1. Statistical Evaluation of "Simple Fix with Filter" Solution to the Precipitation Truncation Problem

1.1 Introduction

The precipitation truncation problem refers to the underestimation of precipitation estimates in the WSR-88D Precipitation Processing System (PPS) algorithm due to the cumulative effect of slight truncations in the algorithm calculation which was described in the year 2000 MOU Report among the NEXRAD Program, the WSR-88D Operational Support Facility[1] and the NWS Office of Hydrology[2] (Seo et al., 2000). It was explained and documented that the precipitation deficits were directly related to the duration of a rain event (rather than the intensity); were consequently of greatest significance in light, stratiform precipitation events and of least significance in heavy, convective downpours; and the effect was worse in the hourly-based accumulation products (DPA, Hourly Digital Precipitation Array is one of them, which gives hourly rainfall estimates at 131× 131 Hydrologic Rainfall Analysis Project (HRAP) grid points) than in the cumulative Storm Total Precipitation product, STP. In last year's MOU Report (Fulton et al., 2001), two solutions were proposed, and one of them, dubbed the "Simple Fix with Filter" had been implemented in Open Radar Product Generation (ORPG) Build 1. The solution corrects most instances of truncation while retaining the inherent resolution of the algorithm's integer precision at 0.1 mm. To handle the unfortunate new problem of anomalous residuals introduced by this simple fix, a filter was implemented on the running-total hourly accumulation field that resets very light accumulations to zero just before creation of all the hourly-based accumulation products. The filter level was set at 0.5 mm with all values below that level set to zero.

The purpose of this study is to statistically evaluate this impact of the precipitation truncation solution on the DPA products. The statistical results can provide valuable guidance to those who have used DPA products generated by earlier version of the PPS without the fix of the precipitation truncation problem.

1.2 Sample Data

The sample data are from the Sterling, Virginia WSR-88D radar site (KLWX) and are spread over July, December 2001 and January, February, March 2002. These months represent times when operational KLWX DPA was archived. The sample data are spread over different months and times and include both stratiform and convective precipitation events. There are 121 independent hours of DPA data with rain, of which 84 hours are from stratiform rain events and 37 hours are from convective rain events. The precipitation type was determined by visual examination of the images of radar echo and determining the dominant precipitation type. Many events have continuous rainfall lasting for over 10 hours. Therefore, the sample data are large enough to generate a statistical

[1] Since renamed Radar Operations Center

[2] Since renamed Office of Hydrologic Development

evaluation. All DPA products examined have valid times at the top of the hour. The DPA data with the precipitation truncation problem (hereafter referred to as NOFIX DPA data) are collected from the KLWX radar running the legacy RPG system which has the precipitation truncation problem. The DPA data with the "Simple Fix with Filter" correction (hereafter referred to as FIX DPA data) are obtained by replaying the Archived II base data (ordered from National Climate Data Center) using the ORPG Build 1 system.

Before processing Archived II base data, all PPS adaptation data fields were checked in the DPA product header to ensure the generated FIX DPA data would have the same adaptation data as those in NOFIX DPA data. Table 1 lists the date, time, type of rain event, and some adaptation data values of all NOFIX and FIX DPA data, while other adaptation data not listed use default PPS values. For the adaptation data, the only changes from default values are the multiplier coefficient and the exponent coefficient in the Z-R relationship and the maximum precipitation rate. For all the convective rain events, 300, 1.4 and 103.8 mm/hr, which are default values, are utilized respectively. Meanwhile, they are changed to be 130, 2.0, and 76.0 mm/hr using the Human Computer Interface (HCI) utility of ORPG for all the stratiform rain events. All convective rain events happened in July, 2001, while in other months stratiform rain events occurred.

Table 1. The characteristics of all sample data.

Date	Time (UTC)	Precipitation Type	Multiplier Coefficient	Exponent Coefficient	Maximum Precipitation Rate (mm/hr)
Jul. 24, 2001	18Z to 23Z	convective	300	1.4	103.8
Jul. 25, 2001	15Z to 23Z	convective	300	1.4	103.8
Jul. 26, 2001	01Z to 05Z, 09Z to 21Z	convective	300	1.4	103.8
Jul. 27, 2001	02Z to 05Z	convective	300	1.4	103.8
Dec. 11, 2001	01Z to 18Z	stratiform	130	2.0	76.0
Dec. 18, 2001	02Z to 08Z, 16Z	stratiform	130	2.0	76.0
Jan. 06, 2002	10Z to 23Z	stratiform	130	2.0	76.0
Jan. 07, 2002	00Z to 02Z	stratiform	130	2.0	76.0
Jan. 24, 2002	09Z to 21Z, 23Z	stratiform	130	2.0	76.0
Jan. 25, 2002	00Z to 09Z	stratiform	130	2.0	76.0

Feb. 07, 2002	03Z to 13Z	stratiform	130	2.0	76.0
Mar. 16, 2002	01Z to 06Z	stratiform	130	2.0	76.0

It was found that there exists gaps in the sample data during some long continuous rain events. Either the lack of NOFIX DPA data (such as 22Z, January 24, 2002) or the lack of Archived II base data (such as 22Z, July 26 to 01Z, July 27, 2001) accounts for these gaps. Due to various reasons, a few of volume scans could not be processed, hence the DPA data at the top of that hour will not be used in the sample data set.

1.3 Statistical Results

The statistical computations are performed for two different types of precipitation events: stratiform precipitation and convective precipitation. For the purpose of statistics, a grid point is counted as a sample grid point only when it is classfied as one with rain in either the FIX DPA data or NOFIX DPA data or both. All such grid points are included in the statistical evaluation. In all statistical computations, the FIX DPA data are considered as the "true value". The absolute error is the subtraction of FIX DPA data from NO FIX DPA data at the same HRAP grid point and the same time. The rain volume is defined as the product of depth and area of rainfall. Since the DPA product gives hourly rainfall estimates at 131 × 131 quasi-rectangular HRAP grid points of nominal grid size of 4 km × 4 km, "mm·km^2" is simply adopted as the unit of rain volume.

Before the statistical computations were performed, FIX DPA data and NOFIX DPA data were displayed to visually prove some conclusions in the 2000 MOU Report. It was stated that the net impact of precipitation truncation problem on the DPA product was that, after the first hour, accumulations will be underestimated by, on average, 1.5 to 2.0 mm per hour for all hourly-based products, and the effect was cumulative: the running-hourly-total grid-field will be diminished by an additional 1.5 to 2.0 mm/hr for each hour that rain continues steadily. One Hour Precipitation (OHP) products at the beginning and ending hour of the rain event were compared to show such cumulative effect. Here, this cumulative effect was proved in the display of DPA data as well.

Fig. 1 and Fig. 2 show the display of NOFIX and FIX DPA data at the early time and 12 hours later for a continuous stratiform (10Z and 22Z, January 6, 2002) and convective (09Z and 21Z, July 26, 2001) precipitation event respectively.

In Fig. 1, the two top panels give the display of NOFIX DPA data (left panel) and FIX DPA data (right panel) at the early time (10Z) of a continuous stratiform precipitation event on January 6, 2002, while two bottom panels are for 12 hours later (22Z). At the early time, the two panels appear similar, however the FIX DPA data shows the larger rain area. After 12 hours, two panels show significant differences. The FIX DPA data shows a larger rain area (94272 km^2), where the NO FIX DPA data shows a dispersed, smaller rain area (29696 km^2). The maximum rainfall amount in FIX DPA is also significantly greater than that in NOFIX DPA (10.29 mm vs 6.49 mm).

Fig 2 depicts that the cumulative effect exists in the convective precipitation event as well. However, the effect is not so serious as that in the stratiform precipitation event.

