regions identified by the algorithm. The meteorologists located AP regions by examination of the raw ASR–9, NEXRAD composite, and TDWR composite data. Polygons were used to classify a region as containing only AP or, AP returns above a nominal level (corresponding to valid weather returns within the polygon). An automated scoring program then computed the PEAP and PEW statistics by a pixel–by–pixel comparison of the meteorologist identified AP and weather regions with the algorithm identified AP. Statistics were computed for pixels whose VIP level was $\geq$2 or $\geq$3. For a human identified pixel of AP to be scored as "edited," the algorithm specified value must be either reduced in intensity by at least one level or removed. Any pixels with valid weather returns that were reduced in intensity or removed by the editing algorithm were classified as an algorithm failure.

4. PERFORMANCE RESULTS WITH CURRENT PARAMETERS

Nine mixed weather and AP cases from MEM were analyzed to assess the performance of the algorithm. These cases would be considered the most challenging and the most operationally significant. In fact, most of the serious algorithm failures reported at the ITWS prototypes is AP embedded in stratiform weather echoes. For these cases, the PEAP for level 2 and greater was only 68 percent, while the PEW was quite low, i.e., < 0.5 percent (Table 1). If we consider level 3 as the minimum editing threshold, the PEAP increases to 82 percent. These results were somewhat less

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encouraging than those determined during the1994 algorithm testing. While the algorithm was able to remove the majority of AP in the most recent cases, the edited precipitation product would be more useful if the PEAP is increased. In addition, the PEW is extremely low and any slight increase in this regard should not deter from the reliability of this product.

Table 1. Algorithm Performance with Current and Modified Parameter Set

Parameter Set	PEAP Level 2+	PEW Level 2+	PEAP Level 3+	PEW Level 3+
Current	**68%**	**0.2%**	**82%**	**0.3%**
Modified	**84%**	**1.6%**	**93%**	**1.4%**

An excellent example of the challenges faced with removing AP from the ASR–9 data are provided by the case with mixed AP and weather from MEM on 29 July 1998 shown in Figure 1.

The upper left panel is the raw ASR–9 data, the NEXRAD composite data are shown in the upper right, and the edited ASR–9 image is depicted in the lower left. An examination of the raw ASR–9 image shows there are significant areas of Level 1–6 AP contamination in the NW, NE, and SE quadrants; which can be distinguished from the polygons enclosing the weather regions. The AP contamination is intermingled with weather returns between a range of 30 to 95 km and an azimuth of 250 to 310 degrees. There are also weather echoes located from 90 to 110 km and 330 to 345 degrees. There is also a small weather cell (not depicted by a polygon) completely embedded in an AP region at a distance of approximately 45 km/020 degrees. With the current editing parameters (lower left panel), the algorithm does a good job of either removing or reducing the intensity of the AP. Even so, there are still significant areas of level 3–6 AP residue in primarily the NW and NE quadrants. A careful examination of the NEXRAD composite data (upper right) reveal several possible causes for the unedited AP. First, there are significant areas of level 1 clear–air returns located in all quadrants. Second, the NEXRAD data are contaminated with isolated pixels of AP residue identified by the three large AP polygons to the south, east, and northeast of the ARENAS (black rectangles). Also, the weather echoes to the west and northwest would adversely impact editing performance. Fi-

