SATELLITE

SATELLITE RAINFALL ESTIMATING PROGRAM OF THE NOAA/NESDIS SYNOPTIC ANALYSIS BRANCH

1. The SAB QPE Operation: The 1986 Verification Results
2. A Case Study: Texas Hill Country, July 1987

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ABSTRACT

The Synoptic Analysis Branch (SAB) of NESDIS produces satellite quantitative precipitation estimates (QPE) for heavy rainfall, concentrating on situations where there is flash flooding potential or occurrence. Estimates are sent on AFOS to aid the NWS in issuing watches and warnings. Over 1850 precipitation estimate messages were sent in 1986, and 5500 man-hours were spent on heavy precipitation monitoring and estimating. The NWS Southern Region was the most frequent recipient of estimates, followed closely by the Central Region; together they received 80% of the messages. A case study of the Texas Hill Country flash flood of July 17, 1987 is presented. This is an example of the type of QPE work done in SAB and also clearly shows several heavy rainfall signatures on the satellite imagery. A verification study of the 1986 convective estimates is presented, showing an average error of 31% with a strong tendency to underestimate large amounts. The estimate quality for this Texas case appears to be typical. Recommendations are made to users of satellite rainfall estimates based on the experience of this analyst and this verification study.

1. THE SAB QPE OPERATION

1.1 Introduction

The Synoptic Analysis Branch (SAB) of the National Environmental Satellite, Data, and Information Service (NESDIS) is responsible for precipitation estimates for heavy rain and snow over the U.S. mainland. This program, Quantitative Precipitation Estimates (QPE), began experimentally in 1978 and became fully operational in its present form in 1983. The estimates are sent on AFOS in messages directed to the National Weather Service Offices and Forecast Offices. The SAB is colocated with the National Meteorological Center and provides them with the estimates and regular briefings. (2)

Estimates are made using the various techniques developed by Scofield (3, 4, 5) and Spayd (6) for convective rainfall, precipitation with extratropical cyclones, and heavy rain from tropical cyclones. The techniques are based on the MB infrared enhancement. Estimates are done on the Interactive Flash Flood Analyzer (IFFA), which is a man-machine McIDAS type of interactive computer system.

1.2 Estimating techniques

The rainfall estimates for convection are computed half-hourly using the technique developed by Scofield (3, 4). The technique uses an empirically derived decision-tree and relates half-hourly cloud-top temperatures and cloud-top growth to maximum half-hourly rainfall amounts. The SAB meteorologist draws isohyets of estimated rainfall by comparing changes in consecutive IR and visible images and applying the technique to the active portions of the convective clouds. Rainfall estimates are also adjusted for overshooting tops, convective cluster, and line mergers, the saturated environment with stationary storms, divergence aloft, low-level inflow, storm movement, and the available moisture. Figure 1 shows the decision-tree currently used by SAB. It contains the following recent improvements: a rain-burst factor for very heavy rain in the first half hour, a factor for strong low-level inflow, and a speed-of-storm factor.

The convective technique was originally designed for deep convective systems with a high tropical tropopause and use of the MB IR enhancement. Many times, convection is capped by a stable layer below the tropopause or by a lower tropopause. When this happens, temperatures warmer than $-62°C$ occur in the anvil, called warm-top convection. Using the MB enhancement and the original technique would give estimates much too small. Soundings are used to spot these situations, and modifications are then made to the decision-tree.

For estimating rain and snowfall with extratropical cyclones, Scofield has developed a technique that uses satellite, radar, and conventional data (5). This technique uses satellite signatures that correlate strongly with heavy precipitation. In many cases these signatures evolve through a predictable life-cycle of growth and decay. Using schematics of the satellite signatures along with radar and conventional data, the SAB meteorologists produce rain and snowfall estimates for winter storms.

A tropical cyclone estimation technique developed by Spayd and Scofield (6) is used by SAB for tropical storms and hurricanes that move over land. This technique assigns rainfall rates to tropical cyclone cloud features such as the wall cloud, the central dense overcast, and the banding features. This must be used in combination with the regular convective technique, particularly as the storm weakens over land. Most of the time there is no need for this technique in our operations, but it was used frequently in 1985 when 8 tropical systems moved inland over the United States.

1.3 Summary of QPE operations

Figure 2 shows plots of the total hours spent on QPE work for the 3 yr from 1984 to 1986. There is a maximum during the warm half of the year for estimates with convective rainfall. Secondary maximums are seen during the Fall and Winter seasons during periods of increased extratropical cyclone activity. The total number of hours has steadily increased

RAINFALL IS COMPUTED ONLY FOR THE ACTIVE PORTION OF THE THUNDERSTORM SYSTEM:

The following are clues for helping to make this decision.

o Area of IR temperature gradient at upwind end of anvil for a thunderstorm system in strong vertical wind shear.
o Center of the anvil with a tight, uniform IR temperature gradient around entire anvil for a thunderstorm system with no vertical wind shear.
o Area near and under an overshooting top.
o Portion of anvil that is brighter and/or more textured.
o Half of anvil bounded by edge which moves least (comparison of last two IR or VIS pictures).
o Area near "upper level" (500 mb – 200 mb) upwind end of anvil.
o Area near low-level inflow.
o Area under a radar echo.

STEP 2

HALF-HOURLY RAINFALL ESTIMATES IN INCHES ARE COMPUTED FROM THE FOLLOWING FACTORS:

FACTOR 1

Rain Burst Factor.

When to use:

o For the first half hour estimate (in some cases of very active quasi-stationary convection will also use for the second half hour estimate).
o For convection embedded in moist environments. (But not large scale overrunning.)
o For convection whose cloud bases are significantly above freezing.
o For convective clusters initiated by solar differential heating or boundary intersections.

When not to use:

o If storms are moving fast.

If not applicable, go to FACTOR 2.

If applicable, skip FACTOR 2 and go to FACTOR 3.

Estimate amounts of $1.0 \rightarrow 2.0$ inches in area of colder tops.