Besides visually showing the cumulative effect in Figs. 1 and 2, some statistical results are

Fig.1. The display of one-hour rainfall from NOFIX (left panels) and FIX DPA (right panels) for a stratiform precipitation event (Jan. 6, 2002) during the first hour (top panels) and 12 hours later (bottom panels).

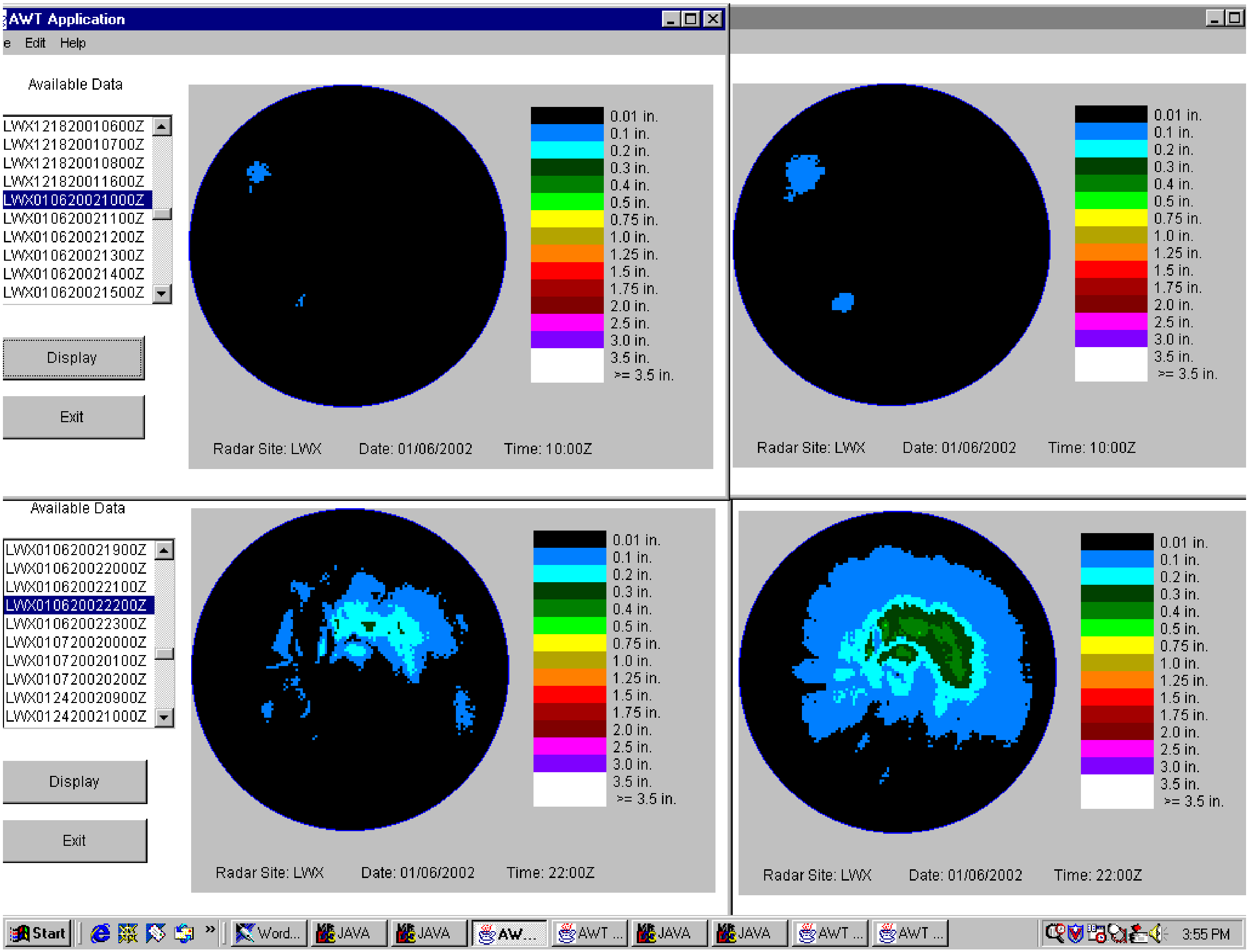
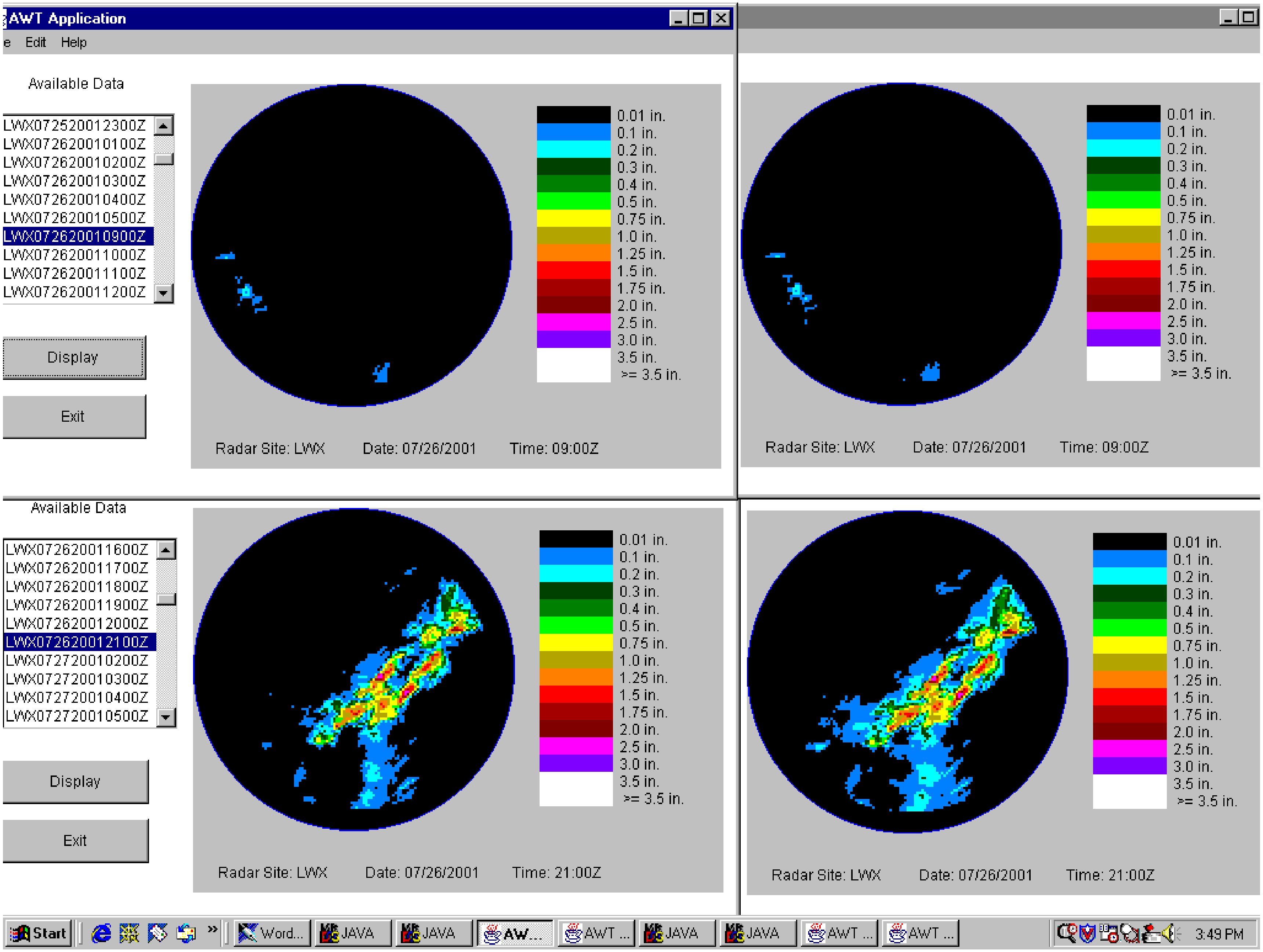


Fig.2. Same as Fig. 1 but for a convective precipitation event (Jul. 26, 2001).



presented in Table 2 to quantitatively show the effect. Tables 2a and 2b list the mean absolute error (MAE), the root mean square error (RMSE), maximum values (MAX) of FIX DPA and NOFIX DPA and their difference (MAX-DIF), the rain volumes (RV) of FIX DPA and NOFIX DPA and their difference (RV-DIF), etc. at early time and 12 hours later for the two rain events.

