VERIFICATION OF SAB'S SATELLITE PRECIPITATION ESTIMATES FOR THE 1984 CONVECTIVE SEASON

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The Synoptic Analysis Branch of the National Environmental Satellite, Data, and Information Service produces estimates of precipitation from satellite pictures, and disseminates this information to the National Weather Service on an operational basis. These estimates, when used in conjunction with local radars, provide timely and needed rainfall information and play an important role in the issuance of Flash Flood Watches and Warnings. Verification of these estimates is difficult because precipitation reports from exactly the same time period and location as the estimates are extremely rare. A system which attempted to minimize these temporal and spatial problems was developed and used for the verification of the operational estimates for the 1984 convective season. The estimate program, the verification system, the procedure used, and problems with the system are described. The statistical results are presented and recommendations to users are made based on these findings.

1. THE ESTIMATE PROGRAM

Since 1978, the Synoptic Analysis Branch (SAB) of the National Environmental Satellite, Data, and Information Service (NESDIS) has provided National Weather Service (NWS) Forecast Offices and other users with real-time estimates of precipitation from satellite pictures. The SAB meteorologists produce a satellite precipitation estimate message (SPE) when precipitation estimates approach or exceed the three-hourly flash flood guidance rates issued by the NWS River Forecast Centers. The estimates are computed for individual counties and disseminated on the NWS's Automation of Field Operations and Services (AFOS) communications system. Not all of SAB's estimates are disseminated, since many estimates are well below flash flood producing thresholds. In addition, some heavy precipitation events have unrecognizable signatures in the satellite imagery; hence some events go unestimated.

The SAB meteorologists closely monitor the growth and movement of convective cells with the help of IFFA, the Interactive Flash Flood Analyzer. "The IFFA is a refinement of the University of Wisconsin's Man-Computer Interactive Data Access System (McIDAS). The IFFA, as noted by Clark and Borneman (2) allows the satellite meteorologist to use multiple image and graphic frames, and to magnify and compare consecutive visible and infrared images with surface observations in order to locate the areas of heaviest rainfall rates and take into account storm motion. Locating these areas requires much experience, since the coldest enhancements might not necessarily be where the heaviest rain is falling. An important factor in the estimation process is the shape of the storm. The estimator must determine the location of the thunderstorm anvil's cirrus blowoff and whether the storm is wedge-shaped or circular. The estimated isohyets are then drawn using the Scofield-Oliver Estimation Technique (3), which takes into account many factors. Some of these include: the rate of areal expansion of the storm, the merging of cells, the presence of overshooting tops, the warming or cooling of tops, and the temperature of the coldest top. There are also adjustments for stationary storms, divergence aloft, precipitable water content, and mean relative humidity.

Satellite precipitation estimates, when used by NWS offices in conjunction with local radars, provide timely and much needed rainfall information. They let the operational meteorologists in the field offices know that a big event is evolving and can be instrumental in the subsequent issuance of Flash Flood Watches and Warnings, which save lives and property. Throughout this paper, one should not lose sight of the fact that the SPE program is truly amazing, considering that information from satellite pictures taken from more than 22,000 miles in space is being used to make rainfall estimates for an individual county.

2. VERIFICATION

"Establishing a scientifically sound verification method for convective precipitation estimates is difficult because of the complexities involved in the temporal and spatial qualities of heavy precipitation. Precipitation reports from exactly the same time period and location as the estimate are extremely rare" (2). With regard to the temporal problem, the half-hour estimates are usually accumulated in three hour or storm duration totals that may or may not correspond to the time period of the actual rainfall. The majority of rainfall observations from cooperative observers are available only every 24 hours. Regarding the spatial problem, heavy warm-season precipitation is usually a mesoscale event and it is highly unlikely that the maximum reported values will be representative of the amount that actually falls. The maximum rainfall usually falls between the rain gauges! These problems show that it is very difficult to make a direct comparison between the estimates and the report, unless the poor temporal and spatial qualities of the data are somehow taken into account.

A system which attempted to minimize these problems was developed and used for the verification of the operational estimates from May through July of 1984. This paper will describe the verification system, the procedure used, and the problems with the system. The statistical results will be discussed and recommendations to users of the SPE information will be made based on these findings.