GO TO FACTOR 3

FACTOR 2

CLOUD-TOP TEMPERATURE AND CLOUD GROWTH AND/OR LOW LEVEL INFLOW FACTOR.
Determine amount that the coldest cloud tops increased within half-hour and determine intensity of low level inflow; select estimate amount according to strongest growth rate and/or low level inflow (use A, B, or C below):

A. AVERAGE DIVERGENCE ALOFT AND AVERAGE LOW LEVEL INFLOW

Determine estimate according to gray shade and growth rate when average diffluence aloft and low level inflow are apparent:

	$>2/3°$ LAT	$>1/3°$ $\leq 2/3°$ LAT	$\leq 1/3°$ LAT or same	Areal Decrease of Shade or Warming from White to Rpt. Gray or Within the Rpt Gray	Coldest Tops 1 or More Shades Warmer
Med Gray (-32 to 41°C)	0.25	0.15	0.10	0.05	T
Lt Gray (-41 to -52°C)	0.50	0.30	0.15	0.10	
Dk Gray (-52 to -58°C)	0.75	0.40	0.20	0.15	
Black (-58 to -62°C)	1.00	0.60	0.30	0.20	
Rpt Gray* (-62 to -80°C)	1.05-1.95	0.65-0.95	0.35-0.55	0.30	
(EQUILIBRIUM LEVEL)					
White (Below -80°C)	2.00	1.00	0.60	0.40	0.10

*Colder repeat gray shades should be given higher rainfall estimates.

B. STRONG DIVERGENCE ALOFT FACTOR* OR STRONG LOW LEVEL INFLOW FACTOR**

Determine estimate according to gray shade when strong diffluence or strong low level inflow is apparent:

Med Gray	Lt Gray	Dk Gray	Black	(EQUILIBRIUM LEVEL) Rpt Gray	White
0.15	0.30	0.40	0.60	0.60-1.00	1.00

C. STRONG DIVERGENCE ALOFT AND STRONG LOW LEVEL INFLOW FACTORS

Determine estimate according to gray shade when both strong diffluence and strong low level inflow are apparent:

Med Gray	Lt Gray	Dk Gray	Black	(EQUILIBRIUM LEVEL) Rpt Gray	White
0.25	0.50	0.75	1.00	1.00-2.00	2.00

*IR imagery shows edges of thunderstorm anvil along the upwind end forming a large angle of between 50-90 degrees pointing into the wind; 200-mb analysis often shows these storms just downwind from where the polar jet and subtropical jet separate.
**VIS/IR imagery show clusters along an organized boundary with organized low level moisture convergence.

GO TO FACTOR 3

FROM FACTOR 1 OR 2

FACTOR 3

OVERSHOOTING TOP FACTOR. ESTIMATE AN ADDITIONAL 0.30 INCHES FOR COLDER TOPS IN THE AREA OF THE OVERSHOOTING TOPS.

*High-resolution visible imagery is the best data for determining this factor.

FACTOR 4

THUNDERSTORM OR CONVECTIVE CLOUD LINE MERGER FACTOR. Add 0.50 to the colder tops in the area of the merger.

FACTOR 5

SPEED OF STORM (S)/SATURATED ENVIRONMENT FACTOR.

Speed of Storm (S) = speed of upwind edge of the thunderstorm.

If upwind edge moves 1° lat, S = 1/4.
If upwind edge moves ½° lat, S = 1/2.
If upwind edge moves ¼° lat, S = 3/4.
If upwind edge is stationary (or builds upwind), S = 1.
If upwind edge is stationary (or builds upwind for ≥ 1 hour, then S = 1 and use the following Saturated Environment Factor lookup table:

Add to the colder tops whose upwind edge is stationary for a given amount of time:

	Med Gray	Lt Gray	Dk Gray	Black	(EQUILIBRIUM LEVEL) Rpt Gray	White
≥ 1 hour but ≤ 2 hours	0.20	0.20	0.20	0.20	0.30	0.30
> 2 hours	0.40	0.40	0.40	0.50	0.50	0.50

FACTOR 6

MOISTURE CORRECTION FACTOR = Precipitable Water x Relative Humidity (surface to 500mb)

STEP 3

FACTORS ARE SUMMED AND MULTIPLIED BY MOISTURE CORRECTION AND SPEED OF CONVECTIVE STORM FACTORS

TOTAL HALF-HOURLY CONVECTIVE RAINFALL ESTIMATES (in inches) =

Rain Burst Factor[1] or (Cloud-Top Temperature and Cloud Growth Factor or Divergence Aloft Factor)[2] + Overshooting Top Factor[3] + Merger Factor[4] + Saturated Environment Factor[5] x Moisture Correction Factor[6] x S[5]
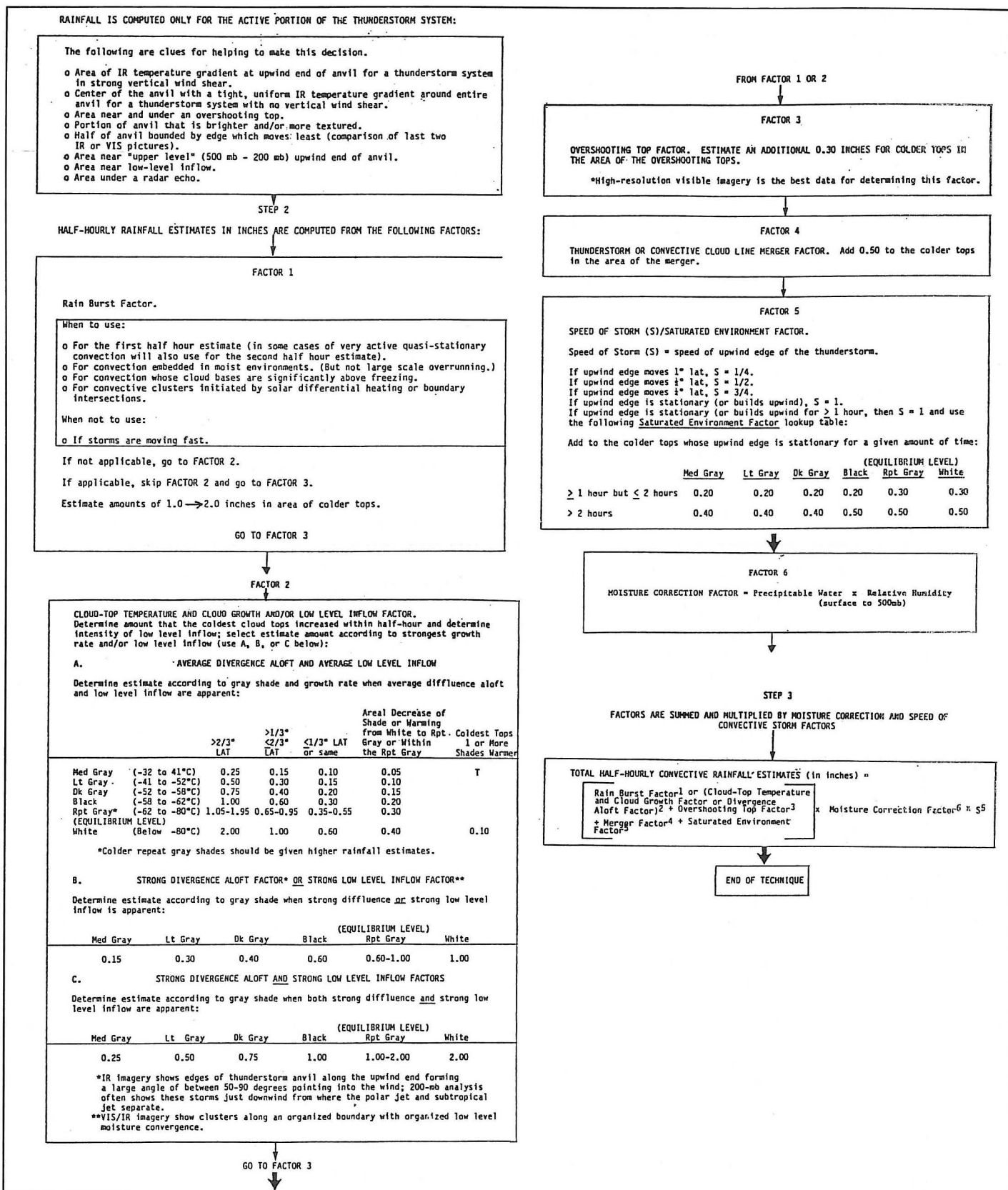
END OF TECHNIQUE

