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NASA Technical Memorandum 73288

An Atlas of 1977 and 1978 GEOS-3 Radar Altimeter Data for Tropical Cyclone Studies

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AC 804 824-3411

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An Atlas of 1977 and 1978 GEOS-3 Radar Altimeter Data for Tropical Cyclone Studies

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FOREWORD

This document's primary purpose is to provide the means for locating and extracting GEOS-3 altimeter data acquired for the analysis of specific hurricanes, typhoons, and other tropical cyclones. This data may also be extremely useful in the analysis of the behavior of the altimeter instrument in the presence of severe meteorological disturbances as well as provide a data base which can be useful in the resolution of apparently anomalous geoid or sea surface characteristics.

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LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

This document is the result of recent efforts to correlate all of the GEOS-3 satellite altimeter schedule information with all of the available 1977 and 1978 tropical cyclone positional information. The time period covers from March 23, 1977 through Nov. 23, 1978. The geographical region includes all ocean area north of the equator divided into the following operational areas: the Atlantic area (which includes the Caribbean and Gulf of Mexico); the eastern Pacific area; the central and western Pacific area; and the Indian Ocean area.

During this reporting period, an effort was maintained to schedule the GEOS-3 altimeter consistent with available tropical cyclone location information. However, the effort was not nearly as intense as that employed during the 1975 season. The results of the 1977 and 1978 efforts appear consistent with the conclusions reached after the 1975 and 1976 efforts - that, with the large number of uncontrolled variables associated with the GEOS-3 altimeter operations, the success ratio is mainly due to chance.

The approach taken in producing this document consists of the following steps:

1. All available source material concerning tropical cyclones was collected.

2. The date/time/location information was extracted for each disturbance.

3. This information was compared with the GEOS-3 altimeter ON/OFF history information to determine the existence of any altimeter data close enough in both time and location to make the data potentially useful for further study (the very liberal criteria used was time less than 24 hours and location within 25 degrees).

4. Geographic plots (cyclone versus GEOS-3 orbit track) were produced for all of the events found showing the approximate location of the cyclone and the GEOS-3 orbit traces for the full day.

5. The geographic plots were annotated with the available cyclone track information and the pertinent GEOS-3 altimeter schedule information (orbit number, time of the point of closest approach, etc.).

6. The basic source material as well as the resulting geographic plots were grouped together and are presented for each of the tropical cyclones considered.

The altimeter mode information indicated on the daily GEOS/Cyclone plots can be decoded as follows:

Mode #	Mode
702	• Altimeter Intensive Mode
	• Data Rate - Lo (TM Form 1)
	• Altitude Data Rate - 10/sec.
	• Waveform Data and Rate - 16 averaged waveform samples at one per 2.2 seconds each.
	• Both pre and post bit-cal performed
703	• Global Mode Data
	• Lo Data Rate (TM Form 1)
	• Both pre and post bit-cal performed
711	• Altimeter Intensive Mode
	• Data Rate - Hi (TM Form 3)
	• Altitude Data Rate - 100/sec.
	• Waveform Data and Rate - 8 even numbered instantaneous waveform samples at 100/sec each. 16 averaged waveform samples at one per 3.2 seconds each
	• Both pre and post bit-cal performed

Mode #	Mode
708	• Altimeter Intensive Mode
	• Data Rate - Hi (TM Form 2)
	• Waveform Data and Rate - 16 instantaneous waveform samples at 100/sec. each
	• Both pre and post bit-cal performed
	• 16 averaged waveform samples at one per 3.2 seconds each
802	• Altimeter Intensive Mode
	• Data Rate Lo (TM Form 1)
	• 16 averaged waveform samples at one per 2.2 seconds each
803	• Global Mode Data
	• Lo Data Rate (TM Form 1)
808	• Altimeter Intensive Mode
	• Data Rate Hi (TM Form 2)
	• 16 instantaneous waveform samples at 100/sec. each
	• 16 averaged waveform samples at one per 3.2 seconds each

2.0 ATLANTIC AREA TROPICAL CYCLONES - 1977

The 1977 Atlantic hurricane season can be characterized as an inactive one. There were six named tropical cyclones, of which five reached hurricane force.

The first storm was named on August 29, an extremely late start. Since 1886, fewer than 10% of the seasons began at this late date. Closely related is the length of time between beginning and ending dates, which was only 51 days in 1977. The average for the past 19 years is 110 days.

Examination of the storm tracks in Figure 2.1 shows that all storm genesis occurred west of longitude 60°W. This has happened only one other time (1972) in the past 30 years. This westward shift is reflected in the number of hurricane days, since there was no opportunity for a storm to travel across the tropical Atlantic.

In connection with the season's late start, the following is noted. Neither of the parameters (low sea surface temperatures and high vertical wind shear), usually indications of suppressed storm activity, were significantly below or above, respectively, their prohibiting threshold values over the tropical waters.

Only one tropical storm (Babe) made landfall in the United States this season. This is less than the average for this century of 3.2 tropical cyclone landfalls, including 1.8 hurricanes. Babe caused damage estimated at $10 million, but no loss of life.

Hurricane Anita was the fourth most intense storm of record in the Gulf of Mexico. The central pressure reached 926 mb and maximum winds were 150 kt. Anita made landfall along a sparsely populated region of the Mexican coast.

2.1 General

The data presented in this section on tropical cyclones occurring in the Atlantic area during 1977 were extracted from the

Monthly Weather Review article "Atlantic Hurricane Season of 1977". Also used was the NOAA Technical Memorandums from the National Hurricane Center, entitled "Annual Data and Verification Tabulation Atlantic Tropical Cyclones 1977", by Miles B. Lawrence.

During the 1977 season there were a total of 6 cyclones that occurred in this area as listed below:

Hurricane Anita	8/29/77 - 9/2/77
Hurricane Babe	9/3/77 - 9/8/77
Hurricane Clara	9/5/77 - 9/11/77
Hurricane Dorothy	9/26/77 - 9/30/77
Hurricane Evelyn	10/13/77 - 10/15/77
Tropical Storm Frieda	10/16/77 - 10/18/77

Ground track plots of the Atlantic tropical cyclones, 1977 are shown in Figure 2.1.

Results of the comparison of the cyclone information and the GEOS-3 schedule information indicates that all of the cyclones may have associated GEOS-3 altimeter data. All information as available for these cyclones along with any promising GEOS-3 ground track maps are presented in the following sections.

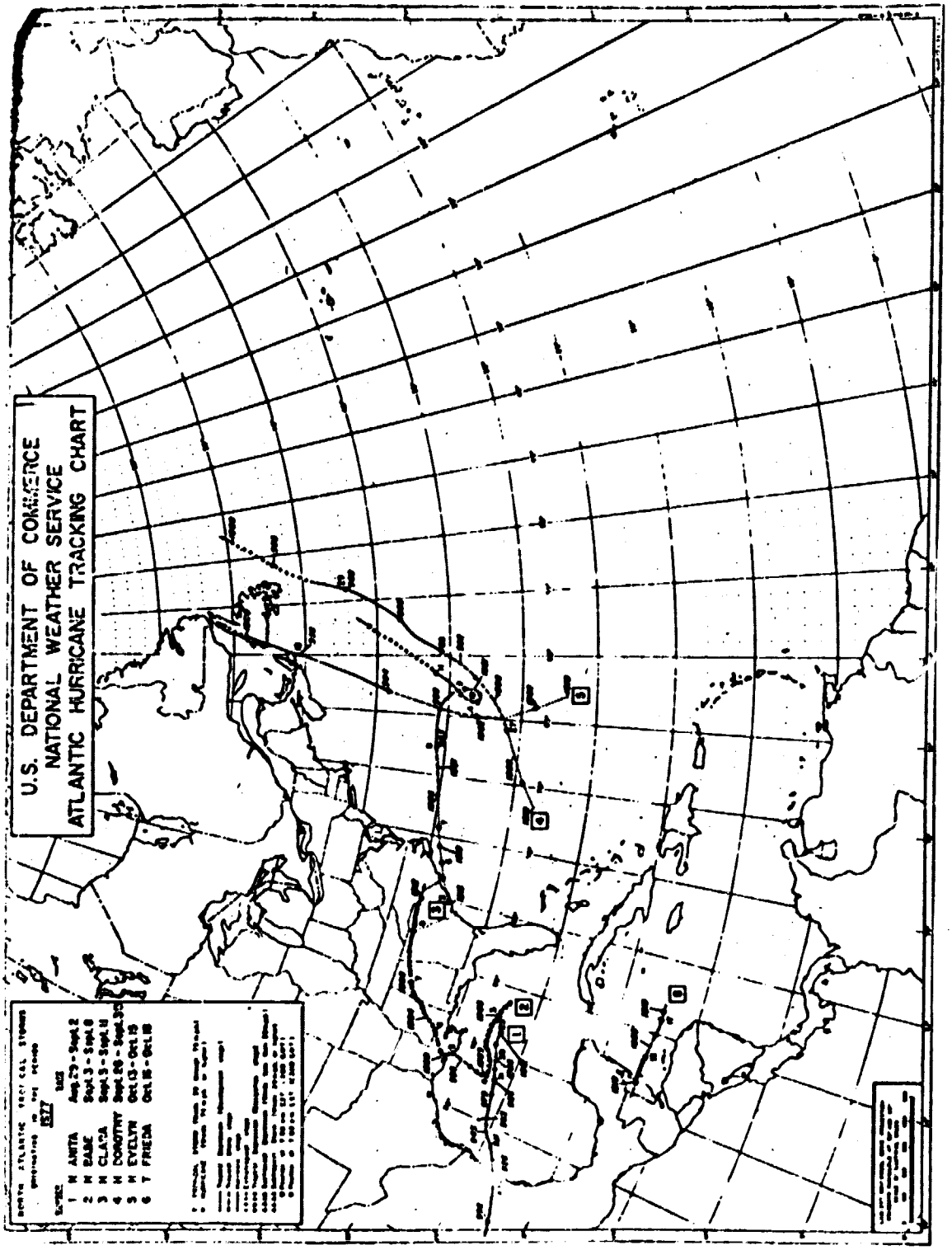

Figure 2.1. Tracks of North Atlantic Tropical Cyclones, 1977.

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2.2 HURRICANE ANITA

August 29 - September 2, 1977

The origins of Anita have been traced to a tropical wave that moved off the African coast on August 16. This wave traveled westward across the Atlantic, then headed west-northwestward as it neared the Caribbean.

On August 23, just northeast of the Windward Islands, the wave moved under a 200 mb cold low, and the associated cloudiness reflected this upper level cyclonic circulation pattern. The cloud system now continued northwestward while the upper low moved west, and by August 27 most of the associated weather was over Florida and the northern Bahamas

Disturbed weather persisted for several days, producing several inches of rain. On August 28 the system shifted into the eastern Gulf of Mexico where the upper level flow pattern was mainly anticyclonic.

A tropical depression formed in the east central Gulf of Mexico on August 29. Its center was about 200 n mi south-southwest of New Orleans. This system, steadily intensifying, moved west-southwestward for the next four days, making landfall on the morning of September 2 along the upper Mexican coast. Anita's forward speed was about 4 kt when south of New Orleans and gradually accelerated to 10 kt just prior to landfall.

Anita attained tropical storm strength near 0600 GMT August 30, or about 19 h after becoming a tropical depression. Twelve hours later, hurricane force was reached. Strengthening continued until a minimum pressure of 926 mb was measured just prior to landfall. Maximum surface winds are estimated to have reached 150 kt.

On August 29 and 30, Anita's central pressure dropped at the rate of 0.5 mb h^{-1} and this rate increased to 2.0 mb h^{-1} for the following two days.

A hurricane watch was placed along the Texas and southwest Louisiana coast at 2200 GMT August 30. A hurricane warning was issued at 1000 GMT September 1 from just south of Corpus Christi, TX to Brownsville, TX. The United States does not issue hurricane warnings for Mexico, but the Mexican government was notified of the potential danger.

Soon after warnings were issued, Anita made a small shift in direction from a heading of 260 to 235 , and it was at this time apparent that the main threat from this dangerous storm would be to the northeast Mexican coast.

Landfall occurred at 1100 GMT September 2 about 80 n mi north of Tampico (or 145 n mi south of Brownsville). The nearest population center in the path of Anita was the inland village of Soto La Marina, 165 n mi south of the United States border and 24 n mi inland.

The following factors appear to have provided the opportunity for Anita to develop to such an intense storm. First, the rather slow forward speed of movement allowed for almost 96 h of continuous strengthening over the warm waters of the Gulf of Mexico. Second, during this time, Anita was embedded in warm, moist tropical air and encountered no intrusions of nontropical air from further north. The ridge across the east-central United States to the north of Anita was well-developed. This was the case all during Anita's history in the Gulf. Another point of interest concerns the extension of the high pressure ridge southwestward across Texas and into northern Mexico. This feature is responsible for Anita's change to a heading of 235 .

On August 25, several days prior to Anita's formation, the NOAA ship RESEARCHER measured an eddy in the sea surface temperature field in the north central Gulf of Mexico. This eddy was, in some locations, as much as 1 C warmer than the surrounding waters. Finally, an experimental criterion for storm development (Shapiro, 1977) indicated favorable conditions in the Gulf of Mexico several days before Anita's arrival.

Mexican newspapers reported that inland floods and landslides killed 10 persons in an area of Mexico from La Pesca inland to Cuidad Victoria.

The portion of the Mexican coast that was most affected by the hurricane is sparsely settled and damage estimates are not available. It can be stated that extensive losses were sustained by inhabitants of fishing and farming communities in the path of the storm.

South Texas rainfall was approximately 2 inches. Mexican totals are not known, but a report from Soto La Marina indicated a 6 h total of 17.52 inches.

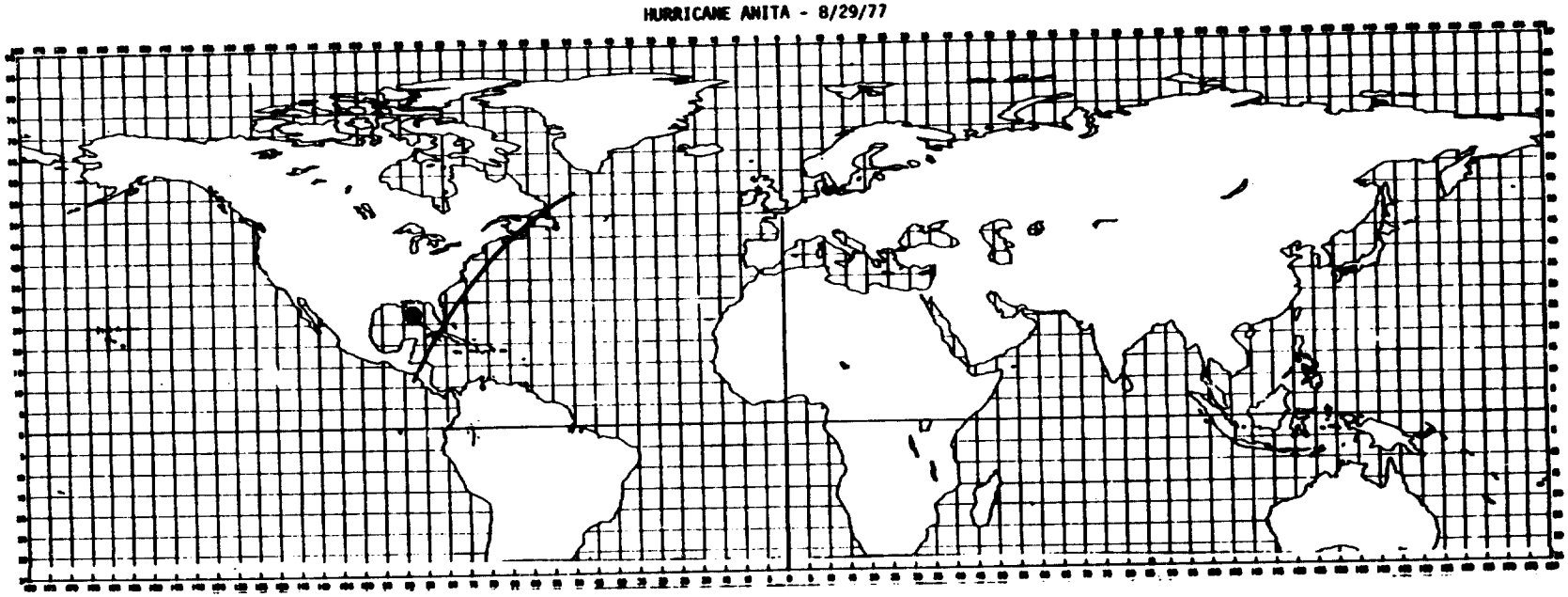
Almost 100,000 people evacuated coastal locations. Of this, 35,000 were from along the Mexican coast. The remainder were from Texas and Louisiana including 7000 workers from offshore oil drilling platforms.

STORM: HURRICANE ANITA

DATE: Aug. 29 - Sept. 2, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
8/29	1200 Z	27.0N	88.0 W			Tropical Depression
8/30	0600 Z	26.8N	89.8 W			Hurricane
	1200 Z	26.7	90.3			
	1800 Z	26.5	90.6			
8/31	0000 Z	26.4N	91.0 W			Hurricane
	0600 Z	26.3	91.4			
	1200 Z	26.2	91.8			
	1800 Z	26.1	92.3			
9/01	0000 Z	25.9N	92.8 W			Hurricane
	0600 Z	25.8	93.7			
	1200 Z	25.5	94.7			
	1800 Z	25.2	95.5			
9/02	0000 Z	24.6N	96.7 W			Hurricane
	0600 Z	24.2	97.1			
	1200 Z	23.7	98.0			
	1800 Z	23.1	99.2			
9/03	0000 Z	22.5N	101.0 W			Tropical Storm

HURRICANE ANITA - 8/29/77



LOCATION

TIME	LATITUDE	LONGITUDE
1200Z	27.0N	88.0W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
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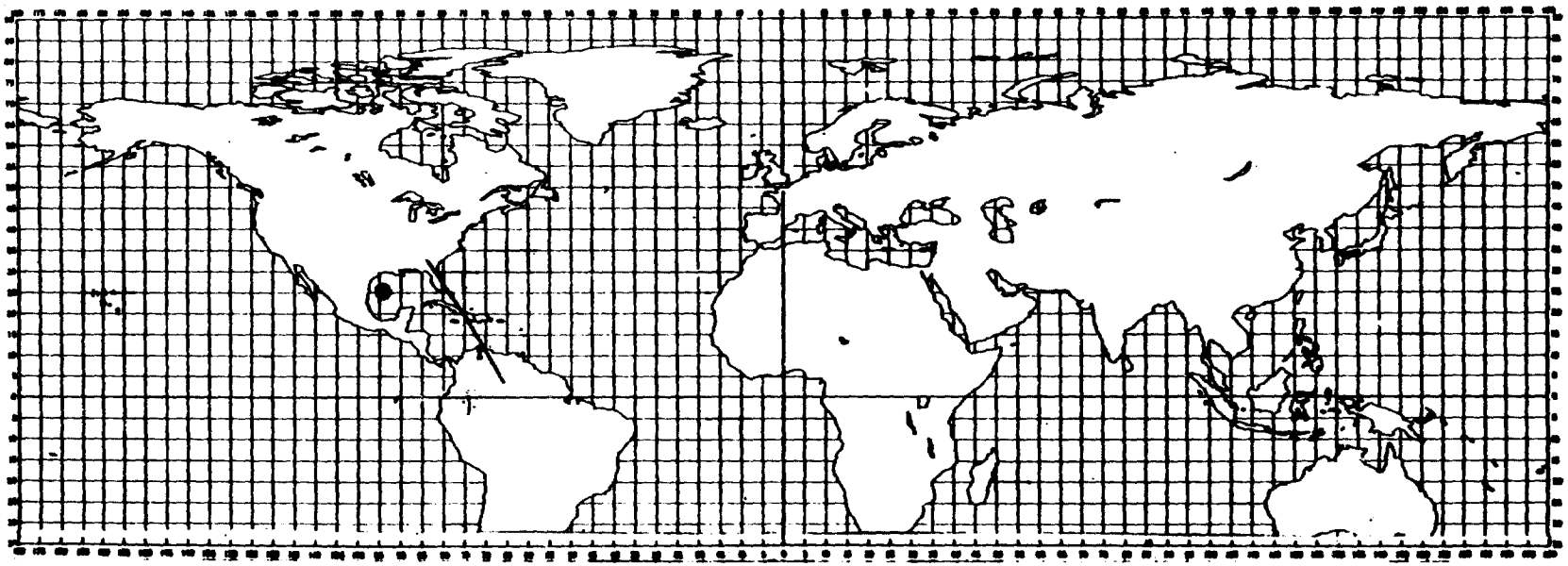
HURRICANE ANITA - 9/1/77



LOCATION

TIME	LATITUDE	LONGITUDE
00002	25.9N	92.8W
0600	25.8	93.7
1200	25.5	94.7
1800	25.2	95.5

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.ID
12387	296.12	123409	124400	123717	124339	808	143

2.3

HURRICANE BABE
September 3-8, 1977

The formation of Babe resulted from the interaction between an African wave and a cold upper low. The wave moved into the Atlantic from Africa on August 23 and reached the Gulf of Mexico on September 2, where a 200 mb low was located over the extreme northeast Gulf. On September 3, the 200 mb low had moved to the central Gulf of Mexico and westerly surface winds at data buoy EB-44 (26 N, 86 W) confirmed that a surface low had formed in the east central Gulf.

Convection was not concentrated near the low center, but extended in a band from the central Gulf to the mouth of the Mississippi River, then eastward to just offshore of the Florida panhandle. Gale-force winds within this band of convection led to the designation of Babe as a tropical storm. Gale warnings were posted from Morgan City, La., to Pensacola, Fla., at 1600 GMT September 3. This action was taken even though the system had not acquired tropical structure, in order not to confuse the public at a time of immediate threat.

Early on September 4, the band of convection and strong winds moved inland and weakened. Interest shifted to the central Gulf, where the strongest winds were drawing in closer to the low center. The upper flow over this system was now anticyclonic and the transition to a warm core tropical storm was completed by midday on September 4.

The storm had been moving west to southwest, but large 24 h pressure falls along the central Gulf coastal states diminished this westward steering. This, combined with large pressure falls over east Texas and small rises over Florida, resulted in a northward movement by the afternoon of September 4.

At 1903 GMT September 4, an Air Force reconnaissance aircraft reported a 70 kt surface wind 55 n mi southeast of the storm center. It was now evident that these winds were associated with a narrow band of strong convection well removed from the center, were transitory and were not representative of the strength of the system. The same report showed the lowest pressure to be 1000 mb, well above that generally believed to be required for sustained winds of hurricane strength with the existing peripheral pressures.

Babe continued northward and made landfall on the morning of September 5. Winds decreased rapidly thereafter and the storm was reduced to a depression by midafternoon of the same day.

Gale warnings were issued on September 3 in connection with a band of convection along the north central Gulf of Mexico coast.

By 0000 GMT September 5, shortly after receipt of the 70 kt reconnaissance report, the storm center was only 70 n mi from the Louisiana coast. Since some slight strengthening had been indicated by reconnaissance reports and satellite pictures, it was already after dark, and the center of the storm was expected to reach the coast by daybreak, it was decided to take the course of least regret and designate Babe as a hurricane. Hurricane warnings were posted at that time from Vermilion Bay, La., to the mouth of the Mississippi River. Post analysis does not demonstrate that hurricane strength was reached before 0600 GMT on September 5, when Air Force reconnaissance reported a central pressure of 995 mb. Maximum sustained winds over water are not believed to have exceeded 65 kt, and it is doubtful that any hurricane-force winds occurred over land.

The highest wind reported on land was a Coast Guard reading of a gust of 46 kt at Grand Isle, La. It is felt that higher wind speeds occurred closer to the storm center. Highest sustained wind reported was 40 kt at Boothville.

A number of tornadoes occurred after the storm moved inland. On September 5 six were reported in southeastern Louisiana and three in southern Mississippi. One or possibly more tornadoes occurred on September 6 near Tuscaloosa, Ala. as the depression approached that area, and there was a report of a possible tornado in northwestern Georgia on the afternoon of September 7.

Highest tide readings were generally near 5 ft above mean sea level in southeast Louisiana. This resulted in some flooding. However, water levels were already somewhat above normal, since Anita had passed by this area only several days earlier.

The remnants of Babe traveling across the southeastern states caused considerable flash flooding. Up to 7 inches of rain fell over the mountain areas of Tennessee and the Carolinas, and up to 4 inches elsewhere.

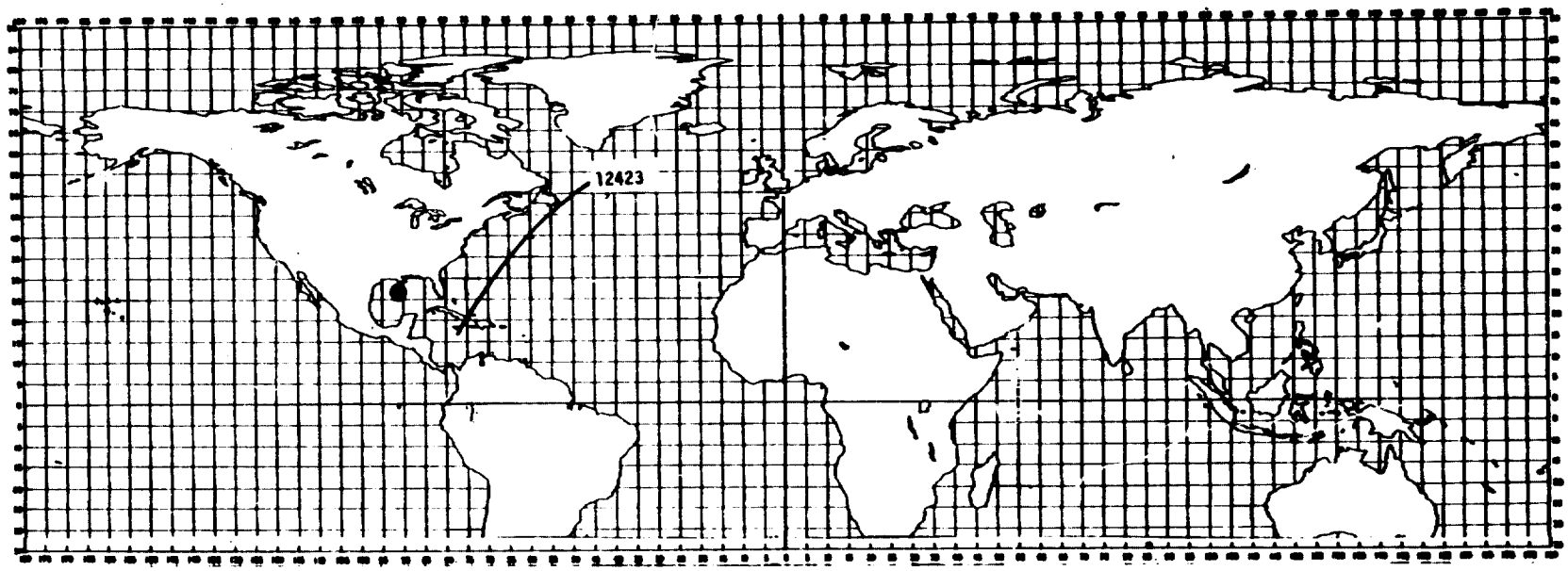
Babe's damage estimate is $10 million, mostly in southern Louisiana. Property damage was primarily the result of coastal flooding. Crop damage, mainly sugar cane, was caused by heavy rain and wind. Evacuation estimates for the low-lying areas of coastal Louisiana are in the 20,000-30,000 range. No fatalities have been reported.

STORM: HURRICANE BABE

DATE: Sept. 3-8, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/3	1200Z	27.5N	87.5W			Tropical Depression
9/4	1800Z	27.5N	91.7W			Tropical Storm
9/5	0000Z	28.0N	91.6W			Hurricane
	0600Z	28.7	91.4			
	1200Z	29.5	91.2			
	1800Z	29.8	91.6			
9/6	1200Z	31.0N	90.0W			Tropical Depression
9/7	1200Z	34.0N	87.5W			Tropical Depression
9/8	1200Z	35.0N	82.5W			Tropical Depression

HURRICANE BABE - 9/4/77

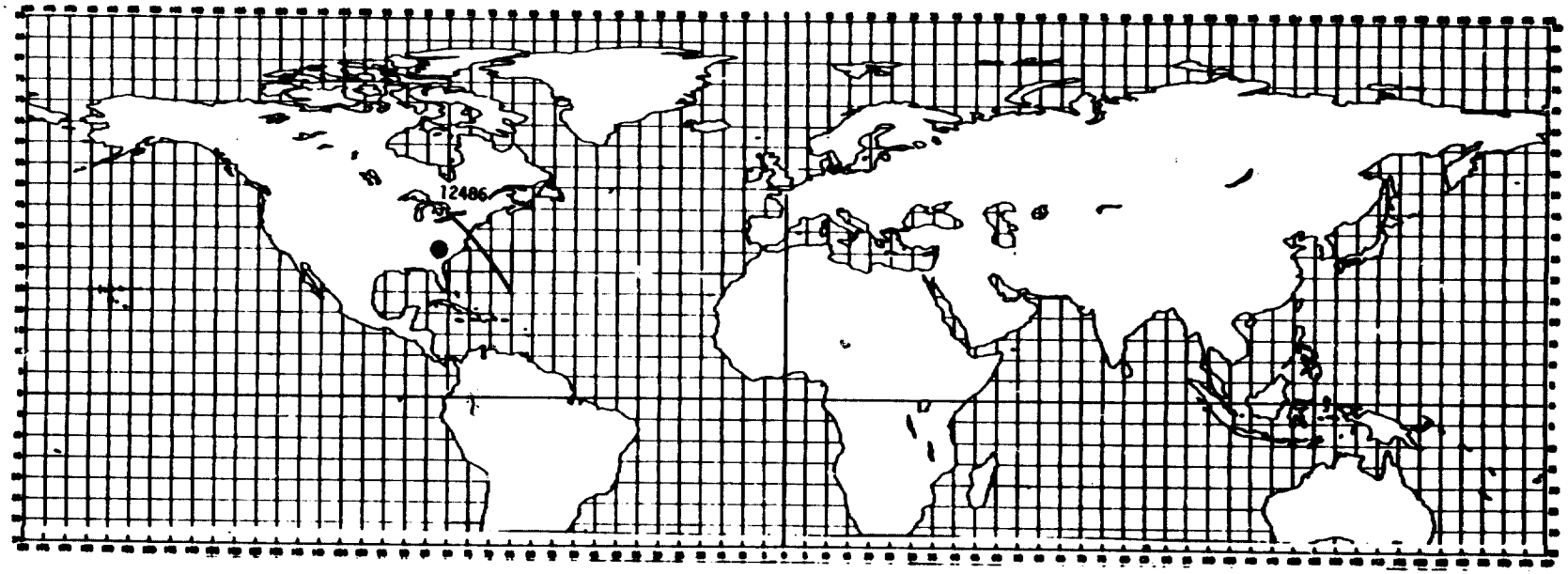


LOCATION

TIME	LATITUDE	LONGITUDE
1800Z	27.5N	91.7W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	ORBIT #
12423	104.51	013818	022300	021313	022337	808	171

HURRICANE BABE - 9/8/77



LOCATION

TIME	LATITUDE	LONGITUDE
1200Z	35.0N	82.5W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	RATIO,P
12486	309.19	123034	124300	123906	124430	808	141

2.4 HURRICANE CLARA
September 5-11, 1977

Clara's origin was unusual. The cloud system within which it developed was a convective band containing gale force winds and was associated with the early stages of Babe. On September 4, as this system moved over southeast Georgia, a weak mid-tropospheric circulation formed. By 1200 GMT September 4, this circulation was affecting the surface and a depression became located just north of Charleston, S.C. Charleston reported a west surface wind and a 24 h pressure fall of 4 mb. This depression drifted east-northeastward during the next 36 h, slowly becoming better organized.

The depression was located a short distance south of Cape Hatteras late on September 6 when it accelerated and began strengthening. Clara reached storm intensity by 0000 GMT September 8 when the center was 200 n mi east of Cape Hatteras. The lowest sea level pressure of 993 mb and maximum sustained winds of 65 kt were reached on the morning of September 8.

The central pressure began to rise as a trough in the westerlies which had caused Clara to accelerate, passed to the north and east. Reconnaissance aircraft reported that hurricane-force winds continued for at least 12 more hours after the lowest pressure was reached.

Strong high-level winds over the center caused continued weakening as convection was sheared off toward the east. Clara turned southeast and traversed a tight loop before accelerating northeastward. The storm was absorbed in an extratropical low pressure system on September 11 several hundred miles northeast of Bermuda.

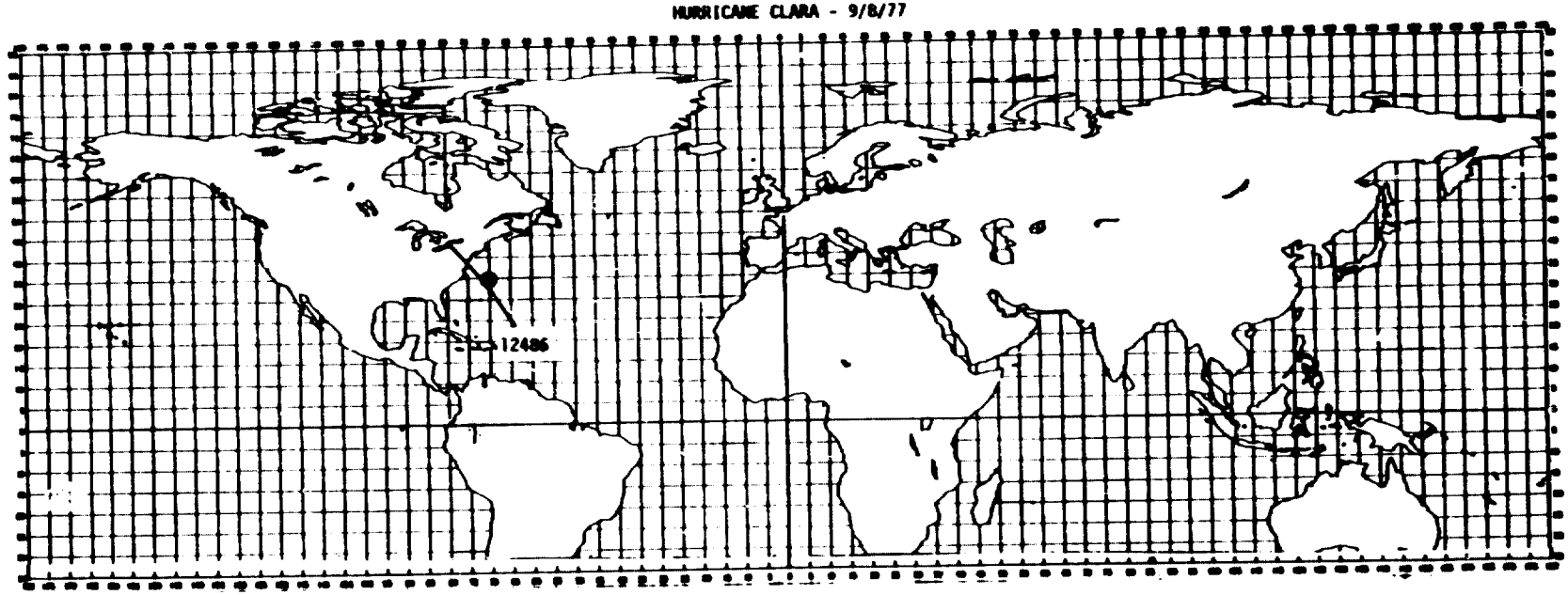
Clara briefly threatened Bermuda on September 10 while a minimal tropical storm, but no gales were reported from the island. There are no known casualties or damages in connection with Clara.

STORM: HURRICANE CLARA

DATE: Sept. 5-11, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/5	1200Z	33.5 N	80.0W			Tropical Depression
9/6	1200Z	34.0 N	77.0W			Tropical Depression
9/7	1200Z	34.5 N	74.5W			Tropical Depression
9/8	0000Z	35.1 N	71.7W			Tropical Storm
	0600Z	35.3	69.7			
	1200Z	35.5	67.7			
	1800Z	35.6	66.2			
9/9	0000Z	35.5 N	64.6W			Hurricane
	0600Z	34.8	63.5			
	1200Z	34.0	62.8			
	1800Z	33.4	62.8			
9/10	0000Z	32.8 N	63.2W			Tropical Storm
	0600Z	32.8	63.6			
	1200Z	33.0	63.8			
	1800Z	33.5	63.7			
9/11	0000Z	34.2 N	63.2W			Tropical Depression
	0600Z	34.8	62.5			

HURRICANE CLARA - 9/8/77



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	35.1N	71.7W
0600Z	35.3	69.7
1200Z	35.5	67.7
1800Z	35.6	66.2

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	RATIO.P
12486	309.19	123034	124000	123906	124430	808	141

2.5

HURRICANE DOROTHY
September 26-30, 1977

Hurricane Dorothy is associated with a tropical wave that entered the eastern Atlantic in mid-September. This wave passed through the central Lesser Antilles on September 21 with thunderstorm gusts to 60 kt reported at Guadeloupe and Martinique. Rainfall amounts in this region were 5-8 inches and there was some flash flooding.

This heavy weather is attributed to high-level divergent flow associated with the east side of a 200 mb trough located over the eastern Caribbean. As the wave moved westward, directly under the trough, the convection diminished and the wave weakened.

After crossing Hispaniola on September 23, the weather system associated with the wave moved northward through the eastern Bahamas. This change in direction was caused by the presence of a stationary f[illegible]al trough off the southeastern United States. On the afternoon of September 25, a low pressure system developed within the disturbed weather and becam[illegible] a tropical depression on September 26 to the north of the Bahamas. The depress[illegible]y this time was moving northeastward at 10-15 kt and it strengthened to a tropical storm on the morning of September 27 with 45 kt and 1000 mb as measured by reconnaissance aircraft.

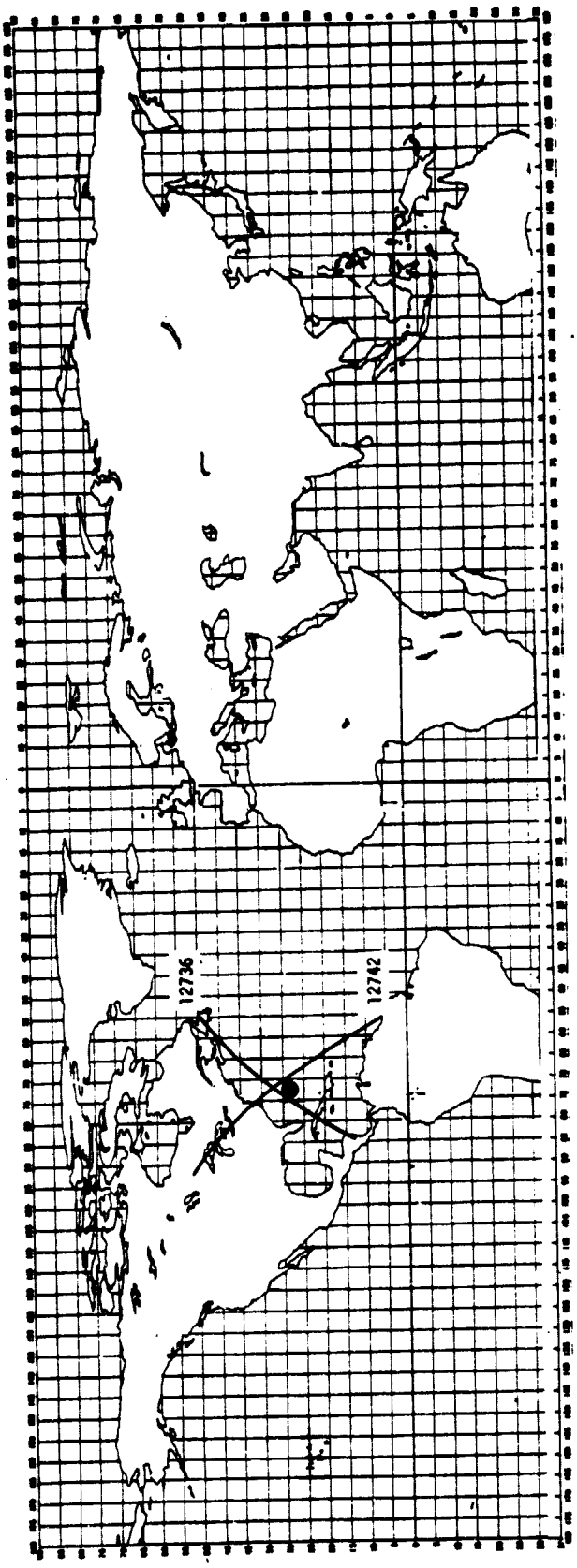
Dorothy reached hurricane force on the morning of September 28. It then accelerated to a forward speed of 20 kt as a major trough approached from the west. Tropical characteristics were lost as Dorothy moved over colder waters. The remnants were absorbed by a frontal low pressure system to the east of Newfoundland on September 30.

Maximum storm strength was estimated at 980 mb and 75 kt on the evening of September 28. The only problems in connection with Dorothy were in the form of a threat to North Atlantic shipping lanes.

STORM: HURRICANE DOROTHY

DATE: Sept. 26-30, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/26	1800Z	28.5	72.0W			Tropical Depression
9/27	1200Z	30.9	65.8W			Tropical Storm
	1800Z	31.9	63.6			
9/28	0000Z	33.2	61.8W			Hurricane
	0600Z	34.4	60.8			
	1200Z	35.5	59.7			
	1800Z	37.0	58.8			
9/29	0000Z	38.3	57.0W			Hurricane
	0600Z	40.0	5[illegible].5			
	1200Z	42.0	54.0			
9/30	0000Z	47.0	51.0W			Tropical Depression
	0600Z	50.5	47.5			



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12736	98.56	043604	051730	051144	052245	808	101
12742	306.63	144645	145600	144904	150302	808	106

LOCATION

TIME	LATITUDE	LONGITUDE
1800Z	28.5N	72.0W

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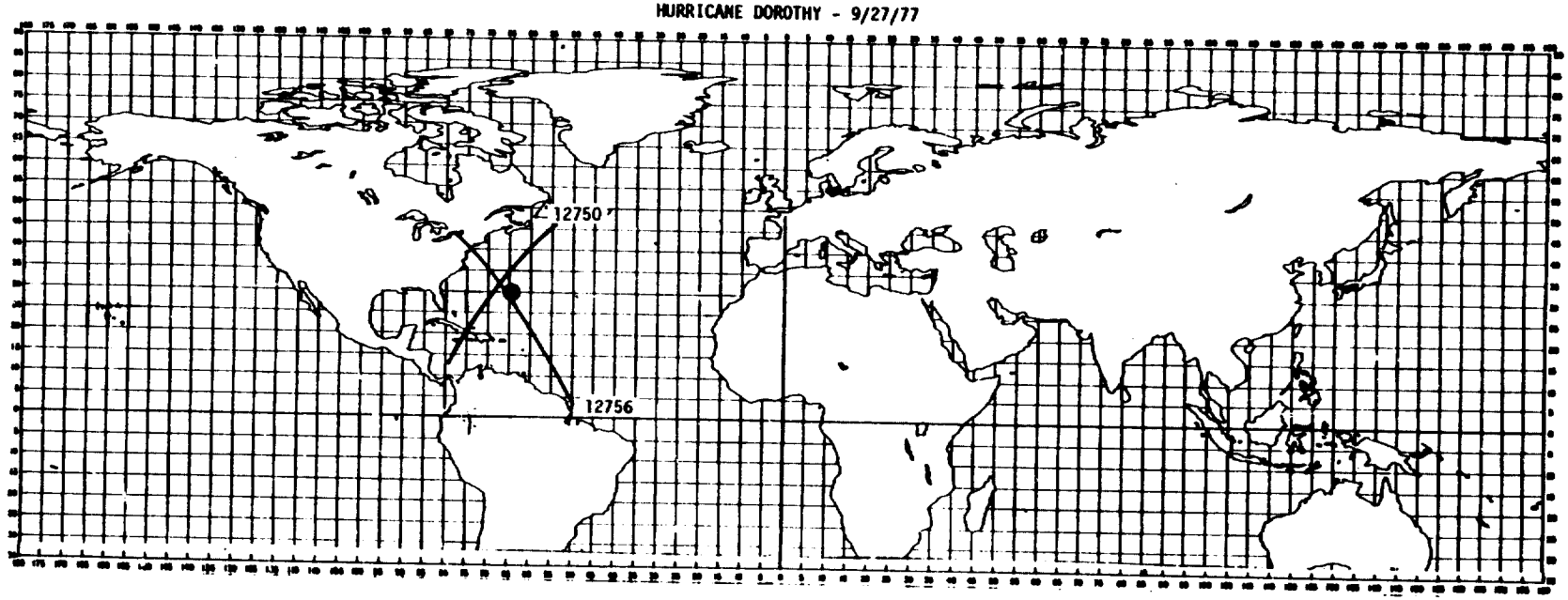
HURRICANE DOROTHY - 9/27/77

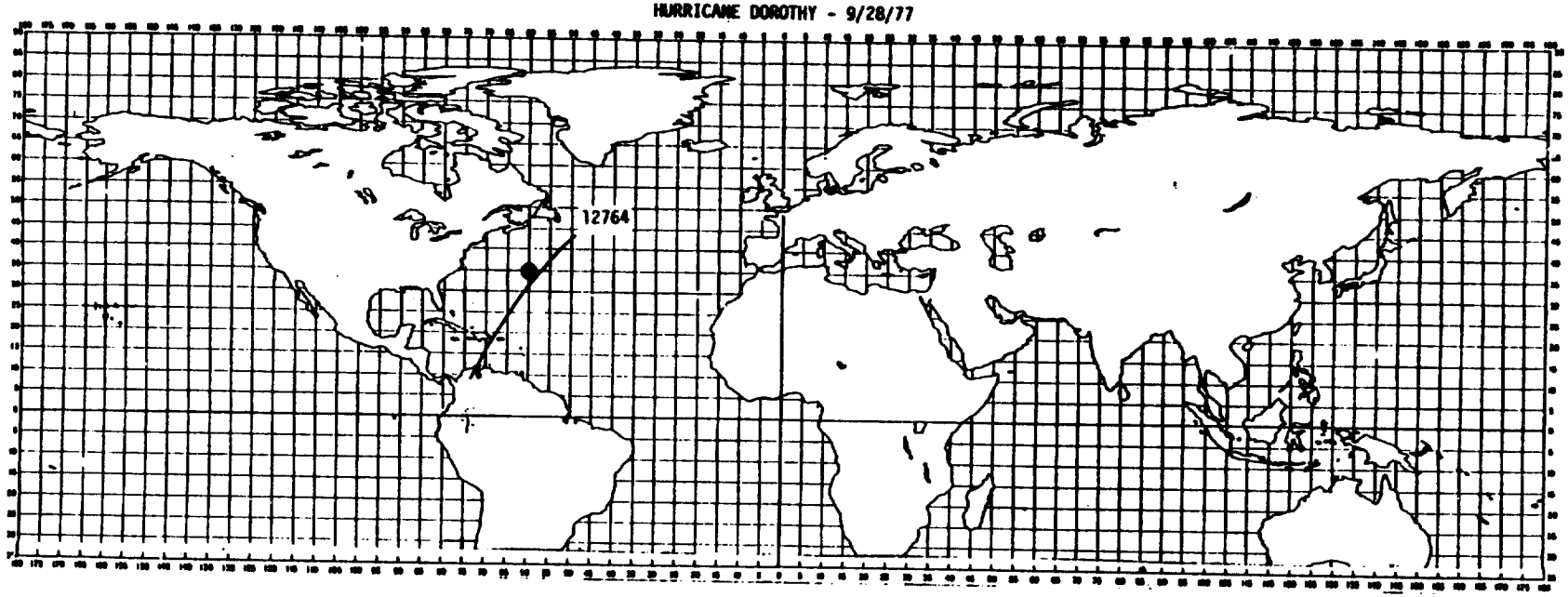


LOCATION

TIME	LATITUDE	LONGITUDE
1200Z	30.9N	65.8W
1800Z	31.9	63.6

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
12750	104.05	042100	050200	045721	050747	808	114
12756	312.11	143142	144000	143304	144500	808	119

HURRICANE DOROTHY - 9/28/77

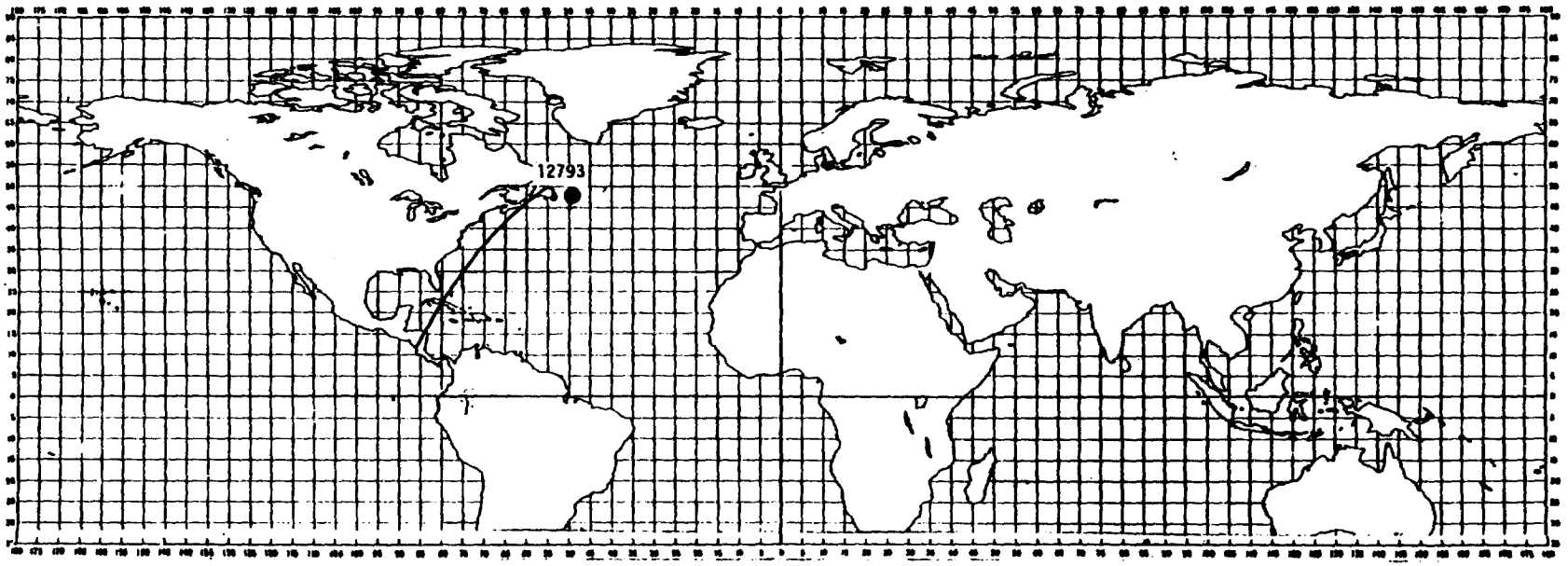


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	33.2N	61.8W
0600	34.4	60.8
1200	35.5	59.7
1800	37.0	58.8

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
12764	109.53	040557	044600	044313	044313	808	129

HURRICANE DOROTHY - 9/30/77



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	47.0N	51.0W
0600	50.5	47.5

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
12793	95.18	051738	055300	055243	060431	808	160

2.6

HURRICANE EVELYN
October 13-15, 1977

In a manner similar to Dorothy, Hurricane Evelyn had its origin as a tropical wave which interacted with an upper level cold low. This interaction occurred on October 12 in the southwest North Atlantic. As the upper low passed southward, the high-level circulation pattern became favorable for development and satellite pictures indicated that a surface depression had formed on October 13, 400 n mi south of Bermuda.

The depression headed toward Bermuda, and at 0920 GMT October 14 the Naval Air Station on the island recorded a wind shift and minimum pressure of 1003.8 mb. This, as well as some earlier ship reports, allowed a determination that Evelyn had become a tropical storm early on October 14.

After crossing Bermuda, Evelyn accelerated north-northeastward in the strong flow to the east of an intensifying 500 mb low. Strengthening occurred as a forward speed of 30 kt was reached. An Air Force reconnaissance flight measured 994 mb central pressure and flight level winds of 72 kt at 0000 GMT October 15. Based on these data, Evelyn was upgraded to a hurricane.

Meanwhile, an intense nontropical storm to the west was paralleling Evelyn's track. The frontal cloud band approached Evelyn from the west. Even after the front was merging with the storm, a ship reported 1001 mb and 68 kt (highest surface winds reported) near the southwest tip of Newfoundland at 1800 GMT October 15.

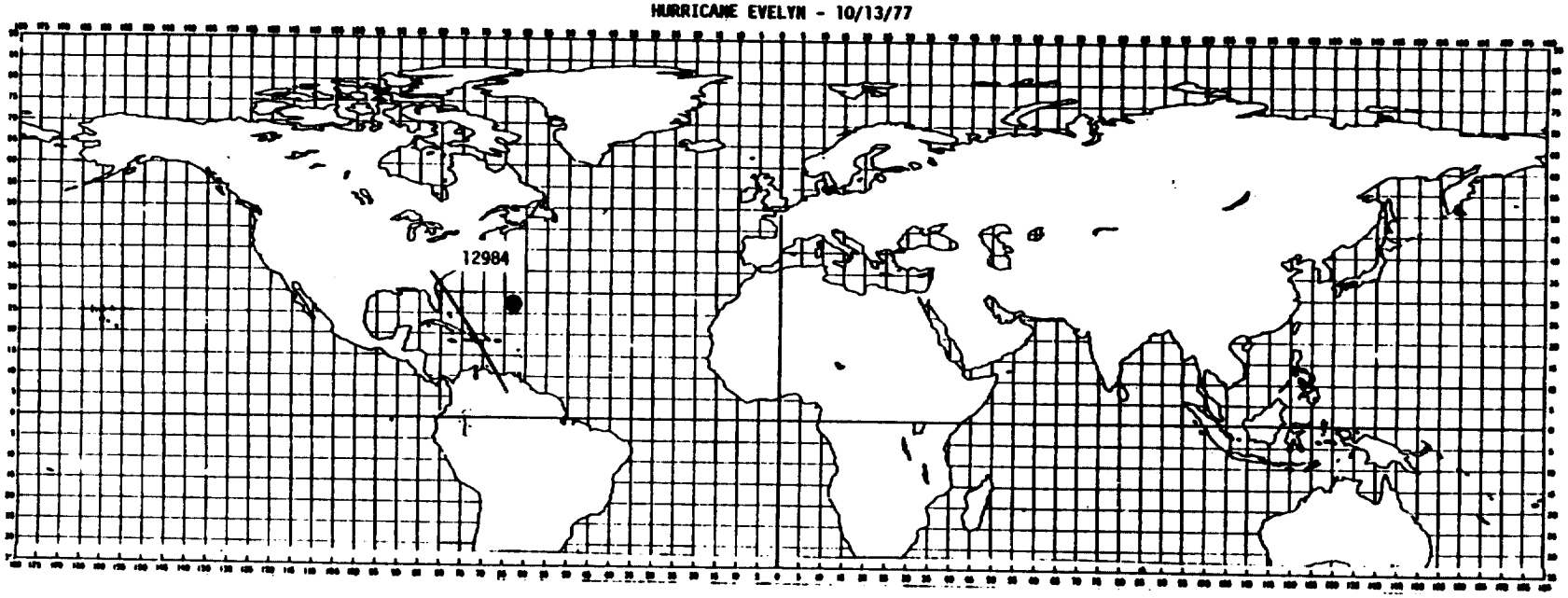
The storm weakened rapidly as it crossed western Newfoundland, and no reports of damage or casualties have been received.

STORM: HURRICANE EVELYN

DATE: Oct. 13-15, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
10/13	1800Z	27.0N	63.0W			Tropical Depression
10/14	0000Z	29.0N	64.0W			Tropical Storm
	0600Z	30.9	64.9			
	1200Z	33.0	64.9			
	1800Z	35.9	64.4			
10/15	0000Z	39.2N	63.3W			Hurricane
	0600Z	42.4	61.5			
	1200Z	45.5	60.1			
	1800Z	47.4	59.2			

HURRICANE EVELYN - 10/13/77

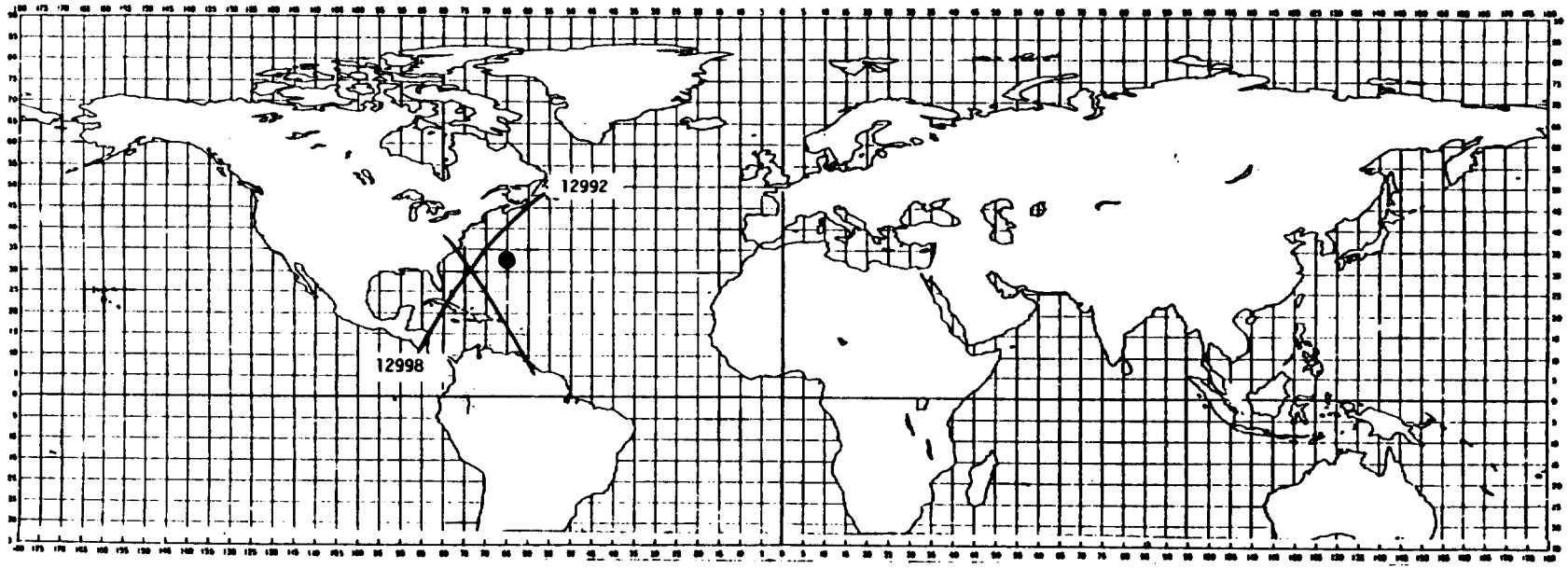


LOCATION

TIME	LATITUDE	LONGITUDE
1800Z	27.0N	63.0W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
12984	298.58	171758	172500	172049	172841	802	145

HURRICANE EVELYN - 10/14/77

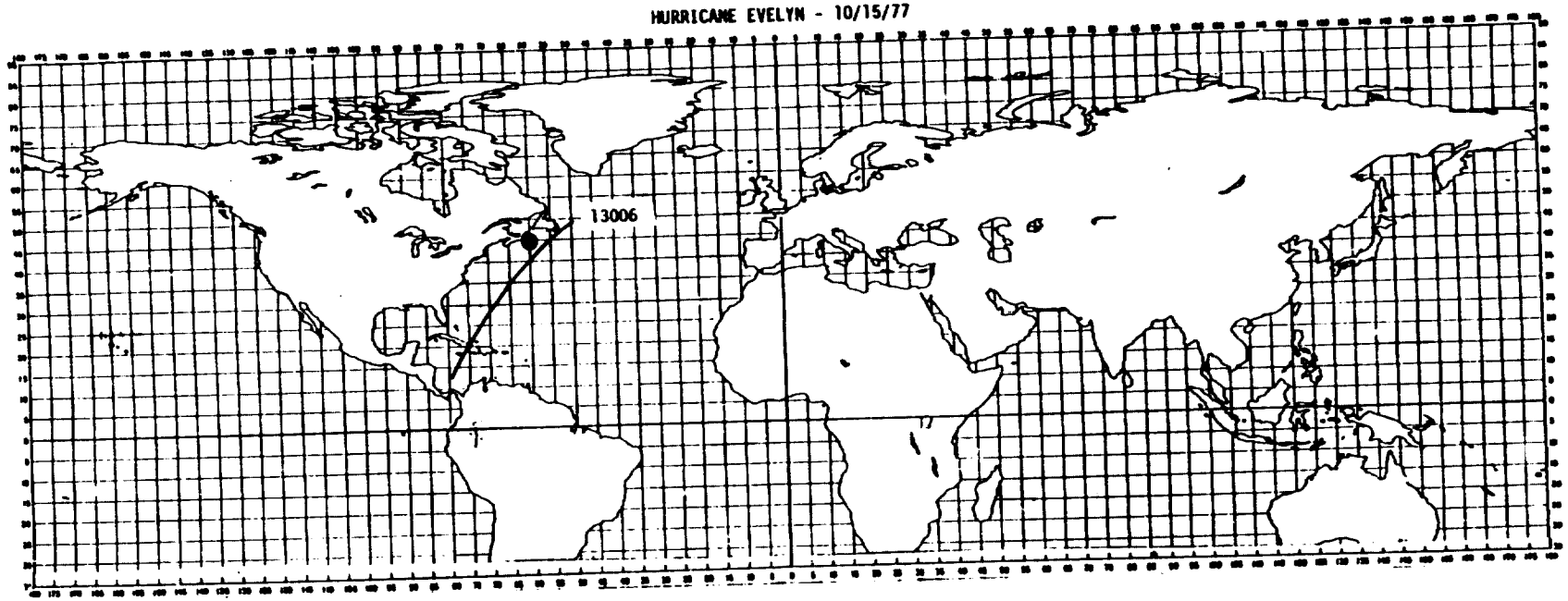


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	29.0N	64.0W
0600Z	30.9	64.9
1200Z	33.0	64.9
1800Z	35.9	64.4

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
12992	96.00	065213	073100	072732	073900	802	152
12998	304.06	170255	171200	170526	171425	802	157

HURRICANE EVELYN - 10/15/77



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	32.9N	63.3W
0600Z	42.4	61.5
1200Z	45.5	60.1
1800Z	47.4	59.2

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
13006	101.49	063710	071400	071304	072346	802	165

2.7

TROPICAL STORM FRIEDA
October 16-18, 1977

Frieda was a short-lived tropical storm. Its origins can be traced to a tropical wave which passed off the African coast on October 4. It traveled westward for the next 10 days without incident. Then a large convective cloud mass associated with this wave moved from the central Caribbean on October 14 to the northwest Caribbean on October 15 and 16.