2.1 VERIFICATION MATERIALS

1) updated versions of an in-house NMC 24-hour precipitation chart, which includes station, automatic rain gauge, and class 1 and 2 cooperative observer reports (Class 1 cooperative observers report every day. Class 2 observers

only report when the daily precipitation reaches the same threshold amount - usually 0.1 inch.)

2) satellite pictures (2 km. resolution KB8 and DB5 sectors for visible and MB-curve enhanced infrared pictures)

3) county overlays for both precipitation chart and satellite pictures

4) estimators' logbook and worksheets

5) special weather, flash flood, and severe weather statements from AFOS and telephone reports

6) contoured copies of estimate event totals

7) road atlas to check distances (for location errors)

3. VERIFICATION SYSTEM AND PROCEDURES

SAB is technically responsible for monitoring and estimating excessive precipitation for the entire country. There are many factors involved in the decision making process to estimate precipitation and disseminate guidance products to the National Weather Service. First, there is a physical limit to the volume of estimates calculated on the IFFA system using a 30 minute image cycle. Therefore, a priority system is used to determine operational event areas when more than one area is present. NWS Satellite Field Services Stations (SFSS) act as backup when multiple heavy precipitation events are present. SAB meteorologists must use their interpretation skills to decide which areas deserve the most attention. To assist them in this decision, SAB meteorologists consult with the Heavy Precipitation Branch of NMC, coordinate with SFSS's, and receive calls from NWS Forecast Offices requesting estimates for threatened areas. Finally, there are some heavy precipitation events that go unestimated because of weak or unrecognizable satellite signatures.

The verification system involves comparisons between maximum estimates (storm totals) and maximum observations (mainly 24-hour totals). Cases studied were those for which both an estimate was made (SPE) and the Observed Reported (OR) values were at least two inches. It is important two emphasize that reports of two or more inches for which estimates were not made were not considered in the statistics (see Appendix, Part 1). Cases where estimates of two or more inches were made, but where reports verified under two inches also were not considered.

Case Used in Verification Study
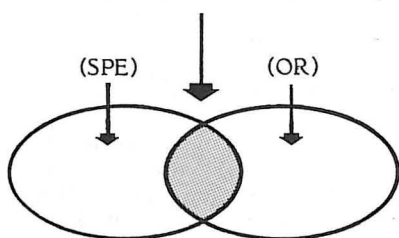
The temporal and spatial problems discussed previously were taken into account by the creation of a "Time + Density-of-Observations Confidence Factor." This was needed in order to be assured that the estimated and observed values being matched were indeed good comparisons. For example, an estimate of 2" from a single storm from 13Z-17Z and a 24-hour observation of 2" at the right location is not a good comparison if satellite photos show that the 2" reported fell from two separate storms. Without a confidence rating, which would be a poor one in this example, this would have appeared to have been a perfect estimate. In actuality, it was correct for the wrong reason. Another example might be that 3" was estimated but 8" was the 24-hour observation. If there was heavy rain before or after the estimated times, this might account for the 5" difference. A poor confidence rating in this situation prevents the comparison from being seriously considered for statistical purposes.

The following method of categorizing cases is a first attempt at handling the temporal and spatial problems; the definitions and breakdowns given below are necessarily subjective.

Time Confidence was defined as follows:

1 = HIGHLY CONFIDENT. Satellite pictures show that no precipitation fell before and/or after the estimate time.

2 = SOMEWHAT CONFIDENT. Light precipitation fell before and/or after the estimate time, but the bulk of the total probably fell during the estimate time.

3 = NOT MUCH CONFIDENCE. Precipitation, possibly heavy, fell before and/or after the estimate time.

Density-of-Observations Confidence was defined as follows:

0 = very dense
0.5 = somewhat dense
1.0 = somewhat sparse
1.5 = very sparse

The Density rating was proportional to the size of the county. On the internal NMC 24-hour precipitation chart, two or three observations in a small county would get a rating of 0 (good). But two or three observations in a large county might get a rating of 1 (fair to poor). If the observations were too far apart of if there were no observations at all, then a comparison was not made.

The Time/Density confidence was the sum of the Time and Density ratings.

The following breakdown was decided for the Time/Density ratings:

1.0 = excellent comparisons
1.5-2.0 = good comparisons
2.5-4.5 = poor comparisons — bad for verification

The range of values for the Density confidence was set up so that very sparse observations (1.5 rating) could make a highly confident Time rating (1) become

bad for verification purposes, since the sum (2.5) is a poor comparison. The Time/Density cutoff of 2.5 seemed reasonable, since without any Density rating at all, a Time rating between 2 (somewhat confident) and כ (not much confidence) would be a natural cutoff point.