Fig. 1. Decision-tree for the convective storm technique. This includes the latest improvements. See Scofield (2,3) for details on how to use it.
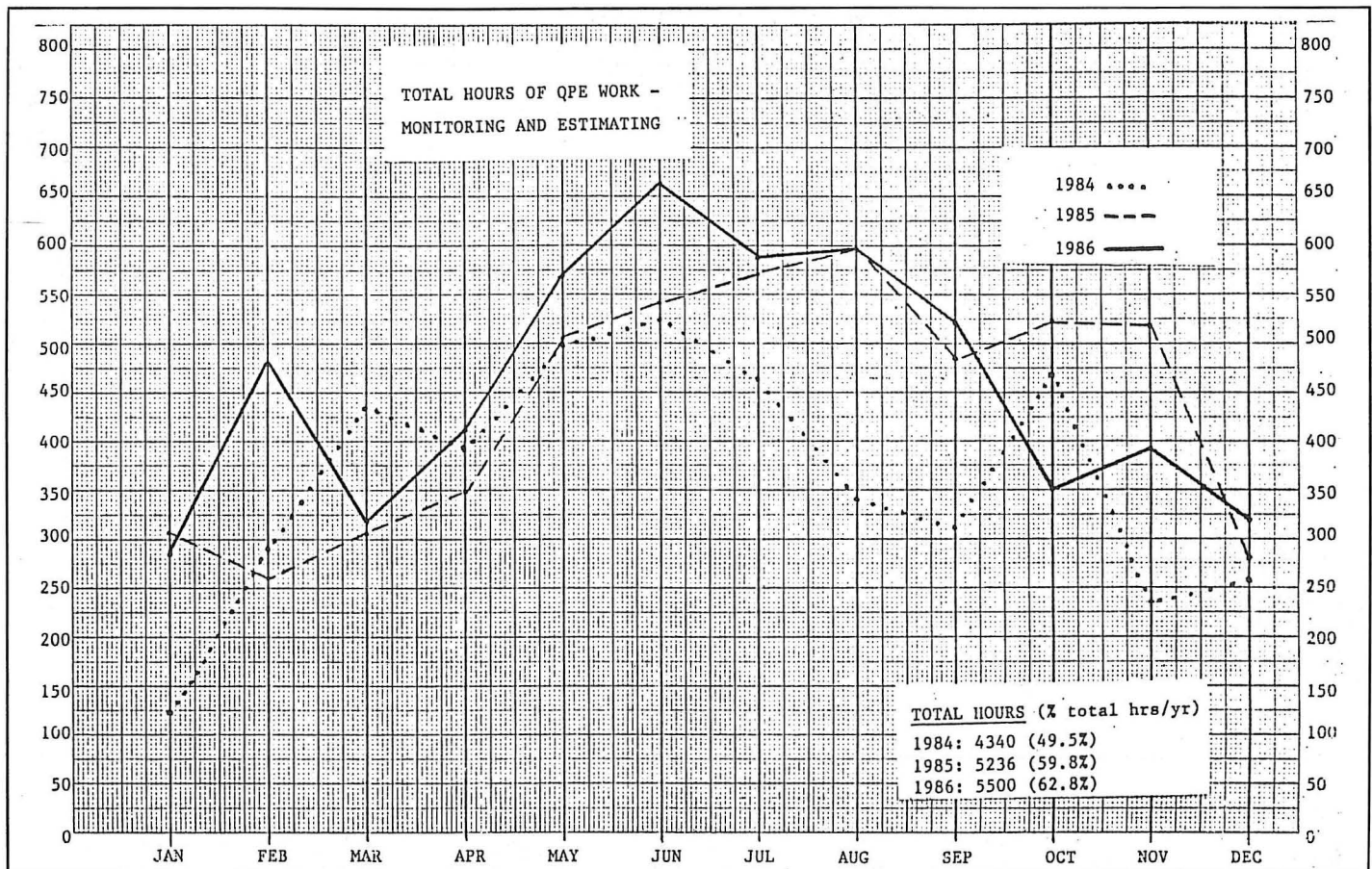
Fig. 2. Total number of hours spent on QPE work at SAB for 1984–1986.

over these 3 yr to 5500 man-hours in 1986, or 63% of the total hours in the year. This increase is probably because the QPE meteorologists are becoming more confident and experienced in using the satellite QPE techniques.