The statistical results listed in Tables 2a and 2b clearly showed the cumulative effect. For the stratiform rain event (Table 2a), the absolute value of MAE, RMSE, MAX-DIF, and RV-DIF at early time are all much lower than those at 12 hours later: 0.55 mm vs 1.85 mm, 0.59 mm vs 2.28 mm, 0.90 mm vs 3.80 mm, 2139 mm·km^2 vs 174431 mm·km^2, respectively. This is also true for the convective rain event (Table 2b): 0.27 mm vs 0.94 mm, 0.37 mm vs 1.10 mm, 0.17 mm vs 1.74 mm, 496 mm·km^2 vs 43098 mm·km^2, respectively. These numbers proved that the truncated hourly rainfall at later time of a rain event is much greater than that at early time, hence the impact of precipitation truncation is more severe for the longer duration of precipitation. On the other hand, comparing the stratiform rain event (Table 2a) to convective rain event (Table 2b), it can be seen that the absolute value of MAE, RMSE, MAX-DIF, and RV-DIF for the stratiform rain event are all greater than those for the convective rain event at both early time and 12 hours later. For example, at the early time of rain event, the comparison of stratiform rain event (Table 2a) vs. convective rain event (Table 2b) is: absolute value of MAE, 0.55 mm vs 0.27 mm; RMSE, 0.59 mm vs 0.37 mm; MAX-DIF, 0.90 mm vs 0.17 mm; RV-DIF, 2139 mm·km^2 vs 496 mm·km^2. At 12 hours later, it is: MAE, 1.85 mm vs 0.94 mm; RMSE, 2.28 mm vs 1.10 mm; MAX-DIF, 3.80 mm vs 1.74 mm; RV-DIF, 174431 mm·km^2 vs 43098 mm·km^2. These comparisons supported the conclusion mentioned above that the cumulative effect in the convective precipitation event is not so serious as that in the stratiform precipitation event.

Table 3 presents more ensemble statistical results which are computed using all sample data for both types of precipitation. Shown are total number of sample grid points, the number of sample grid points with lower or greater FIX DPA and its percentage, MAE, RMSE, maximum difference, RV, etc. A sample grid point with lower (greater) FIX DPA is one at which the value of FIX DPA is less (not less) than the value of NOFIX DPA.

From Table 3, it can be seen that the statistical results show some similarities and discrepancies between the stratiform precipitation and the convective precipitation. Both stratiform precipitation and convective precipitation show negative MAE values as expected, and the grid points with greater FIX DPA dominate. However, corrected hourly rainfall amounts for the two different precipitation types are significantly different. The absolute value of MAE and RMSE for the stratiform precipitation are much greater than those for the convective precipitation, i.e., 1.22 mm vs 0.68 mm, 1.52 mm vs 0.89 mm as shown previously. The percentage of the grid points with lower FIX DPA in all grid points with rain for the stratiform precipitation is much less than that for the convective precipitation, i.e., 0.2% vs 1.2%. The reason why there exists the grid points with lower FIX DPA is likely from the filter effect of the "Simple Fix with Filter" (at 0.5 mm (0.02")) solution. A filter was imposed on the running-total hourly accumulation field to handle anomalous residuals.

The anomalous residual problem is a consequence of the methodology of the computation of hourly-based accumulations and the resolution of the algorithm (0.1 mm). All hourly-based accumulations in the PPS algorithm are determined via a methodology whereby a "running-hourly rainfall total" field is maintained by adding in new contributions from the most recent scan-to-scan

Table 2a. Comparison of statistical results at the early time and 12 hours later for the stratiform rain event (10Z and 22Z, January 6, 2002) (MAE: mean absolute error, RMSE: root mean square error, MAX: maximum values, MAX-DIF: difference of MAX between FIX and NOFIX DPA, RV: rain volumes, RV-DIF: difference of RV between FIX and NOFIX DPA).

Time	MAE (mm)	RMSE (mm)	MAX (mm)		MAX-DIF (mm)	RV (mm·km^2)		RV-DIF (mm·km^2)	RV Ratio (NOFIX/FIX)
			NOFIX DPA	FIX DPA		NOFIX DPA	FIX DPA		
10Z	-0.55	0.59	0.60	1.50	0.90	352	2491	2139	0.141
22Z	-1.85	2.28	6.49	10.29	3.80	49550	223981	174431	0.221

Table 2b. Comparison of statistical results at the early time and 12 hours later for the convective rain event (09Z and 21Z, July 26, 2001) (MAE: mean absolute error, RMSE: root mean square error, MAX: maximum values, MAX-DIF: difference of MAX between FIX and NOFIX DPA, RV: rain volumes, RV-DIF: difference of RV between FIX and NOFIX DPA).

Time	MAE (mm)	RMSE (mm)	MAX (mm)		MAX-DIF (mm)	RV (mm·km^2)		RV-DIF (mm·km^2)	RV Ratio (NOFIX/FIX)
			NOFIX DPA	FIX DPA		NOFIX DPA	FIX DPA		
09Z	-0.27	0.37	4.60	4.87	0.17	1652	2148	496	0.769
21Z	-0.94	1.10	59.57	61.31	1.74	252326	295424	43098	0.854

Table 3. The ensemble statistical results for both precipitation types.

Type	Total Number of Sample Grid Points	Number of Grid Points with Lower FIX DPA and Percentage (%)	Number of Grid Points with Greater FIX DPA and Percentage (%)	Mean Absolute Error (mm)	Root Mean Square Error (mm)	Maximum Difference (mm)	RV (mm·km^2)		RV Ratio (NOFIX/FIX)
							NOFIX DPA	FIX DPA	
stratiform	223294	396 (0.2)	222898 (99.8)	-1.22	1.52	7.50	1424770	5785328	0.246
convective	28283	331 (1.2)	27952 (98.8)	-0.68	0.89	4.98	1543851	1849558	0.835

period at each grid point and then subtracting out old contributions from the period phased out of the hour. During the entire cycle of precipitation at a given grid point, this methodology sometimes results in the fractions of accumulation added in that do not exactly equal to the fractions subtracted out, thus unfortunately resulting in a slight but persistent non-zero accumulation at the end of the event.

Due to the imposed filter, some very light but real accumulations (less than 0.5 mm in one hour) might be discarded in FIX DPA data. Hence, there exists some grid points with lower FIX DPA rainfall. This negative effect from the filter is more severe for the convective precipitation (1.2%). The reason is possibly from the different adaptation data values of the multiplier coefficient and the exponent coefficient in the Z-R relationship for the stratiform (130, 2.0) and convective (300, 1.4) precipitation events. For the stratiform precipitation, the filter level of 0.5 mm hourly rainfall corresponds to about 15 dBZ, while it is about 21 dBZ for the convective precipitation. Since the greater reflectivity threshold is used for the convective precipitation, more grid points with real rainfall accumulations could be discarded which implies more severe negative effect from the filter. However, none of them is a severe problem in the solution. Overall, the solution corrected the precipitation truncation with only very slight negative effect from the filter.

