

A. Introduction.

Tropical Storm Allison, although never reaching hurricane strength, proved to be a very destructive event. Allison caused nearly one half billion dollars in damages during a six-day period due mainly to the flooding from the torrential rains that fell along the upper Texas coast and over the western two-thirds of Louisiana. The looping storm, which produced over twenty-nine inches of rain in a few areas of central Louisiana, will long be remembered as one of the wettest ever for the state of Louisiana.

B. Synoptic Features

The formation of Tropical Storm Allison can be attributed to at least three meteorological phenomena: the remnants of the east Pacific Hurricane Cosme, the northern portion of a westward moving tropical wave and a strong anticyclone at 200-millibars over the Gulf of Mexico. These three factors in addition to a building ridge of high pressure over the central plains provided the environment that created Allison. A strong mid- to upper level-trough in the westerlies which turned Cosme to the north and spread the remnants of that storm over northern Mexico and the western Gulf of Mexico had been replaced by a large well-defined 200-millibar anticyclone that covered the entire Gulf of Mexico. To the north, moderate to strong ridging occurred on 22 through 24 June, and during this time the northern portion of tropical wave number eight had moved into the western Gulf of Mexico.

Heavy thunderstorms began to develop over the Gulf of Mexico on 22 June and by 23 June the activity became concentrated over the northwest portion of the Gulf. Data from upper-air soundings indicated that the circulation from the remnants of Cosme were just to the southwest of Brownsville, Texas, at 1200 UTC on 23 June. During the following twenty-four hours, a new broad weak surface circulation developed just off the upper Mexican coast.

Based upon surface observation along the coast and data from offshore oil rigs, the area of disturbed weather was upgraded to Tropical Depression Number Two at 1800 UTC on 24 June. The depression gradually became better organized during the next two days. Early on the morning of 26 June, Air Force reconnaissance aircraft detected a large area of 40-to 45-knot winds at a flight level of 1500 feet; and the depression was officially upgraded to Tropical Storm Allison at 1200 UTC 26 June. However, post-analysis indicated the depression probably reached tropical storm strength near 0000 UTC on 26 June. At 0100 UTC on 26 June the ship M/T Jacinth (LAOE2), located about 100 nautical miles northeast of the estimated center of the storm, reported east-southeast winds of 35 knots with gusts to 45 knots.

By 1200 UTC 26 June a frontal trough in the westerlies moving across the western United States began to erode the ridge of high pressure to the north of Allison, and the storm began to accelerate toward the north in advance of the trough. The center of Allison moved inland on the middle Texas coast near the northeast end of Matagorda Bay at 1300 UTC 26 June with a central pressure of 1002 millibars. The central pressure of the storm continued to decrease and reached an estimated minimum reading of 999 millibars at 0100 UTC 27 June while the center of Allison was located just to the west-northwest of Houston, Texas. Thereafter, the storm began to weaken, was downgraded to a tropical depression by 1200 UTC 27 June, and became an extratropical low pressure center by 0000 UTC 28 June.

Allison turned toward the northeast by 0600 UTC 27 June in advance of a fast-moving frontal trough. However, the trough weakened and lost its influence on the storm. By 0000 UTC 28 June the building ridge of high pressure in the wake of the frontal trough began to drive the now-extratropical low pressure center in a clockwise loop back toward the south and then toward the southwest (see FIG. 1).

The extratropical low pressure center moved toward the southwest through 0600 UTC 30 June and crossed the northerly track that Tropical Storm Allison had made three days earlier just to the west of Houston, Texas. After the low completed a 360° clockwise loop over western Louisiana and eastern Texas, the ridge to the north collapsed and the low center turned back to the northeast.

At 0000 UTC 01 July both a cutoff 700- through 500-millibar low over eastern South Dakota and southwestern Minnesota and the closed 700-through 500-millibar circulation of the extratropical low pressure over northwestern Louisiana were analyzed (not shown). By 1200 UTC 01 July the 500-millibar low over Louisiana and Arkansas became an open trough, and the closed 500-millibar low center to the north (then over Iowa and northern Missouri) became the dominant center. Thereafter, only at the surface and the 850-millibar level could the remnants of Allison be tracked with any degree of certainty. Figure 1 shows the complete track of Allison during its various stages. Table 1 contains the best track positions and intensities.

The remnants of Allison, now reinforced at the mid and upper levels of the atmosphere by a short wave trough from the westerlies, moved northeastward over northwestern Kentucky on 2 July and remained quasi-stationary near the convergence of the Kentucky/Illinois/Indiana borders until the morning of 4 July. During the 4th, a second short wave trough moved into the dominant frontal trough that contained the remnants of Allison and created a second cut-off circulation center at the 700- and 500-millibar levels well to the south of the residual circulation, which remained over the Kentucky/southwestern Ohio area. However, once again the remnants of Allison at the surface and 850-millibar level remained intact and were traced southward into Alabama by the evening of 4 July. Thereafter, the remnants drifted westward and finally dissipated over northwest Louisiana and east Texas on 6 and 7 July after dropping an additional inch or two of rain over portions of the still-flooded rivers of east Texas and western Louisiana.

C. METEOROLOGICAL STATISTICS.

1. WINDS

Wind gusts to tropical-storm force occurred in the clusters of heavy showers and thunderstorms as early as 24 June. Practically all of the strongest surface winds and peak gusts measured in Allison occurred in the clusters of heavy thunderstorms that developed in the right half of the tropical cyclone's circulation. Satellite pictures in Fig. 2 show the heavy thunderstorm activity that had developed by 26 and 27 June. Strongest winds and peak gusts from the offshore oil rigs occurred as these heavy thunderstorms crossed over the observation platforms. Table 2 lists some of the coastal and offshore observations. Note: The oil rigs L40 and 01T measured maximum sustained winds of 50 and 40 knots, respectively, on 26 June while in heavy precipitation. Also the coastal observation site 7R5 recorded a peak gust of 60 knots in a thunderstorm.