In order to eliminate some unnecessary bias, the Time/Density confidence was assigned before the magnitude error was assessed. Once this rating was obtained, the procedure involved placing the county overlay on the 24-hour precipitation chart and matching the maximum estimate with the nearest maximum observation within a "reasonable distance", provided that both were for the same event. The "reasonable distance" was considered to be less than 30 miles because it is close enough to represent the same event, yet far enough away to allow many comparisons to be made. As it turned out, most cases had location errors of less than 20 miles.

In this proeceudre there are subjective decisions to be made. This is illustrated in the following examples. Dashed lines represent miles away from County A; the small box is County A and the large box is County B. In all three cases, an estimate of 3.7" was made for County A.


(1)   (2)
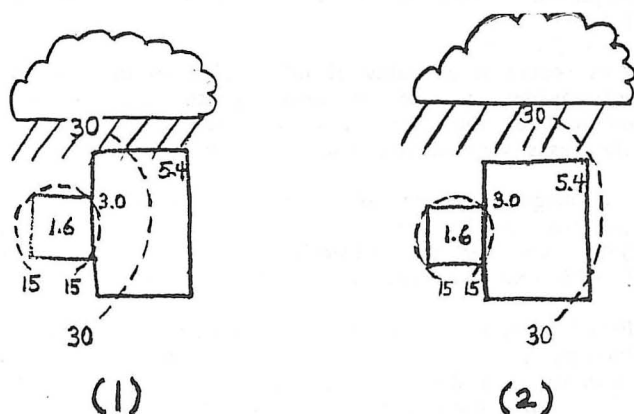
CASE 1 - Choose observed value to be 3.0" since 5.4" is greater than 30 miles away. Result: 0.7" overestimate.

CASE 2 - Choose observed value to be 5.4" since it is the maximum within 30 miles, provided that it is certain that the 5.4" value in County B was the same event that was estimated for in County A. Result: 1.7" underestimate.

(3)
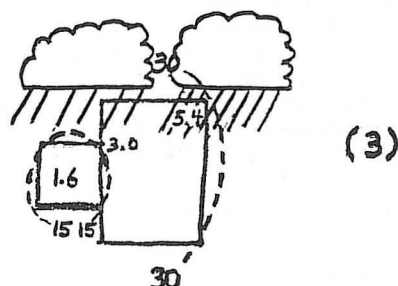
CASE 3 - choose observed value to be 3.0" (even though 5.4" is the maximum within 30 miles) because the 5.4" value may be associated with a different event. Result: 0.7" overestimate.

The following example shows that the maximum values are what counted in this verification system:
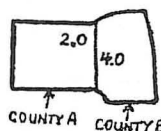
Suppose that 2.2" is the estimate for County A (see picture 4). Also, suppose that 2.0" is observed in County A and 4.0" is observed in County B, which is adjacent to County A. It is tempting to compare the 2.2" estimate with the 2.0" report, since it is for the same county. But since 4.0" is the maximum (within 30 miles and for the same event), the comparison should be between the 2.2" estimate and the 4.0" observation.

4. PROBLEMS WITH THE VERIFICATION SYSTEM

The biggest problem with this system is that despite efforts to establish guidelines, it still remains highly subjective. This would probably be true of any verification system of this nature.

Another problem is that a "dense" network of observations on the precipitation chart is not really dense in actuality. That is, two observations in a small or medium-sized county is quite dense for that chart; however, in reality, the observations are really quite sparse. Thus even an estimate/observation comparison with a perfect Time/Density rating may not be correct. It is, however, the best that can be done with the available "real-time" operational data. Perhaps for future verification studies, data other than "real-time" could be used, including climatic data from Asheville, North Carolina or mesoscale network data such as that provided by the Illinois State Water Survey.

On the 24-hour precipitation chart, an area is left blank if there were no observations or there was no rainfall. Some cases had to be dismissed from the statistics because the chart was blank and there were "no observations." However, in actuality, the reason that the chart was blank might have been that no rain fell — not that data were missing. For example, this might occur if the meteorologist estimates too far into the anvil cirrus of a thunderstorm. Thus, since one cannot tell whether data were missing or whether no rain fell, some 0" observations were not inlcuded as cases. This probably biased the data somewhat on the good side.