Finally, the value of maximum difference between NOFIX and FIX DPA data indicates that the maximum underestimated hourly precipitation by the precipitation truncation problem could be 7.50 mm for the stratiform precipitation and 4.98 mm for the convective precipitation. Such significant deficit must be considered when using DPA product generated by earlier version of ORPG without the fix of the precipitation truncation problem.

Since it was stated in the 2000 MOU Report that the quantitative impact of the precipitation truncation problem on DPA was directly proportional to the duration of precipitation whether rainfall rates were light or heavy, more statistical computations were performed to investigate the differences with respect to the precipitation duration and rain rates (represented by hourly rainfall amount). The statistical results are plotted in Figs. 3, 4, and 5. Fig. 3 shows the dependence of absolute value of MAE and RMSE on precipitation duration for the stratiform precipitation (Fig. 3a) and convective precipitation (Fig. 3b) events.

Figs. 3a and 3b show that in both stratiform and convective precipitation, the absolute value of MAE and RMSE increase as the precipitation duration increases to some value (5 hours for the stratiform precipitation and 8 hours for the convective precipitation), and finally decrease with longer precipitation durations (there exists a fluctuation period for the stratiform precipitation).

The next two figures show the dependence of absolute value of MAE and RMSE on rain rates for the stratiform precipitation (Fig. 4) and convective precipitation (Fig. 5) events. In Figs. 4 and 5, both the absolute value of MAE and RMSE have the same trends with increasing rain rate in either precipitation type. In the stratiform precipitation (Fig. 4), they initially increase with rain rate (to 8-9 mm/hour), then start to decrease and finally fluctuate. In the convective precipitation (Fig. 5), they also initially increase with rain rate (to 6-8 mm/hour), then decrease slightly and increase again until final decreasing.

These figures illustrate two inconsistencies from the conclusion stated in the 2000 MOU Report. The first one is that the absolute value of MAE and RMSE, i.e., the incremental truncated rainfall, do not always increase with precipitation duration, which is inconsistent with the previous conclusion. The second inconsistency is that the truncated rainfall amounts are indeed related to the

Fig. 3. The dependence of absolute value of MAE (solid line) and RMSE (dash line) on precipitation duration for the stratiform (a) and convective (b) precipitation.

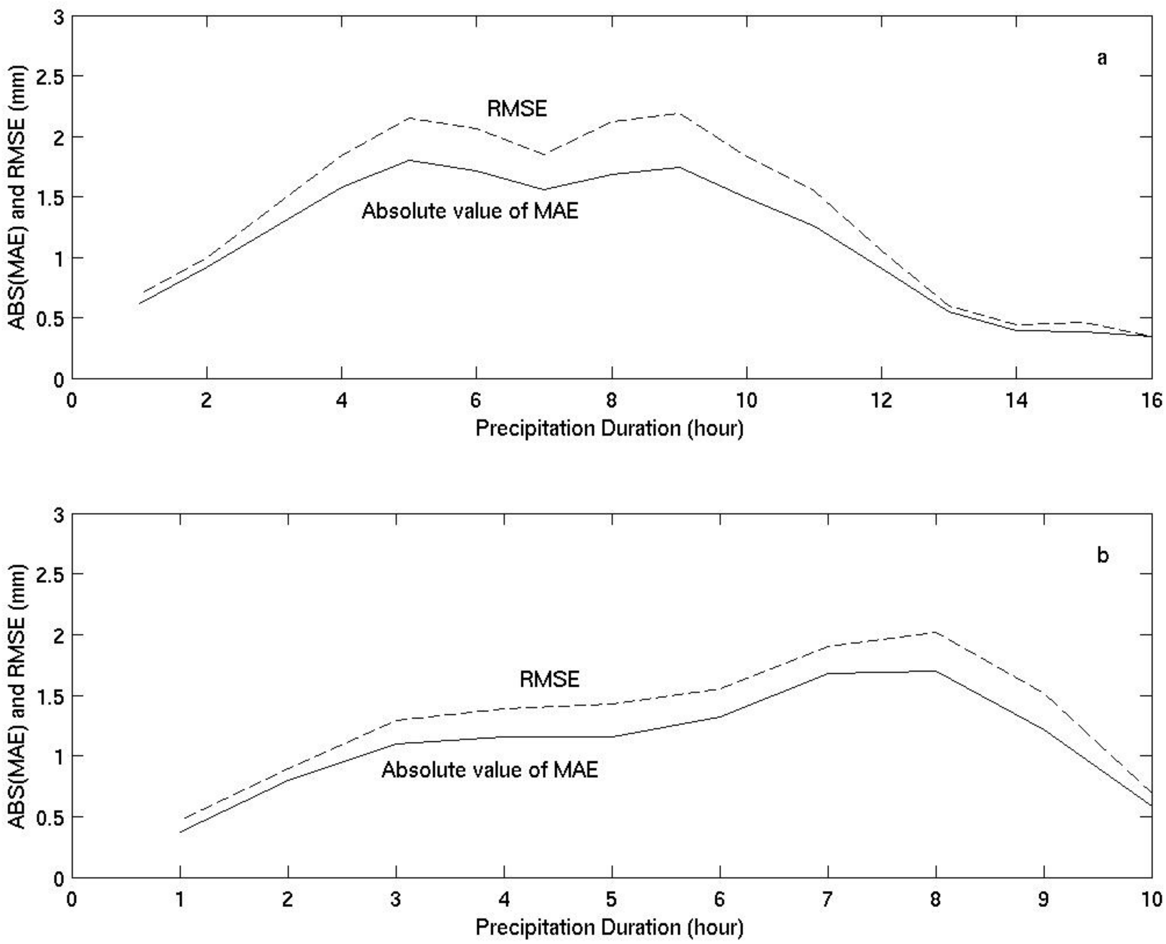


Fig. 4. The dependence of absolute value of MAE (a) and RMSE (b) on rain rates (represented by hourly rainfall amount) for the stratiform precipitation.