Meanwhile, a cold front had moved across the Gulf of Mexico on October 12 and its remnants, a baroclinic zone of frontal cloudiness, became located in the northwest Caribbean. The cloudiness from the wave merged with the front on the 16th, and a second cold front moved into the same area soon after, apparently reinforcing the surface horizontal wind shear and temperature gradient in this region.

Late on October 16 a reconnaissance aircraft located a surface circulation center just east of Swan Island, and this was identified as a tropical depression. The center remained very well defined until midday on October 18. It moved steadily and slowly westward from its inception until late on October 18 when it crossed the coast of Belize in Central America just north of Belize City. For most of Frieda's duration, the associated circulation pattern was confined to the lower troposphere as evidenced by the lack of mid and upper cloudiness near the center. Therefore, the storm's motion was contolled by the easterly trades which resulted in a steady westward course.

On October 17 a reconnaissance aircraft reported a band of strong westerly winds between the center and the north coast of Honduras. Winds of 60 kt were measured at a flight level of 1500 ft, 50 n mi south of the center. Surface winds of 50 kt were estimated at this same position.

It was the receipt of the above wind information that resulted in the upgrading of this depression to a tropical storm. Other factors contributing to this decision were 1) satellite pictures indicating a very well-defined low-level center and 2), the occasional heavy rainfall associated with this system. Swan Island reported 4.46 inches during a 30 h period and Grand Cayman had 5.42 inches during a 36 h period.

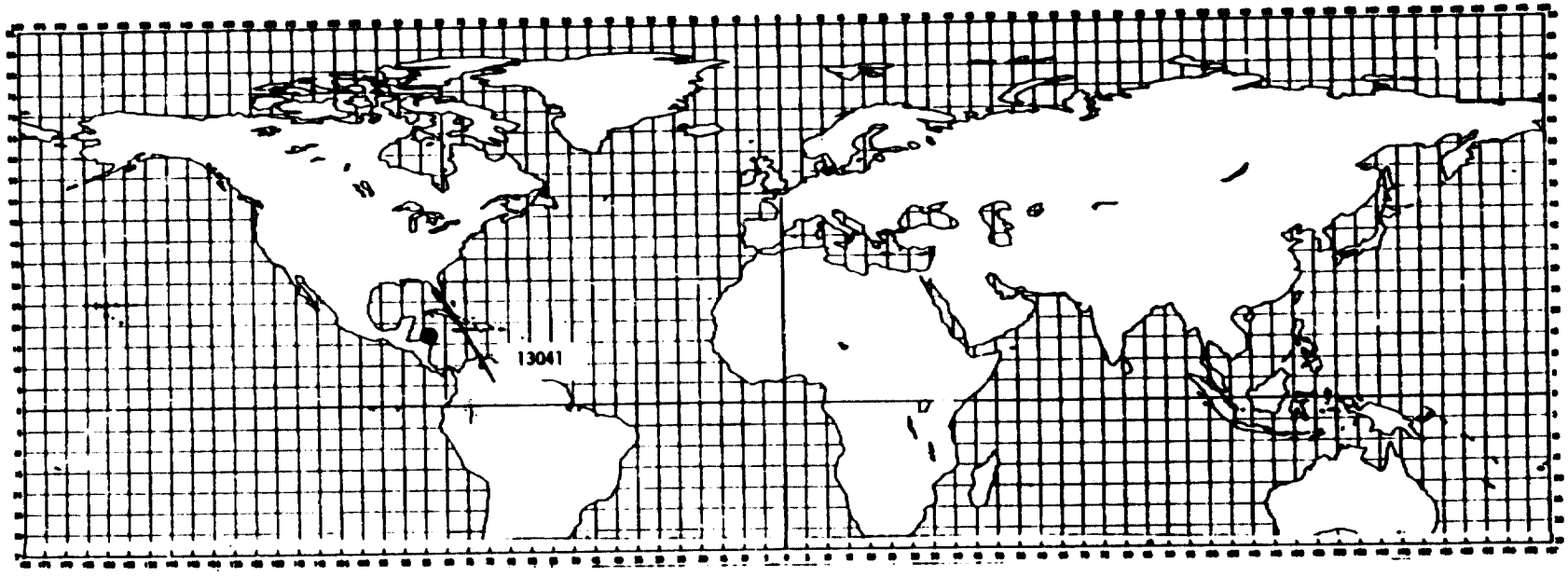
By the time of landfall, maximum winds had decreased to well below gale force. Belize City, just south of the point of landfall, had only light rain and light westerly winds. There have been no reports of damage or casualties.

STORM: TROPICAL STORM FRIEDA

DATE: Oct. 16-18, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
10/17	1200Z	17.2N	83.9W			Tropical Depression
	1800Z	17.2	84.4			
10/18	0000Z	17.3N	85.0W			Tropical Depression
	0600Z	17.4	85.8			

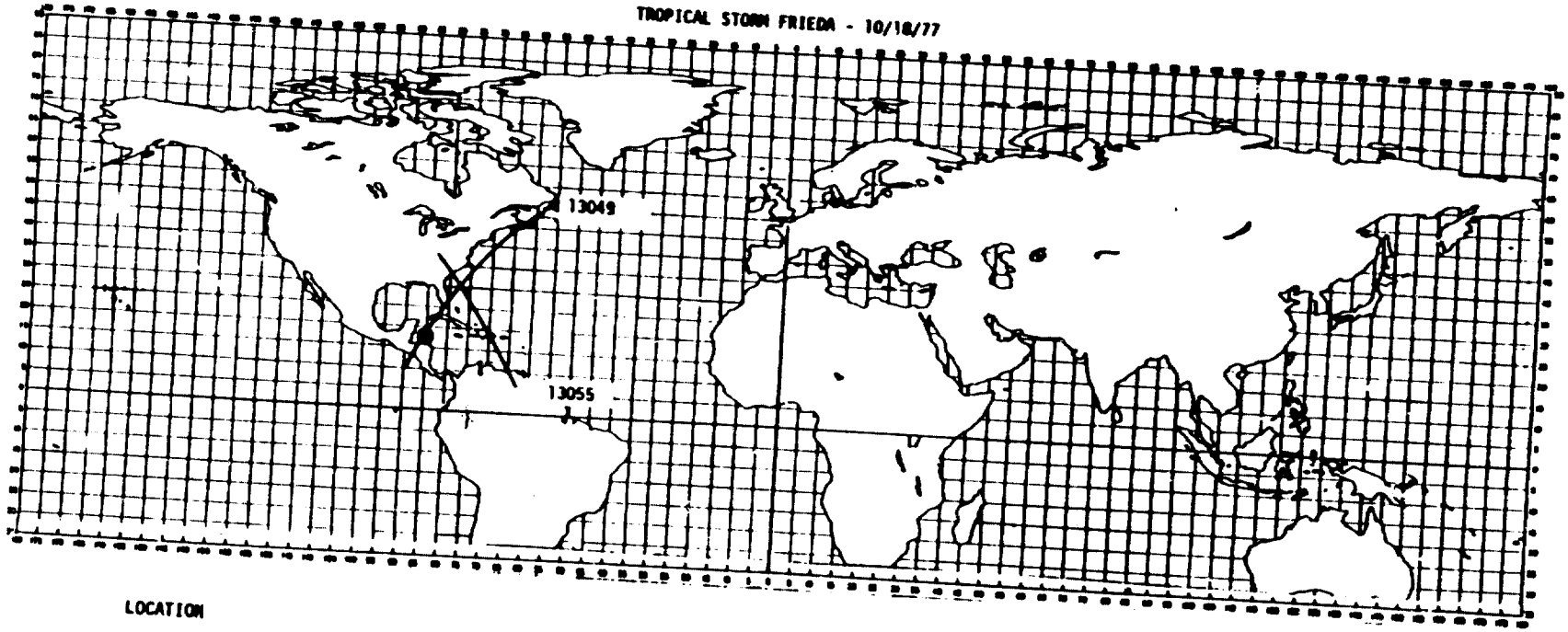
TROPICAL STORM FRIEDA - 10/17/77



LOCATION

TIME	LATITUDE	LONGITUDE
1200Z	17.2N	83.9W
1800Z	17.2	84.4

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
13041	295.20	175932	180600	180236	180821	808	107



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	17.3N	85.0W
0600Z	17.4	85.8

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIT(S)
13049	92.62	073347	082000	080821	082040	808	114
13055	300.68	174428	175200	174712	175529	808	122

3.0 ATLANTIC AREA TROPICAL CYCLONES - 1978

During the 1978 Atlantic Hurricane season, there were a total of twelve systems, of which five became hurricanes. Included in this total was an unnamed subtropical storm which occurred during January 1978.

Comparison of this season's statistics to the long-term averages (9.8 storms, of which 6.0 are hurricanes) indicates a slightly higher-than-normal number of storms for 1978.

Inspection of Figure 3.1 shows that three tropical storms made landfall along the coastline of the western Gulf of Mexico. Other than extreme rainfall, there were no other noteworthy events in connection with these storms.

Hurricane Greta raked over the sparsely populated northeast corner of the Honduras with winds in excess of 110 knots, but by the time of landfall in Belize, the storm's intensity had diminished to below 100 knots. Limited damage reports indicate that this was not a disastrous storm.

The U. S. East Coast and most of Florida again were spared from a major hurricane.

3.1 General

The data presented in this section on tropical cyclones occurring in the Atlantic area during 1978 were extracted from the Monthly Weather Review's article "Atlantic Hurricane Season of 1977", and the NOAA Technical Memorandums from the National Hurricane Center, entitled "Annual Data and Verification Tabulation Atlantic Tropical Cyclones - 1978", by Miles B. Lawrence. During the 1978 season there were a total of 12 cyclones that occurred in this area as listed below:

Subtropical Cyclone One	1/18/78 - 1/22/78
Tropical Storm Amelia	7/30/78 - 7/31/78
Tropical Storm Bess	8/5/78 - 8/8/78
Hurricane Cora	8/7/78 - 8/11/78
Tropical Storm Debra	8/26/78 - 8/29/78
Hurricane Ella	8/29/78 - 9/5/78
Hurricane Flossie	9/3/78 - 9/16/78
Hurricane Greta	9/13/78 - 9/19/78
Tropical Storm Hope	9/11/78 - 9/21/78
Tropical Storm Irma	10/2/78 - 10/5/78
Tropical Storm Juliet	10/7/78 - 10/11/78
Hurricane Kendra	10/28/78 - 11/3/78

Ground track plots of the Atlantic Tropical Cyclones, 1978 are shown in Figure 3.1.

Results of the comparison of the cyclone information and the GEOS-3 schedule information indicates that 11 of the cyclones (all except Irma) may have associated GEOS-3 altimeter data. All information as available for these 11 cyclones along with any promising GEOS-3 ground track maps are presented in the following sections.

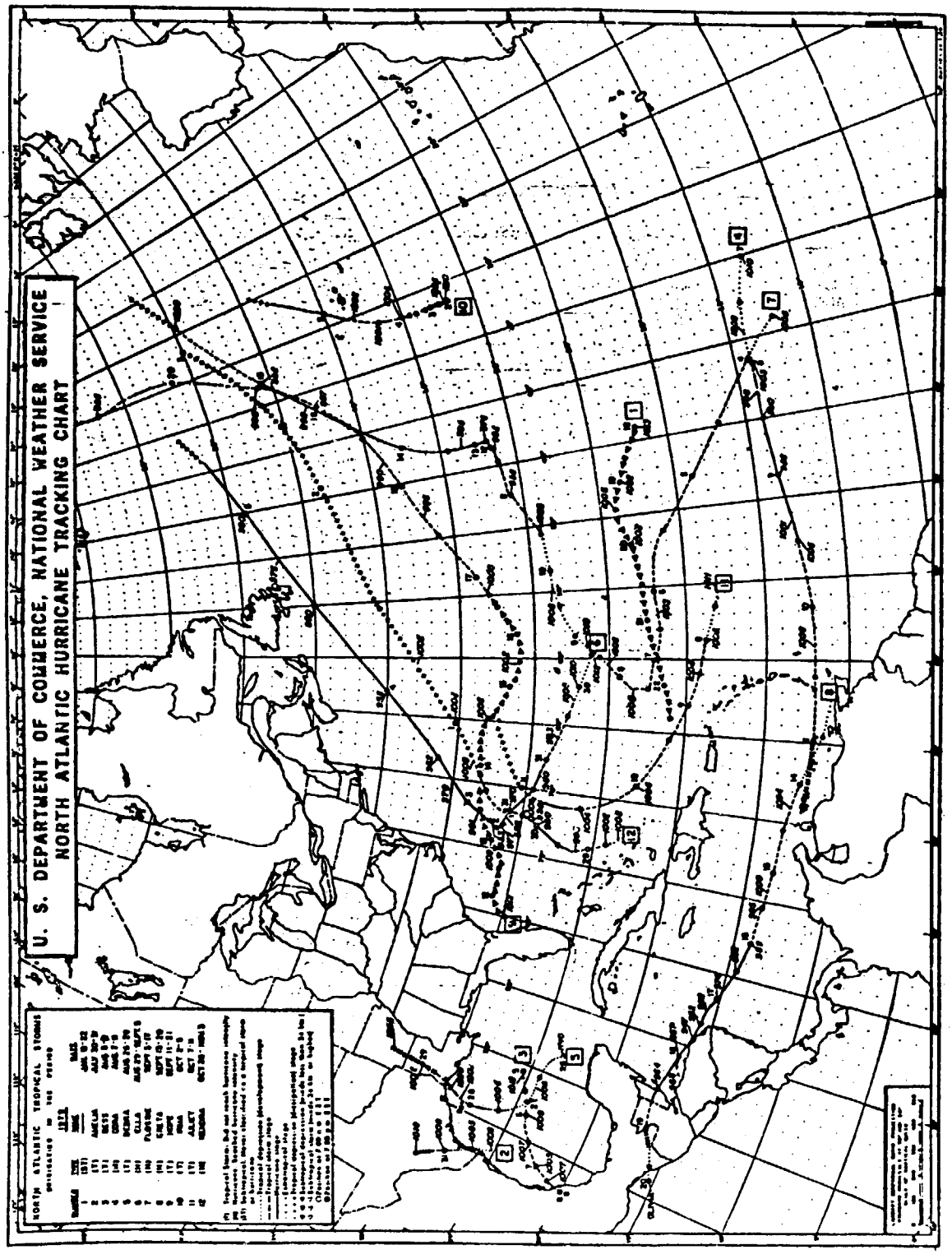


Fig. 3.1 Tracks of 1978 North Atlantic tropical cyclones.

3.2 SUBTROPICAL CYCLONE ONE
January 18-22, 1978

Subtropical Cyclone One occurred in January 1978 and records indicate that this is the first time that a tropical cyclone of at least storm intensity formed in this month.

The storm originated 1500 n mi east northeast of Puerto Rico on January 18, 1978. Maximum of 40 kt and a minimum sea level pressure of 1002 mb were reached on the 20th and 21st.

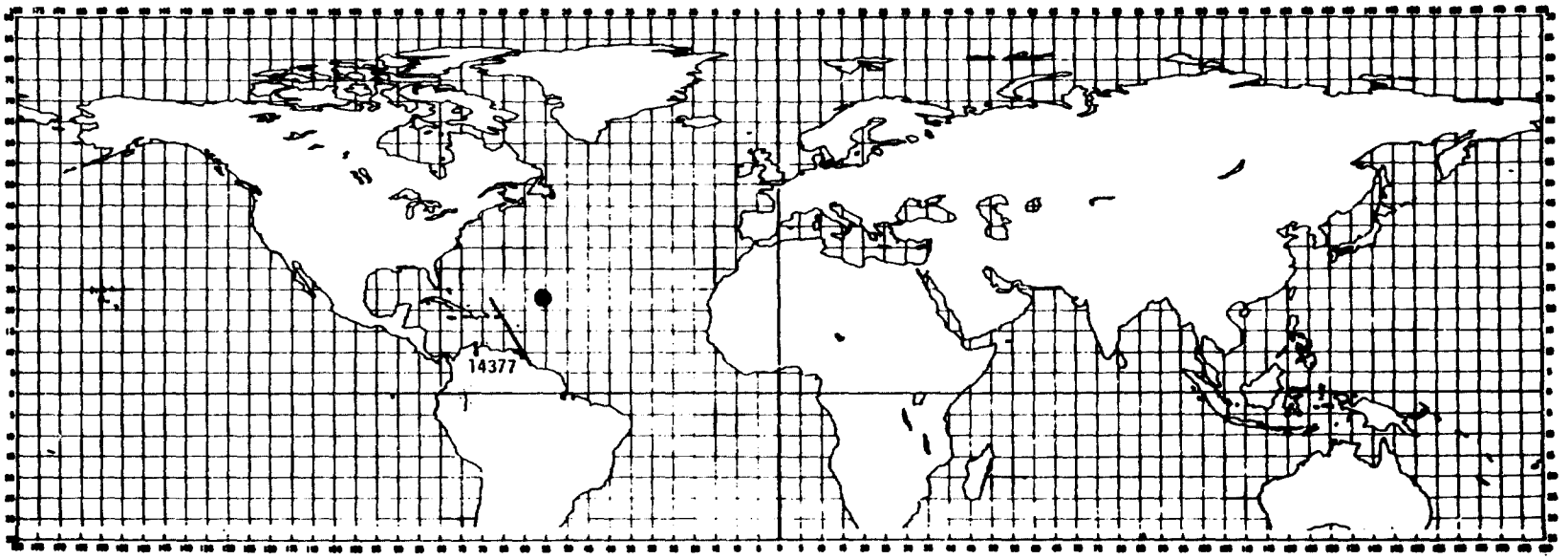
It is of interest to note that this rare storm occurred only several days prior to two extreme weather events - a late January Ohio Valley storm and a northeast coastal storm two weeks later. Both of these events created favorable conditions for subtropical storm development.

STORM: SUBTROPICAL CYCLONE ONE

DATE: January 18-22, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
1/18	0600Z	22.0N	44.0W			Subtropical Storm
	1800Z	23.0	46.0			
1/19	0600Z	23.5N	47.5W			Subtropical Storm
	1800Z	24.0	49.5			
1/20	0600Z	23.5N	52.0W			Subtropical Storm
	1800Z	23.0	55.0			
1/21	0600Z	22.5N	57.5W			Subtropical Storm
	1800Z	22.0	59.5			
1/22	0600Z	21.5N	62.0W			Subtropical Storm
	1800Z	21.0	64.0			

SUBTROPICAL CYCLONE ONE - 1/20/78

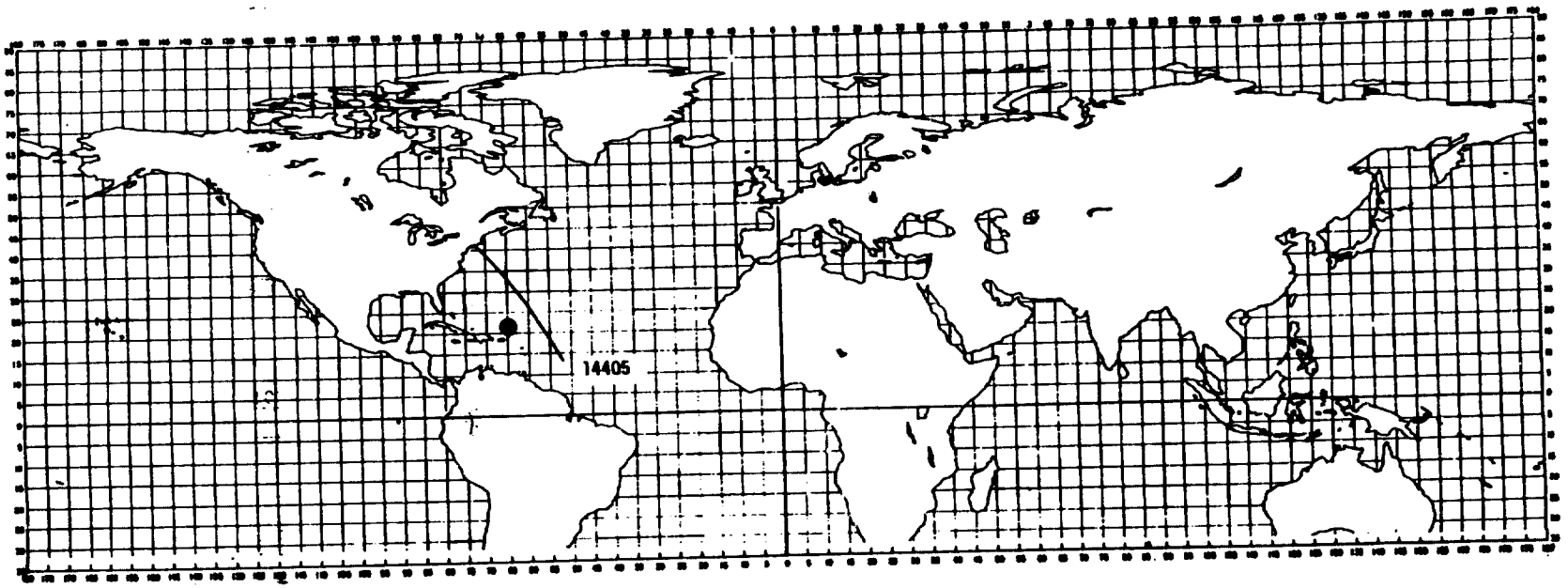


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	23.5N	52.0W
1800Z	23.0	55.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
14377	304.52	041929	042600	042147	042615	808	149

SUBTROPICAL CYCLONE ONE - 1/22/79



LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	21.5N	62.0W
1800Z	21.0	64.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
14405	315.49	034922		035348	040310	808	170

3.3 TROPICAL STORM AMELIA
July 30-31, 1978

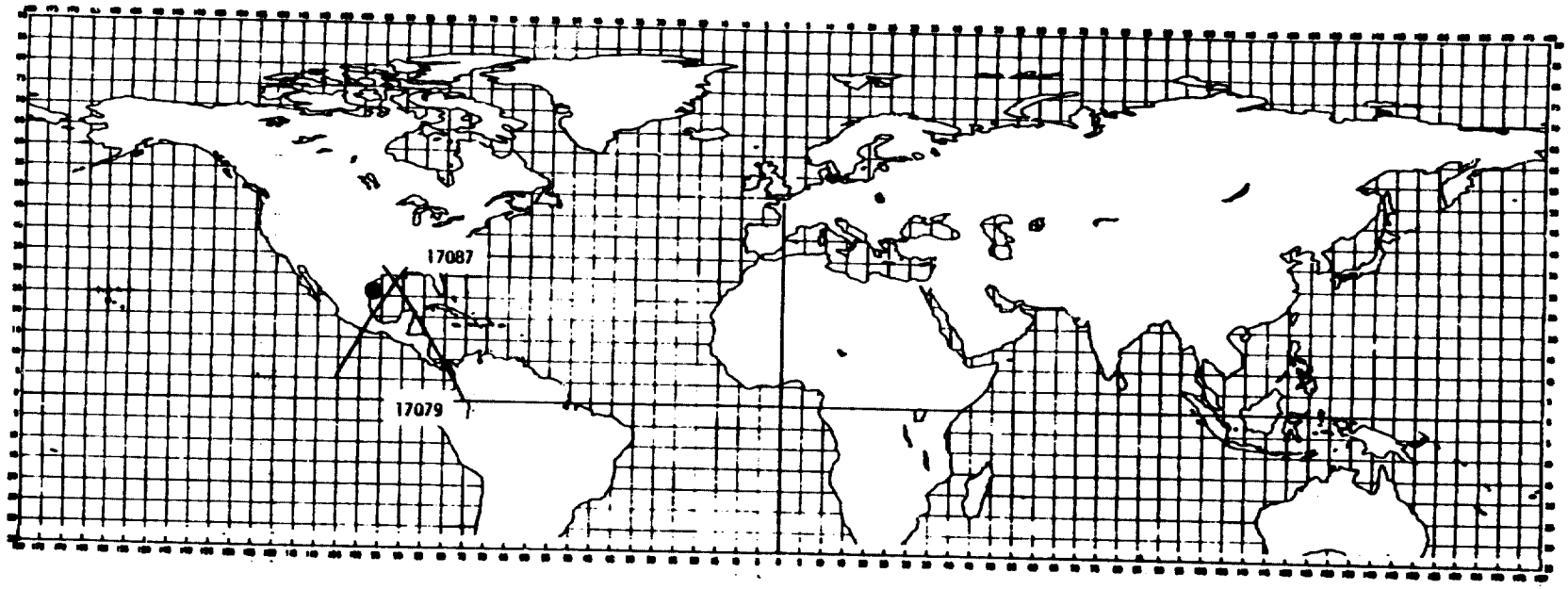
Tropical Storm Amelia, whose winds did not exceed 45 kt, will be remembered mainly for the extreme amounts of rainfall produced over central Texas. The largest amounts were recorded over the area from San Antonio to Abilene. Twenty-six inches were recorded in 12 h just northeast of Abilene. Amounts of more than 30 inches were recorded northwest of San Antonio. There were 33 known deaths in connection with the rainfall and disastrous flooding, along with property damage estimated to be in the tens of millions of dollars.

STORM: TROPICAL STORM AMELIA

DATE: July 30-31, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
7/30	1200Z	26.5N	97.0N			Tropical Depression
7/31	0000Z	26.4N	97.4W			Tropical Storm
	0600Z	27.2	97.8			
	1200Z	28.0	98.2			

TROPICAL STORM AMELIA - 7/30/78

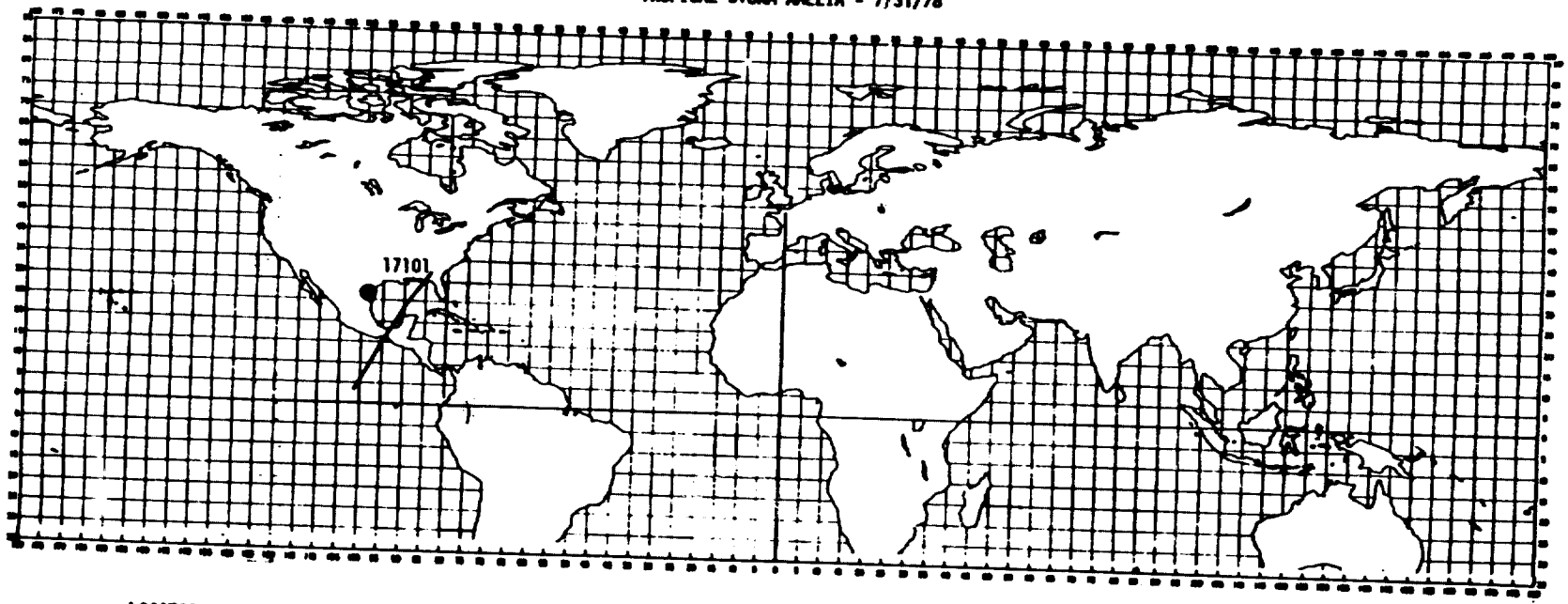


LOCATION

TIME	LATITUDE	LONGITUDE
1200Z	26.5N	97.0W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17079	284.55	034828	035800	034919	035834	802	163
17087	81.97	172242	180500	180401	181056	802	166

TROPICAL STORM AMELIA - 7/31/78



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	26.4N	97.4W
0600Z	27.2	97.8
1200Z	28.0	98.2

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17101	87.47	170736	175100	174839	175655	802	105

3.4 TROPICAL STORM BESS

August 5-8, 1978

Bess developed from a low pressure system that formed on a dissipating cold front over northeastern Georgia on August 1. This low moved south, then southwestward, reaching the extreme northeast Gulf of Mexico on the 3rd. Satellite, buoy and aerial reconnaissance data suggested that a closed circulation formed by 1200 GMT on the 5th in the central Gulf. On the next day Bess was designated a tropical storm.

Bess moved slowly across the southwest Gulf of Mexico for the next three days, making landfall near Nautla, Mexico, early on August 8, approximately 350 n mi south of Brownsville, Texas. Maximum sustained surface winds reached 45 kt on August 7 with a minimum sea level pressure of 1005 mb.

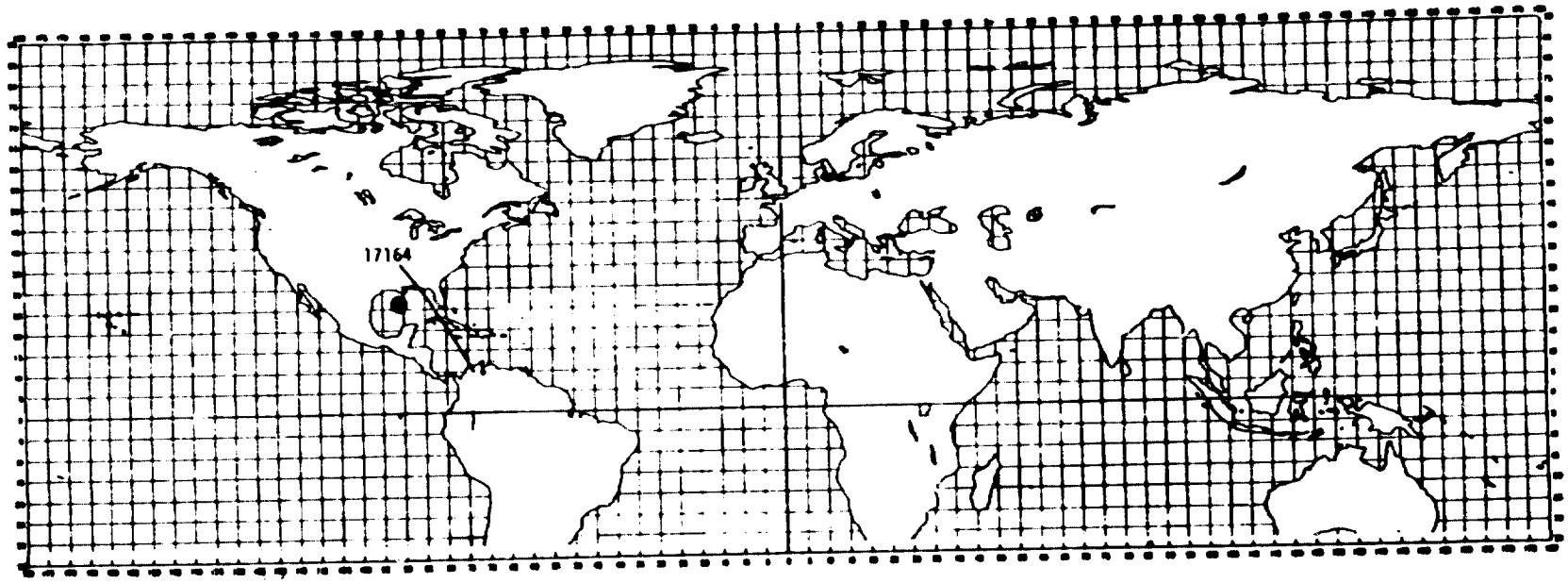
Satellite data indicated that rainfall associated with this storm decreased rapidly after landfall. There were neither casualties nor significant damage attributed to Bess.

STORM: TROPICAL STORM BESS

DATE: August 5-8, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
8/5	0600Z	25.3N	90.5W			Tropical Depression
	1800Z	24.9	92.0			
8/6	0600Z	24.2N	93.5W			Tropical Storm
	1800Z	23.9	94.0			
8/7	0000Z	23.3N	95.0W			Tropical Storm
	0600Z	22.8	95.7			
	1200Z	22.2	96.2			
	1800Z	21.6	96.6			
8/8	0000Z	21.1N	96.8W			Tropical Storm
	0600Z	20.4	96.9			

TROPICAL STORM BESS - 8/5/78

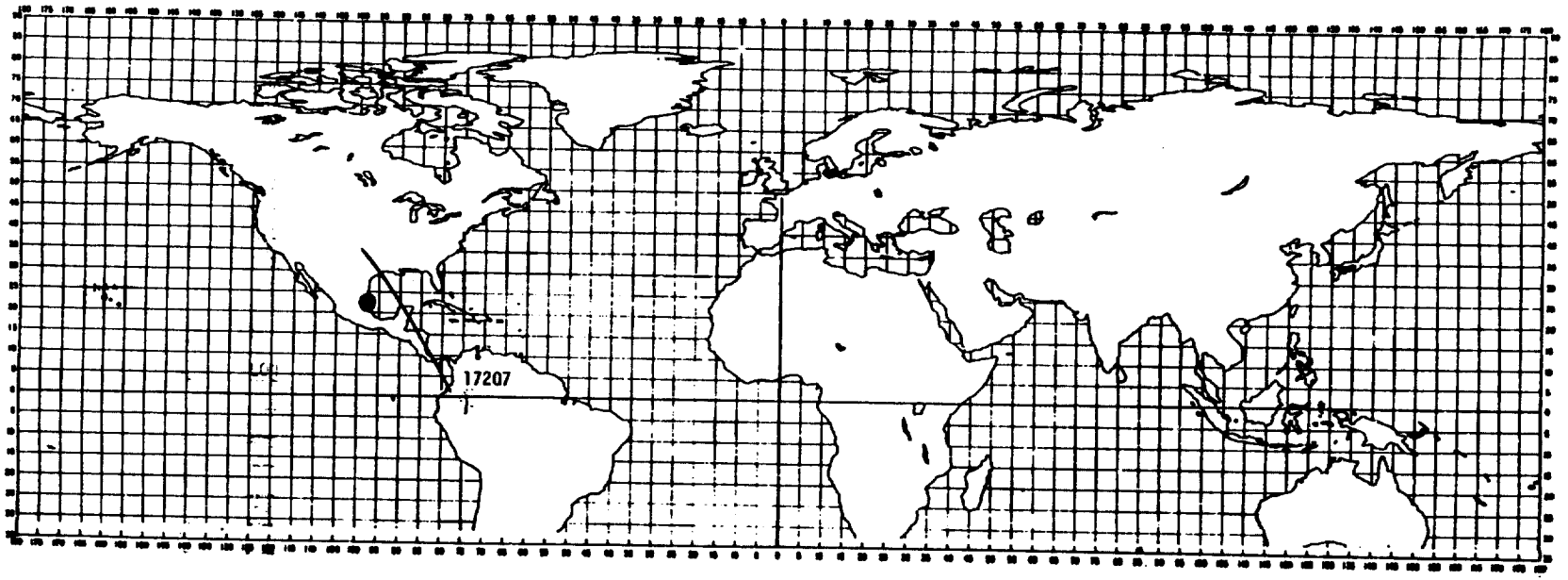


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	25.3N	90.5W
1800Z	24.9	92.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17164	292.21	035938	040800	040255	040952	802	143

TROPICAL STORM BESS - 8/8/78



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	21.1N	96.8W
0600Z	20.4	96.9

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17207	283.38	045606	050400	045639	045639	802	114

3.5

HURRICANE CORA
August 7-11, 1978

A weather disturbance moved off of the African coast on August 4, 1978. It continued westward for two days, then shifted northward and developed into a tropical depression. This depression intensified to tropical storm strength on August 8 at a location almost 1000 n mi west of the Azores. Later that same day the storm intensified to hurricane status.

Cora was now moving almost due west at about 20 kt and this motion continued as the storm moved into the extreme southeast Caribbean.

The storm weakened on August 9 while still east of the lesser Antilles. Reconnaissance flights measured the highest winds at 55 kt this same afternoon. By the 11th Cora had lost all evidence of circulation and was downgraded to a tropical wave. It continued into the southwest Caribbean and dissipated.

A point of interest is that Cora was identified as a tropical storm and later a hurricane solely on the basis of satellite pictures. Maximum wind speed was 80 kt and minimum sea level pressure was 980 mb during the period 0000-0600 GMT August 9.

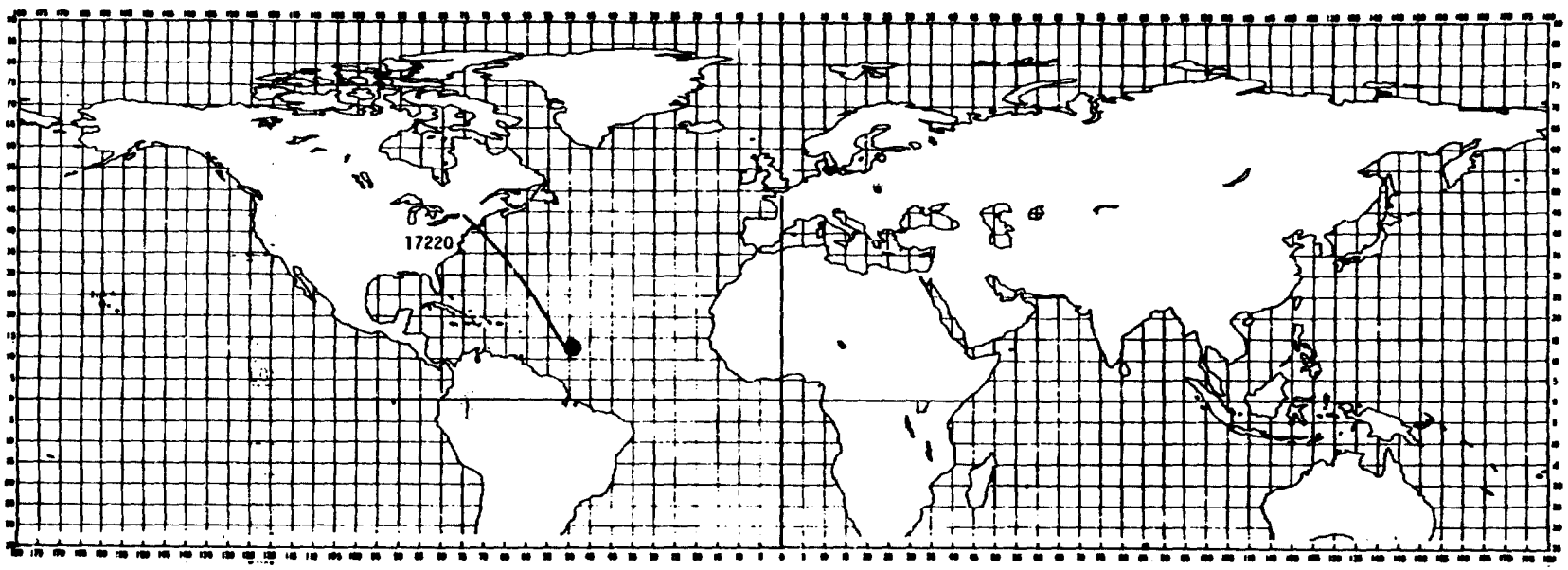
There were no reports of damage or deaths due to the storm .

STORM: HURRICANE CORA

DATE: August 7-11, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
8/7	0600Z	13.0N	35.0W			Tropical Depression
	1800Z	13.9	38.0			
8/8	0600Z	14.0N	41.5W			Tropical Storm
	1200Z	14.0	41.8			
	1800Z	14.0	43.2			Hurricane
8/9	0000Z	14.0N	44.9W			Hurricane
	0600Z	13.9	46.8			
	1200Z	13.6	48.6			
	1800Z	13.2	50.6			
8/10	0000Z	12.8N	52.8W			Tropical Storm
	0600Z	12.4	54.8			
	1200Z	12.2	56.8			
	1800Z	12.1	58.8			
8/11	0000Z	12.0N	60.9W			Tropical Depression
	0600Z	12.0	62.8			

HURRICANE CORA - 8/9/78

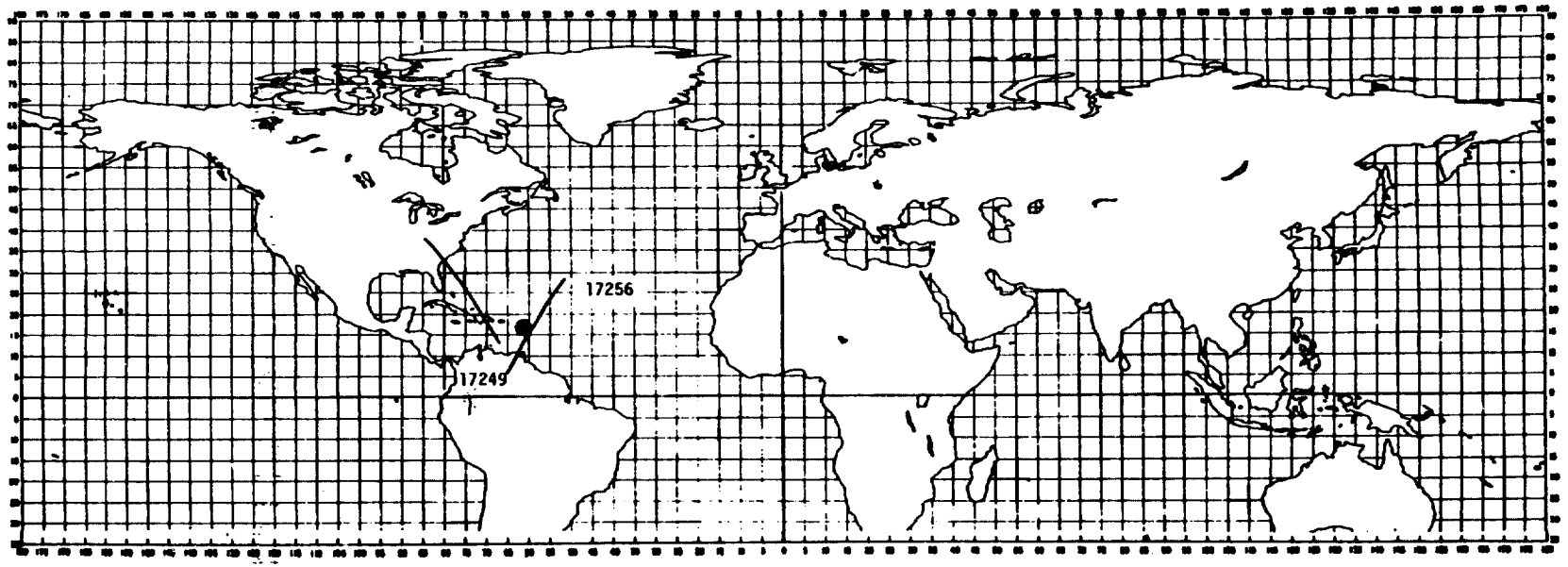


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	14.0N	44.9W
0600Z	13.9	46.8
1200Z	13.6	48.6
1800Z	13.2	50.6

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17220	314.19	025913	030330	030326	031256	802	122

HURRICANE CORA - 8/11/79



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	12.0N	60.9W
0600Z	12.0	62.8

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17249	299.87	041048	041505	041501	042149	802	144
17256	122.62	160314	165100	164523	165129	802	148

3.6 TROPICAL STORM DEBRA
August 26-29, 1978

Debra's origin can be traced to an upper tropospheric low pressure system which formed over southwest Florida on August 25. For 36 h this low drifted southwestward, reaching a position just north of the Yucatan Peninsula. Meanwhile, cloudiness, which appeared to be associated with a tropical wave, moved from the northwest Caribbean to the vicinity of the Yucatan Peninsula. These two resulted in forming a tropical depression at 1200 GMT August 26, 400 n mi south of New Orleans.

This system was upgraded to tropical storm Debra at 1800 GMT on August 28 on receipt of reconnaissance data of 40 kt surface winds. Debra was an immediate coastal threat and gale warnings were posted from Galveston, Texas to Grand Isle, Louisiana at 1800 GMT on the 28th.

The storms maximum intensity (50 kt surface winds and 1000 mb central pressure) was reached at 0000 GMT August 29, just before landfall.

After hitting land, Debra moved north-northeastward across central Louisiana and into Arkansas and finally into the Ohio Valley.

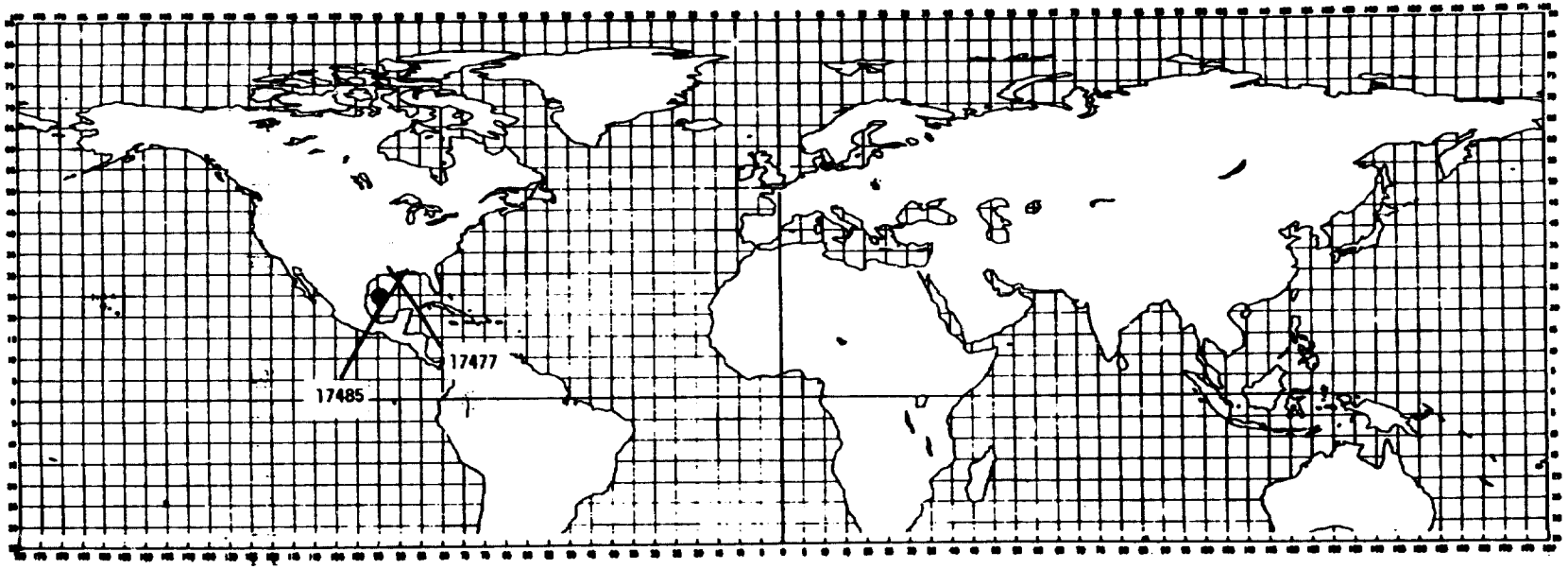
The greatest recorded rainfall of 10.6 inches occurred at Freshwater Bayou Lock, Louisiana. Tornadoes occurred in Texas, Louisiana and Mississippi. Two deaths were attributed to the storm while damage was considered to be minimal. However, an estimated 3000 persons were evacuated from low-lying coastal areas of Louisiana.

STORM: TROPICAL STORM DEBRA

DATE: August 26-29, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
8/26	0600Z	23.2N	88.5W			Tropical Depression
	1800Z	24.4	90.5			
8/27	0600Z	24.6N	92.5W			Tropical Depression
	1800Z	26.0	94.0			
8/28	0600Z	27.8N	94.5			Tropical Depression
	1800Z	28.7	94.1			Tropical Storm
8/29	0000Z	29.6	93.6			Tropical Storm
	0600Z	32.0	93.0			Tropical Depression

TROPICAL STORM DEBRA - 8/27/78

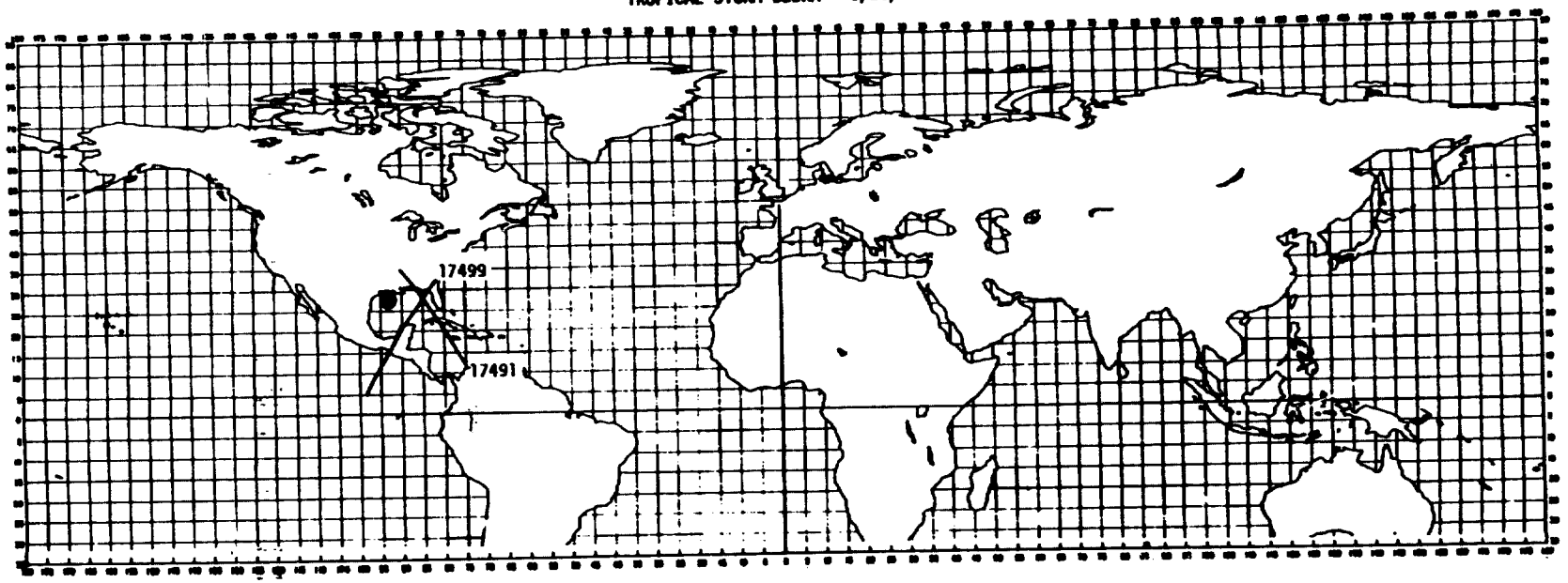


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	24.6N	92.5W
1800Z	26.0	94.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17477	286.54	065614	070500	070049	070604	802	175
17485	83.97	203028	211400	211151	211904	802	180

TROPICAL STORM DEBRA - 8/28/78



LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	27.8N	94.5W
1800Z	28.7	94.1

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17491	292.04	064108	065100	064520	065117	802	106
17499	89.47	201521	205900	205632	210458	802	110

3.7

HURRICANE ELLA

August 29 - September 5, 1978

Ella's formation occurred within a decaying, quasi-stationary frontal zone over the central North Atlantic Ocean. Ship and satellite data allowed the determination that a tropical depression had formed about 500 mi southeast of Bermuda on August 30 at 0000Z.

The depression headed toward the west-northwest at a speed of 10-15 kt. A ship report of 47 kt winds just north of the center at 2000 GMT on the 30th indicated that tropical storm intensity had been reached several hours earlier. Almost 24 h later, another ship reported winds of 70 kt and a sea level pressure of 980 mb, which agreed closely with an Air Force reconnaissance mission. Thus, Ella was upgraded to a hurricane at 1800 GMT on August 31, while located 500 n mi southeast of Cape Hatteras, North Carolina. Intensification had been continuous since the outset, but late on September 1 the storm began to weaken. After reaching a minimum of 959 mb at 2100 on the 1st, the central pressure rose more than 20 mb during the next 24 h.

On September 3, another trough moved from the Great Lakes eastward destroying the blocking ridge and causing large pressure falls. Ella responded and began accelerating toward the northeast reaching a speed of 40 kt by the 5th of September. The storm passed very close to the southeast tip of Newfoundland and became extratropical as it combined with a frontal system over the North Atlantic.

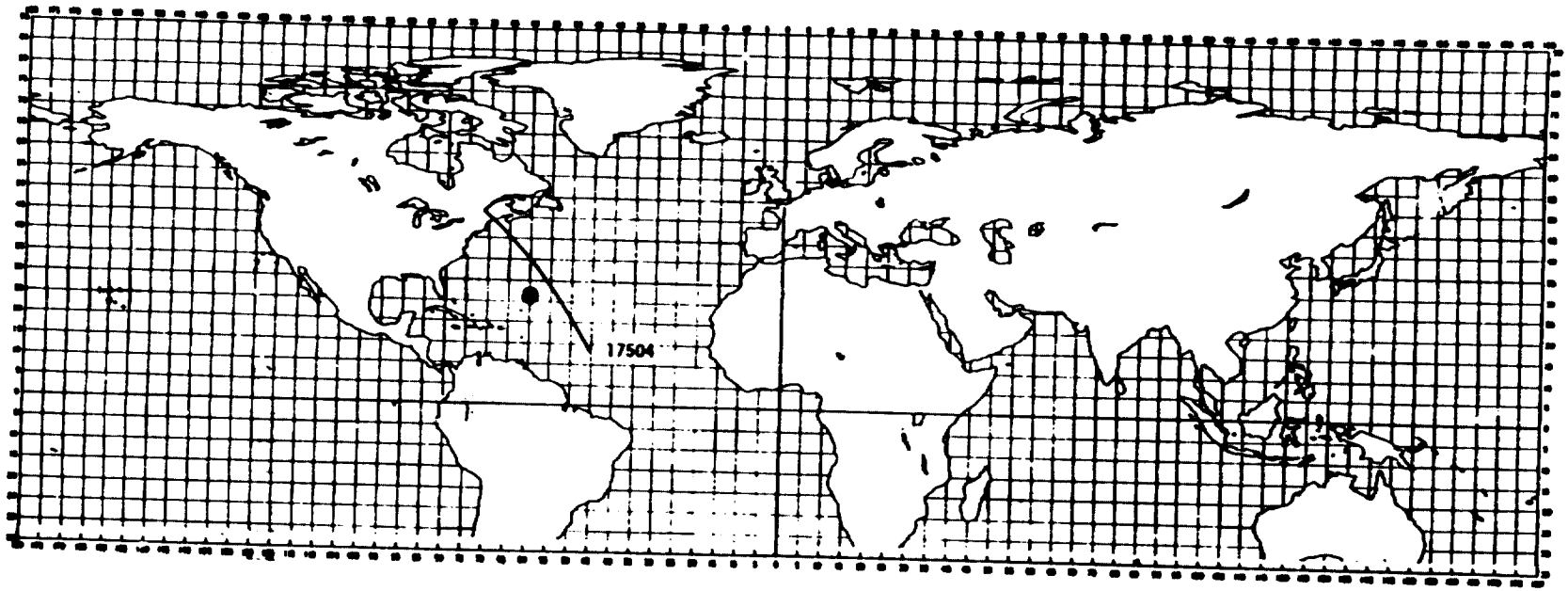
The only damage caused by the storm was beach erosion on the Outer Banks and tourist industry in this area suffered a "major disappointment" as a result of publicity in connection with the hurricane threat.