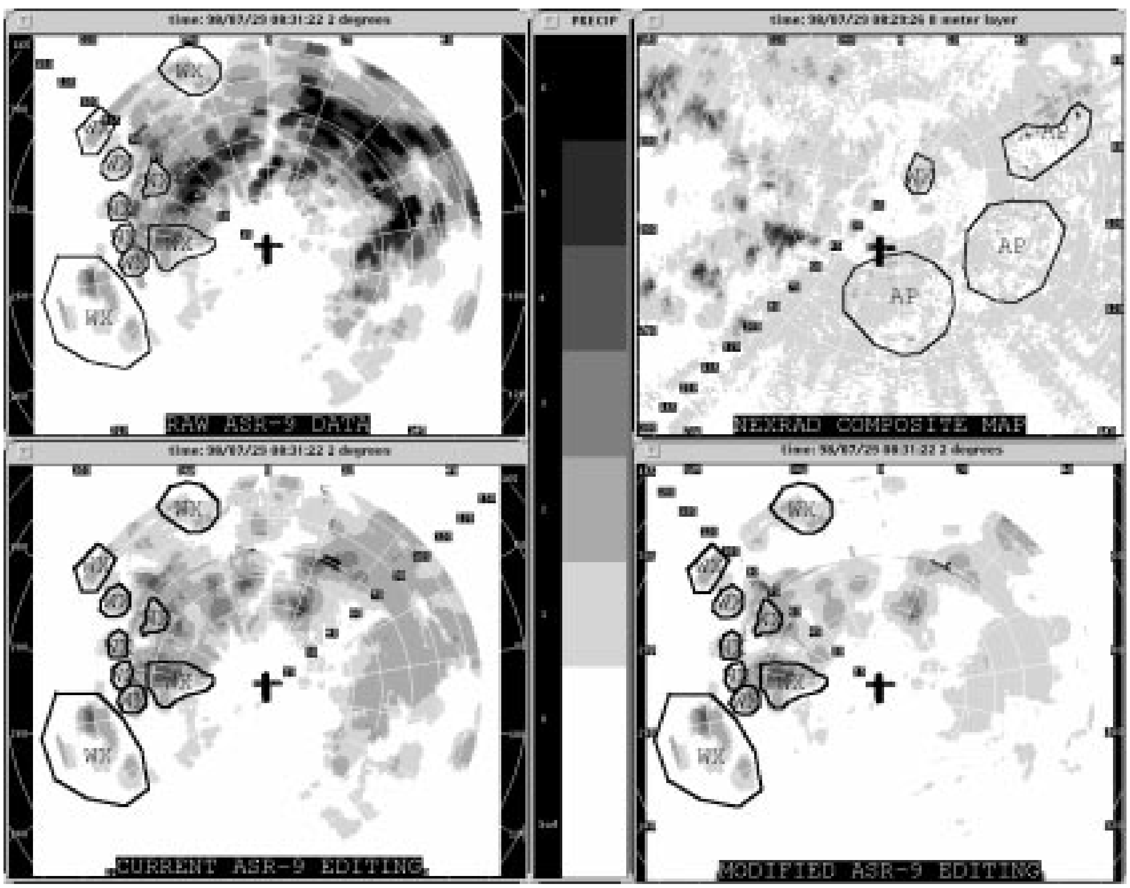

Figure 1. This is a graphic showing the performance of the AP editing algorithm for the 980729 MEM case. All of the data are shown in the standard NWS VIP levels based on the grey scale in the center of the image. The upper left panel displays the raw ASR–9 precipitation field, while the upper right panel shows the corresponding NEXRAD composite reflectivity map. The bottom two panels exhibit the edited ASR–9 precipitation product with the current and modified adaptation parameters. The MEM airport is shown by the black rectangles on each image. All of the images are centered on the airport in order to facilitate a direct comparison. Even so, the coordinate system is different by a 3 degree offset which accounts for a small locational discrepancy between the ASR and NEXRAD data.

nally, there is a small level 2/3 weather echo just east of the NEXRAD (identified with a polygon) which is associated with a larger region of AP contamination in the raw ASR–9 image.