Strongest 1-minute winds over land ranged from 35 to 45 knots with a gust to nearly 50 knots. The Galveston weather office measured the strongest 1-minute wind of 45 knots at 1238 UTC on 26 June which was near the time Allison made landfall. Table 3 lists selected meteorological data from various land observation points along Allison's track. Notice that the maximum wind and peak gust at Lake Charles occurred twenty-four hours after Allison made landfall; or as can be seen in the satellite picture in Fig. 2B, the maximum winds and gusts did not occur until the strong thunderstorms reached the Lake Charles area. Figure 3 shows selected wind speed observations versus time during the various stages of Allison.

2. PRECIPITATION

Torrential rains accompanying Allison fell along the upper Texas coast and over the western two-thirds of Louisiana. Nearly 30 inches (29.52) fell in a six-day period at a few locations in north-central Louisiana and amounts of 10 to 15 inches were common along the upper Texas coast. The small community of Winfield, Louisiana, had 29.52 inches of rain from 26 June through 01 July, with 17 inches falling in a three-day period. Portions of Harris County, Texas, received over 18 inches. Figure 4 shows rainfall amounts from Allison for Harris County, Texas, which includes the greater Houston area. Tables 3 and 4 contain rainfall amounts from various locations affected by Allison or its remnants.

3. PRESSURE

Table 1 contains a list of the best track pressure estimates for Tropical Storm Allison and Fig. 5 shows the best track minimum central pressure curve. Based upon satellite imagery and surface observations from oil rigs, initial central pressure estimates on 24 June were near 1008 millibars. Air Force reconnaissance data on 25 June indicated that the central pressure decreased slightly to 1005 millibars. By the time Air Force reconnaissance reached the center of Tropical Storm Allison on the morning of 26 June, the storm's broad center of circulation appeared to be near the middle Texas coast. Lowest pressure

measurements from the aircraft indicated that the central pressure had fallen to 1002 millibars when Allison's center moved onshore near the northeast end of Matagorda Bay. The central pressure of the storm continued to decrease for an additional twelve hours after landfall and reached an estimated minimum reading of 999 millibars at 0100 UTC 27 June when the storm was centered just to the west-northwest of Houston, Texas. Thereafter, gradual weakening occurred and the storm was downgraded to a depression by 1200 UTC 27 June.

D. CASUALTY and DAMAGE STATISTICS

The death toll in Tropical Storm Allison was eleven. Three deaths occurred in Texas, three in Louisiana and five in Mississippi. Two teenage boys drowned in Beaumont after the rubber raft they were riding in capsized and they were swept down a drainage pipe by the flood runoff of Allison. Also an eighteen year old boy drowned while swimming in Spring Creek in northern Harris County. The three deaths in Louisiana and the five in Mississippi were all by drowning.

Initial dollar-damage estimates from Allison may run as high as one half billion dollars. Almost all damage occurred from the flooding produced by the heavy rains. Early estimates indicate from 200 to 400 million dollars in damages occurred in Texas while upwards to 100 million was reported in Louisiana. Mississippi claimed nearly 60 million in damages.

E. WARNING and FORECAST CRITIQUE

Table 5 contains a listing of all warnings issued by the National Hurricane Center (NHC) for Allison. The timing and geographical coverage of the initial tropical storm watch was excellent. Even though the system was a tropical depression at the time the watch was issued, the potential for development of the depression to tropical storm strength was recognized and the issuance of the watch was appropriate.

Model guidance varied considerably from forecast to forecast. However, overall the NHC 83 model outperformed all others. Frequently, large discrepancies were observed in the forecast tracks of the QLM and SANBAR. None of the models forecast the 360° loop that occurred over eastern Texas and western Louisiana.

The initial NHC forecast, issued at 1800 UTC 24 June, proved to be one of the best forecasts made for this system, since it predicted landfall within 20 miles of the actual point of landfall and was only 11 hours fast in timing. Following forecasts varied only in timing since the forecast direction remained northerly.

The major problem faced by forecasters was determining if and when the depression needed to be upgraded to a tropical storm. The depression was upgraded to a tropical storm at 1200Z 26 June. Post-analysis indicates the system probably reached tropical storm strength near 0000Z 26 June. However, in this particular situation forecasters were dealing with a 10-knot difference in wind speed in deciding whether it should have been a depression or a storm. In retrospect, with Allison the wind proved to be insignificant; it was the excessive amount of rain that did the damage.

Acknowledgement

Special thanks to the National Weather Service (NWS) offices along the upper Texas coast and in western Louisiana, the WSFO in Memphis and the WSFO in Louisville for their cooperation in supplying statistical data for Allison. Also, a special thanks to the Meteorological Services Division NWS at Southern Region Headquarters.