Estimates for an area are usually stopped when the storm intensity is weakening. However, light to moderate rain may continue to fall for some time after the estimate has ended; this additional rainfall appears on the 24-hour precipitatin chart but would not be accounted for in the estimates. Also, some precipitation may fall before the storm displays heavy rainfall characteristics and before estimates have begun. While a Time Confidence rating of "2" attempts to account for any light precipitation that falls before and/or after the estimate time, this is often difficult to determine from satellite pictures.

5. QUANTITATIVE RESULTS

Statistical results are contained in Table 1.

Column 1 is the observed rainfall in inches, beginning with two inches.

Column 2 is the number of cases within each category.

Column 3 is the sum of the absolute values of the errors (estimates minus observations).

Column 4 is the average absolute error in inches. It is Column 3 divided by column 2.

Column 5, the average % error, is the value from column 4 divided by the midpoint of the range in Column 1.

Column 6 is the % of cases that were underestimated for each rainfall category.

Column 7 is the average absolute error of the underestimates (in inches).

Column 8 is the % of cases that were overestimated for each rainfall catgegory.

Column 9 is the average error of the overestimates ("absolute" error here is redundant since the estimate minus the observation is positive for overestimates).

Note: When Columns #6 and #8 add up to 100%, one can then add (Col 6)x(Col 7) + (Col 8)x(Col 9) to get column 4. If Columns #6 and #8 do not add up to 100%, this is because there were perfect estimates.

Of the 327 cases that were verified from May 1 to July 30, 1984, 268 had Time/Density Confidence values of 1.0, 1.5, and 2.0. The results of these good comparisons will now be explained.

The main finding of this study was that the average percent error ranged from 28.0% to 33.3% for rainfalls from 2" to 6" and it was very consistent for nearly every rainfall category. Stated another way, the average absolute error ranged from 0.7" for 2-3 inch rains to only 1.8" for 5-6 inch rains. These findings are very good, especially when one considers the complexities involved in satellite precipitation estimation.

Another important and interesting discovery was that as the rainfall events get larger, there is a large centage of cases that are underestimated. This was true for each month individually and for the summer as a whole.

One might have expected more overestimates than underestimates because of the sparsity of data. However, the statistics showed that for all of the cases there were nearly the same amount of underestimates (49.6%) as overestimates (46.6%).

6. QUALITATIVE RESULTS

The location error of the estimates is difficult to specify since the estimates are made for a county (or part of a county), but not for a specific point. It is probably safe to say that the average estimate was off by no more than 10-20 miles. Most of the maximum observations occurred within the estimated county. Only a few estimates were more than 30 miles off.

It was observed that when the precipitation event is widespread, with similar amounts over a large area, the estimates were extremely good. Errors for estimates for localized convective events were more variable.

There were many cases where a Mesoscale Convective Complex (MCC) or a thunderstorm complex covered a large area and produced very cold enhancements. The estimator's attention was understandably focused on these MCC-type storms when a smaller, less menacing-looking cell would develop ahead of these clusters. It was these smaller cells which occassionally produced heavier rains than the big clusters.

7. CONCLUSIONS AND RECOMMENDATIONS TO USERS OF SPE INFORMATION

The results of this study are based on a limited number of cases from May - July, 1984. Verification was not possible from late July through most of August as a result of the GOES-East satellite failure. This study has provided SAB and users of SAB's estimates with preliminary verification results. In order for quantitative correction factors to be established, a larger sample of statistics must be acquired. More verification is planned for the near future.

This report is probably of most value to users of SPE information in the Midwest, South, and Southeast portions of the country, since that is where most of the cases were located (see Appendix, Part 2).

The magnitude error of most SPE's is less than 33% and the location error is relatively small. Thus, when SPE's are used in conjunction with local radars, they provide quite accurate rainfall information.

Finally, since underestimates increased as event size increased, users should feel very confident that if an estimate is made for 5" or more, then more than 80% of the time there will be at least 5" observed.

