CHAPTER III - SUMMARY OF WESTERN NORTH PACIFIC AND NORTH INDIAN OCEAN TROPICAL CYCLONES

1. GENERAL

During the calendar year 1988, JTWC issued warnings on 27 tropical cyclones in the western North Pacific - one super typhoon, 12 typhoons, 13 tropical storms and one tropical depression. This includes Typhoon Uleki (01C), which initially developed in the central North Pacific (Table 3-1). The total number of western North Pacific tropical cyclones is lower than the climatological mean of 30.7, and two above the 1987 total (Table 3-2). Five tropical cyclones - one of typhoon and four of tropical storm intensity - developed in the North Indian Ocean. This is average. The climatological mean is 4.7. During 1988, warnings were issued on a total of 32 northern hemisphere tropical cyclones. A chronology of western North Pacific and North Indian Ocean tropical cyclones is provided in Figure 3-1.

For the year, there were 114 "warning days" in the western North Pacific. A warning day is defined as a day during which JTWC issued warnings on at least one tropical cyclone. A "one-cyclone day" refers to a day when we were warning on only one tropical cyclone. A "two-cyclone day" refers to a day when we warned on two different tropical cyclones simultaneously. A "three-cyclone day" means JTWC was warning on three tropical cyclones at once. Considering only the western North Pacific, there were 15 two-cyclone days and four three-cyclone days (Table 3-3). When North Indian Ocean tropical cyclones are included, there were 128 warning days of which 16 were two-cyclone days and four were three-cyclone days. There were no four-cyclone or five-cyclone days. Thus, JTWC was in northern hemisphere warning status 35 percent of the year; we were in a multiple-cyclone situation (that is, warning on two or more tropical cyclones at the same time) for 20 days or six percent of the year.

JTWC issued 471 warnings on 27 western North Pacific tropical cyclones and 44 warnings on five North Indian Ocean tropical cyclones, for a grand total of 515 warnings. There were 33 initial Tropical Cyclone Formation Alerts issued for western North Pacific disturbances and four for the North Indian Ocean. Twenty-six western North Pacific and four North Indian Ocean tropical cyclones developed subsequent to the issuance of an Alert. Only one western North Pacific tropical cyclone-Tropical Storm Elsie (11W)-regenerated, and an Alert was issued prior to regeneration. Typhoon Uleki (01C) was passed to JTWC from CPHC while in warning status, so JTWC did not issue an Alert (Table 3-4). In the western North Pacific, the false alarm rate was 21 percent and the mean lead time (to issuance of the first warning) was 8.5-hours. For the North Indian Ocean, the false alarm rate was zero and the mean lead time was 5.1 hours. An Alert was not issued for Tropical Cyclone 02B.

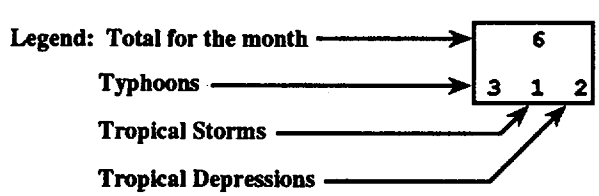
TABLE 3-1

WESTERN NORTH PACIFIC
1988 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE		PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS KT (M/SEC)	ESTIMATED MSLP - MB
(01W)	TY ROY	08 JAN - 18 JAN	41	115 (59)	927
(02W)	TY SUSAN	30 MAY - 03 JUN	17	80 (41)	963
(03W)	TD 03W	04 JUN - 05 JUN	6	30 (15)	1000
(04W)	TY THAD	20 JUN - 25 JUN	21	70 (36)	972
(05W)	TS VANESSA	26 JUN - 29 JUN	12	45 (23)	991
(06W)	TY WARREN	12 JUL - 20 JUL	30	115 (59)	927
(07W)	TS AGNES	29 JUL - 30 JUL	8	40 (21)	994
(08W)	TS BILL	07 AUG - 08 AUG	5	45 (23)	991
(09W)	TS CLARA	10 AUG - 12 AUG	6	45 (23)	991
(10W)	TY DOYLE	15 AUG - 21 AUG	24	115 (59)	927
(11W)	TS ELSIE	28 AUG - 29 AUG	6	35 (18)	997
(11W)	TS ELSIE*	31 AUG	4	45 (23)	991
(12W)	TY FABIAN	30 AUG - 03 SEP	18	75 (39)	968
(13W)	TS GAY	02 SEP - 04 SEP	6	45 (23)	991
(14W)	TY HAL	08 SEP - 17 SEP	37	105 (54)	938
(01C)	TY ULEKI	08 SEP - 13 SEP	21	90 (46)	954
(15W)	TS IRMA	12 SEP - 15 SEP	16	55 (28)	984
(16W)	TS JEFF	14 SEP - 16 SEP	9	45 (23)	991
(17W)	TS KIT	19 SEP - 22 SEP	12	55 (28)	984
(18W)	TS LEE	21 SEP - 24 SEP	15	55 (28)	984
(19W)	TS MAMIE	22 SEP - 23 SEP	4	45 (23)	991
(20W)	STY NELSON	01 OCT - 08 OCT	30	140 (72)	898
(21W)	TY ODESSA	11 OCT - 16 OCT	22	90 (46)	954
(22W)	TY PAT	18 OCT - 22 OCT	17	75 (39)	968
(23W)	TY RUBY	21 OCT - 28 OCT	30	125 (64)	916
(24W)	TY SKIP	03 NOV - 11 NOV	30	125 (64)	916
(25W)	TY TESS	04 NOV - 06 NOV	10	65 (33)	976
(26W)	TS VAL	22 DEC - 26 DEC	14	55 (28)	984
		TOTAL	471		

* REGENERATED

TABLE 3-2 LEGEND



The criteria used in Table 3-2 are as follows:

1. If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.

2. If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3. If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

TABLE 3-2

WESTERN NORTH PACIFIC TROPICAL CYCLONE DISTRIBUTION

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1959	0	1	1	1	0	1	3	8	9	3	2	2	31
	000	010	010	100	000	001	111	512	423	210	200	200	17 7 7
1960	1	0	1	1	1	3	3	9	5	4	1	1	30
	001	000	001	100	010	210	210	810	041	400	100	100	19 8 3
1961	1	1	1	1	4	6	5	7	6	7	2	1	42
	010	010	100	010	211	114	320	313	510	322	101	100	20 11 11
1962	0	1	0	1	3	0	8	8	7	5	4	2	39
	000	010	000	100	201	000	512	701	313	311	301	020	24 6 9
1963	0	0	1	1	0	4	5	4	4	6	0	3	28
	000	000	001	100	000	310	311	301	220	510	000	210	19 6 3
1964	0	0	0	0	3	2	8	8	8	7	6	2	44
	000	000	000	000	201	200	611	350	521	331	420	101	26 13 5
1965	2	2	1	1	2	4	6	7	9	3	2	1	40
	110	020	010	100	101	310	411	322	531	201	110	010	21 13 6
1966	0	0	0	1	2	1	4	9	10	4	5	2	38
	000	000	000	100	200	100	310	531	532	112	122	101	20 10 8
1967	1	0	2	1	1	1	8	10	8	4	4	1	41
	010	000	110	100	010	100	332	343	530	211	400	010	20 15 6
1968	0	1	0	1	0	4	3	8	4	6	4	0	31
	000	001	000	100	000	202	120	341	400	510	400	000	20 7 4
1969	1	0	1	1	0	0	3	3	6	5	2	1	23
	100	000	010	100	000	000	210	210	204	410	110	010	13 6 4
1970	0	1	0	0	0	2	3	7	4	6	4	0	27
	000	100	000	000	000	110	021	421	220	321	130	000	12 12 3
1971	1	0	1	2	5	2	8	5	7	4	2	0	37
	010	000	010	200	230	200	620	311	511	310	110	000	24 11 2
1972	1	0	1	0	0	4	5	5	6	5	2	3	32
	100	000	001	000	000	220	410	320	411	410	200	210	22 8 2
1973	0	0	0	0	0	0	7	6	3	4	3	0	23
	000	000	000	000	000	000	430	231	201	400	030	000	12 9 2
1974	1	0	1	1	1	4	5	7	5	4	4	2	35
	010	000	010	010	100	121	230	232	320	400	220	020	15 17 3
1975	1	0	0	1	0	0	1	6	5	6	3	2	25
	100	000	000	001	000	000	010	411	410	321	210	002	14 6 5
1976	1	1	0	2	2	2	4	4	5	0	2	2	25
	100	010	000	110	200	200	220	130	410	000	110	020	14 11 0
1977	0	0	1	0	1	1	4	2	5	4	2	1	21
	000	000	010	000	001	010	301	020	230	310	200	100	11 8 2
1978	1	0	0	1	0	3	4	8	4	7	4	0	32
	010	000	000	100	000	030	310	341	310	412	121	000	15 13 4
1979	1	0	1	1	2	0	5	4	6	3	2	3	28
	100	000	100	100	011	000	221	202	330	210	110	111	14 9 5
1980	0	0	1	1	4	1	5	3	7	4	1	1	28
	000	000	001	010	220	010	311	201	511	220	100	010	15 9 4
1981	0	0	1	1	1	2	5	8	4	2	3	2	29
	000	000	100	010	010	200	230	251	400	110	210	200	16 12 1
1982	0	0	3	0	1	3	4	5	6	4	1	1	28
	000	000	210	000	100	120	220	500	321	301	100	100	19 7 2
1983	0	0	0	0	0	1	3	6	3	5	5	2	25
	000	000	000	000	000	010	300	231	111	320	320	020	12 11 2
1984	0	0	0	0	0	2	5	7	4	8	3	1	30
	000	000	000	000	000	020	410	232	130	521	300	100	16 11 3
1985	2	0	0	0	1	3	1	7	5	5	1	2	27
	020	000	000	000	100	201	100	520	320	410	010	110	17 9 1
1986	0	1	0	1	2	2	2	5	2	5	4	3	27
	000	100	000	100	110	110	200	410	200	320	220	210	19 8 0
1987	1	0	0	1	0	2	4	4	7	2	3	1	25
	100	000	000	010	000	110	400	310	511	200	120	100	18 6 1
1988	1	0	0	0	1	3	2	5	8	4	2	1	27
	100	000	000	000	100	111	110	230	260	400	200	010	14 12 1
(1959-1988) AVG	0.6	0.3	0.6	0.7	1.2	2.1	4.5	6.2	5.7	4.5	2.8	1.4	30.6
CASES	17	9	18	22	37	63	134	185	172	136	83	43	919