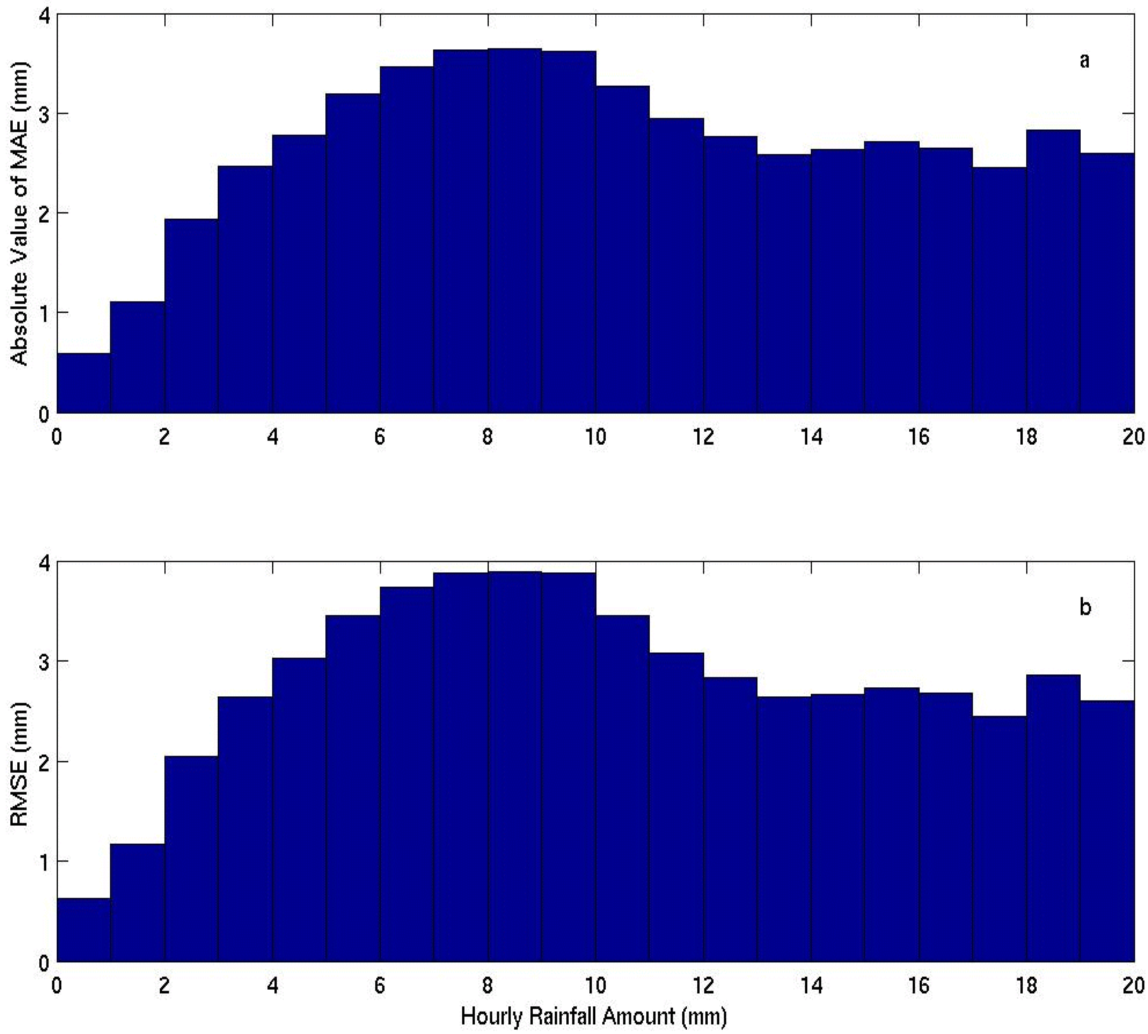
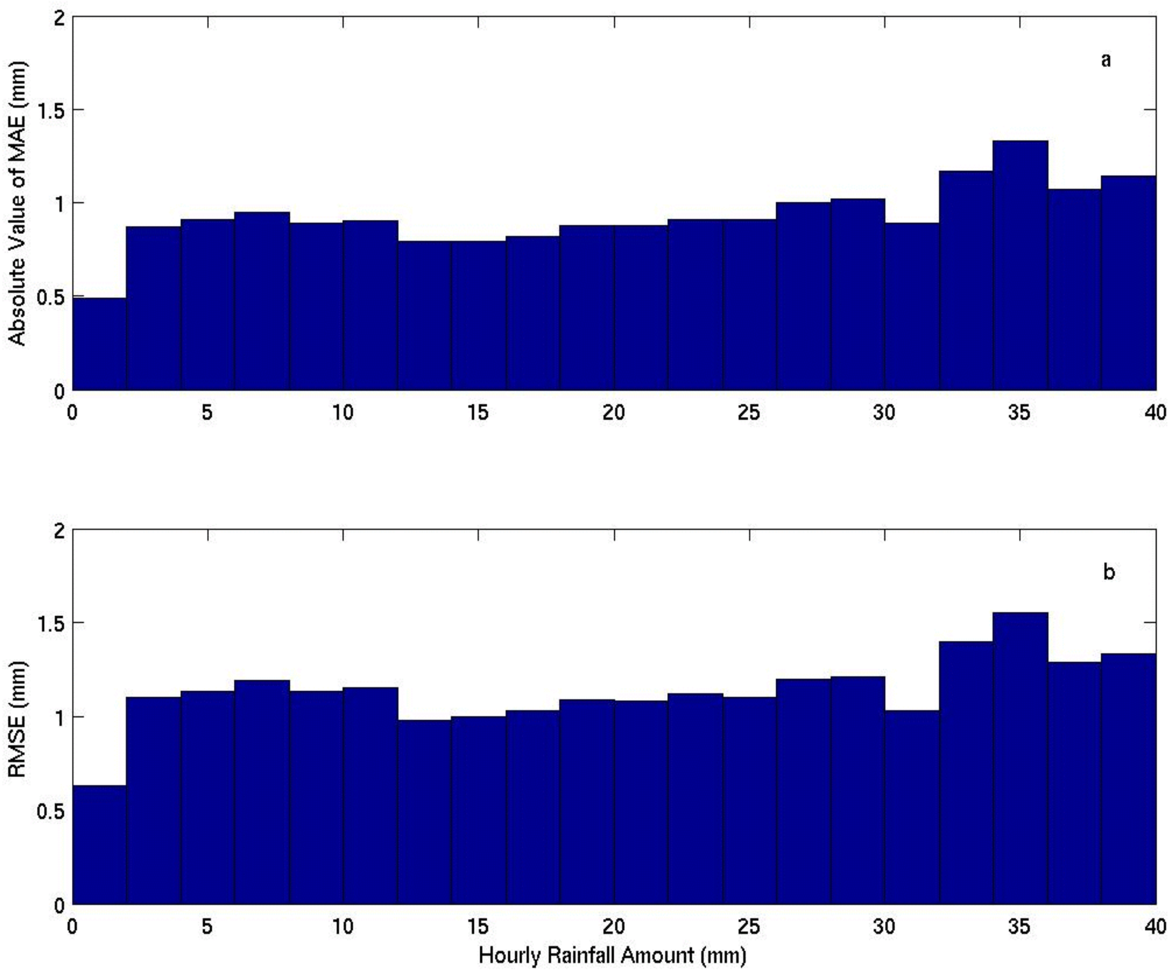


Fig. 5.   Same as Fig. 4 but for the convective precipitation.



rain rates, which is inconsistent with the earlier conclusion that the impact of the truncation problem is same whether the rainfall rates are light or heavy.

To study the reason causing the inconsistencies and to demonstrate the cumulative effect, further statistical computations were performed which calculate the distributions of MAE as a function of both rain rates and the precipitation duration. The results are presented in Tables 4 and 5. Table 4 shows the results from the stratiform precipitation and Table 5 from the convective precipitation. In the two tables, value 1 indicates that the number of sample grid points is less than 20, hence no reliable statistical results could be generated. Since there are more sample grid points from the stratiform precipitation events, Table 4 has more valid data than Table 5.

Again, it is obvious from the two tables that the impact of precipitation truncation problem is related to both the rain rates and the precipitation duration. However, further investigation of the tables and code design of PPS revealed the actual reason which causes the inconsistencies. It comes from the code design which prevents the running-hourly accumulations from becoming negative by a bottom "floor" of zero. It means that the minimum value of the running-hourly accumulations is no less than zero and thus the value in DPA cannot be negative. It also means that the hourly truncated rainfall amounts cannot exceed the actual hourly rainfall amounts. The decreasing trend with longer precipitation durations in Figs. 3a and 3b must be caused by those grid points with longer precipitation durations but light rain rates. This is the reason which causes the first inconsistency related to decreasing trend of MAE and RMSE at longer durations. The reason to cause the second inconsistency (shown in Figs. 4 and 5) is that the rain rates limit the actual hourly truncated rainfall amounts which makes the truncated rainfall amounts indeed related to the rain rates.