5. DISCUSSION OF PARAMETER MODIFICATIONS

An analysis was undertaken to identify the major causes and characteristics of AP breakthrough. This required a qualitative assessment of the types of returns in the composite map versus the edited ASR–9 reflectivity images. As shown in Figure 2, more than one–half of the AP breakthrough regions were associated with weather echoes. The second most common reason for unedited AP was due to clear–air returns in the composite maps. This was unexpected since AP returns should not be validated based on clear–air data. Finally, AP breakthrough in primarily the NEXRAD map accounted for approximately ten percent of the editing failures. The next step was to determine the maximum composite reflectivity level which was used to validate the AP returns. The results showed that the vast majority, i.e.,~75 percent of the unedited AP regions were associated with only level one composite values (Table 2). In fact, the highest frequency was level 1 composite values confirming level 2 AP. Also, slightly less than ninety percent of all unedited AP regions were only associated with level 1 or 2 reflectivity in the composites. These statistics show that it was very rare for moderate or high reflectivity values to cause AP regions to remain unedited.

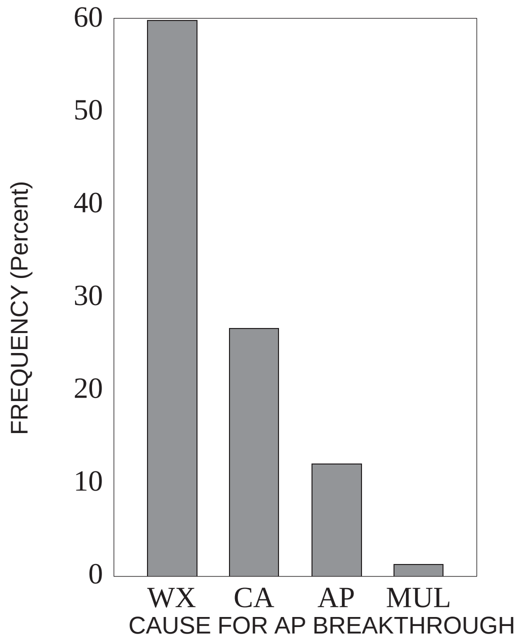

Figure 2. Frequency of ASR–9 AP Algorithm Failure Modes.

Table 2. Frequency Table of Unedited ASR–9 AP Reflectivity Levels (Top) Versus NEXRAD Composite Levels (Left)

VIP	2	3	4	5	6
1	49.27	14.06	7.88	2.23	0.13
2	7.09	4.07	1.57	1.83	0.13
3	1.18	0.52	1.44	1.18	0.13
4	1.44	0.52	0.13	0.26	0
5	0.52	0	0.26	0	0
–	3.41	0.52	0	0.13	0

Based on the analysis presented herein and empirical observations of algorithm failure modes during prototype operations, several parameter modifications designed to improve the overall editing performance were investigated. Each of the parameter modifications are listed in Table 3. The clear–air condition threshold (THLEVEL) was increased from 17 to 22 dBZ in order to compensate for higher clear–air returns during cases of nocturnally induced AP. The reflectivity values used in the look–up table (MINREF) were generally increased by 5 dBZ for all levels. In the case of level 1 and 2 NEXRAD data, the increase was 10 dBZ to match the TDWR parameter settings. Finally, the minimum number of points above a given reflectivity threshold (PERCENTTOFIND) was increased from 12 to 20 percent for level 2 and 20 to 30 percent for level 3 and greater. This final change was made based on the observation that isolated clear–air or AP breakthrough values in the composite maps were causing significant areas of AP to remain unedited.

Table 3. List of Algorithm Parameter Modifications (Current / Modified)

Parameter Name	TDWR Value	NEXRAD Value
THLEVEL	17 / 22	17 / 22
MINREF1	17 / 22	12 / 22
MINREF2	22 / 27	17 / 27
MINREF3	27 / 32	27 / 32
MINREF4	32 / 37	32 / 37
MINREF5	37 / 42	37 / 42
MINREF6	42 / 47	42 / 47
PERCENTTOFIND2	12 / 20	12 / 20
PERCENTTOFIND3	20 / 30	20 / 30
PERCENTTOFIND4	20 / 30	20 / 30
PERCENTTOFIND5	20 / 30	20 / 30
PERCENTTOFIND6	20 / 30	20 / 30