APPENDIX

1. ADDITIONAL INFORMATION ON STORMS FOR WHICH ESTIMATES WERE NOT MADE

Since this study only involved cases for which estimates were computed, it was useful to see how frequently a big storm went unestimated. From May 1- July 30, 1984 there were 40 cases of convective storms which had at least 3" of rain but for which no estimates were computed. These were not included in the statistics. There were 174 cases of storms with 3" or more which had estimates and were included in the statistics. Thus, based on those cases which were able to be verified, it was found that a large event was missed only about 19% (or 40/214) of the time. There are many reasons that an estimate for a heavy rainfall event may not be made at SAB. Some of these include:

1) The estimator is too busy computing estimates for many scattered thunderstorms or for a MCC-type system and composing SPE messages for other locations.

2) The rainfall rate may not exceed the flash flood guidance values for the area.

3) The precipitation might be a warm top event on the satellite imagery and goes undetected.

4) The event could have a subtle heavy rainfall signature and goes undetected.

5) Problems with the IFFA system and/or the manual back-up procedure.

2. GEOGRAPHICAL DISGTRIBUTION OF CASES THAT WERE ABLE TO BE VERIFIED

STATE	SUMMER TOTAL	STATE	SUMMER TOTAL
Texas	48	Colorado	7
Oklahoma	29	Georgia	5
Arkansas	27	South Dakota	5
Tennessee	27	Wisconsin	5
Louisiana	23	Florida	4
Missouri	22	Pennsylvania	4
Iowa	21	South Carolina	4
Mississippi	19	Minnesota	2
Kansas	17	Illinois	1
Nebraska	16	Montana	1
Kentucky	15	New Jersey	1
Alabama	11	New Mexico	1
North Carolina	10	New York	1
		West Virginia	1

TOTAL # OF STATES: 27
TOTAL # OF ESTIMATES: 327

3. THE STATISTICS

Time/Density Confidence:
1.0,1.5,2.0

Table 1.   STATISTICAL SUMMARY FOR   SUMMER, 1984 (May 1 - July 30)

Observed Amounts:	# of cases	Sum of EST.-OBS.	Avg. of EST.-OBS.	Avg. % error	% of cases underest'd	Avg. EST.-OBS. for underest's	% of cases overest'd	Avg.(EST.-OBS.) for overest's
2.0 - 2.9	130	91.6	0.7	28.0	35.7	0.4	60.0	0.9
3.0 - 3.9	72	71.4	1.0	18.6	52.8	0.9	43.1	1.2
4.0 - 4.9	40	59.9	1.5	33.3	65.0	1.6	32.5	1.5
5.0 - 5.9	8	14.2	1.8	32.7	87.5	1.9	12.5	1.2
6.0 - 6.9	5	14.5	2.9	44.6	80.0	3.2	20.0	1.8
7.0 - 7.9	6	11.8	2.0	26.7	83.3	2.0	16.7	0.1
8.0 - 8.9	5	14.2	2.8	32.9	100	2.8	0	---
9.0 - 9.9								
10.0 -10.9								
11.0 -11.9	1	4.1	4.1	35.7	100	4.1	0	---
12.0 -12.9								
13.0 -13.9	1	7.0	7.0	51.9	100	7.0	0	---

OTHER FACTS:

TOTAL NUMBER OF CASES: 268

% OF TOTAL CASES UNDERESTIMATED: 49.6

% OF TOTAL CASES OVERESTIMATED: 46.6

% OF TOTAL CASES PERFECT: 3.7

ESTIMATES MINUM OBSERVATIONS — MAY, 1984   Time/Density Confidence: 1.5, 2.0

Number of cases: 66

Observed Amounts: (inches)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9
	-1.0	-1.7	-2.4	-2.5	-3.2	-1.3
	-0.8	-1.5	-2.0	-2.1		
	-0.6	-1.5	-1.9	-1.6		
	-0.5	-1.4	-1.9	-1.1		
	-0.3	-1.3	-1.6			
	-0.3	-0.8	-1.4			
	-0.2	-0.7	-1.4			
	-0.2	-0.7	-0.7			
	-0.1	-0.6	-0.4			
	-0.1	-0.6	-0.3			
	-0.1	-0.5				
	0.0	-0.4				
	0.0	-0.3				
	0.1	-0.1				
	0.1	0.0				
	0.1	0.1				
	0.1	0.4				
	0.1	0.6				
	0.3					
	0.3					
	0.3					
	0.3					
	0.5					
	0.5					
	0.6					
	0.7					
	0.8					
	0.8					
	1.3					
	1.3					
	1.8					
	2.4					
# of Cases	32	18	10	4	1	1

FOOTNOTES AND REFERENCES

1. Glenn Field is currently completing his Masters Degree in Meteorology at the University of Wisconsin at Madison. He received his B.S. Degree in both Meteorology and Economics from Wisconsin in 1983. During the past four summers, Mr. Field has worked for the National Environmental Satellite, Data, and Information Service (in Washington, D.C. and Redwood City, California) and the National Weather Service (in Jacksonville, Florida). Mr. Field completed this study while working as a summer employee in the Synoptic Analysis Branch, NOAA/NESDIS, where he has recently become a permanent employee.