In the second column (Italic font) of Table 4 for the stratiform rain events, which has very light rainfall (0 to 1 mm/h), the MAE values are all between -0.54 and -0.66 mm, and no cumulative effect manifests. With the code design of "no negative accumulations", such light rainfall (0 to 1 mm/h) are nearly all truncated in every hour, which gives almost zero rainfall value in NOFIX DPA for every hour. Therefore, the MAE simply represents the mean rainfall amounts which are caught in FIX DPA data but truncated in NOFIX DPA data. In order to demonstrate the cumulative effect, continuously heavy enough rainfall are needed. In the 8th column (Bold font) of Table 4, which has the relatively heavy rainfall (6 to 7 mm/h), the cumulative effect is apparent from the 3rd hour to the 6th hour. During these hours, each hour has an additional truncated rainfall of about 1 mm compared to the previous hour, which is less than the value of 1.5 to 2.0 mm from the theoretical analysis. The MAE values start to fluctuate in later hours. The sample data are too sparse for the convective precipitation events to demonstrate the cumulative effect in Table 5.

In summary, the cumulative effect is demonstrated in the statistical results even if the value (1.0 mm) is less than the value from the theoretical analysis (1.5 to 2.0 mm). The code design of "no negative accumulations" is the reason that the actual truncated rainfall are related to both the rain rates and the precipitation duration: the longer the precipitation duration and greater rain rates, the more truncated rainfall.

On the other hand, the mean relative error (MRE, defined as the percentage value of (NOFIX DPA - FIX DPA)/FIX DPA) were computed which represents the percentage of truncated rainfall amounts. The distributions of MRE as a function of both rain rates and the precipitation duration for the stratiform and convective precipitation are given in Tables 6 (stratiform) and 7 (convective). From the two tables it can be seen that the percentage of truncated rainfall for the stratiform

Table 4. MAE (mm) distribution as a function of rain rates and precipitation duration for the stratiform precipitation.

Precipitation Duration (hour)	Rain Rates (mm/hr)												
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13
1	*-0.54*	-0.77	-0.89	-0.80	-0.78	-0.66	-0.69	1	1	1	1	1	1
2	*-0.64*	-1.00	-1.30	-1.31	-1.33	-1.42	-1.37	-1.28	-1.31	-1.44	-1.40	1	1
3	*-0.63*	-1.14	-1.89	-2.15	-2.21	-2.33	**-2.46**	-2.57	-2.44	-2.41	-2.56	-2.43	-2.46
4	*-0.65*	-1.23	-2.09	-2.60	-2.90	-3.31	**-3.44**	-3.45	-3.53	-3.45	-3.42	-3.43	-3.28
5	*-0.66*	-1.25	-2.23	-2.91	-3.57	-4.12	**-4.32**	-4.48	-4.52	-4.52	-4.69	1	1
6	*-0.63*	-1.28	-2.29	-3.05	-3.66	-4.50	**-5.16**	-5.30	-5.28	1	1	1	1
7	*-0.60*	-1.34	-2.31	-2.95	-3.45	-4.13	-4.38	-4.61	-4.87	-4.88	-4.96	1	1
8	*-0.58*	-1.32	-2.25	-3.21	-3.76	-4.40	-5.27	-5.77	-6.16	-6.27	1	1	1
9	*-0.59*	-1.26	-2.24	-3.24	-4.05	-4.99	-6.10	-6.78	1	1	1	1	1
10	*-0.58*	-1.23	-2.18	-3.18	-3.91	-5.17	1	1	1	1	1	1	1
11	*-0.59*	-1.17	-2.14	-2.75	-4.00	1	1	1	1	1	1	1	1
12	*-0.55*	-1.13	-2.14	1	1	1	1	1	1	1	1	1	1
13	*-0.51*	1	1	1	1	1	1	1	1	1	1	1	1

Table 5. Same as Table 4 but for the convective precipitation.

Precipitation Duration (hour)	Rain Rates (mm/hr)												
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26
1	-0.41	-0.53	-0.53	-0.58	-0.62	-0.60	-0.56	-0.56	-0.54	-0.54	-0.61	-0.61	-0.56
2	-0.72	-1.02	-1.07	-1.05	-0.99	-0.97	-0.96	-0.99	-0.93	-1.03	-1.08	-0.99	-1.10
3	-0.90	-1.53	-1.63	-1.67	-1.55	-1.65	-1.36	-1.36	-1.52	-1.45	-1.29	-1.46	-1.63
4	-0.91	-1.76	-1.64	-1.89	-1.91	-2.03	-1.95	1	1	-1.74	1	1	1
5	-0.87	-1.81	-1.62	-2.06	1	1	1	1	1	1	1	1	1
6	-0.97	-2.17	-1.97	-1.75	1	1	1	1	1	1	1	1	1
7	-1.11	-2.28	1	1	1	1	1	1	1	1	1	1	1
8	-1.05	1	1	1	1	1	1	1	1	1	1	1	1

Table 6. MRE (%) distribution as a function of rain rates and precipitation duration for the stratiform precipitation.

Precipitation Duration (hour)	Rain Rates (mm/hr)												
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13
1	-90	-64	-38	-24	-18	-12	-10	1	1	1	1	1	1
2	-96	-80	-55	-38	-30	-26	-21	-17	-15	-15	-14	1	1
3	-96	-86	-78	-63	-50	-43	-38	-35	-29	-26	-25	-21	-20
4	-97	-91	-86	-75	-65	-60	-53	-46	-42	-37	-33	-30	-26
5	-98	-93	-90	-84	-80	-75	-66	-60	-54	-49	-45	1	1
6	-97	-93	-93	-89	-83	-83	-80	-71	-62	1	1	1	1
7	-98	-95	-94	-86	-78	-76	-68	-62	-57	-52	-48	1	1
8	-98	-94	-93	-93	-85	-81	-80	-76	-73	-67	1	1	1
9	-98	-91	-91	-93	-92	-93	-93	-92	1	1	1	1	1
10	-97	-89	-88	-93	-88	-95	1	1	1	1	1	1	1
11	-96	-88	-86	-81	-92	1	1	1	1	1	1	1	1
12	-96	-85	-89	1	1	1	1	1	1	1	1	1	1
13	100	1	1	1	1	1	1	1	1	1	1	1	1

Table 7. Same as Table 6 but for the convective precipitation.

Precipitation Duration (hour)	Rain Rates (mm/hr)												
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26
1	-40	-16	-9	-7	-6	-5	-4	-3	-3	-2	-2	-2	-2
2	-70	-33	-20	-14	-10	-8	-7	-6	-5	-5	-5	-4	-4
3	-81	-50	-31	-21	-16	-13	-9	-8	-8	-7	-5	-6	-6
4	-83	-57	-30	-25	-19	-17	-14	1	1	-7	1	1	1
5	-83	-56	-30	-25	1	1	1	1	1	1	1	1	1
6	-89	-74	-37	-24	1	1	1	1	1	1	1	1	1
7	-91	-77	1	1	1	1	1	1	1	1	1	1	1
8	-96	1	1	1	1	1	1	1	1	1	1	1	1

precipitation is much greater that for the convective precipitation, which supports the conclusion that the precipitation deficits were of greater significance in light, stratiform precipitation events and of lesser significance in heavy, convective downpours. For the stratiform precipitation, when rain rates are light and/or rain duration is long, over 90% rainfall can be truncated. In most stratiform cases, over 50% rainfall is truncated.

The convective precipitation has much better results. However, when rain rates are less than 4 mm/hr, about 50% to 90% rainfall are still truncated. Such severe impact of the precipitation truncation problem must be considered when using DPA products generated by earlier version of the PPS without the fix of the problem.