STORM: HURRICANE ELLA

DATE: August 29 - September 5, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
8/29	0600Z	26.2N	60.0W			Tropical Depression
8/30	0600Z	27.0N	62.0W			Tropical Depression
	1800Z	27.3	63.1			Tropical Storm
8/31	0000Z	27.6N	64.2W			Tropical Storm
	0600Z	28.2	65.9			
	1200Z	28.8	67.6			Hurricane
	1800Z	29.3	68.8			
9/1	0000Z	29.6N	70.0W			Hurricane
	0600Z	30.1	71.1			
	1200Z	30.7	71.8			
	1800Z	31.1	72.3			
9/2	0000Z	31.2N	72.7W			Tropical Depression
	0600Z	31.4	73.1			
	1200Z	31.6	73.3			
	1800Z	31.9	73.0			
9/3	0000Z	32.3N	72.8W			Subtropical Depression
	0600Z	33.0	72.4			
	1200Z	33.8	71.7			
	1800Z	35.0	70.2			
9/4	0000Z	36.2N	68.3W			Subtropical Depression
	0600Z	38.0	66.0			
	1200Z	40.0	63.0			
	1800Z	42.5	59.5			
9/5	0000Z	45.0N	55.0W			Subtropical Depression
	0600Z	47.2	50.2			
	1200Z	49.0	45.0			

HURRICANE ELLA - 8/29/78

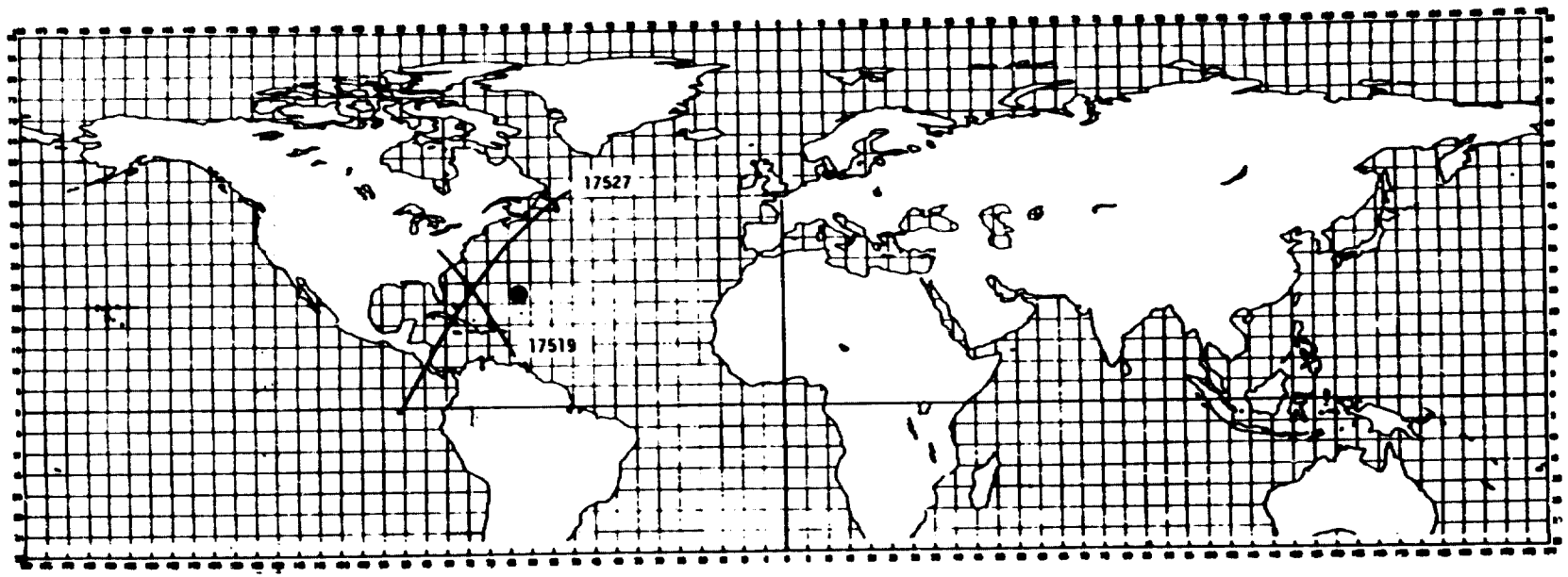


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	26.2N	60.0W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17504	322.86	044415	045300	045053	045900	802	114

HURRICANE ELLA - 8/30/78

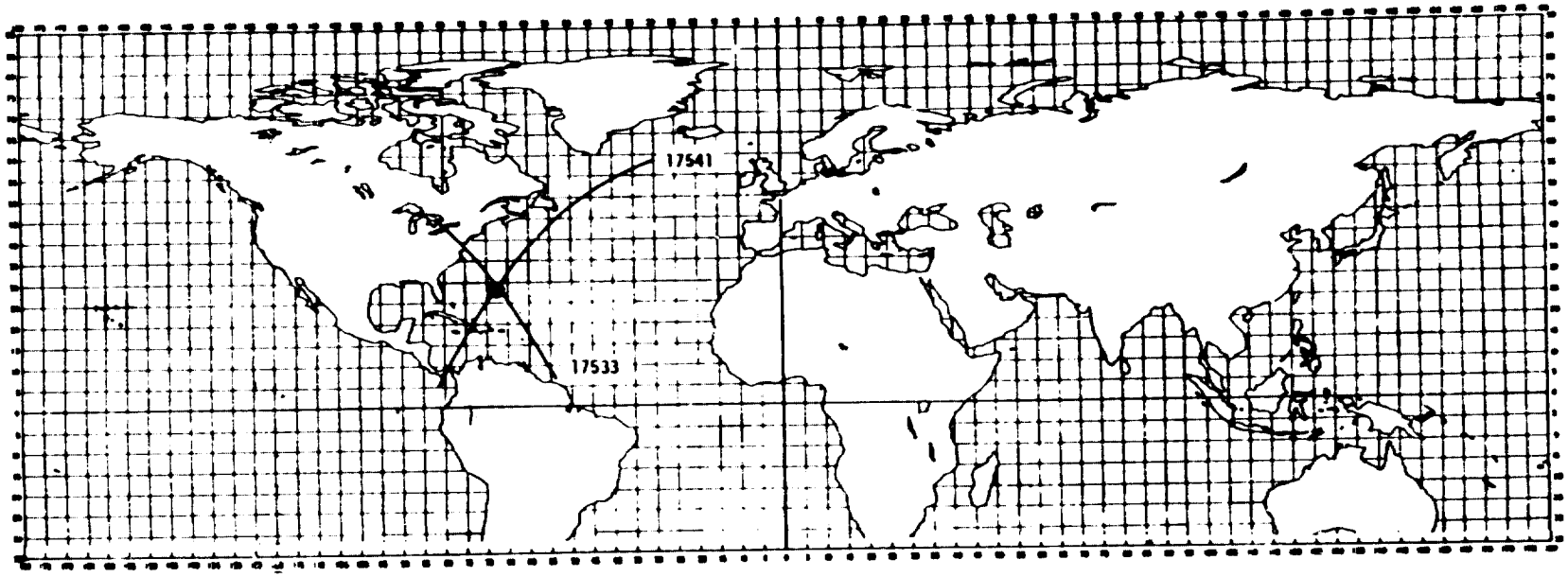


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	27.0N	62.0W
1800Z	27.3	63.1

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17519	303.04	061055	061800	061520	062218	802	125
17527	100 46	194508	202600	201927	203600	802	129

HURRICANE ELLA - 8/31/78

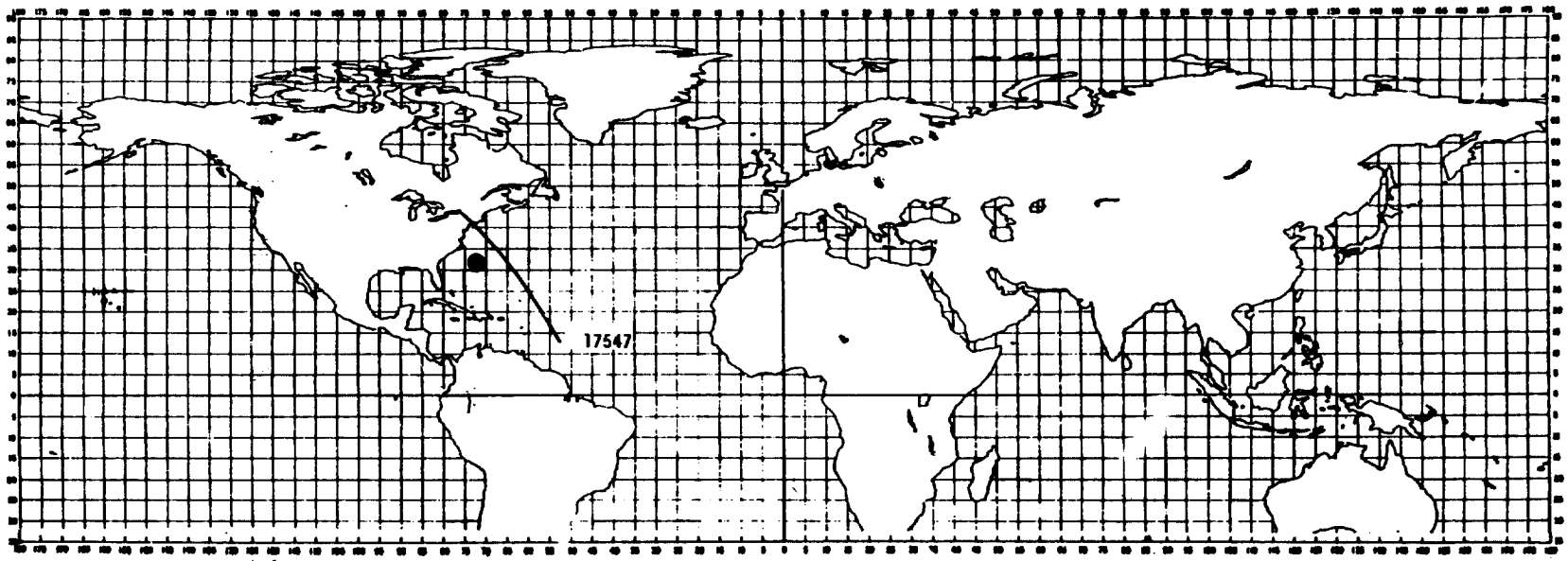


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	27.6N	64.2W
0600Z	28.2	65.9
1200Z	28.8	67.6
1800Z	29.3	68.8

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17533	308 53	055549	060500	055838	060900	802	134
17541	105.96	193002	201200	200159	201900	802	139

HURRICANE ELLA - 9/1/78

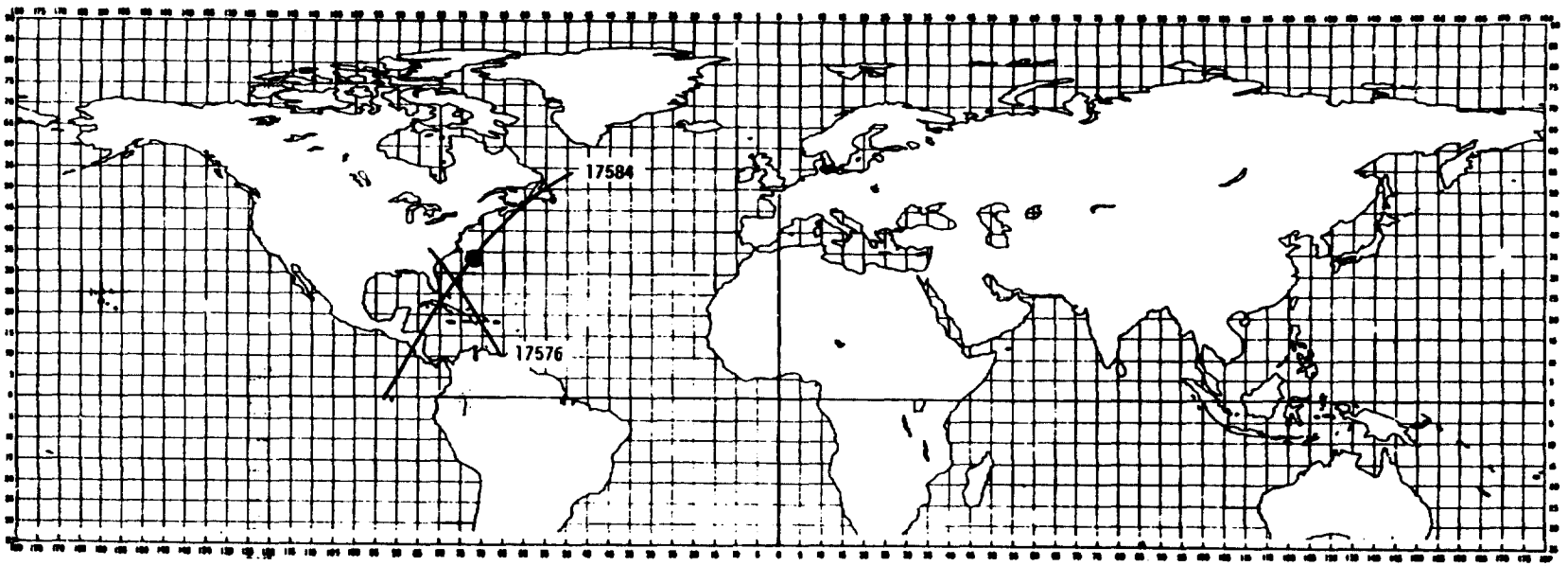


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	29.6N	70.0W
0600Z	30.1	71.1
1200Z	30.7	71.8
1800Z	31.1	72.3

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17547	314.03	054042	055100	054449	055428	802	145

HURRICANE ELLA - 9/3/78

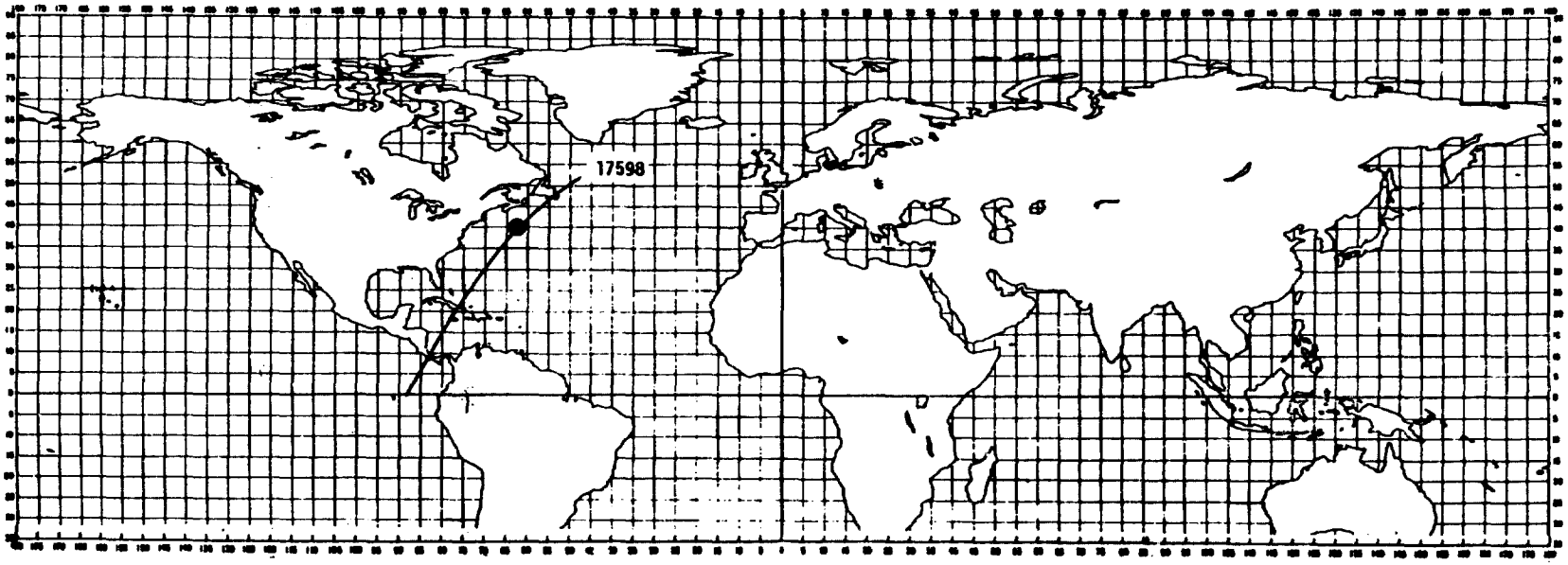


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	32.3N	72.8W
0600Z	33.0	72.4
1200Z	33.8	71.7
1800Z	35.0	70.2

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17576	299.71	065216	070100	065624	070211	802	166
17584	97.14	202630	210700	210022	211700	802	172

HURRICANE ELLA - 9/4/78



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	36.2N	68.3W
0600Z	38.0	66.0
1200Z	40.0	63.0
1800Z	42.5	59.5

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17598	102.64	201123	204000	204633	210200	802	110

3.8

HURRICANE FLOSSIE
September 3-16, 1978

Flossie formed off the western coast of Africa on August 31, 1978 and strengthened into a depression on September 4 as it moved midway across the Atlantic.

Flossie moved at 20 kt toward the northwest then west, for several days, with little change in strength. On September 7 the subtropical high-pressure ridge, to Flossie's north, weakened in response to the development of a strong extratropical low at higher latitudes.

Now moving northeastward, reintensification occurred and tropical storm strength was regained on the 10th. Far out in the Atlantic and no threat to land, Flossie was upgraded to a hurricane at 0600 GMT on September 12, 1978. Maximum winds of 85 kt and minimum sea-level pressure of 976 mb are based on satellite data and were reached on the 13th. Finally, moving off toward the northeast, Flossie became extratropical 700 n mi north of the Azores on the 15th.

The track of Flossie was confined to the open North Atlantic Ocean and this storm was never a threat to any land area.

STORM: HURRICANE FLOSSIE

DATE: September 3-17, 1978

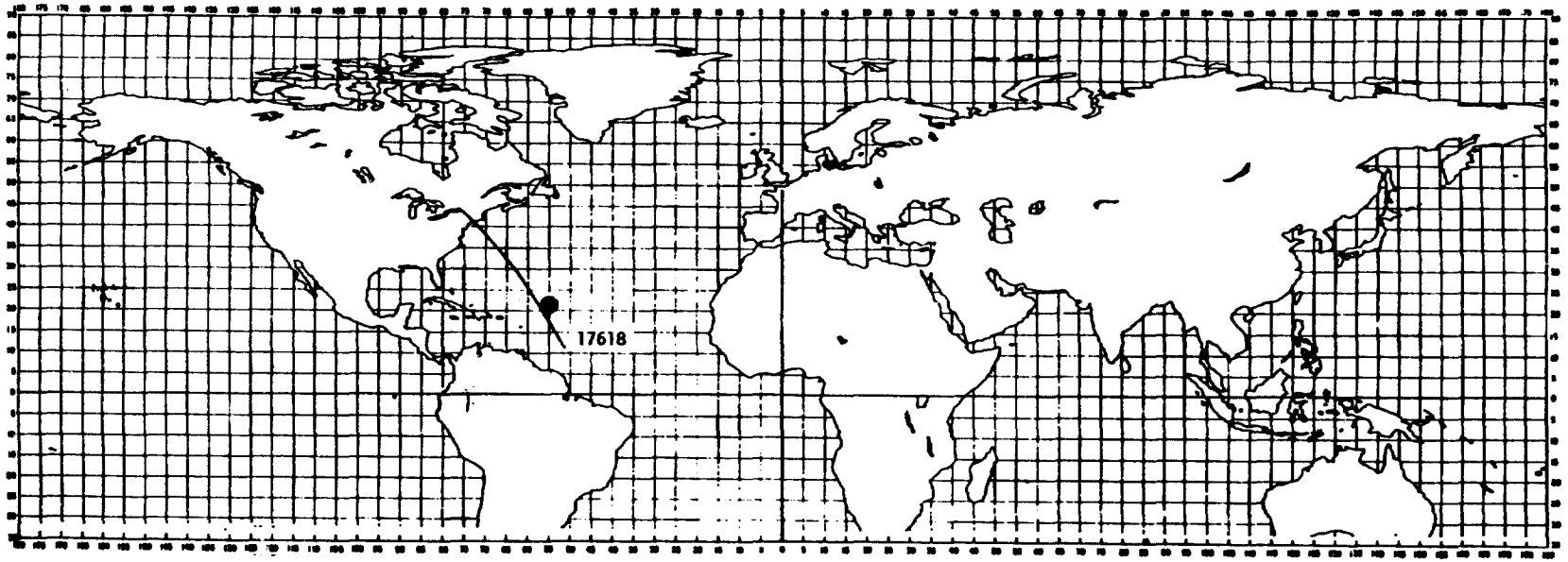
Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/3	1800Z	12.0N	39.0W			Tropical Depression
9/4	1200Z	14.2N	41.2W			Tropical Storm
	1800Z	15.5	42.9			
9/5	0000Z	16.7N	44.8W			Tropical Storm
	0600Z	17.8	46.4			
	1200Z	18.9	47.9			
	1800Z	20.3	49.5			
9/6	0000Z	21.2N	51.2W			Tropical Storm
	0600Z	22.0	53.2			
	1200Z	22.1	55.1			
	1800Z	21.8	56.8			
9/7	0000Z	21.7N	58.0W			Tropical Storm
	0600Z	21.8	59.0			
	1200Z	22.2	60.0			
	1800Z	22.3	61.2			
9/8	0000Z	22.6N	62.0W			Tropical Depression
	0600Z	23.5	62.0			
	1200Z	24.3	61.1			
	1800Z	25.8	60.0			
9/9	0600Z	27.4N	58.4W			
	1800Z	28.2	56.0			
9/10	0600Z	29.0N	53.3W			Tropical Depression
	1800Z	29.1	50.7			

STORM: HURRICANE FLOSSIE

DATE: (cont.)

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/11	0000Z	29.2N	50.5W			Tropical Depression
	0600Z	29.7	49.1			
	1200Z	30.7	47.5			
	1800Z	31.0	45.7			
9/12	0000Z	31.3N	44.7W			Hurricane
	0600Z	31.4	44.0			
	1200Z	31.6	43.5			
	1800Z	31.7	43.0			
9/13	0000Z	31.8N	42.9W			Hurricane
	0600Z	32.1	43.0			
	1200Z	32.6	43.0			
	1800Z	33.6	43.1			
9/14	0000Z	34.6N	43.1W			Hurricane
	0600Z	35.9	42.9			
	1200Z	37.4	41.9			
	1800Z	39.3	40.6			
9/15	0000Z	40.9N	38.5W			Tropical Storm
	0600Z	43.1	35.9			
	1200Z	45.7	32.8			
	1800Z	47.7	29.4			

HURRICANE FLOSSIE - 9/6/78

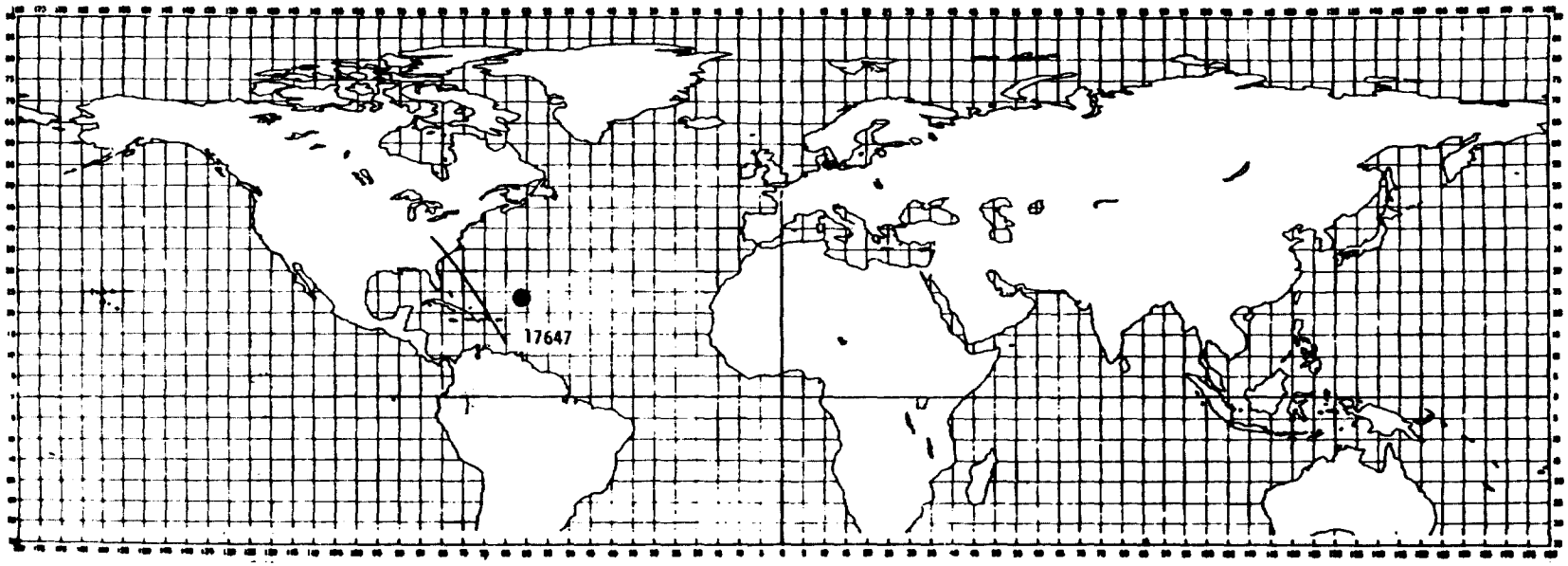


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	21.2N	51.2W
0600Z	22.0	53.2
1200Z	22.1	55.1
1800Z	21.8	56.8

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17618	316.20	060657	061300	061134	062045	802	125

HURRICANE FLOSSIE - 9/8/78

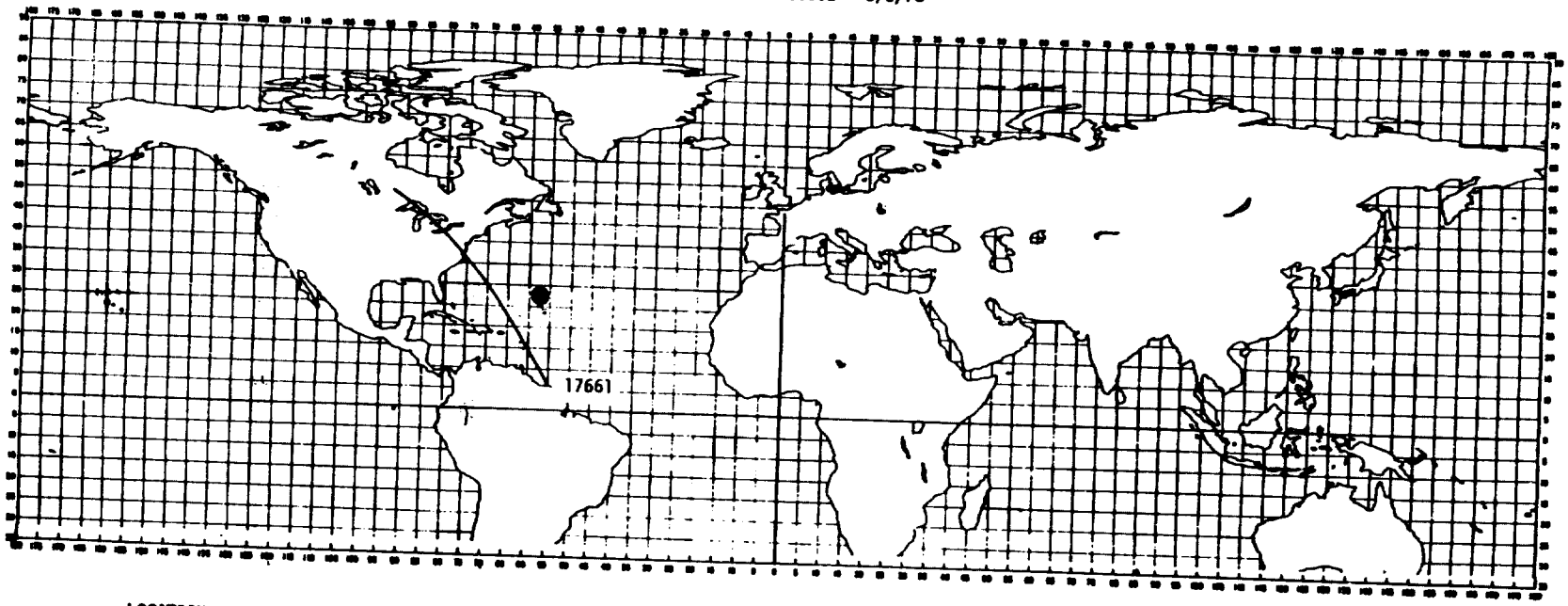


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	22.6N	62.0W
0600Z	23.5	62.0
1200Z	24.3	61.1
1800Z	25.8	60.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17647	301.88	071831	072400	072243	072944	802	146

HURRICANE FLOSSIE - 9/9/78

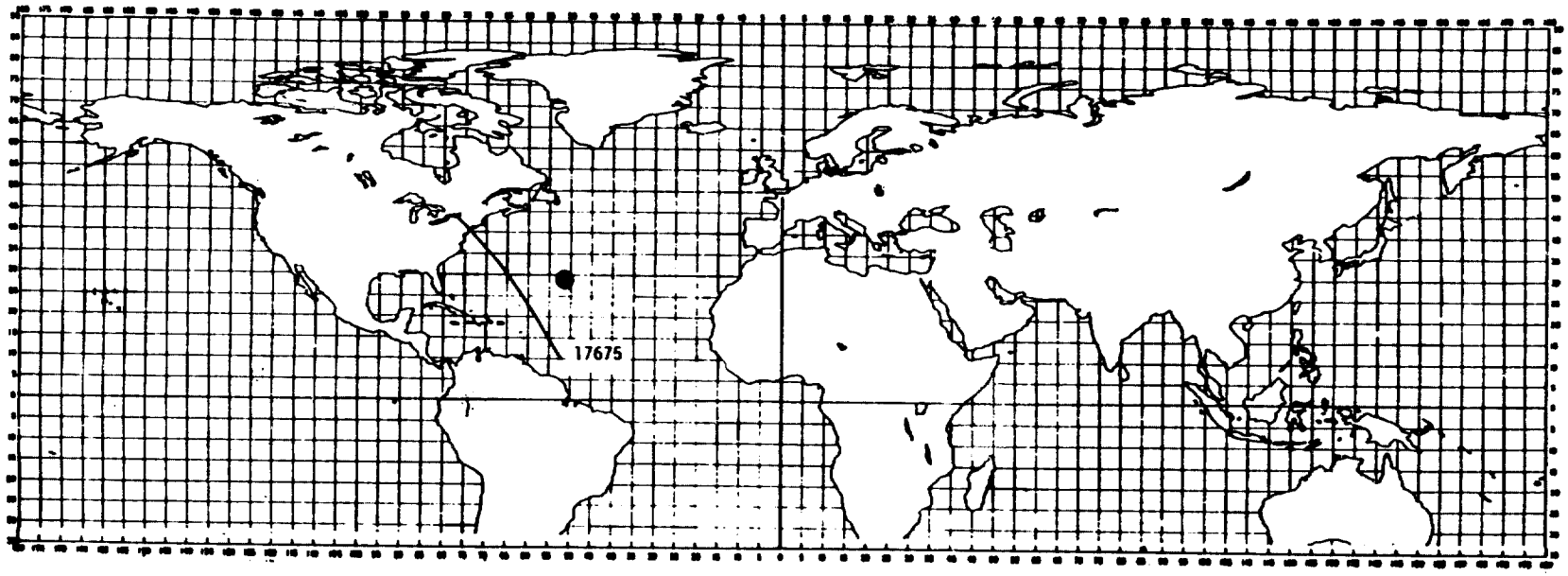


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	27.4N	58.4W
1800Z	28.2	56.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17661	307.38	070324	071000	070557	071943	802	157

HURRICANE FLOSSIE - 9/10/78

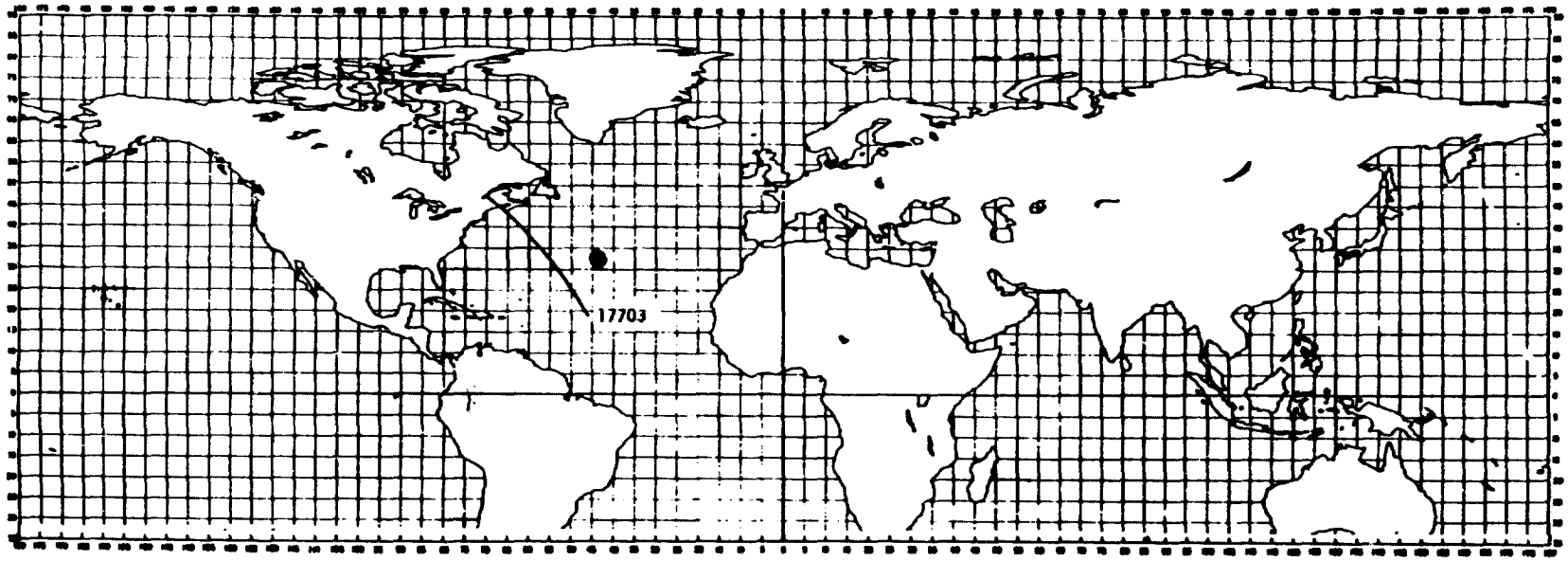


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	29.0N	53.3W
1800Z	29.1	50.7

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17675	312.88	064818	065500				

HURRICANE FLOSSIE - 9/12/78



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	31.3N	44.7W
0600Z	31.4	44.0
1200Z	31.6	43.5
1800Z	31.7	43.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17703	323.88	061805	062600	062502	063300	802	112

3.9

HURRICANE GRETA
September 13 - 20, 1978

The first signs of any disturbance was a tropical wave which occurred on the 10th, halfway between Africa and the Windward Islands. Barbados reported winds gusting to 45 kt as the wave moved into the Caribbean on the 13th, and a depression was formed 75 n mi west-northwest of Port-of-Spain, Trinidad. Greta was named on the 14th while just north of the Netherlands, Antilles.

Hurricane strength was reached on 1200 GMT on September 16, 1978 at a location due south of Jamaica. The central pressure reached its minimum of 947 mb (115 kt maximum winds) early on the 18th. The eyewall of Greta crossed over the extreme northeast coast of Honduras during this time of maximum intensity.

The hurricane weakened as it continued westward, landfalling near Stann Creek, Belize at 0000 GMT on September 19th. Greta decreased to below storm strength over northwest Guatemala by 1200 GMT on September 19th.

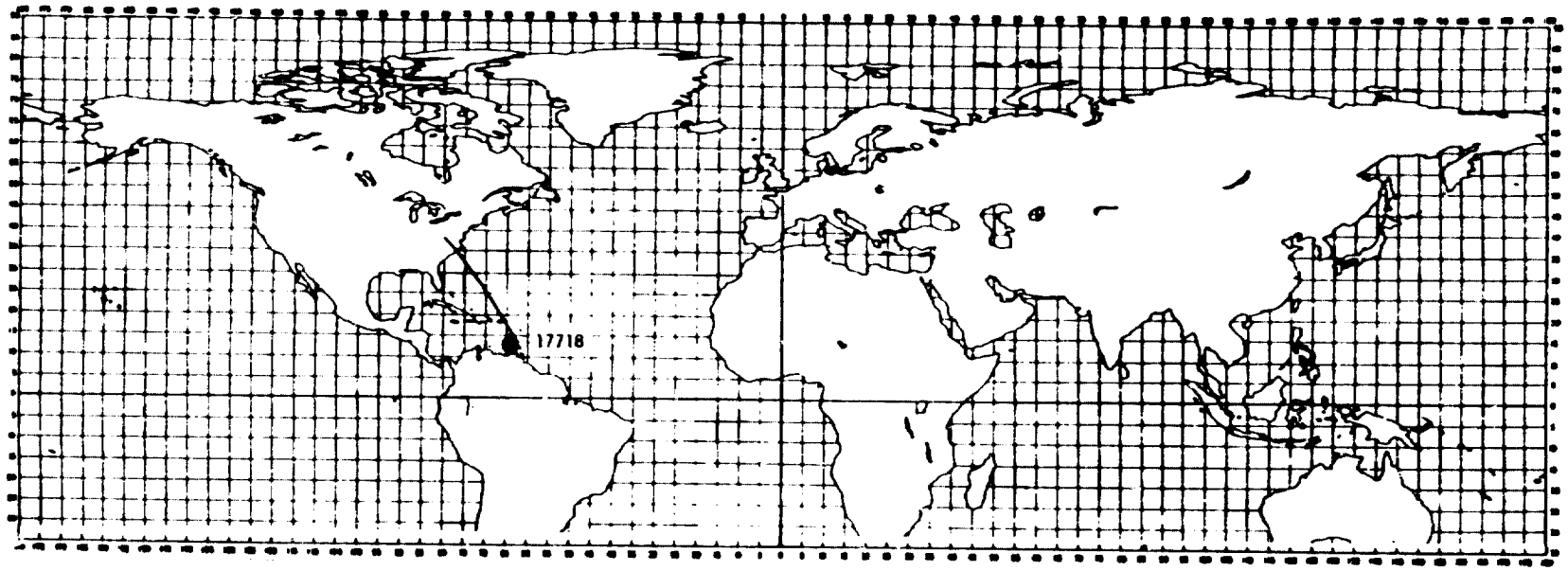
Five deaths were contributed to Greta while damage was estimated at $25 million, mainly from crops and utilities damages.

STORM: HURRICANE GRETA

DATE: September 13-20, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/13	1800Z	11.5N	64.5W			Tropical Depression
9/14	0600Z	12.5N	67.5W			Tropical Storm
	1200Z	12.5	67.5			
	1800Z	13.0	69.0			
9/15	0000Z	13.3N	70.4W			Tropical Storm
	0600Z	13.4	71.7			
	1200Z	13.5	73.1			
	1800Z	13.7	74.2			
9/16	0000Z	13.8N	75.3W			Hurricane
	0600Z	13.8	76.7			
	1200Z	14.0	77.7			
	1800Z	14.3	78.7			
9/17	0000Z	14.6N	74.6W			Hurricane
	0600Z	14.9	80.5			
	1200Z	15.2	81.6			
	1800Z	15.5	82.6			
9/18	0000Z	15.6N	83.4W			Hurricane
	0600Z	15.8	84.3			
	1200Z	16.4	85.6			
	1800Z	16.6	86.9			
9/19	0000Z	17.0	88.2			Tropical Storm
	0600Z	17.0	89.4			
	1800Z	15.8	93.0			
9/20	0600Z	15.2N	94.0W			Tropical Depression

HURRICANE GRETA - 9/13/78

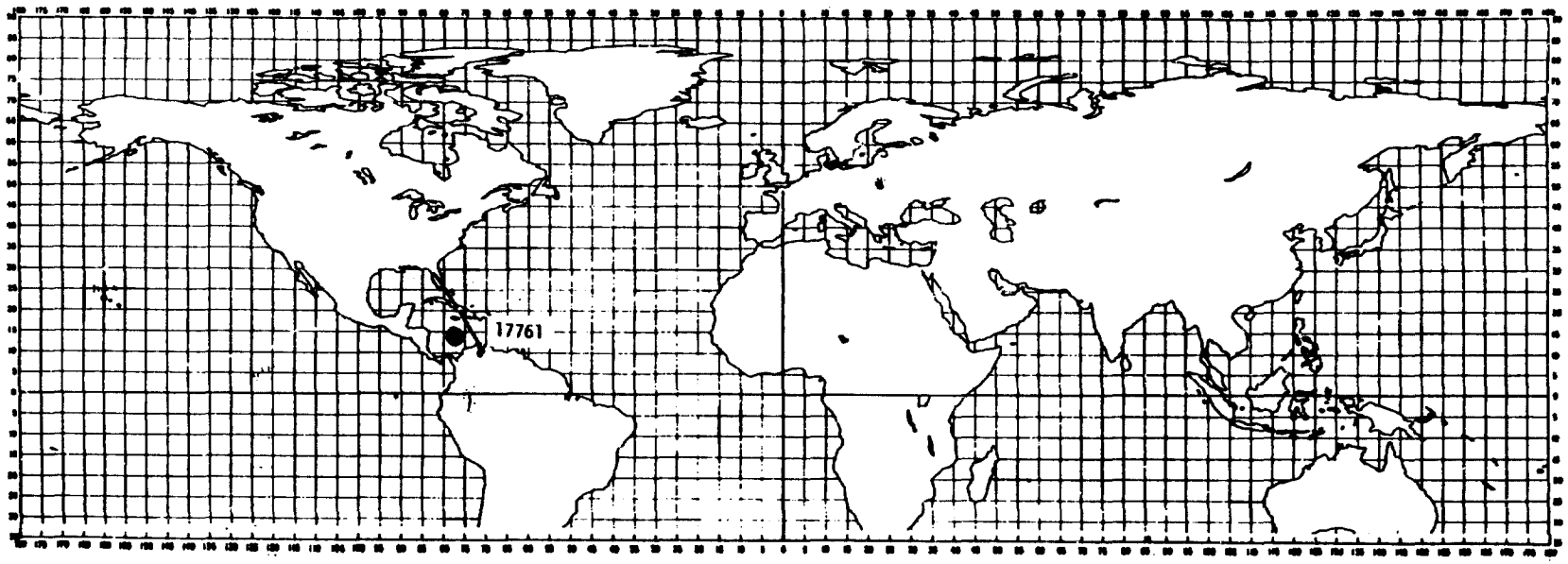


LOCATION

TIME	LATITUDE	LONGITUDE
1800Z	11.5N	64.5W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17718	304.05	074445	074930	074918	075616	802	123

HURRICANE GRETA - 9/16/78

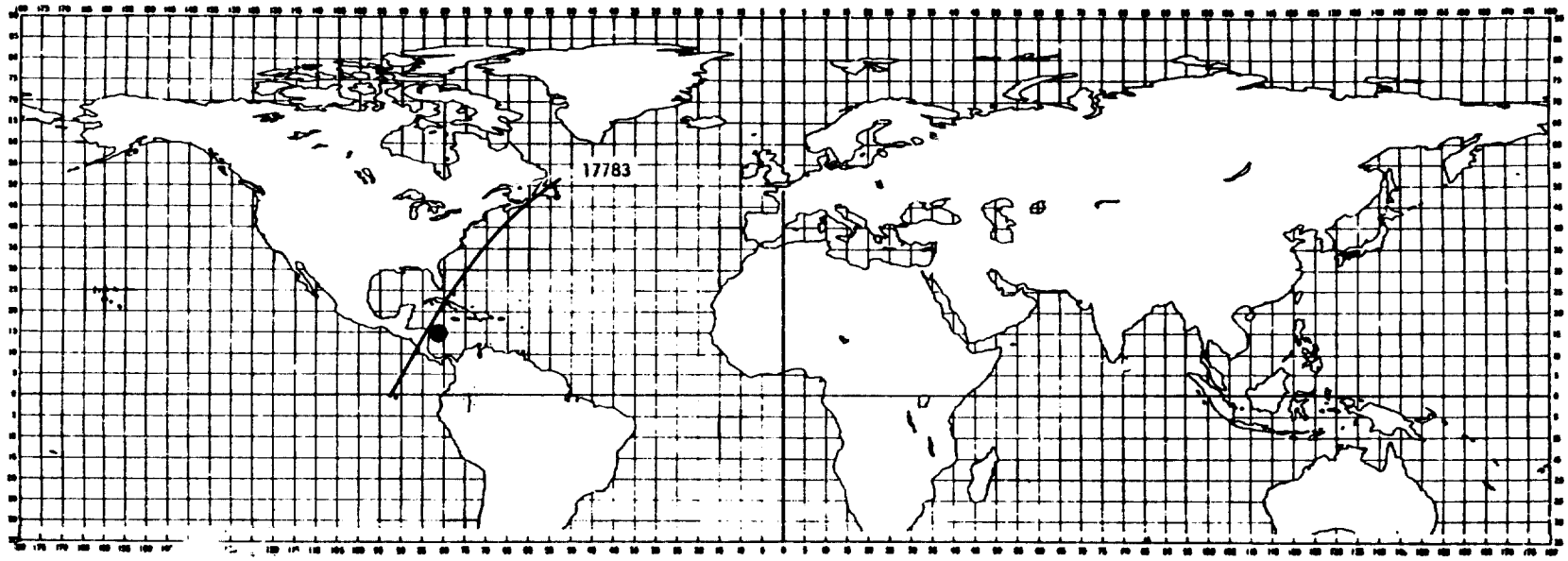


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	13.8N	75.3W
0600Z	13.8	76.7
1200Z	14.0	77.7
1800Z	14.3	78.7

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17761	?95.23	084112	084600	084517	085003	802	152

HURRICANE GRETA - 9/17/78

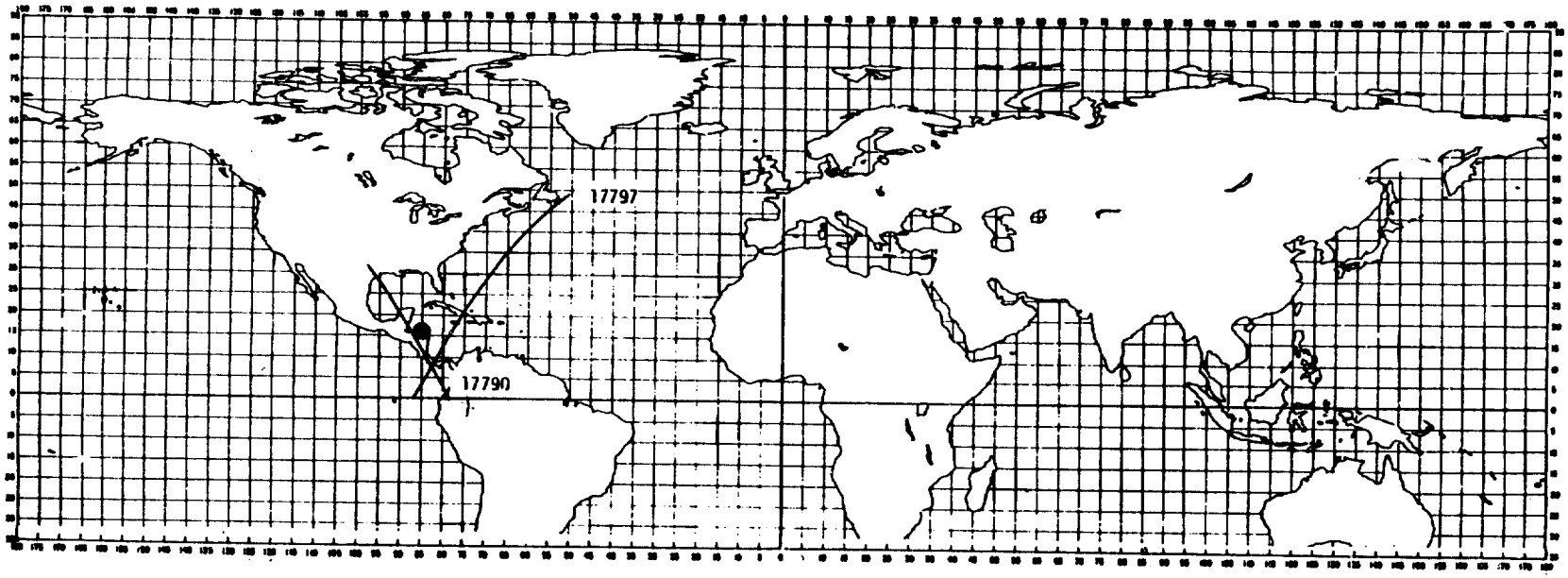


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	14.6N	79.6W
0600Z	14.9	80.5
1200Z	15.2	81.6
1800Z	15.5	82.6

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17783	98.16	220018	224600	223418	225112	802	167

HURRICANE GRETA - 9/18/78

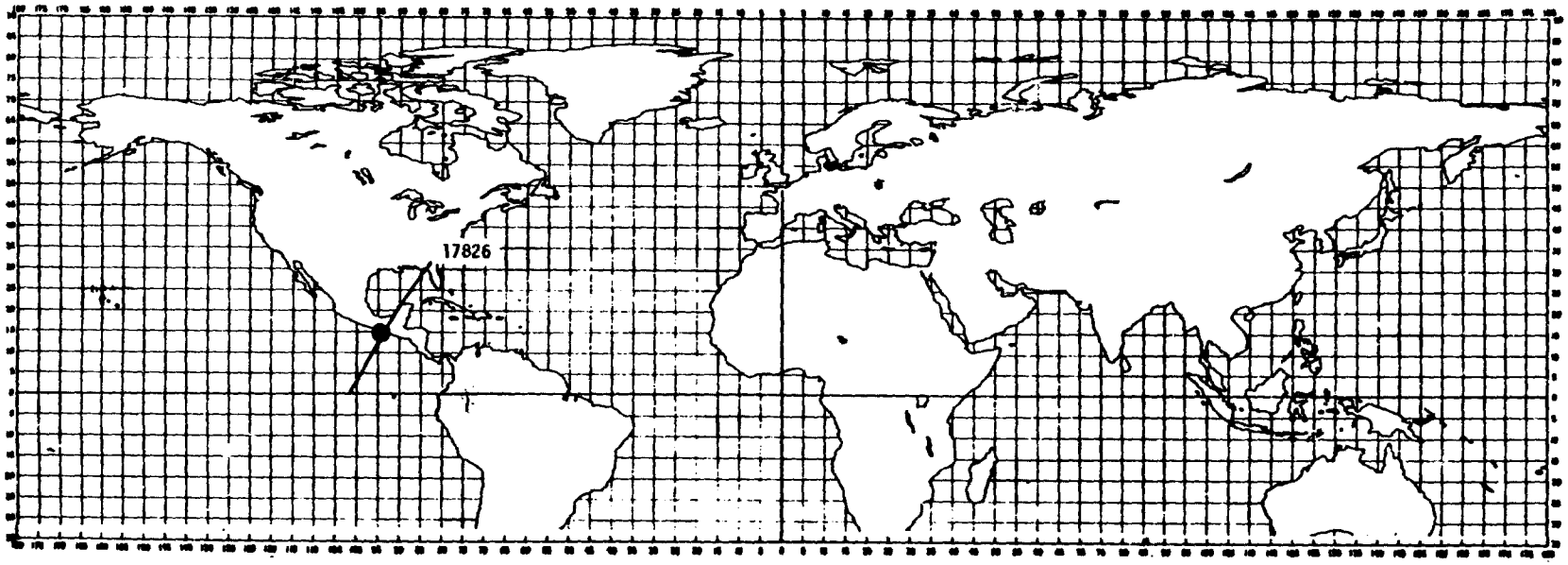


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	15.6N	83.4W
0600Z	15.8	84.3
1200Z	16.4	85.6
1800Z	16.6	86.9

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17790	280.91	095245	095800	095322	100223	802	106
17797	103.66	214512	223200	222038	223600	802	109

HURRICANE GRETA - 9/20/78



LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	15.2N	94.0W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17826	89.34	225645	234300	233843	234622	802	136

3.10 TROPICAL STORM HOPE
September 11-21, 1978

A mid-tropospheric low-pressure system contributed to the formation of a subtropical depression just offshore of the northeast coast of Florida on September 11, 1978. The depression moved east-northeastward for a few days, strengthening to a subtropical storm on the 14th, while passing a short distance north of Bermuda. Bermuda was not affected significantly as there was a broad area of light winds near the storm center.

On September 17, Hope was designated a tropical storm. The storm accelerated toward the northeast and reached maximum strength on the 19th and became extratropical to the northwest of the British Isles on September 21. Hope did not affect land and there were no reports of marine-related incidents.

STORM: TROPICAL STORM HOPE

DATE: September 11-21, 1978

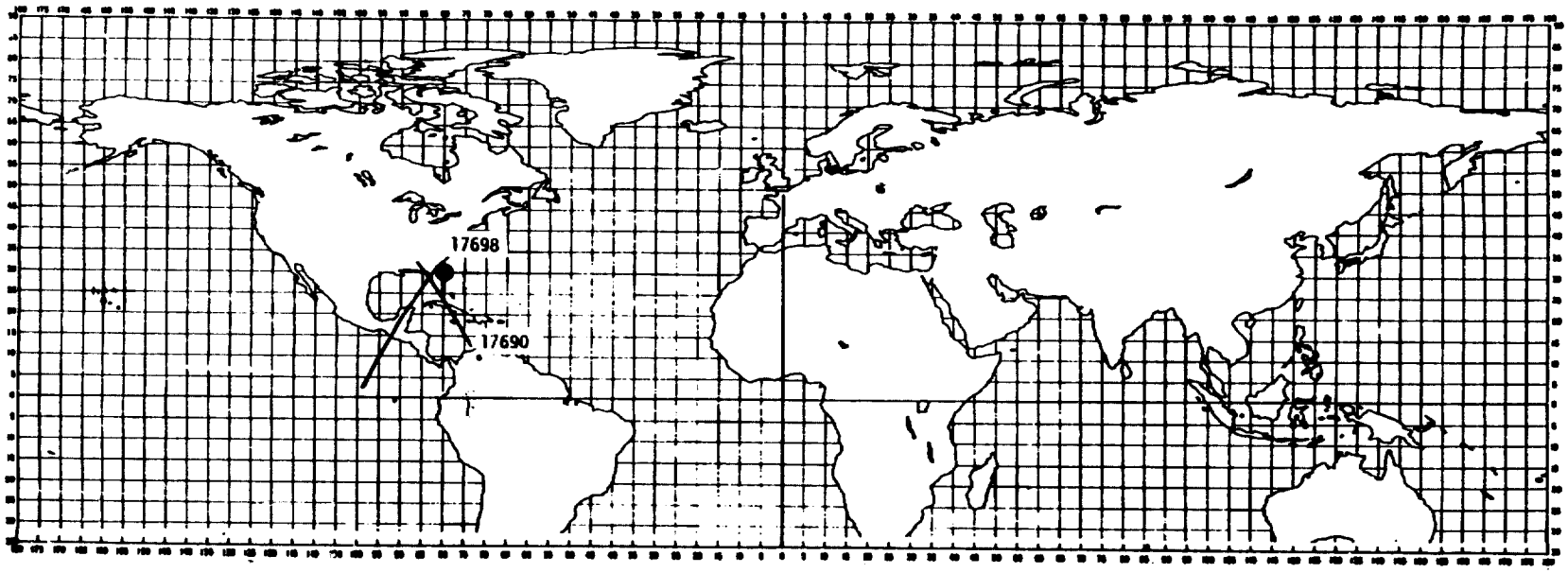
Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/11	1800Z	28.9N	80.0W			Subtropical Storm
9/12	0600Z	31.0N	78.9W			Subtropical Storm
	1800Z	31.0	76.5			
9/13	0600Z	32.0N	74.5W			Subtropical Storm
	1800Z	33.0	72.2			
9/14	0600Z	33.2N	68.5W			Subtropical Storm
	1800Z	33.0	65.0			
9/15	0600Z	31.7N	62.2W			Subtropical Storm
	1800Z	31.0	60.2			
9/16	0600Z	31.2N	58.1W			Subtropical Storm
	1800Z	32.4	56.0			
9/17	0600Z	33.0N	54.8W			Tropical Storm
	1200Z	33.8	53.4			
	1800Z	35.0	51.8			
9/18	0000Z	36.0N	49.9W			Tropical Storm
	0600Z	37.0	47.8			
	1200Z	38.0	45.2			
	1800Z	39.1	43.0			

STORM: TROPICAL STORM HOPE

DATE: September 11-21, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/19	0000Z	40.1N	40.5W			Tropical Storm
	0600Z	41.2	38.5			
	1200Z	42.5	36.5			
	1800Z	44.0	35.0			
9/20	0000Z	45.5N	33.0W			Tropical Storm
	0600Z	48.2	30.0			
	1200Z	51.5	29.5			
	1800Z	54.0	29.5			
9/21	0000Z	57.0N	30.0W			Tropical Storm
	0600Z	59.5	28.0			

TROPICAL STORM HOPE - 9/11/78

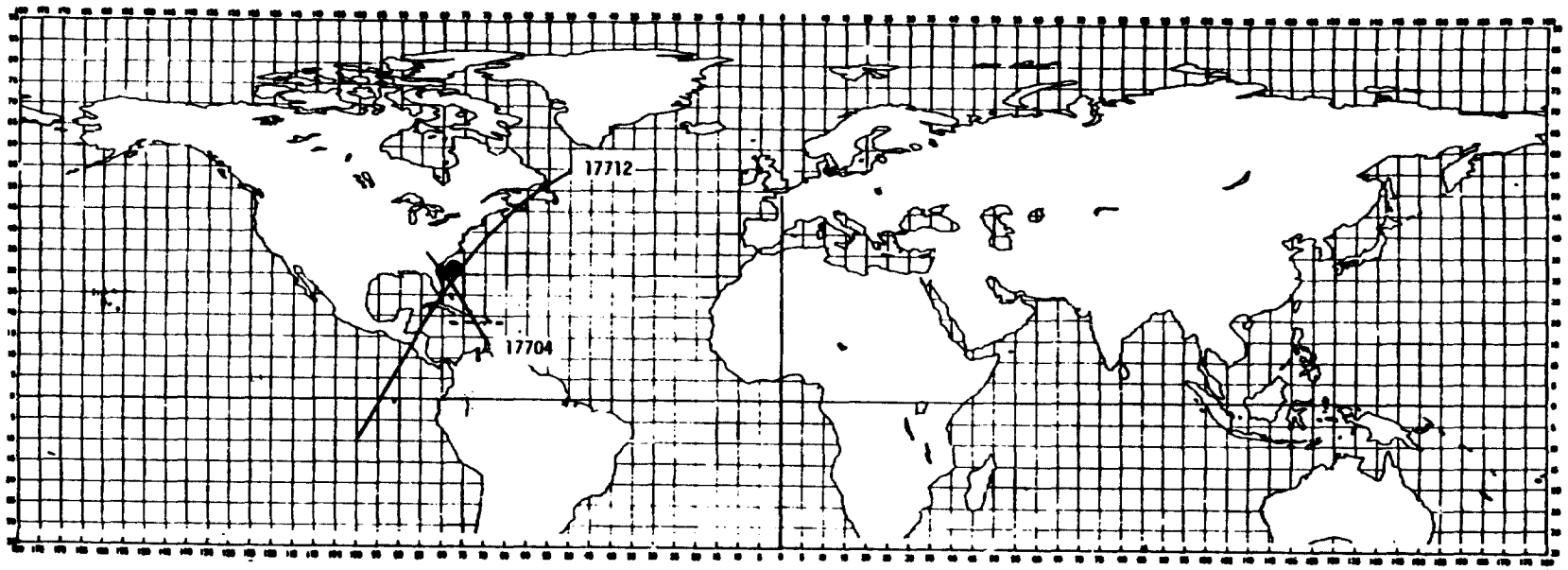


LOCATION

TIME	LATITUDE	LONGITUDE
1800Z	29.8N	80.0W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17690	293.05	081458	082330	081908	082457	802	104
17698	90.48	214911	223030	223016	223858	802	108

TROPICAL STORM HOPE - 9/12/78

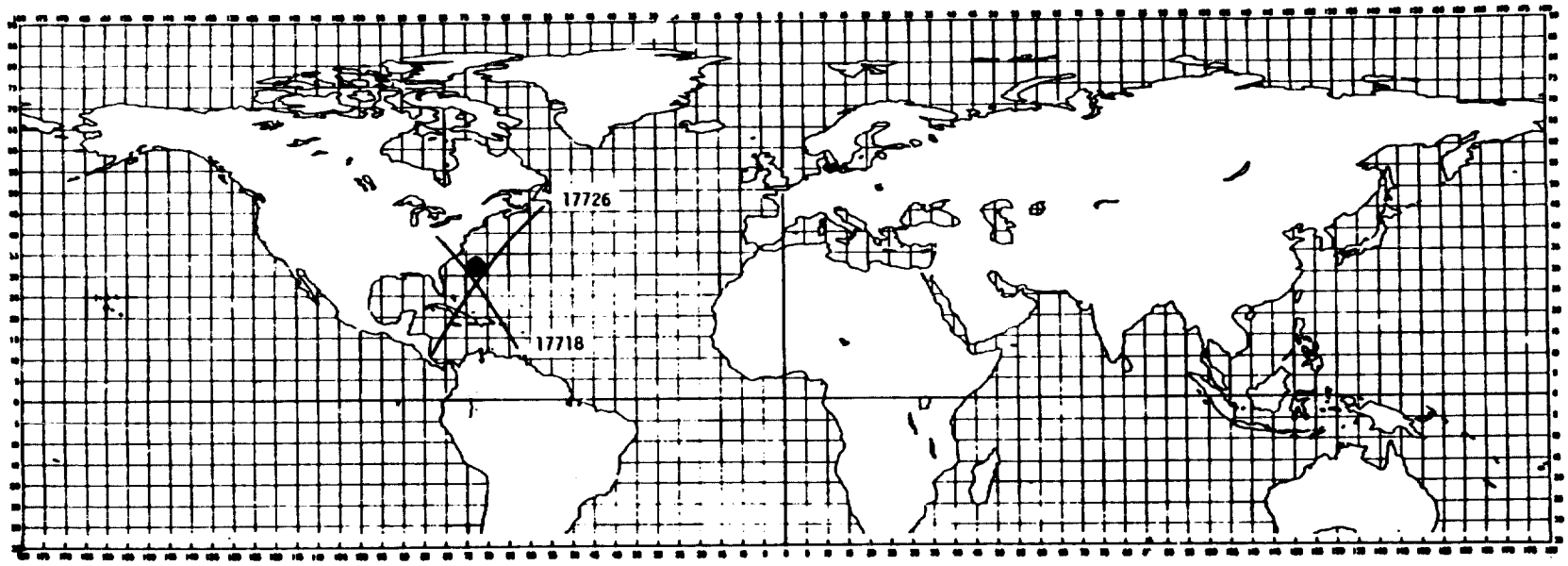


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	31.0N	78.9W
1800Z	31.0	76.5

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17704	298.55	075951	080900	080356	081034	80c	113
17712	95.98	213405	221530	220746	222727	802	117