Table 1. Preliminary best track, Tropical Storm Allison 24-27 June 1989

DATE/TIME (UTC)	POSITION		PRESSURE (MB)	WIND SPEED (KT)	STAGE
	LAT. (° N)	LONG. (° W)			
24/1800	27.0	96.0	1008	30	Tropical Depression
25/0000	27.0	96.0	1006	30	"
0600	27.2	96.0	1005	30	"
1200	27.4	95.9	1005	30	"
1800	27.6	95.8	1005	30	"
26/0000	27.8	95.8	1004	35	Tropical Storm
0600	28.1	95.8	1004	35	"
1200	28.6	95.7	1003	40	"
1800	29.1	95.7	1001	45	"
27/0000	29.7	95.7	999	45	"
0600	30.2	95.3	1000	35	"
1200	30.6	94.9	1002	30	Tropical Depression
1800	30.9	94.6	1004	30	"
28/0000	31.1	94.2	1004	30	Extratropical
0600	31.1	93.9	1005	30	"
1200	31.0	93.7	1006	30	"
1800	30.6	93.8	1007	25	"
29/0000	30.5	94.2	1008	25	"
0600	30.3	94.6	1008	25	"
1200	30.1	95.0	1008	25	"
1800	29.8	95.2	1008	25	"
30/0000	29.6	95.3	1009	20	"
0600	29.7	95.7	1010	20	"
1200	30.4	95.7	1011	20	"
1800	31.1	95.5	1010	20	"
01/0000	31.8	95.1	1010	20	"
0600	32.3	94.5	1010	20	"
1200	32.8	93.8	1010	20	Remnants
02/0000	34.5	91.0	1009	20	"
1200	36.5	89.5	1009	20	"
03/0000	37.8	87.5	1007	20	"
1200	38.5	87.5	1009	20	"
04/0000	38.0	88.0	1011	20	"
1200	37.0	87.0	1012	20	"
05/0000	33.0	88.0	1010	20	"
1200	32.0	87.0	1012	20	"
06/0000	31.0	89.0	1012	20	"
1200	33.5	94.0	1015	15	"
07/0000	-----DISSIPATED-----				

landfall:

26/1300	28.7	95.7	1002	40	Tropical Storm
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lowest pressure:

27/0040	29.8	95.6	999	45	Tropical Storm
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Table 2. Meteorological data for Tropical Storm Allison from selected coastal and offshore observation points.

<u>STATION</u>	<u>LOCATION</u>		<u>MAX WINDS (KT)</u>		<u>CURRENT WEATHER</u>	<u>TYPE</u>	<u>HEIGHT ABV SURFACE (FT)</u>
	<u>LAT(N)</u>	<u>ION(W)</u>	<u>DATE/TIME(UTC)</u>				
PTAT2	27.8	97.1	080/23+25	24/1900		C-MAN	
T46	28.0	95.9	100/30+40	24/1645	R-F	SAWRS	
O.CHIEF	28.2	96.3	ESE/30	25/1400		OIL RIG	
LAOE2	28.6	94.3	ESE/35+45	26/0100	R+	SHIP	
01T	28.1	94.4	100/50	26/1315	WOXORF	SAWRS	110
L40	28.2	94.2	110/40	26/1055	RW		132
RPE	29.7	93.9	120/20+38	26/1618			35
5R0	28.2	93.8	180/30+35	26/1648		SAWRS	120
SRST2	29.6	94.0	160/33+41	27/0700		C-MAN	
WC459A	28.3	93.0	SSE/34+37	27/0715		OS/AMOS	80
VR119G	29.1	92.5	S/30+36	27/1307		OS/AMOS	80
7R5	29.8	93.3	210/30+60	27/1324	1/8TRWF		35
WC66C	29.7	93.1	SSE/41+49	27/1428		OS/AMOS	70
SM108G	28.4	92.0	SW/32+35	28/1229		OS/AMOS	80
7W2	28.5	92.5	240/35+40	28/1254	1TRWF		
7R8	28.3	92.0	270/30	28/1451	5R-F		
EC42B	29.5	92.8	SE/44+51	29/1508		OS/AMOS	70

Table 3. Selected meteorological and hydrological statistics for Tropical Storm Allison, 24-27 June 1989 and total rainfalls which includes rainfall associated with the remnants of Allison.

<u>LOCATION</u>	<u>STRONGEST SUSTD WINDS (KT)</u> <u>DATE/TIME (UTC)</u>		<u>PEAK GUST (KT)</u> <u>DATE/TIME (UTC)</u>		<u>MIN PRESS (MB)</u> <u>DATE/TIME (UTC)</u>		<u>RAINFALL (IN)</u> <u>24HR TOTAL</u>		<u>STORM</u> <u>TOTAL (IN)</u>	<u>STORM SURGE (FT)</u> <u>LOCATION & DATE/TIME (UTC)</u>
<u>Texas</u>										
Corpus Christi (WSO)	020/20	25/1950	27	25/0201	1005.8	26/2150 /2350	0.89	0000/25 0000/26	1.40	2.3 North Padre Is. 24/2300
Palacios (WSO)	240/14	26/1754			1002.9	26/1953				
	320/14	27/1655								
Galveston (GLS)	120/45	26/1238	49	26/1536	1003.3	27/0030	4.15	26th	7.89	2.7 Flagship pier 26/1530
Houston Hobby (HOU)	090/25	26/1643	39	26/1630	1001.5	26/2350	7.24	26th	11.89	
Houston Intercontinental (IAH)	090/34	27/0052	46	27/0052	999.9	27/0042	10.34	0600/26 0600/27		
Alvin (WSO)	090/18	26/1457	32	26/1457			1.90	1200/26 1200/27	6.58	
Houston Downtown							7.65	26th	10.78	
Port Arthur/Beaumont (WSO)	---/26	27/0653 /0855	40	27/0641	1003.3	27/0653	6.92	1300/26 1300/27		2.8 Sabine Pass 27/1449

Table 3. cont.