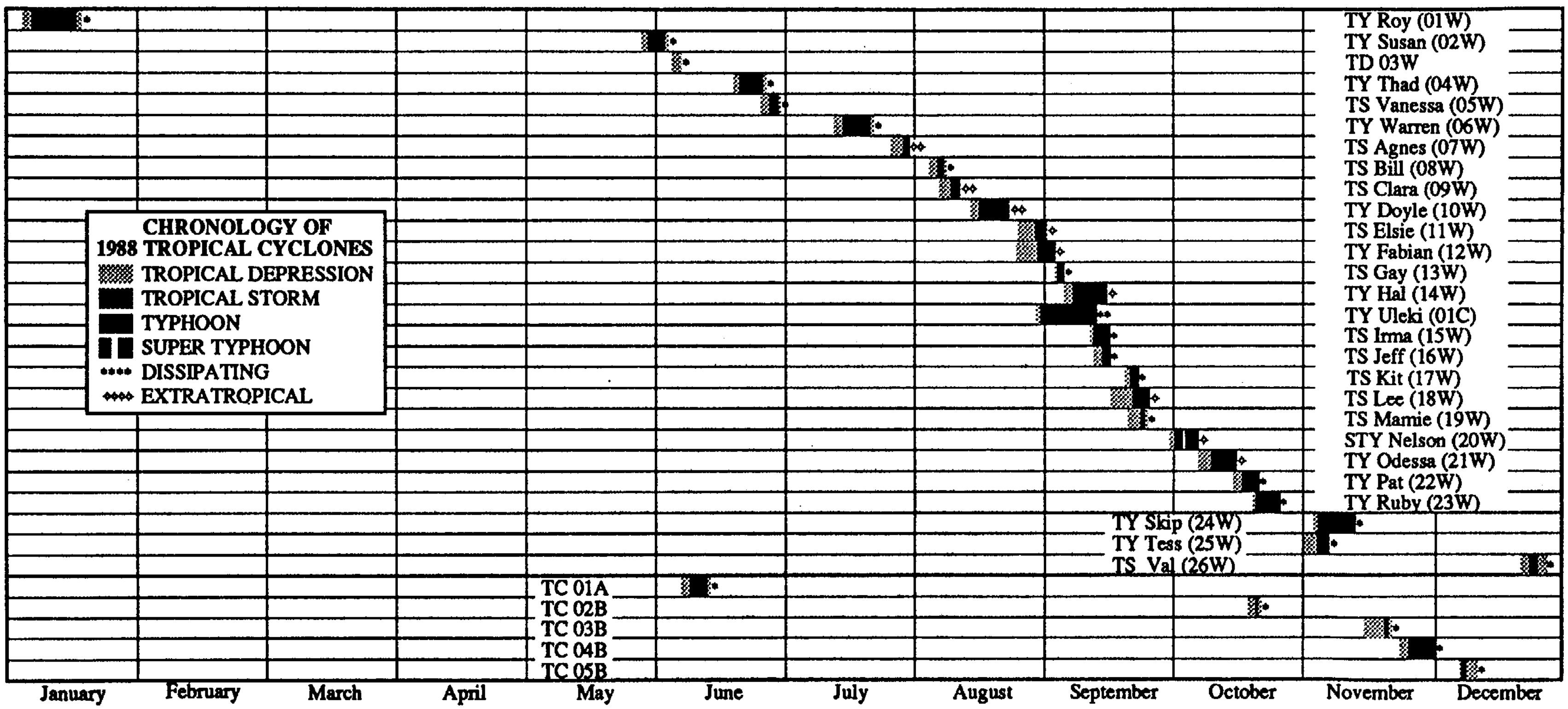

CHRONOLOGY OF
1988 TROPICAL CYCLONES
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON
DISSIPATING
EXTRATROPICAL
TY Roy (01W)
TY Susan (02W)
TD 03W
TY Thad (04W)
TS Vanessa (05W)
TY Warren (06W)
TS Agnes (07W)
TS Bill (08W)
TS Clara (09W)
TY Doyle (10W)
TS Elsie (11W)
TY Fabian (12W)
TS Gay (13W)
TY Hal (14W)
TY Uleki (01C)
TS Irma (15W)
TS Jeff (16W)
TS Kit (17W)
TS Lee (18W)
TS Mamie (19W)
STY Nelson (20W)
TY Odessa (21W)
TY Pat (22W)
TY Ruby (23W)
TY Skip (24W)
TY Tess (25W)
TS Val (26W)
TC 01A
TC 02B
TC 03B
TC 04B
TC 05B
January
February
March
April
May
June
July
August
September
October
November
December

Figure 3-1

TABLE 3-3

WESTERN NORTH PACIFIC TROPICAL CYCLONE SUMMARY

TYPHOONS

(1945 - 1958)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.4	0.1	0.3	0.4	0.7	1.1	2.0	2.9	3.2	2.4	2.0	0.9	16.3
CASES	5	1	4	5	10	15	28	41	45	34	28	12	228

(1959 - 1988)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.3	0.1	0.2	0.5	0.7	1.0	2.7	3.2	3.3	3.0	1.7	0.7	17.4
CASES	8	2	6	15	20	31	81	96	98	91	50	20	518

TROPICAL STORMS AND TYPHOONS

(1945 - 1958)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.4	0.1	0.4	0.5	0.8	1.6	3.0	3.9	4.1	3.3	2.8	1.1	22.0
CASES	6	1	6	7	11	22	42	54	58	46	39	16	308

(1959 - 1988)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.5	0.3	0.5	0.7	1.0	1.8	4.1	5.3	5.0	4.1	2.6	1.3	27.2
CASES	16	9	14	21	31	53	122	160	150	122	78	38	814

FORMATION ALERTS: 26 OF 33 INITIAL FORMATION ALERTS DEVELOPED INTO SIGNIFICANT TROPICAL CYCLONES (NOT INCLUDING ONE ON A SYSTEM THAT REGENERATED). TROPICAL CYCLONE FORMATION ALERTS WERE ISSUED FOR ALL OF THE SIGNIFICANT TROPICAL CYCLONES THAT DEVELOPED IN 1988.

WARNINGS:

NUMBER OF CALENDAR WARNING DAYS: 114
NUMBER OF CALENDAR WARNING DAYS WITH TWO TROPICAL CYCLONES: 15
NUMBER OF CALENDAR WARNING DAYS WITH THREE TROPICAL CYCLONES: 4

TABLE 3-4

TROPICAL CYCLONE FORMATION ALERT SUMMARY
WESTERN NORTH PACIFIC OCEAN

YEAR	INITIAL TCFAS	TROPICAL CYCLONES WITH TCFAS	TOTAL TROPICAL CYCLONES	FALSE ALARM RATE
1975	34	25	25	26%
1976	34	25	25	26%
1977	26	20	21	23%
1978	32	27	32	16%
1979	27	23	28	15%
1980	37	28	28	24%
1981	29	28	29	3%
1982	36	26	28	28%
1983	31	25	25	19%
1984	37	30	30	19%
1985	39	26	27	33%
1986	38	27	27	29%
1987	31	24	25	23%
1988	33	26	27	21%
(1975-1988)				
AVERAGE	33.3	25.7	26.9	21.8%
TOTALS	464	360	377	

2. WESTERN NORTH PACIFIC TROPICAL CYCLONES

Distinguishing features of the 1988 western North Pacific tropical cyclone season were the low number of super typhoons (1), the short average lifespan of the tropical cyclones, the aclimatic location of the monsoon trough and an active Tropical Upper-Tropospheric Trough (TUTT). The northward displacement of the monsoon trough during the summer and early fall and the active TUTT may have accounted for the relatively large number of tropical cyclones that had anomalous tracks. The normal lifespan of a tropical cyclone in the western North Pacific usually exceeds four warning days. This year JTWC encountered a large number of tropical cyclones (13) that were in warning status for four days or less. The short lifespans led to a relatively low number of warnings and forecast verifications.

JANUARY THROUGH MAY

Typhoon Roy (01W) was only the second typhoon in the past twelve years to develop in the western North Pacific during January. The typhoon's near miss of Guam resulted in the most destruction since Super Typhoon Pamela (1976) struck the island. After Roy (01W) there was a long break in activity until the end of May. The synoptic pattern during the last week of May was anomalous, with low-level southwesterlies extending across the northern Philippine Sea into the northern Marianas and southern Bonin Islands. Surface pressures in the monsoon trough were 4 to 5 mb below normal. Cyclonic vortices in the trough were transitory until Typhoon Susan (02W) formed off the coast of Luzon.

JUNE

As Susan (02W) moved northeastward, Tropical Depression 03W developed in the enhanced low-level southwesterly monsoonal flow left behind Susan (02W). Then Tropical Depression 03W moved into a subsidence area over China and dissipated. A two week hiatus in tropical cyclone activity followed. Then Typhoon Thad (04W) formed in the eastern Carolines. It tracked over 2000 nm (3704 km) during its lifetime, recurving just east of the island of Luzon and passing 80 nm (148 km) southeast of Okinawa. With Thad (04W) weakening over water to the north, Tropical Storm Vanessa (05W) generated to the south in the Philippine Sea. It was the first "straight-runner" of the year. Vanessa (05W) tracked across the Philippine Islands and into the South China Sea before dissipating over southern China.