Finally, the total accumulated rainfall amounts of all the stratiform precipitation events, all the convective precipitation events, and all the precipitation events from both NOFIX DPA and FIX DPA sample data are shown in Figs. 6, 7, and 8, respectively. These figures can show the impact of the precipitation truncation on the equivalent of monthly or seasonal rainfall amounts. For example, Fig. 6 can be considered as a fair representation of the winter seasonal rainfall from the stratiform precipitation. From these figures, it can be seen that the monthly, seasonal, and overall truncated rainfall amounts could be in ranges of 1 inch to 3 inches. Once again, the very significant impact of the truncation problem on the long-term (monthly and seasonally) rainfall estimates is revealed.

1.4 Summary and Conclusions

The precipitation truncation problem and its quick fix solution, "Simple Fix with Filter", have been described in the previous years' 2000 and 2001 MOU Final Reports. The "Simple Fix with Filter" solution was implemented in ORPG Build 1. The quantitative evaluation of the impact of this solution on the hourly DPA product is investigated by statistical analyses from 121 independent hours of rainfall data which are spread over several months and two different precipitation types: the stratiform and convective precipitation. The statistics prove that the expected results are achieved. The corrected rainfalls are greater than the original amounts, more so for the stratiform precipitation events than for the convective precipitation events. The maximum hourly truncated rainfall amounts for DPA are as high as 7.50 mm. The cumulative effect is demonstrated in the tables which show the distribution of MAE with the different rain rates and precipitation duration.

Even though the coding anomaly of PPS only promises that the impact of the precipitation truncation problem is the same whether rainfall rates are light or heavy, the code design of "no negative accumulations" implies that the actual truncated rainfall amounts are in fact related to both rain rates and precipitation duration: the longer the precipitation duration and greater rain rates, the greater is the truncation. The significant truncated rainfalls must be considered when using DPA products generated by earlier version of OPRG without the fix of the precipitation truncation problem.

Fig. 6. Total rainfall amounts of all the stratiform precipitation events from NOFIX DPA (top) and FIX DPA (bottom).

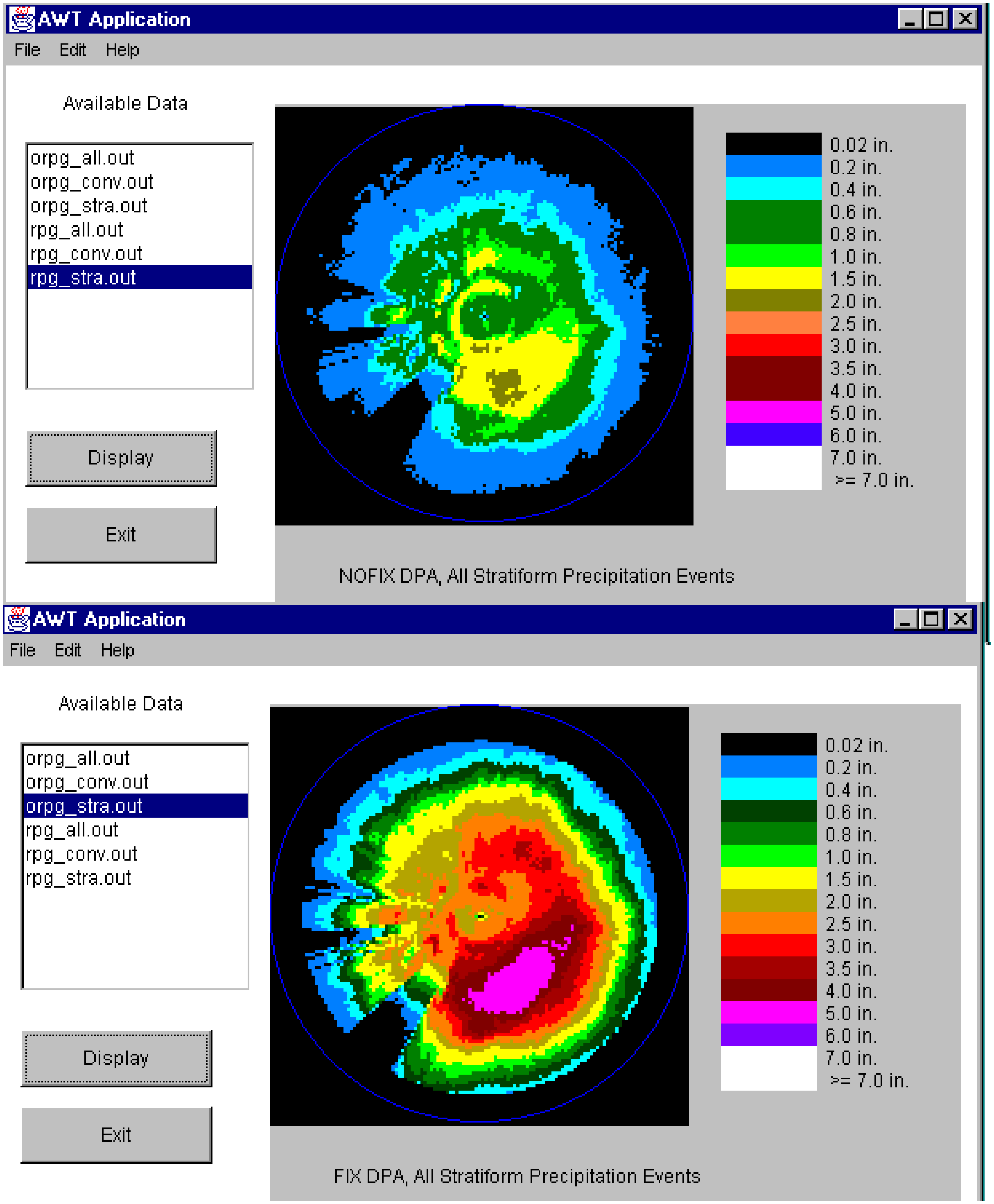
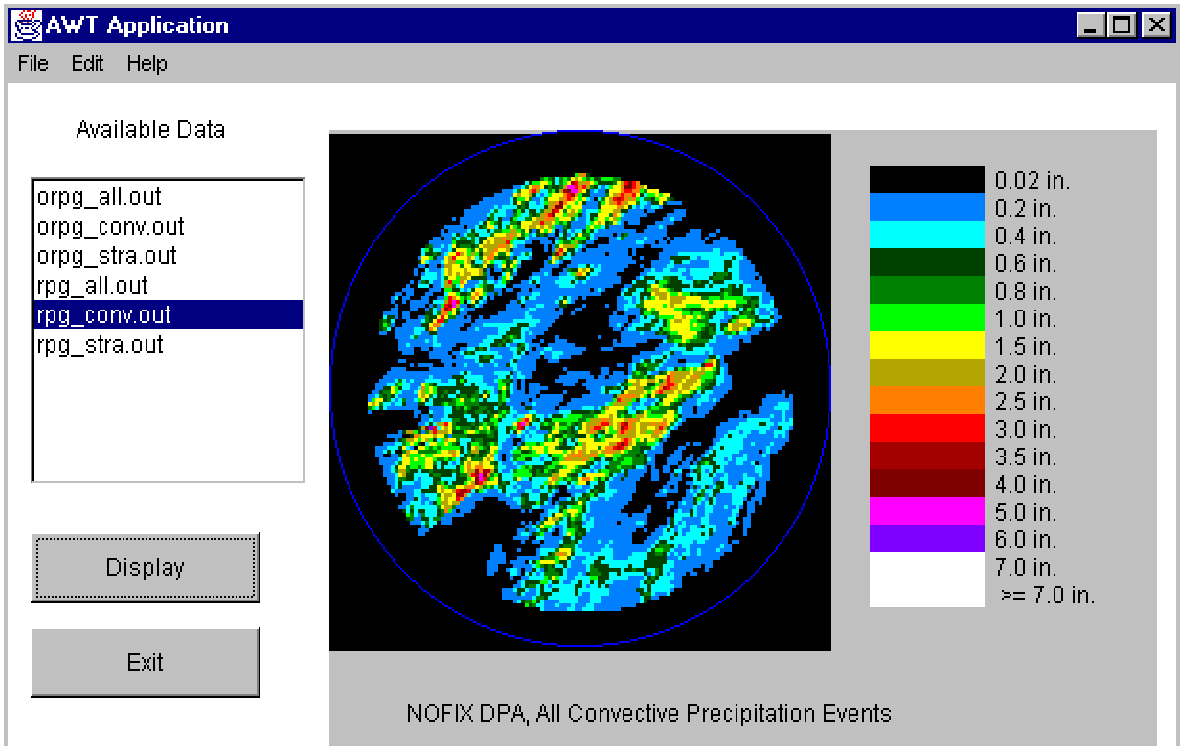


Fig. 7. Same as Fig. 6 but for all the convective precipitation events.