<u>LOCATION</u>	<u>STRONGEST SUSTD WINDS (KT)</u> <u>DATE/TIME (UTC)</u>	<u>PEAK GUST (KT)</u> <u>DATE/TIME (UTC)</u>	<u>MIN PRESS (MB)</u> <u>DATE/TIME (UTC)</u>	<u>RAINFALL (IN)</u> <u>24HR TOTAL</u>	<u>STORM</u> <u>TOTAL (IN)</u>	<u>STORM SURGE (FT)</u> <u>LOCATION & DATE/TIME (UTC)</u>
<u>LOUISIANA</u>						
Lake Charles (WSO)	180/37 27/1250	48 27/0727	1004.1 27/0752	6.92 27th	14.95	
SHREVEPORT (WSO)	NE /20 27/—	34 30/—	1007.4 27/2151	3.70 27th	9.20	
Baton Rouge (WSO)				4.90 28th	10.33	
<u>KENTUCKY</u>						
Louisville (WSFO)				3.70 1200/01 1200/02	4.75	

Table 4. Supplementaryinfall storm totals (in) from Tropical Storm Allison and the storm's remnants.

<u>LOCATION</u>	<u>AMOUNT</u>	<u>DATES (UTC)</u>
Winnfield, LA	29.52	26 June - 01 July
Gorum Fire Tower, LA (Natchitoches Parish)	19.17	26 June - 01 July
Harris County, TX	18.3	22/0000 - 30/0400
Memphis Agriculture Cntr. Memphis, TN	4.13	30/1300 - 03/1300
Dyersburg, TN	3.59	30/1300 - 03/1300
Grand Junction, TN	4.71	30/1300 - 03/1300
Covington, TN	2.61	30/1300 - 03/1300
Milan, TN	3.74	30/1300 - 03/1300
Paris, TN	3.55	30/1300 - 03/1300
Collierville, TN	5.25	01/0600 - 04/0600
Nashville, TN	1.14	01/0600 - 04/0600
Crossville, TN	3.64	01/0600 - 05/0600
Elkton, KY	4.75	01/1300 - 03/1300
Fort Campbell, KY	4.01	01/1300 - 04/1300
Franklin, KY	6.57	01/1300 - 04/1300

Table 5. Summary of Tropical Storm Allison Warnings issued by the National Hurricane Center.

<u>DATE/TIME</u> <u>(UTC)</u>	<u>ACTION</u>	<u>LOCATION</u>
24/2200	Tropical Storm Watch in effect...	From Baffin Bay, TX to Morgan City, LA.
26/1200	Tropical Storm Warnings in effect for winds up to 40 mph with gusts to 55 mph mainly north and east of center...	From Freeport, TX to Morgan City, LA.
26/1600	Tropical Storm Warnings continue in effect for winds up to 50 mph with gusts to 65 mph...	From Freeport, TX to Morgan City, LA.
26/2200	Tropical Storm Warnings continue in effect for winds up to 45 mph with gusts to 55 mph...	From Freeport, TX to Morgan City, LA.
27/0400	Tropical Storm Warnings continue in effect fo winds up to 40 mph with gusts to 50 mph...	From Freeport, TX to Morgan City, LA.
27/1000	Discontinue Tropical Storm Warnings...	From Freeport, TX to Morgan City, LA.

Table 6. Chance of the center of Allison passing within 65 miles of the listed locations by date and time (CDT) indicated. Probabilities in percent. X means probabilities less than 2 percent.

Advisory Date/Time Probability Thru	24/5PM 27/1PM	24/930PM 27/7PM	25/5AM 28/1AM	25/11AM 28/7AM	25/5PM 28/1PM	25/930PM 28/7PM	26/5AM 29/1AM	26/11AM 29/7AM
MMSO 238N 982W	06	09	10	06	07	X	X	04
MMIM 222N 979W	03	05	06	03	03	X	X	02
Cedar Key, FL.	X	02	02	X	X	X	X	X
St Marks, FL.	02	03	03	02	02	X	X	X
Apalachicola, FL.	02	03	03	03	03	X	X	X
Panama City, FL.	03	04	04	03	03	X	X	X
Pensacola, FL.	05	05	05	05	05	X	X	05
Mobile, AL.	06	07	07	07	07	X	X	07
Gulfport, MS.	08	08	08	08	08	X	X	08
Buras, LA.	08	09	09	08	08	X	X	08
New Orleans, LA.	09	10	10	10	10	X	X	10
New Iberia, LA.	13	13	12	14	13	02	04	15
Port Arthur, TX.	18	16	15	19	18	11	17	35
Galveston, TX.	24	19	18	27	23	22	34	99
Freeport, TX.	32	21	19	38	28	32	99	99
Port O Connor, TX.	46	24	23	99	99	99	99	99
Corpus Christi, TX.	28	22	23	26	39	34	21	15
Brownsville, TX.	16	22	26	14	17	10	04	08
GULF 29N 85W	02	03	03	02	02	X	X	02
GULF 29N 87W	04	05	05	04	04	X	X	04
GULF 28N 89W	05	07	07	06	06	X	X	05
GULF 28N 91W	09	11	11	09	10	X	X	08
GULF 28N 93W	16	18	17	16	17	08	10	14
GULF 28N 95W	50	30	26	99	99	57	99	99
GULF 27N 96W	99	99	99	99	99	99	99	13
GULF 25N 96W	11	36	99	10	12	04	X	06