JULY

Almost two weeks passed after Vanessa's (05W) demise before Typhoon Warren (06W) developed in the eastern Caroline Islands. Warren (06W) was the second tropical cyclone of the year to threaten Guam. Warren (06W) was the second "straight-runner" of the year and maintained a west-northwestward track during almost its entire lifetime. The system skirted northern Luzon prior to making landfall in southeastern China. Tropical Storm Agnes (07W) followed a week later and was noteworthy for several reasons. It was the last of only two tropical cyclones to develop in July, a month that normally averages five systems and played a major role in the changing synoptic pattern during late July. When Warren (06W) dissipated, the monsoon trough remained much farther north than normal. Agnes (07W) formed in the area of lower pressures southeast of Japan where the monsoon trough merged with a mid-latitude low pressure system to the northeast. Agnes (07W) followed the path of least resistance and accelerated north-northeastward along the trough axis.

AUGUST

Once Agnes (07W) went extratropical the monsoon trough underwent a major readjustment. It now stretched eastward from the Gulf of Tonkin, across the South China Sea, through the Luzon Strait and abruptly terminated near Okinawa. Tropical Storm Bill

(08W) consolidated rapidly at the eastern end of the monsoon trough, brushed by the island of Okinawa and reached a peak intensity of 45 kt (23 m/sec) before making landfall near Shanghai, China. Bill (08W) remained well organized even after making landfall, and caused widespread destruction and loss of life in China. The other four tropical cyclones that developed in August (Clara (09W), Doyle (10W), Elsie (11W) and Fabian (12W)) all formed north of 20° North latitude. Tropical Storm Clara (09W) began in the easterly trade winds as an area of weakly organized convection 540 nm (1,000 km) north of Wake Island. Clara (09W) initially tracked westward, then abruptly changed direction toward the north. Throughout its short lifespan, the system was consistently hindered by vertical wind shear and only peaked at an intensity of 45 kt (23 m/sec). Typhoon Doyle (10W) also fell into the track category of "other" due to its erratic behavior. Initially, Doyle (10W) moved rapidly toward the south-southwest and looped before tracking northeastward. To make the forecasts more complicated, Doyle (10W) interacted with a TUTT cell while maintaining typhoon intensity. Once Doyle (10W) was extratropical, Tropical Storm Elsie (11W) and Typhoon Fabian (12W) formed from persistent convection in the monsoon trough. Both displayed erratic movement during their early stages and underwent binary interaction before transitioning into extratropical systems.

SEPTEMBER

With Elsie (11W) and Fabian (12W) going extratropical, Tropical Storm Gay (13W) generated in the monsoon trough 420 nm (778 km) east of Okinawa and attained a peak intensity of 45 kt (23 m/sec). It took the path of least resistance and tracked up the trough to the northeast. Gay (13W) was short-lived. It was followed by a more normal synoptic situation, where the monsoon trough shifted equatorward. The monsoon trough later expanded, stretching from Vietnam to 175° East longitude, and spawned seven tropical cyclones. As Gay (13W) dissipated east of Japan and Uleki (01C) churned across the Central Pacific, Typhoon Hal (14W) formed just west of Wake Island. Its development was aided by upper-level divergence from a TUTT cell to its north. Hal (14W) combined with Typhoon Uleki (01C), Tropical Storm Irma (15W), and later with Tropical Storm Jeff (16W) to create two separate three-storm situations. In the meantime, Typhoon Uleki (01C) became the third hurricane in the past thirty years to form in the central North Pacific and cross the international dateline while in a warning status. Tropical Storms Irma (15W) and Jeff (16W) developed in Hal's (14W) strong low-level southwesterly inflow. As Hal (14W), with a large ragged eye, tracked northward, Irma (15W) and Jeff (16W) followed and were sheared away. Once Hal (14W) went extratropical east of Japan, Tropical Storm Kit (17W) developed in the monsoon trough 240 nm (444 km) east of the Philippine Islands. Kit (17W) was a "straight-runner" and tracked over the northern tip of Luzon. It made landfall over southern China, causing loss of life and property damage. While Kit (17W) was moving into Luzon, Tropical Storm Lee (18W) was slowly developing. Lee (18W) tracked over 1,300 nm (2408 km) during a four day period as an identifiable area of convection before the first warning was issued. It then moved northwestward before recurving to the northeast and tracking within 45 nm (83 km) southeast of Okinawa. Tropical Storm Mamie (19W) formed in tandem with Kit (17W) and was the second significant tropical cyclone to develop in the South China Sea. Mamie (19W) had an anomalous track. After a prolonged southwestward movement, it made a sharp turn and moved northward towards Hong Kong.

OCTOBER

Once Lee (18W) and Mamie (19W) were gone, there was a five day break before Super Typhoon Nelson (20W). It was the only super typhoon of 1988. The tropical cyclone initially moved westward towards the Philippine Islands, then west-northwestward as it tracked along the southwestern side of the subtropical ridge. A break in the ridge northwest of Nelson (20W) was identified and recurvature was correctly forecast. Nelson (20W) rapidly deepened for two days and reached super typhoon intensity shortly before recurvature. It then recurved and threatened Okinawa. Later, as the system became extratropical and accelerated toward the northeast, it also threatened Japan. While Nelson (20W) was weakening and accelerating, Typhoon Odessa (21W) began as an area of convection superimposed on broad low-level easterly tradewinds 600 nm (1111 km) south-southeast of Japan. During its first two days, Odessa (21W) moved rapidly to the west-northwest at a speed of 17 to 18 kt (32 to 33 km/hr). It began a gradual recurvature and moved toward the cooler, drier polar air mass from the Asian continent. Initially, interaction with cold air was expected to weaken the tropical cyclone. Instead, Odessa (21W) intensified into a midget typhoon, peaking at an intensity of 90 kt (46 m/sec). At the same time Tropical Storm Pat (22W) formed equatorward of 10° North latitude. The system tracked westward and attained a peak intensity of 75 kt (39 m/sec) prior to making landfall over central Luzon. Pat (22W) then moved west-northwestward across the South China Sea, tracking over the island of Hainan Dao and dissipating 30 nm (56 km) northeast of Hanoi, Vietnam. As Pat (22W) was winding down in the South China Sea, Typhoon Ruby (23W) was intensifying in the Philippine Sea. Ruby (23W) was the fifth tropical cyclone to track across the Philippine Islands and the third system to affect Vietnam in 1988. It tracked in a west-northwestward direction throughout its lifetime. The system reached a peak intensity of 125 kt (64 m/sec) shortly before making landfall in the Philippines. The result was extensive damage and loss of life. In the Philippines alone, at least 300 persons were killed and over 470,000 were left homeless. Ruby (23W) passed 65 nm (120 km) north-northeast of Manila, causing the strongest winds at Clark Air Base since 1978. Ruby (23W) then tracked into the South China Sea. Later, flash flooding from the dissipating system's torrential rainshowers resulted in over 100 deaths, hundreds of thousands homeless and widespread destruction of crops in Vietnam.

NOVEMBER THROUGH DECEMBER

November marked a change in the synoptic flow pattern as the northeast monsoon became well established across the South China Sea and southeastern Asia. Easterly tradewinds dominated the Philippine Sea north of the near-equatorial trough. After a one week respite, Typhoon Skip (24W) appeared. It was a "straight-runner" and covered over 2,000 nm (3704 km) during its nine day lifetime. Skip (24W) tracked through the Philippine Islands and into the South China Sea. The system caused widespread damage to crops in the Philippines, killed over 100 persons and left over 600,000 homeless. Typhoon Tess (25W) formed in the near-equatorial trough before Skip (24W), but was slow to intensify. It was the only tropical cyclone to track across southern Vietnam this year. After Skip (24W) and Tess (25W), a break in tropical cyclone activity occurred until the third week of December. Following a massive outbreak of polar air from Asia, the southern Philippine Sea filled with convection and a near-equatorial trough formed. Tropical Storm Val (26W), which developed in the trough, proved difficult to position and hard to forecast. While decelerating from 25 kt (46 km/hr), Val (26W) peaked at an intensity of 55 kt (28 m/sec). Finally, the low-level circulation separated from the deep convection and was carried to the southwest along the edge of the winter monsoon.