TROPICAL STORM HOPE - 9/13/78

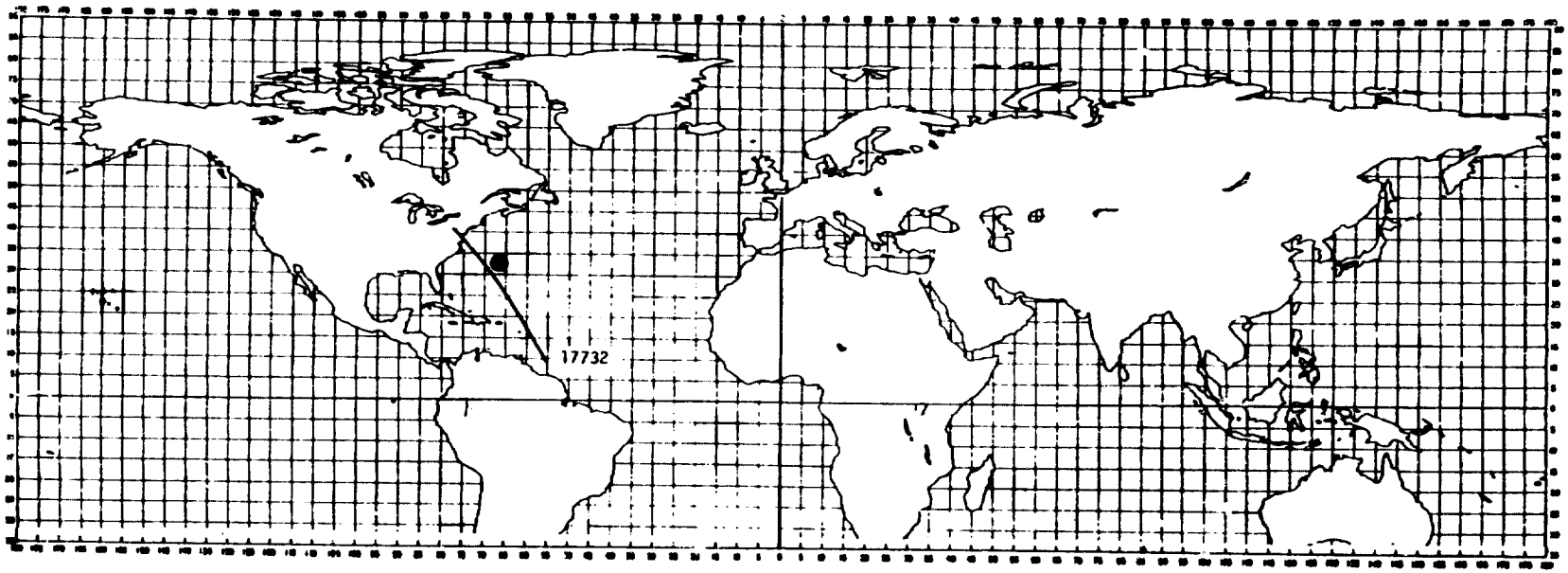


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	32.0N	74.5W
1800Z	33.0	72.2

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17718	304.05	074445	075400	074918	075616	802	123
17726	101.48	211858	220000	215507	220542	802	128

TROPICAL STORM HOPE - 9/14/78

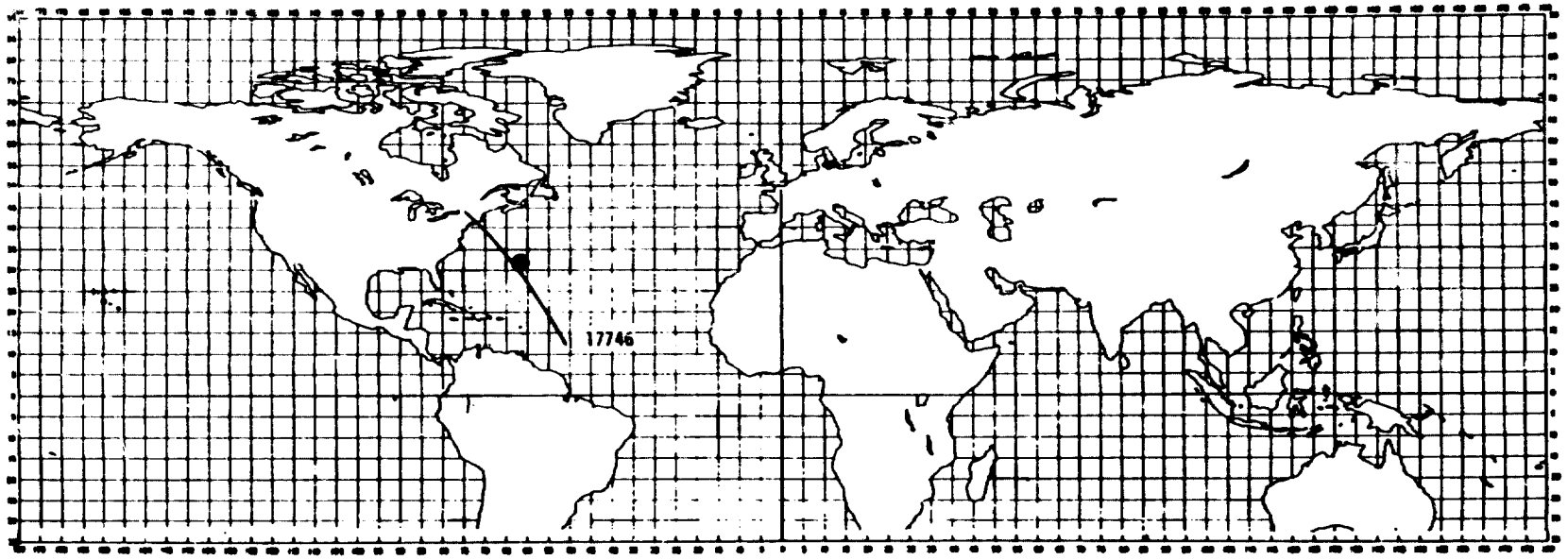


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	33.2N	68.5W
1800Z	33.0	65.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSI	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17732	309.55	072938	073900	073240	074226	802	133

TROPICAL STORM HOPE - 9/15/78

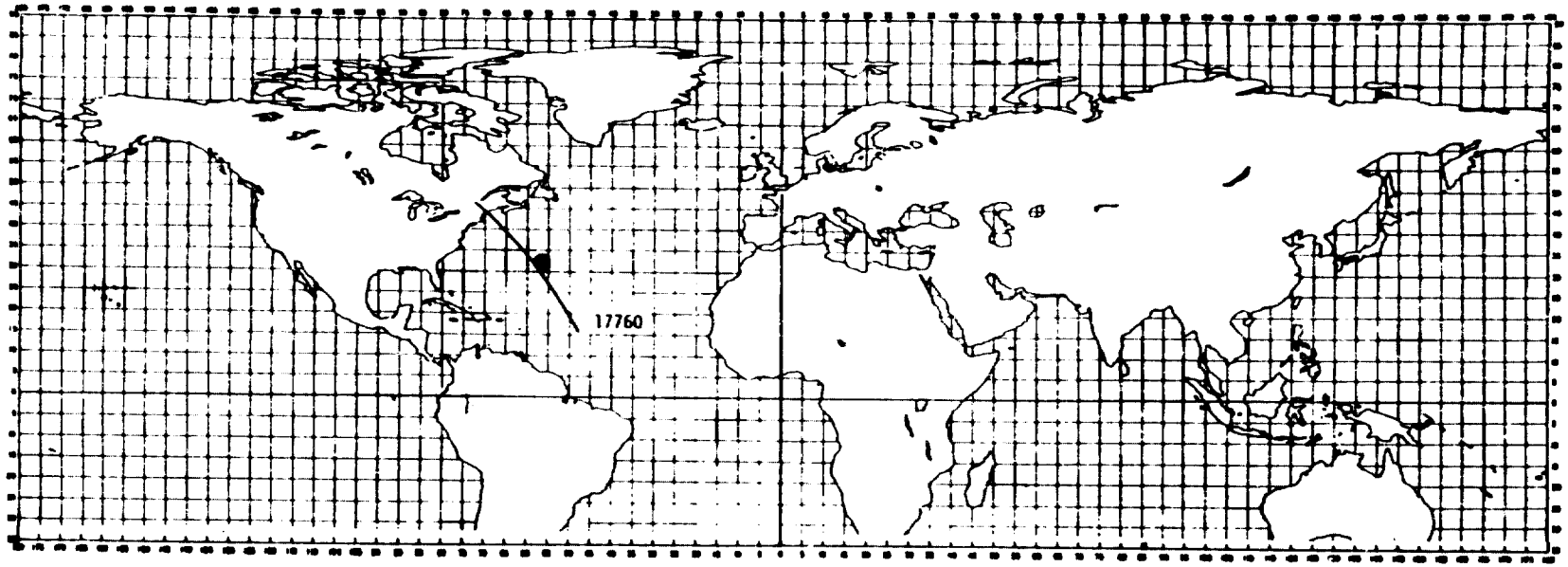


LOCATION

TIME	LATITUDE	LONGITUDE
1500Z	31.7N	62.2W
1800Z	31.0	60.2

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17746	315.05	071432	072500	071853	072820	802	141

TROPICAL STORM HOPE - 9/16/78

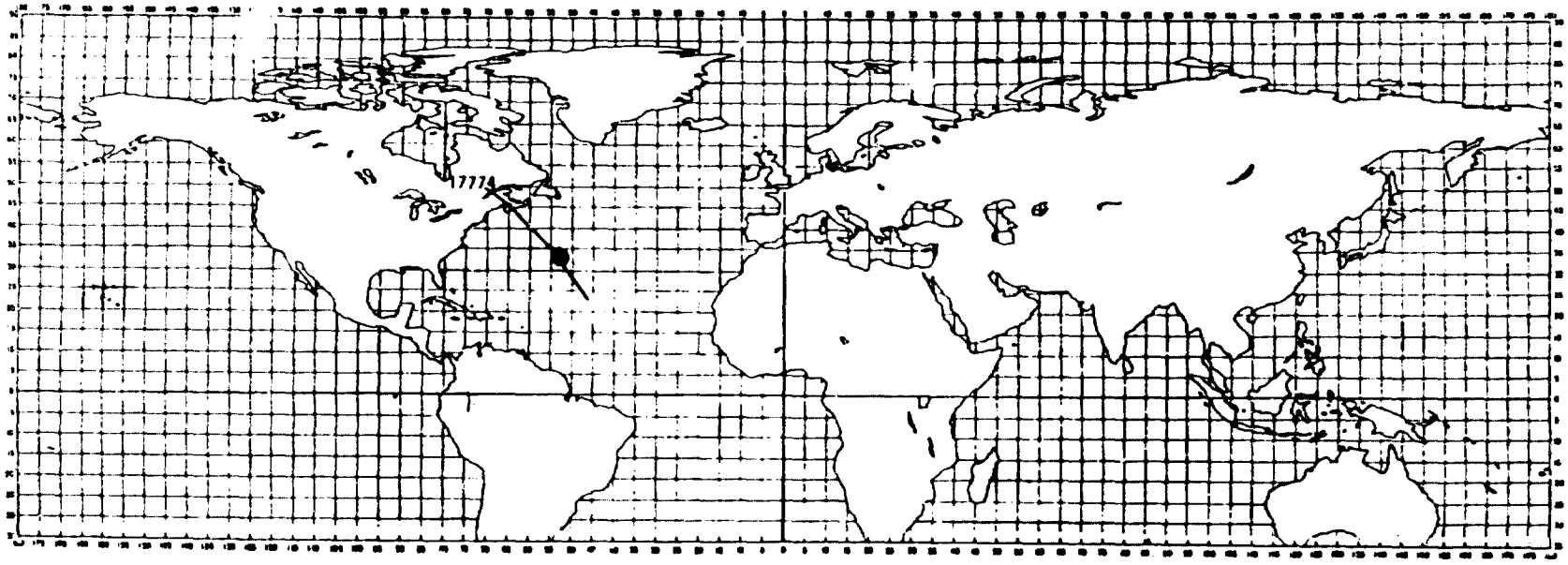


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	31.2N	58.1W
1800Z	32.4	56.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
17760	320.55	065925	070900	070519	071400	802	151

TROPICAL STORM HOPE - 9/17/78



LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	33.0N	54.8W
1200Z	33.8	53.4
1800Z	35.0	51.8

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UMIQ
17774	326.05	064418	065400	065203	070000	802	161

3.11 TROPICAL STORM JULIET
October 7-11, 1978

A weak tropical wave moved off of the African coast on September 30. It traveled west-northwestward, reaching a position 600 n mi east of the Leeward Islands on October 6. By 1800 GMT on the 7th, the system was classified as a tropical depression.

On the 9th, the depression reached tropical storm strength. The storm passed 150 n mi north of San Juan on October 9th and was located 300 n mi southwest of Bermuda at 1200 GMT on the 11th, before becoming absorbed by a developing extratropical low-pressure system.

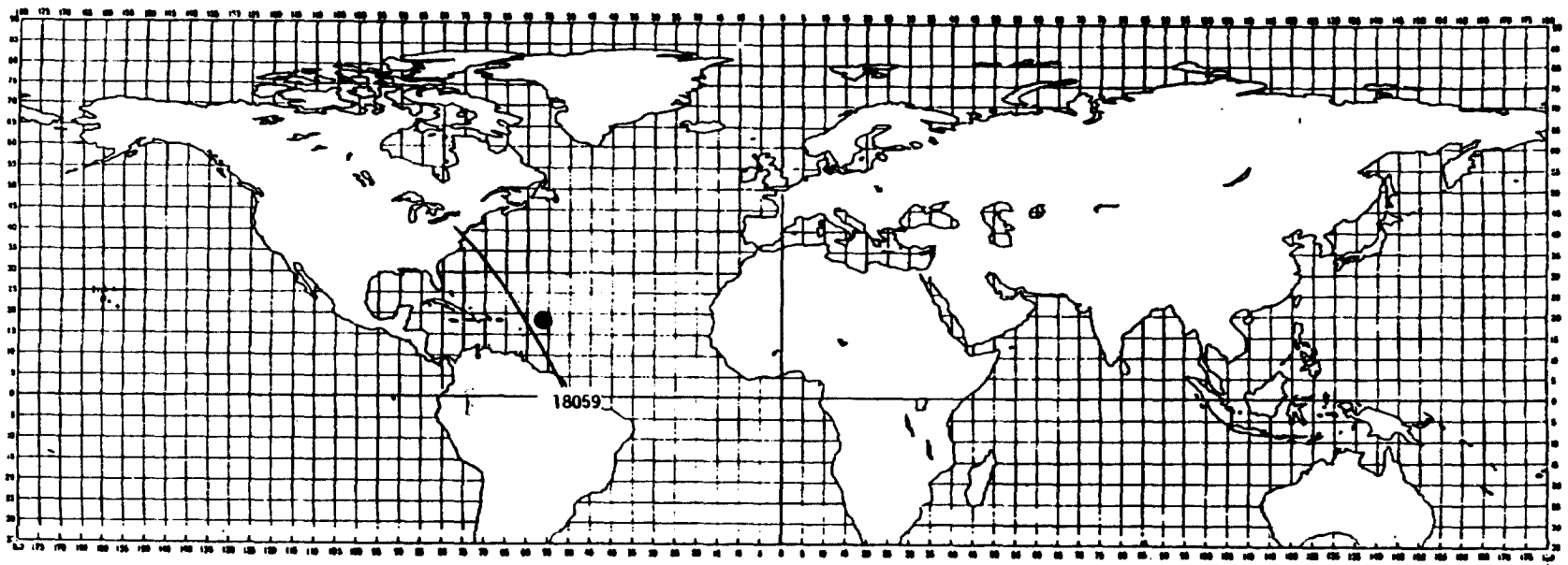
No death or damage reports were received in connection with Juliet.

STORM: TROPICAL STORM JULIET

DATE: October 7-11, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
10/7	1800Z	18.2N	56.5W			Tropical Depression
10/8	1200Z	18.8N	58.7W			Tropical Storm
	1800Z	19.0	59.8			
10/9	0000Z	19.3N	60.9W			Tropical Storm
	0600Z	19.7	62.0			
	1200Z	19.9	63.0			
	1800Z	20.3	64.2			
10/10	0000Z	20.9N	65.4W			Tropical Storm
	0600Z	21.7	67.0			
	1200Z	22.8	68.8			
	1800Z	24.3	70.1			
10/11	0000Z	26.2N	70.9W			Tropical Storm
	0600Z	28.3	71.0			
	1200Z	30.2	69.9			

TROPICAL STORM JULIET - 10/7/78

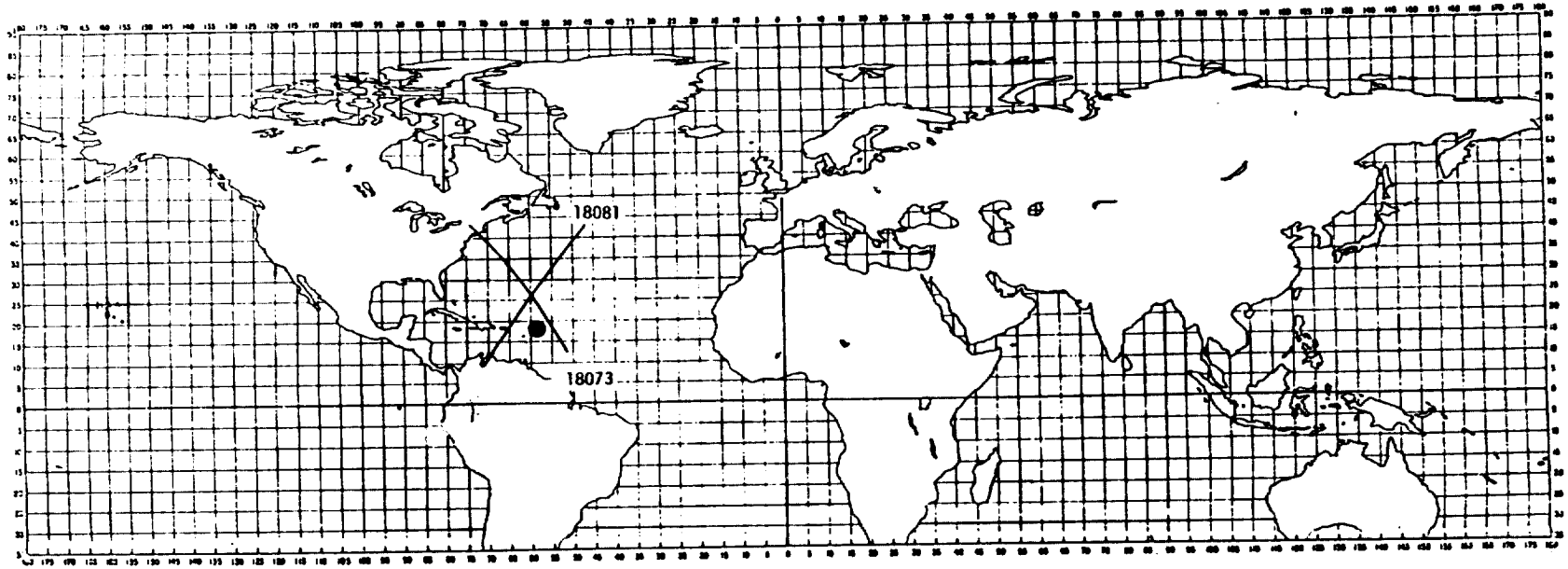


LOCATION

TIME	LATITUDE	LONGITUDE
1800Z	18.2N	56.5W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18059	309.45	101056	101600	101255	102334	803	176

TROPICAL STORM JULIET - 10/8/78

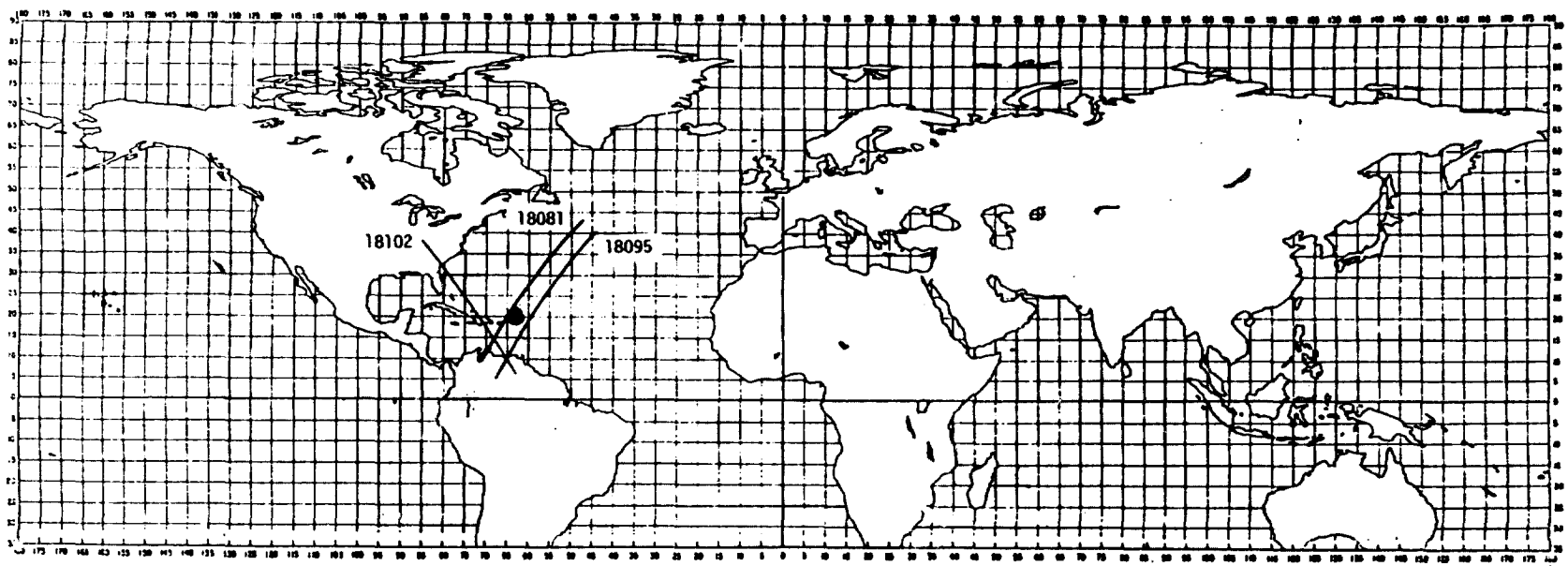


LOCATION

TIME	LATITUDE	LONGITUDE
1200Z	18.8N	58.7W
1800Z	19.0	59.8
2400Z	20.9	65.4

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18073	314.95	095550	100200	100047	100925	803	188
18081	112.38	233003	001400	000720	001720	803	101

TROPICAL STORM JULIET - 10/9/78

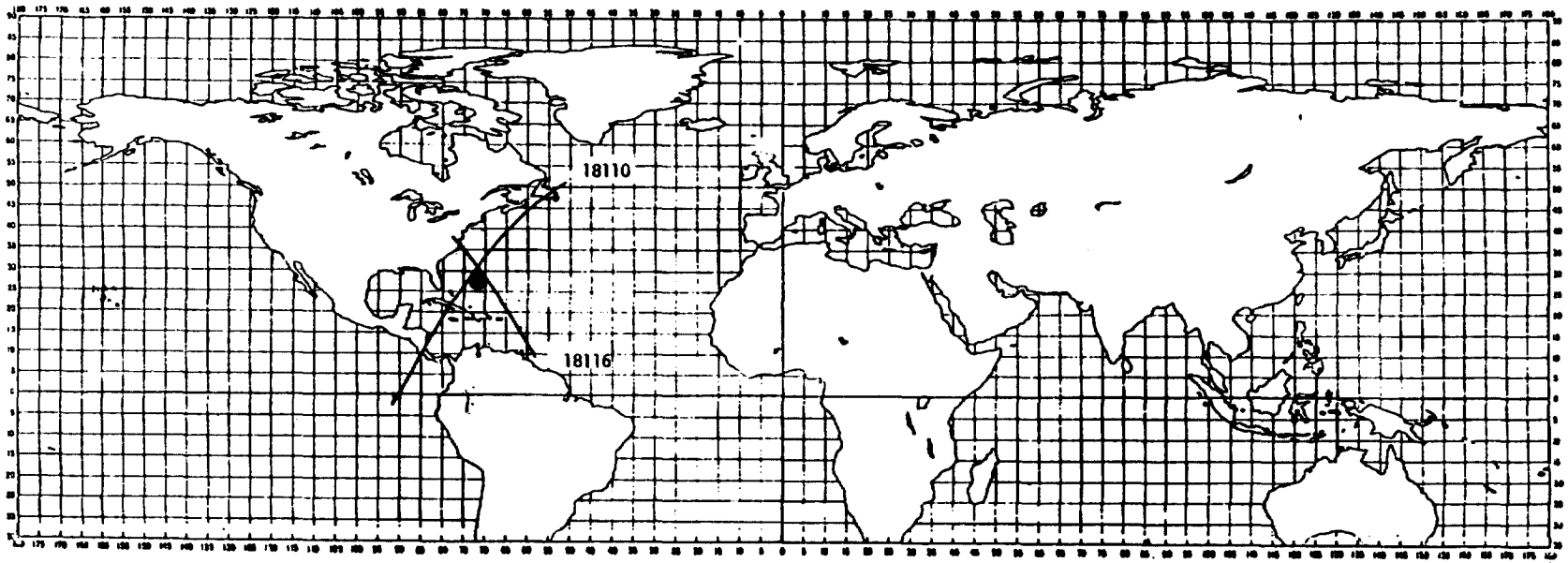


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	19.3N	60.9W
0600Z	19.7	62.0
1200Z	19.9	63.0
1800Z	20.3	64.2
2400Z	20.9	65.4

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18081	112.38	233003	001400	000720	001720	803	101
18095	117.88	231456	000000	235337	000306	803	115
18102	300.63	110722	111400	111103	111829	803	122

TROPICAL STORM JULIET - 10/11/78



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	26.2N	70.9
0600Z	28.3	71.0
1200Z	30.2	69.9

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18110	98.03	004135	002300	011626	013200	803	129
18116	306.13	105215	110100	105714	110400	803	136

3.12

HURRICANE KENDRA

October 28 - November 3, 1978

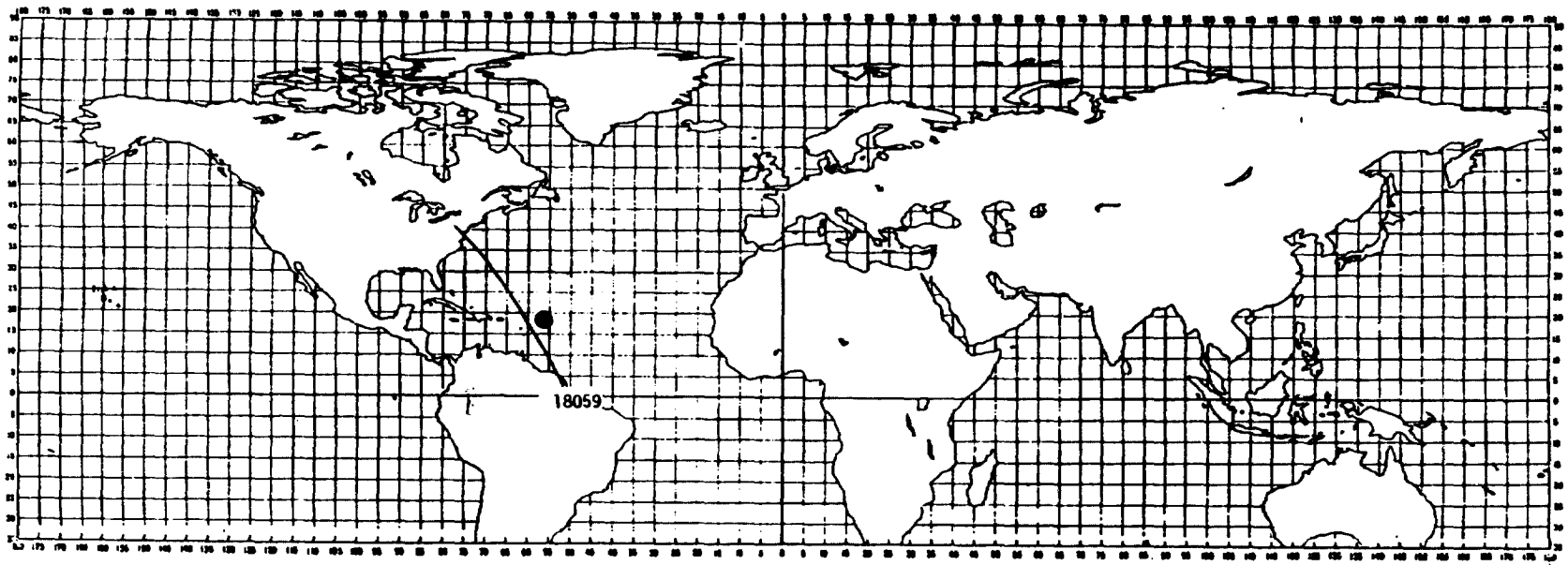
A depression developed just east of the Bahamas on the afternoon of October 28th.

Kendra was named as a tropical storm at 0000 GMT on the 29th. Hurricane status was reached on the afternoon of the 29th, when a reconnaissance plane estimated 70 kt surface winds.

There was little change in strength during the next day as the hurricane moved north-northeastward. Weakening ensued and by October 31, Kendra was downgraded to a tropical storm. The system was finally absorbed by another extratropical low over the northeast Atlantic.

This storm was responsible for one death and $6 million in damages.

TROPICAL STORM JULIET - 10/7/78

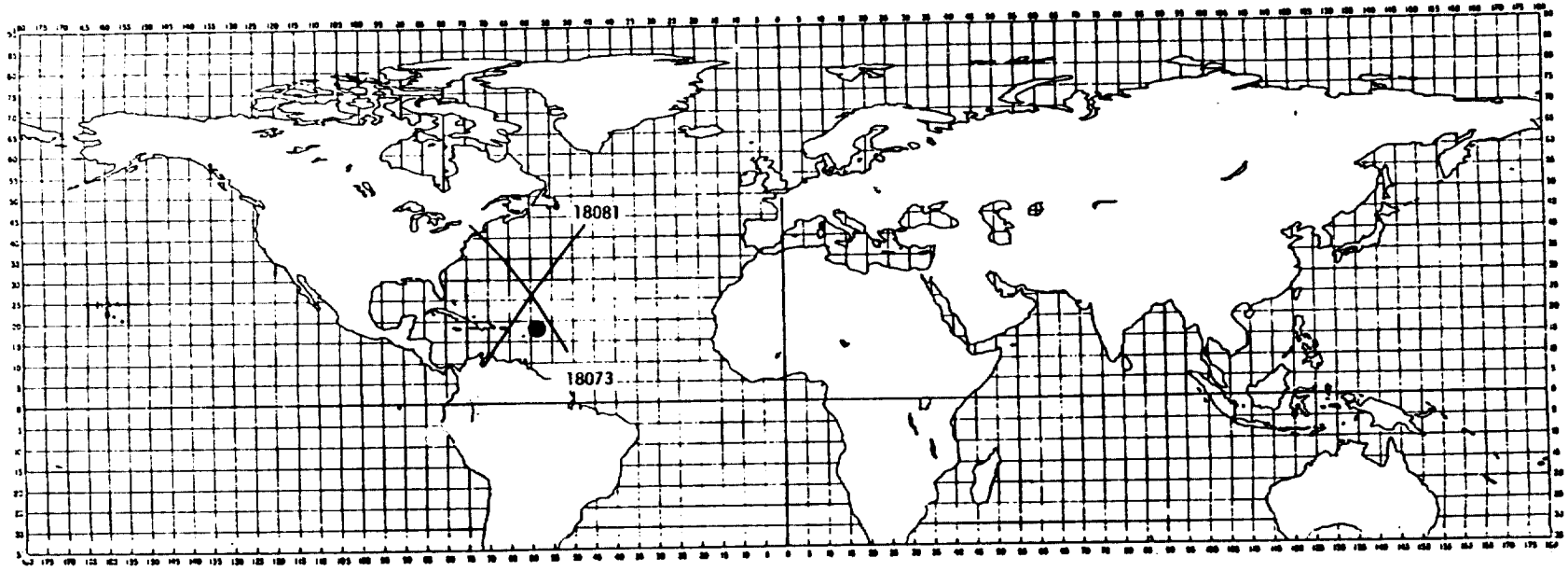


LOCATION

TIME	LATITUDE	LONGITUDE
1800Z	18.2N	56.5W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18059	309.45	101056	101600	101255	102334	803	176

TROPICAL STORM JULIET - 10/8/78

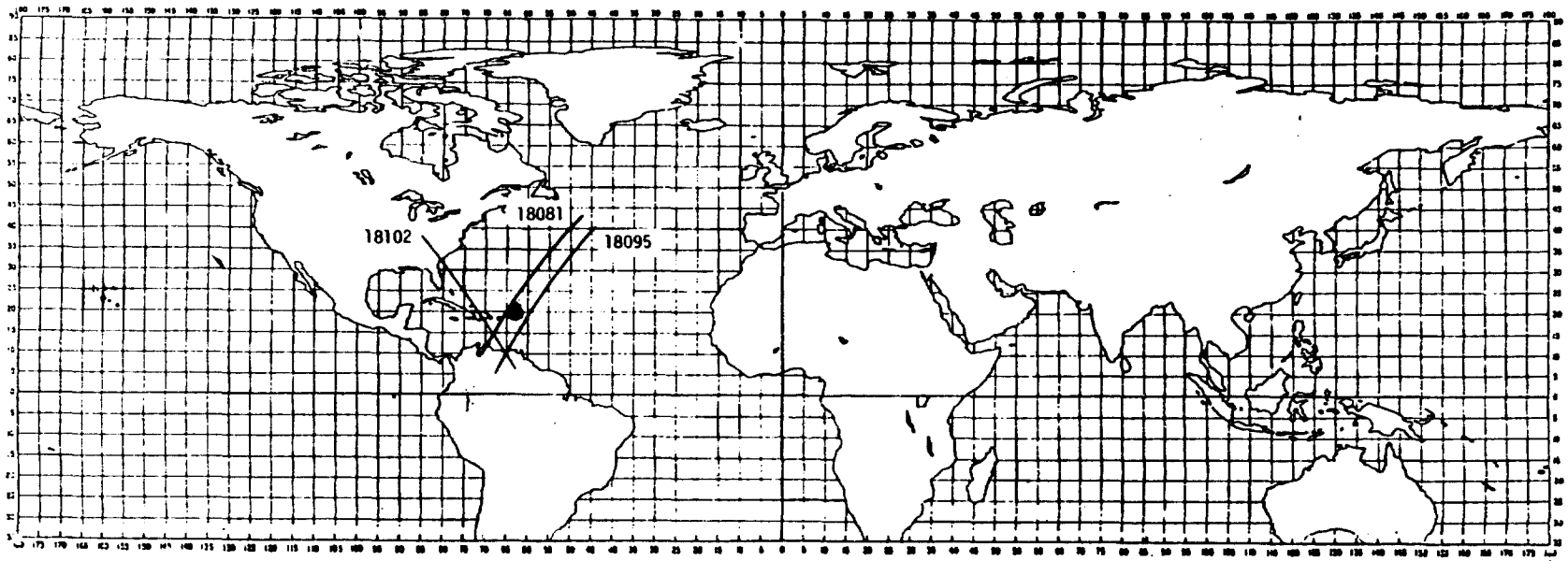


LOCATION

TIME	LATITUDE	LONGITUDE
1200Z	18.8N	58.7W
1800Z	19.0	59.8
2400Z	20.9	65.4

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18073	314.95	095550	100200	100047	100925	803	188
18081	112.38	233003	001400	000720	001720	803	101

TROPICAL STORM JULIET - 10/9/78

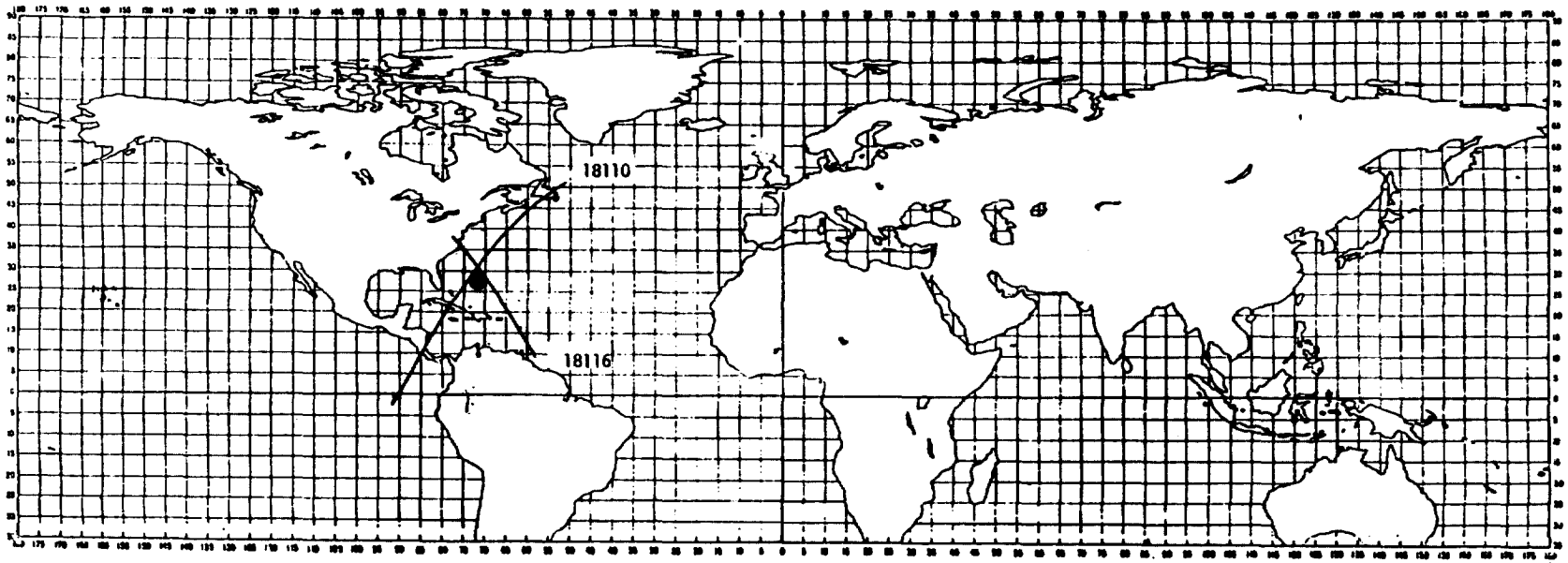


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	19.3N	60.9W
0600Z	19.7	62.0
1200Z	19.9	63.0
1800Z	20.3	64.2
2400Z	20.9	65.4

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18081	112.38	233003	001400	000720	001720	803	101
18095	117.88	231456	000000	235337	000306	803	115
18102	300.63	110722	111400	111103	111829	803	122

TROPICAL STORM JULIET - 10/11/78



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	26.2N	70.9
0600Z	28.3	71.0
1200Z	30.2	69.9

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18110	98.03	004135	002300	011626	013200	803	129
18116	306.13	105215	110100	105714	110400	803	136

3.12

HURRICANE KENDRA

October 28 - November 3, 1978

A depression developed just east of the Bahamas on the afternoon of October 28th.

Kendra was named as a tropical storm at 0000 GMT on the 29th. Hurricane status was reached on the afternoon of the 29th, when a reconnaissance plane estimated 70 kt surface winds.

There was little change in strength during the next day as the hurricane moved north-northeastward. Weakening ensued and by October 31, Kendra was downgraded to a tropical storm. The system was finally absorbed by another extratropical low over the northeast Atlantic.

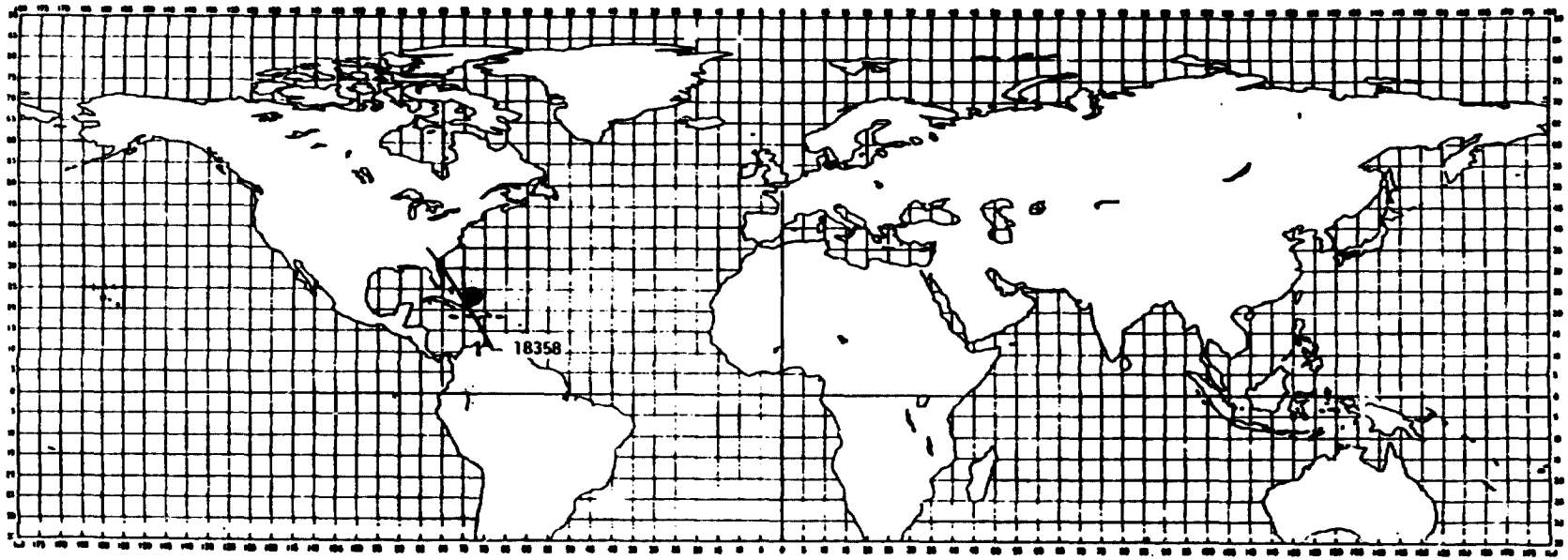
This storm was responsible for one death and $6 million in damages.

STORM: HURRICANE KENDRA

DATE: October 28 - November 3, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
10/28	1800Z	24.2N	73.0W			Tropical Storm
10/29	0600Z	25.4N	73.9			Hurricane
	1800Z	26.2	74.1			
10/30	0000Z	27.3N	73.7W			Hurricane
	0600Z	28.1	73.5			
	1200Z	28.9	72.6			
	1800Z	29.3	72.3			
10/31	0000Z	30.0N	72.0W			Tropical Storm
	0600Z	30.5	72.1			
	1200Z	31.1	71.9			
	1800Z	31.7	71.7			
11/1	0000Z	32.6N	70.5W			Tropical Storm
	0600Z	35.1	65.4			
	1800Z	40.6	55.5			
11/2	0600Z	43.5N	44.0W			Tropical Depression
	1800Z	46.0	35.0			
11/3	0600Z	50.0N	27.0W			Tropical Depression

HURRICANE KENDRA - 10/28/78

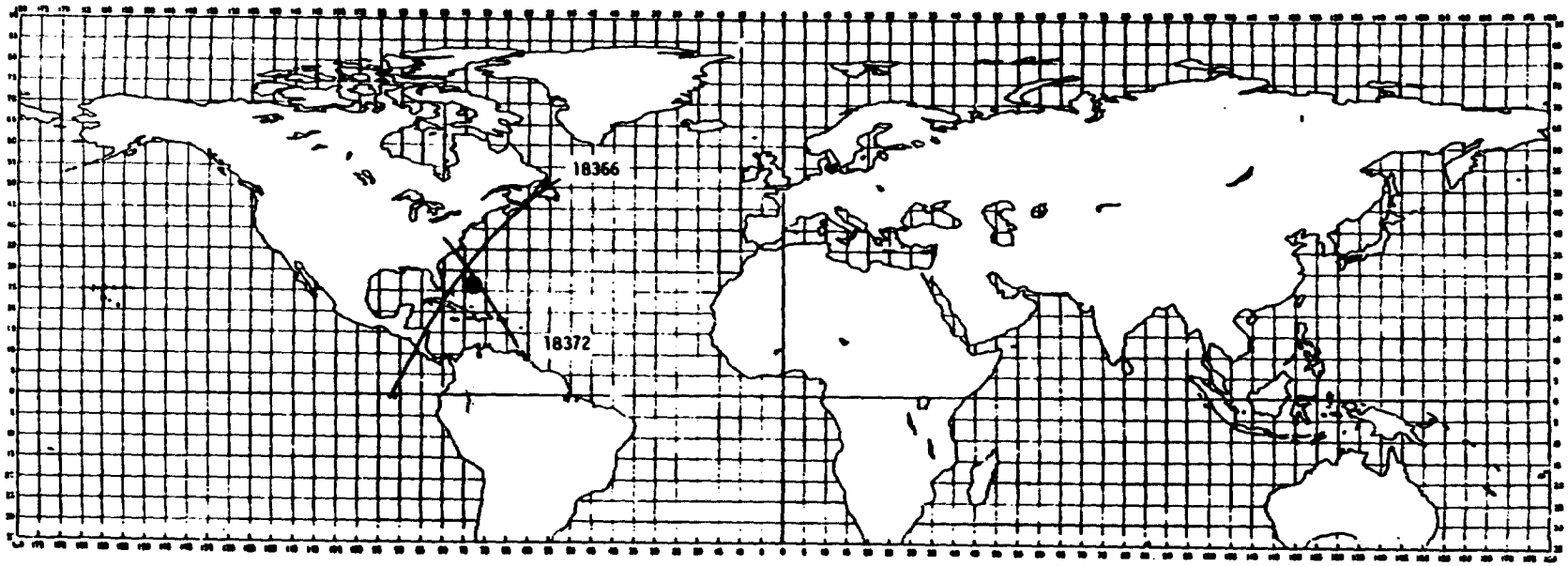


LOCATION

TIME	LATITUDE	LONGITUDE
1800Z	24.2N	73.0W

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18358	298.38	132219	132900	132634	133302	803	175

HURRICANE KENDRA - 10/29/78

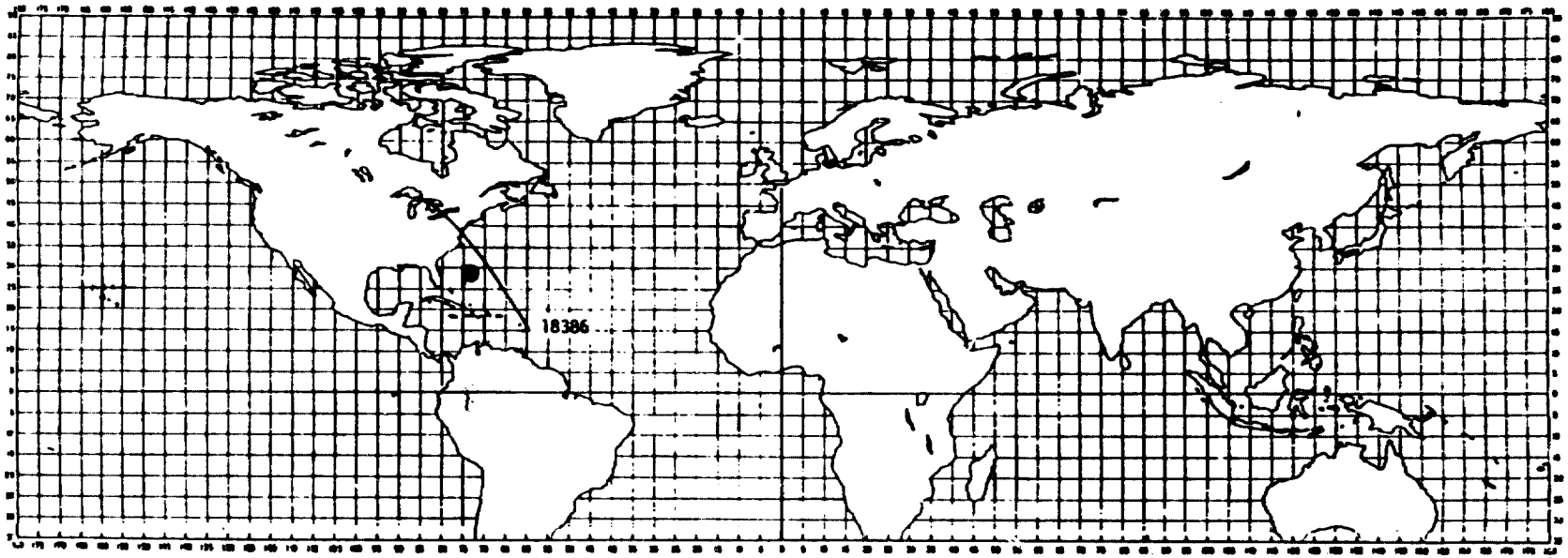


LOCATION

TIME	LATITUDE	LONGITUDE
0600Z	25.4N	73.9W
1800Z	26.2	74.1

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18366	95.81	025632	033830	033102	034700	803	181
18372	303.88	130711	131600	131145	131844	803	188

HURRICANE KENDRA - 10/30/78

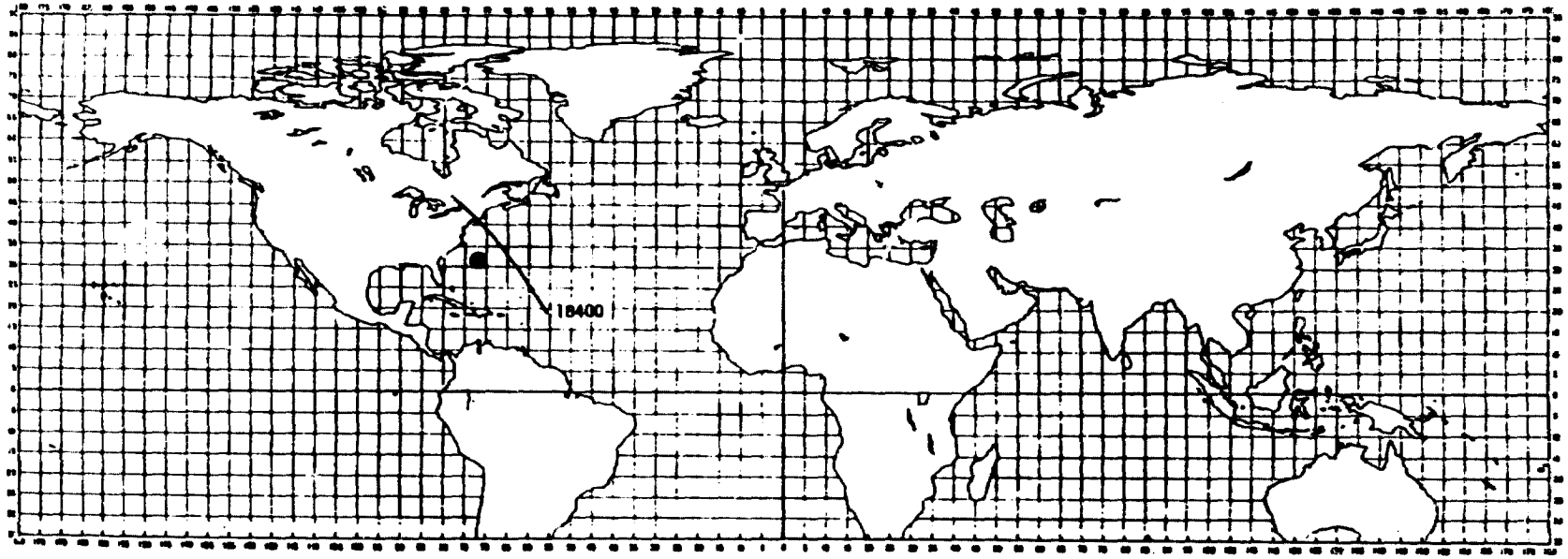


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	27.3N	73.7W
0600Z	28.1	73.5
1200Z	28.9	72.6
1800Z	29.3	72.3

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18386	309.39	125204	130200	125747	130748	803	10s

HURRICANE KENDRA - 10/31/78

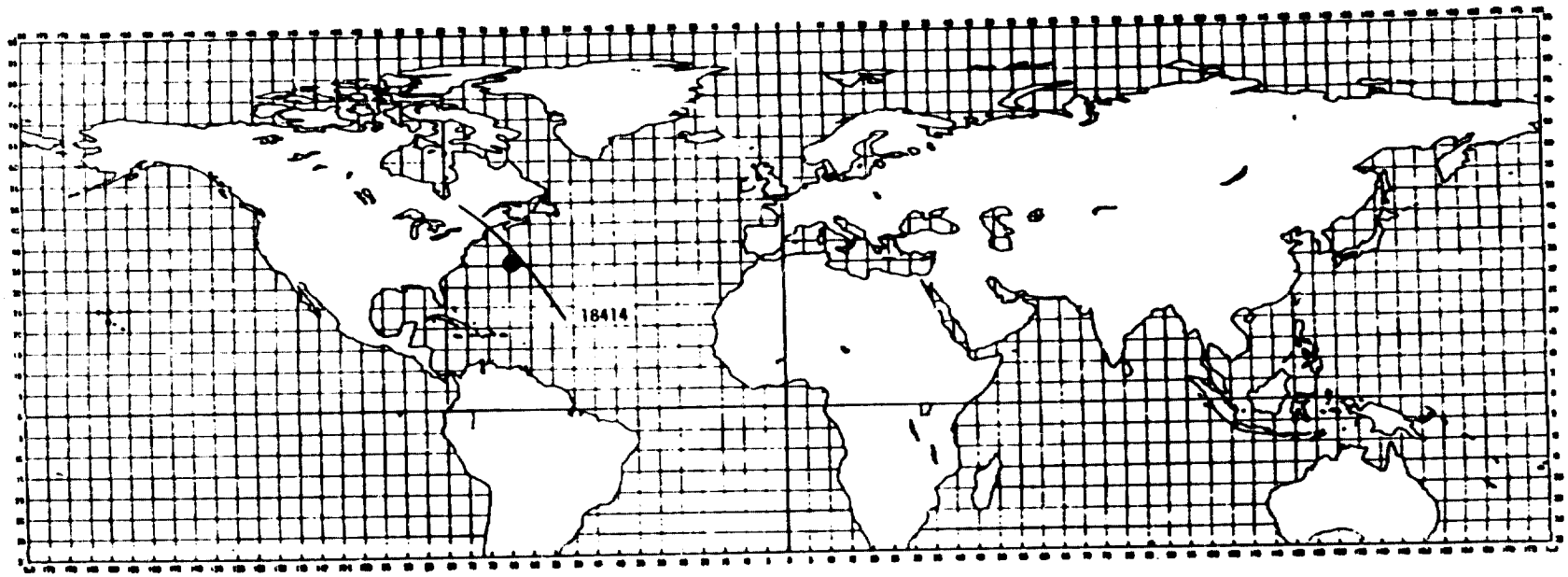


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	30.0N	72.0
0600Z	30.5	72.1
1200Z	31.1	71.9
1800Z	31.7	71.7

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ
18400	314.89	123657	124800	124350	125058	803	121

HURRICANE KENDRA - 11/1/78



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	32.5N	70.5W
0600Z	35.1	65.4
1800Z	40.6	55.5

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIT
18414	320.39	122149	123300	123006	123600	803	134

4.0 EASTERN PACIFIC/U. S. WEST COAST AREAS - 1977

Tropical cyclone activity in the eastern Pacific began on May 25 and ended on October 23, 1977. This tropical cyclone season was exceptional in that one of the hurricanes (Doreen) became the second such storm within a year to bring heavy rains to Southern California. The previous hurricane (Kathleen, 1976) was the first tropical cyclone to hit southern California since 1939.

4.1 General

All of the data presented in this section on the tropical cyclones occurring in the eastern Pacific were extracted from the Monthly Weather Review articles by E. B. Gunther. During the 1977 season there were 17 cyclones that occurred in this area as listed below.

*Tropical Storm Ava	(5/25/77 - 5/30/77)
Tropical Cyclone Two	(5/30/77 - 6/01/77)
*Tropical Cyclone Three	(6/09/77 - 6/11/77)
Tropical Storm Bernice	(6/25/77 - 6/28/77)
Hurricane Claudia	(7/03/77 - 7/07/77)
Tropical Cyclone Six	(7/08/77 - 7/09/77)
Tropical Cyclone Seven	(7/09/77 - 7/10/77)
*Tropical Cyclone Eight	(7/25/77 - 7/25/77)
*Tropical Cyclone Nine	(8/09/77 - 8/02/77)
*Hurricane Doreen	(8/13/77 - 8/18/77)
Tropical Cyclone Eleven	(9/03/77 - 9/04/77)
Tropical Storm Emily	(9/13/77 - 9/14/77)
Tropical Cyclone Thirteen	(9/19/77 - 9/23/77)
Hurricane Florence	(9/20/77 - 9/24/77)
Tropical Storm Glenda	(9/23/77 - 9/27/77)
Hurricane Heather	(10/04/77-10/23/77)
Tropical Cyclone Seventeen	(10/22/77-10/23/77)

Results of the comparisons of the cyclone information and the GEOS-3 schedule information indicates that 5 cyclones may have associated GEOS-3 altimeter data. These cyclones are noted by an * in the above tabulation.

Information on these cyclones along with any promising GEOS-3 ground tracks are presented in the following sections.

Figures 4.1 and 4.2 show the ground tracks for all of the tropical cyclones for this region for 1977.

