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ATC-312

Accuracy of Motion-Compensated NEXRAD Precipitation

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16. Abstract

A number of Federal Aviation Administration (FAA) aviation weather systems utilize Next Generation Weather Radar (NEXRAD) precipitation products including the Integrated Terminal Weather System (ITWS), Corridor Integrated Weather System (CIWS), Medium Intensity Airport Weather System (MIAWS), and the Weather and Radar Processor (WARP). The precipitation products from a NEXRAD [e.g., base reflectivity, composite reflectivity (CR), and vertical integrated liquid (VIL)] are generally only updated once with each NEXRAD volume scan, nominally at 5-6 minute intervals. Hence, the indicated position of storms may not correspond to the actual position due to movement of the storms since the last NEXRAD product update.

This latency is particularly a concern in terminal applications such as MIAWS, which use the NEXRAD precipitation product to provide time-critical information on moderate and heavy precipitation impacts on the final approach and departure corridors and runways. In order to provide a more accurate depiction, the MIAWS precipitation map is updated (advected) every 30 seconds, based on the motion of the storms. The CIWS system performs a similar advection of NEXRAD data before mosaicking the precipitation products from individual NEXRADs. In both cases, motion vectors used for advection are generated by spatial cross-correlation of two consecutive precipitation maps (Chornoboy et al., 1994).

This report addresses the accuracy of the advected precipitation map as compared to the current NEXRAD precipitation map, using seven MIAWS cases from the Memphis, TN test bed and Jackson, MS prototype. We find that the advected precipitation product is significantly more accurate at providing a depiction of the current intensity of the storms as a function of location. Without advection, the precipitation product from successive NEXRAD volume scans differs by at least one VIP level for over 47.5% of the one-square-kilometer pixels and has VIP-level differences of two levels or more for 6.9% of the pixels in cases where both products had precipitation in a location. The advected precipitation product differ by one or more levels in only 17.2% of the pixels and a VIP-level difference of two or more levels is observed in only 1.6% of the pixels. The percentage of cells in which there is precipitation in one map and no precipitation in the other is reduced from over 22% to less than 11% by use of advection.

The analysis approach utilized did not quantitatively determine the relative importance of storm growth and decay over the period of the volume scan versus errors in storm motion estimation in causing the differences between the advected precipitation field and the current precipitation field.

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1. INTRODUCTION

A number of Federal Aviation Administration (FAA) aviation weather systems utilize Next Generation Weather Radar (NEXRAD) precipitation products including the Integrated Terminal Weather System (ITWS), Corridor Integrated Weather System (CIWS), Medium Intensity Airport Weather System (MIAWS), and the Weather and Radar Processor (WARP). The precipitation products from a NEXRAD [e.g., base reflectivity, composite reflectivity (CR), and vertical integrated liquid (VIL)] are only updated once with each NEXRAD volume scan. Hence, the indicated position of storms may not correspond to the actual position due to movement of the storms since the last NEXRAD product update.

Two systems developed by MIT Lincoln Laboratory, however, are using a motion compensation scheme whereby the NEXRAD precipitation map is advected to attempt to more accurately depict the relative location of the precipitation between regular NEXRAD updates (which occur every five to six minutes in precipitation mode). MIAWS, which provides weather information to moderate-capacity airports that are not slated to receive an ITWS or Wind Shear Processor (WSP), is one such system (Rappa et al., 2000). MIAWS currently displays the one-kilometer (km) resolution CR product, edited to remove anomalous propagation (AP). Since the CR map is only updated every five to six minutes, the MIAWS precipitation map is updated (advected) every 30 seconds based on the motion of the storms. The motion vectors are generated by an image-processing technique that compares the output from two consecutive precipitation maps (Chornoboy et al., 1994). In addition, a precipitation impact processor generates moderate ("MOD") and heavy ("HVY") alerts when level three or greater precipitation impacts the airport's runways or approach or departure corridors. Thus, the accuracy of the advected precipitation is important not only in depicting the current location of storm cells, but also in that it serves as input for the impact processor.

CIWS provides traffic flow managers (Command Center, en route facilities, and major terminals), supervisors and area managers, and airline operations centers with accurate, rapidly-updated information on storm locations, echo tops, and forecast positions over the Great Lakes and Northeast corridors (Evans et al., 2002). The use of motion advection for CIWS is motivated by the need to accurately portray storm locations and storm extent. The storm extent issue arises because CIWS mosaics over 25 NEXRADs to provide a single VIL precipitation product. If no allowance is made for motion, differing update times of the individual radars causes an overestimate of the spatial extent of a storm in the direction of motion of the storm. In addition, the apparent location of the storm can change drastically over short periods of time. To accurately portray the location of storm cells, CIWS advects the precipitation products from each of the individual radars prior to mosaicing them (Evans et al., 2002). The CIWS NEXRAD mosaic is updated every two and one-half minutes and the precipitation location is determined by working backwards from the time of the next scheduled update. The precipitation map for each radar is advected using the same techniques described above to the time at which the next mosaic update will take place. Once the advected position of the precipitation is determined for individual radars, the products are mosaiced and updated on the user's displays.

This report proceeds as follows: In section 2.1, the methodology used to analyze the data is discussed. The approach used to quantitatively compare the accuracy with and without advection was to compare the NEXRAD CR product from one volume scan to the same product for the next volume scan on a pixel-by-pixel basis. The analysis approach utilized did not quantitatively determine the relative importance of storm growth and decay over the period of the volume scan versus errors in storm motion estimation in causing the differences between the advected and current precipitation fields. Section 2.2 describes the three case studies used in this report. These include one case with airmass thunderstorms, a high-speed squall-line case, and the passage of a tropical storm with variable storm motion and excellent storm dynamics. Sections 2.3 and 2.4 examine the analysis in detail and section 3 summarizes the results of the study.

2. DATA ANALYSIS AND RESULTS

2.1 METHODOLOGY

This analysis included seven weather cases - five from the MEM MIAWS testbed and two from the JAN MIAWS prototype. The seven cases included a variety of storm motions, including two cases with slow-moving storms (about 10 knots forward motion), two with moderate-speed storms (20-25 knots), two fast-moving cases (45-55 knots), and one tropical storm case with variable speed and direction (see Table 1). This set of cases will hopefully capture advection errors that could occur in a wide array of scenarios. It should be stressed that although this report utilizes data from the MEM and JAN MIAWS, the results can be applied to any system that advects NEXRAD data in a similar manner.

Two different analysis techniques were used. The first method compared one NEXRAD-generated CR map to the following NEXRAD-generated CR map five to six minutes later. This technique ignored advection all together, leaving only the storm's motion and growth and decay as causes for differences between the precipitation maps. This comparison will serve as a "baseline" to show the errors that would be expected without advection, and the improvements realized by using the advection technique.

The second comparison used the same analysis technique, but compared a NEXRAD-generated CR map to the algorithm-generated advected map immediately preceding it to determine if there were errors in the advection. The reason for using the last advected map before a new volume scan was three-fold. First, the precipitation maps being compared were almost always less than 40 seconds apart temporally; thus, there would be very little change in the actual location of the weather during that short time period. Additionally, owing to the small time difference between the precipitation maps, storm growth and decay in that period would also be negligible. Therefore, these two maps, if they both represented what was actually occurring, should be nearly identical. Finally, any errors in the extrapolation technique would compound over the advection period (five to six minutes) and the last advected map should, therefore, have the greatest degree of advection error.