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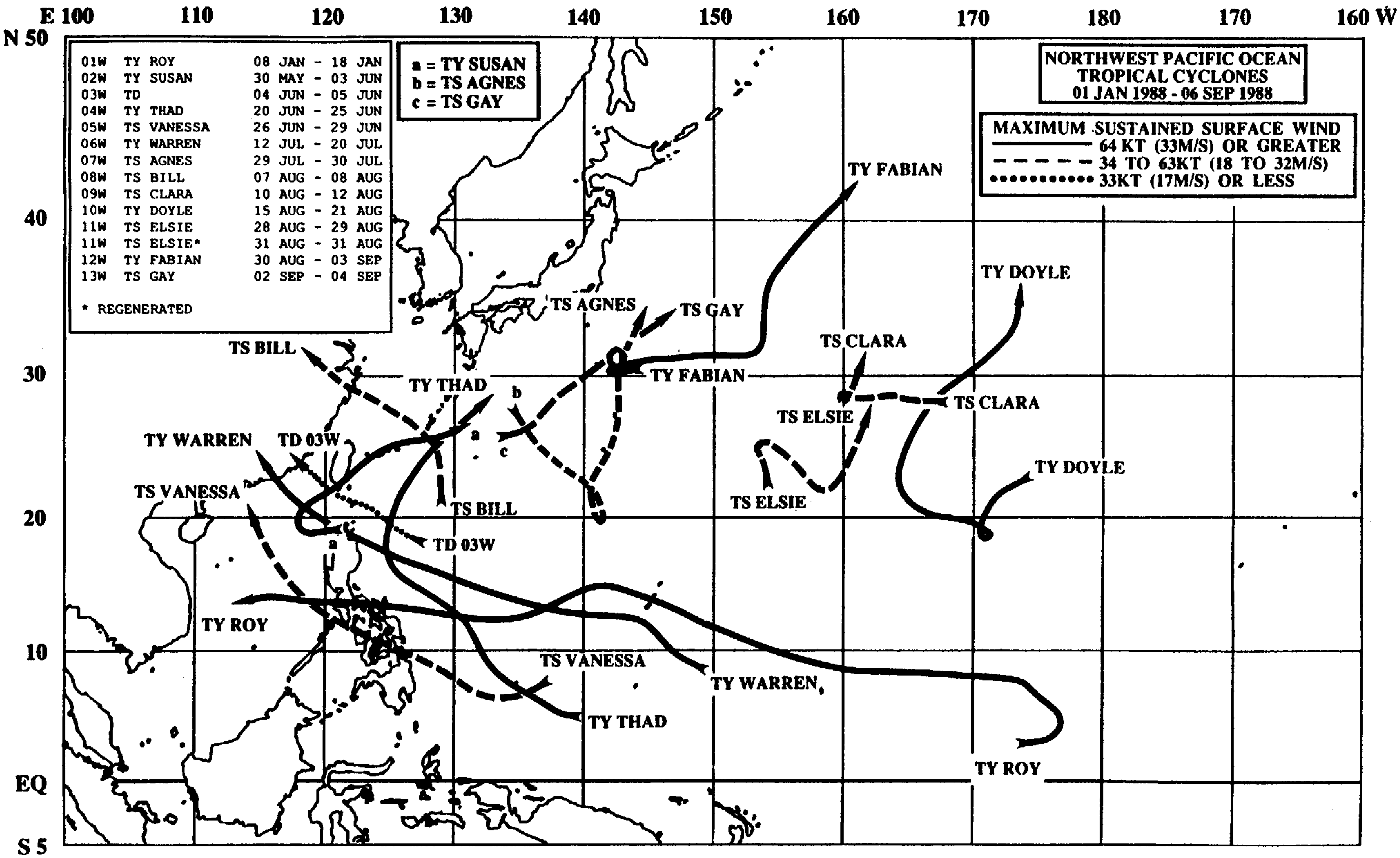
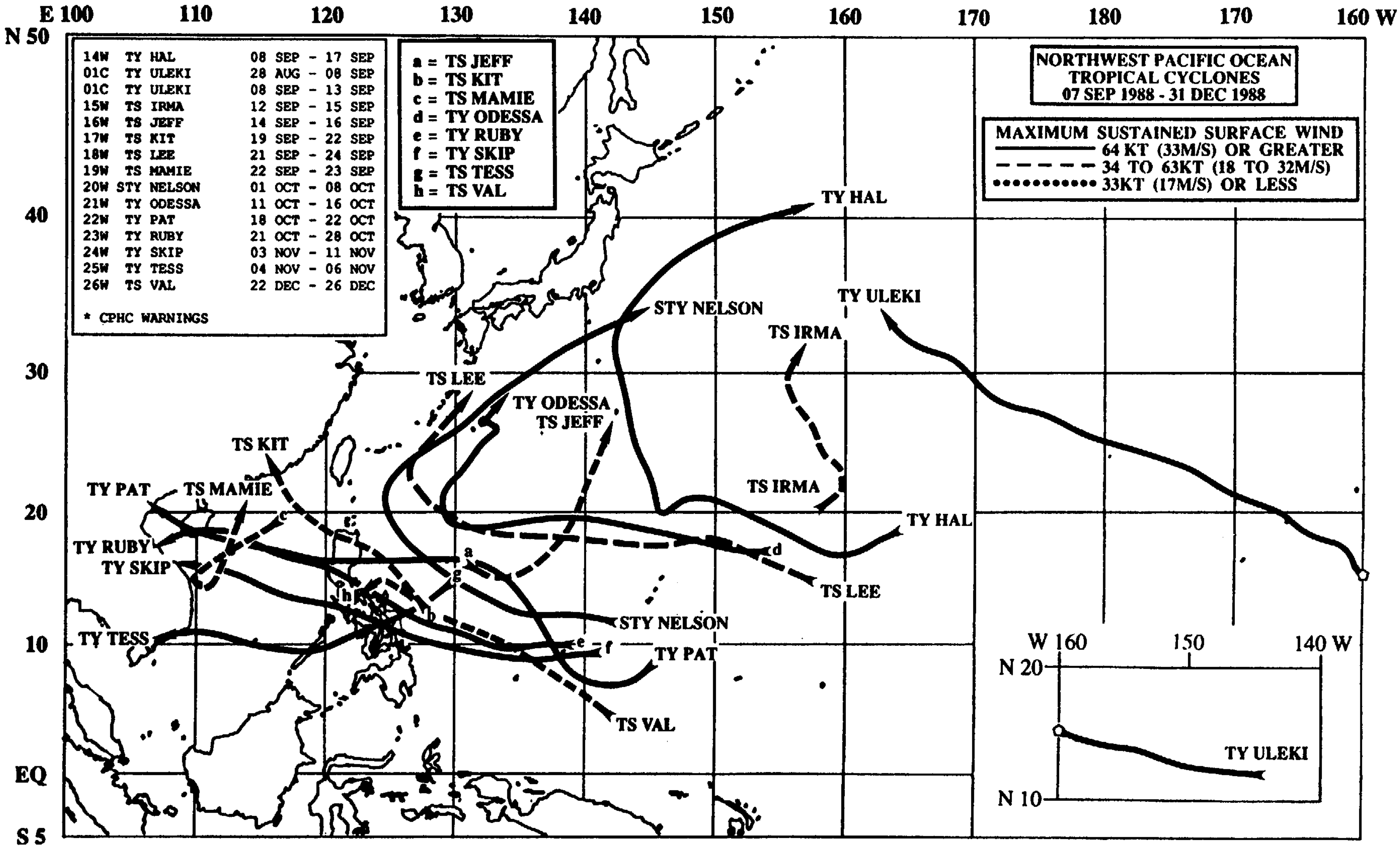
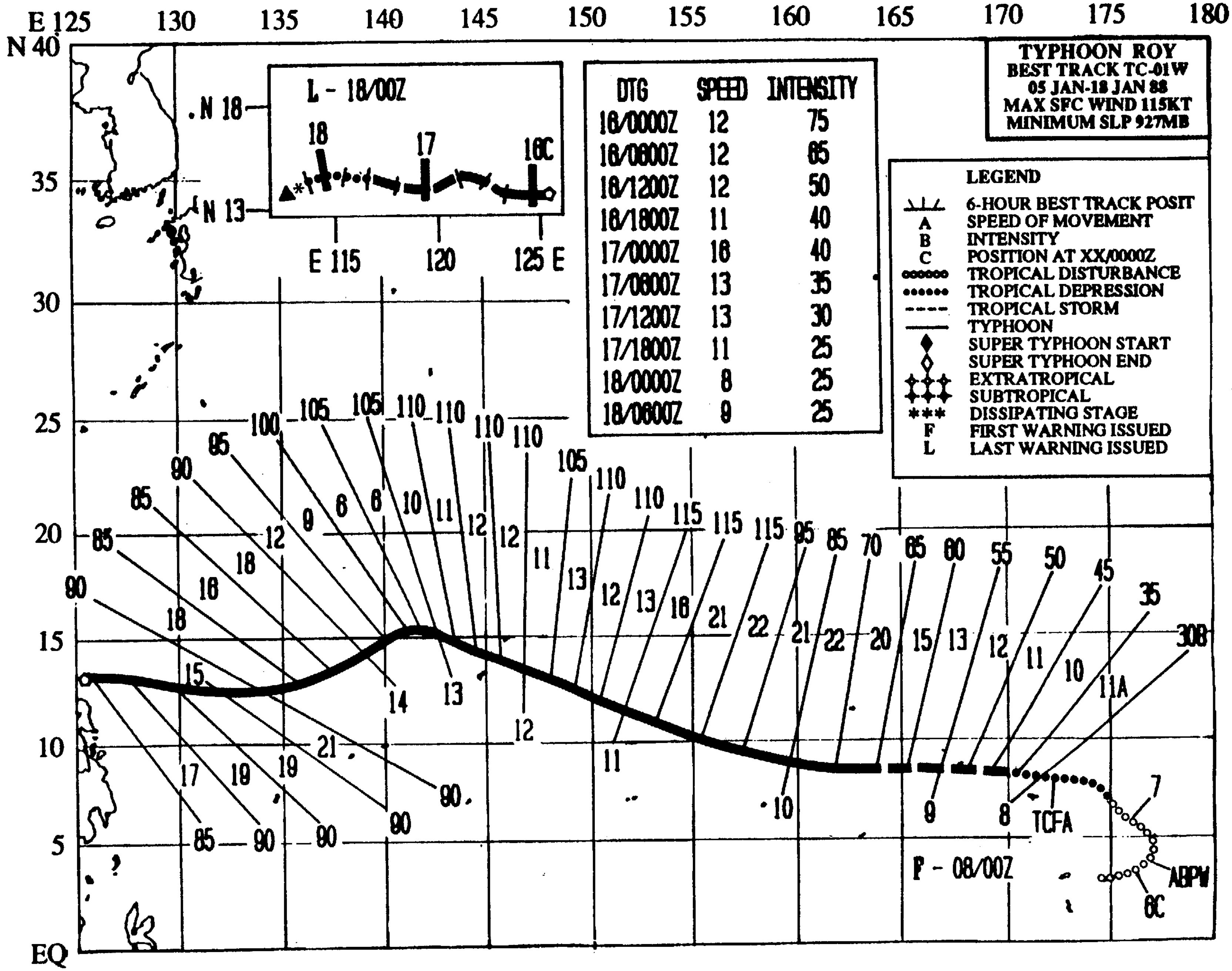

NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
01 JAN 1988 - 06 SEP 1988
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
01W TY ROY 08 JAN - 18 JAN
02W TY SUSAN 30 MAY - 03 JUN
03W TD 04 JUN - 05 JUN
04W TY THAD 20 JUN - 25 JUN
05W TS VANESSA 26 JUN - 29 JUN
06W TY WARREN 12 JUL - 20 JUL
07W TS AGNES 29 JUL - 30 JUL
08W TS BILL 07 AUG - 08 AUG
09W TS CLARA 10 AUG - 12 AUG
10W TY DOYLE 15 AUG - 21 AUG
11W TS ELSIE 28 AUG - 29 AUG
11W TS ELSIE* 31 AUG - 31 AUG
12W TY FABIAN 30 AUG - 03 SEP
13W TS GAY 02 SEP - 04 SEP
* REGENERATED
a = TY SUSAN
b = TS AGNES
c = TS GAY
E 100
110
120
130
140
150
160
170
180
170
160 W
N 50
40
30
20
10
EQ
S 5
TY FABIAN
TY DOYLE
TS AGNES
TS GAY
TS CLARA
TS BILL
TY THAD
TY FABIAN
TS ELSIE
TS CLARA
TY WARREN
TD 03W
TS VANESSA
TS BILL
TS ELSIE
TY DOYLE
TD 03W
TY ROY
TS VANESSA
TY WARREN
TY THAD
TY ROY
a
b
c


NORTHWEST PACIFIC OCEAN
TROPICAL CYCLONES
07 SEP 1988 - 31 DEC 1988
14W TY HAL 08 SEP - 17 SEP
01C TY ULEKI 28 AUG - 08 SEP
01C TY ULEKI 08 SEP - 13 SEP
15W TS IRMA 12 SEP - 15 SEP
16W TS JEFF 14 SEP - 16 SEP
17W TS KIT 19 SEP - 22 SEP
18W TS LEE 21 SEP - 24 SEP
19W TS MAMIE 22 SEP - 23 SEP
20W STY NELSON 01 OCT - 08 OCT
21W TY ODESSA 11 OCT - 16 OCT
22W TY PAT 18 OCT - 22 OCT
23W TY RUBY 21 OCT - 28 OCT
24W TY SKIP 03 NOV - 11 NOV
25W TY TESS 04 NOV - 06 NOV
26W TS VAL 22 DEC - 26 DEC
* CPHC WARNINGS
a = TS JEFF
b = TS KIT
c = TS MAMIE
d = TY ODESSA
e = TY RUBY
f = TY SKIP
g = TS TESS
h = TS VAL
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
E 100
110
120
130
140
150
160
170
180
170
160 W
N 50
40
30
20
10
EQ
S 5
TY HAL
STY NELSON
TY ULEKI
TS IRMA
TS LEE
TY ODESSA
TS JEFF
TS KIT
TY PAT
TS MAMIE
TY RUBY
TY SKIP
TS IRMA
TY HAL
TS LEE
STY NELSON
TY TESS
TY PAT
TS VAL
W 160
150
140 W
N 20
N 10
TY ULEKI



DTG	SPEED	INTENSITY
16/0000Z	12	75
16/0600Z	12	65
16/1200Z	12	50
16/1800Z	11	40
17/0000Z	16	40
17/0600Z	13	35
17/1200Z	13	30
17/1800Z	11	25
18/0000Z	8	25
18/0600Z	9	25

TYPHOON ROY (01W)

Typhoon Roy was the first significant tropical cyclone of 1988 in the western North Pacific. It formed as a "twin" (Figure 3-01-1) with its southern hemisphere counterpart, Tropical Cyclone 07P (Anne). During a period of eleven days in January, Roy made a 4000 nm (7408 km) westward trek, caused significant damage on Kwajalein Atoll and the islands of Guam and Rota, crossed the Philippine Islands and dissipated over the South China Sea. Typhoon Roy's close approach to Guam resulted in the most destruction since Super

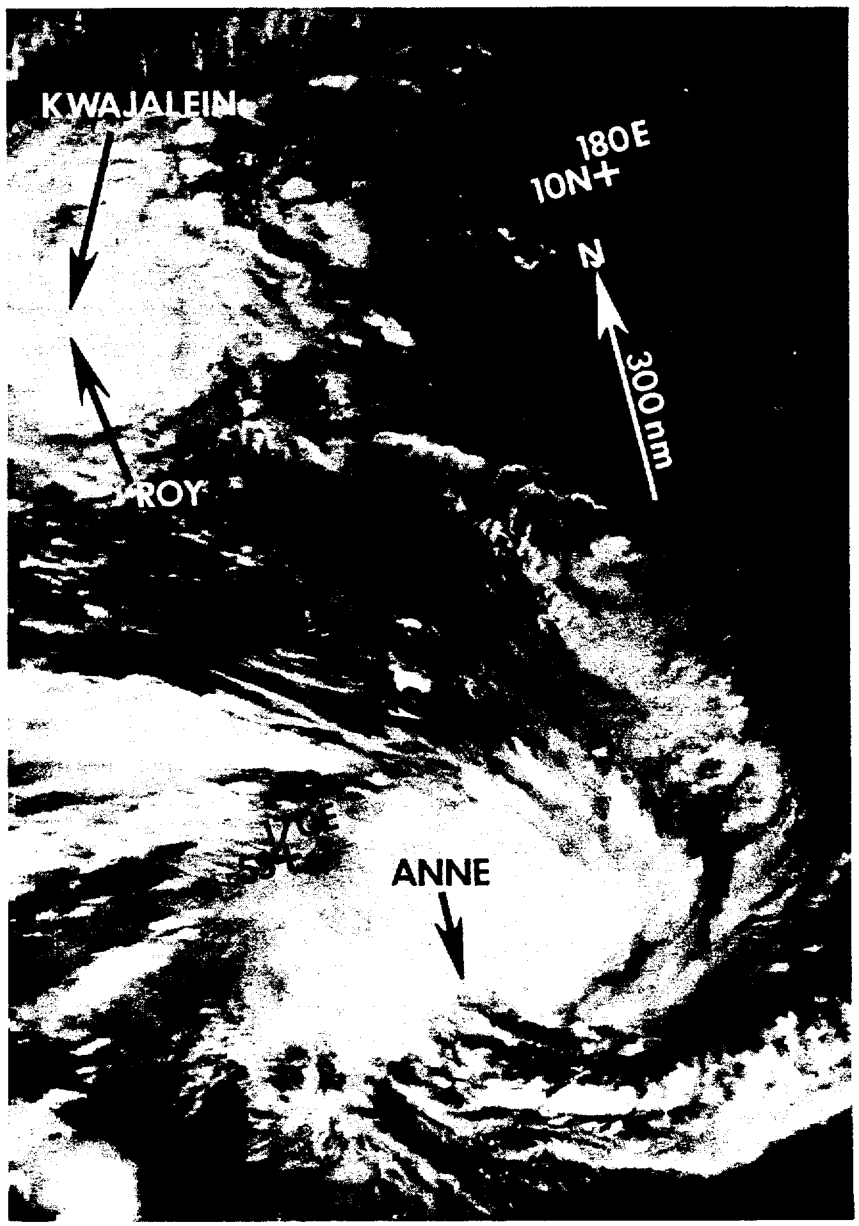


Figure 3-01-1. Typhoon Roy (01W) with its southern hemisphere counterpart, Tropical Cyclone 07P (Anne) (081957Z January NOAA infrared imagery).

Typhoon Pamela (1976).

Prior to tropical cyclone genesis, above normal sea surface temperature anomalies and greater than normal cloudiness persisted in the central Pacific Ocean. Roy began in this area of increased cloudiness southeast of the Marshall Islands, with persistent convection first noted on the Significant Tropical Weather Advisory at 060600Z. The suspect area was mirrored by another area of persistent convection in the southern hemisphere, which developed into Tropical Cyclone 07P (Anne). A band of anomalous low-level equatorial westerlies was located between the two cloud systems. Gradient-level wind reports from Tarawa (WMO 91610) in the Kiribati Islands during early January consistently indicated moderate westerly winds. (Climatic windflow at Tarawa for January is east-northeasterly at 12 kt (6 m/sec).)

By 7 January, Roy's cloud organization had improved and JTWC issued a Tropical Cyclone Formation Alert at 072000Z. Satellite intensity technique estimates of 30 kt (15 m/sec) combined with synoptic reports of 30 kt (15 m/sec) surface winds and a 997 mb surface pressure from Majuro (WMO 91376) prompted the issuance of the first warning on Tropical Depression 01W at 080000Z. (Tropical Cyclone 07P (Anne) in the southern hemisphere reached tropical storm intensity 12-hours earlier). As Tropical Depression 01W moved north of Majuro, the island experienced maximum sustained winds of 35 kt (18 m/sec) with gusts to 45 kt (23 m/sec), and several buildings suffered minor structural damage.