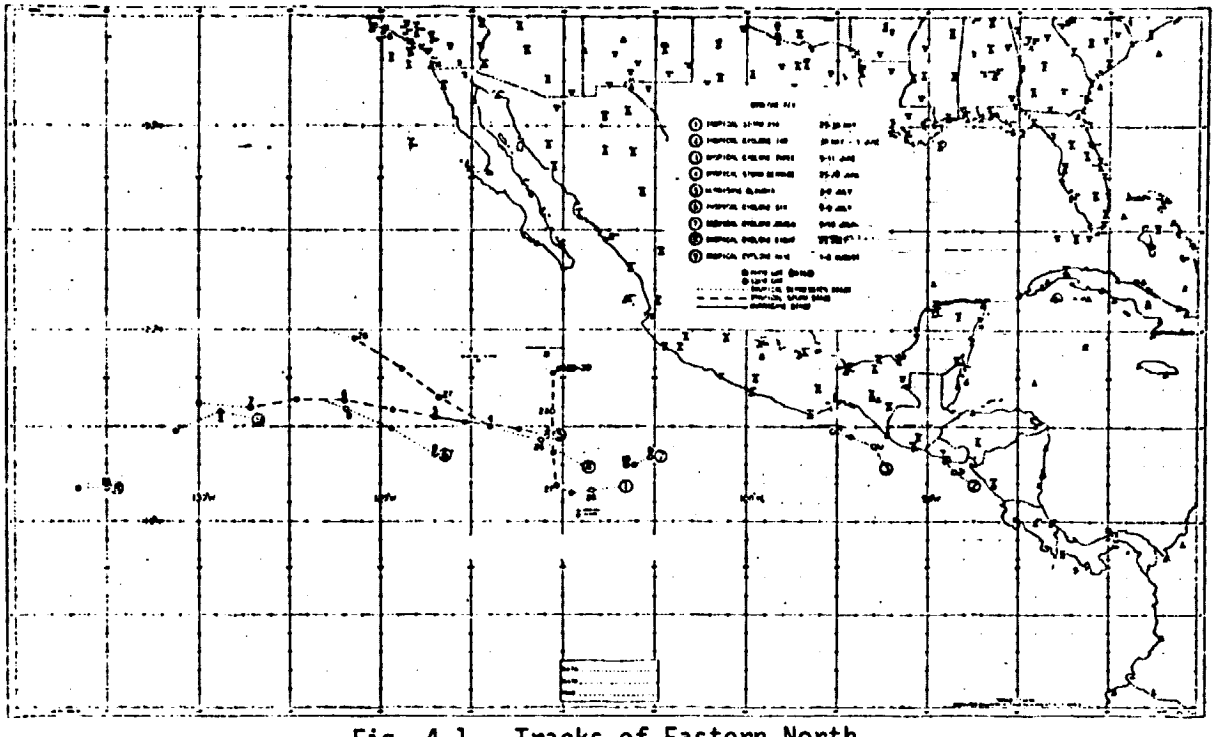


Fig. 4.1 Tracks of Eastern North Pacific Tropical Cyclones 1-9, 1977

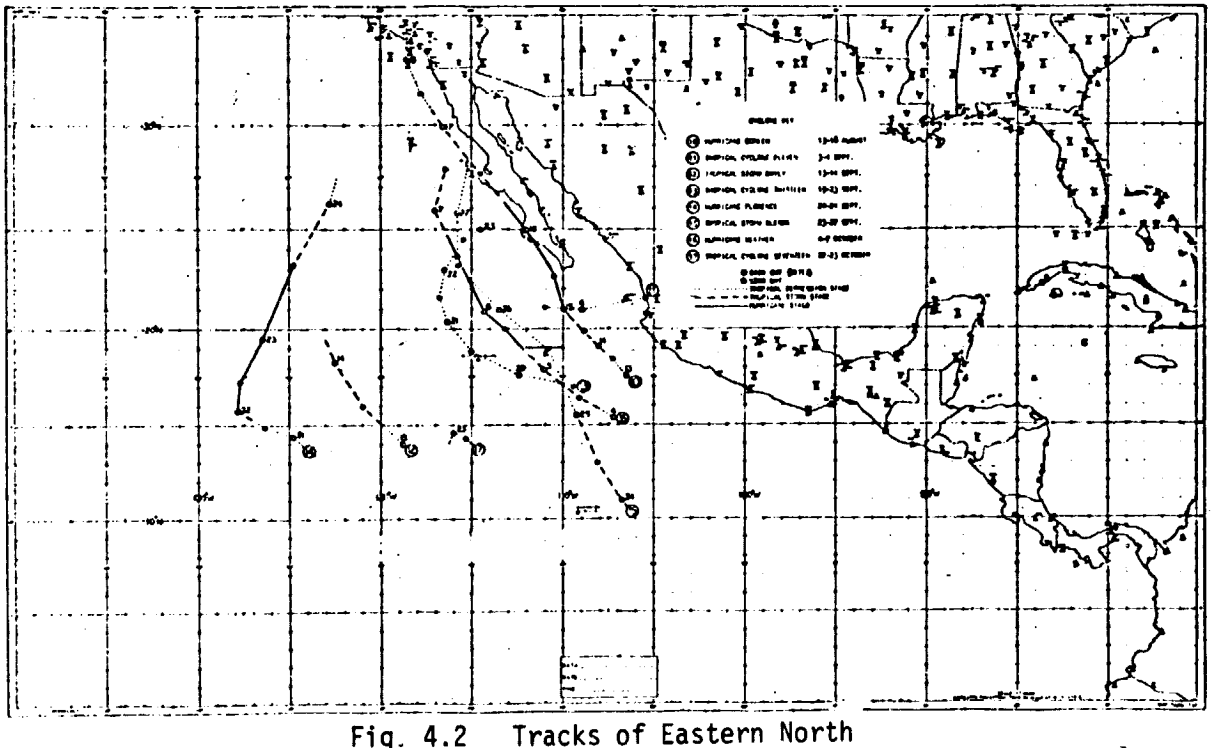


Fig. 4.2 Tracks of Eastern North Pacific Tropical Cyclones 10-17, 1977

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4.2

TROPICAL STORM AVA
May 25-30, 1977

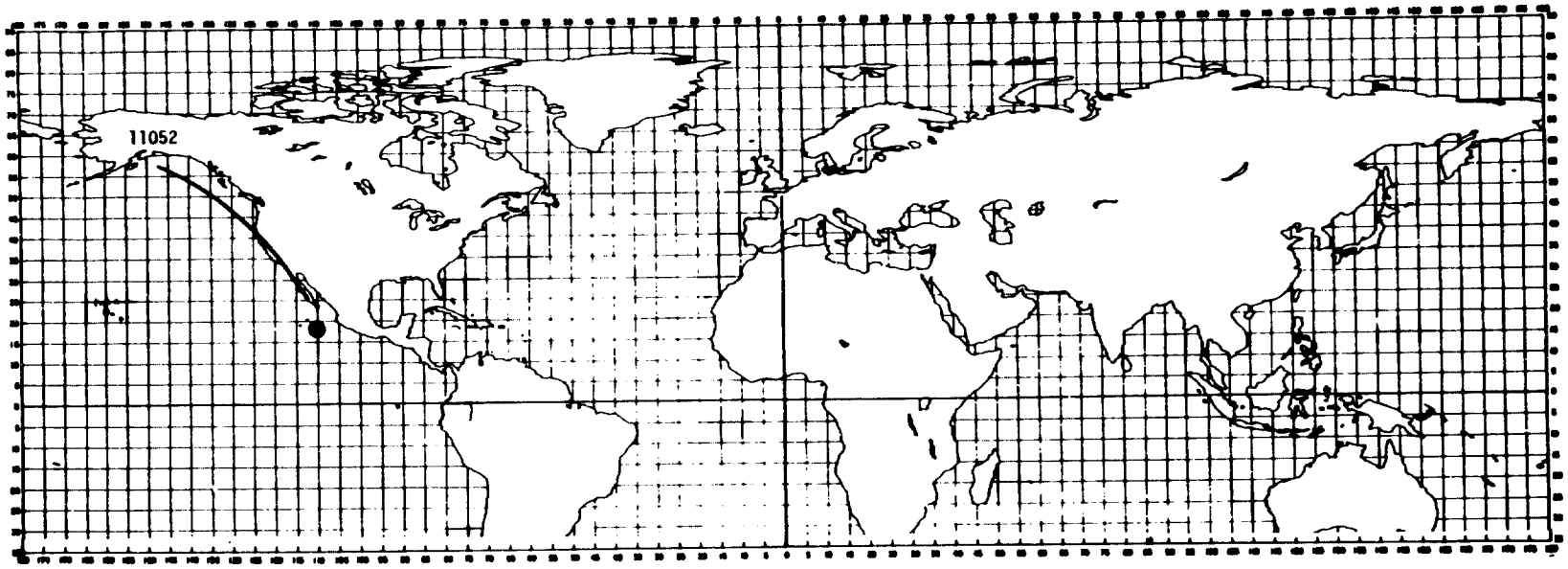
The first tropical cyclone of the 1977 season began as a tropical disturbance at 0600 GMT May 24 500 n mi south-southwest of Acapulco, Mexico. Centered near 9.5 N, 103.5 W, the disturbance was embedded in a broad band of convective activity extending westward from Panama and Costa Rica. Moving northwest at 8 kt the disturbance began to slowly intensify. By 1500 GMT May 25 satellite imagery showed circulation about the center and the disturbance was upgraded to a tropical depression near 11.8 N, 107.0 W or 500 n mi southwest of Acapulco. Turning westward, the depression continued to intensify. By 1200 GMT May 26 wind had increased to 40 kt near the center and the depression was upgraded to Tropical Storm Ava near 11.5 N, 109.6 W. At 1800 GMT the tanker CHEVRON AMSTERDAM passed through the center of Ava reporting light variable winds, an air temperature of 77 F and a sea surface temperature of 82 F. The storm then turned sharply to the north under the influence of an upper level trough moving across Baja California and northern Mexico. Continuing to intensify over the relatively warm water, Ava reached its maximum intensity of 55 kt at 1200 GMT May 29 near 17.8 N, 110.7 W or 60 n mi south-southeast of Socorro Island. At 2337 GMT May 28 Air Force reconnaissance located the center of Ava with a poorly defined eye at 17.8 N, 109.9 W. No longer under the influence of the upper level trough moving across northern Mexico, Ava slowed to a near stationary position at 18.0 N, 110.0 W. A second reconnaissance flight through the storm at 1735 GMT May 29 located the center near 18.2 N, 110.0 W. The eye, better defined, was open to the south. Surface winds 40 n mi from the center were estimated near 30 kt. Winds on Socorro Island, 60 n mi to the northwest, were northerly at 35 kt. The cargo ship THOMPSON LYKES, 80 n mi east-southeast of Ava, reported southwesterly 15 kt winds. Ava was downgraded to a tropical depression at 1800 GMT May 29 with the center still near 18.0 N, 110.0 W. Flow aloft at 200 mb had weakened and become more westerly. The deep-layer circulation between 1000-100 mb had also weakened and shifted from southwest to northwest. Lacking upper level support and with sea surface temperatures cooling to 75 F, the depression began to slowly dissipate. The cyclone was downgraded to a tropical disturbance after 1200 GMT May 30 with the center near 18.0 N, 110.2 W.

STORM: TROPICAL STORM AVA

DATE: May 25-30, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
5/25	1500Z	11.8N	107.0W			Tropical Depression
5/26	0000Z	11.8N	108.5W			Tropical Storm
	1200Z	11.5	109.6			
5/27	0000Z	11.9N	110.3			Tropical Storm
	1200Z	13.7	110.5			
5/28	0000Z	15.8N	110.7W			Tropical Storm
	1200Z	17.8	110.7		55	
	1800Z	17.9	110.3			
5/29	0000Z	17.9	110.2			Tropical Depression
	1200Z	17.9	110.1			
	1800Z	18.0	110.0			
5/30	0000Z	18.0N	110.1W			Tropical Depression
	1200Z	18.0	110.2			

TROPICAL STORM AVA - May 30, 1977



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	18.0N	110.1W
1200Z	18.0	110.2

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
11052	261.74	035455	040200	040256	041341	808	101

4.3 TROPICAL CYCLONE THREE

June 9-11, 1977

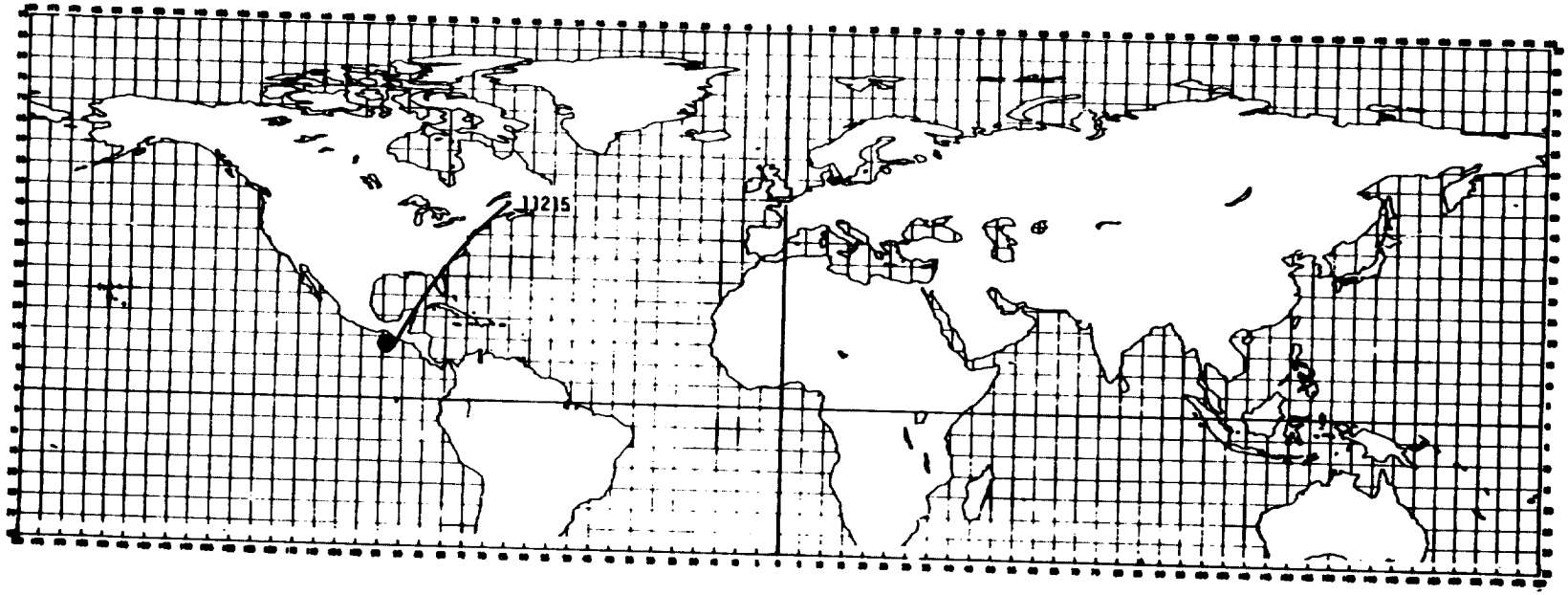
A tropical disturbance 80 n mi off the Guatemalan coast at 0000 GMT June 8 became the third tropical cyclone of the 1977 season. Drifting slowly west-northwest, the disturbance was upgraded to a tropical depression at 1800 GMT June 9 near 13.2 N, 92.5 W. The ships SAMUEL CHASE, TEXACO GEORGIA, MAERSK COMMANDER and TASMANIC were helpful in locating the center of the depression. Moving northwest at 9 kt, the depression began to drift across the Gulf of Tehuantepec on the extreme southern Mexican coast. By 0000 GMT June 10 the depression had moved to 14.0 N, 93.0 W. It then turned west-northwest and moving at 6 kt began to slowly dissipate. At 1800 GMT the SANTA MARIA, 70 n mi west-northwest of the depression, reported that it was under the influence of the depression with east-northeasterly 10 kt winds and sea surface temperature of 88 F. In spite of the warm water, satellite imagery at 0000 GMT June 11 showed the cyclone to be dissipating rapidly near 14.8 N, 95.2 W or about 80 n mi south of Salina Cruz on the southern Mexican coast.

STORM: TROPICAL CYCLONE THREE

DATE: June 9-11, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
6/9	1800Z	13.2N	92.5W			Tropical Depression
6/10	0000Z	14.0N	93.0W		30	Tropical Depression
	0600Z	14.5	93.7			
	1200Z	14.5	94.3			
6/11	0000Z	14.8N	95.2W			Tropical Depression

TROPICAL CYCLONE THREE - 6/10/77



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	14.0N	93.0W
0600Z	14.5	93.7
1200Z	14.5	94.3

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	RUNTO.#
11215	94.14	162528	171200	170021	171221	808	152

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4.4 TROPICAL CYCLONE EIGHT
July 25, 1977

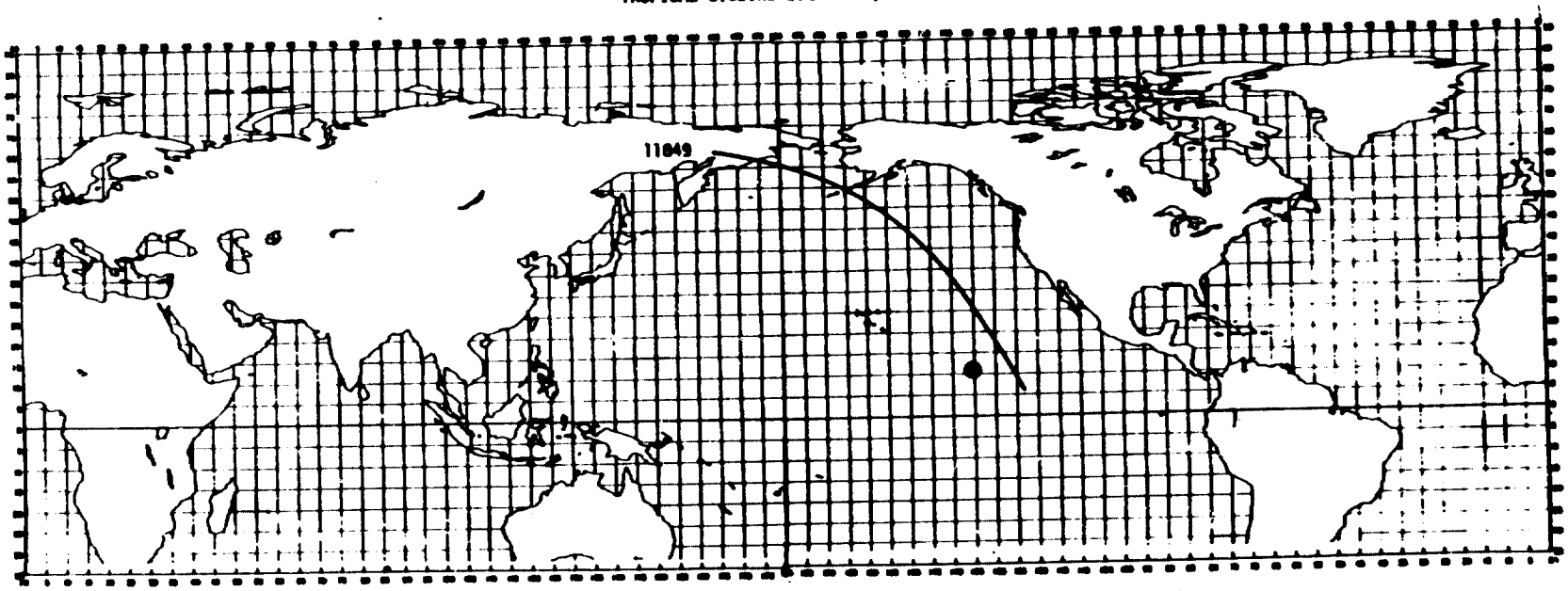
The eighth cyclone of the season began as a disturbance near 11.7 N, 128.5 W at 1800 GMT July 23. Moving west at 12-14 kt, the disturbance began to intensify over 80 F water. By 0000 GMT July 25 satellite movie loops showed cyclonic circulation about the center and the disturbance was upgraded to a tropical depression near 11.8 N, 135.0 W. The depression continued to move west, but slowed to 7 kt and began to weaken. By 1200 GMT the center had dissipated into an area of disorganized convective activity near 11.8 N, 136.5 W.

STORM: TROPICAL CYCLONE EIGHT

DATE: July 25, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
7/25	0000Z	11.8N	135.0W		25	Tropical Depression
	1200Z	11.8	136.5		25	

TROPICAL CYCLONE EIGHT - 7/25/77



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	11.0N	135.0W
1200Z	11.8	136.5

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	ANTQ.#
11849	239.62	115525	120000	115805	121730	808	106

4.5 TROPICAL CYCLONE NINE
August 1-2, 1977

Tropical cyclone nine was another short-lived depression lasting only 20 h. The cyclone began as a disturbance near 10.5 N, 118.0 W at 1200 GMT July 30. Moving northwest at 12 kt, the disturbance began to slowly intensify over 80 F water. By 1800 GMT July 31 the center was near 14.5 N, 122.5 W. It then turned to the west and by 1600 GMT August 1 was upgraded to a tropical depression near 15.4 N, 127.1 W. By 0600 GMT August 2 the center was near 15.8 N, 130.1 W. It then turned southwest and, moving at 15 kt over 78 F water, began to weaken. The final advisory on the depression was issued at 1200 GMT August 2 with the center near 14.8 N, 131.2 W.

STORM: TROPICAL CYCLONE NINE

DATE: August 1-2, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
8/1	1600Z	15.4N	127.1W			Tropical Depression
8/2	0000Z	15.8N	128.9W		30	Tropical Depression
	0600Z	15.8	130.1			
	1200Z	14.8	131.2			

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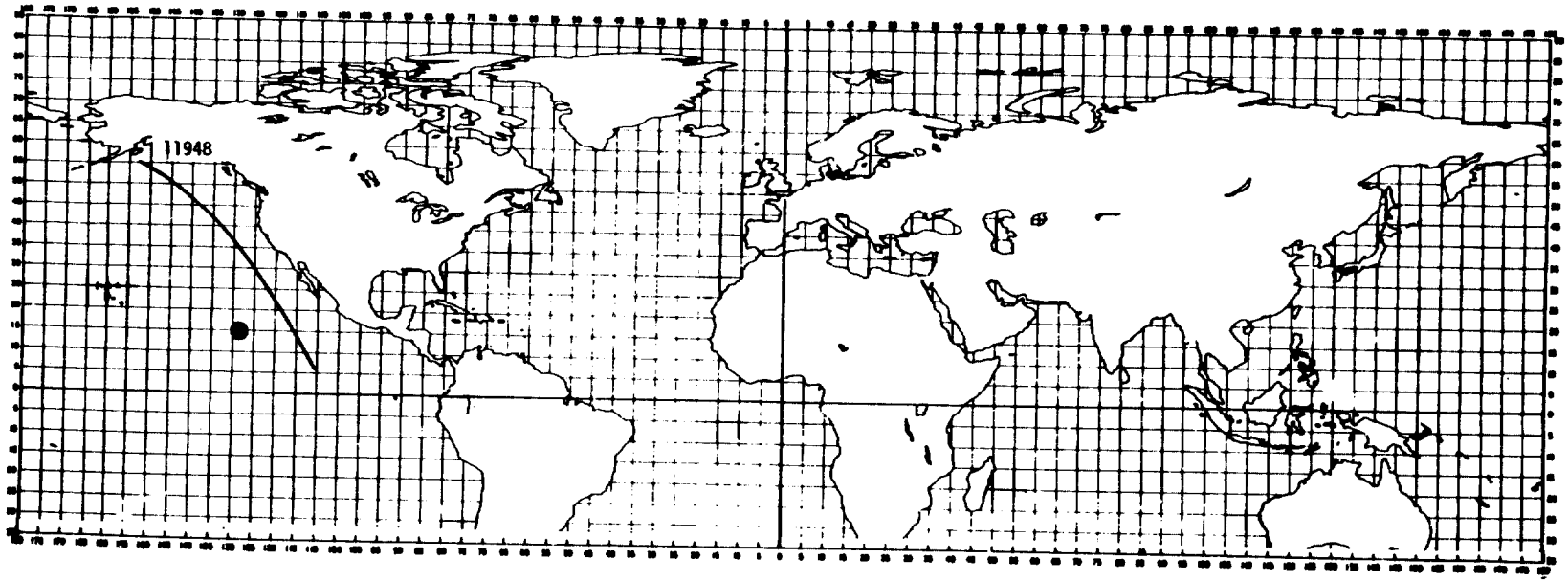
TROPICAL CYCLONE NINE - 8/1/77



LOCATION

TIME	LATITUDE	LONGITUDE
1600Z	15.4N	127.1W
2400Z	15.8	128.9

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
11948	252.75	115136	120000	115354	120901	808	109

4.6

HURRICANE DOREEN
August 13-18, 1977

Doreen began as a tropical disturbance 100 n mi west of Acapulco, Mexico, at 0000 GMT August 11. Ship reports along the Mexican coast helped to locate the disturbance. Reports from the ARGO LEADER, MALMROS MONSOON, ROLLNES, MEADOWBANK, PRAG and LYNTON GRANGE were especially helpful. Drifting west at 6 kt, the disturbance was upgraded to a tropical depression at 0000 GMT August 13 with the center near 17.6 N, 106.5 W or 400 n mi west of Acapulco. The cyclone then turned northwest and began to slowly intensify over 82 F water. By 1800 GMT winds had increased to 45 kt and the depression was upgraded to Tropical Storm Doreen near 18.8 N, 107.7 W or 460 n mi west-northwest of Acapulco. At 1742 GMT August 14 Air Force reconnaissance located the center of Doreen near 20.3 N, 109.3 W or 160 n mi south of the tip of Baja California. A second penetration of the storm was made at 1958 GMT. Based on extrapolated sea level pressure (979 mb), the storm was upgraded to Hurricane Doreen with 65 kt winds near the center. The eye, open to the southwest, was 15 n mi in diameter. Reports from the ships STAR MALMANGER, OGDEN JORDAN, ALBANY, MARITIME RELIANCE and TEMPLE INN helped to confirm satellite and reconnaissance positions.

Turning to the north-northwest and increasing its speed to 9 kt, Doreen passed 30 n mi west of the tip of Baja California at 1300 GMT August 15. By 1800 GMT the hurricane had moved to 23.6 N, 110.8 W or about 15 n mi off the west coast of extreme southern Baja. The cargo ship EXPORT BUYER, 120 n mi southeast of Doreen at 1800 GMT, reported southerly 45 kt winds, moderate rain, 16 ft wind waves and 24 ft swells resulting in combined seas of 29 ft. Another ship, the TEMPLE INN, 260 n mi southeast of Doreen, reported southeasterly 40 kt winds with 22 ft wind waves. The Air Force made another reconnaissance flight through Doreen at 1820 GMT August 15 and reported the eye with a closed wall 10 n mi in diameter no longer open to the southwest. Turning more to the northwest and increasing its speed to 18 kt, Doreen drifted onshore briefly near San Carlos on the west coast of Baja. By 0000 GMT August 16 the center was near 25.0 N, 112.0 W. The ship ARTHUR MAERSK, 80 n mi to the northwest, helped to locate the center. As Doreen moved northwest over cooler 72 F water the hurricane began to weaken. By 0600 GMT August 16 winds had decreased to 50 kt and the hurricane was downgraded to a tropical storm near 26.4 N, 113.2 W. Drifting

onshore again, Doreen moved to the tip of Point Eugenia peninsula by 1200 GMT August 16. By 1300 GMT the storm was offshore again moving northwest over the Bay of Sebastian Vizcaino. Winds near the center had decreased to 35 kt over water that were now near 68°F. The ship DANWOOD ICE, 30 n mi northeast of Doreen, reported east-southeasterly 32 kt winds. Winds near the center of Doreen continued to decrease as the storm drifted toward the Southern California coast. By 0600 GMT August 17 Doreen's winds had decreased to 30 kt and Doreen was downgraded to a tropical depression near 30.7 N, 117.0 W or 130 n mi south of San Diego. By 1800 GMT the cyclone was 70 n mi southwest of San Diego and winds had decreased to 25 kt. With satellite imagery showing weak low-level cyclonic circulation, the final advisory on the depression was issued at 0000 GMT August 18 with the center near 33.0 N, 118.6 W or 25 n mi north-northwest of San Clemente Island off the Southern California coast. Remnants of Doreen then drifted slowly northeast across Southern California.

While Doreen was off the central Mexican coast and still south of Baja California, another disturbance, developing near 15.0 N, 119.0 W, began to drift eastward into the cyclonic flow associated with Doreen. Ships within 300 n mi of this new disturbance reported moderate to heavy rain. As Doreen moved northward along the Baja California coast, this moisture was carried northward around Doreen and into Southern California. This moist tropical air began to enhance shower and thundershower activity over the Southern California desert areas on August 15. Flash flood watches and warnings already in effect for heavy thundershowers over the Colorado River Valley and eastern desert areas were extended along with heavy rain warnings for most of Southern California by August 16.

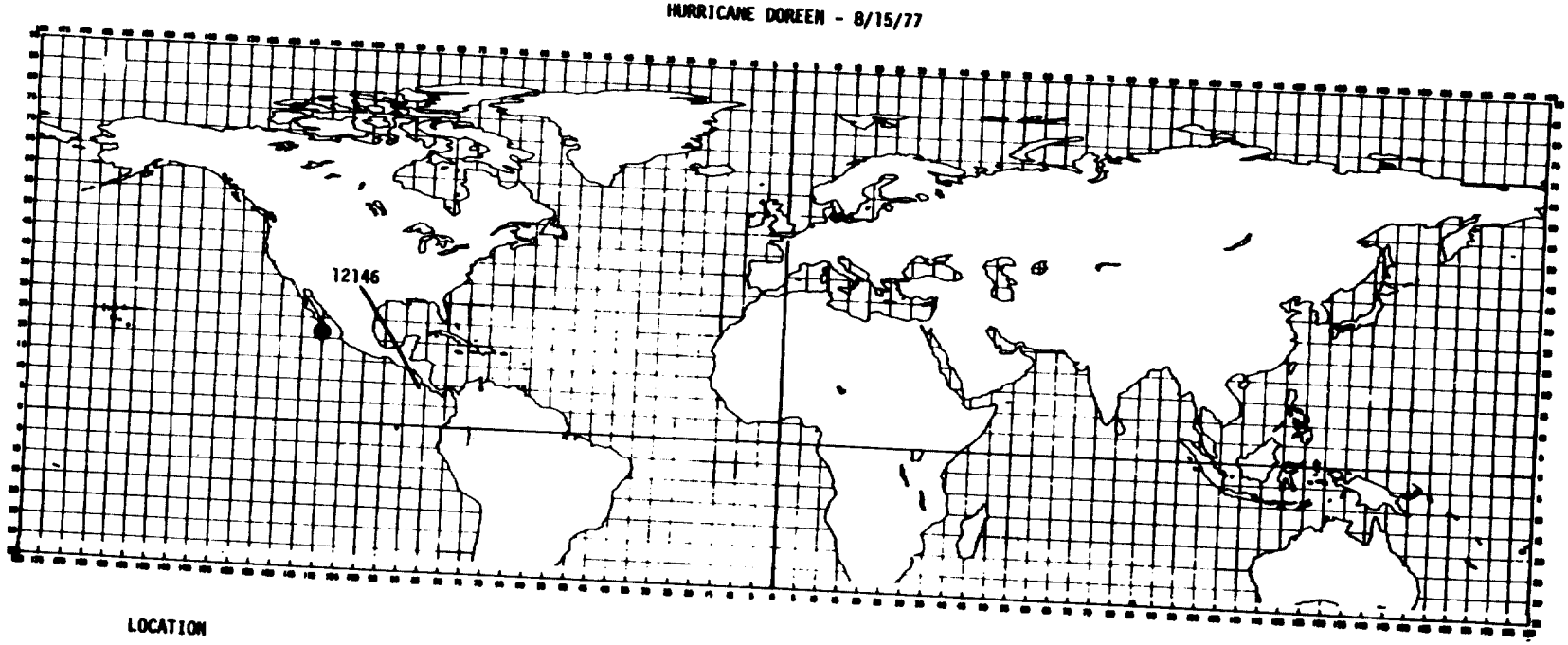
Rain moving northward with Doreen reached San Diego early on August 16, spreading northward to the Los Angeles basin and Mojave Desert by afternoon, and the Owens Valley and southern San Joaquin Valley by evening. On the coast, rain reached as far north as Santa Barbara by early the following morning. Rain continued over Southern California through late evening August 17 and a few showers lingered in the Los Angeles area until late morning August 18. An average of 2-4 inches of rain fell over the low-lying areas of Southern California during the 3-day period and as much as 7½ inches in the higher mountains.

STORM: HURRICANE DOREEN

DATE: August 13-18, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
7/13	0000Z	17.6N	106.5W			Tropical Depression
	1200Z	18.4	107.3			
	1800Z	18.8	107.7			Tropical Storm
7/14	0000Z	19.2N	108.2W			
	1200Z	19.9	109.0			
	1800Z	20.3	109.3		65	Hurricane
7/15	0000Z	21.0N	110.0W		65	
	1200Z	22.7	110.6		65	
7/16	0000Z	25.0N	112.1W		65	
	0600Z	26.4	113.2		65	Tropical Storm
	1200Z	27.6	114.6			
7/17	0000Z	29.9N	116.5W			
	0600Z	30.7	117.0			Tropical Storm
	1200Z	31.4	117.8			
7/18	0000Z	33.0N	118.6W			

HURRICANE DOREEN - 8/15/77



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	21.0N	110.0W
1200Z	22.7	110.6

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
12146	278.89	114428	115400	114824	115337	808	108

5.0 EASTERN PACIFIC/U. S. WEST COAST AREAS - 1978

Tropical cyclone activity over the Eastern Pacific in 1978 began May 30 and ended October 20. The 1978 season was 7 days shorter than the 1977 season. Although shorter in days, there was a 24% increase in the number of cyclones and the number reaching tropical storm or hurricane intensity nearly doubled from 47% in 1977 and to 86% in 1978.

In 1978, the tropical cyclone season was exceptional in that one of the hurricanes (Norman) became the third such storm in as many years to bring extensive rains to southern and central California. Only three tropical cyclones moved onshore during the 1978 season.

5.1 General

The data presented in this section were extracted from the "Monthly Weather Review", July 1979, Volume 107.

Listed below are the 1978 Tropical Cyclones in the Eastern Pacific/U. S. West Coast.

*Hurricane Aletta	5/30/78 - 5/31/78
Tropical Storm Bud	6/17/78 - 6/20/78
Hurricane Carlotta	6/17/78 - 6/20/78
Hurricane Daniel	6/26/78 - 7/03/78
Tropical Cyclone Five	6/30/78 - 7/02/78
*Tropical Storm Emilia	7/06/78 - 7/10/78
Hurricane Fico	7/09/78 - 7/17/78 (1)
Hurricane Gilma	7/13/78 - 7/20/78
*Hurricane Hector	7/22/78 - 7/29/78
Tropical Cyclone Ten	8/08/78 - 8/08/78
Hurricane Iva	8/11/78 - 8/15/78
Hurricane John	8/18-78 - 8/23/78 (1)
Hurricane Kristy	8/18/78 - 8/26/78 (1)
Tropical Storm Lane	8/19/78 - 8/20/78 (1)
Tropical Storm Miriam	8/23/78 - 8/27/78 (1)
Hurricane Norman	8/30/78 - 9/06/78

Tropical Cyclone Seventeen	9/08/78 - 9/09/78
Hurricane Olivia	9/20/78 - 9/23/78
Tropical Storm Paul	9/23/78 - 9/26/78
Hurricane Rosa	10/02/78 - 10/7/78
Tropical Storm Sergio	10/18/78 - 10/20/78

(Note 1 - These are also listed in Section 7 as they continued into that area.)

Ground track plots of these tropical cyclones are shown in Figures 5.1, 5.2 and 5.3.

Results of the comparison of the cyclone information and the GEOS-3 altimeter schedule information indicates that only three of the cyclones (marked with an * above) may have associated GEOS-3 altimeter data. All information as available for these cyclones along with any promising GEOS-3 ground track maps are presented in the following sections.

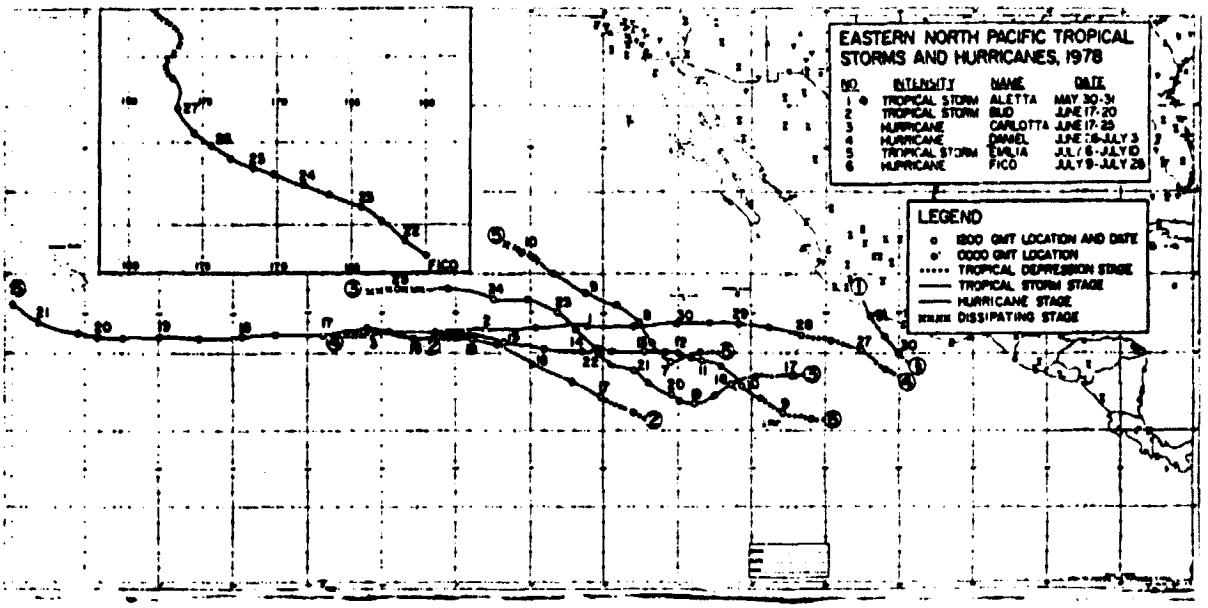


Fig. 5.1 Tracks of Eastern Pacific/
U. S. West Coast Cyclones
1-6, 1977

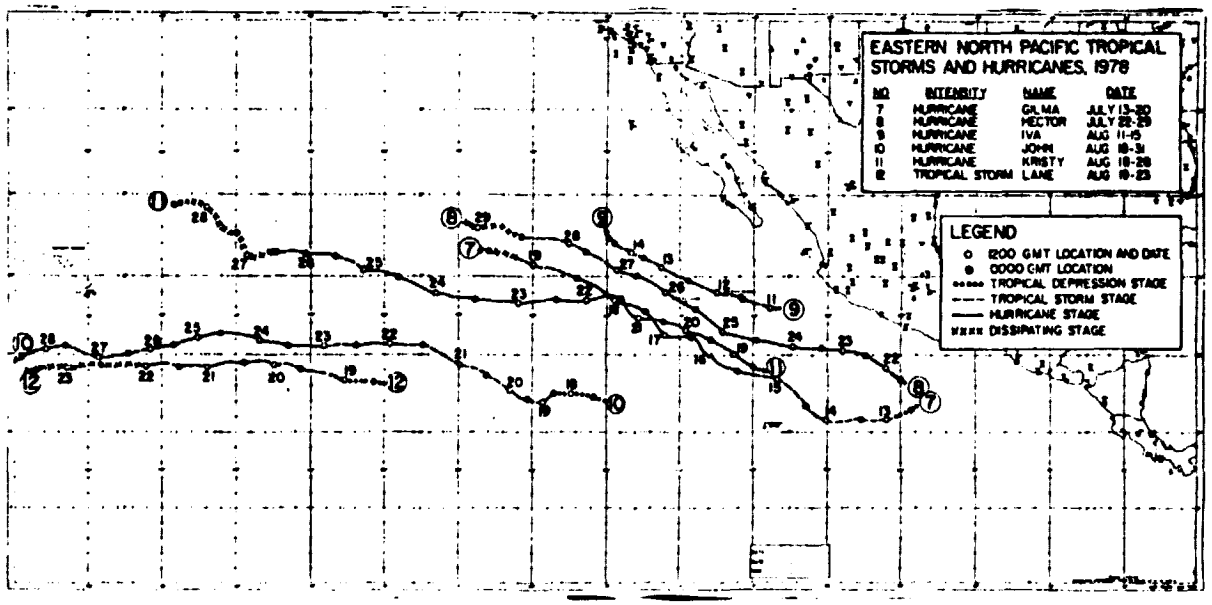


Fig. 5.2 Tracks of Eastern Pacific/
U. S. West Coast Cyclones
7-12, 1977

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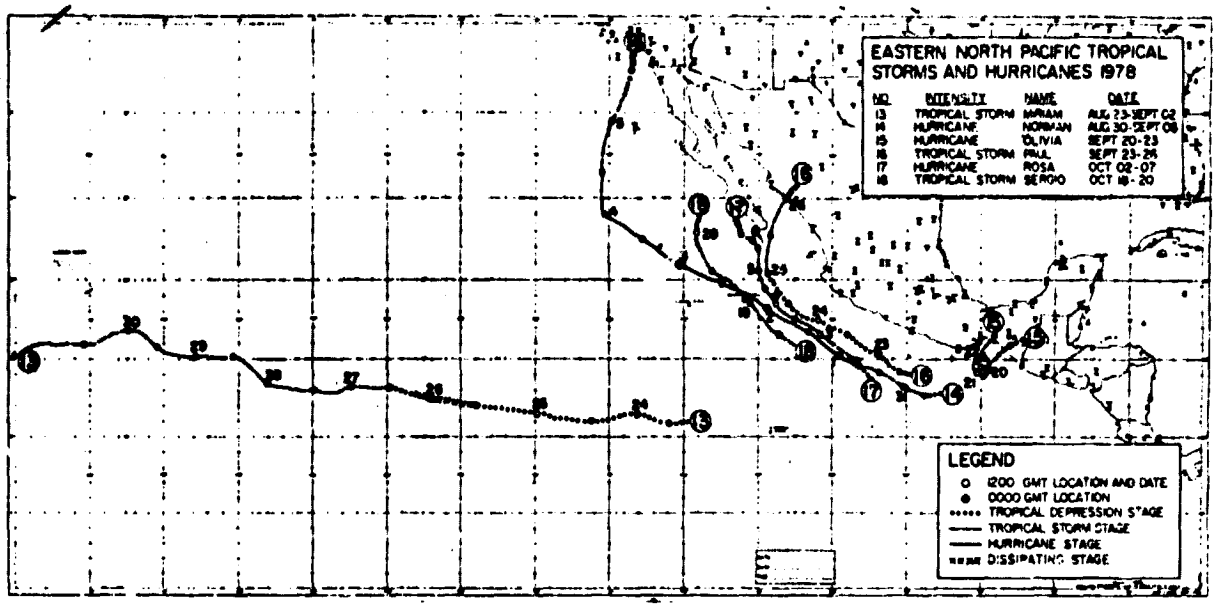


Fig. 5.3 Tracks of Eastern Pacific/
U. S. West Coast Cyclones
13-18, 1977

5.2

HURRICANE ALETTA
May 30-31, 1978

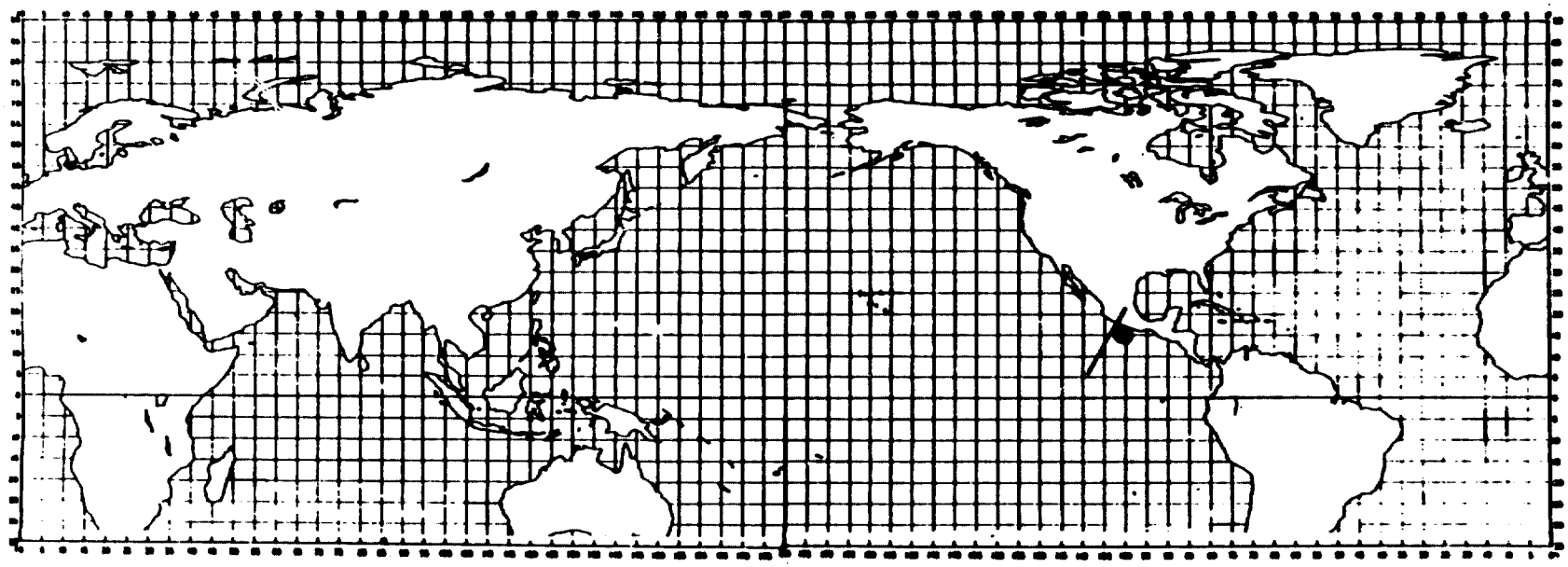
Hurricane Aletta started the 1978 tropical cyclone season as a small disturbance over the eastern Gulf of Tehuantepec on May 27. The disturbance moved southwest at 20 kt reaching 10.0°N, 100.0°W by late evening on the 28th. Between 0600 and 1200 GMT May 30, satellite imagery showed the center of the disturbance expanding rapidly to a diameter of 300 n mi. With cyclonic circulation visible about the center by 1200 GMT May 30, the disturbance was upgraded directly to Tropical Storm Aletta near 15.0°N, 100.0°W or 110 n mi s ·h of Acapulco, Mexico. By 2200 GMT May 30, a small eye was visible on satellite pictures. Aletta continued to move northwest and was upgraded to a hurricane with 65 kt winds near 16.2°N, 101.0°W at 0000 GMT May 31. Aletta was now 90 n mi west-southwest of Acapulco and moving northwest at 8 kt. By 0600 GMT May 31, winds near the center (16.8PN, 101.6°W) had decreased to 50 kt and the hurricane was downgraded to a tropical storm again.

STORM: HURRICANE ALETTA

DATE: May 30-31, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
5/30	1200	15.0N	100.0W			Tropical Storm
	1800	15.6N	100.5W			
5/31	0000	16.2N	101.0W			Hurricane
	0600	16.8	101.6		65	Tropical Storm
	1800	18.0	102.1			

HURRICANE ALETTA - 5/30/78



LOCATION

TIME	LATITUDE	LONGITUDE
0000	16.2	101.0
0600	16.8	101.6
1800	18.0	102.1

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
16220	75.90	104030	104115	112521	112814	802	119

5.3 TROPICAL STORM EMILIA
July 6-10, 1978

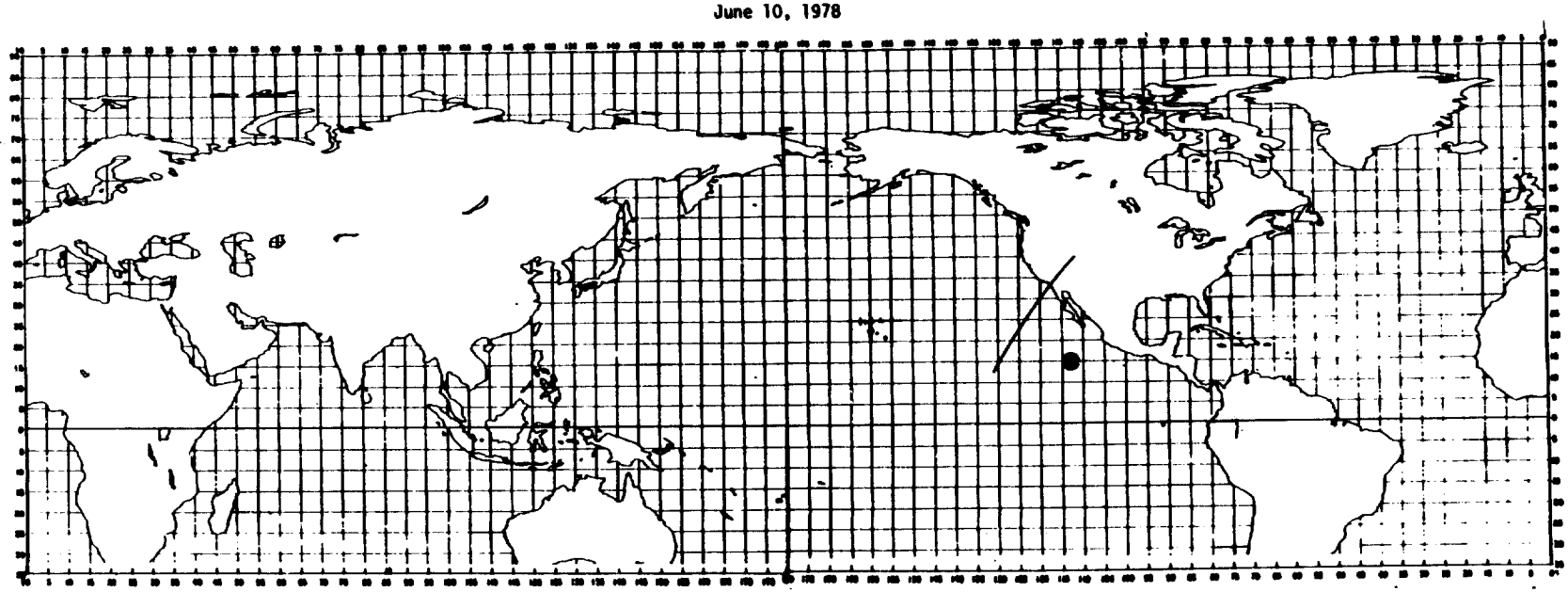
Emilia became the sixth tropical cyclone of the 1978 season. Emilia was upgraded to a tropical depression at 1800 GMT July 6 near 15.0°N, 112.5°W or 750 mi west of Acapulco. Twenty-five knot winds near the center increased to 35 kt by 0000 GMT July 7 and the depression was upgraded to Tropical Storm Emilia at 15.0°N, 113.5°W. Emilia's winds began to slowly decrease as the storm moved over cooler 79°F water. By 0600 GMT July 10 winds had decreased to 30 kt and the storm was downgraded to a tropical depression near 20.7°N, 124.5°W.

STORM: TROPICAL STORM EMILIA

DATE: July 6-10, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
7/6	1800	15.0N	112.5W			Tropical Depression
7/7	0000	15.0N	113.5W			Tropical Storm
	1200	14.5N	115.4W			
7/8	2315	17.9N	119.1W			Tropical Storm
7/9	0600	18.4N	120.2W		55	Tropical Storm
	1200	18.8N	121.3W			
7/10	0600	20.7N	124.5W			Tropical Depression
	1800	21.7N	126.7W			

TROPICAL STORM EMILIA
June 10, 1978



LOCATION

TIME	LATITUDE	LONGITUDE
0600	18.4	120.2
1200	18.8	21.7
1800	21.7	126.7

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
16804	48.00	171923	172007	175849	180556	802	106

5.4

HURRICANE HECTOR
July 22-29, 1978

The ninth cyclone of the 1978 season began as a disturbance 170 n mi south of the Guatemalan coast on July 19. The disturbance moved rapidly west-northwest. By 0000 GMT July 22, the disturbance was upgraded to a tropical depression near 13.4°N, 100.2°W or 200 n mi south of Acapulco. Winds increased to 35 kt by 0600 GMT July 22 and the depression was upgraded to Tropical Storm Hector near 13.7°N, 100.7°W. By 0000 GMT July 23, Hector was 200 n mi southwest of Acapulco and winds had increased to 60 kt. The storm then turned west and, with winds increasing to 65 kt, was upgraded to a hurricane near 15.3°N, 104.1°W at 1200 GMT July 23. By 0600 GMT July 25, winds reached their maximum intensity of 120 kt near 16.2°N, 111.1°W or 150 n mi south of Socoro Island. At 0000 GMT July 26, Hector began to slowly weaken over 81° F. water. By 1800 GMT July 27, winds had decreased to 60 kt and the hurricane was downgraded to a tropical storm near 20.9°N, 120.3°W. Hector continued to move west-northwest over colder 78° F water. Low clouds, spreading rapidly around the west and south quadrants reduced winds to 30 kt and the storm was downgraded to a tropical depression near 22.4°N, 126.1°W at 0000 GMT July 29.

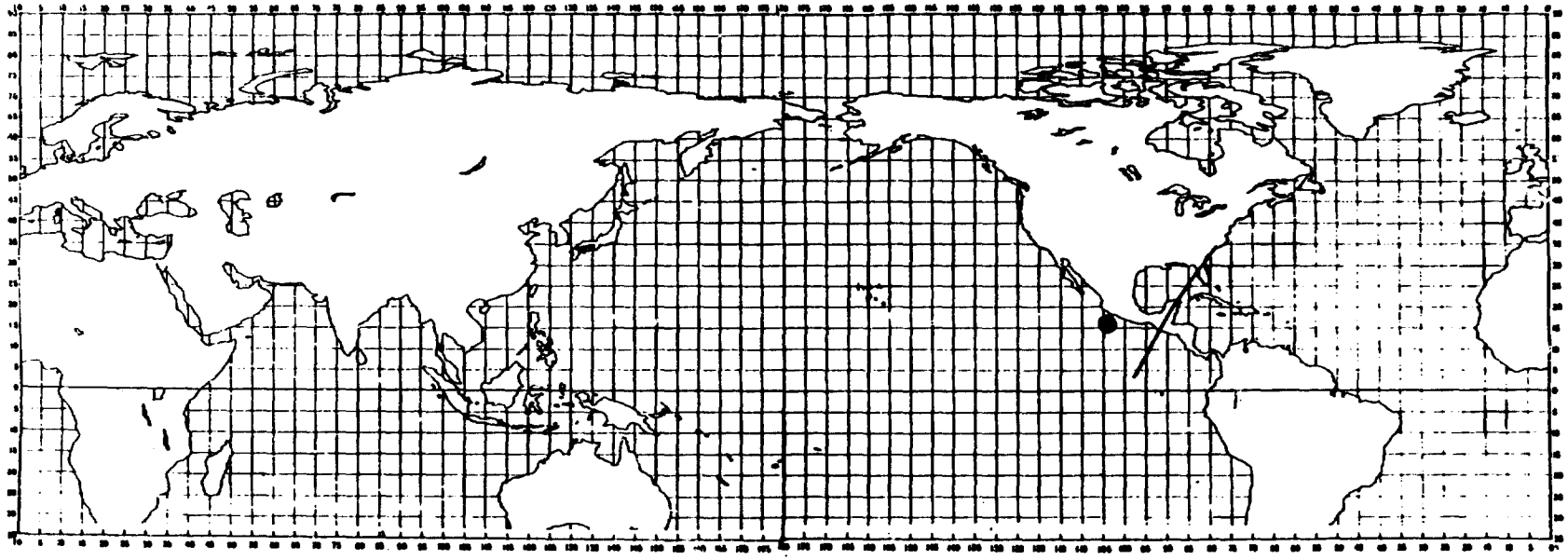
STORM: HURRICANE HECTOR

DATE: July 22-29, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
7/22	0000 0600	13.4N 13.7N	100.2W 100.7W			Tropical Depression Tropical Storm
7/23	1200	15.3N	104.1W			Hurricane
7/24	2315	16.0N	109.8W			Hurricane
7/25	0600	16.2N	111.1W		120	Hurricane
7/26	0000 1800	18.0N 19.8N	114.0W 116.9W			Hurricane
7/27	1800	20.9N	120.3W			Tropical Storm
7/28	2400	22.4N	126.1W			Tropical Depression
7/29	1800	23.5N	130.0W			Tropical Depression

HURRICANE HECTOR

July 22, 1978



LOCATION

TIME	LATITUDE	LONGITUDE
0600	16.2	111.1
0000	18.0	114.0
1800	23.5	130.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
16973	88.64	155957	160044	164135	64848	802	155

6.0 CENTRAL AND WESTERN PACIFIC AREAS - 1977

6.1 General

All of the data on the tropical cyclones occurring in these areas were extracted from the Joint Typhoon Warning Center (JTWC) document entitled "1977 Annual Typhoon Report".

During 1977, the western North Pacific experienced the smallest number of typhoons since JTWC's formation in 1959. Of the 21 numbered tropical cyclones occurring during 1977, only eleven developed to the mature stage, including one super typhoon, while eight peaked out as tropical storms, and two did not develop beyond the depression stage. The months January through June were completely void of typhoons and had only two tropical storms, Patsy in March and Ruth in June, along with tropical disturbance TD-02 in May. This early season lull in activity was similar to that observed in 1973 and 1975. Tropical cyclone occurrences were near normal during July, but fell to a record low for August when only a tropical storm was observed.

Only 12 multiple-storm days occurred in 1977. This is also a record low of multiple storm days observed since JTWC began keeping records in 1959.

Ground track plots for all of the western Pacific cyclones are shown in Figures 6.1 through 6.6.

All storms as identified by the JTWC document are listed below with their periods of occurrence.

Storm	Date
Tropical Storm Patsy	3/23/77 - 3/03/77
Tropical Disturbance-02	5/26/77 - 5/27/77
*Tropical Storm Ruth	6/14/77 - 6/17/77
*Tropical Disturbance-04	7/05/77 - 7/6/77
*Typhoon Sarah	7/16/77 - 7/21/77
*Typhoon Thelma	7/21/77 - 7/26/77

Storm	Date
Typhoon Vera	7/28/77 - 8/1/77
*Tropical Storm Wanda	7/31/77 - 8/4/77
Tropical Storm Amy	8/20/77 - 8/23/77
*Super Typhoon Babe	9/02/77 - 9/10/77
Tropical Storm Carla	9/03/77 - 9/05/77
*Typhoon Dinah	9/14/77 - 9/23/77
Tropical Storm Emma	9/15/77 - 9/20/77
Tropical Storm Freda	9/23/77 - 9/25/77
Typhoon Gilda	10/03/77 - 10/10/77
Tropical Storm Harriet	10/16/77 - 10/20/77
Typhoon Ivy	10/21/77 - 10/27/77
Typhoon Jean	10/28/77 - 11/03/77
Typhoon Kim	11/06/77 - 11/17/77
Typhoon Lucy	11/28/77 - 12/07/77
Typhoon Mary	12/20/77 - 1/03/78

In the following sections, GEOS-3 ground track plots and additional cyclone information are given for the Pacific area cyclones which appear to have accompanying GEOS-3 altimeter data (as identified by * in the preceding list).