The analysis was accomplished by comparing the two 1-kilometer Cartesian precipitation maps pixel-by-pixel and outputting the difference in weather levels between identically located pixels in the two maps. These differences were then summed for each case. In theory, the NEXRAD generated precipitation product would serve as truth and any differences in the values of the pixels would be attributable to either errors in the advection technique or growth and decay of storms cells. In this report, we do not attempt to discern the causes for errors observed, nor do we classify whether the last advected map had values greater or less than the NEXRAD-generated truth map (the absolute value of the difference was used).

TABLE 1
Summary of cases by storm speed.

STORM SPEED	CASES
FAST (45-55 kts)	011214 (JAN) 020513 (MEM)
MODERATE (20-25 kts)	020605 (MEM) 020613 (MEM)
SLOW (10 kts)	020528 (MEM) 020609 (MEM)
VARIABLE	020926 (JAN)

2.2 CASE DESCRIPTIONS

Three case studies will be discussed in detail in this report. The first, partially represented in Figure 1, is from the JAN MIAWS prototype on the evening of 011213-011214. A rapidly advancing line of thunderstorms crossed the airport (at the center in each panel) around 0045 UTC. There was considerable storm growth and evolution south of the main line, while decay was taking place ahead of the line to the east and along the tail end of the line to the southwest. The cells tracked NE at 55 knots, while the entire line moved ENE at a lesser rate. If the storm motion algorithm incorrectly calculates the forward motion of the cells, one would expect that error to be magnified with faster moving storms as time increases since the last NEXRAD update. This potential error, combined with extensive growth and decay, make this particular example a "worst case scenario" as far as advection is concerned. In addition, storms with a high rate of forward motion will also make a non-advected product much more inaccurate as the amount of time since the last update increases.

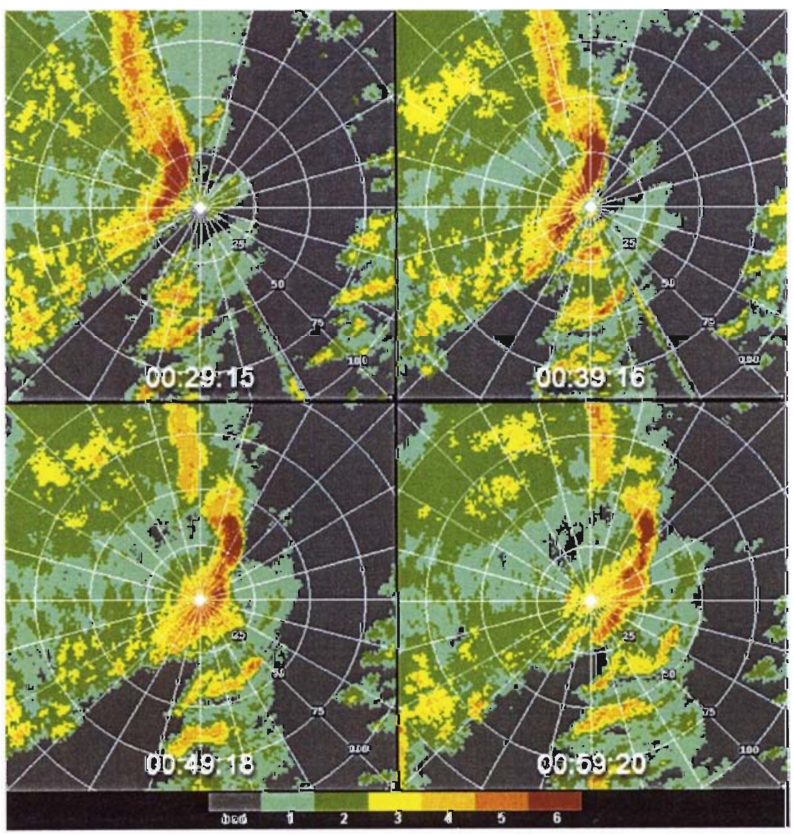

Figure 1. A line of thunderstorms passing over the JAN MIAWS prototype on the evening of 011213-011214. The storms were moving NE at about 55 knots. In all figures, range rings are in 25 km increments and times in UTC.

The second case, 020609, is from MEM and is a summertime airmass thunderstorm case with a high degree of storm growth and decay and very slow cell motion (about 10 knots). The data from this day is useful in determining the accuracy of an advected precipitation product during periods with a high amount of storm growth and decay. Figure 2 shows scattered thunderstorms during a one-hour period of storm growth to the southwest and north-northwest of the MEM airport (just below center in each image). Figure 3 depicts considerable decay in these same areas about three hours later.

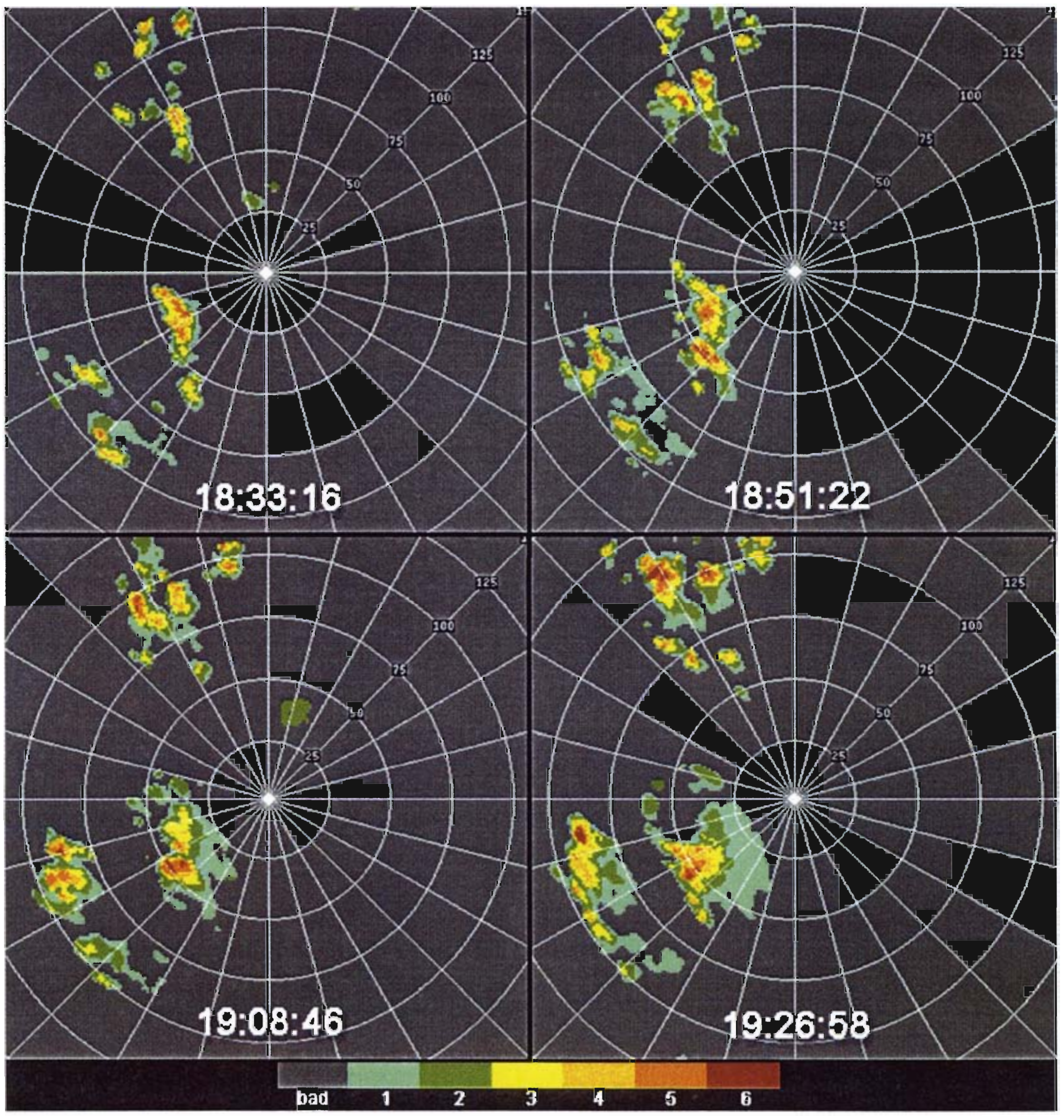

Figure 2. Scattered thunderstorms in a growth stage near the MEM MIAWS testbed on the afternoon of 020609. The storms were moving north at about 10 knots.