Figure 3 shows the satellite precipitation estimate (SPE) messages sent in 1986. A total of 1866 messages were sent. The pattern throughout the year is similar to that for the total hours of QPE work. There is a much sharper maximum during the summer season because SPE messages are sent more frequently for the rapidly changing conditions with convective rainfall, and often several convective events are occurring at the same time.

Table 1 shows which parts of the nation receive the most messages. Texas leads all states by a large margin. States in the NWS Southern and Central Regions receive around 80% of the messages. California and Arizona received most of the messages for the Western Region and are in the top ten. The Eastern Region received fewer than normal in 1986 because of the extreme drought in the Middle Atlantic and Southeast states.

1.4 Verification for 1986

1.4.1 *Problems*. There are many problems involved in getting good verification of satellite rainfall estimates. Because of the mesoscale nature of heavy convection and the sparcity of the raingage network, rarely does the heaviest rain occur where the measurement is made. There is a similar temporal problem because rainfall is usually measured at fixed time periods and the estimate could be for any time period.

1.4.2 *Procedures*. The procedures for verification were made simple enough to be done in an operational environment with the limited computer facilities available. A more objective and comprehensive verification will be possible in the future with the increased capabilities of the next IFFA system. Data were gathered once a day, for just the maximum

Table 1a. The top ten States receiving SPE messages in 1986.

STATE	No. of SPE's	% of Total
1. Texas	557	21.9%
2. Kansas	169	6.6
3. Oklahoma	164	6.4
4. Missouri	138	5.4
5. Iowa	87	3.4
6. Nebraska	82	3.2
7. California	79	3.1
8. Illinois	77	3.0
9. Arizona	74	2.9
10. South Dakota	74	2.9

Table 1b. The distribution of SPE messages by NWS regions in 1986.

1. Southern Region	1092	42.9%
2. Central Region	936	36.7
3. Eastern Region	285	11.2
4. Western Region	235	9.2
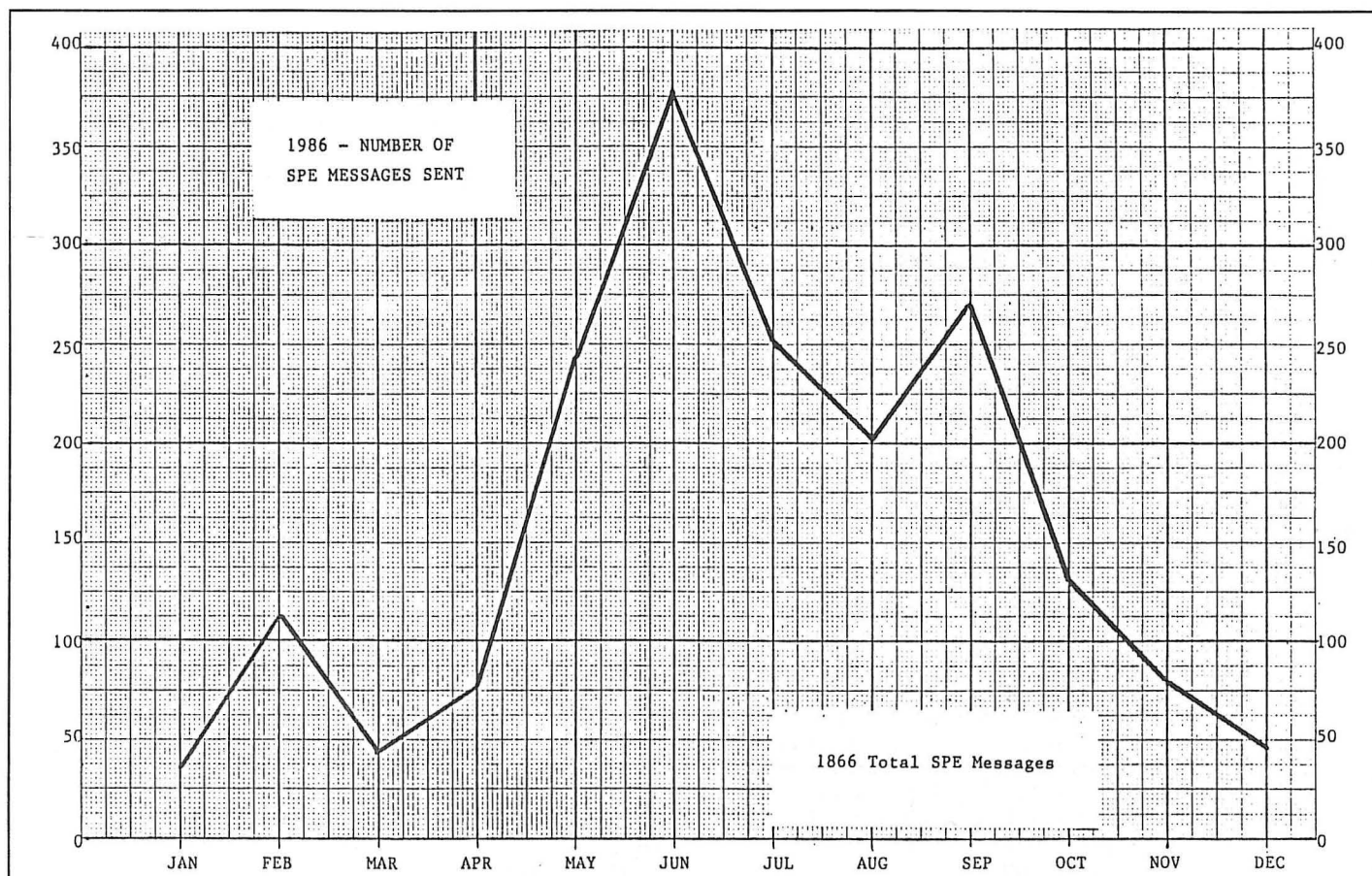
Fig. 3. Total satellite precipitation estimate messages sent for 1986.

rainfall points, for all significant rainfall events for which estimates were done for the previous 24 hr ending at 1200 GMT that day. This study was done for the maximum convective estimates from April to November 1986. Observed amounts of 2 in or more were verified. Estimates were usually compared with an NMC 24-hr precipitation plot that includes station, automatic raingage, and class 1 and 2 cooperative observer reports. A search was then done for the maximum report within a reasonable radius, usually less than 30 mi, and this was compared with the estimate for verification.