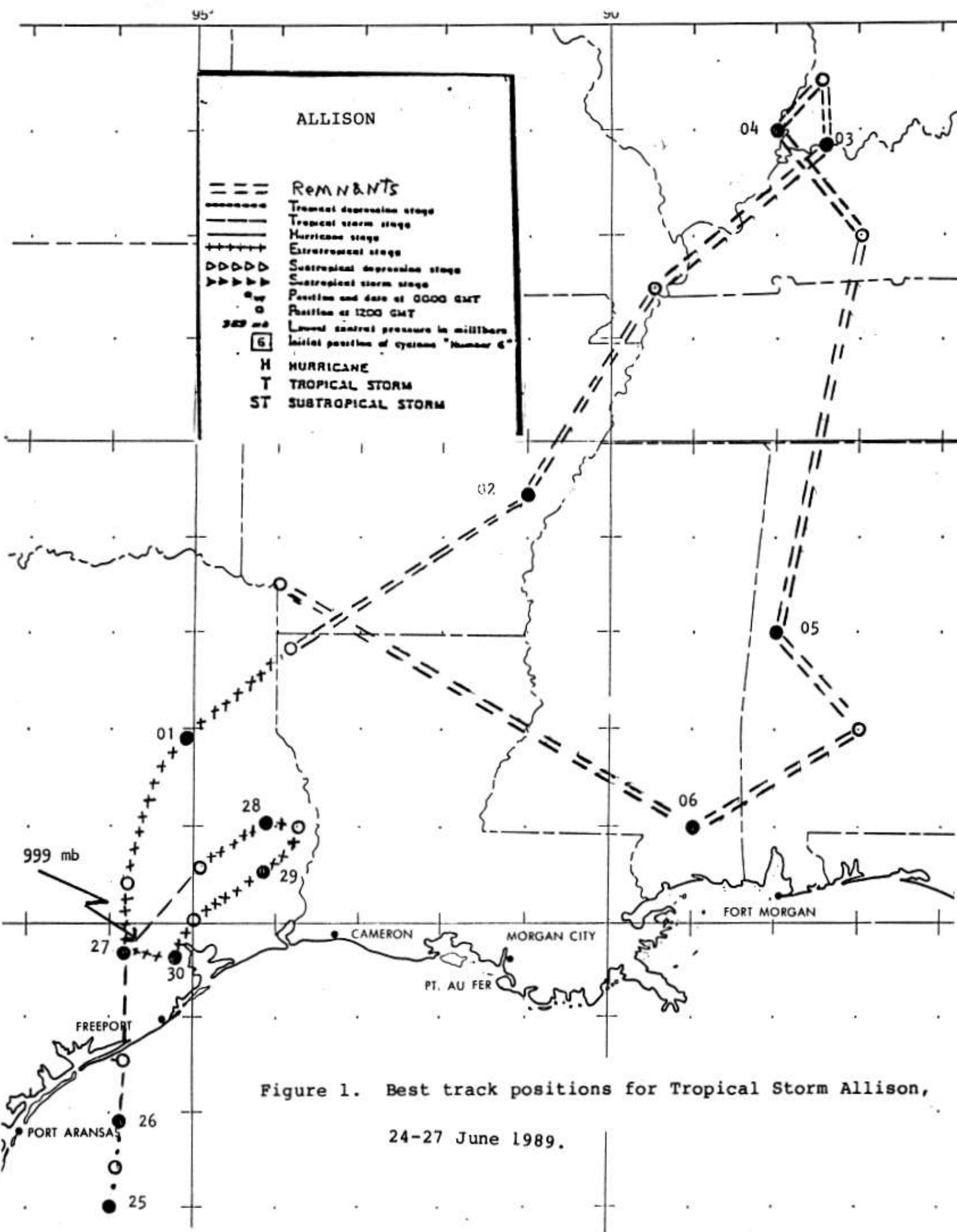
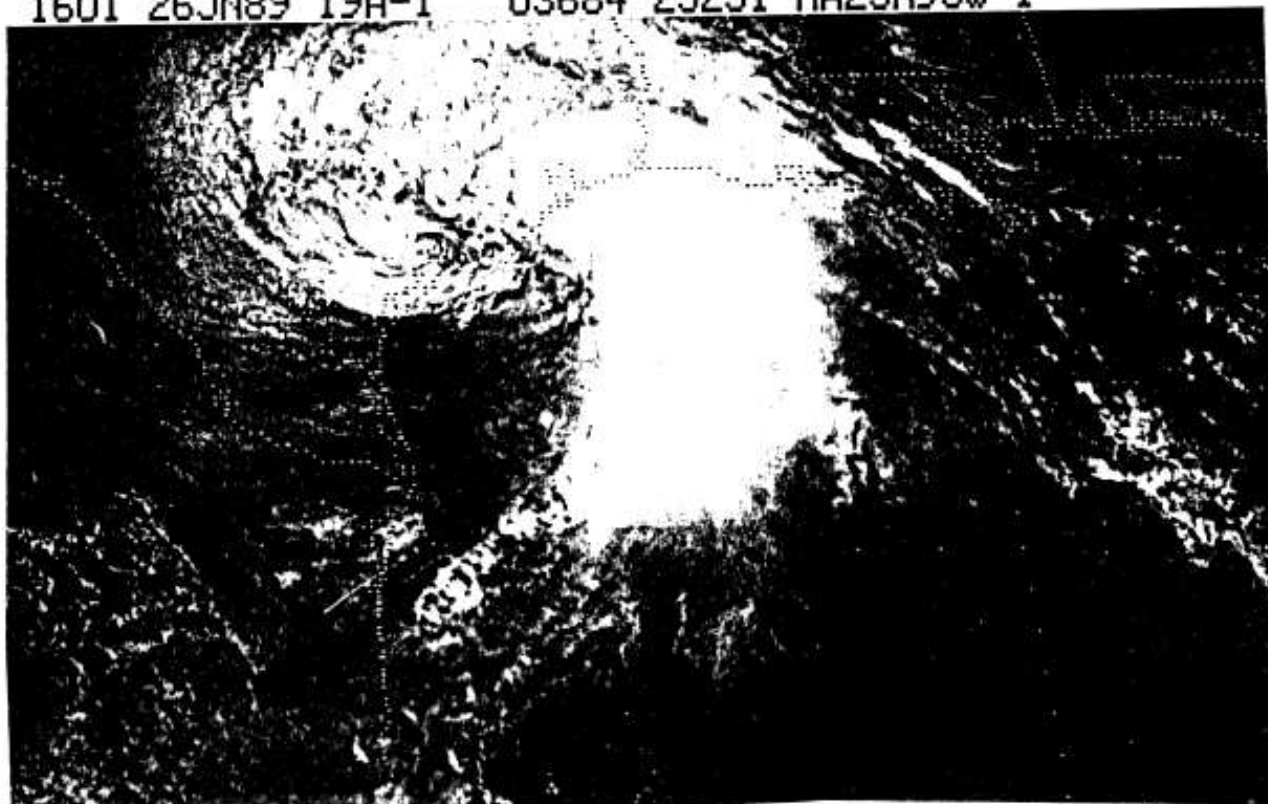


Figure 1. Best track positions for Tropical Storm Allison, 24-27 June 1989.