Satellite reconnaissance continued to detect deepening of the system and Tropical Depression 01W was upgraded to a tropical storm at 080600Z. Roy (Figure 3-01-1) passed 35 nm (65 km) south of Kwajalein Atoll at 081800Z. Kwajalein Island (WMO 91366) reported maximum sustained winds of 48 kt (25 m/sec) with a peak gust of 57 kt (29 m/sec), a minimum sea-level pressure (MSLP) of 992 mb and light-to-moderate structural damage. Ebeye

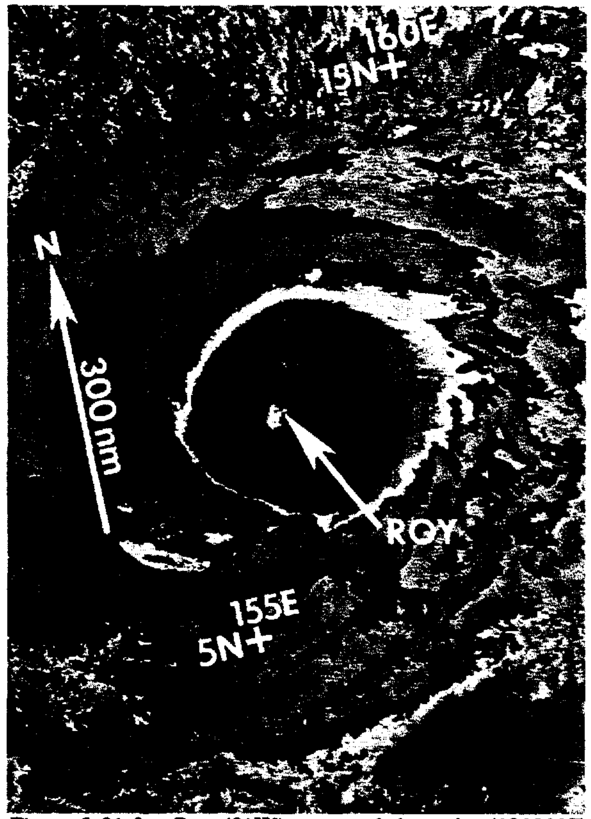


Figure 3-01-2. Roy (01W) near peak intensity (100823Z January DMSP enhanced infrared imagery).

Island just 4 nm (7 km) to the north experienced moderate-to-severe structural damage, one death and loss estimates of five million dollars. Both islands had 20 to 22 ft (6.1 to 6.7 m) surf and low-lying areas were flooded. Using their weather radar, meteorologists on Kwajalein were the first to detect the formation of Roy's eye at 081000Z. Later at 091200Z, a satellite estimate of 65 kt (33 m/sec) resulted in the upgrade to typhoon intensity.

While at a forward speed of 22 kt (41 km/hr) at 101200Z, Roy (Figure 3-01-2) reached a peak intensity of 115 kt (59 m/sec) 510 nm (945 km) east-southeast of Guam. The typhoon was embedded in a moderate mid-tropospheric east-southeasterly flow south of the subtropical ridge axis, as indicated by aircraft reports at 500 mb (Figure 3-01-3). Then Typhoon Roy slowed to 12 kt (22 km/hr) as it approached Guam (Figure 3-01-3). Detachment 2, 20 Weather

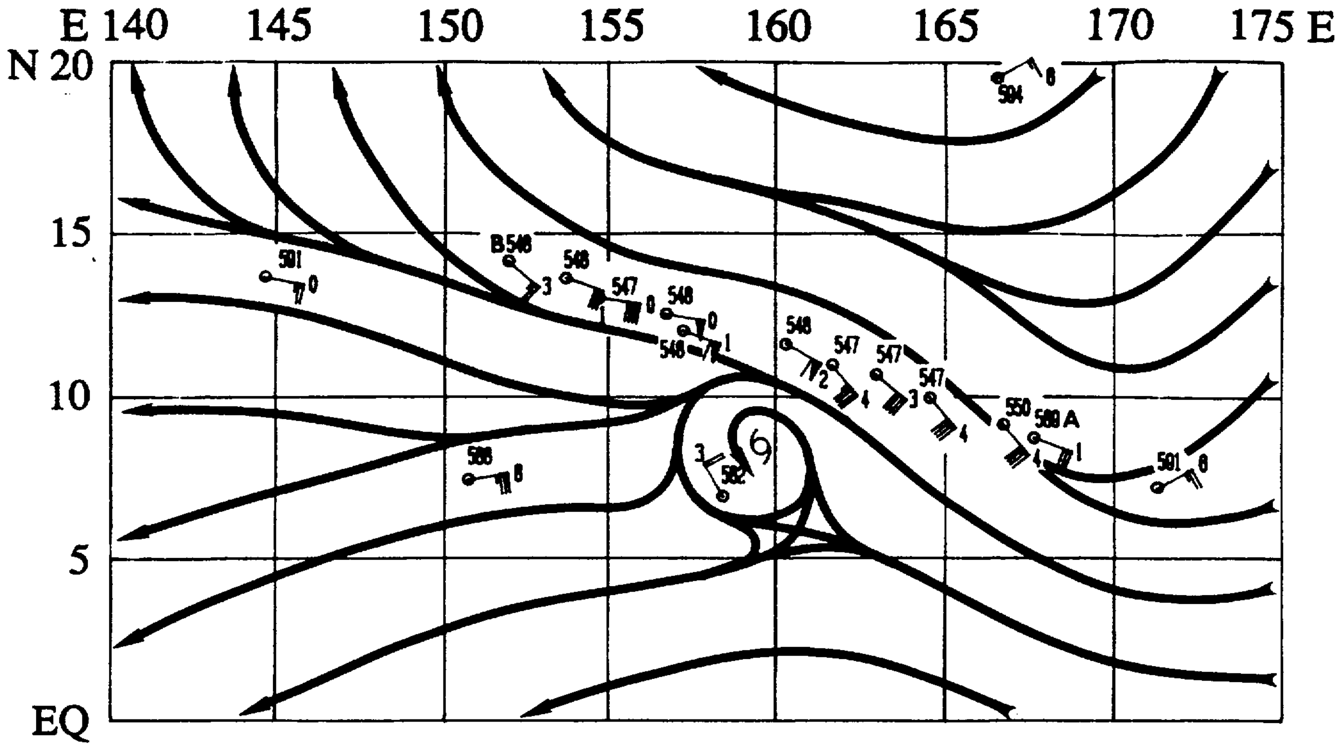


Figure 3-01-3. 100000Z January 500 mb streamline analysis with additional reports along the aircraft track to the north of Roy. The aircraft reports are from point A (100057Z) to point B (100340Z).

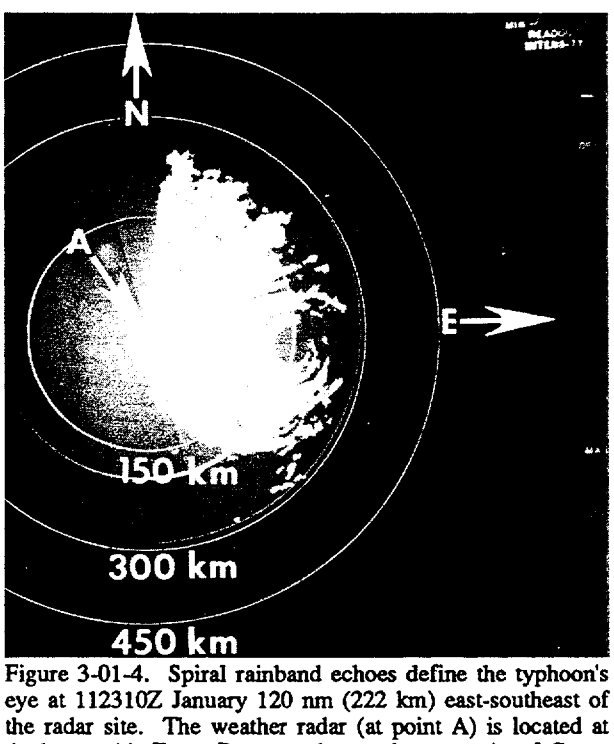
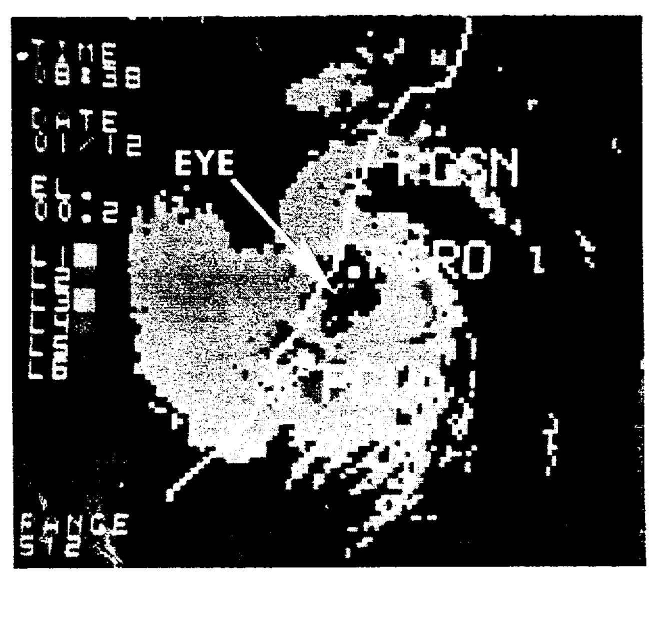


Figure 3-01-4. Spiral rainband echoes define the typhoon's eye at 112310Z January 120 nm (222 km) east-southeast of the radar site. The weather radar (at point A) is located at Andersen Air Force Base on the northeastern tip of Guam (photo courtesy of MSgt Robert W. Yates and Detachment 2, 20th Weather Squadron).

Figure 3-01-5. 110838Z January digitized radar display of Roy's rain shield. Note the island of Rota (call sign PGRO) lies within the ragged eye. The call sign PGUA marks the location of Andersen Air Force Base on Guam and PGSN the airfield on Saipan (photo courtesy of MSgt Robert W. Yates and Detachment 2, 20th Weather Squadron).