1.4.3 *Results.* The results of the verification are in Table 2. Over 500 points were included and were broken into three amount categories. The average percent error ranged from 28% to 36% with an overall average error of 31%. These results were very close to those of a similar study done by Field in 1984 (7). Average absolute error ranged from 0.8 to 1.1 in for observed values up to 5 in and increased to 2.5 in for larger amounts. The results are also separated into underestimates and overestimates. They show a strong tendency to overestimate for smaller amounts and underestimate for larger amounts.

These quantitative results along with the 1984 study should help establish the accuracy and credibility of satellite rainfall estimates and the QPE program for the users and the general scientific community.

1.4.4 *Conclusions and recommendations for users.* The average error figures given above and in the table should give the user a good feel for the accuracy of the estimates. The tendency to overestimate and underestimate in certain situations can also be useful to the SPE user, and statistics on this are presented in the verification table. Since large amounts are usually underestimated, the users can be pretty sure (60%–80% confident) that if the estimate is 4 in or larger, at least 4 in has fallen. The degree of confidence increases to 80% for amounts over 5 in. As can be seen in the following case study, when the estimates reach and exceed 4 in, the forecaster in the WSFO can be increasingly certain that more than that has fallen and a very serious situation could be developing. On the other hand, estimates are usually too high for smaller amounts but by only an average of 0.9 in, which is probably not significant in most cases.

It is recommended that estimates be used in conjunction with local radar. An exact average location error cannot be given, but from this study most estimates appear to be off by no more than 20 mi. Since locations in SPE messages are given by county, an error of this size could put the location in an adjacent county. The user should be aware of this and be ready to make adjustments. Radar can help locate the estimates much more exactly, and all estimates should be compared with local radar. A location error has no effect on the quality of the estimated amount.

A comparison of verification between the summer season and the transition seasons shows a much greater accuracy for the larger amounts in the summer season. This is to be expected because the convective estimating technique was originally designed for cold cloud-top convection of less than

Table 2. Verification summary for SAB convective rainfall estimates for Apr.–Nov. 1986 (All verification points).

Observed Amounts	No. of Points	FOR ALL POINTS		UNDERESTIMATES		OVERESTIMATES	
		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	186	0.8	33.0	17.2	0.4	78.0	0.9
3.0–5.0	251	1.1	27.9	57.0	1.0	39.0	1.2
greater than 5.0	80	2.5	35.7	77.5	2.8	21.3	1.7

TOTALS:
Total Number of Points: 517
Percent of Total Underestimated: 45.8%
Percent of Total Overestimated: 50.3%
Average Error for All Points: 30.9%

−62°C in the summertime (repeat gray on the MB enhancement). During the transition seasons, tops are more frequently warmer than this and, although a warm-top adjustment is made to the estimates, they are more likely to be underestimates and by larger amounts. The user should be aware of this particular situation.

Satellite estimates are attempted equally for all regions of the continental United States, but there are several unique problems encountered in the East and the West. Orographic effects are not accounted for and this should be kept in mind, particularly over the western states and in the Appalachians. The area from the Appalachians eastward is particularly hard to do estimates for because satellite signatures of heavy rainfall are often weak there. In recent years, more of an effort is being made by the SAB meteorologists to do estimates and send messages for these more subtle signatures.

2. THE TEXAS HILL COUNTRY FLASH FLOOD OF JULY 1987: A CASE STUDY

The Texas Hill Country flash flood of July 17, 1987, is presented here as an example of a situation for which satellite precipitation estimates are done. It is also an interesting case study that has several indications of extremely heavy rainfall on the satellite imagery.

2.1 Synoptic features

The synoptic situation showed no clear-cut features at the surface to focus the convection over this area. High pressure centered over the Middle Atlantic states extended westward to Texas, where southeasterly winds brought moisture off the Gulf of Mexico with dew points near 75°F. Moisture was high at all levels with precipitable water near 2 in from the surface to 500 mb, and relative humidities near 80%. The 850-mb chart in Fig. 4 shows strong southerly winds with high dew points up to 18°C. A strong trough can also be seen extending from eastern New Mexico to southwest Texas. This short-wave trough extended up through the middle and upper levels of the atmosphere and was probably the main feature that initiated the strong convection.

2.2 Satellite imagery

The satellite picture at 0400 GMT shows the onset of the heavy rain (Fig. 5). The infrared picture has the MB enhancement, which highlights the coldest cloud tops of the heavy convection. Clearing is seen over southwest Texas and at high levels over southeast New Mexico behind the upper trough. A north-to-south area of convection is north of Del

Rio ahead of the trough. East of this, two separate black spots of strong new convection are first seen on this picture over the Hill Country northwest of San Antonio. The next four pictures are enlarged in Fig. 6. At 0430 GMT a merger is seen between the two separate cold spots of convection that were seen at 0400 GMT. Colder cloud tops (repeating lighter gray shades) result. Increasingly cold cloud tops and mergers are both indications of heavy rain. Also, this convection cluster of cold cloud tops remains stationary for this series of pictures—another indication of heavy rainfall. The stationary cluster is seen at 0500 GMT. Another merger is seen at 0530 GMT as the north-to-south area moving east-
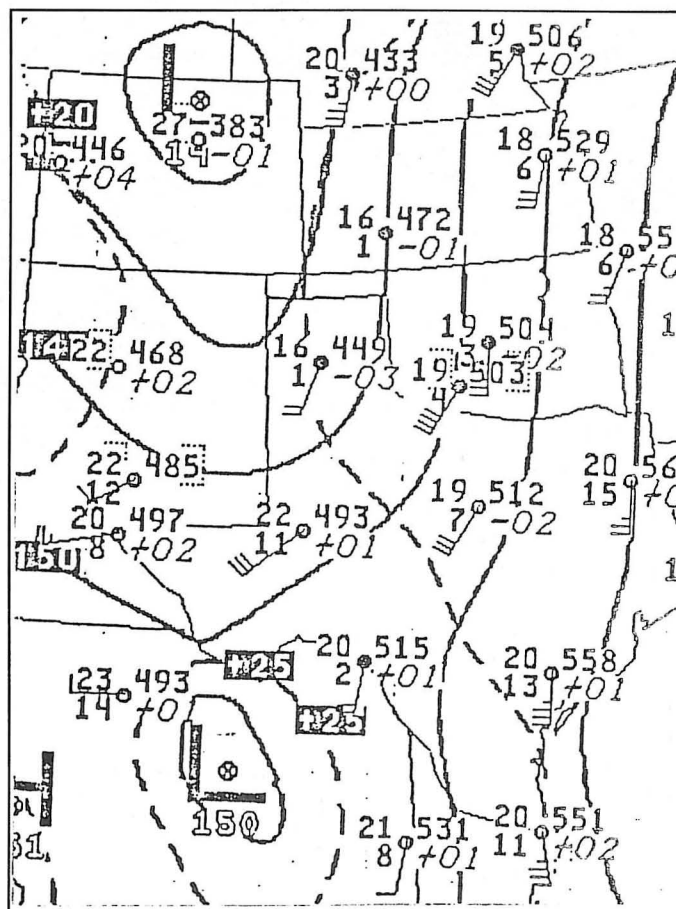