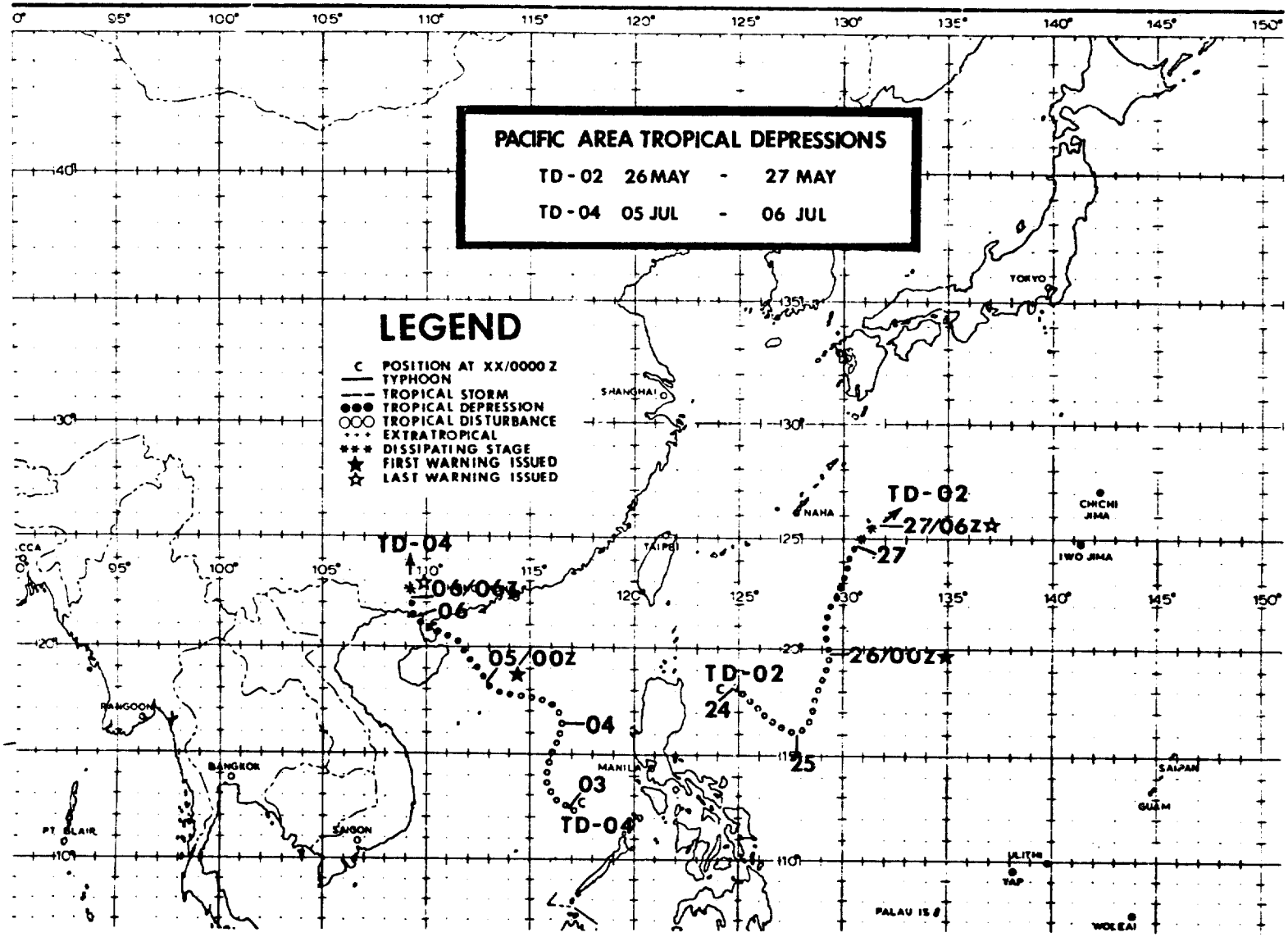

PACIFIC AREA TROPICAL DEPRESSIONS
TD-02 26 MAY - 27 MAY
TD-04 05 JUL - 06 JUL
LEGEND
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
TD-04
06/06Z
06
05/00Z
04
03
TD-04
TD-02
24
25
26/00Z
TD-02
27/06Z
27
TOKYO
SHANGHAI
NAHA
TAIPEI
CHICHI JIMA
IWO JIMA
SAIPAN
GUAM
MANILA
BANGKOK
RANGOON
SAIGON
PT BLAIR
YAP
ULITHI
PALAU IS
WOLEAI

FIGURE 6.1

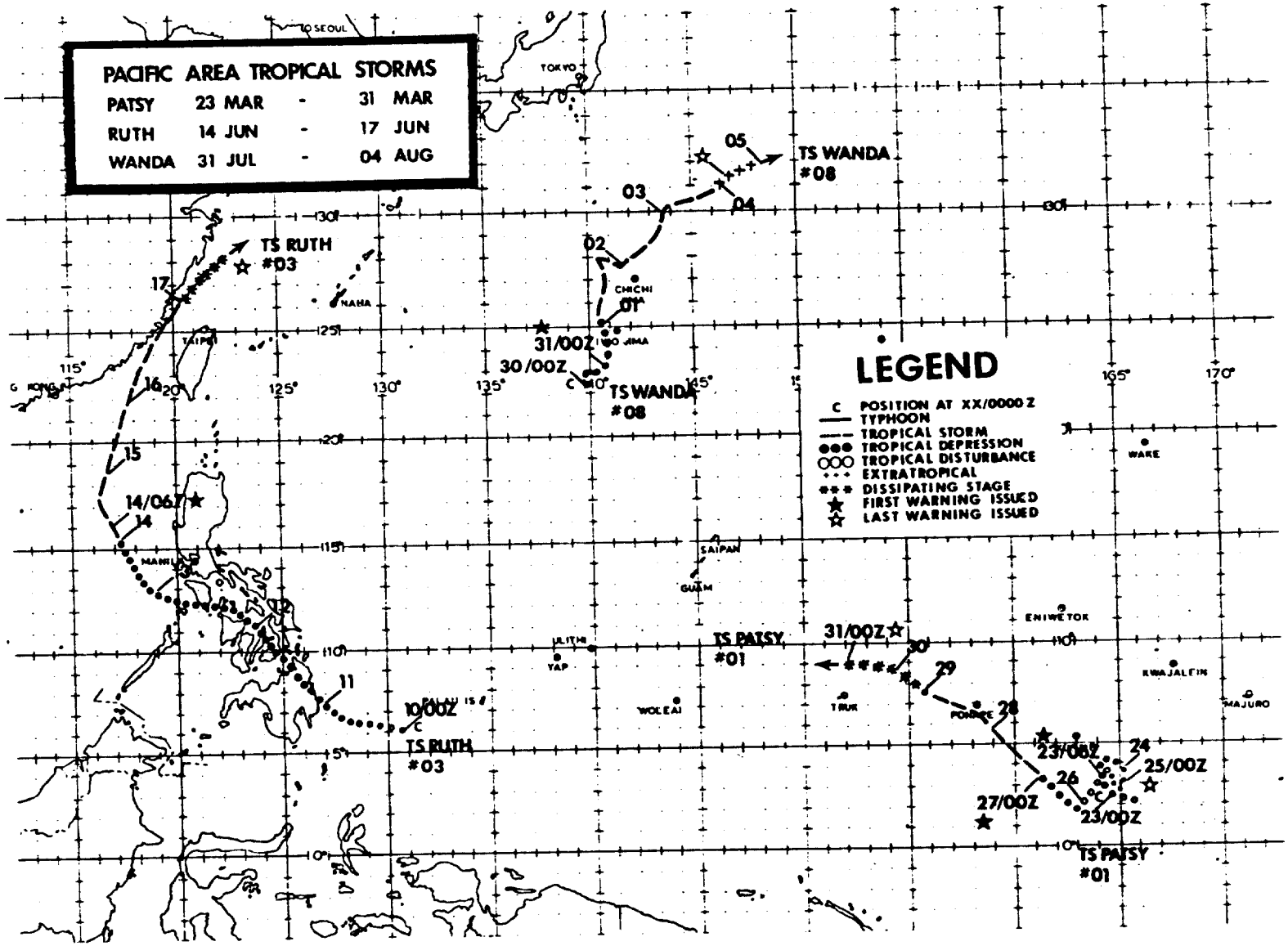

PACIFIC AREA TROPICAL STORMS
PATSY 23 MAR - 31 MAR
RUTH 14 JUN - 17 JUN
WANDA 31 JUL - 04 AUG
TO SEOUL
TOKYO
TS WANDA #08
TS RUTH #03
NAHA
CHICHI JIMA
HAHA JIMA
TAIPEI
G. KONG
MANILA
SAIPAN
GUAM
ULITHI
YAP
WOLEAI
TRUK
PONAPE
ENIWETOK
KWAJALEIN
MAJURO
WAKE
TS PATSY #01
LEGEND
C POSITION AT XX/0000Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED

FIGURE 6.2

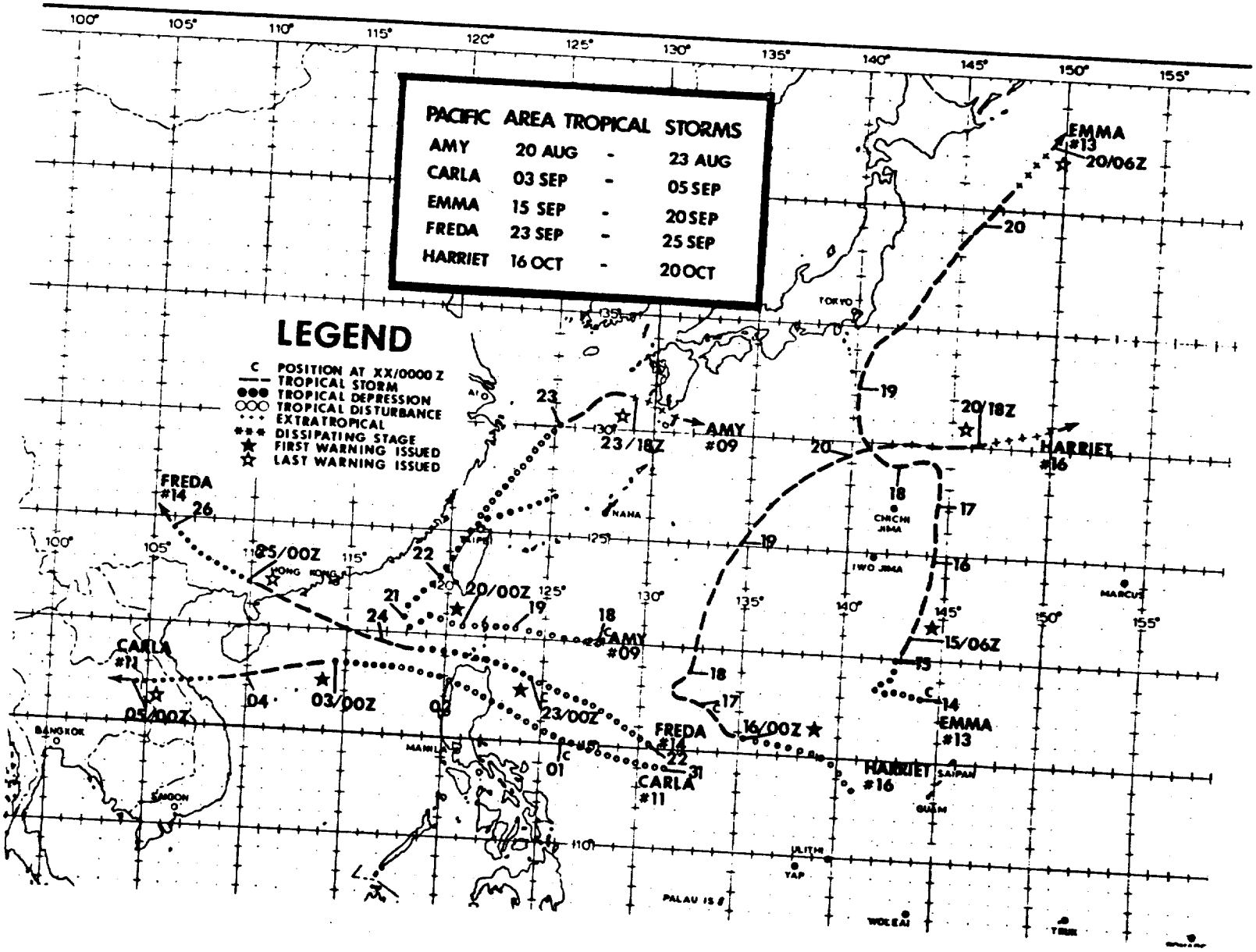

PACIFIC AREA TROPICAL STORMS
AMY 20 AUG - 23 AUG
CARLA 03 SEP - 05 SEP
EMMA 15 SEP - 20 SEP
FREDA 23 SEP - 25 SEP
HARRIET 16 OCT - 20 OCT
LEGEND
C POSITION AT XX/0000 Z
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
EMMA #13
20/06Z
HARRIET #16
20/18Z
AMY #09
23/18Z
FREDA #14
25/00Z
20/00Z
CARLA #11
05/00Z
03/00Z
23/00Z
16/00Z
15/06Z
TOKYO
NANA
CHICHI JIMA
IWO JIMA
MARCUS
HONG KONG
BANGKOK
MANILA
SAMOON
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK

FIGURE 6.3

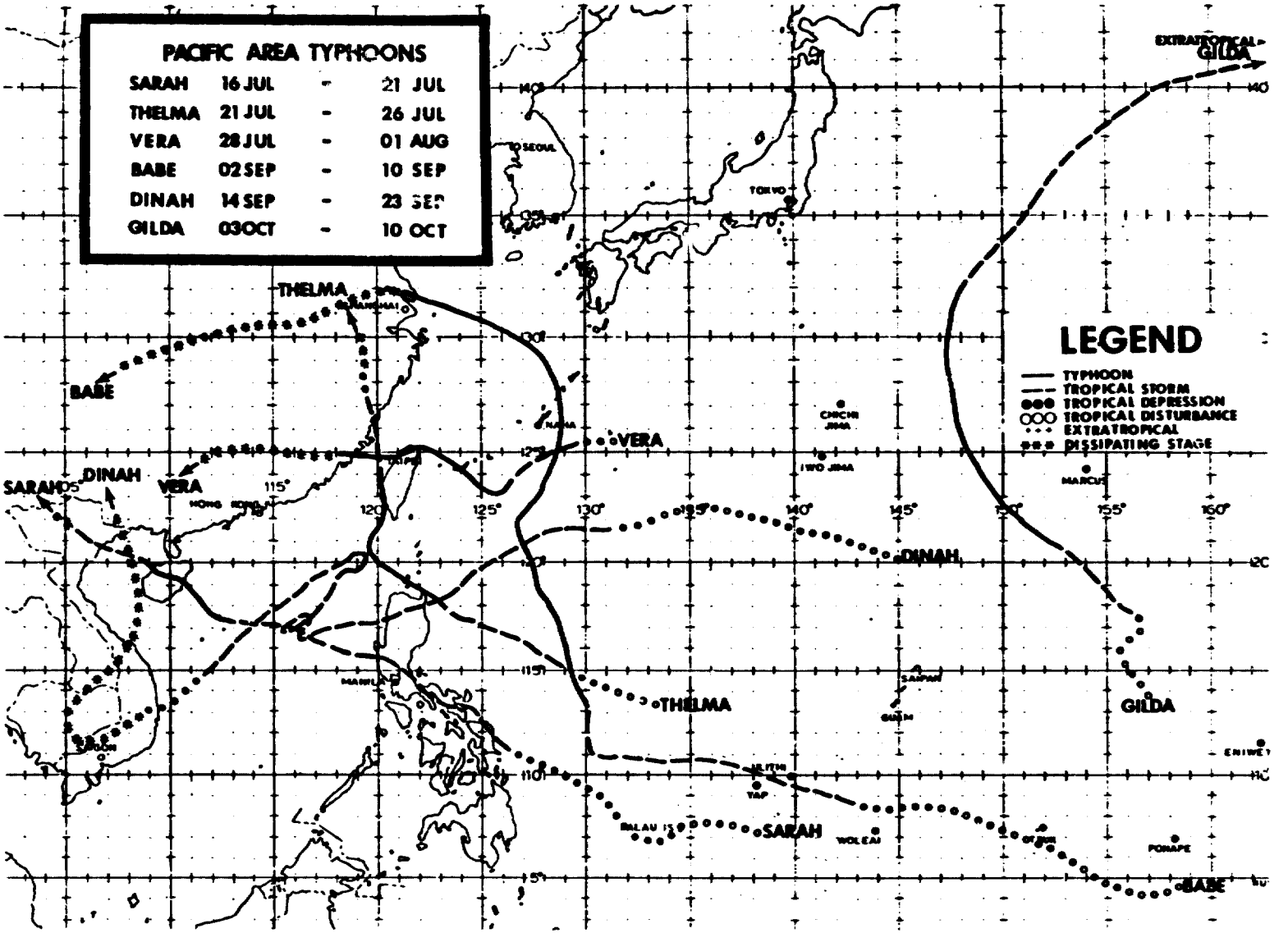

PACIFIC AREA TYPHOONS
SARAH 16 JUL - 21 JUL
THELMA 21 JUL - 26 JUL
VERA 28 JUL - 01 AUG
BABE 02 SEP - 10 SEP
DINAH 14 SEP - 23 SEP
GILDA 03 OCT - 10 OCT
LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
EXTRATROPICAL GILDA
THELMA
BABE
VERA
DINAH
SARAH
GILDA
SEOUL
TOKYO
CHICHI JIMA
IWO JIMA
MARCUS
SAIPAN
GUAM
YAP
WOLEAI
PONAPE
ENIWET
HONG KONG
MANILA
115°
120°
125°
130°
135°
140°
145°
150°
155°
160°

FIGURE 6.4

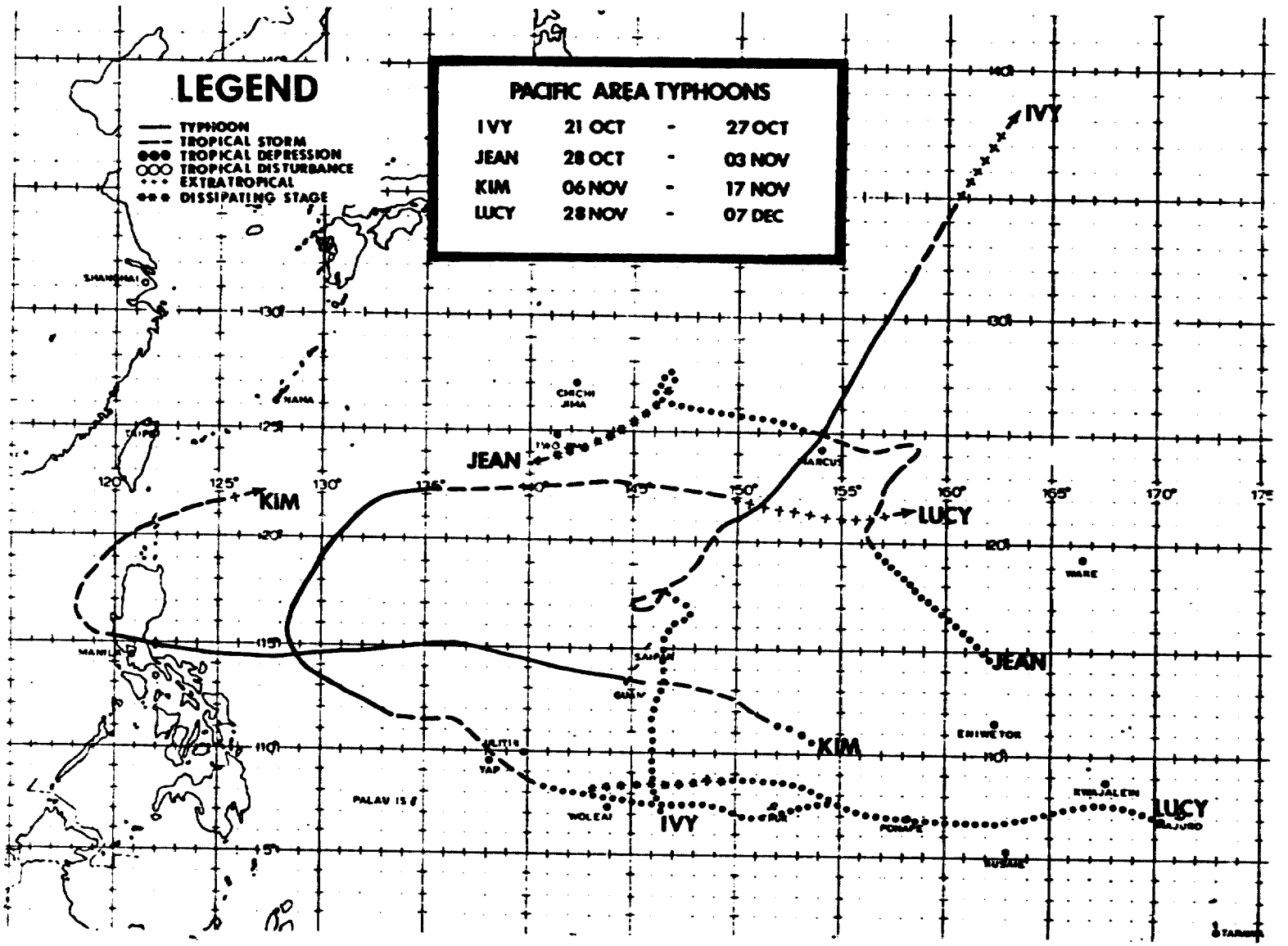

LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
PACIFIC AREA TYPHOONS
IVY 21 OCT - 27 OCT
JEAN 28 OCT - 03 NOV
KIM 06 NOV - 17 NOV
LUCY 28 NOV - 07 DEC
IVY
JEAN
KIM
LUCY
SHANGHAI
NAHA
CHICHI JIMA
IWO
MARCUS
WAKE
SAIPAN
GUAM
YAP
ENIWETOK
PALAU IS
WOLEAI
PONAPE
KUSAIE
KWAJALEIN
MAJURO
TARAWA

FIGURE 6.5

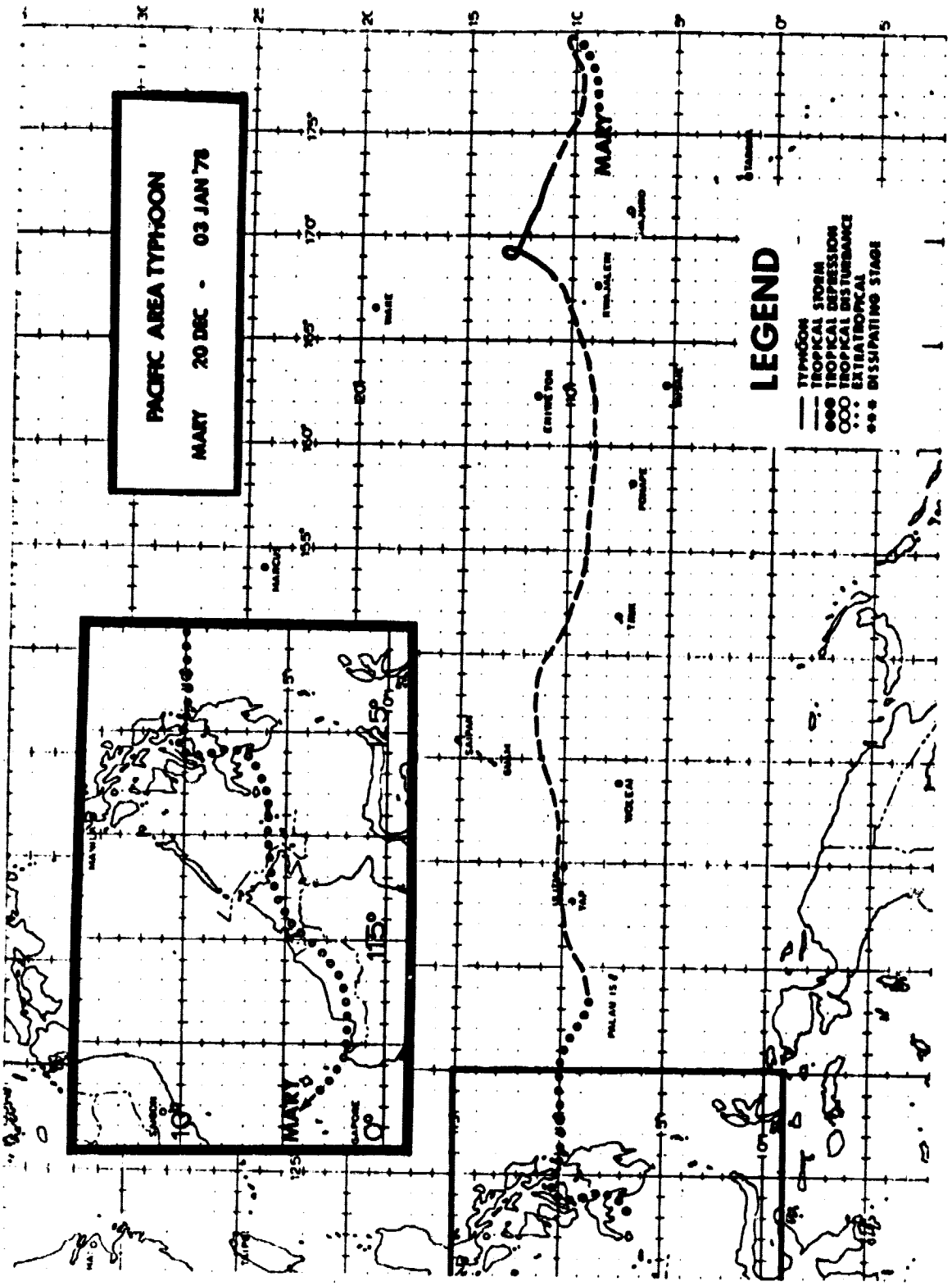

PACIFIC AREA TYPHOON
MARY 20 DEC - 03 JAN 78
LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
MARY
MARY
115°

FIGURE 6.6

6.2 TROPICAL STORM RUTH

June 14-17, 1977

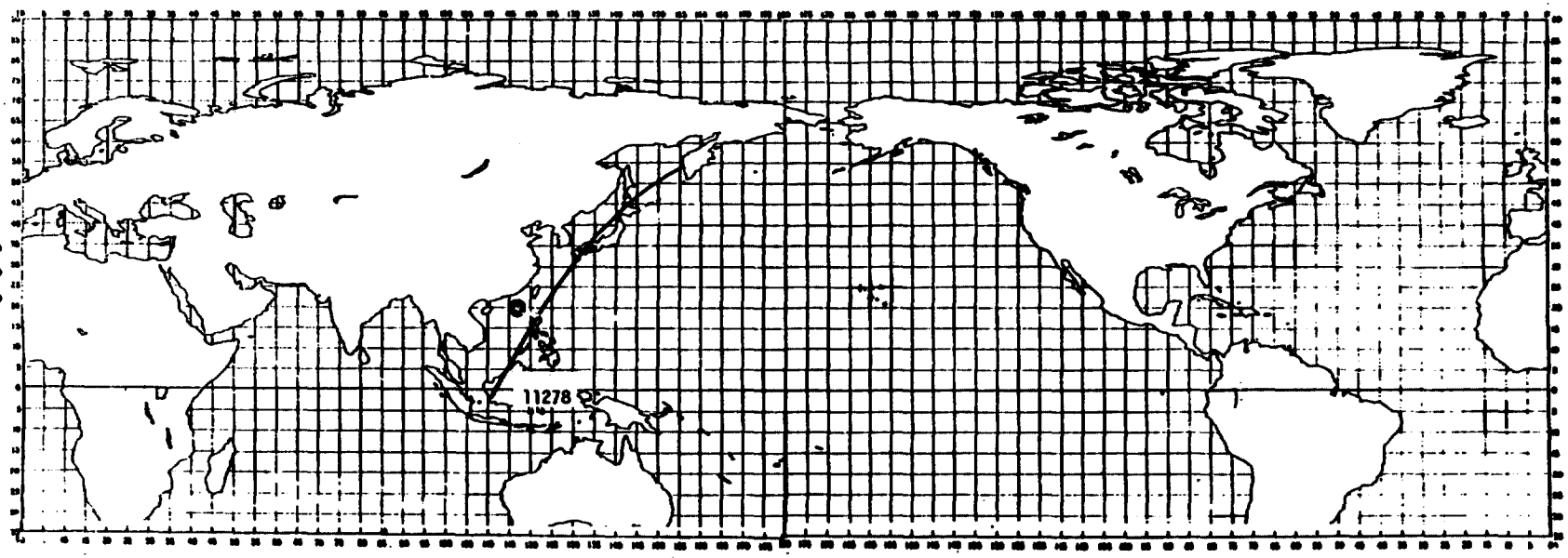
No descriptive information was available for this storm.

STORM: TROPICAL STORM RUTH

DATE: June 14-17, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
6/14	0600Z	16.0N	116.9E		40	Tropical Storm
	1200	16.8	116.6		50	
	1800	17.7	116.4		55	
6/15	0000Z	18.6N	116.4E		60	Tropical Storm
	0600Z	19.3	116.7		60	
	1200Z	20.1	117.0		55	
	1800Z	21.0	117.3		50	
6/16	0000Z	22.2N	117.7E		45	Tropical Storm
	0600Z	23.3	118.1		40	
	1200Z	24.3	118.7		40	
	1800Z	25.3	119.5		35	
6/17	0000Z	26.4N	120.6E		30	Tropical Storm
	0600Z	27.6	121.7		25	
	1200Z	28.3	123.2		20	

TROPICAL STORM RUTH - 6/15/77



6.2-3

LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	18.6N	116.4E
0600Z	19.3	116.7
1200Z	20.1	117.0
1800Z	21.0	117.3

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIT.#
11278	298.84	031741	040300	035102	040808	808	124

6.3 TROPICAL DISTURBANCE FOUR
July 5-6, 1977

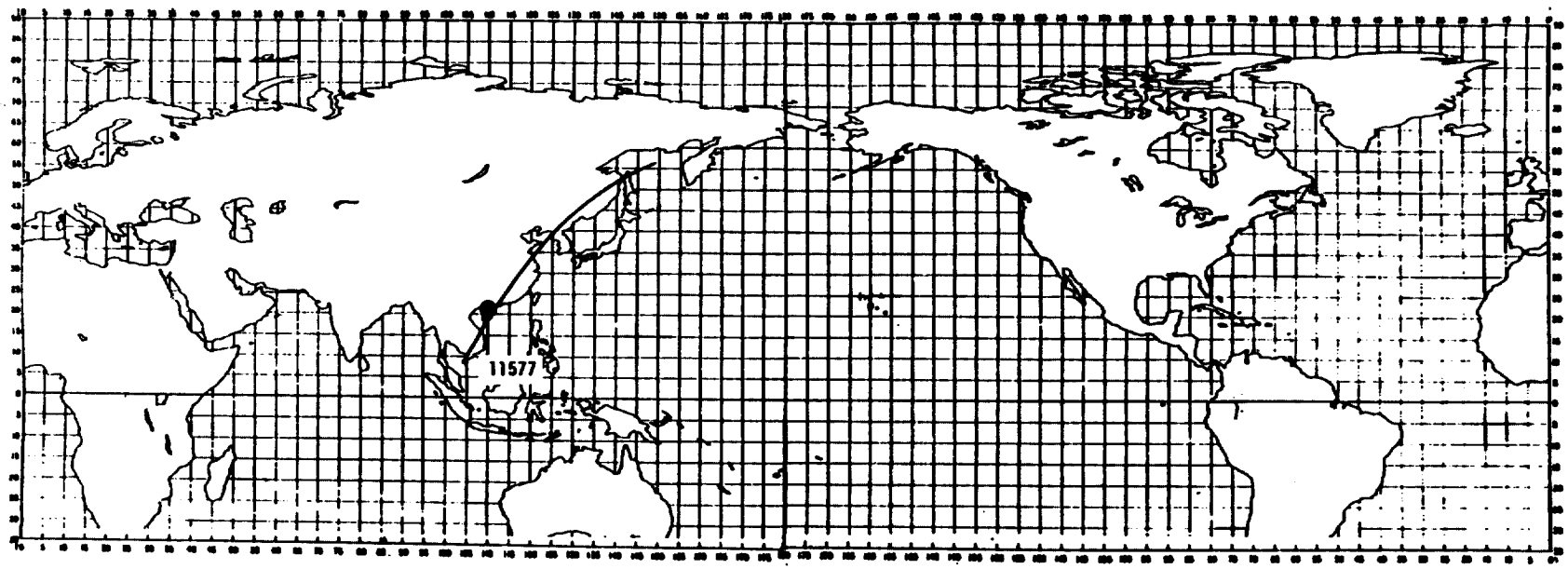
No descriptive information was available for this disturbance.

STORM: TROPICAL DISTURBANCE FOUR

DATE: July 5-6, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
7/5	0000Z	17.7N	113.6E		30	Tropical Depression
	0600Z	18.6	112.5		30	
	1200	19.8	111.8		30	
	1800	20.4	110.5		25	
7/6	0000Z	21.2N	109.4E		20	Tropical Depression
	0600	22.3	109.1		20	

TROPICAL DISTURBANCE TD-04 - 7/6/77



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	21.2M	109.4E
0600Z	22.3	109.1

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
11577	287.38	063037	071500	070301	071837	808	121

6.4

TYPHOON SARAH
July 16-21, 1977

The first typhoon of the 1977 season did not occur until mid-July. Meteorological satellite data on the morning of July 13th showed an area of convection some 225 nm (417 km) east of Koror in the Palau Islands. This tropical disturbance meandered on a 10 kt, westward track and crossed Koror at 1200 on the 14th. On the morning of the 15th, the system exhibited increased organization and a Tropical Cyclone Formation Alert was issued at 0000Z. Simultaneously, the disturbance took a more climatological, west-northwestward track and showed evidence of possessing multiple circulation centers.

During the 16th, satellite data hinted that the western-most circulation center was becoming the dominant one. Reconnaissance aircraft refuted this however, and fixed the primary center approximately 200 nm east of the satellite positions. At 0943Z aircraft observed 38 kt winds at 700 mb and estimated surface winds at 25 kt. Satellite data an hour later showed that convection in the area had, in fact, consolidated around the aircraft-fixed circulation center, and the first warning was issued at 1200Z.

By the evening of the 16th, TD 05 had accelerated to 17 kt, and satellite data illustrated increased organization. At 1800Z the depression was upgraded to Tropical Storm Sarah, while located 30 nm east of the Philippine Island of Samar. During the subsequent 24 hours, Sarah, possessing 40 kt intensity moved on a west-northwest to northwest heading. At 2355Z on the 17th, Clark Air Base observed a minimum sea level pressure of 997.3 mb; winds were from the northwest at 12 kt. Within two hours winds at the Air Base had become southerly. Synoptic reports were of great value during this period. The mountainous terrain prevented aircraft reconnaissance of the low level circulation center, while frictional effects weakened and disorganized Sarah making satellite positioning very difficult.

From the evening of the 16th until the morning of the 20th upper level patterns in Sarah's environment were favorable for enhancement of her upper level outflow, which would normally result in intensification. The Tropical Upper Tropospheric Trough (TUTT) was oriented east-west, north of her and was enhancing outflow in the north semicircle; strongly divergent winds south

of the tropical storm increased outflow to the south. While over land, however, Sarah could not intensify since the latent and sensible heat required to maintain sufficient thermal and related pressure gradients were not available. The tropical storm entered the South China Sea on the afternoon of the 18th and immediately began to intensify.

On the evening of the 19th, a midtropospheric low over south central China deepened and weakened the subtropical ridge north of Sarah; she responded and turned to the northwest; toward Hainan Island, still intensifying. Sarah was upgraded to a typhoon at 1800Z and six hours later reached its maximum intensity of 75 kt. At 2100Z Hsi-Sha-Tao reported sustained winds of 60 kt from the west-southwest and a sea level pressure of 977.5 mb.

Sarah went ashore on Hainan Island on the evening of the 20th. At 1200Z Ch'iung-Hai reported 10 kt winds from the west and a sea level pressure of 987.5 mb. At this time Sarah's intensity was estimated to be 70 kt. Meanwhile, the mid-level low over China had receded toward the north and the subtropical ridge began to build westward, north of Sarah. During the subsequent six hours, the typhoon slowed to 8 kt and took a westward course, passing north of the central mountain range of Hainan. At 1800Z Tan-Hsien was near the center when it reported 15 kt winds from the east-northeast and a sea level pressure of 969.5 mb.

Typhoon Sarah entered the Gulf of Tonkin on the morning of the 21st with an estimated 65 kt intensity. The typhoon accelerated to 15 kt and went ashore near Haiphong. At 0600Z on the 21st, Kien-an Phulien, a Haiphong suburb, reported north-northwesterly winds of 30 kt and a sea level pressure of 986.9 mb. Six hours later these values had changed to 30 kt from the south and 988.5 mb with pressure rising rapidly.

The final warning on Sarah was issued at 1200Z on the 21st as she was dissipating over the Red River Valley, northwest of Hanoi. Very little damage occurred during Sarah's existence. Only Hanoi Radio reported cases of destruction with no casualties.

Typhoon Sarah's track is shown in Figure 6.7.

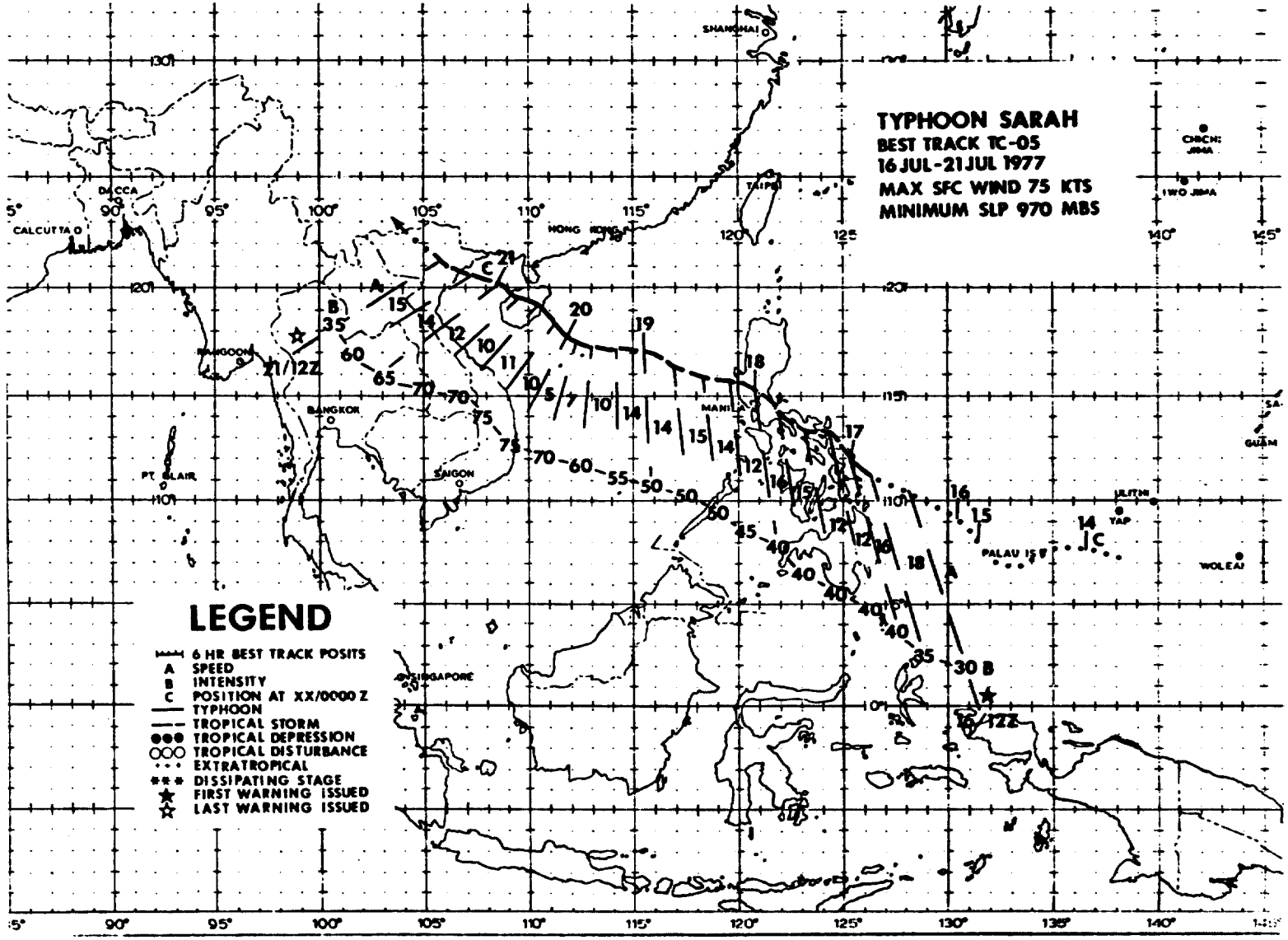

TYPHOON SARAH
BEST TRACK TC-05
16 JUL - 21 JUL 1977
MAX SFC WIND 75 KTS
MINIMUM SLP 970 MBS
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SHANGHAI
TAIPEI
HONG KONG
DACCA
CALCUTTA
RANGOON
BANGKOK
SAIGON
MANILA
PT BLAIR
SINGAPORE
YAP
ULITHI
PALAU IS
WOLEAI
GUAM
CHICHI JIMA
IWO JIMA

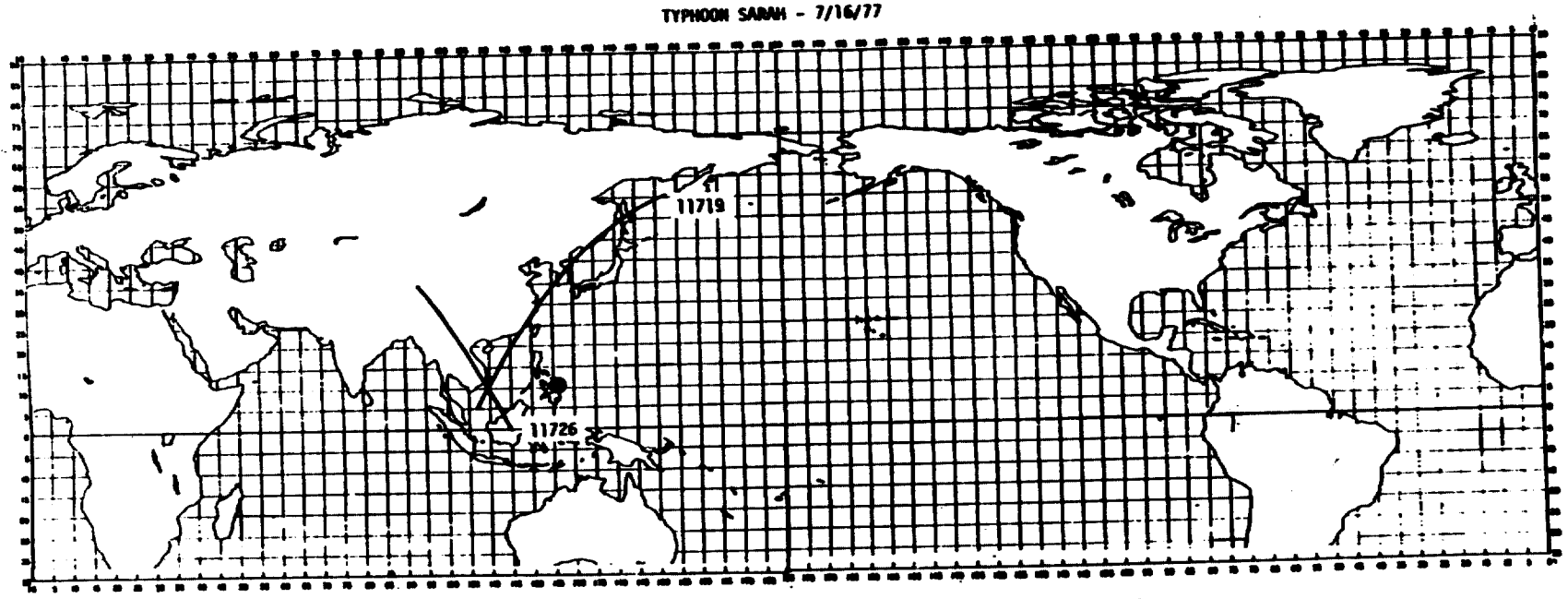
Figure 6.7

STORM: TYPHOON SARAH

DATE: July 16-21, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
7/16	1200Z	10.5N	128.1E		30	Tropical Depression
	1800	11.2	126.4		35	Tropical Storm
7/17	0000Z	12.2N	125.2E		40	Tropical Storm
	0600Z	13.1	124.4		40	
	1200Z	13.4	123.2		40	
	1800	14.2	122.0		40	
7/18	0000Z	15.3N	120.8E		40	Tropical Storm
	0600Z	15.8	119.7		45	
	1200Z	15.9	118.3		50	
	1800Z	16.6	116.9		50	
7/19	0000Z	17.1N	115.5E		50	Tropical Storm
	0600Z	17.1	114.1		55	
	1200Z	17.2	113.0		60	
	1800Z	17.4	112.3		70	Typhoon
7/20	0000Z	17.7N	111.9E		75	Typhoon
	0600Z	18.4	111.2		75	
	1200Z	19.3	110.5		70	
	1800Z	19.5	109.5		70	
7/21	0000Z	20.2N	108.5E		65	Typhoon
	0600Z	20.6	107.2		60	
	1200Z	21.3	105.7		35	Tropical Storm

TYPHOON SARAH - 7/16/77



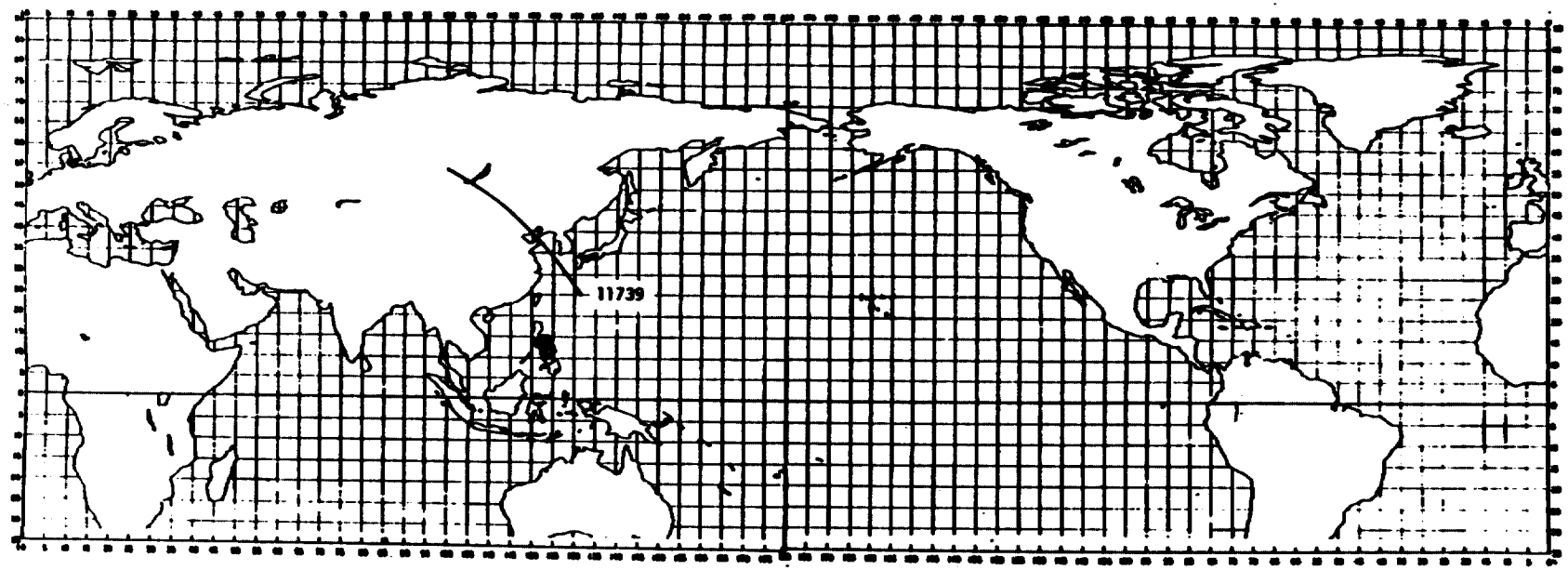
6.4-5

LOCATION

TIME	LATITUDE	LONGITUDE
1200Z	10.5N	128.1E
1800Z	11.2	126.4

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
11719	291,57	072342	080900	075622	081241	808	143
11726	114,31	191610	191700	191641	192650	808	147

TYPHOON SARAH - 7/17/77

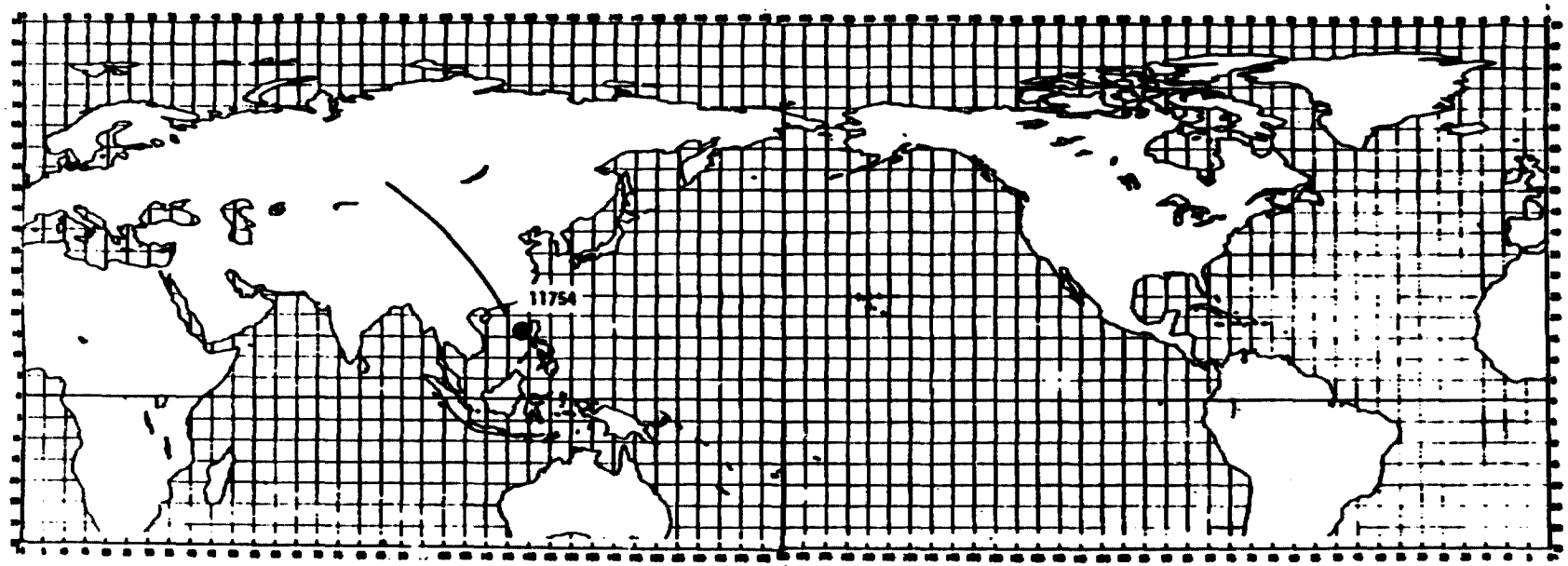


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	12.2N	125.2E
0600Z	13.1	
1200Z	13.4	
1800Z	14.2	

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	RNTQ,P
11739	145.12	171920	172800	172800	173640	808	152

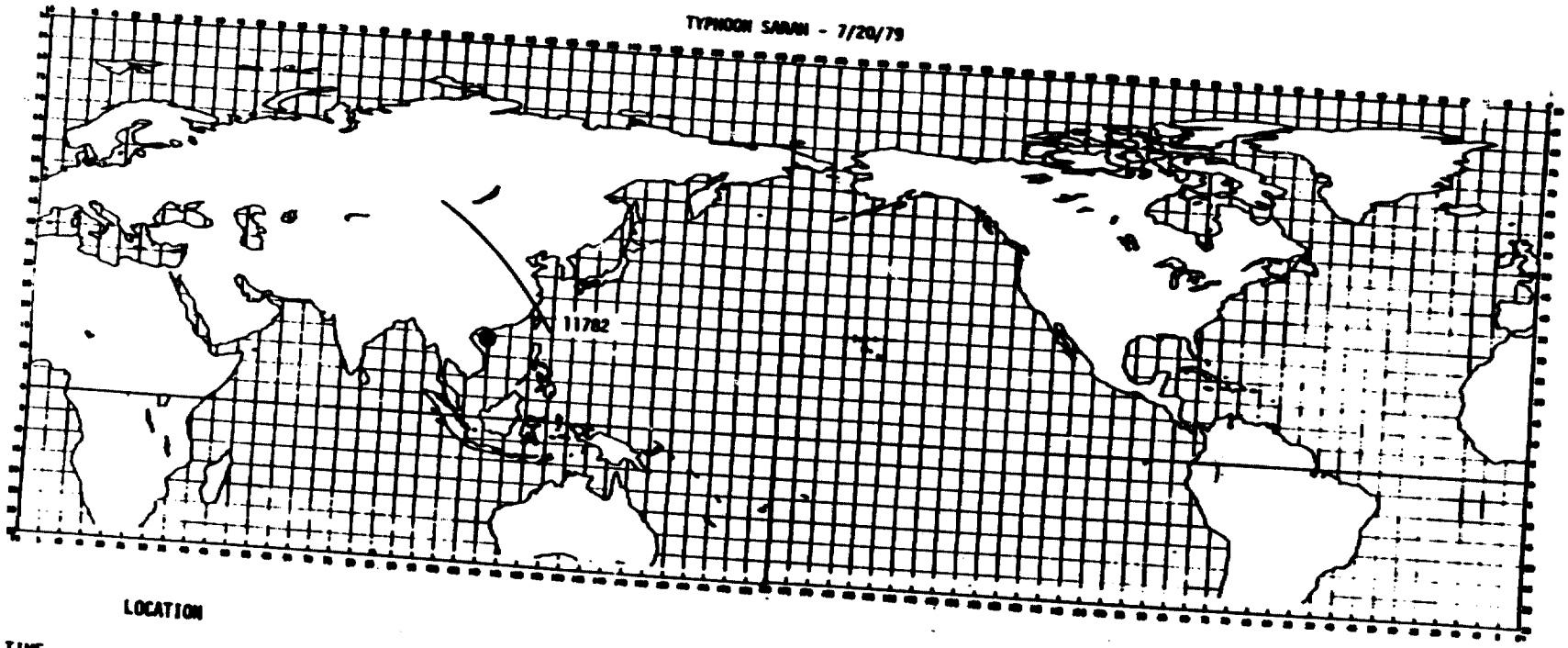
TYPHOON SARAH - 7/18/77



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	15.3N	120.8E
0600Z	15.8	119.7
1200Z	15.9	118.3
1800Z	16.6	116.9

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	NODE	UNITS
11754	125.2E	184604	185400	185400	190000	808	107

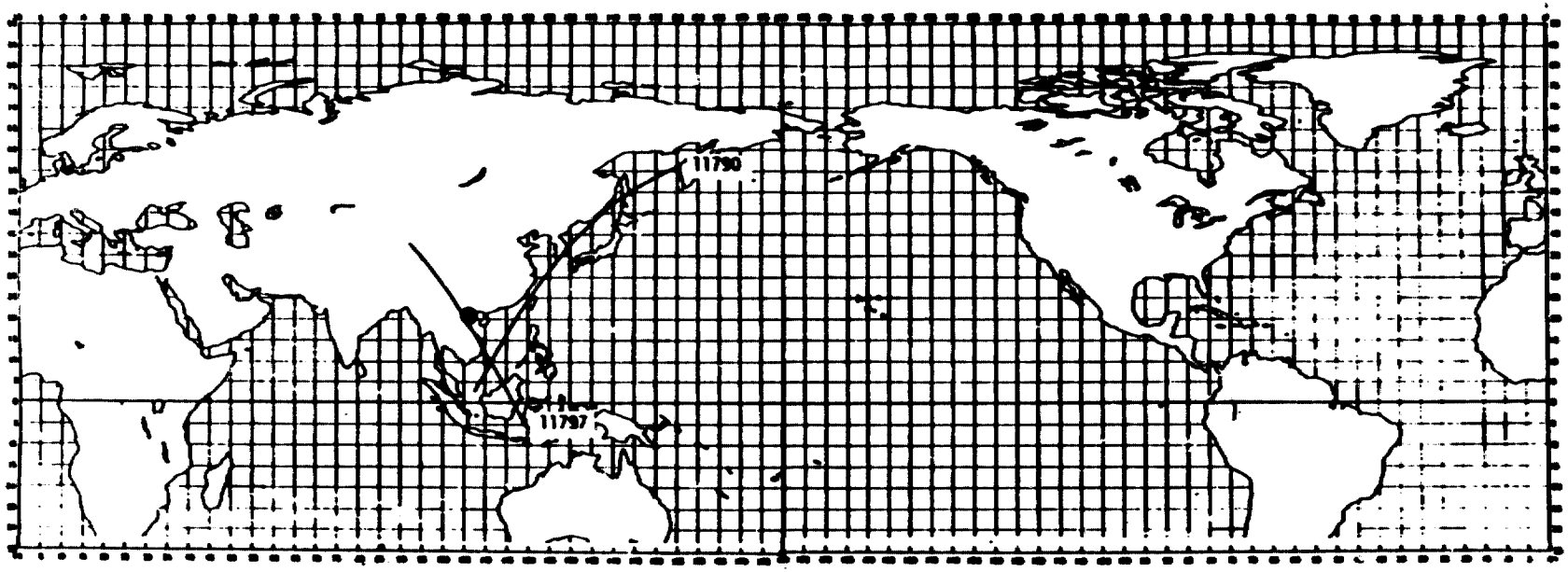


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	17.7N	111.9E
0600Z	18.4	111.2
1200Z	19.3	110.5
1800Z	19.5	109.5

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	AUTO.P
11782	136.25	181558	182500	182350	183206	808	127

TYPHOON SARAH - 7/21/79



6.4-9

LOCATION

TIME	LATITUDE	LONGITUDE
00002	20.2N	108.5E
06002	20.6	107.2
12002	21.3	105.7

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	RUNTO.P
11790	293.67	075014	083500	082305	083941	868	131
11797	116.38	194242	194900	194300	195413	808	134

6.5

TYPHOON THELMA
July 21-26, 1977

Thelma, the second typhoon of the 1977 season, wrought more destruction on Taiwan than any event since World War II. While Typhoon Sarah was still crossing the South China Sea, Thelma was detected by satellite on the morning of the 20th as a tropical disturbance in the central Philippine Sea. The disturbance continued to organize during the subsequent 24 hours, and the first warning was issued on TD 06 at 0000Z on the 21st.

Reconnaissance aircraft at 0918Z on the 21st found flight level winds of 55 kt, a central pressure of 993 mb, and surface winds estimated at 50 kt. Based on the aircraft data and corroborating satellite data, TD 06 was upgraded to Tropical Storm Thelma at 1200Z. During the following 30 hours, Thelma continued to intensify at a rate of 5 kt per 6 hours. At 2050Z on the 22nd, aircraft fixed the tropical storm 255 nm northeast of Manila, and observed 60 kt winds at its 700 mb flight level. The aircraft further indicated that the central pressure had fallen to 965 mb. As a result of those observations, the system was upgraded to Typhoon Thelma at 0000Z on the 23rd.

The trigger for Thelma's intensification was nearly identical to that of Sarah's a week earlier. Highly efficient outflow channels in the TUTT, to the north, and by strongly divergent upper level northeasterlies over Indonesia and the South China Sea, to the south. This situation lasted from the 21st to the 24th when the TUTT receded northward, and Thelma ceased her intensification.

The typhoon continued to move northwestward at 9 kt toward the southern periphery of the mid-tropospheric subtropical ridge. On the evening of the 23rd, the storm entered the Bashi Channel, passing 10 nm northeast of Escarpada Point on northeastern Luzon. At this time the Kakuho Maru reported 80 kt winds and 20 ft seas just northwest of the center.

Since the time of Thelma's development, the midtropospheric subtropical ridge had been intense over the western Pacific and extended well into China. By 1200Z on the 23rd, geopotential heights at the 500 mb level began to fall over northern China as a low developed over eastern Mongolia and deepened rapidly. On the morning of the 24th, the subtropical ridge north of the tropical system showed signs of weakening.

During the evening of the 24th, reconnaissance aircraft positioned Thelma 145 nm south-southwest of Kao-hsiung, which indicated that the storm was beginning to move northward. At this time the typhoon attained its maximum intensity of 85 kt with a minimum pressure of 957 mb, and slowed to 6 kt. At 1800Z the passenger liner, President McKinley, reported 45 kt winds and 20 ft seas while some 70 nm northeast of the eye.

On the morning of the 25th, radar data showed that Thelma had turned toward the north-northeast and had accelerated to 10 kt. When satellite confirmed the radar movements, the 241800Z warning was amended to reflect the system's impending threat to southern Taiwan. During early afternoon of the 25th, Thelma crashed into Kao-hsiung harbor. The Chinese Weather Central reported that Kao-hsiung observed 86 kt peak winds accompanied by a 991.5 mb pressure minimum at 250939 local. Satellite, aircraft, radar, and synoptic data all indicated that the typhoon was small, but very intense. Most damage was confined to the direct path of Typhoon Thelma as the central mountain range of Taiwan drastically weakened the peripheral winds east of the typhoon's track.

After moving across southwestern Taiwan, Thelma began to weaken and move on a track slightly west of north. On the evening of the 25th, Thelma entered the Taiwan Straits, and on the following morning went ashore on mainland China, 30 nm north of Fu-Chou with 50 kt winds.

During her rampage over Taiwan, Thelma claimed more than 30 lives, injured thousands, and rendered an estimated 5000 homeless. The typhoon raped down 53 steel towers supporting high-tension power lines. The loss of power shut down more than one-half of the island's 45,000 factories. Taiwan's largest harbor of Kao-hsiung was virtually destroyed. All eight giant cranes used to load and unload cargo were badly damaged or destroyed. At least 17 ships capsized in the harbor. In her few short hours over southern Taiwan, Thelma left destruction amounting to several millions of dollars (U.S.). According to the Central Weather Bureau of Taiwan, Typhoon Thelma was the most destructive tropical cyclone to hit Taiwan in more than 80 years.

Typhoon Thelma's track is shown in Figure 6.8.