1601 26JN89 19A-1 03684 23251 MA25N95W-1



1701 27JN89 19A-1 02878 23293 MA31N94W-1

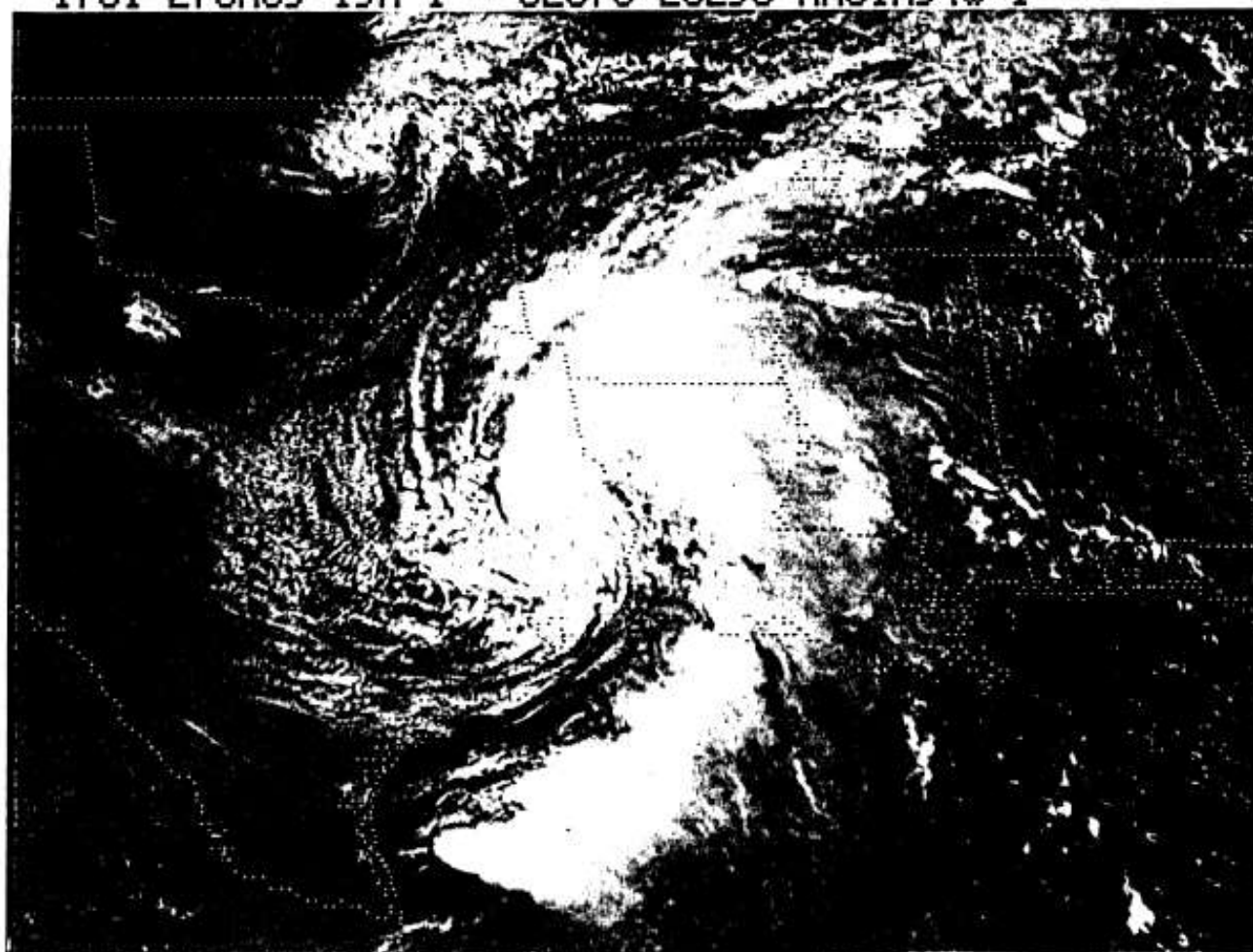


Figure 2. GOES 7 satellite pictures of Tropical Storm Allison.