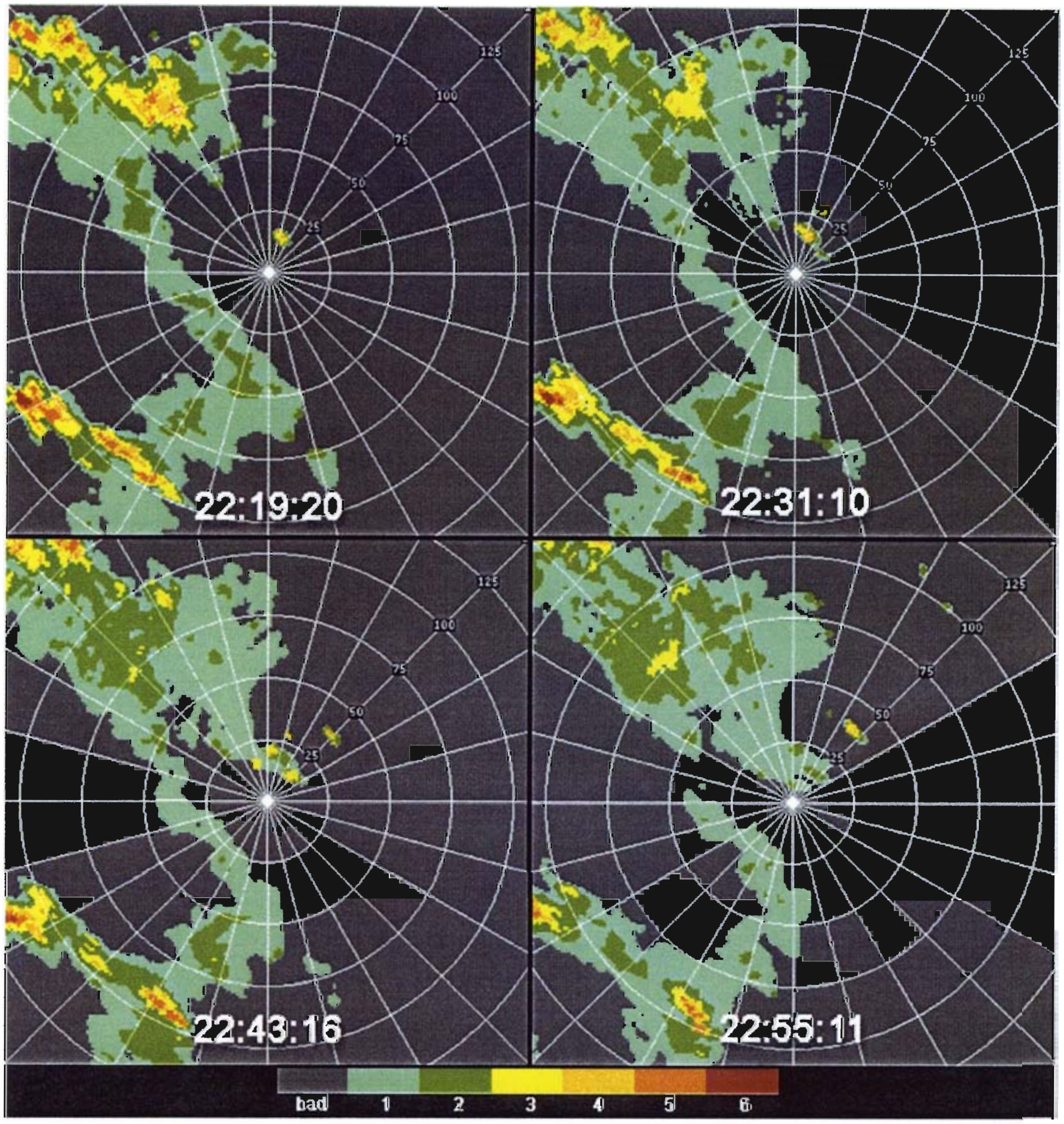

Figure 3. Scattered thunderstorms in a decay stage near the MEM MIAWS testbed on the afternoon of 020609.

The third case, which is depicted in Figure 4, was from 020926, when Tropical Storm Isidore made landfall along the central Gulf Coast and it's remnants moved northward through the state of Mississippi and over JAN. The main precipitation shield moves well ahead of the center of circulation (on its north side), as seen in the first few images in Figure 4. The low itself then follows, with an arc-shaped band of convection that impacts JAN around 1600 UTC. As the low moves farther inland, considerable decay takes place. This case is interesting not only for the storm evolution, but varying degrees of storm motion, as the precipitation literally wraps around the attendant surface low. Thus, while the entire system moves north through Mississippi, the heaviest precipitation in the convective band is primarily moving southwest, south, or southeast, depending on it's position with regards to the center of low pressure.