Fig. 4. The 850 mb chart for 0000 GMT July 17, 1987.

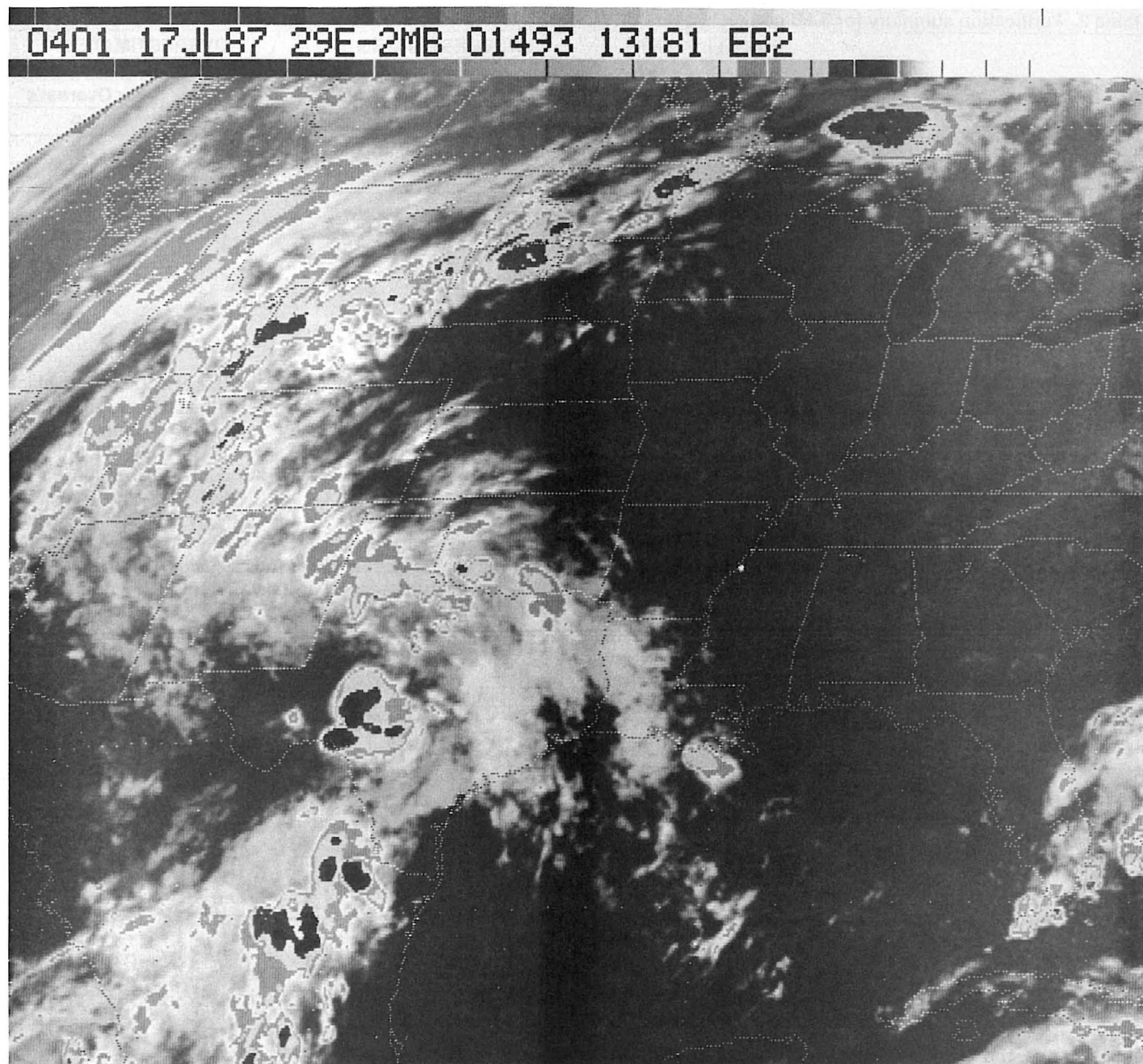`0401 17JL87 29E-2MB 01493 13181 EB2`

Fig. 5. The 0400 GMT July 17, 1987 IR satellite imagery with the MB enhancement.

ward merges with the stationary cluster. At 0600 GMT the coldest cloud tops remain stationary and the two merged areas form one large mesoscale convective system. This system moves slowly eastward in later pictures (not shown). Tropical moisture at mid and high levels feeding across Mexico from Tropical Storm Dora in the east Pacific can be seen in Fig. 5, and may have contributed somewhat to the intensity of the heavy rainfall.