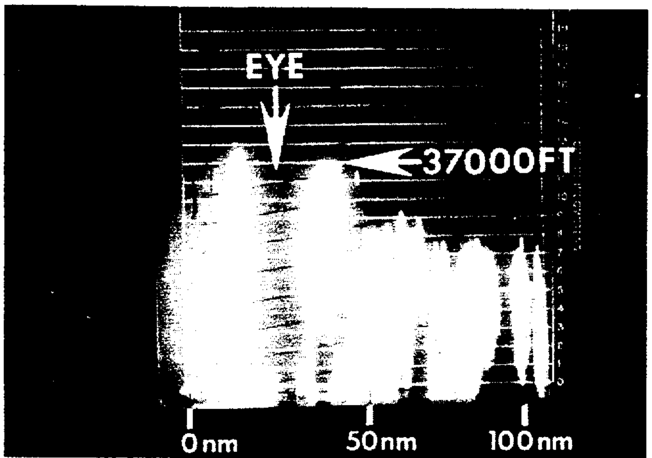


Figure 3-01-6. At 110838Z January the Andersen Air Force Base weather radar display paints 37,000 feet (11.3 km) rain echo tops in the outer eye wall cloud. The radar returns in the lower left of the picture and closest to the radar site are attenuated due to heavy rain (photo courtesy of MSgt Robert W. Yates and Detachment 2, 20th Weather Squadron).

Squadron at Andersen Air Force Base on Guam first detected the eye on radar at 111930Z (Figure 3-01-4). These weather radar data were instrumental in tracking Typhoon Roy's center, as it made its closest point of approach (Figures 3-01-5 and 3-01-6) 32 nm (59 km) north of Guam at 120930Z . Wind estimates near the center were 110 kt (57 m/sec). However, Andersen Air Force Base on the northeastern tip of Guam measured maximum sustained winds of 66 kt (34 m/sec) with peak gusts to 98 kt (50 m/sec) as the eye wall passed just to the north. Buildings, particularly those on the northern part of Guam, sustained light-to-moderate structural damage (Figure 3-01-7). Crops and vegetation on Guam suffered extensive damage, with estimates of losses as high as 23.5 million dollars. As a credit to the disaster preparedness team, no severe injuries or loss of life were

Figure 3-01-7. Roy almost went on a shopping spree as indicated by the structural damage to the Andersen Air Force Base commissary on Guam.

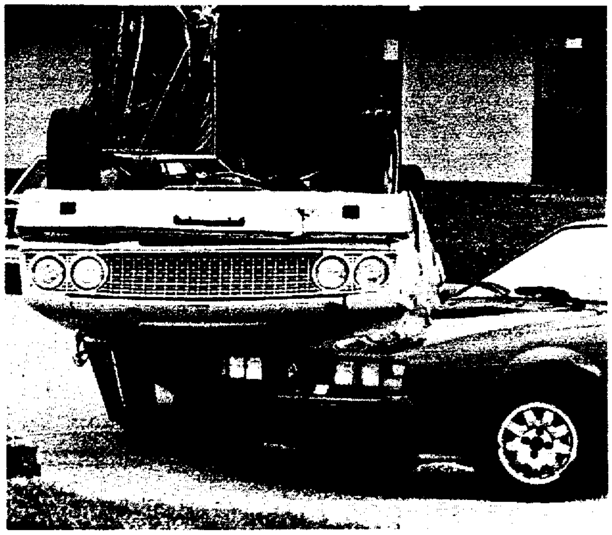


Figure 3-01-8. Strong winds rearranged these parked vehicles.

reported on Guam (Figure 3-01-8).

In comparison, the island of Rota, 40 nm (74 km) north-northeast of Guam, suffered the heaviest damage. At 120724Z, shortly before eye passage, Rota's automated weather observing equipment reported maximum sustained winds of 71 kt (37 m/sec) with peak gusts to 104 kt (54 m/sec). Because of apparent communication problems, no further data were received until the 120905Z report of 60 kt (31 m/sec) with gusts to 89 kt (46 m/sec). Residents of Rota described the eye passage as a marked lessening of wind speed and clearing skies from 120730Z to 120810Z. Concurrently, a microbarograph trace from the Naval Oceanography Command Detachment, Agana, located on central Guam indicated a minimum sea-level pressure of 979 mb from 120800Z to 121000Z (Figure 3-01-9). A large percentage of the homes on Rota were destroyed and the remainder damaged. Four minor injuries were reported, which resulted when a flying roof impacted another building where people had sought shelter. Numerous coconut trees were downed and all crops destroyed. With an estimated 95 percent of the utility poles knocked down, lack of power and potable water completely disrupted the community.

After moving through the southern Marianas, Roy continued to slow. Earlier analysis of 500 mb aircraft reports revealed a mid-tropospheric anticyclone east of the Philippine Islands with ridging extending to the northeast of Roy's center. As Typhoon Roy approached the Mariana Islands, it apparently responded to the weaker mid-level steering flow and decelerated. A weakness in the subtropical ridge was located almost due north of Guam . It was initially thought that Roy would weaken the subtropical ridge and ultimately recurve. However, this did not happen. Instead, the lower tropospheric ridge built, as reflected by 700 mb pressure-height rises at Iwo Jima (WMO 47971). In turn the typhoon accelerated to the southwest. (By this time, Roy's maximum sustained winds had weakened to 90 kt (46 m/sec). This intensity was maintained until reaching the mountainous terrain of southern Luzon.)

At 141800Z, Roy returned to a more westward course along the southern edge of the subtropical ridge and increased its speed of 20 kt (37 km/hr). From 160000Z to 170000Z, Roy tracked across southern Luzon. The mountains and increased vertical wind shear further

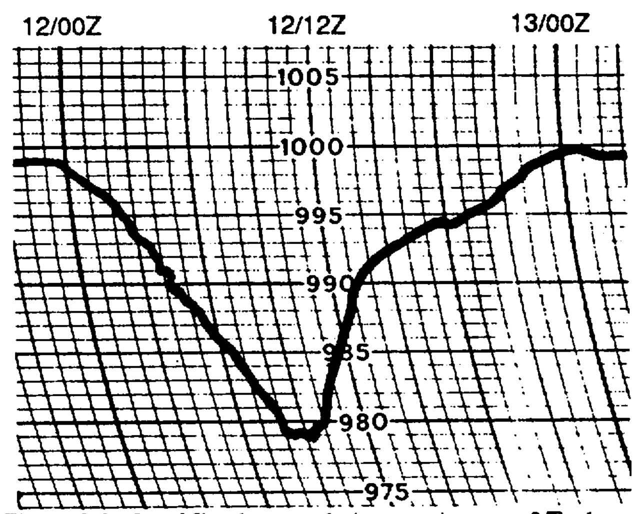


Figure 3-01-9. Microbarograph (pressure) trace of Typhoon Roy (01W) recorded at the Naval Oceanography Command Detachment, Agana, Guam indicates a minimum sea-level pressure of 979 mb from 120800Z to 121000Z January.

weakened Roy from 75 kt (39 m/sec) to 40 kt (21 m/sec). Once in the South China Sea, Roy's interaction with the low-level northeasterly flow of the winter monsoon spawned gales, but dissipation was imminent. At 171200Z, Tropical Storm Roy was downgraded to a tropical depression and the final warning followed at 180000Z.

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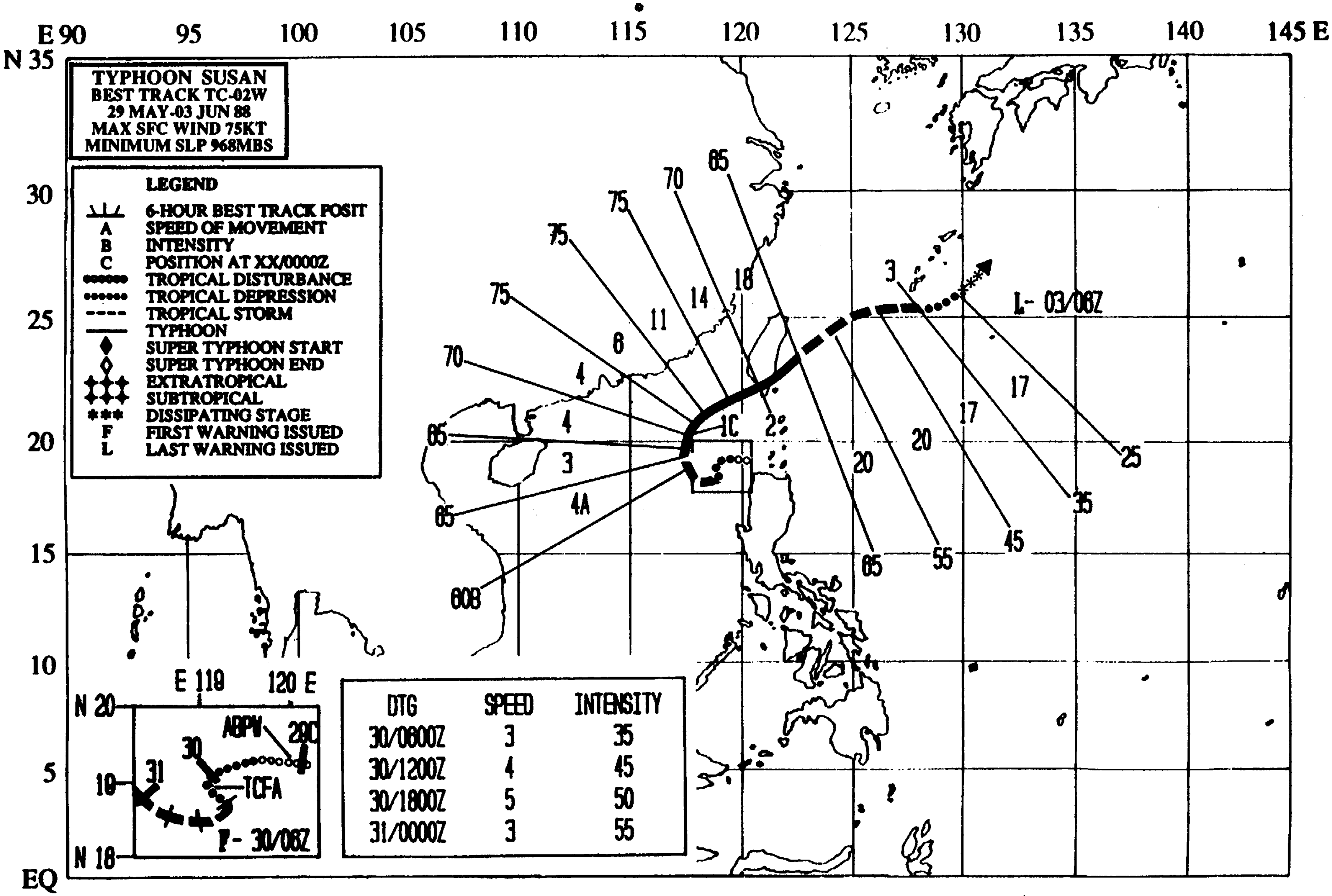