2. Clark, D. and R. Borneman, 1984: Satellite Precipitaation Estimates Program of the Synoptic Analysis Branch. Tenth Conference on Weather Forecasting and Analysis, June 25-29, 1984. Clearwater Beach, FL, 392-399.

3. Scofield, R. A., 1984: The NESDIS Operational Convective Precipitation Estimation Technique. Tenth Conference on Weather Forecasting and Analysis, June 25-29, 1984, Clearwater Beach, FLk, 171-180.

4. Spayd, L. E., Jr. and R. A. Scofield, 1983: Operationally Detecting Flash Flood Producing Thunderstorms Which Have Subtle Heavy Rainfall Signatures in GOES Imagery. Fifth Conference on Hydrometeorology, Oct. 17-19, 1983, Tulsa, OK, 190-197.

ACCOMMODATIONS

All sessions will be held at the Hilton Plaza Inn, Kansas City, Mo. A block of rooms has been set aside for the meeting at the following special rates: $43 single; $54 double (plus tax). Check-in time is 1:00 pm, Check-out time is 1:00 pm. Kindly make your reservations prior to June 2, 1986, by writing directly to: Hilton Plaza Inn, 45th and Main, Kansas City, Mo. 64111, (Tel: 816-753-7400). Be sure to mention the American Meteorological Society's name when making reservations.

REGISTRATION

The conference registration desk will be open Monday, June 16, from 7:30 pm and on Tuesday through Friday from 8:00 am. Pre-registration fees are: $95 AMS/NWA members, speakers, and session chairpersons; $115 nonmembers; and $55 AMS Kansas City Chapter members, students, and AMS members 65 or older, not regularly employed. Payment must be received prior to June 11, 1986. Registration fees at the meeting are: $115 AMS members, speakers, and session chairpersons; $135 nonmembers; and $60 AMS Kansas City Chapter members, students, and AMS members 65 or older, not regularly employed. Registration fee includes a preprint volume, and luncheon ticket. Preprint volumes will be available at the time of registration. We urge you to pre-register by sending the appropriate remittance together with your name, affiliation, and complete mailing address to: American Meteorological Society, 45 Beacon Street, Boston, MA 02108, Attn: Eleventh Conference on Weather Forecasting and Analysis

TRANSPORTATION

Hilton Plaza Inn is about a 30 minute drive from the Kansas City (MCI) Airport. There is a bus that runs to and from the airport to the hotel ("Kansas City Express") every hour for $8.50 one way. Taxi fare to the hotel is about $25.00.

ICEBREAKER

An Icebreaker (cash bar) will be held on Tuesday, June 17 at 5:30 pm.

SPOUSES' COFFEE

A spouses' coffee will be held Tuesday, June 17 at 10:00 am.

SHORT COURSE

A short course on the Verification and Evaluation of Weather Forecasts, sponsored by the American Meteorological Society, will be held at the Hilton Plaza Inn, June 14 - 16, 1986. The Short Course will immediately precede the Eleventh Conference on Weather Forecasting and Analysis.

LUNCHEON

A luncheon will be held on Wednesday, June 18 at 11:40 am. Additional luncheon tickets will be available for purchase at $15.00.

CORRECTIONS TO:

Verification of SAB's Satellite Precipitation Estimates for the 1984 Convective Season
by Glenn Field
Aug 1985, PP 36-44

1. Pages 39-40, paragraph 2.1 should read:

   Class 2 observers only report when the daily precipitation reaches some threshold amount - usually 0.1 inch.

2. Page 41 picture top of second column should be labeled 4.

3. Page 43, Table 1, Columns 3,4 and 7 are absolute values.

4. Page 44 Table should be labeled:

   ESTIMATES MINUS OBSERVATIONS - MAY 1984 and should read: Table 2. These statistics from May, 1984 are an example of the type of data that went into the computation of the statistical summary shown in Table 1.