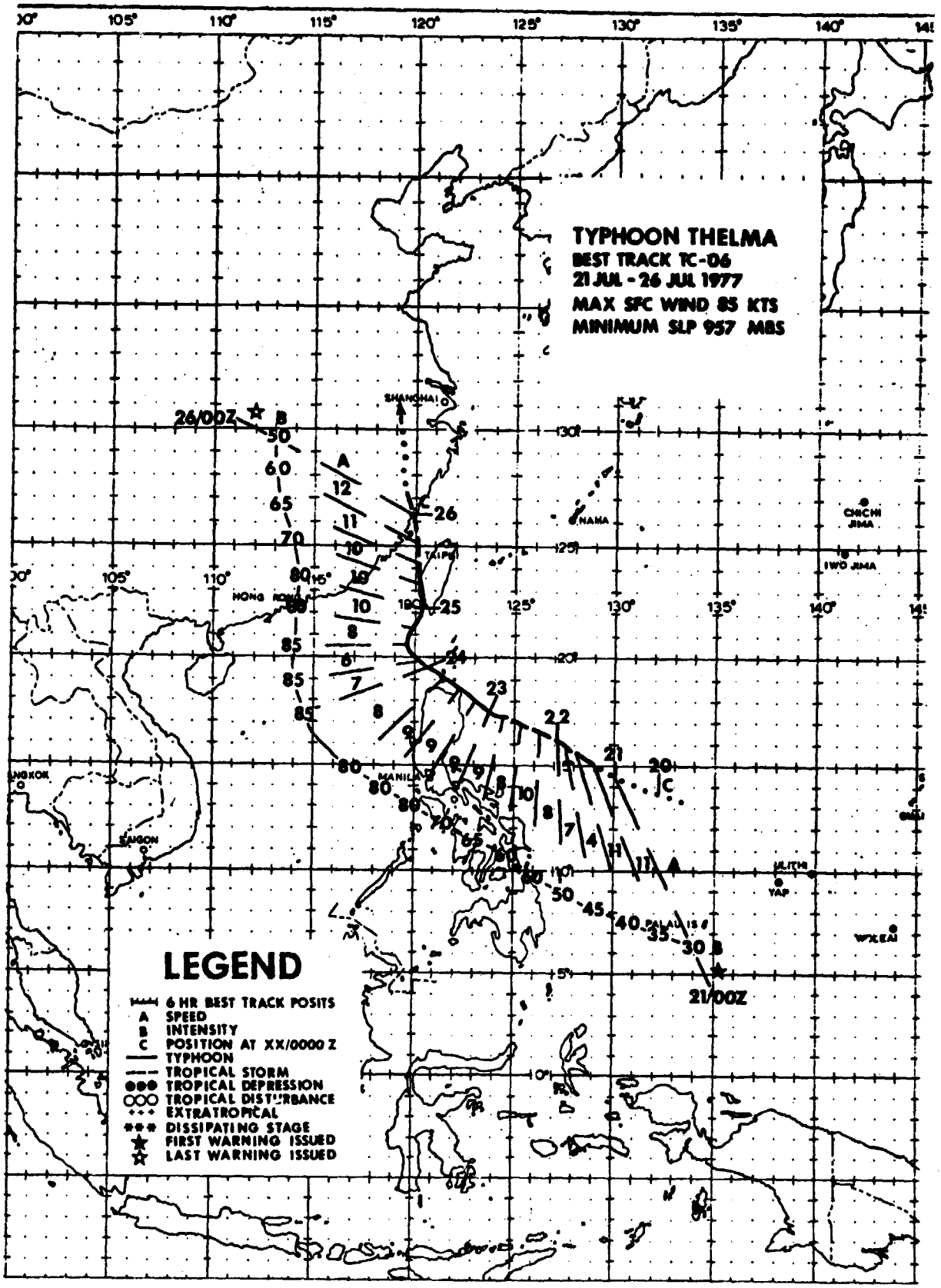

TYPHOON THELMA
BEST TRACK TC-06
21 JUL - 26 JUL 1977
MAX SFC WIND 85 KTS
MINIMUM SLP 957 MBS
26/00Z
21/00Z
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SHANGHAI
NAHA
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
SAIGON
YAP
WAKE

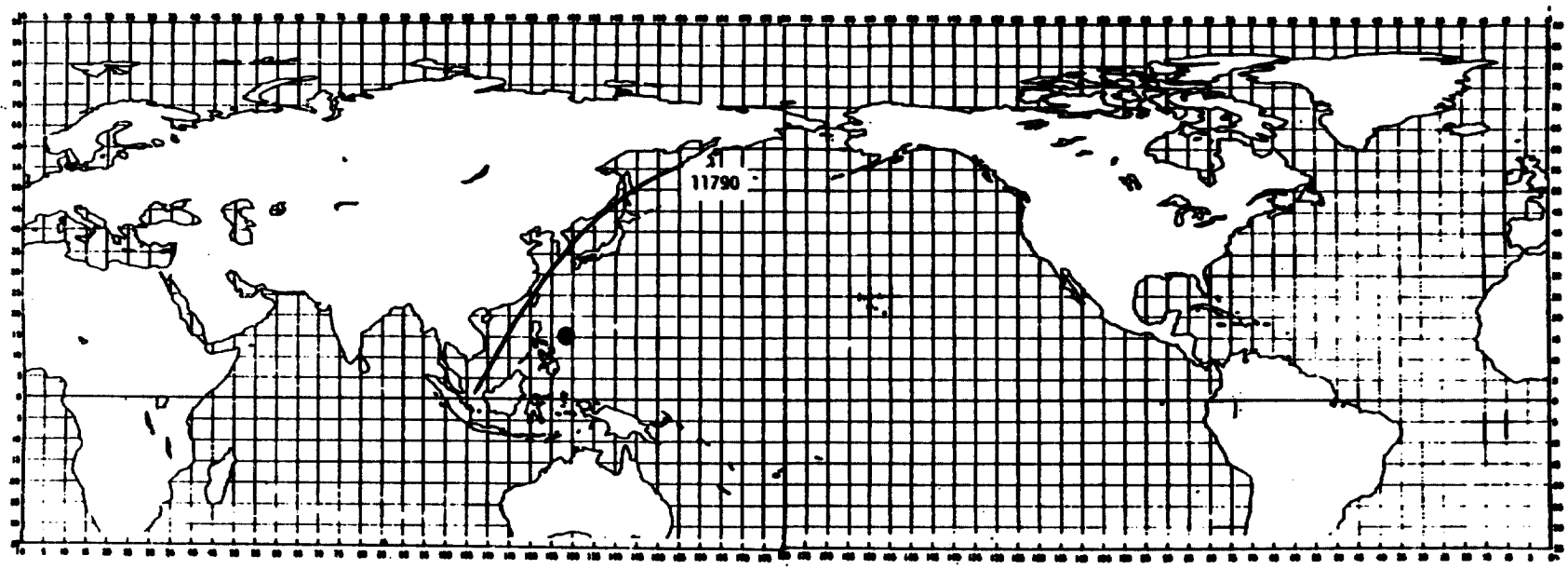
Figure 6.8

STORM: TYPHOON THELMA

DATE: July 21-26, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
7/21	0000Z	14.6N	130.1E		30	Tropical Depression
	0600Z	15.1	129.0		35	Tropical Storm
	1200Z	15.6	128.1		40	
	1800Z	15.8	127.7		45	
7/22	0000Z	16.2N	127.1E		50	Tropical Storm
	0600Z	16.6	126.3		60	
	1200Z	16.9	125.4		60	
	1800Z	17.2	124.6		65	Typhoon
7/23	0000Z	17.5N	123.8E		70	Typhoon
	0600Z	18.0	123.1		80	
	1200Z	18.6	122.4		80	
	1800Z	19.0	121.5		80	
7/24	0000Z	19.6N	120.7E		85	Typhoon
	0600Z	19.9	120.1		85	
	1200Z	20.4	119.7		85	
	1800Z	21.3	119.8		80	
7/25	0000Z	22.2N	120.2E		80	Typhoon
	0600Z	23.2	120.2		70	
	1200Z	24.2	120.1		65	
	1800Z	25.2	120.0		60	Tropical Storm
7/26	0000Z	26.3N	119.7E		50	Tropical Storm

TYPHOON THELMA - 7/21/77



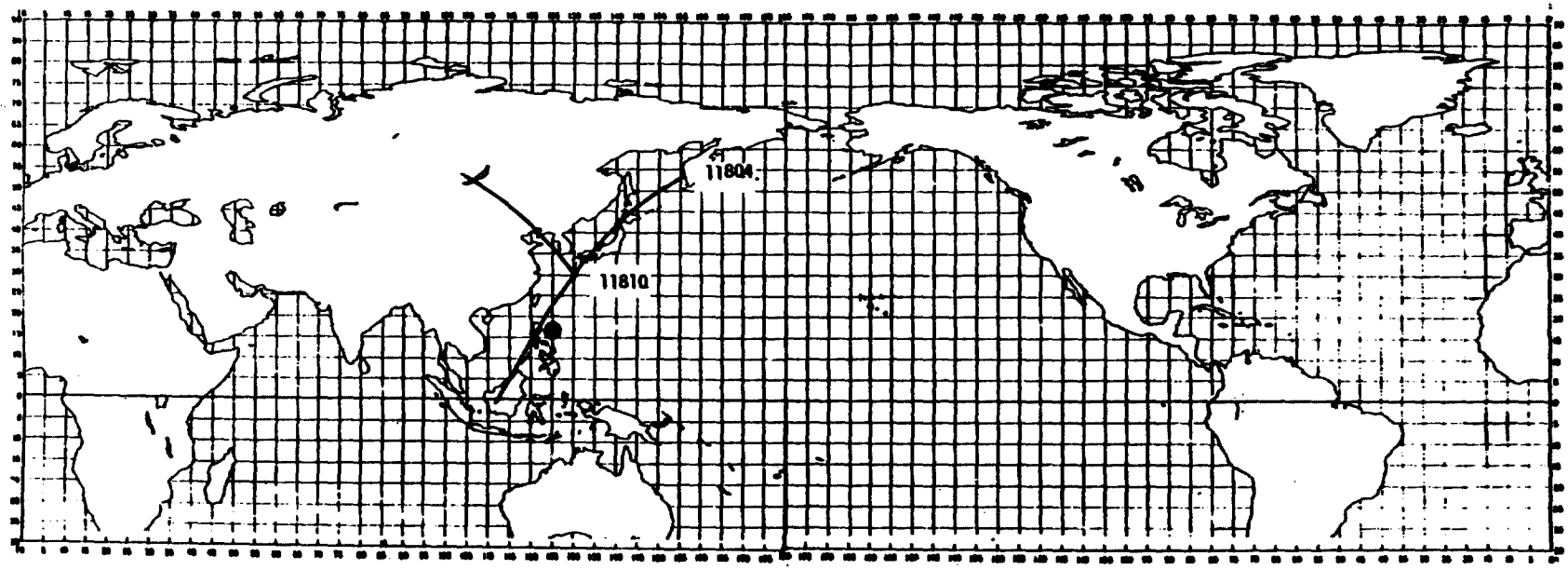
6.5-5

LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	14.6N	130.1E
0600Z	15.1	129.0
1200Z	15.6	128.1
1800Z	15.8	127.7

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
11790	293.67	075014	083400	093203	083941	808	131

TYPHOON THELMA - 7/22/77



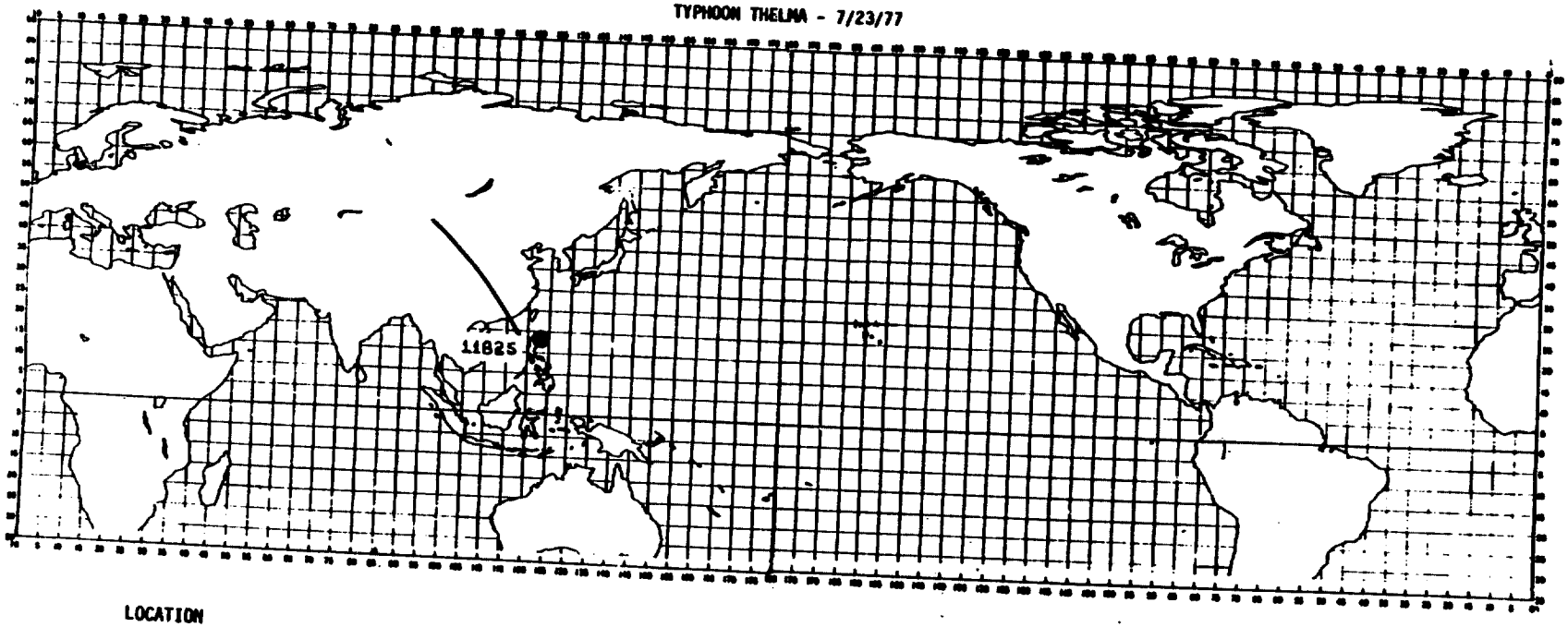
6.5-6

LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	16.2N	127.1E
0600Z	16.6	126.3
1200Z	16.9	125.4
1800Z	17.2	124.6

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
11810	147.22	174553	175600	175600	180326	808	139
11804	299.15	073511	082000	080832	082540	808	137

TYPHOON THELMA - 7/23/77

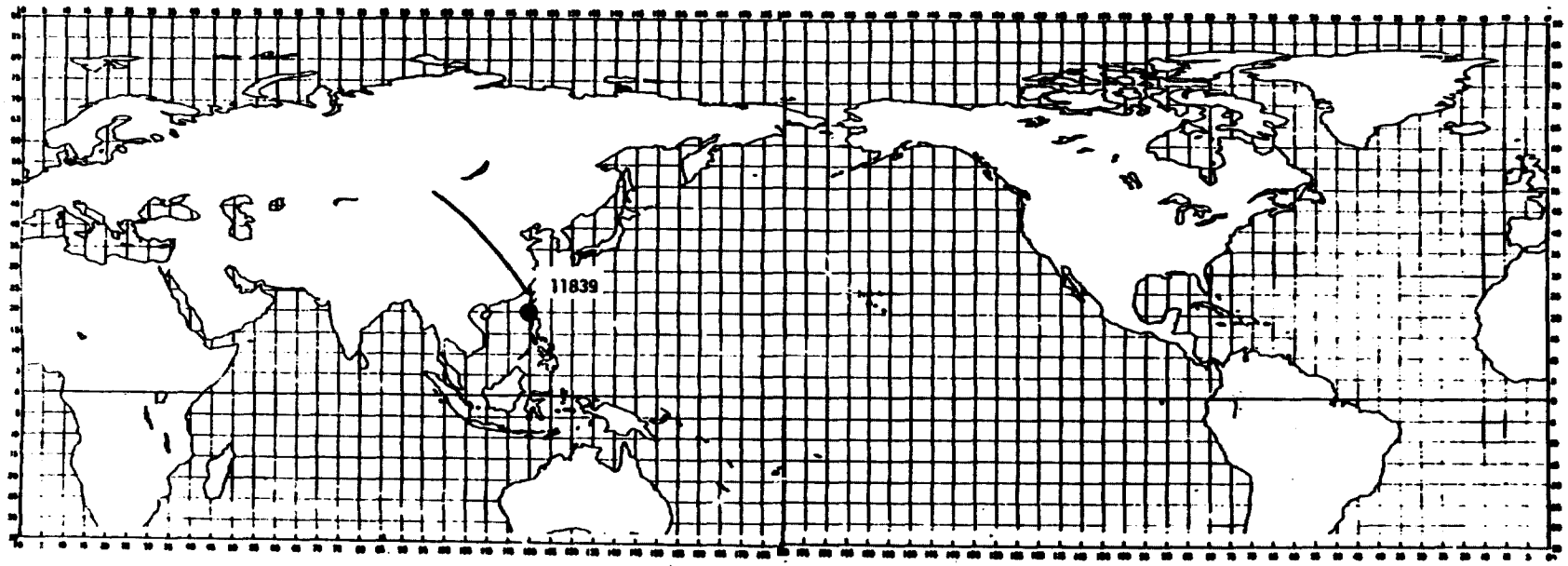


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	17.5N	123.8E
0600Z	18.0	123.1
1200Z	18.6	122.4
1800Z	19.0	121.5

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
11825	127.38	19136	191900	191900	192708	808	145

TYPHOON THELMA - 7/24/77



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	19.6N	120.7E
0600Z	19.9	120.1
1200Z	20.4	119.7
1800Z	21.3	119.8

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
11839	132.86	185734	190600	190600	191308	808	154

6.6

TROPICAL STORM WANDA

July 31-Aug. 4, 1977

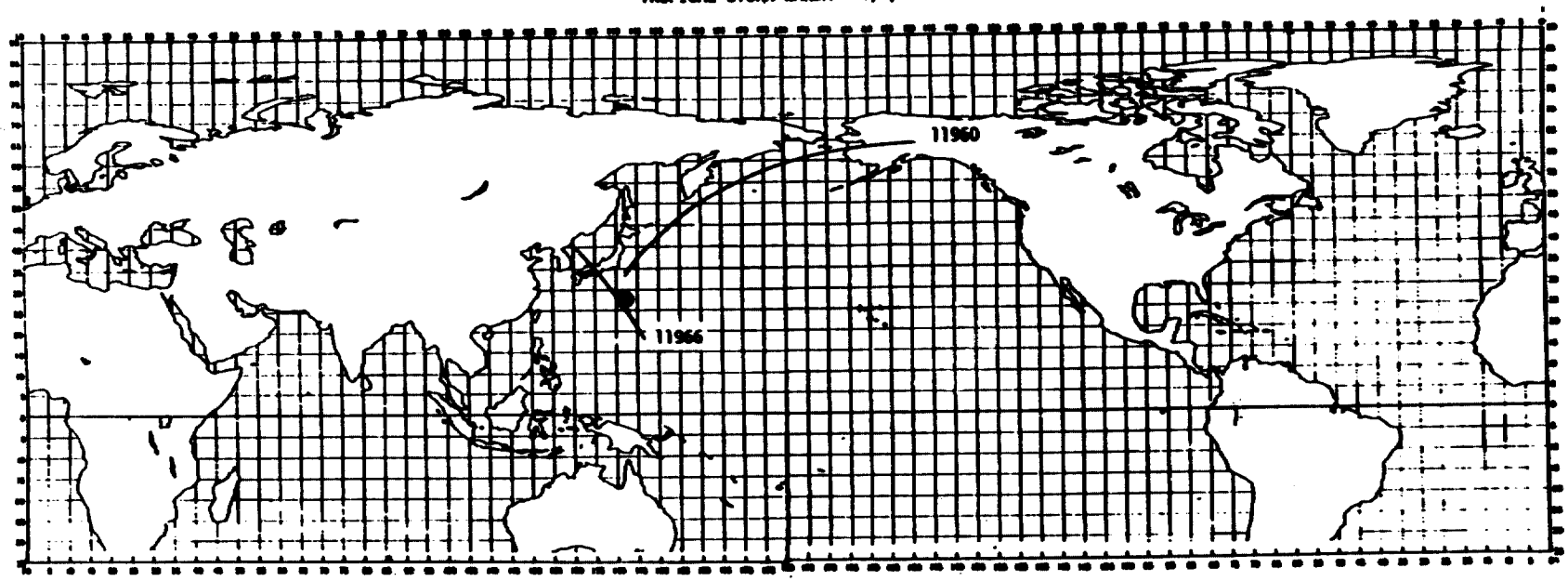
No descriptive information or track map was available for this storm.

STORM: TROPICAL STORM WANDA

DATE: July 31 - Aug. 4, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
7/31	0600Z	23.5N	140.9E		30	Tropical Depression
	1200Z	24.0	140.9		30	
	1800	24.5	140.8		30	
8/1	0000Z	25.1N	140.6E		35	Tropical Storm
	0600Z	25.7	140.3		35	
	1200Z	26.5	140.7		35	
	1800Z	27.2	140.8		35	
8/2	0000Z	27.7N	140.4E		35	Tropical Storm
	0600Z	27.7	141.4		35	
	1200Z	28.4	142.6		35	
	1800Z	29.1	143.2		40	
8/3	0000Z	30.0N	143.5E		45	Tropical Storm
	0600Z	30.4	144.2		45	
	1200Z	30.5	145.0		40	
	1800Z	30.8	145.7		35	
8/4	0000Z	31.2N	146.3E		30	Tropical Depression
	0600Z	31.5	146.8		30	

TROPICAL STORM WANDA - 8/2/77



6.6-3

LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	27.7N	140.4E
0600Z	27.7	141.4
1200Z	28.4	142.6
1800Z	29.1	143.2

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
11960	308.83	081312	085300	083933	085259	808	121
11966	156.90	182354	183300	183008	183627	808	124

6.7 SUPER TYPHOON BABE

September 2-10, 1977

During August 1977, no typhoons were observed. The JTWC significant Tropical Weather Advisory of 31 August stated, "the probability is that the remainder of 1977 should see an increase in typhoon activity." The next day, September 1, the seedling of the year's 10th tropical cyclone and the only super typhoon was first observed. Babe was a very challenging storm in that during her lifetime she threatened virtually every major DoD facility in the western North Pacific.

Satellite data on the 1st at 0143Z and 0000Z synoptic data indicated a weak surface circulation with associated convection near 7N,150E. Based on this data, a Tropical Cyclone Formation Alert was issued. At this time, there was a tropical upper tropospheric trough (TUTT) present at 200 mb to the north of the alert area. The TUTT maintained its position through the 3rd at 0000Z and the divergence on the southern side of the TUTT aided in the development of the seedling into Tropical Depression 10 (TD 10).

The first warning on TD 10 was issued on the 2nd at 0000Z. An aircraft fix on the 2nd at 0052Z estimated the maximum surface wind to be 40 kt. On the following warnings (0600Z), TD 10 was upgraded to Tropical Storm Babe. With the TUTT circulation providing fair outflow conditions aloft, Babe slowly intensified as she moved westward across the warm Philippine Sea. Babe was being steered at this time by a well developed mid-tropospheric subtropical ridge which extended from the dateline into central China. With this westward movement expected to continue, Babe was forecast to cross the Republic of the Philippines and pose a threat to Subic Bay and Clark AB. The westward movement continued until the 5th at 0000Z when signs of a change in direction of movement first appears. Between the 2nd and the 4th, Babe had an average speed of 14 kt. By the 4th at 1200Z, the speed had dropped to 8 kt, further dropping to 5 kt in the following 12 hours.

On the 5th at 0000Z, an upper air trough in the mid-latitude westerlies appeared over northeastern Asia. A weakness in the subtropical ridge between the trough and Babe became evident and increased the probability of a more northerly storm track. A change in Babe's direction of movement was first noted by satellite data at 2155Z on the 5th and confirmed by aircraft reconnaissance at 2243Z.

Taiwan, which was still recovering from the effects of earlier typhoons, Thelma and Vera, was now threatened again. Aircraft data between the 5th at 0832Z and the 7th at 2204Z showed Babe to have undergone rapid deepening with the central pressure dropping from 988 mb to 907 mb, a rate of 1.3 mb/hr. This rapid deepening was in response to the divergent southwesterly flow ahead of the strong upper air trough now stretching from east of Japan into central Taiwan, which provided a strong outflow channel aloft. Babe was upgraded to a typhoon on the 6th at 0000Z and a super typhoon on the 8th at 0000Z.

Up until 0000Z on the 8th, Babe was still forecast to cross Taiwan and then dissipate in mainland China prior to full recurvature. On the 7th at 1200Z, however, another upper air trough moved into northern China. This short wave additionally weakened the mid-tropospheric ridge over southeastern China. A low soon developed in this trough over Korea indicating the trough would move slowly and possibly deepen. This increased the probability that Babe would recurve much earlier than expected. This came to pass and Taiwan was relieved. Okinawa and Japan now faced the fury of Babe. Aircraft and radar data showed Babe began recurvature to the northeast after the 8th at 0600Z and while weakening at a rate of 5 kt/6 hr. Conditions of readiness were set for southern Japan and aircraft evacuated Kadena AB for appropriate "safe haven" locations.

During Babe's north-northeastward transit, the upper air low which had formed over Korea moved south-southwestward, deepened and cut-off from the main upper air trough. This allowed ridging to the east and northeast of Babe to build east-west to the north of Babe and the cut-off low steering Babe toward Korea, and eventually Shanghai. Evidence of a Juhiwhara type effect between Babe's circulation and the cut-off low also appeared. Babe finally steered around the northern periphery of the cut-off low and hit the People's Republic of China just north of Shanghai on the 11th at 0000Z with surface winds of 65 kt.

The greatest damage from super typhoon Babe occurred after she recurved and headed for Japan. Newspaper reports described Babe as "the worst typhoon to threaten Japan in 18 years." Babe struck the Japanese island of Okino-Erabu with winds of 135 kts injuring 45 people and destroying 1600 homes. Kadena AB recorded maximum sustained winds of 36 kt on the 9th and a peak gust of 60 kt at 1328Z. Babe also disrupted maritime activities sinking a Panamanian

freighter with 16 reported dead or missing and damaging approximately 100 Japanese fishing vessels which sought safety in the East China Sea.

Typhoon Babe's track is shown in Figure 6.9.

STORM: SUPER TYPHOON BABE

DATE: Sept. 2-10, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/2	0000Z	8.3N	144.6E		30	Tropical Depression
	0600Z	8.5	143.0		35	Tropical Storm
	1200	8.9	141.5		35	
	1800Z	9.4	140.1		40	
9/3	0000Z	9.8N	138.7E		40	Tropical Storm
	0600	10.4	137.3		45	
	1200	10.7	136.0		50	
	1800Z	10.7	135.0		55	
9/4	0000Z	10.7N	134.1E		60	Tropical Storm
	0600Z	10.8	133.3		60	
	1200Z	10.8	132.4		60	
	1800Z	10.9	131.9		60	
9/5	0000Z	11.0N	131.5N		60	Tropical Storm
	0600Z	10.9	131.0		60	
	1200Z	11.1	130.3		60	
	1800Z	12.1	130.3		60	
9/6	0000Z	13.2N	130.1E		65	Typhoon
	0600Z	14.2	129.7		70	
	1200Z	15.2	129.1		75	
	1800Z	15.9	128.8		80	
9/7	0000Z	16.7N	128.6E		85	Typh
	0600Z	17.7	128.3		95	
	1200Z	18.5	127.8		115	
	1800Z	19.5	127.5		115	
9/8	0000Z	20.5N	127.3E		130	Super Typhoon
	0600Z	21.4	126.8		130	
	1200Z	21.9	126.8		130	
	1800Z	22.6	127.4		125	Typhoon
9/9	0000Z	23.6N	128.0E		120	Typhoon
	0600Z	25.0	128.6		115	
	1200Z	26.9	128.7		110	
	1800Z	29.2	127.9		105	

STORM: SUPER TYPHOON BABE

DATE: (cont.)

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/10	0000Z	30.7N	125.3E		105	Typhoon
	0600Z	30.9	124.2		95	
	1200Z	31.2	123.3		85	
	1800Z	31.5	122.3		70	

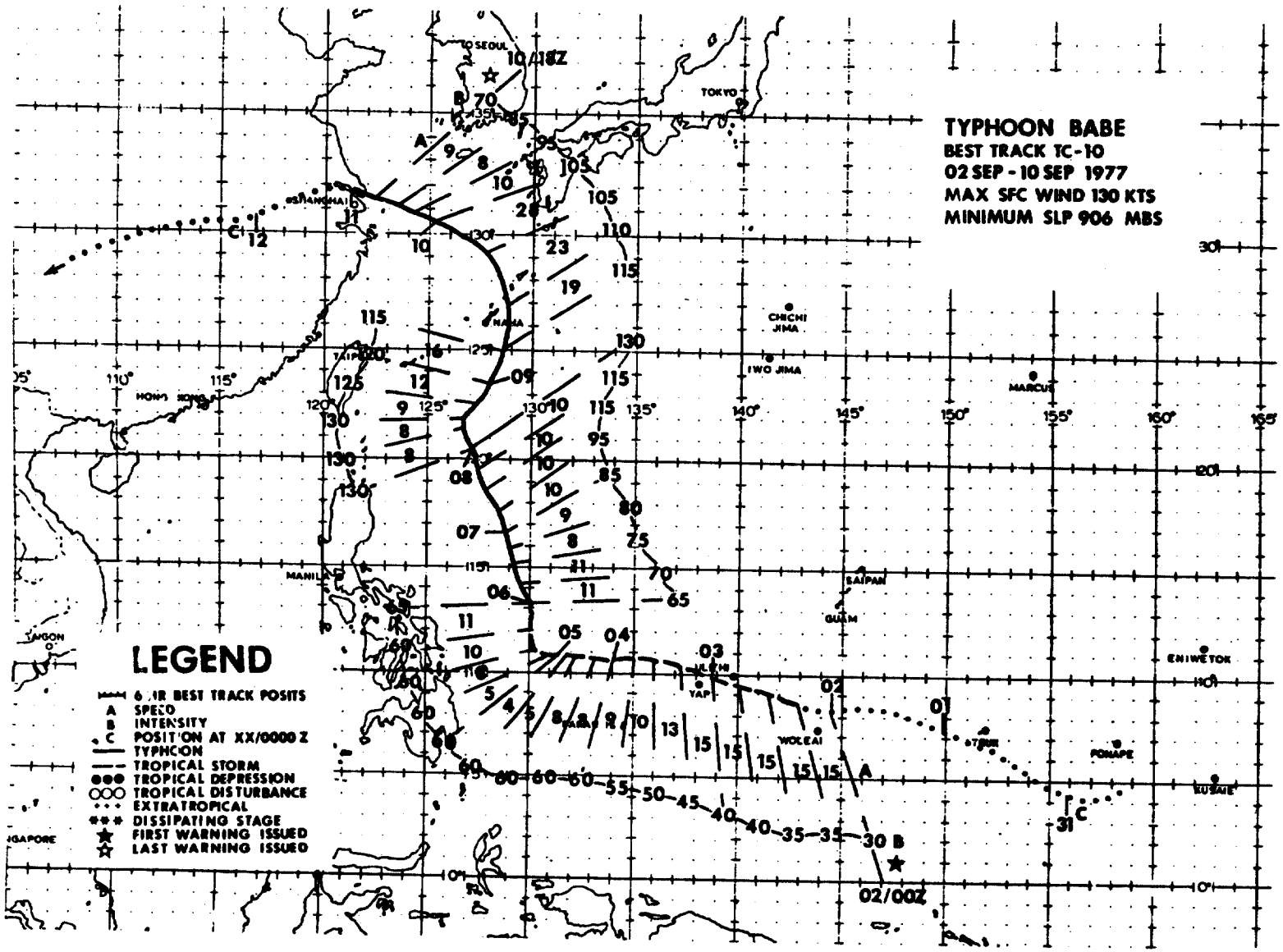
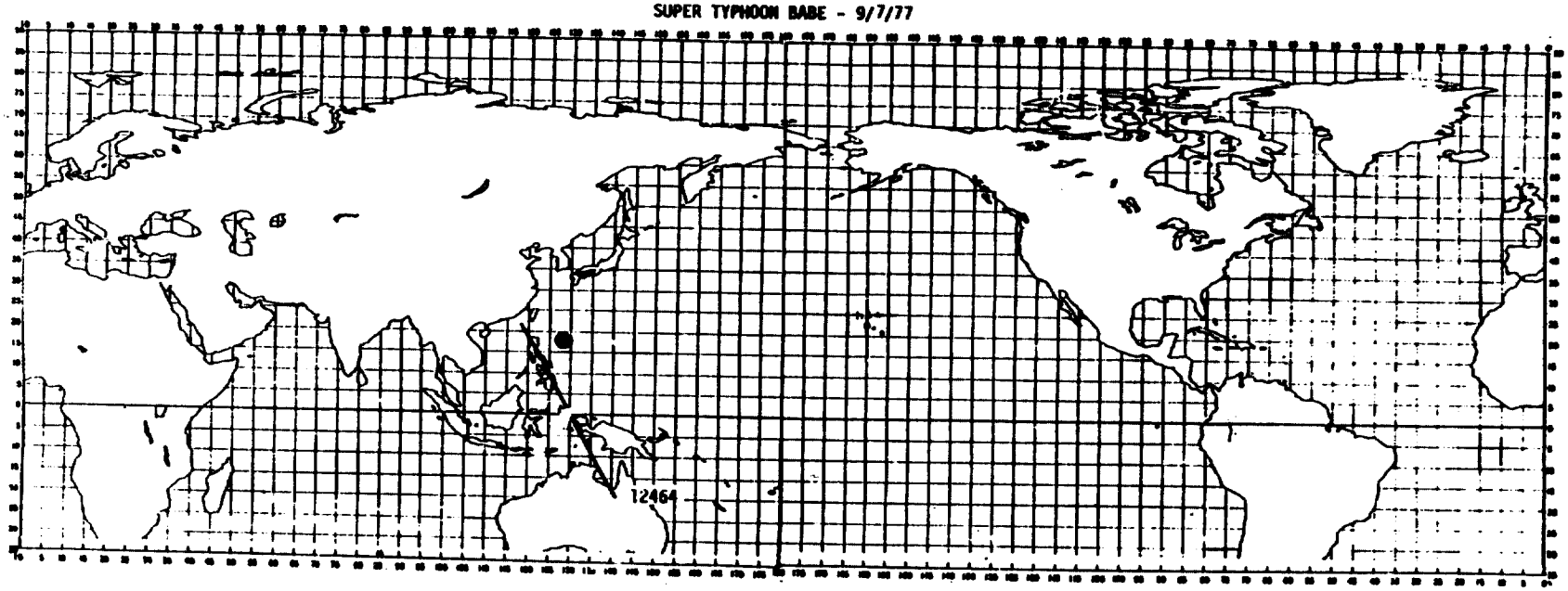

TYPHOON BABE
BEST TRACK TC-10
02 SEP - 10 SEP 1977
MAX SFC WIND 130 KTS
MINIMUM SLP 906 MBS
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SEOUL
TOKYO
SHANGHAI
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
HONG KONG
MANILA
SAIPAN
GUAM
YAP
WOLEAI
TRUK
PONAPE
KUSAIE
ENIWETOK
SINGAPORE
02/00Z

Figure 6.9

SUPER TYPHOON BABE - 9/7/77



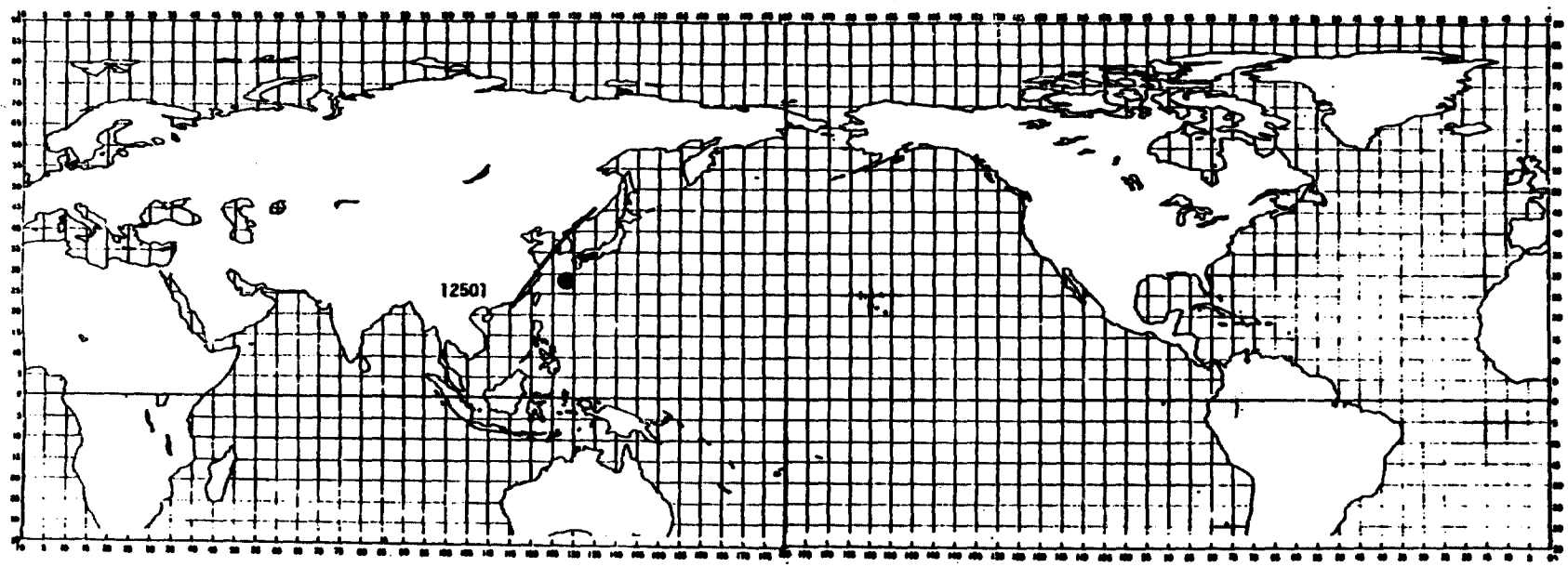
6.7-7

LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	16.7N	128.6E
0600Z	17.7	128.3
1200Z	18.5	127.8
1800Z	19.5	127.5

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
12464	146.23	231122	005700	004800	010000	802	125

SUPER TYPHOON BABE - 9/9/77



6.7-8

LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	23.6N	128.0E
0600Z	25.0	128.6
1200Z	26.9	128.7
1800Z	29.2	127.9

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.ID
12501	289.35	135718	143700	143400	144100	802	156

6.8

TYPHOON DINAH

September 14-23, 1977

Dinah, the 5th typhoon of 1977, displayed the most unusual behavior. While over the South China Sea, the storm executed two hairpin turns and one loop before meandering over Southeast Asia during dissipation. Dinah's development, however, was a more normal sequence of events.

"Super" Typhoon Babe's extensive circulation system aided the monsoon trough to move north of its normal location. After Babe dissipated over eastern China, the monsoon trough extended from Southeast Asia to the Mariana Islands along 20 degrees north latitude. South of the trough, deep southwesterly flow produced localized gale force winds and extensive areas of thundershower activity. North of the trough, steady easterlies prevailed. Although the opposing currents produced considerable cyclonic shear and relative vorticity within the trough, the counter proauctive northeasterlies in the upper troposphere produced enough vertical shear to prevent significant tropical cyclone development. Meteorological satellite data during this 2nd week of September period showed several loosely organized areas of convection within the monsoon trough. On the 12th, synoptic data located a low level circulation center 400 nm north of Guam. Maximum intensity near the center was estimated to be 20 kt while localized gale force winds continued within the southwest monsoon current to the southern and eastern periphery of the monsoon trough. (Islanders in the southwest flow could not believe there was not a tropical storm or typhoon nearby.)

The circulation center initially moved northwestward at an average speed of 16 kt. Synoptic reports and satellite imagery revealed a tropical upper-tropospheric trough (TUTT) oriented east west and just north of the position of the low to mid-level monsoon trough. By 1200Z on the 12th, a westward moving cyclone within the TUTT became positioned northeast of the surface disturbance. This orientation relieved much of the previously inhibiting vertical shear and provided an area of divergence aloft. This new flow pattern permitted the surface disturbance greater vertical growth and intensification. Satellite data soon identified a distinct vortex which separated from the areas of southwest monsoon cloudiness. At 0100Z on the 14th, a formation alert was issued. The disturbance now moved westward as it entered the steering influence of an anticyclone over the East China Sea. Satellite pictures soon

showed larger and better developed banding features. Since corresponding surface reports also indicated intensification, the first warning was issued for TD 12. Post analysis, however, found that the disturbance had achieved tropical depression intensity by 1800Z on the 13th and tropical storm stage by 0000Z on the 14th. This was the period of maximum TUTT interaction. Because of the favorable conditions present during this time, another disturbance about 300 nm north of Guam developed into Tropical Storm Emma.

As TD 12 grew and became Tropical Storm Dinah, the pressure gradient between the storm and the subtropical ridge increased. The associated easterly steering currents correspondingly increased and accelerated Dinah to a maximum speed of 19 kt. An intensifying, mid-tropospheric high over eastern China was now the primary source of these easterlies. As this high pressure cell continued to build, Dinah was steered in a southwesterly direction towards the Republic of the Philippines. Forward speed decreased as the gradient slackened. Steady intensification continued as upper level outflow was well established in all quadrants. This trend persisted until Dinah reached minimum typhoon strength at 0600Z on the 15th just 100 nm off northern Luzon. With a maximum intensity of 55 kt, the storm entered Luzon 35 nm south of Escarpada Point at 1500Z on the 15th. That evening Dinah passed near Tuguegarao, a station in northeastern Luzon which experienced 96 kt peak winds and a mean sea level pressure of 977.0 mb.

Upon entering the South China Sea after 7 hours over land, Dinah weakened to 40 kt, but quickly reintensified to 50 kt winds within 14 hours. Headed west-southwestward, Dinah entered an area of weaker steering currents. The dominating anticyclone over China was beginning to weaken and mid-latitude westerlies began extending southward. By the 17th, the continued weakening of the steering currents caused the storm to slow to 9 kt movement.

For the next 4 days, Dinah exhibited unusual behavior. The weakening subtropical ridge over China broke down into a series of smaller high cells while the southwest monsoon deepened. Caught between these oscillating and opposing steering sources, Dinah abruptly turned northeast and then executed a loop during the 17th. As the southwest monsoon strengthened and became the dominant steering flow, the storm was directed northeastward toward Taiwan.

Intensification resumed as a result of the enhanced monsoon. The weakening subtropical ridge and increasing outflow aloft also contributed to Dinah's growth. By 1800Z on the 18th, typhoon strength was again achieved.

After being displaced north nearly 150 nm, movement slowed to 5 kt as Dinah's steering flow became less effective. By the 19th an advancing mid-latitude trough over China aided in steering Dinah eastward. Sustained winds of 65 kt persisted as satellite imagery at 1201Z on the 19th revealed an eye. At 0000Z on the 20th, Dinah reached a short-lived maximum intensity of 75 kt. Ever since Dinah's origin, the southwest monsoon was the major feeding current. By 0600Z, this flow was being diverted into the beginnings of Tropical Storm Freda in the Philippine Sea and Dinah began to weaken.

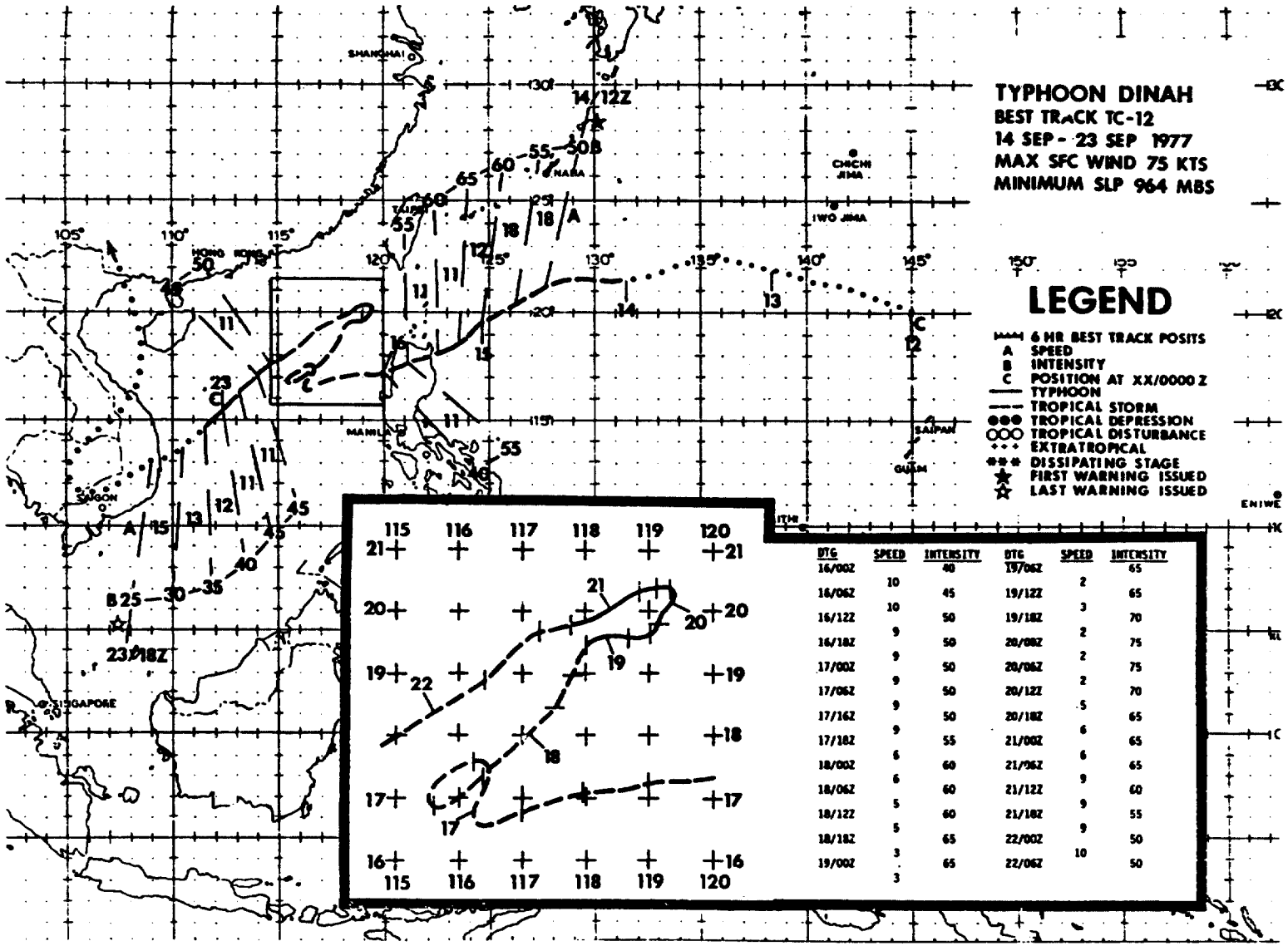
As the mid-latitude trough advanced over China, it did not dig south as forecast and a large high pressure area built in behind it. In response, Dinah did not continue eastward in advance of the trough; it slowed to 2 kt, turned westward, then southwestward being influenced by the intensifying high over China. Dinah was the first storm to be directly affected by an early autumn surge in the northeast monsoon.

The northeasterlies from the strong high over China controlled Dinah's movement for the next 2 days. Diminishing moist southwesterlies and increasing dry northeasterlies steadily weakened the storm. Dinah accelerated southwestward and reached south Vietnam as a weak tropical depression at 1700Z on the 23rd. JTWC's last warning was issued one hour later.

After landfall, Dinah, in its dissipating stage, persisted for 4 days. Tropical Storm Freda and the weakening of the northeast monsoon were the controlling agents in the last days of Dinah's unusual track. After crossing the South China Sea, Freda entered southern China drawing the southwest monsoon northward. Once again embedded in a southwest steering current, TD 12 (Dinah) journeyed northward through Cambodia, northeastward over the Gulf of Tonkin then northward into southern China and finally dissipated.

Dinah's sweep across northern Luzon caused loss of lives and property. Floods and landslides alone caused 15 deaths and 11 missing. Although Dinah remained a safe distance from mainland China while jogging unpredictably over the South China Sea, Hong Kong displayed the Stand By Signal No. 1 for a record 14 hour and 40 minutes.

Typhoon Dinah's track is shown in Figure 6.10.



DTG	SPEED	INTENSITY	DTG	SPEED	INTENSITY
16/00Z		40	19/06Z		65
16/06Z	10	45	19/12Z	2	65
16/12Z	10	50	19/18Z	3	70
16/18Z	9	50	20/00Z	2	75
17/00Z	9	50	20/06Z	2	75
17/06Z	9	50	20/12Z	2	70
17/12Z	9	50	20/18Z	5	65
17/18Z	9	55	21/00Z	6	65
18/00Z	6	60	21/06Z	6	65
18/06Z	6	60	21/12Z	9	60
18/12Z	5	60	21/18Z	9	55
18/18Z	5	65	22/00Z	9	50
19/00Z	3	65	22/06Z	10	50
	3				

Figure 6.10

STORM: TYPHOON DINAH

DATE: September 14-23, 1977

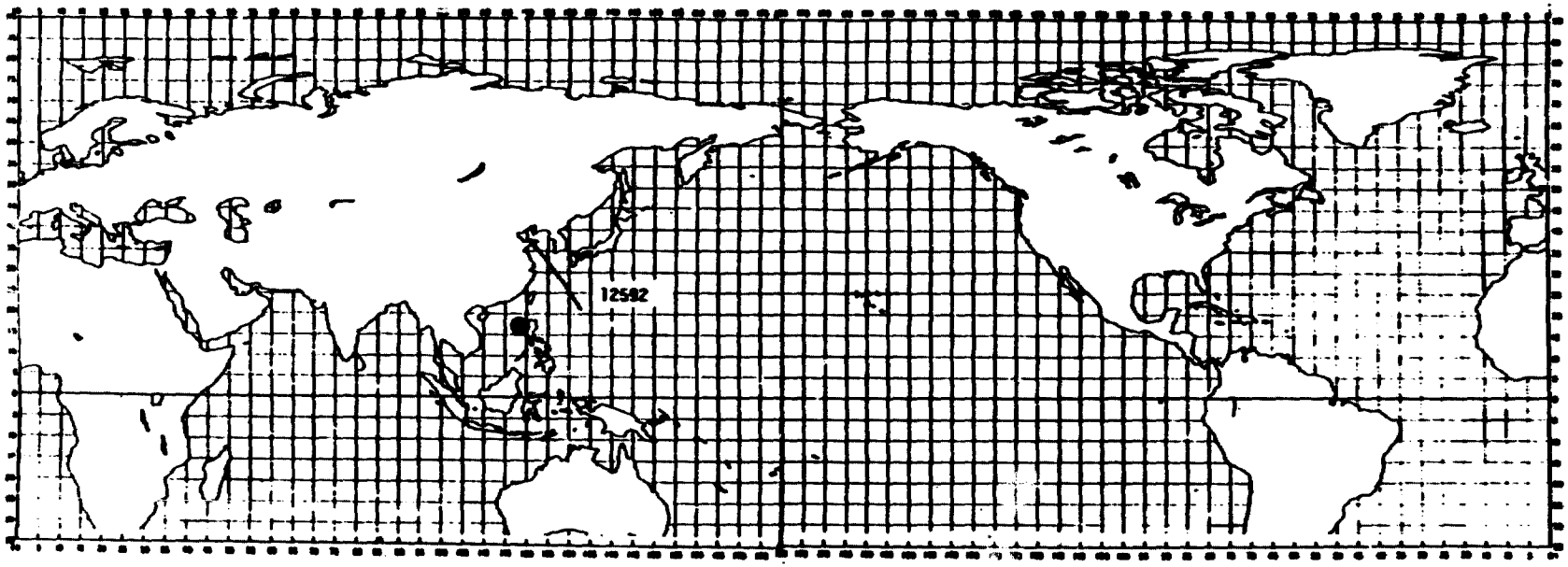
Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/14	1200Z	21.4N	127.8E		50	Tropical Storm
	1800Z	20.5	126.2		55	
9/15	0000Z	19.4N	124.6E		60	Tropical Storm
	0600Z	18.7	123.6		65	Typhoon
	1200Z	18.2	122.6		60	
	1800Z	17.8	121.1		55	
9/16	0000Z	17.3N	120.0E		40	Tropical Storm
	06000Z	17.2	119.0		45	
	1200Z	17.1	117.9		50	
	1800Z	16.8	117.0		50	
9/17	0000Z	16.8N	116.2E		50	Tropical Storm
	0600Z	17.5	116.2		50	
	1200Z	16.9	115.6		50	
	1800Z	17.3	116.3		55	
9/18	0000Z	18.0N	117.1E		60	Tropical Storm
	0600Z	18.4	117.5		60	
	1200Z	19.0	117.8		60	
	1800Z	19.4	118.0		65	Typhoon
9/19	0000Z	19.6N	118.4E		65	Typhoon
	0600Z	19.6	118.7		65	
	1200Z	19.6	119.0		65	
	1800Z	19.8	119.1		70	
9/20	0000Z	20.1N	119.3E		75	Typhoon
	0600Z	20.2	119.3		75	
	1200Z	20.2	119.1		70	
	1800Z	20.2	118.9		65	
9/21	0000Z	20.0N	118.4		65	Typhoon
	0600Z	19.8	117.8		65	
	1200Z	19.7	117.3		60	Tropical Storm
	1800Z	18.9	116.4		55	

STORM: TYPHOON DINAH

DATE: (cont.)

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
9/22	0000z	18.4N	115.7E		50	Tropical Storm
	0600Z	17.8	114.8		50	
	1200Z	17.1	113.9		45	
	1800Z	16.3	113.1		45	
9/23	0000Z	15.5	112.3E		40	Tropical Storm
	0600Z	14.7	111.4		35	
	1200Z	13.7	110.4		20	Tropical Depression
	1800Z	13.1	109.1		25	

TYPHOON DINAH - 9/16/77

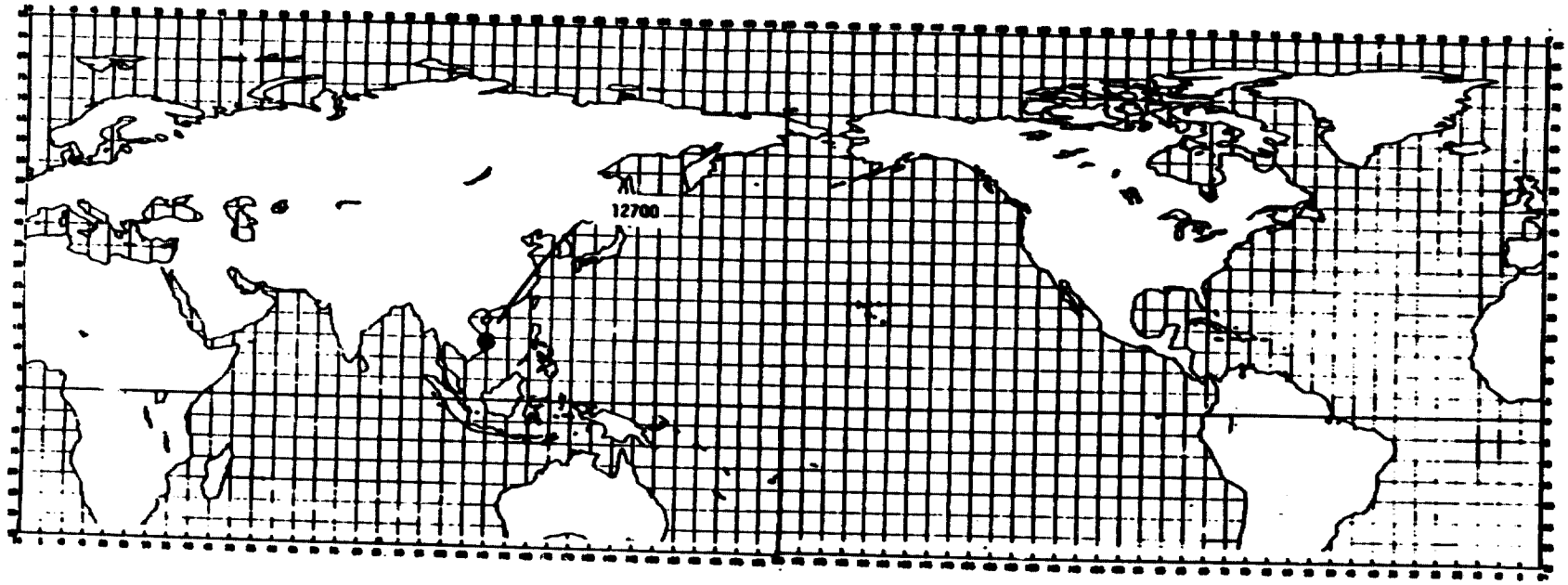


LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	17.3N	120.0E
0600Z	17.2	119.0
1200Z	17.1	117.9
1800Z	16.8	117.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
12592	145.00	001927	002800	002751	003039	808	170

TYPHOON DINAH - 9/23/77



6.8-8

LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	15.5N	112.3E
0600Z	14.7	111.4
1200Z	13.7	110.4
1800Z	13.1	109.1

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	RHTO.F
12700	290.17	153155	161600	160900	161600	808	163

7.0 CENTRAL NORTH PACIFIC AREA - 1978

The Central Pacific saw 1978 as the most active tropical cyclone year on record. The season also produced a cyclone (FICO) with an exceptional length of travel and persistence of hurricane intensity.

7.1 General

The data gathered was extracted from the Annual Typhoon Report of 1978. The 1978 tropical cyclones in the Central Pacific and their periods are listed below.

TYPE	NAME	DATE
Hurricane	FICO	17 Jul - 28 Jul (1)
Tropical Disturbance	10A	07 Aug - 09 Aug
*Hurricane	JOHN	23 Aug - 31 Aug (1)
*Tropical Storm	KRISTY	26 Aug - 28 Aug (1)
*Tropical Storm	LANE	20 Aug - 24 Aug (1)
*Tropical Storm	MIRIAM	28 Aug - 01 Sep (1)
Hurricane	SUSAN	18 Oct - 24 Oct

(Note 1 - These are also listed in Section 5 as they originated in that area and continued into this area). Figures 7.1 and 7.2 show the ground tracks for individual cyclones; Figure 7.3 shows on a daily basis Hurricane Fico as being one of the most intense cyclones of historical record. Results of the comparison of the cyclone information and the GEOS-3 schedule information indicates that four cyclones may have associated GEOS-3 altimeter data. These four are noted by an * in the above tabulation.

All information available for these four cyclones along with any promising GEOS-3 ground track maps are presented in the following sections.