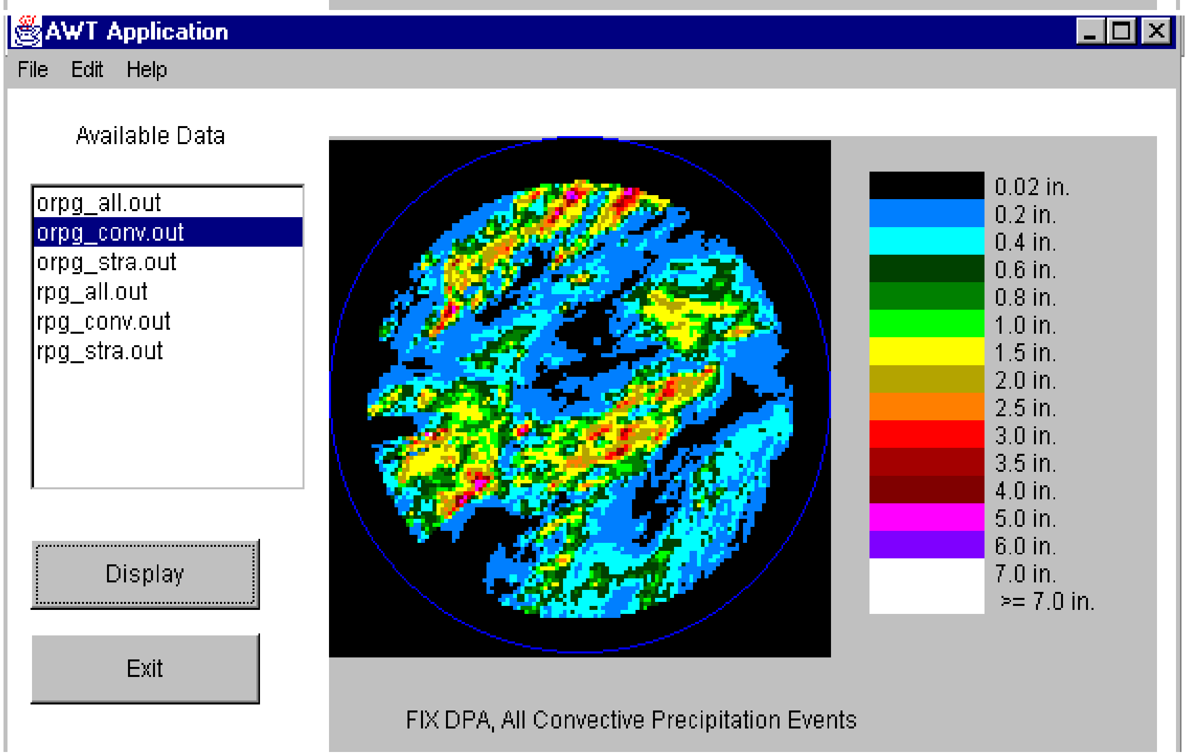
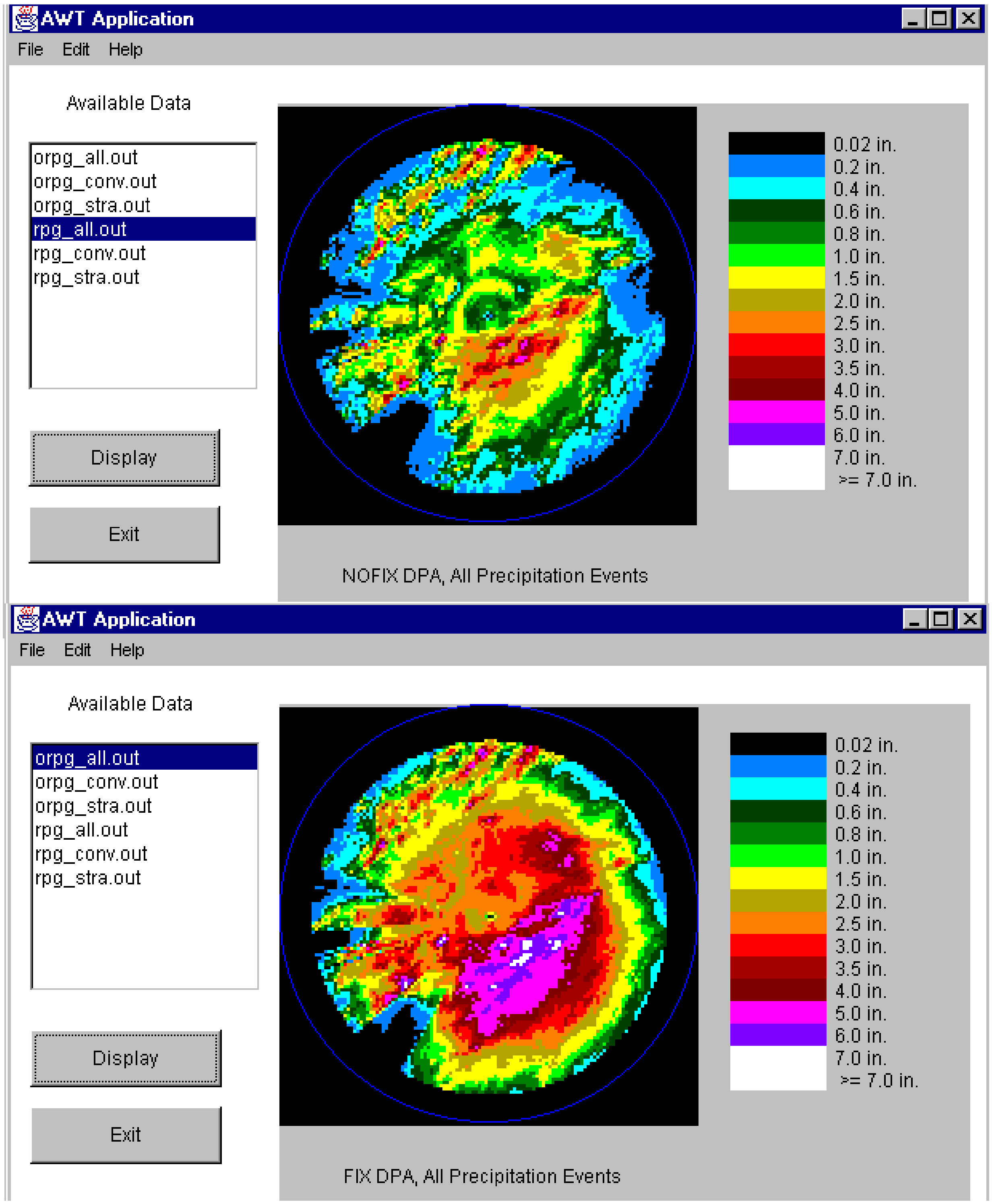


Fig. 8. Same as Fig. 6 but for all the precipitation events



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