6. PERFORMANCE RESULTS WITH OPTIMIZED PARAMETERS

As shown in Table 1, the modified parameter set was responsible for a significant increase in the PEAP for the nine test cases. In particular, the PEAP for level 3 and greater increased by 11 percent, while the increase for level 2 and greater was 16 percent. This was considered extremely significant since those AP values which were further reduced in intensity by the modified parameters did not contribute to the PEAP statistics if the point had already been reduced. Thus, the actual improvement in AP breakthrough mitigation would be more significant than indicated by the performance metrics.

An examination of the PEW performance with the current and modified parameters revealed an increase in the editing of valid weather returns to approximately 1.5 percent for both threshold levels (Table 1). This might be considered a significant increase since the PEW with the current parameters was < 0.5 percent. However, an analysis of the weather pixels which were edited (Level 2 and greater) revealed that very few were actually removed, i.e., 2.4 percent (Table 4). Even fewer of the level 3 and greater weather pixels were removed, i.e., < 1 percent (not shown). Thus, the vast majority of edited weather values were only reduced in intensity, so there would still be a reflectivity value in the edited bin. In fact, more than 80 percent of the edited weather returns were only reduced by one VIP level (Table 4). Finally, the PEW statistics with the modified parameters would still be well below the 10 percent performance specification (Klingle–Wilson, 1995).

The main consideration for establishing the conservative parameters was to mitigate the editing of weather returns for rapidly developing cells. To address this concern with the new parameter set required an evaluation of the PEW performance on days with significant storm growth. Five days from MEM which fit this scenario were analyzed and the results showed there was little difference over that obtained for the mixed weather/AP events. The PEW for level 2 and greater was 1.3 percent, while the PEW for the level 3 threshold was 0.8. This further bolsters the justification for making the parameters more aggressive in order to improve the PEAP.

Table 4. PEW Statistics for Points Which Were Removed versus Reduced in Intensity

Weather Case	Points Removed	Points Reduced (1 level)	Points Reduced (> 1 level)
980605	2.0%	86.8%	11.2%
980621	0.1%	79.3%	20.6%
980702	3.8%	84.9%	11.3%
980723	2.6%	76.0%	21.4%
980724	1.3%	82.1%	16.6%
Overall	2.4%	80.3%	17.3%

A comparison of the editing performance between the current and modified parameters for the MEM case on 980729 showed a significant improvement (see bottom panels of Figure 1). With the new parameters, the large areas of level 3–6 AP breakthrough in the NW and NE quadrants have been significantly edited. Also, the level 2 breakthrough in the NE and SE quadrants has been virtually eliminated. Finally, the AP contamination just east of the NEXRAD has been properly reduced to a level 2/3 echo. There are only two moderate areas of AP contamination which remain located at 73 km/025 degrees and 80 km/315 degrees. An examination of the weather echoes showed little degradation in this regard. All of the weather echoes have maintained their intensity and coverage. This shows the magnitude of editing improvement capable with the new parameters.

7. SUMMARY AND RECOMMENDATIONS

In this report, the performance of the ASR–9 AP editing algorithm with the current and a modified suite of adaptable thresholds was discussed. While the current parameter set edits the majority of AP, there were cases where the performance was significantly degraded. This was especially evident if the AP returns were located in close proximity to either weather echoes or clear–air data in the composite maps. Isolated pixels of AP residue in the composite maps also served to decrease the performance of the editing algorithm. Based on these observations; the parameter set was modified to be more aggressive in terms of the corresponding reflectivity values, the number of valid points within the search region, and the minimum acceptable threshold for the clear–air condition. This resulted in a significant increase in AP editing performance with only a slight increase in the editing of weather. Since most of the weather returns were only reduced by one level, we recommend these modifications be installed as the defaults for this algorithm.

8. ACKNOWLEDGMENTS

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