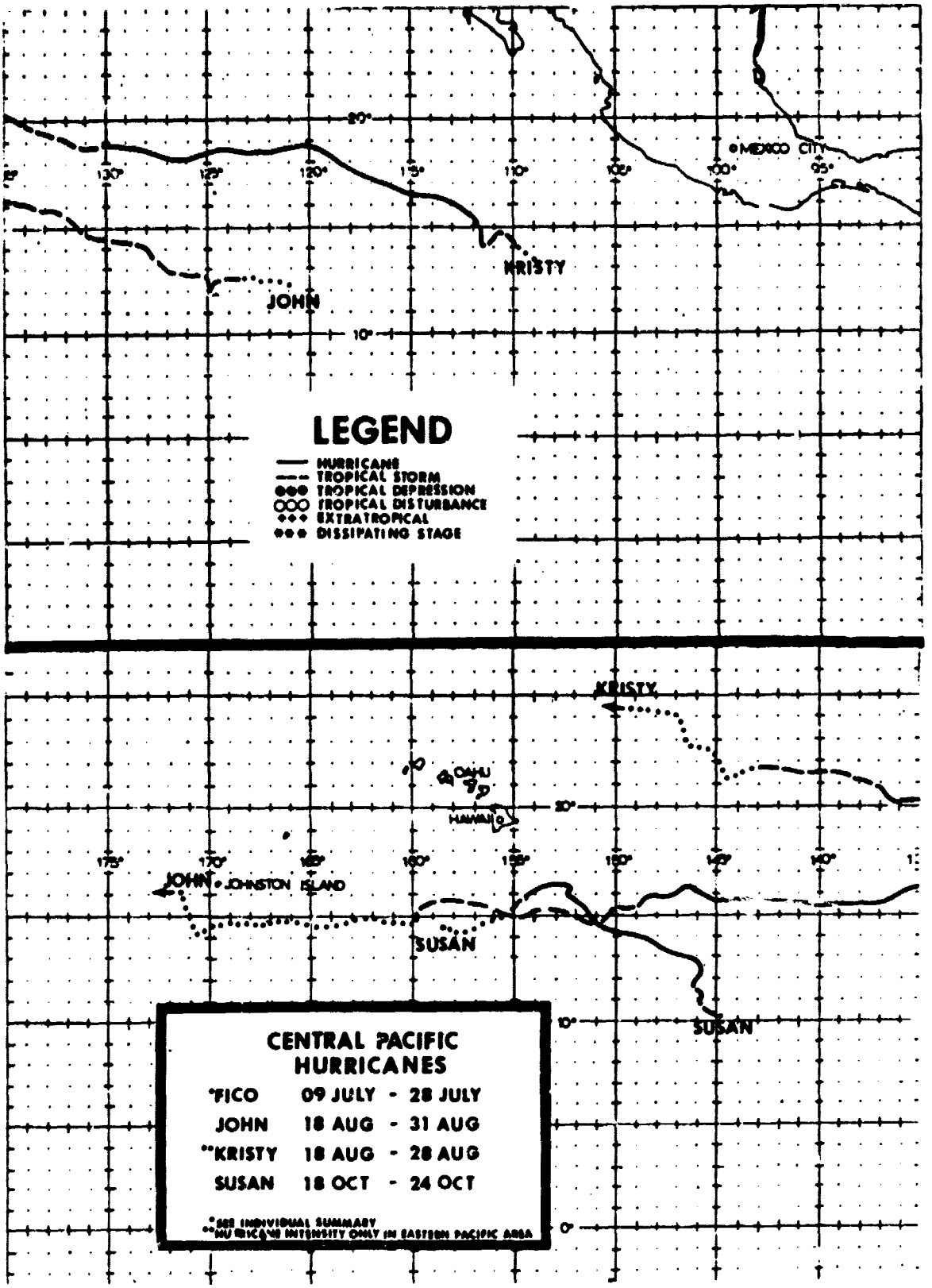

MEXICO CITY
KRISTY
JOHN
LEGEND
HURRICANE
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
KRISTY
OAHU
HAWAII
JOHN
JOHNSTON ISLAND
SUSAN
SUSAN
CENTRAL PACIFIC HURRICANES
*FICO 09 JULY - 28 JULY
JOHN 18 AUG - 31 AUG
**KRISTY 18 AUG - 28 AUG
SUSAN 18 OCT - 24 OCT
*SEE INDIVIDUAL SUMMARY
**HURRICANE INTENSITY ONLY IN EASTERN PACIFIC AREA

Figure 7.1

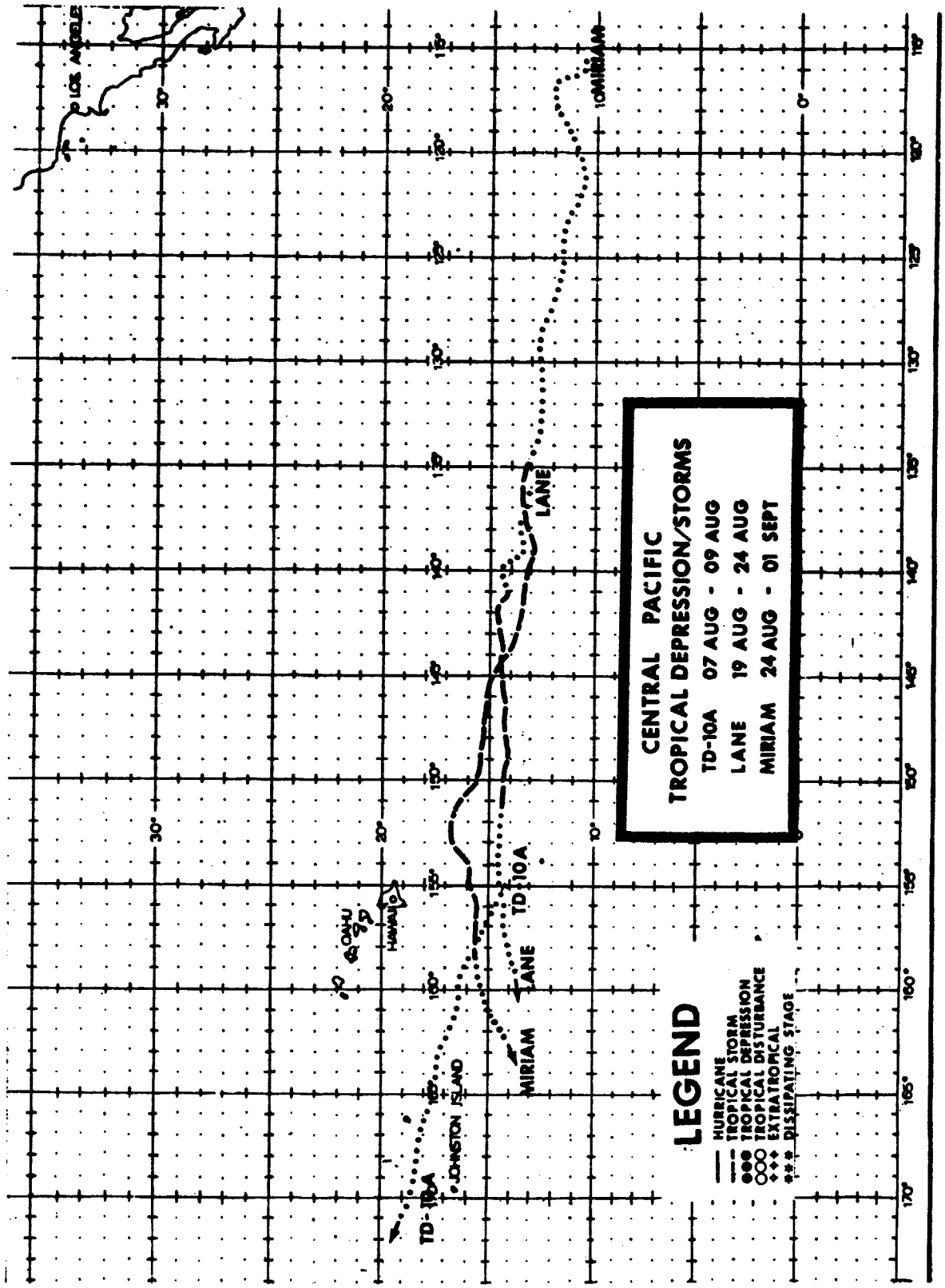

CENTRAL PACIFIC
TROPICAL DEPRESSION/STORMS
TD-10A 07 AUG - 09 AUG
LANE 19 AUG - 24 AUG
MIRIAM 24 AUG - 01 SEPT
LEGEND
HURRICANE
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
LOS ANGELES
HAWAII
OAHU
JOHNSTON ISLAND
TD-10A
LANE
MIRIAM

Figure 7.2

C-3

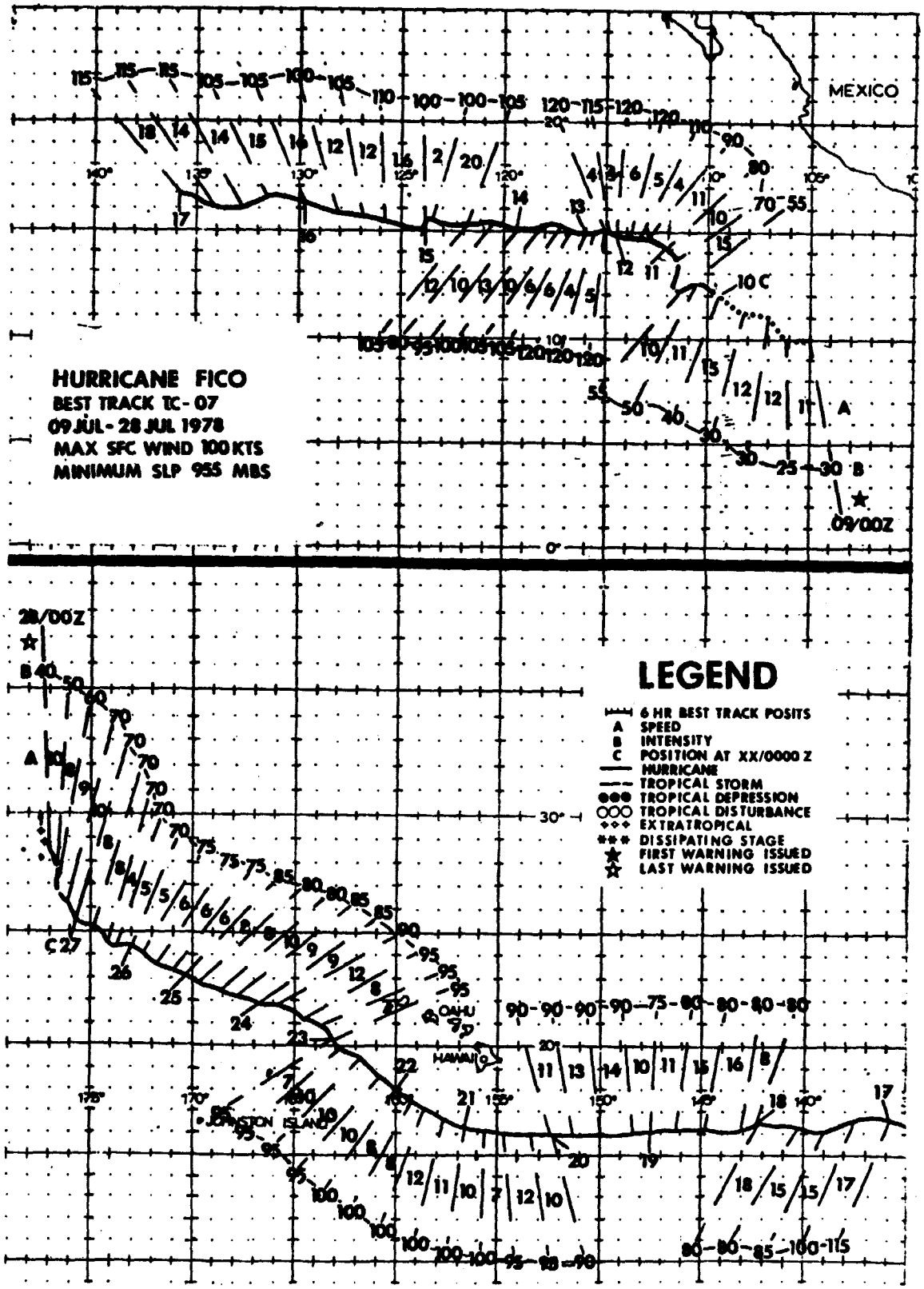

HURRICANE FICO
BEST TRACK TC-07
09 JUL - 28 JUL 1978
MAX SFC WIND 100 KTS
MINIMUM SLP 955 MBS
MEXICO
09/00Z
28/00Z
OAHU
HAWAII
JOHNSTON ISLAND
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
HURRICANE
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED

Figure 7.3

7.2

HURRICANE JOHN
August 23-31, 1978

Hurricane John was named at 0000 GMT, August 19, 1978. Hurricane John passed 300 n miles south of the Hawaiian Islands on August 27. The storm was downgraded to a tropical depression 400 n miles southwest of the Islands on August 28. The depression dissipated rapidly at 0000 GMT, August 31, near 15.9°N, 171.1°W or about 100 n miles southwest of Johnston Island.

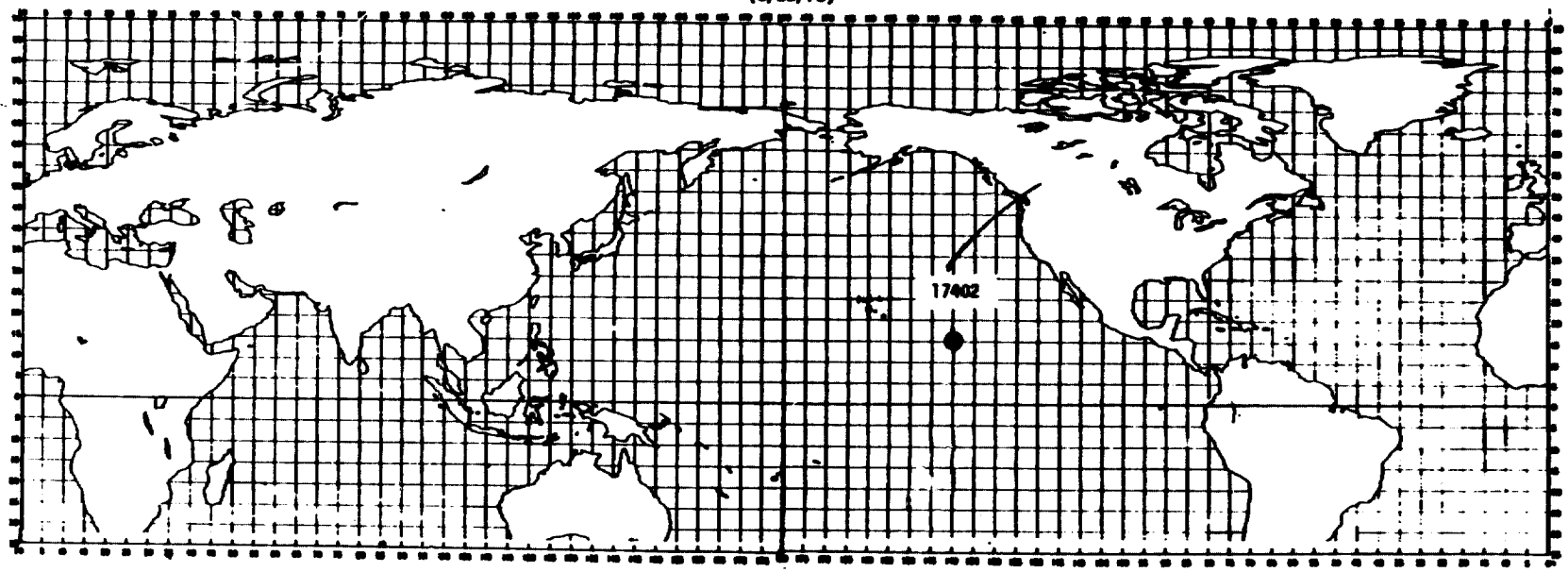
STORM: HURRICANE JOHN

DATE: Aug. 23 - Aug. 31, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
8/23		15.0N	140.0E			Tropical Storm
8/24		15.4N	141.6E		62	Tropical Storm
8/25		16.1N	146.1E		40	Hurricane
8/26		15.4N	149.2E		50	Tropical Storm
8/27		15.0N	152.5E		40	Tropical Storm
8/28		15.2N	156.8E		35	Tropical Storm
8/29		14.9N	159.7E		30	Tropical Depression
8/30		14.9N	166.0E		30	Tropical Depression
8/31		16.0N	172.0E			Tropical Depression

HURRICANE JOHN

(8/22/78)



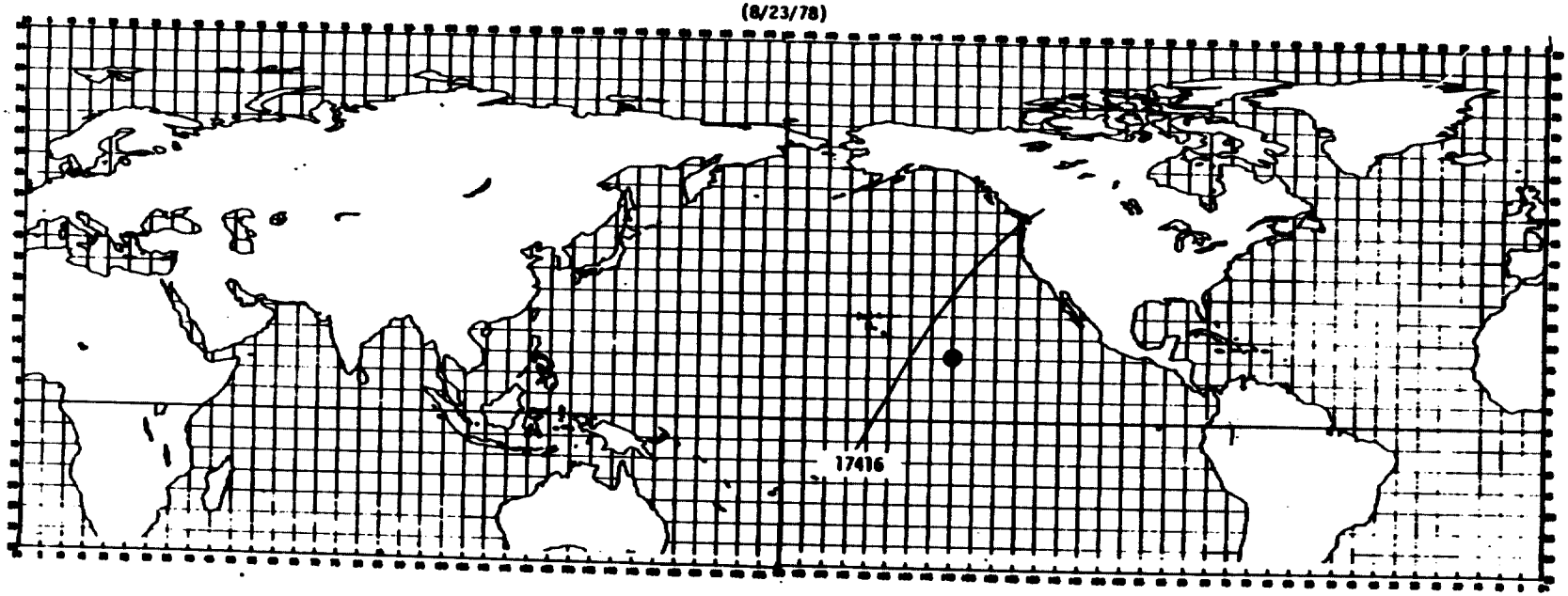
LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	15.0N	140.0E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	ORIG.#
17402	25.66	234252	002500	001712	02218	802	114

HURRICANE JOHN

(8/23/78)



7.2-4

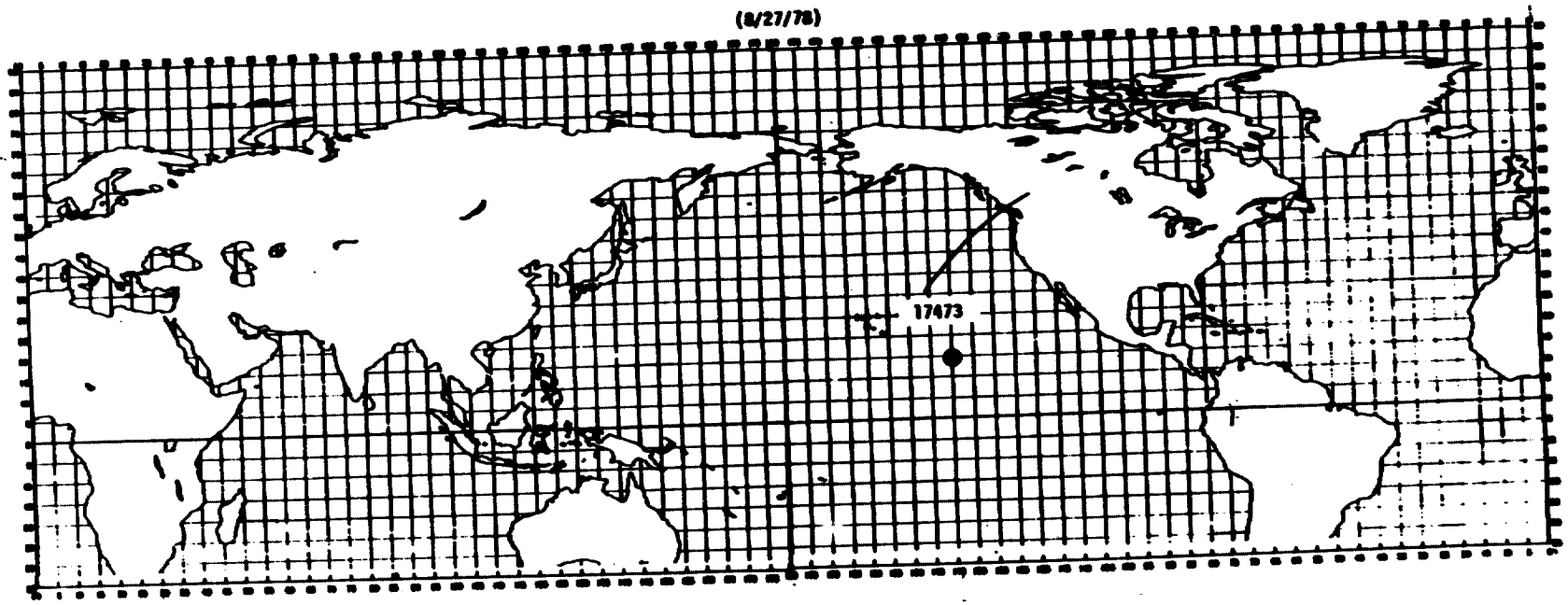
LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	15.0N	140.0E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	ORBIT #
17416	31.16	232746	001246	000259	001954	002	127

HURRICANE JOHN

(8/27/78)



7-25

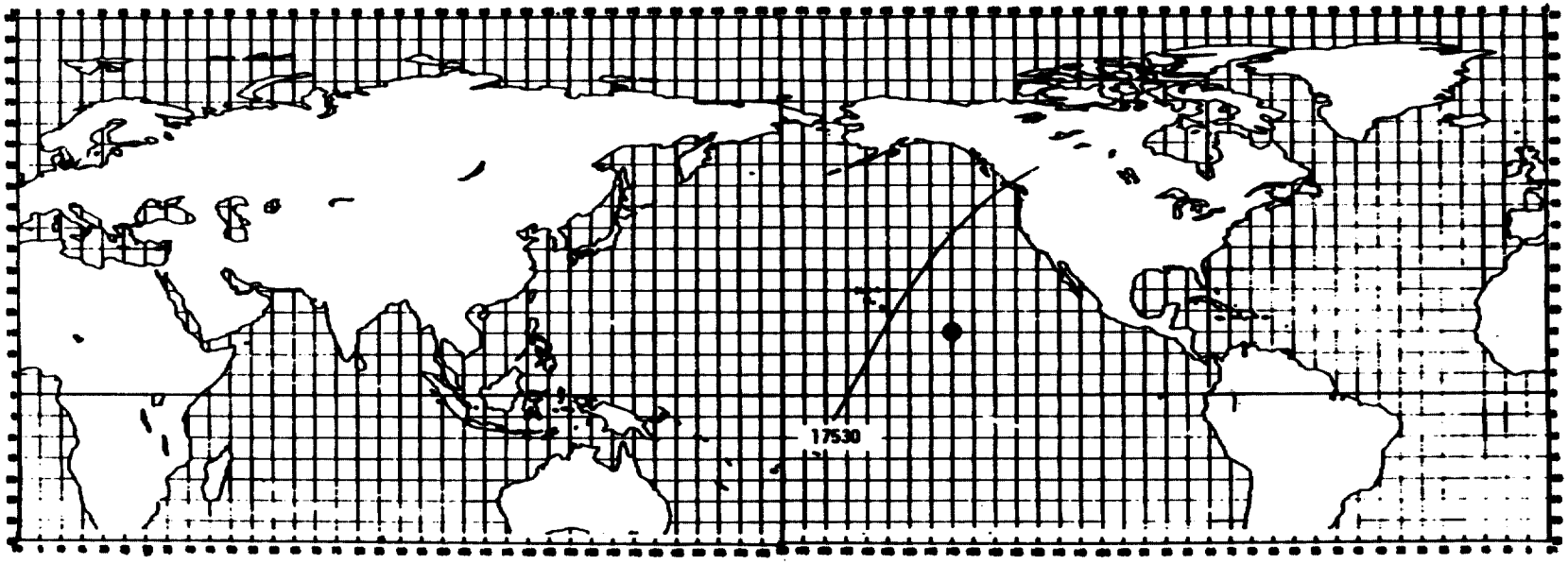
LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	15.0N	140.0E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	NODE	INCLN.
17473	27.83	000907	005307	004351	004856	002	170

HURRICANE JOHN

(8/31/78)



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	15.0N	140.0E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	ORBIT #
17530	24.50	005029	013329	012521	014157	002	131

7.3 TROPICAL STORM LANE
August 20-24, 1978

By 0000 GMT August 19, 1978, a disturbance near 13.2°N, 135.8°W was upgraded as a tropical depression. Winds increased to 35 kt by 1800 GMT, August 19, and the depression was upgraded to Tropical Storm Lane near 13.7°N, 139.0°W. Tropical Storm Lane moved 14.4°N, 139.8°W by 0000 GMT, August 20. Winds near the center had increased to 45 kt. As Lane moved west, it began to move over 78°F water and weaken. Winds decreased to 30 kt by August 22 and the storm was downgraded to a tropical depression. The final advisory on the cyclone was issued at 1800 GMT, August 23, with the center dissipating 280 n mi. south of the Island of Hawaii.

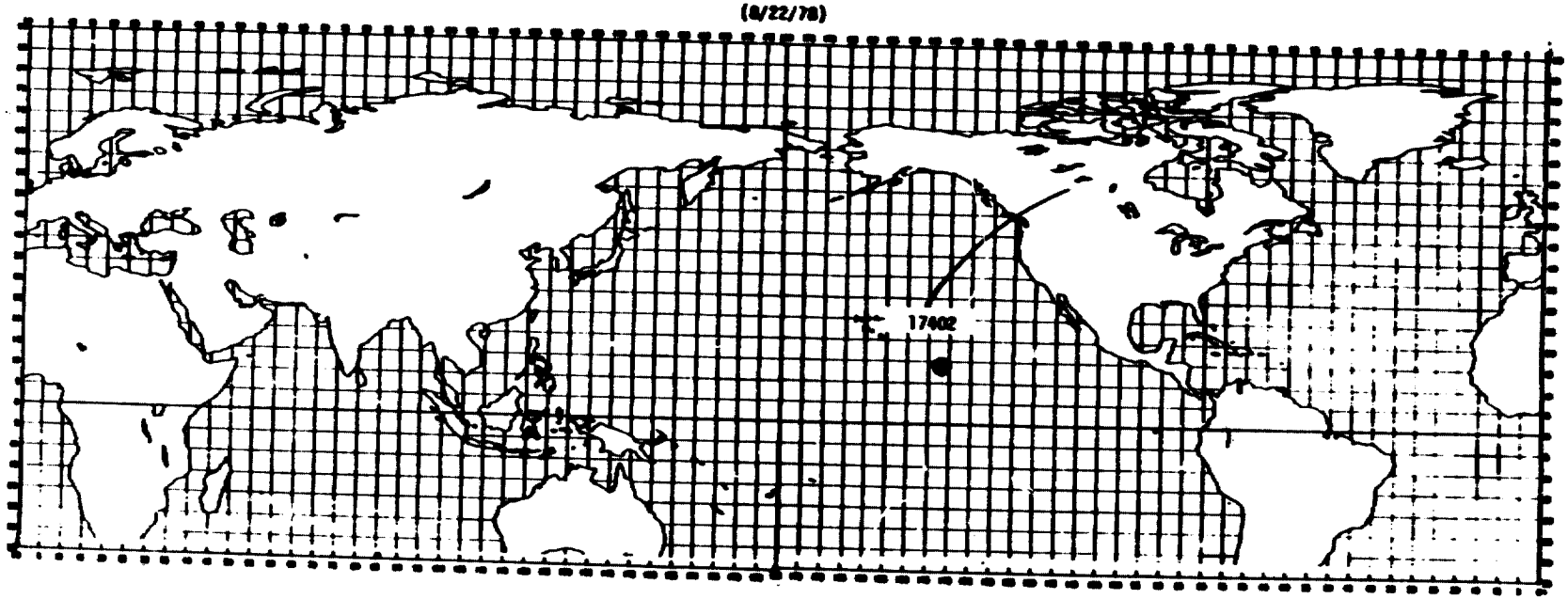
STORM: TROPICAL STORM LANE

DATE: Aug. 20 - 24, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
8/20		14.2N	141.0E		50	Tropical Storm
8/21		14.3N	144.8E		45	Tropical Storm
8/22		14.1N	149.0E		40	Tropical Storm
8/23		14.6N	154.3E		30	Tropical Depression
8/24		13.8N	158.9E		25	Tropical Depression

TROPICAL STORM LANE

(8/22/78)

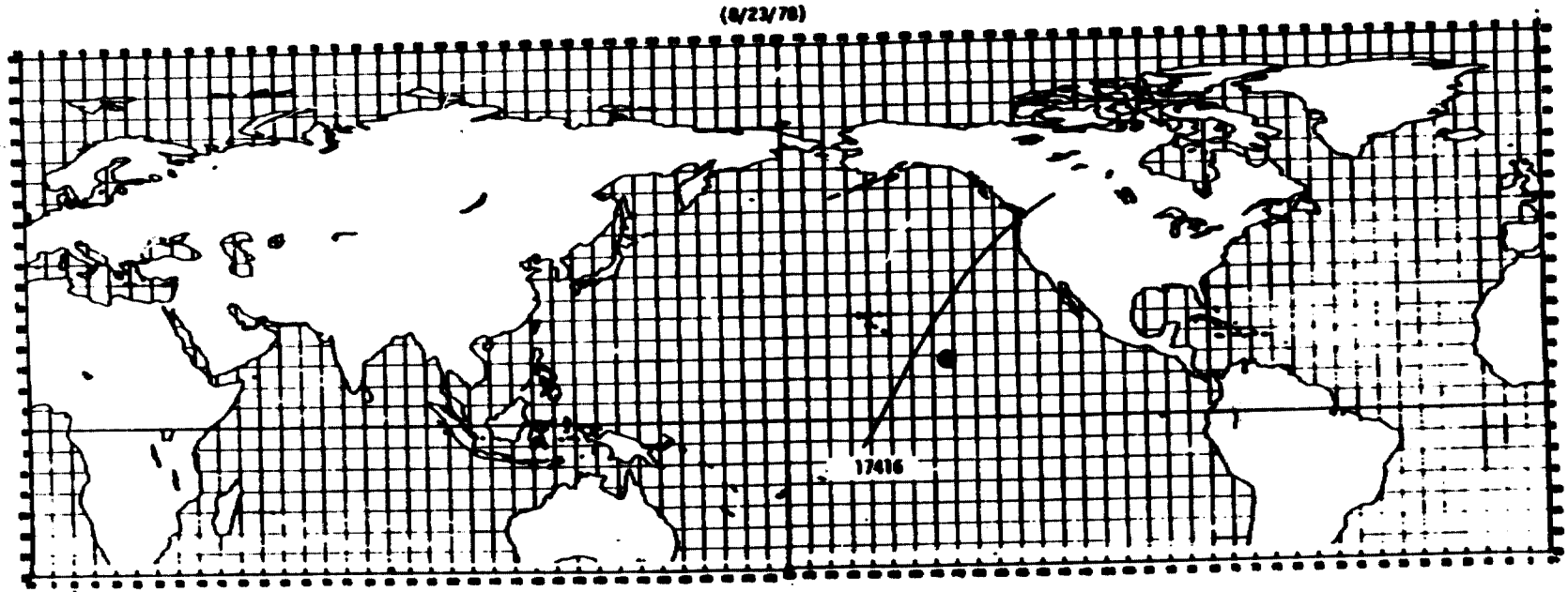


LOCATION

TIME	LATITUDE	LONGITUDE
00002	15.0N	142.0E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	NODE	ORBIT/D
17402	25.66	234252	002352	001712	002218	002	114

TROPICAL STORM LANE
(8/23/78)



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	15.0N	142.0E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA				
17416	31.16	232746	001246	000259	001954	002	127

7.4

TROPICAL STORM MIRIAM

August 28 - September 1, 1978

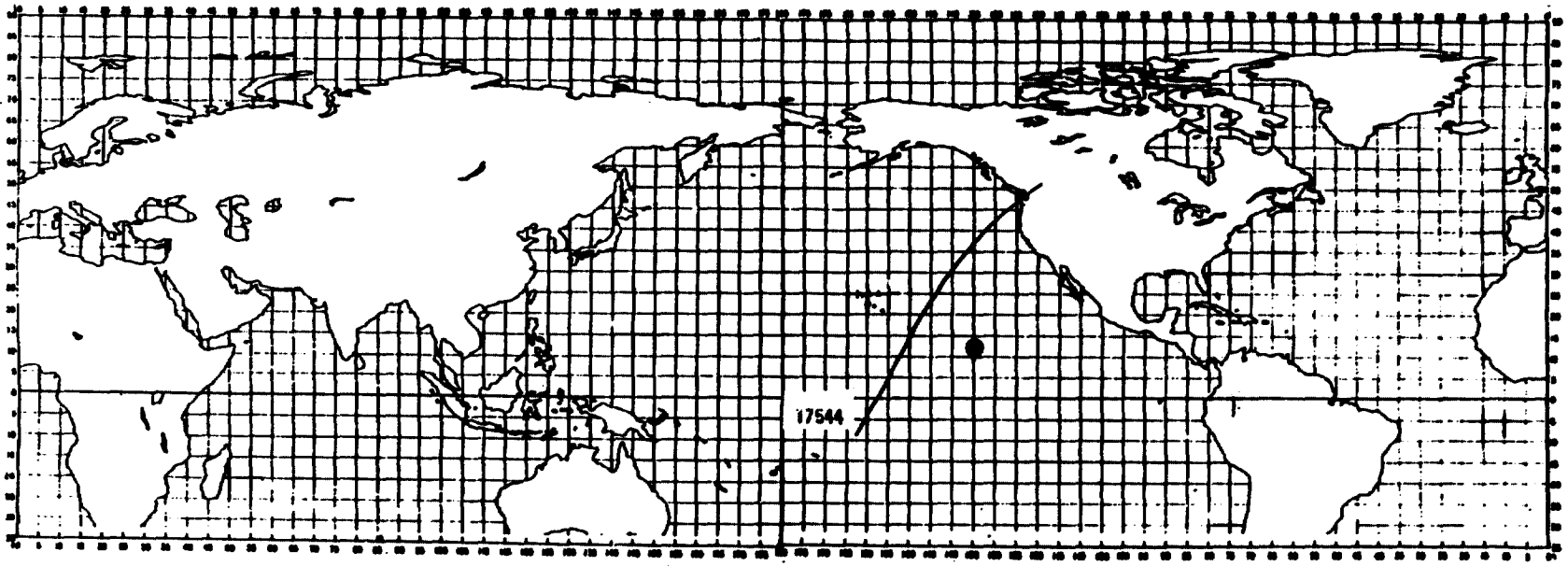
As Tropical Storm Miriam moved into the Central North Pacific area, the winds reached their maximum intensity of 55 kt. and continued through 1800 GMT , August 28 before beginning to slowly decrease again. Moving west-southwest, Miriam passed 200 n miles south of the Island of Hawaii on August 30, Continuing to weaken, the cyclone dissipated 580 n miles southwest of Hawaii on September 1.

STORM: TROPICAL STORM MIRIAM

DATE: Aug. 28 - Sept. 1, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
8/28		13.0N	140.0E		55	Tropical Storm
8/29		15.1N	145.2E		50	Tropical Depression
8/30		15.7N	150.2E		45	Tropical Depression
8/31		15.9N	155.4E		46	Tropical Depression
9/01		14.5N	161.3E		25	Tropical Depression

TROPICAL STORM MIRIAM - August 28-September 1, 1978



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	12.0N	135.0E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
17544	30.00	003522	012022	011021	012813	802	142

7.5

HURRICANE SUSAN
October 18-24, 1978

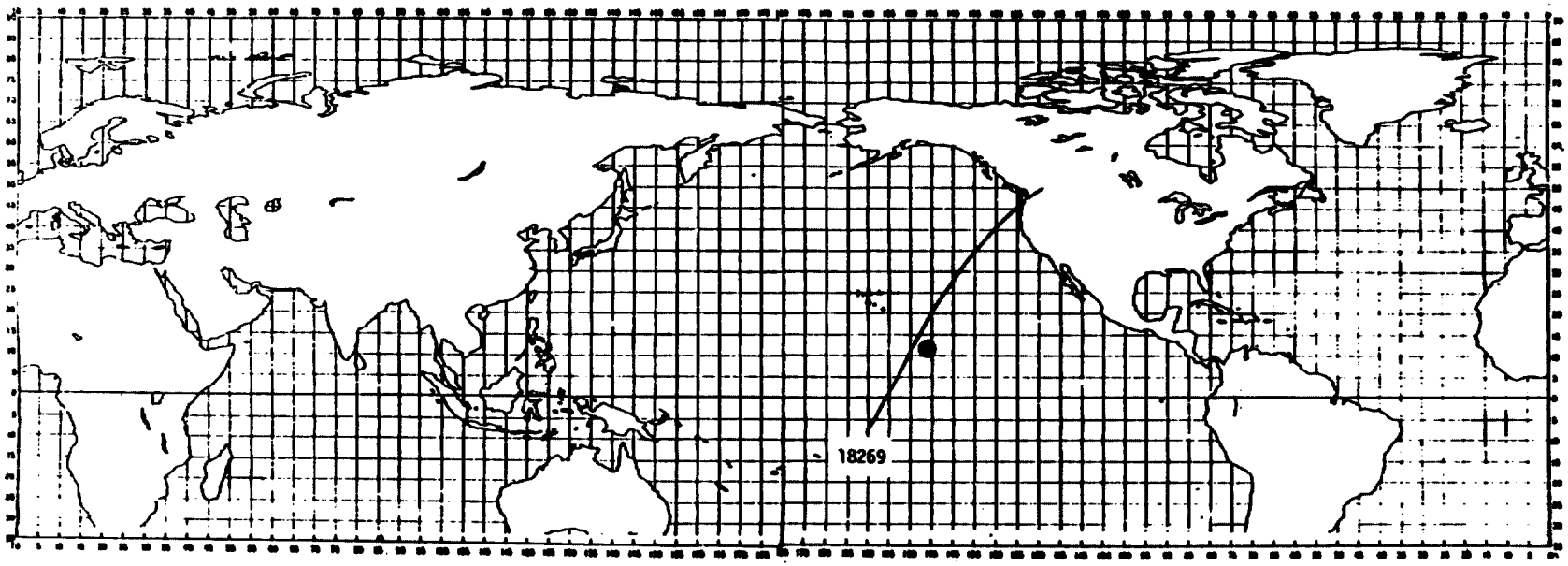
Hurricane Susan was the last storm of the season. Susan attained tropical storm intensity at precisely the same location as the first eastern Pacific storm of the season. Continuing to intensify by the 21st, Susan became one of the two most intense hurricanes on record in the Central Pacific. Susan had maximum winds of up to 120 kt. (62 m/sec). During Susan's peak, she became a real threat to the Hawaiian Islands. After reaching a point 22 n mi. (408 km) southeast of the Big Islands, however, Susan turned sharply to the southwest, rapidly dissipated, and luckily the Hawaiian Islands were once again spared.

STORM: HURRICANE SUSAN

DATE: Oct. 18-24, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
10/18		10.0N	144.8E			Tropical Storm
10/19		11.5N	145.0E			Hurricane
10/20		12.4N	144.8E		75	Hurricane
10/21		18.5N	148.0E		75	Hurricane
10/22		14.9N	151.2E		116	Hurricane
10/23		16.4N	153.0E		90	Hurricane
10/24		14.4N	158.0E		25	Tropical Depression

HURRICANE SUSAN - October 22, 1978



LOCATION

TIME	LATITUDE	LONGITUDE
0000Z	12.0N	147.0E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
18269	31.97	062410	071110	065953	071634	803	187

8.0 NORTH INDIAN OCEAN AREA - 1977

8.1 General

All of the data presented in this section on the cyclones occurring in the North Indian Ocean area were extracted from the Joint Typhoon Warning Center (JTWC) Document, "1977 Annual Typhoon Report".

During 1977, there were five tropical cyclones in the North Indian Ocean, two in the spring and three in the fall. However, these cyclones persisted much longer and were more intense than normal. TC 21-77 for example, developed in the Bay of Bengal, transversed southern India, regenerated in the Arabian Sea, looped while reaching typhoon strength, then finally dissipated over southwestern India after traveling a total of 1387 nm. TC 22-77 was the next and largest cyclone of the season. It became the third and most destructive storm to hit India.

The five tropical cyclones occurring in this area, their ground tracks together with their period of occurrence are shown in Figure 8.1.

Results of the comparison of the cyclone information and the GEOS-3 schedule information indicates that three of the cyclones (all except TC-17 and TC-18) may have associated GEOS-3 altimeter data. All information available for these three cyclones along with any promising GEOS-3 ground track maps are presented in the following sections.

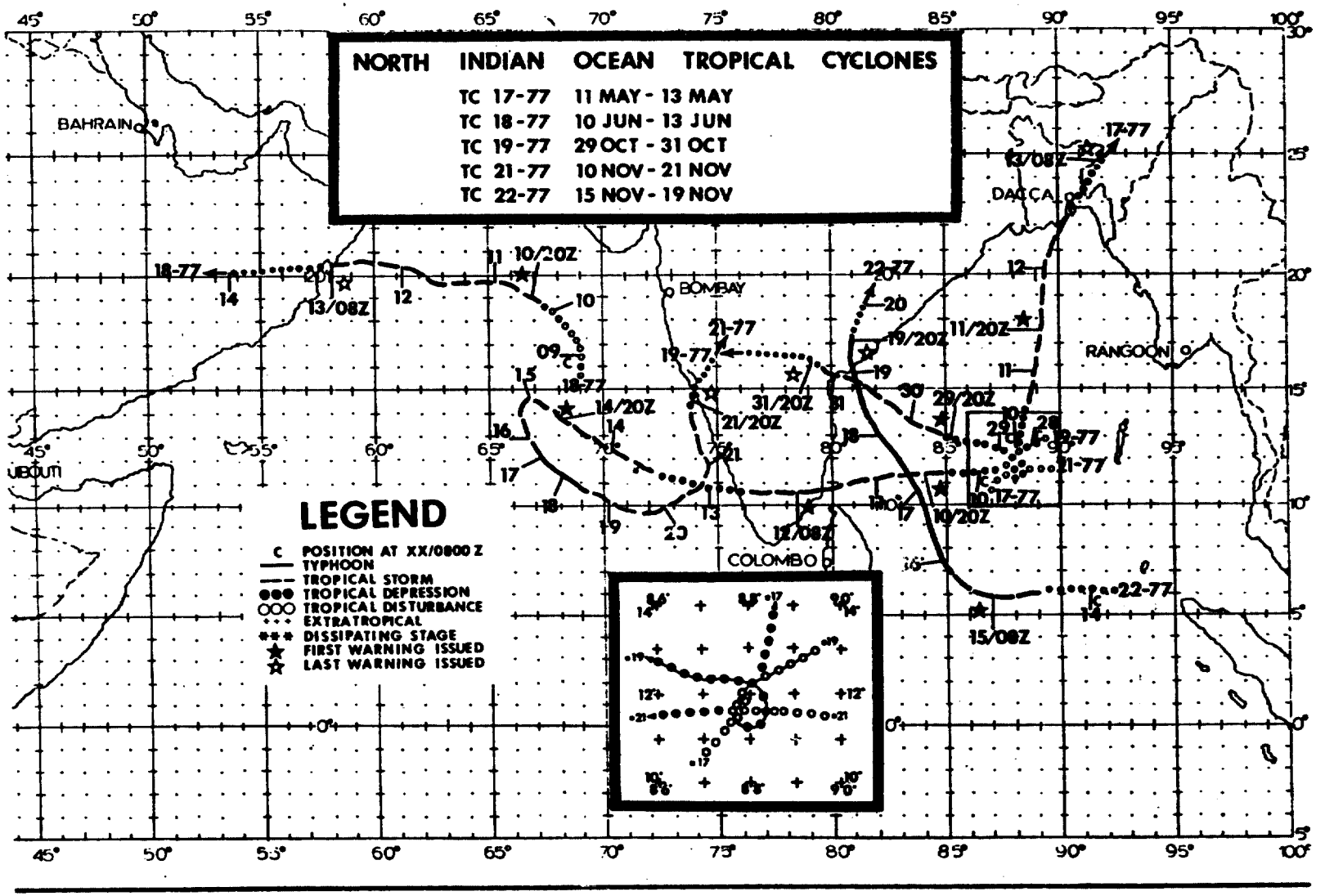

NORTH INDIAN OCEAN TROPICAL CYCLONES
TC 17-77 11 MAY - 13 MAY
TC 18-77 10 JUN - 13 JUN
TC 19-77 29 OCT - 31 OCT
TC 21-77 10 NOV - 21 NOV
TC 22-77 15 NOV - 19 NOV
LEGEND
C POSITION AT XX/0800 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
BAHRAIN
BOMBAY
DACCA
RANGOON
COLOMBO
DJIBOUTI
17-77
18-77
19-77
21-77
22-77
13/08Z
10/20Z
14/20Z
21/20Z
31/20Z
19/20Z
11/20Z
29/20Z
10/17-77
10/20Z
12/08Z
15/08Z
45°
50°
55°
60°
65°
70°
75°
80°
85°
90°
95°
100°
30°
25°
20°
15°
10°
5°
0°

FIGURE 8.1

8.2 TC 19-77

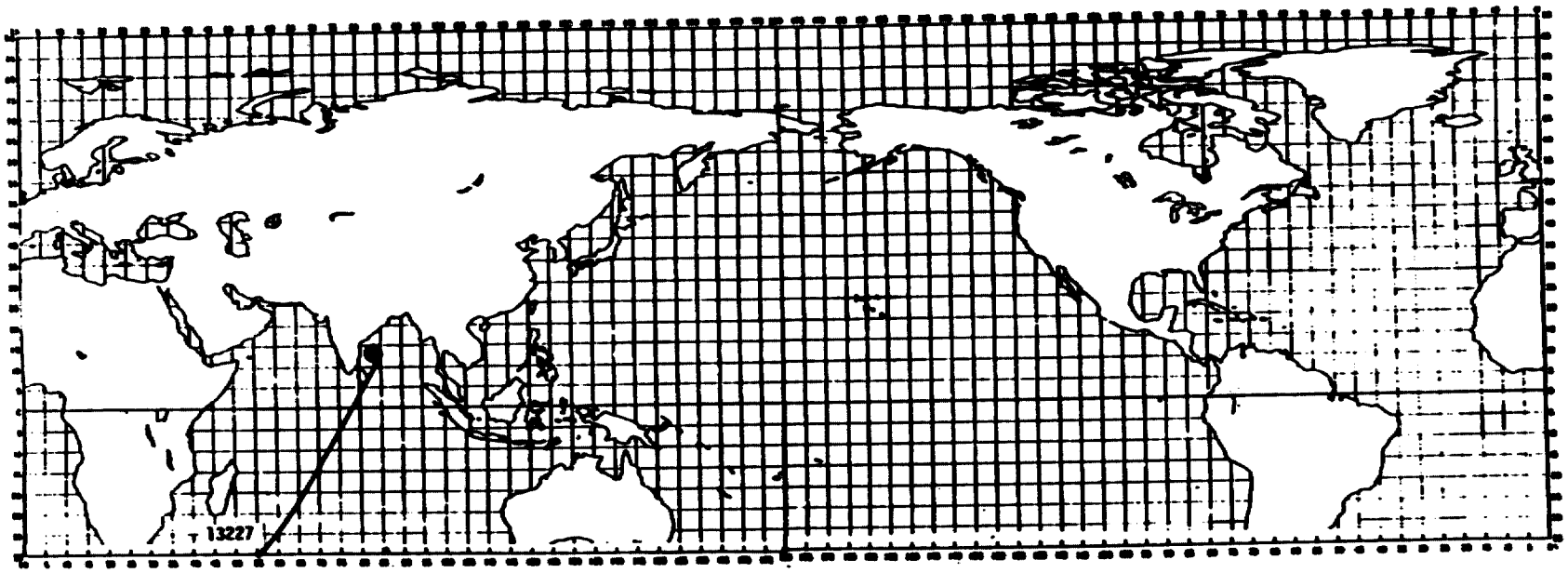
Tropical Cyclone 19-77 formed in the Bay of Bengal on October 29, 1977 at 13° latitude and 89° longitude. It traveled in a northwesterly direction and reached tropical storm strength on October 29 at 2000Z when the first warning was issued. It retained tropical storm strength until it hit land at 15.5° latitude and 80.2° longitude and finally dissipated on October 31 at 2000Z when the last warning was issued.

STORM: TC 19-77

DATE: October 29-31, 1978

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
10/29	2000Z	13.0N	85.2E		35	Tropical Storm
10/30	0800Z	13.9N	83.4E		35	Tropical Storm
	2000Z	14.7	82.8		35	
10/31	0800Z	15.6N	80.3E		40	Tropical Storm
	2000Z	16.3	79.0		30	Tropical Depression

TC 19-77 - October 30, 1977



8.2-3

LOCATION

TIME	LATITUDE	LONGITUDE
0800Z	13.9N	93.4E
2000Z	14.7	92.8

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	ANTO.#
13227	265.23	213056	221850	221850	224048	808	176

8.3 TC 21-77

Tropical Storm 21-77 formed in the Bay of Bengal on November 9, 1977 at 10.5° latitude and 89.7° longitude. It then transversed southern India, regenerated in the Arabian Sea, then looped in a southerly direction gaining typhoon strength before heading northward toward the western Indian coast striking it at 15° latitude and 74° longitude and finally dissipating over southwestern India after traveling a distance of 138.7 n mi or 2570 km.

STORM: TC 21-77

DATE: November 10-12 & 14-21, 1977

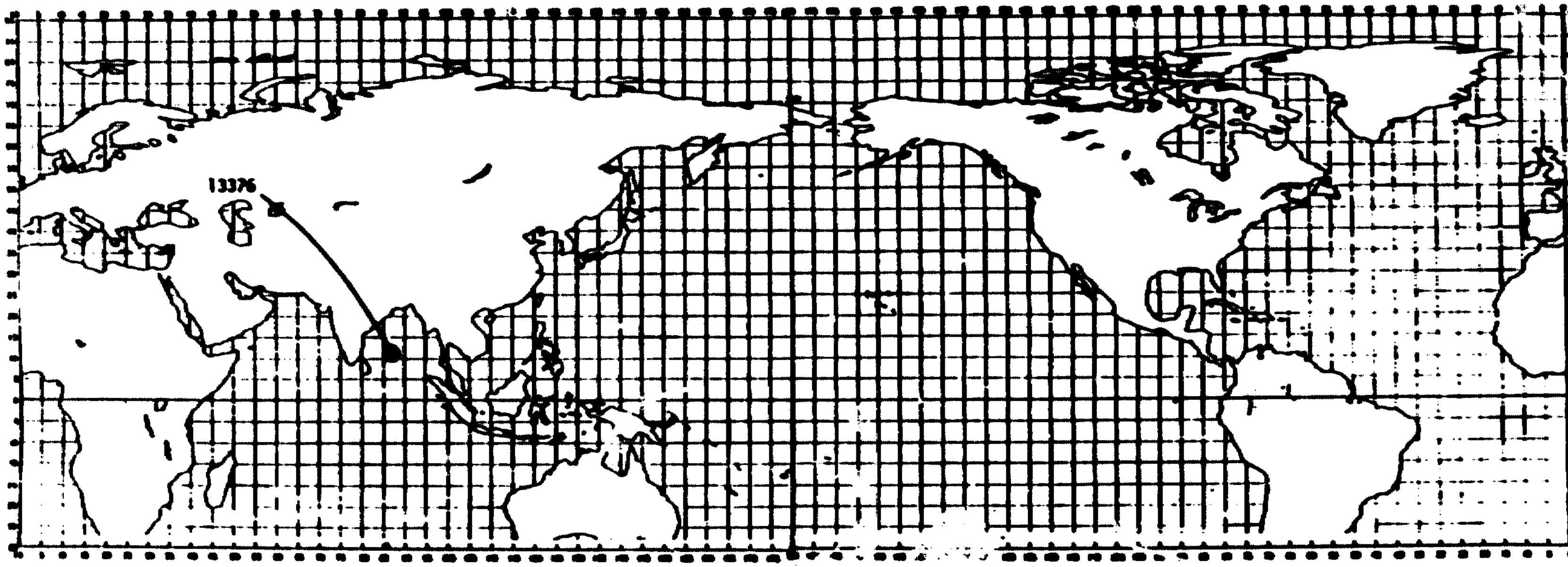
Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
11/10	2000Z	11.4N	83.9E		40	Tropical Storm
11/11	0800Z	11.3N	82.0E		40	Tropical Storm
	2000Z	11.0	80.2		45	
11/12	0800Z	10.8N	78.4E		40	Tropical Storm
11/14	2000Z	13.6N	68.2		45	Tropical Storm
11/15	0800Z	14.5N	66.6E		50	Tropical Storm
	2000Z	13.8	66.4		50	
11/16	0800Z	13.3N	66.8E		60	Tropical Storm
	2000Z	12.7	66.9		65	
11/17	0800Z	12.2N	67.2E		70	Typhoon
	2000Z	11.8	67.4		70	
11/18	0800Z	11.2N	68.2E		70	Typhoon
	2000Z	10.6	69.3		65	

STORM: TC 21-77

DATE: (cont.)

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
11/19	0800Z	10.1N	70.3E		55	Tropical Storm
	2000Z	9.8	71.3		50	
11/20	0800Z	10.0N	72.3E		45	Tropical Storm
	2000Z	10.4	73.2		45	
11/31	0800Z	11.8N	74.7E		45	Tropical Storm
	2000Z	14.5	73.8		35	

TC 21-77 - November 10, 1977

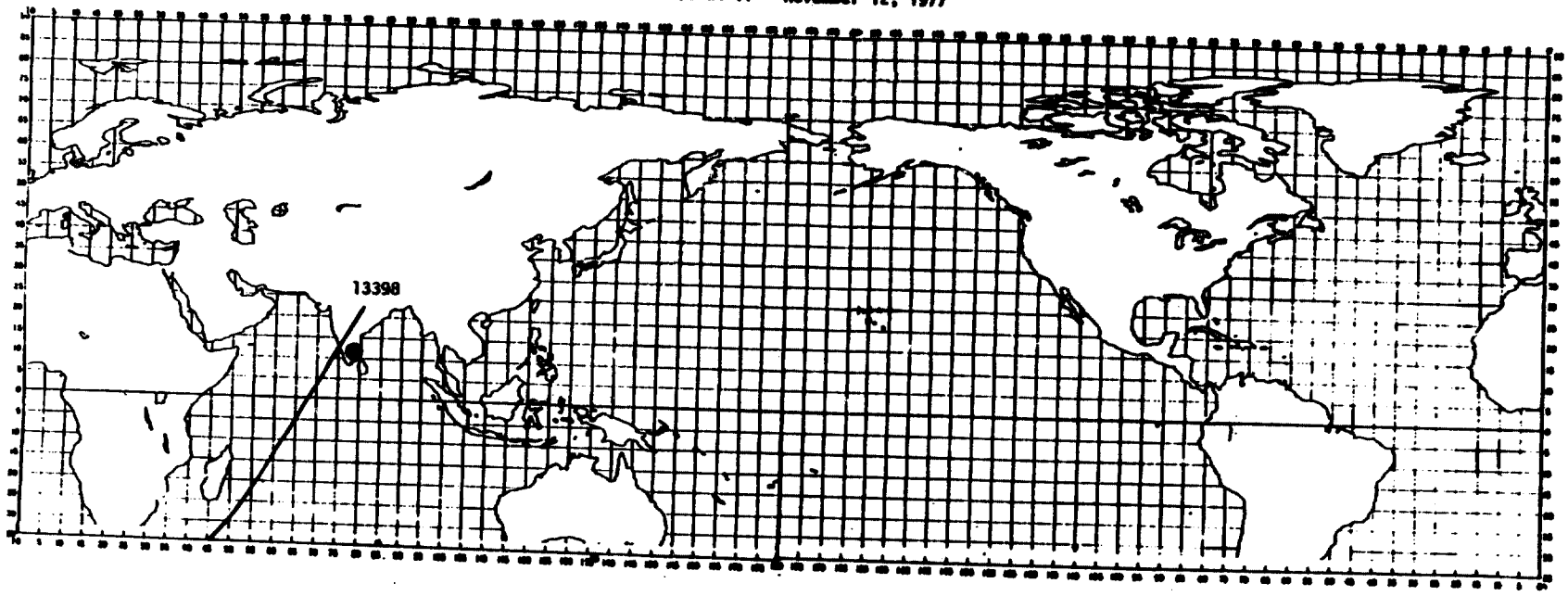


LOCATION

TIME	LATITUDE	LONGITUDE
2000Z	11.4N	83.0E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	ORIG.?
13376	92.19	101623	[illegible]	102030	103157	[illegible]	145

TC 21-77 - November 12, 1977



LOCATION

TIME	LATITUDE	LONGITUDE
0800Z	10.8N	78.4E

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON -	OFF	MODE	JHTO.#
13398	255.10	233535	002200	002022	004506	808	16#

8.4 TC 22-77

November 15-19, 1977

TC 22-77 was the most devastating storm in the Indian Ocean since 1971. It developed 115 kt winds and inundated Southeastern India with heavy rains and high seas. TC 22-77 occurred during the autumn monsoon transition period, when cyclone development is most favorable, and became the only storm to attain typhoon strength this season in the Bay of Bengal.

Meteorological satellites first located TC 22-77 during the morning of the 14th of November as a weak disturbance, approximately 150 nm southwest of the Nicobar Islands. Five hours later new satellite data revealed better defined banding which indicated increased organization. This prompted the issuance of a formation alert the same day at 1310Z. Heading due west along the southern periphery of the mid-tropospheric subtropical ridge, the disturbance quickly accelerated to 13 kt, while steadily intensifying. Later satellite and synoptic data supported a well developed cyclone of about 40 kt. At 0800Z on the 15th the first warning was issued. A post analysis showed that TC 22-77 was rapidly developing during this period.

Ever since TC 22-77 was first detected, an upper tropospheric trough was forming over northern India. By the 15th this trough was firmly established and extended over central India, creating a break in the subtropical ridge. As the cyclone neared India, it began moving northwestward toward the trough induced break. This break also weakened the mid-tropospheric anticyclone and consequently reduced the storm's steering flow, and as a result, TC 22-77 steadily slowed to 4 kt movement. It was now intensifying at the rate of 30 kt per 24 hours, primarily in response to the divergent southwesterly flow produced by the upper level trough above the approaching cyclone. TC 22-77 attained typhoon strength by the afternoon of the 15th, and by 0629Z on the 16th satellite data revealed an eye.

For the next 2 days, TC 22-77 tracked north-northwestward at an average speed of 9 kt, while continuing to strengthen. By the 19th, it began to decelerate and was intensifying 10 kt each day. Successive satellite picutres showed tighter banding features while the eye became more distinct. Approximately 75 nm from the Indian coast, TC 22-77 reached a maximum intensity of 115 kt. Just prior to landfall, TC 22-77 accelerated to 9 kt toward the north-northwest. At 1100Z on the 19th, the storm struck with sustained winds of

105 kt and an 18 ft tidal wave along the coast of Andhra Pradesh about 40 nm south of Vijayawada. TC 22-77 then turned northward over flat farm lands while weakening slowly, and the final warning was issued at 2000Z on the 19th.

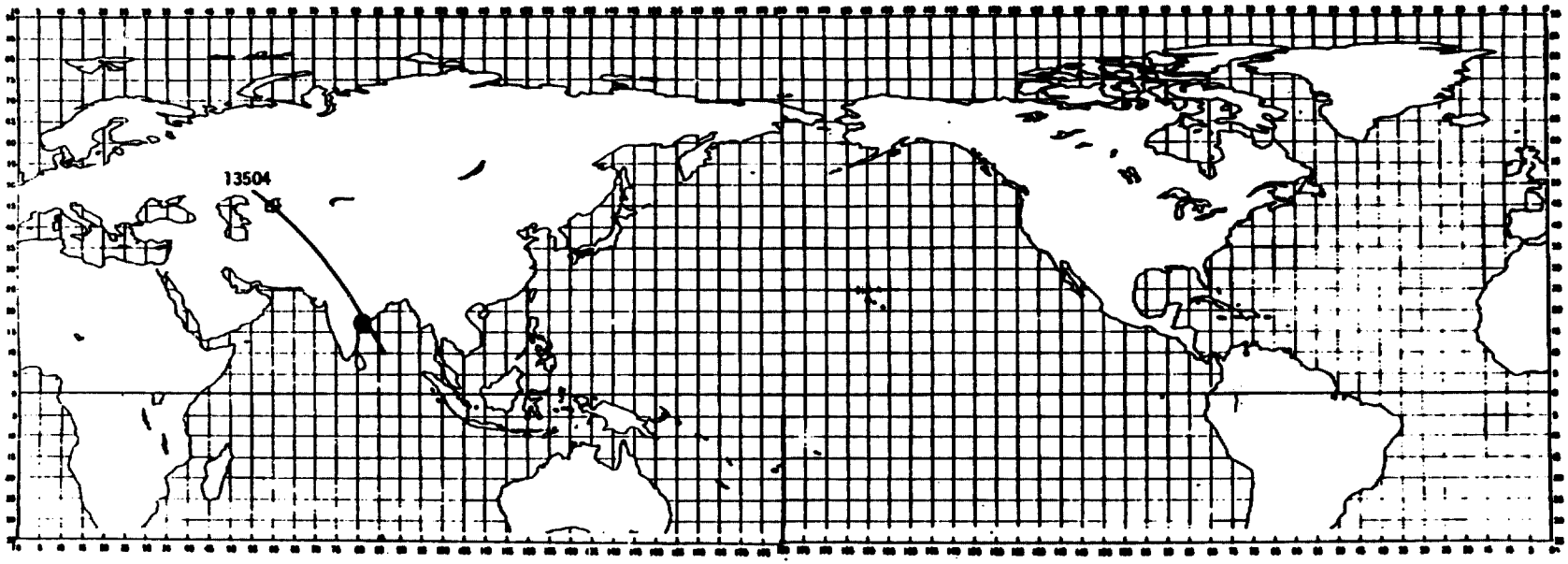
The combined winds, seas and rains generated by TC 22-77 killed nearly 10,000 people, left hundreds of thousands homeless and devastated lands that produce roughly 40 percent of India's food grains. The tidal wave was probably the single most destructive force accompanying the storm. It penetrated 10 nm inland and washed away more than 21 villages.

STORM: TC 22-77

DATE: November 15-19, 1977

Date	Time GMT	Position		Pressure (MBS)	Wind (KTS)	Stage
		Latitude	Longitude			
11/15	0800Z	6.0N	87.0E		50	Tropical Storm
	2000Z	6.5	87.5		65	
11/16	0800Z	7.2N	85.3E		80	Typhoon
	2000Z	8.8	84.6		90	
11/17	0800Z	10.5N	83.9E		95	Typhoon
	2000Z	11.8	83.1		100	
11/18	0800Z	13.0N	82.2E		105	Typhoon
	2000Z	14.1	81.7		110	
11/19	0800Z	15.5N	81.1E		110	Typhoon
	2000Z	17.2	81.0		90	

TC 22-77 - November 19, 1977



LOCATION

TIME	LATITUDE	LONGITUDE
0800Z	15.5N	81.1E
2000Z	17.2	81.0

ORBIT	EQUATOR CROSSING	TIME OF EQUATOR CROSSING	APPROXIMATE PCA	ON	OFF	MODE	UNIQ.#
13504	90.93	112425	112900	112746	113930	802	177

9.0 NORTH INDIAN OCEAN AREA - 1978

9.1 General

The data presented in this section on the cyclones occurring in the North Indian Ocean area were extracted from the Joint Typhoon Warning Center (JTWC) Document, "1978 Annual Typhoon Report."

During 1978, there were four significant tropical cyclones in the North Indian Ocean. These four tropical cyclones, their periods of activity, and their general characteristics are listed below:

Cyclone	Date	Max. Surface Wind	Est. Min. Sea-Level Pressure
TC 18-78	May 15-17	60	955
TC 19-78	Oct 26-28	40	995
TC 20-78	Nov 6-11	80	965
TC 21-78	Nov 20-29	95	955

No GEOS-3 altimeter schedule data was found that correlated with the 1978 North Indian Ocean Tropical Cyclone activity. However, for completeness, the tropical cyclone data is listed.

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15. Supplementary Notes

16. Abstract

This document's primary purpose is to provide the means for locating and extracting GEOS-3 altimeter data acquired for the analysis of specific hurricanes, typhoons, and other tropical cyclones. These data are also expected to be extremely useful in the analysis of the behavior of the altimeter instrument in the presence of severe meteorological disturbances as well as provide a data base which can be useful in the resolution of apparently anomalous geoid or sea surface characteristics. Geographic locations of 1977 and 1978 tropical cyclones have been correlated with the closest approaching orbits of the GEOS-3 satellite and its radar altimeter. The cyclone locations and altimeter data were correlated for the entire 1977-1978 season. The area of coverage includes the entire northern hemisphere. This document is a sequel to NASA TM-X-73282.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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