2.3 SPE messages

A total of eight SPE messages were sent by the SAB on AFOS for this event. Figure 7 shows several of these. The first message for the flash flood area indicated up to 2.5 in through 0500 GMT. Later messages indicated an estimated total of 7 in. A message for estimates through 0530 GMT indicated a half-hour rate of 1.5, or 3 in per hour. A reanalysis for this time period gave an estimated hourly rate nearer to 3.5 in. The first NWS flash flood warning at 0600 GMT mentioned radar- and satellite-derived rates near 4 in. Notice the remarks in several of the messages emphasizing the seriousness of the situation. The remarks in SPE messages usually contain descriptions of what is happening in the imagery, with an emphasis on nowcasting-type information such as movements and trends.
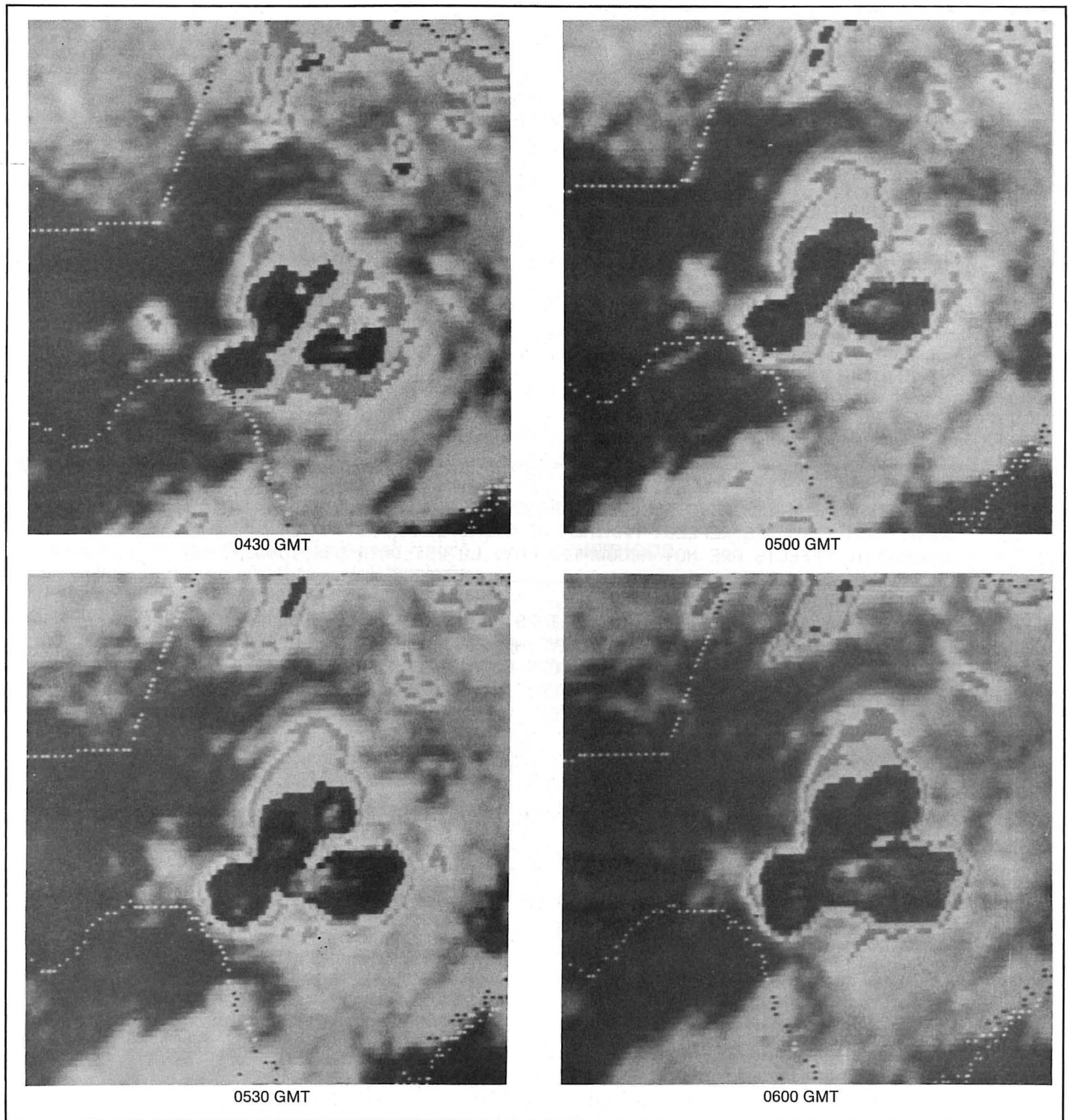
Fig. 6. Enlargements of the imagery for 0430–0600 GMT July 17, 1987.

2.4 The estimates

Figure 8 has an analysis of the rainfall reports (top) and a copy of the IFFA estimates (bottom). The background is the IFFA county map of Texas. Maximum points are indicated by letters listed in the upper left-hand corner. The maximum occurred in western Kerr and northern Real Counties, the

counties in which points C and D are located. This was at the headwaters of the Guadalupe River. The resultant flash flood took the lives of several teenagers when the bus they were riding in was swept away by flood waters several hours later farther downstream over central Kerr County. The Guadalupe River is sketched in across Kerr County with a circled X at the approximate location of the disaster.

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NFDSPENES                        340,1020;300,1020;300,0990;340,0990
SATELL KNFD 170533


SATELLITE PRECIPITATION ESTIMATES... DATE/TIME   7/17/87   0530Z
PREPARED BY THE SYNOPTIC ANALYSIS BRANCH/NESDIS   TEL. 763-8444
QUANTITATIVE VALUES REFLECT MAXIMUM OR SIGNIFICANT ESTIMATES.
OROGRAPHIC EFFECTS ARE NOT ACCOUNTED FOR. LATEST DATA USED: 0500Z   CK
LOCATION                       2 HR TOTALS   REMARKS
SW TX COUNTIES...              03-05Z
VAL VERDE                      1.0"          VAL VERDE CELLS MVG E; SAME FOR
S SUTTON                       1.3           CELLS OVR SUTTON.
E EDWARDS/REAL/W KERR          2-2.5"        MERGER VCNTY OF N REAL 04-05Z.
                                             LEADING EDGED OF COLD TOPS OVR
                                             KERR MVG E...BUT AM AFRAID THAT
                                             W EDGE OVR EDWARDS SHOWS LTL SGNF
                                             MVMNT. THERFORE..OUTFLOW FM VAL
                                             VERDE/SUTTON CNVTN MAY MERGE INTO
                                             ALREADY JUICY SITUATION OVR
                                             EDWARDS/REAL AREA.