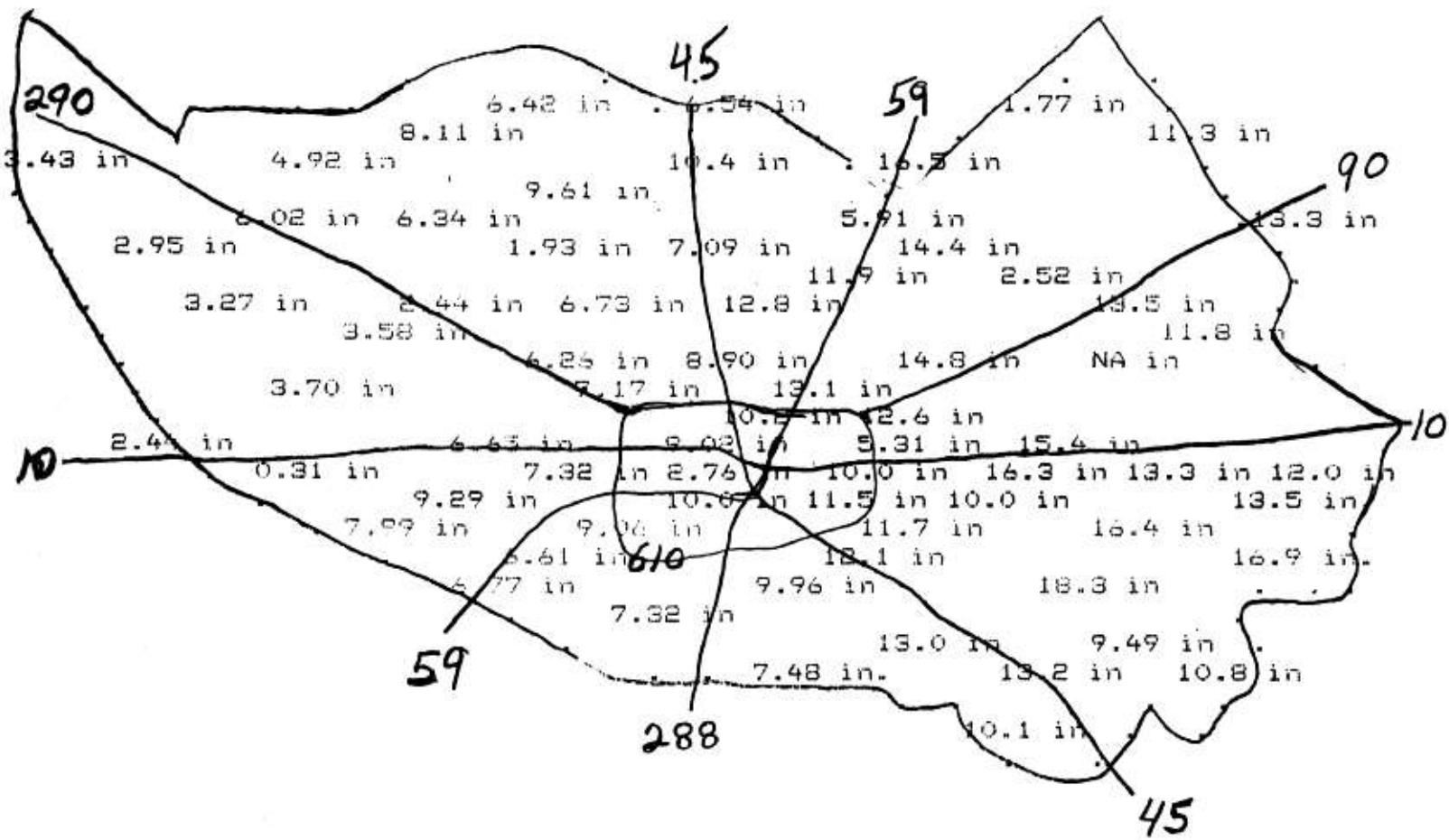


Figure 4. Harris County, Texas, rainfall totals from Tropical Storm Allison and the extratropical stage of the system. Time period: 0000Z 6/23/89 to 0400Z 7/01/89. City of Houston basically enclosed within loop 610.