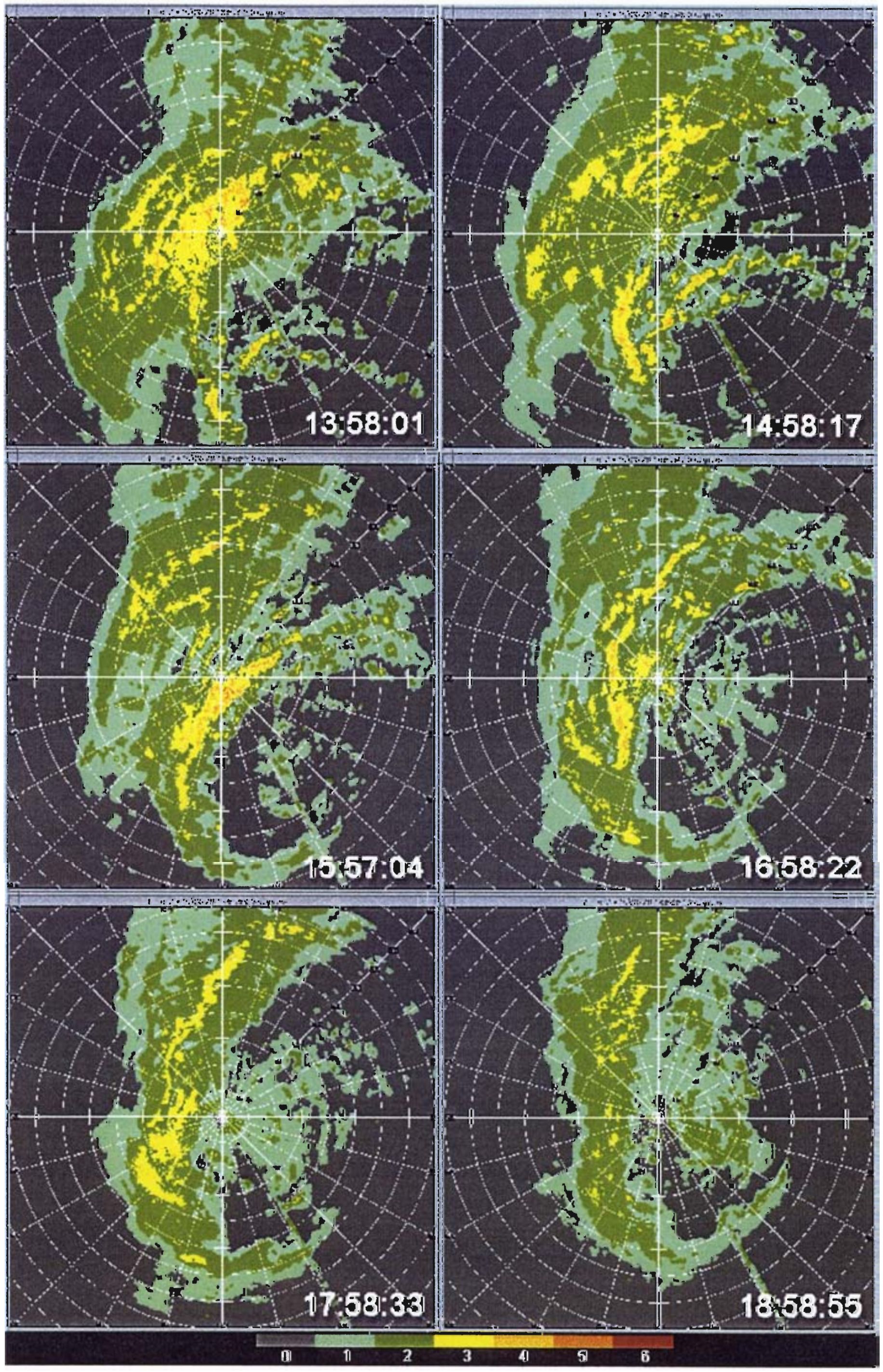

Figure 4. Remnants of Tropical Storm Isidore are clearly visible as the low-pressure system tracked north through southern and central Mississippi near the JAN MIAWS prototype on 020926. The main convective band crossed JAN around 1600 UTC.

2.3 NEXRAD WITHOUT ADVECTION

Using the comparison technique in which one NEXRAD precipitation map is compared to the next (without considering advection); we determine the degree of error that occurs in the first map at the time the second one is received (about five minutes later). This error is calculated by taking the difference between the two images on a pixel-by-pixel basis. Figure 5 shows these results graphically for the first case (011214) around the time of airport impact. The differences are shown using the same six-level color scale as in previous figures; however, Figure 5 does not show the actual precipitation, rather, it depicts the differences between one scan and the next. A difference of one to two levels, for example, is shown in light or medium green, while greater differences are shown in yellow, orange, or red. Due to the high rate of forward motion, we expect the magnitude of error to be substantial by the time the new NEXRAD image is received. This is indeed what happens, as Figure 5 shows some areas with differences of up to six weather levels. In these cases, either a level six storm is occurring in an area where, five minutes earlier, there was not even level one precipitation, or a level six storm has completely cleared an area during the five-minute update. (In this scenario, the latter is less likely due to lingering precipitation behind the main line of storms.)

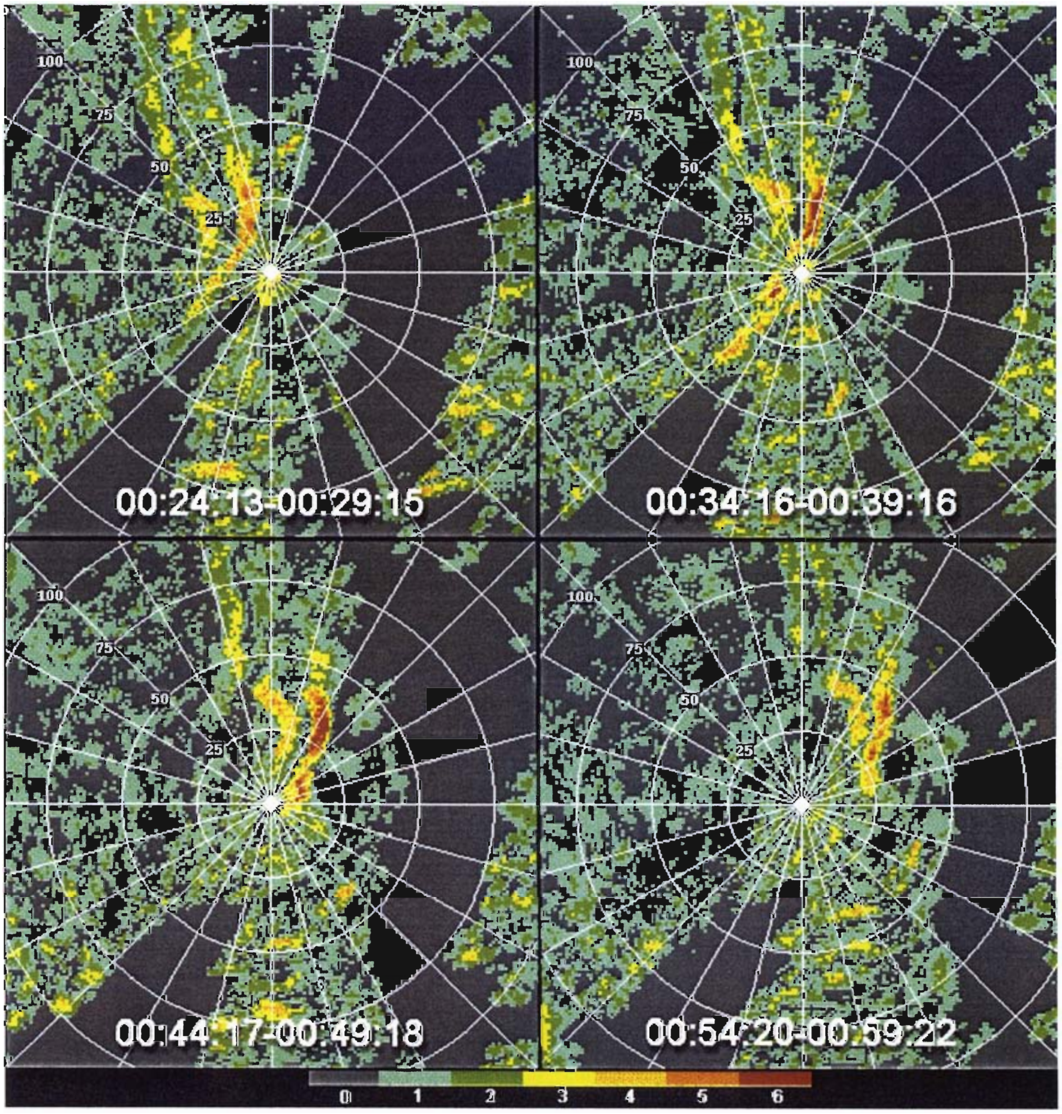

Figure 5. Pixel-by-pixel weather level differences from one NEXRAD CR map to the next for the JAN 011214 case. The color scale shows the weather level differences as depicted in each image (i.e., a difference of 3 weather levels from one scan to the next for a particular pixel is shown in yellow). Times in the lower portion of each panel are the two NEXRAD maps being compared.