SATELLITE PRECIPITATION ESTIMATES... DATE/TIME   7/17/87   0550Z
PREPARED BY THE SYNOPTIC ANALYSIS BRANCH/NESDIS   TEL. 763-8444
QUANTITATIVE VALUES REFLECT MAXIMUM OR SIGNIFICANT ESTIMATES.
OROGRAPHIC EFFECTS ARE NOT ACCOUNTED FOR. LATEST DATA USED: 0530Z   CK
LOCATION                                     REMARKS
SW TX COUNTIES...                            05-0530Z
                                             COLD TOPS MVG THRU E VAL VERDE ARE
                                             INTNSYFYNG. SAME FOR TOPS OVR SUTTON.
                                             AREA OVR EDWARDS HAS STAGNATED AND
                                             INTNSFD...WAITINF FOR APPRCH OF CNVTN
                                             TO WEST. AM ESTMTNG HR HF HR RATE OF 1.5"
                                             OVR E EDWARDS/N REAL. THIS WILL CNTNUE TO
                                             BE A DNGROUS SITUATION FOR NXT CPLE OF HOURS.
                                             EST TOTALS WILL BE FORTHCOMING SHORTLY.


SATELLITE PRECIPITATION ESTIMATES... DATE/TIME   7/17/87   0632Z
PREPARED BY THE SYNOPTIC ANALYSIS BRANCH/NESDIS   TEL. 763-8444
QUANTITATIVE VALUES REFLECT MAXIMUM OR SIGNIFICANT ESTIMATES.
OROGRAPHIC EFFECTS ARE NOT ACCOUNTED FOR. LATEST DATA USED: 0600Z   CK
LOCATION                       TOTALS        REMARKS
SW TX COUNTIES...              03-06Z
VAL VERDE-SUTTON              1-1.5"
MENARD                        1.3
E EDWARDS-REAL                4.0"
KERR                          2.3-3.0 E TO W


SATELLITE PRECIPITATION ESTIMATES... DATE/TIME   7/17/87   1100Z
PREPARED BY THE SYNOPTIC ANALYSIS BRANCH/NESDIS   TEL. 763-8444
QUANTITATIVE VALUES REFLECT MAXIMUM OR SIGNIFICANT ESTIMATES.
OROGRAPHIC EFFECTS ARE NOT ACCOUNTED FOR. LATEST DATA USED: 1030Z   CK
LOCATION                       TOTAL         REMARKS
SW-CNTRL TX CNTYS...           03-1030Z
EDWARDS/REAL/W KERR            WIDESPREAD 5-7"AMNTS;LCLZD HIER AMNTS
GILLESPIE                      5.0"
W BANDERA                      3.9

                               1030 SHWD TOPS OVR REAL/W KERR MVG E..
                               RAINS SHD FINALLY SLACKEN.
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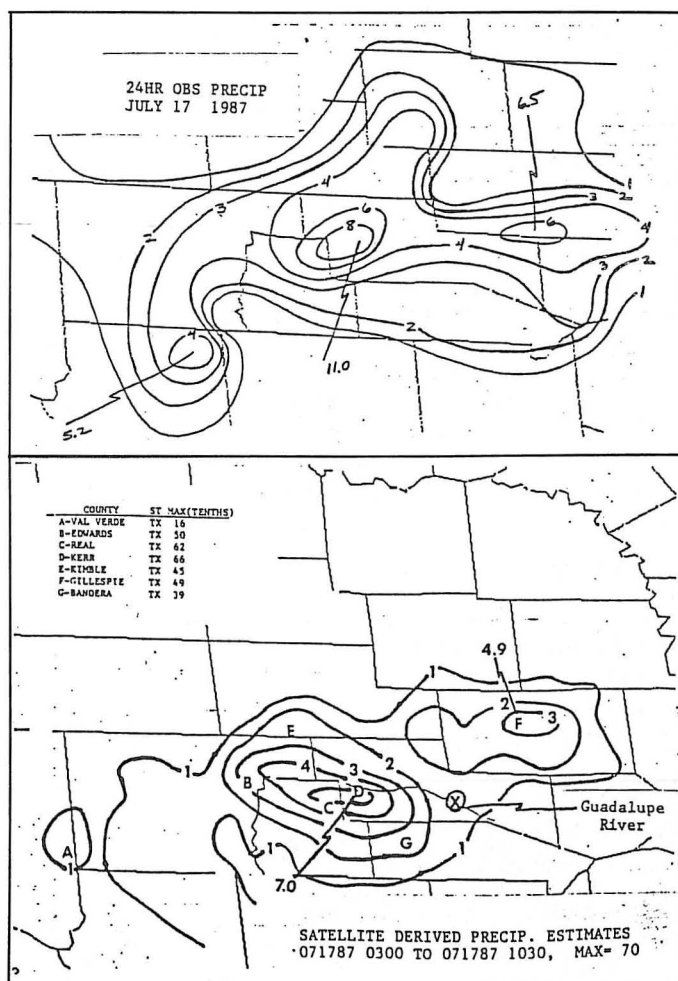Fig. 7. SPE messages sent by SAB for July 17, 1987.

Fig. 8. The computer copy with IFFA county map of Texas (bottom) shows the smoothed rainfall estimates with maximum points indicated by letters; the disaster location along the Guadalupe River is marked by an X. The 24-hr observed rainfall for July 17, 1987, is shown on top.

The estimated total maximum amount was 7 in compared to a maximum report of 11 in. This gives a 36% error of estimate. The location of the estimates was very close to where they actually occurred. It can be seen that these results are very close to the results of the 1986 verification study.

NOTES AND REFERENCES

1. Richard Borneman is a meteorologist with the NESDIS Synoptic Analysis Branch and has been with the group since 1976. Prior to that time, he worked with the Satellite Winds Unit. He has a B.S. degree in meteorology from the Pennsylvania State University.

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7. Field, G., 1985: Verification of SAB's Satellite Precipitation Estimates for the 1984 Convective Season. Nat. Wea. Dig., Vol 10, No. 3, 39–44

8. The verification and 1986 summary portion of this article is condensed from a much more detailed report distributed to the NWS. Anyone who does not have access to this report and desires a copy should contact the author. The information in this article was presented at the 1987 NWA annual meeting in Houston.