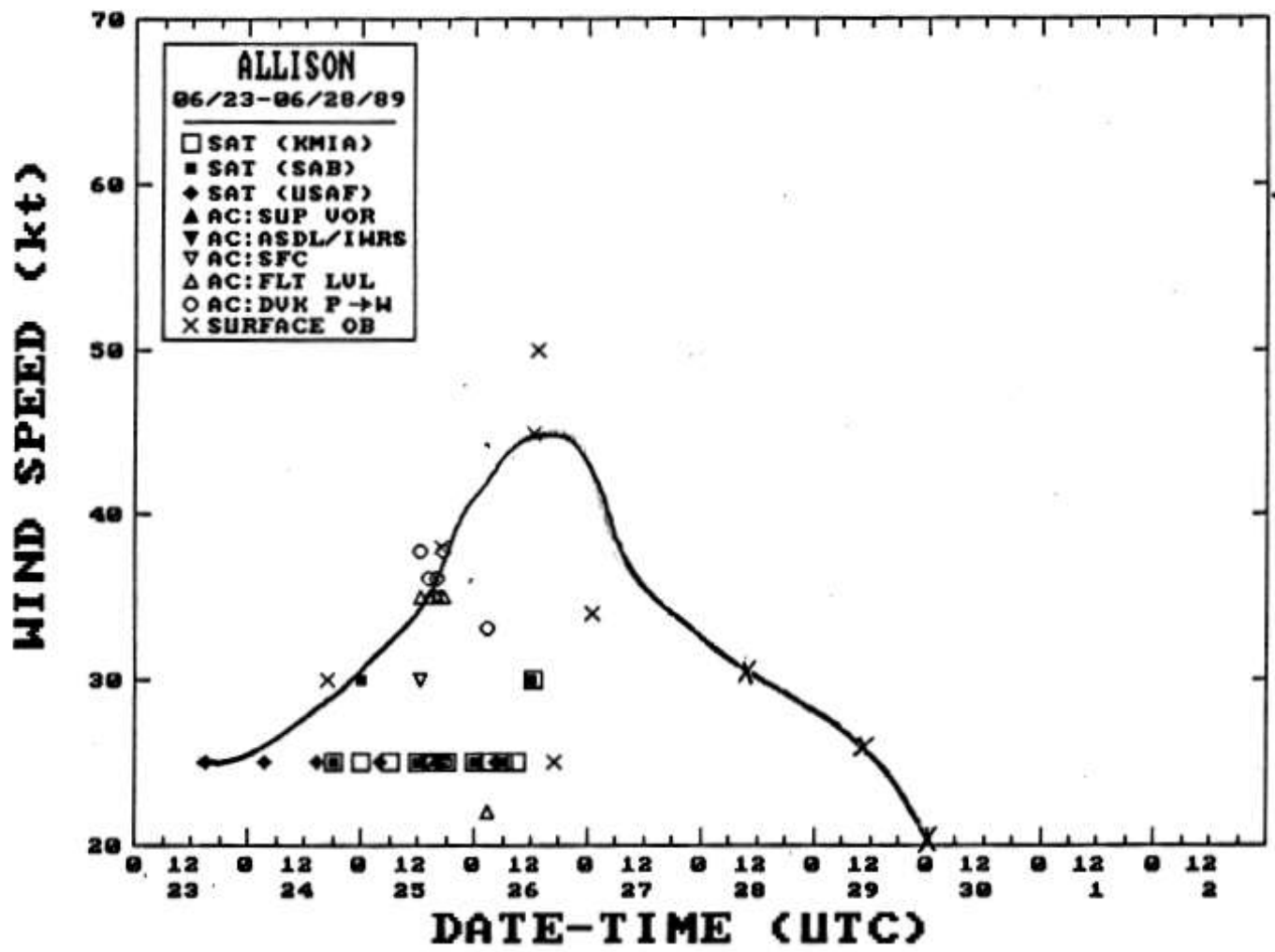


Figure 3. Best track maximum sustained wind speed curve for Tropical Storm Allison, 24-27 June 1989.

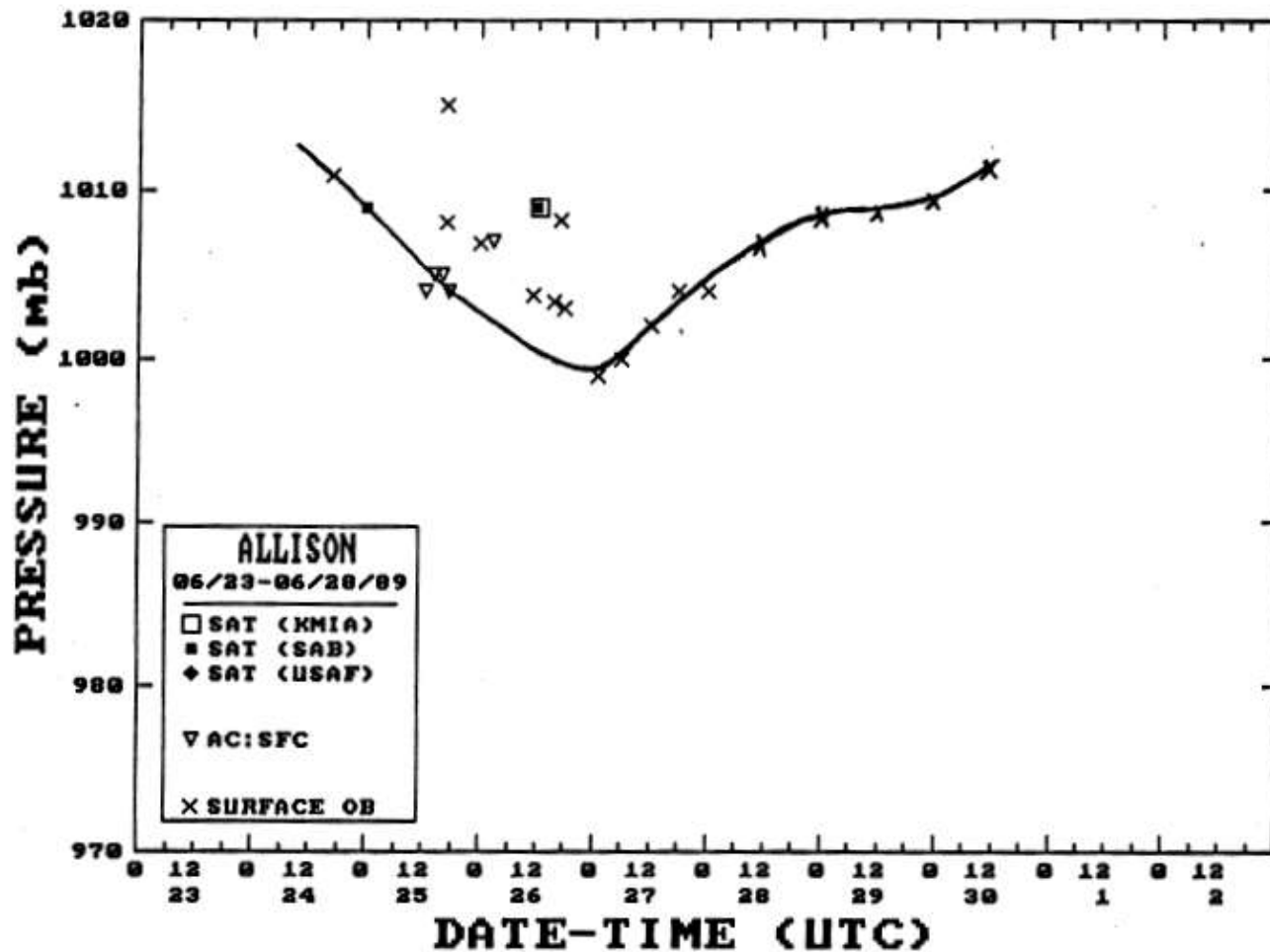


Figure 5. Best track minimum central pressure curve for Tropical Storm Allison, 24-27 June 1989.