As mentioned earlier, the absolute value of the differences is taken, so we cannot definitively determine whether storm motion, growth, or decay is the cause for weather level differences from scan to scan. However, by looking at the actual weather over this period (Figure 1), the differences that arise in the easternmost (right) portion of each panel in Figure 5 are likely due to decay and storm motion, while differences ahead and south of the line (lower portion of each panel) are probably due to growth and motion. The reasoning for the error is not nearly as important as the fact that large differences do exist from scan to scan. Thus, just before a new NEXRAD composite map is received, an old image could be completely invalid when fast-moving storms are present in an area as critical as the near-airport environs, where decisions are made quickly and can change rapidly based on the location of the convection.

Figure 6 shows the pixel-by-pixel weather level differences between succeeding NEXRAD CR maps for select times during the 020609 MEM airmass thunderstorm case. The top two panels show differences during the growth stages of thunderstorms to the northwest and southwest, while the lower two panels depict differences during a period of decay in these same areas. Since the storms are slow moving, there is very little difference in the actual storm positions from one scan to the next; thus, almost all of the differences can be attributed to storm growth and decay, as opposed to Figure 5, in which storm motion played a greater role in scan-to-scan differences. In the growth stage, up to six levels of difference is noted to the northwest (especially in the upper right panel), while a significant amount of growth has also occurred around the 50 km range ring southwest of the NEXRAD in the upper left panel. (The area of level two between 25-50 km north-northeast of center in the upper right panel is an artifact from one of the compared images and is not valid.) During the decay stage, the storm evolution is a slower process; hence the differences from one scan to the next are not as pronounced. However, there are widespread areas of one to two level differences over the western half of each image. The ribbons of level one to two appear due to decay along the edges of the storm cells. So, for airmass thunderstorm cases, updating the precipitation map every five to six minutes when a new volume scan is available is not as big of an issue as for swiftly moving squall line cases. However, growth and decay of the storms will not be captured and will lead to errors in the product that grow exponentially as the image gets older. It should be noted that an advection product that does not take into account storm growth and decay will not reduce the differences that occur from scan to scan, it will only help in more accurately depicting the location of growing or decaying cells.

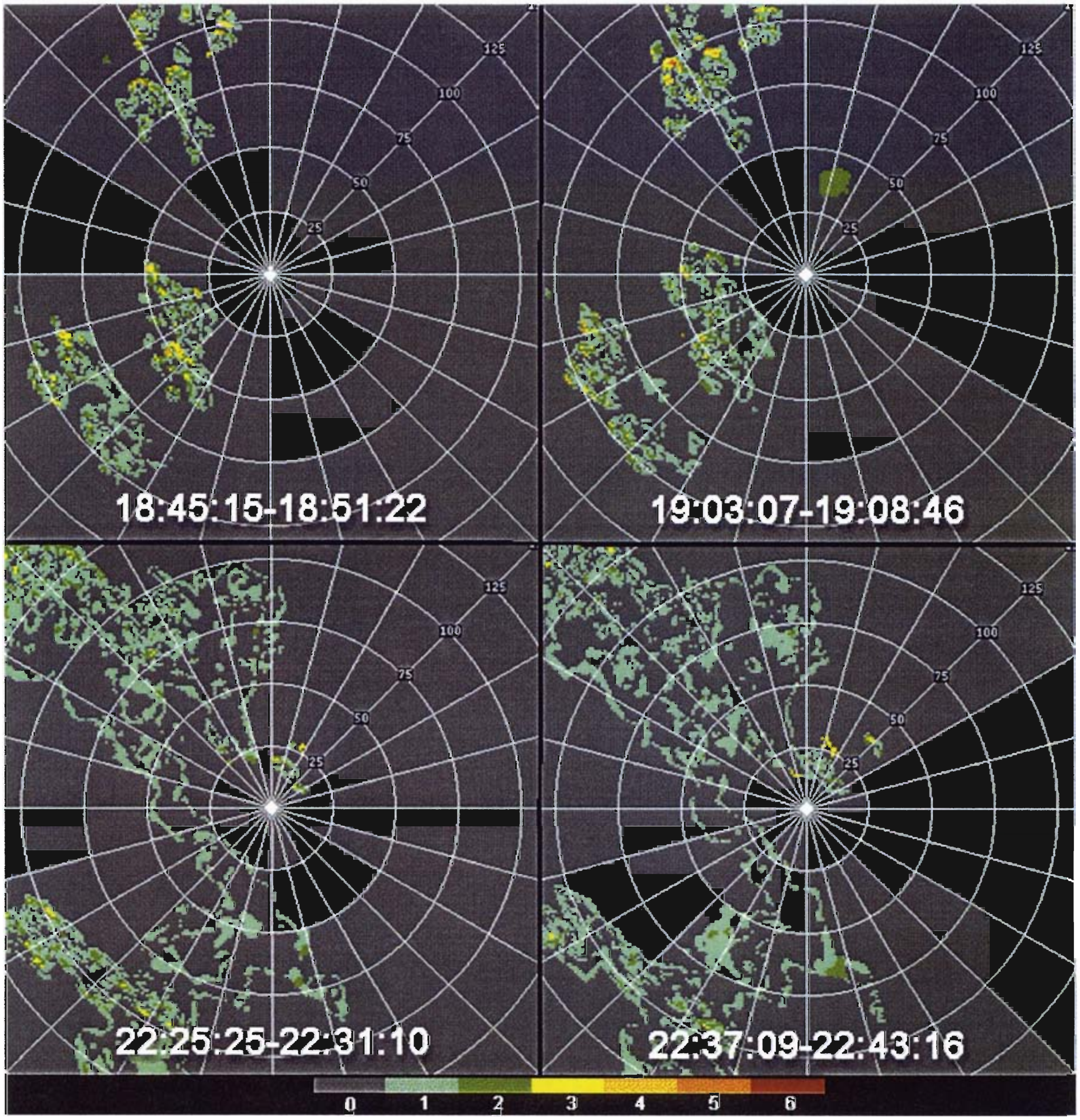

Figure 6. Pixel-by-pixel weather level differences in succeeding NEXRAD CR maps for the MEM 020609 case. The color scale and times are similar to Figure 5.

The third case, 020926 (JAN), was included to illustrate the use of advection when motion is highly variable and there is a fair amount of storm evolution. A tropical storm case fits this description well, especially when the center of the low-pressure area passes through the radar's field of view. Using only the available NEXRAD updates can cause a fairly significant degradation of the precipitation product due to variable storm motion and growth and decay, as illustrated in Figure 7. Up to three to four weather level differences are evident during this time sequence. Recall from the images in Figure 4 that the bulk of the precipitation in this case was level two to three, with some embedded level four to five convective bands. Thus, three to four levels of difference from one NEXRAD update to the next is significant. The series of images in Figure 7 was taken as the main convective band encroached on the airport from the southeast (rotating northwest). The high degree of dynamics (storms rapidly growing and then falling apart) within and very near this main convective band has caused differences of up to four levels over a five-minute period. The motion of the entire system was only moderate, but that motion, combined with the dynamics, produces a large region of unreliable data that misrepresents the actual position of the storms five minutes later.

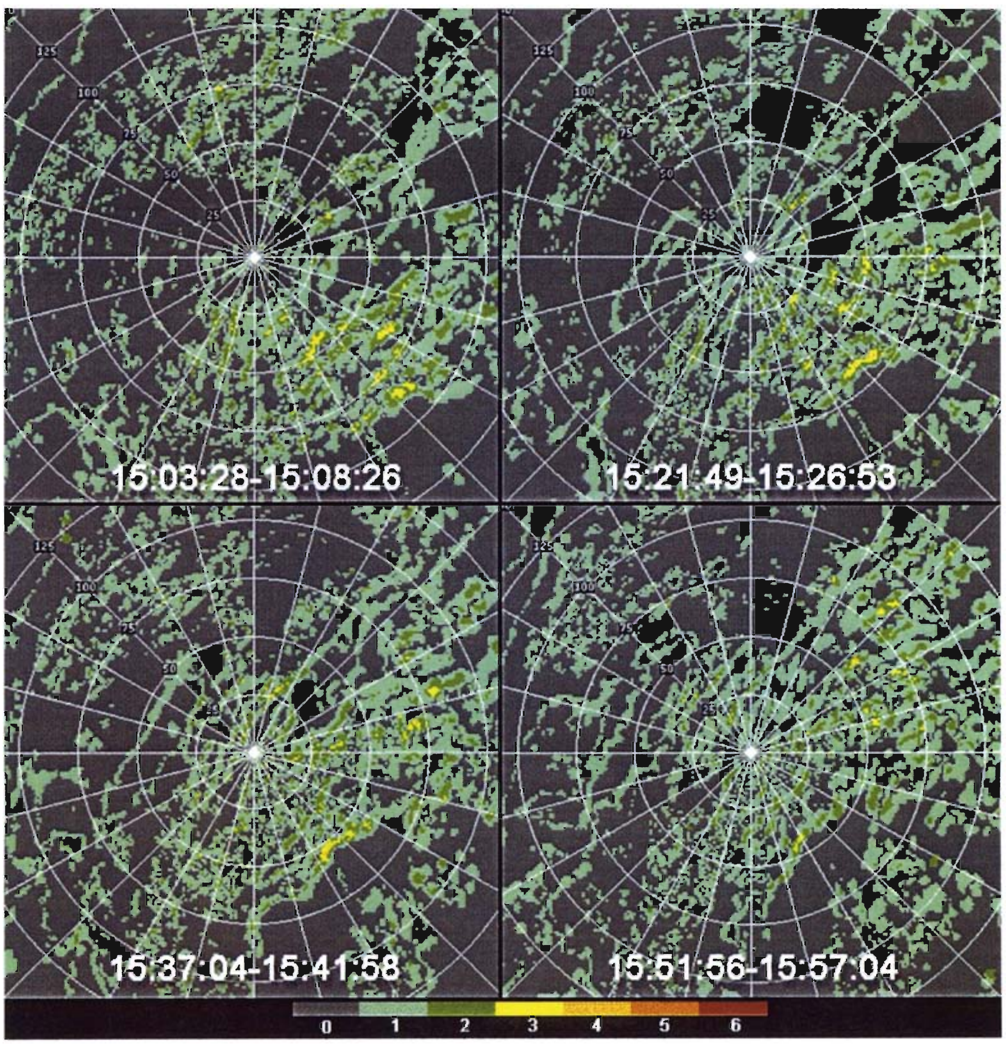

Figure 7. Pixel-by-pixel weather level differences from one NEXRAD CR map to the next for the JAN 020926 case.

Table 2 shows the weather level differences for each case and the average of all cases. The column labeled "Identical" indicates the percentage of each image that had the same weather level from one scan to the next, excluding comparisons of level zero. In all but two cases, this number was less than 50% with the average around 52.5 percent. The average is skewed upwards by the tropical storm case (020926), in which there was a significant amount of stratiform rain, besides the bands of convection. Columns labeled "one level difference", "two level difference", et cetera, indicate the magnitude of the difference between weather levels from scan to scan. These percentages decrease as the magnitude increases, as would be expected. The last column ("precip vs. no precip") indicates the percentage of pixels that, in one scan, contained a weather pixel (level one to six); while in the other scan there was no precipitation (level zero). It does not indicate if the weather pixel was in the old or new scan, but does give an indication of how many pixels contained weather that should not have and vice versa. This statistic ranged from about one-sixth of all pixel comparisons (on 020926) to over one-third (on 020605), and averaged 22.2 percent.

TABLE 2
Weather level differences (pixel-to-pixel) when comparing a NEXRAD-generated composite reflectivity map to the following composite reflectivity map for each case and an average of all cases.

Date	Identical	1 level difference	2 level difference	3 level difference	4 level difference	5 level difference	6 level difference	Precip vs. no precip
011214	47.15 %	44.76 %	6.79 %	1.04 %	0.22 %	0.03 %	0.01 %	27.55 %
020513	48.55 %	41.12 %	7.29 %	2.10 %	0.75 %	0.19 %	0.02 %	19.18 %
020528	53.48 %	40.30 %	4.72 %	1.13 %	0.30 %	0.06 %	0.01 %	21.64 %
020605	36.09 %	48.21 %	10.59 %	3.31 %	1.18 %	0.29 %	0.05 %	33.90 %
020609	45.34 %	43.23 %	8.59 %	2.05 %	0.63 %	0.15 %	0.02 %	29.62 %
020613	38.75 %	47.35 %	9.72 %	2.85 %	0.96 %	0.23 %	0.03 %	30.80 %
020926	61.74 %	35.55 %	2.56 %	0.15 %	0.01 %	0.00 %	0.00 %	15.98 %
ALL	52.42 %	40.67 %	5.42 %	1.08 %	0.31 %	0.07 %	0.01 %	22.24 %

2.4 ADVECTED PRECIPITATION

In the last section, we examined the amount of error from one NEXRAD CR map to the next. However, a technique being utilized by MIAWS takes the latest available NEXRAD image and advects the precipitation map using simple extrapolation techniques as determined by the MIAWS Storm Motion algorithm (Chornoboy et al., 1994). The precipitation map is updated every 30 seconds until a new NEXRAD CR product is received, at which time the NEXRAD-generated precipitation map is displayed. By advecting the precipitation through time, the amount of error that is introduced between NEXRAD updates is significantly reduced (provided the Storm Motion algorithm is performing well). However, the extrapolation techniques do not take into account explicit storm growth and decay that can occur between NEXRAD volume scans or rapid changes in storm motion. We will now examine the improvement that is achieved by using an advected product over a precipitation map that remains static for five to six minutes.

Figure 8 shows, in a manner similar to Figure 5, the weather level differences between the NEXRAD CR map and the advected precipitation map immediately preceding it for the 011214 JAN case. When comparing Figure 8 to Figure 5, it is readily apparent that the use of advection greatly reduces the degree of error between updates. The area covered by yellow, red, and orange, which represent weather level differences of three or more, is significantly reduced. In fact, even the areas with two levels of error are reduced somewhat.

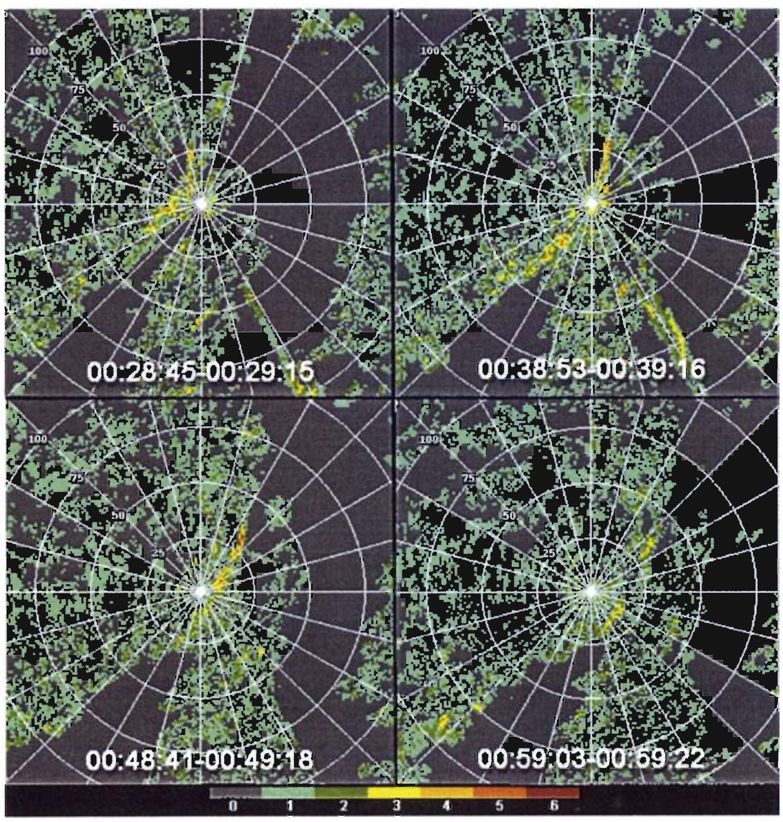

Figure 8. Similar to Figure 5, but comparing the weather level differences between the last advected precipitation map and the new NEXRAD-generated CR map for the JAN 011214 case. The time of the last advected map is listed first in each panel, followed by the time of the NEXRAD CR map.

In summertime airmass thunderstorm cases such as the 020609 MEM case, the storms are moving very slowly, so advecting the precipitation images does not necessarily reduce the errors that result from storm motion because there are so few in the first place. However, in most of these cases, growth and decay of individual cells can take place in a relatively short amount of time. Since advection does not take into account this explicit growth and decay, these errors are not corrected to any great extent. Thus, we would not expect as much of an error reduction when using precipitation advection as in cases with faster motion. Comparing Figure 9 to Figure 6 above, we see that this is indeed the case. While precipitation advection greatly reduced the error rate in the squall line case, there is only a slight reduction in the amount of error for the airmass case. While the areal coverage of pixels with some degree of error remains nearly the same, the magnitude of that error (i.e., level one versus level two) drops. Comparing the statistics in Tables 2 and 3 for this case, we see that the percentage of pixels that are within one level of truth increases significantly when advection is added, so even if the difference is not as noticeable in a qualitative manner, the statistics bear out the benefits of using advection even in an airmass situation.

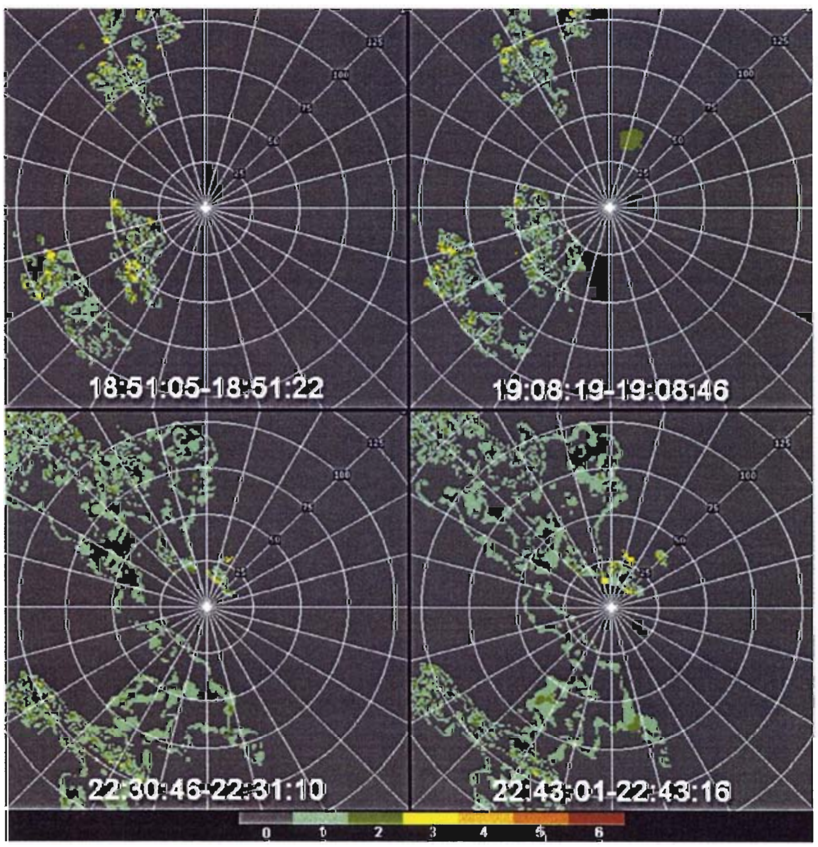

Figure 9. Similar to Figure 6, but comparing the weather level differences between the last advected precipitation map and the new NEXRAD-generated CR map for the MEM 020609 case.

Recall that the tropical storm case from JAN (020926) was included in the database of cases to represent a wide variety of storm motion and strong dynamics that lead to a high degree of storm growth and decay. Figure 10 depicts the error that occurs from the last advected precipitation map to the new NEXRAD product for a short time during this case. It is shown in a manner similar to Figure 7, which represented the error between subsequent NEXRAD updates (ignoring precipitation advection). Comparing the two figures qualitatively, one can clearly see the improvement offered by an advected product. The areas in Figure 7 with three to four levels of difference between updates have been virtually eliminated and most of the error is only one weather level.

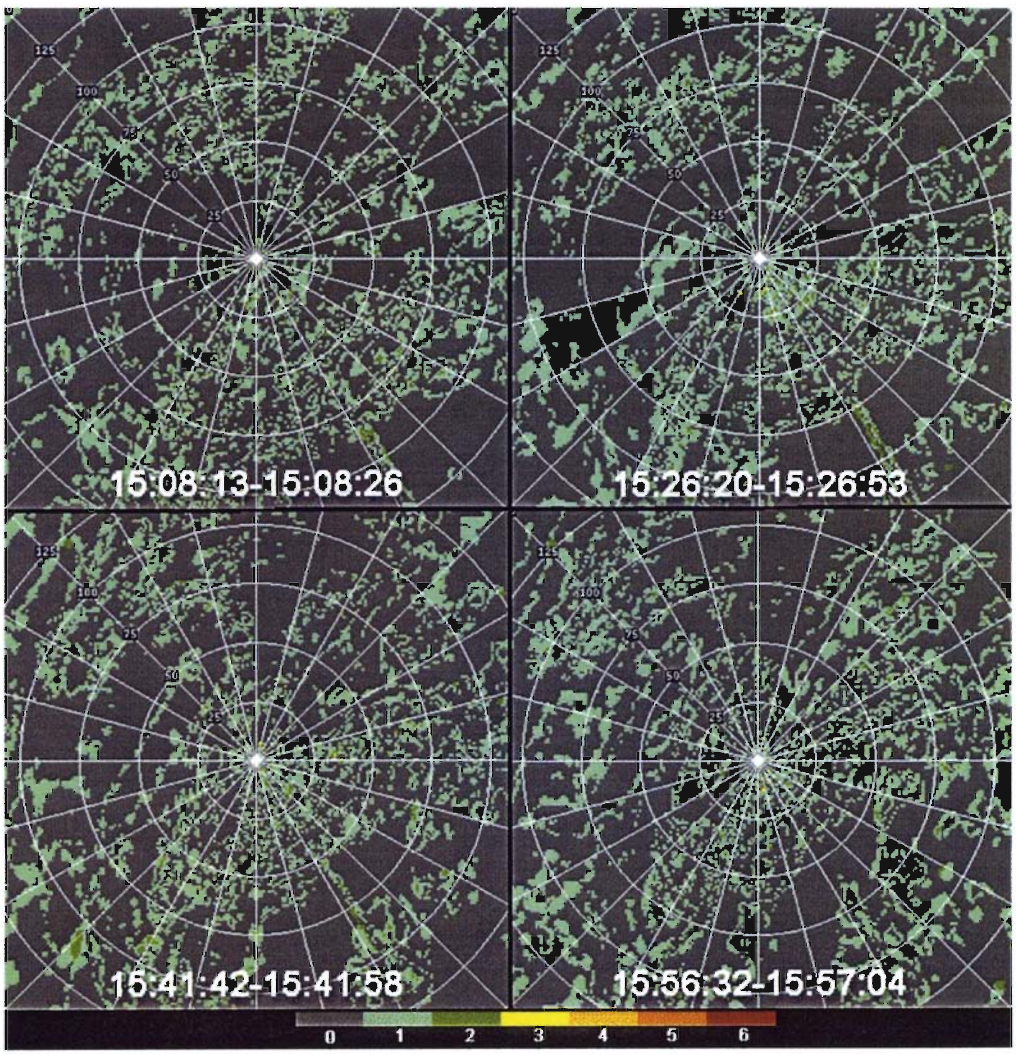

Figure 10. Similar to Figure 7, but comparing the weather level differences between the last advected precipitation map and the new NEXRAD-generated CR map for the JAN 020926 case.

Table 3 quantitatively documents the differences in a similar manner to Table 2. As expected, the fast-moving squall line cases (011214 and 020513) show the greatest disparity between compared precipitation maps, even using advection; however, they are much improved over the values in Table 2. Interestingly enough, the greatest improvements came in the cases with slow storm motion, where advection significantly increased the percentage of identical comparisons (as much as 48% for 020605). As mentioned earlier, advection does not take into account the growth and decay that typically takes place in these slower moving cases, but it does seem to help improve the overall accuracy of the product, even without growth and decay prediction.

TABLE 3
Weather level differences (pixel-to-pixel) when comparing the last advected precipitation maps to the following NEXRAD-generated composite reflectivity maps.

Date	Identical	1 level difference	2 level difference	3 level difference	4 level difference	5 level difference	6 level difference	Precip vs. no precip
011214	60.33 %	37.19 %	2.28 %	0.17 %	0.02 %	0.00 %	0.00 %	19.03 %
020513	77.56 %	16.26 %	1.69 %	0.32 %	0.08 %	0.01 %	0.00 %	9.09 %
020528	82.64 %	13.80 %	1.31 %	0.29 %	0.08 %	0.02 %	0.00 %	8.75 %
020605	84.41 %	10.42 %	1.41 %	0.31 %	0.08 %	0.01 %	0.00 %	8.84 %
020609	84.66 %	11.74 %	1.55 %	0.32 %	0.07 %	0.01 %	0.00 %	8.16 %
020613	84.41 %	10.42 %	1.41 %	0.31 %	0.08 %	0.01 %	0.00 %	8.84 %
020926	79.12 %	17.72 %	0.47 %	0.01 %	0.00 %	0.00 %	0.00 %	10.13 %
ALL	78.81 %	17.15 %	1.29 %	0.21 %	0.05 %	0.01 %	0.00 %	10.56 %

Table 4 sums up the differences between the two comparison techniques using the averages of all cases. The first row shows the weather level differences using only the NEXRAD-generated CR maps (without advection), while the second row shows these differences with advection. As can be seen, the number of pixels that contained weather and were identical from one update to the next (disregarding level zero to level zero comparisons) increased from just above 50 percent to more than 75 percent. Without advection, about seven percent of the pixels disagreed by two levels or more, while adding advection decreased that number to about 1.5 percent. In addition, the percentage of pixels that contained no precipitation (level zero) in one map, but did contain precipitation in the other map, decreased over 50 percent by adding the advection scheme.

TABLE 4
Summary of weather level differences for succeeding NEXRAD composite reflectivity maps and an advected product vs. the following NEXRAD composite reflectivity map.

	Identical	1 level difference	2 level difference	3 level difference	4 level difference	5 level difference	6 level difference	Precip vs. no precip
NEXRAD CR vs following NEXRAD CR	52.42 %	40.67 %	5.42 %	1.08 %	0.31 %	0.07 %	0.01 %	22.24 %
Last advected vs. NEXRAD CR	78.81 %	17.15 %	1.29 %	0.21 %	0.05 %	0.01 %	0.00 %	10.56 %

3. CONCLUSIONS

Advected NEXRAD precipitation products are used in both MIAWS and CIWS systems, under development by MIT Lincoln Laboratory for the FAA. This report has shown that advecting precipitation using a reliable methodology for determining storm motion is worthwhile and can significantly enhance the accuracy of the precipitation product in systems that use sensors with low update rates, such as the 5-6 minute volume scan produced by the NEXRAD. Though storm growth and decay is not accounted for in a pure advection scheme, the airmass thunderstorm case presented clearly shows a benefit to using advection even with little storm motion.

Without advection, the precipitation product from successive NEXRAD volume scans differs by at least one VIP level for just less than one-half of the compared pixels and has VIP level differences of two levels or more for almost 7 % of the pixels in cases where both products had precipitation in that location. The advected precipitation product differs by one level or more in only 17 % of the pixels and a VIP level difference of two or more levels is observed in less than 2 % of the pixels. The percentage of pixels in which there is precipitation in one map and not in the other is reduced from over one-fifth to just over one-tenth by use of advection.

Precipitation advection is very important in the terminal area where small differences in the location of a storm (e.g., to the side of a runway versus over the runway) can necessitate significant changes to air traffic decision-making. The use of advection is particularly important when the user community includes controllers in air traffic control towers, since they can easily compare the location of heavy precipitation with visual observations. This analysis was accomplished using the NEXRAD's composite reflectivity product, which is utilized by MIAWS. However, the results would be applicable to VIL (which is used by CIWS) as well. The database of cases for this study covered as many different scenarios as possible, while still maintaining a manageable dataset. As always, increasing the size of the dataset (provided a representative sample of cases is included) would further validate the statistics and smooth out any large deviations that may occur with a smaller database. However, it is felt that this set of cases, which includes various storm speeds and varying degrees of storms dynamics, is sufficient to draw the conclusions presented here. Also, the approach described did not quantitatively determine the relative importance of storm growth and decay over the period of the volume scan versus errors in storm motion estimation in causing the differences between the advected precipitation field and the current precipitation field. Classifying the reason for the variances between the two maps, although potentially a tedious and time-consuming task, could be a topic of future work.

GLOSSARY

CIWS	Corridor Integrated Weather System
CR	Composite Reflectivity
FAA	Federal Aviation Administration
HVY	Heavy Precipitation Imact (MIAWS)
ITWS	Integrated Terminal Weather System
JAN	Jackson International Airport, MS
MEM	Memphis International Airport, TN
MIAWS	Medium Intensity Airport Weather System
MOD	Moderate Precipitation Impact (MIAWS)
NEXRAD	Next Generation Weather Radar
UTC	Univeral Time Coordinated
VIL	Vertically Integrated Liquid Water
VIP	Video Integrator Processor
WARP	Weather and Radar Processor
WSP	Wind Shear Processor

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