TYPHOON SUSAN
BEST TRACK TC-02W
29 MAY-03 JUN 88
MAX SFC WIND 75KT
MINIMUM SLP 968MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
5
EQ
L- 03/06Z
E 119
120 E
N 20
19
N 18
ABPW
TCFA
F- 30/06Z
DTG SPEED INTENSITY
30/0600Z 3 35
30/1200Z 4 45
30/1800Z 5 50
31/0000Z 3 55

TYPHOON SUSAN (02W)

Susan was a short-lived typhoon with maximum sustained winds of 75 kt (39 m/sec). Slow to exit the the South China Sea, it threatened the southeast of coast of China, then churned across the southern tip of Taiwan and rapidly weakened.

The synoptic pattern during the fourth week of May was anomalous with low-level southwesteries extending across the northern Philippine Sea into the northern Marianas and southern Bonin Islands (Figure 3-02-1). Surface pressures in the monsoonal trough, that was north of this southwesterly flow, were 4 to 5 mb below normal. Cyclonic vortices that formed in the trough were transitory until 28 May when a persistent circulation formed off the northwest coast of Luzon (see Figure 3-02-2). Initially the convection was displaced equatorward of the the low-level circulation center by vertical wind shear, but within a day the cloudiness became more centralized. The cloud system as a whole then appeared to isolate itself from the surrounding zone of maximum cloudiness. The Significant Tropical Weather Advisory was reissued at 290200Z May to include this suspect monsoon depression. Although the upper-level outflow was restricted in the north and west, the amount of central convection and organization continued to increase, prompting JTWC to issue a Tropical Cyclone Formation Alert at 300200Z May. The first warning on Tropical Storm Susan at 300600Z followed from a satellite

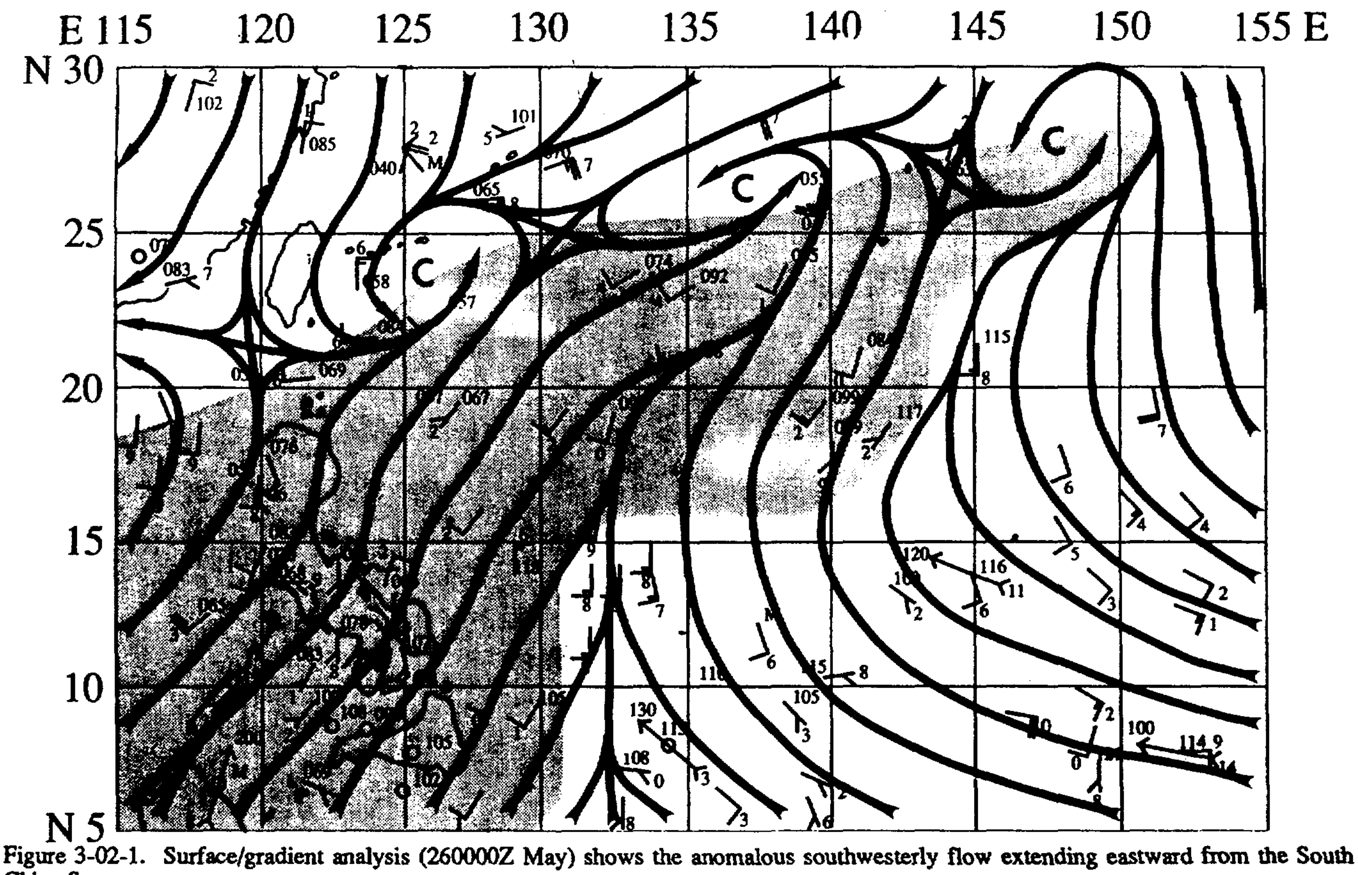


Figure 3-02-1. Surface/gradient analysis (260000Z May) shows the anomalous southwesterly flow extending eastward from the South China Sea.

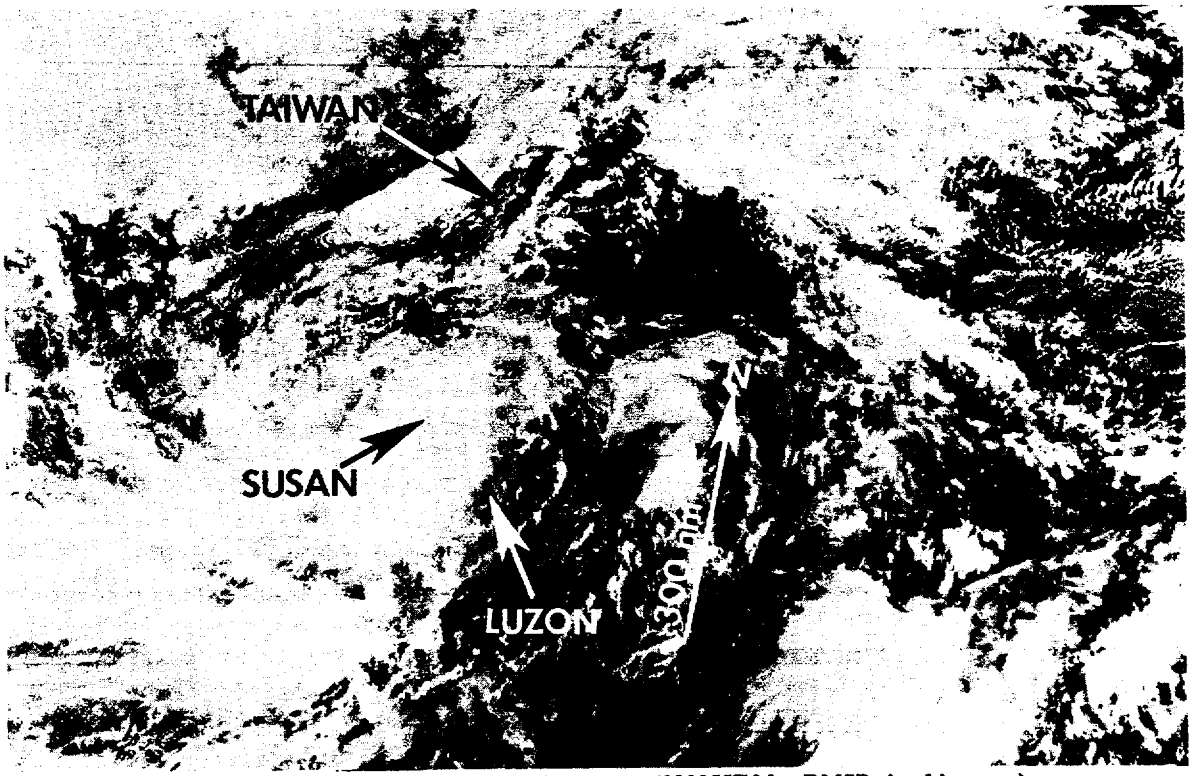


Figure 3-02-2. Susan as a tropical disturbance (280055Z May DMSP visual imagery).

analysis wind estimate of 45 kt (23 m/sec).

At warning time Susan's initial position was 65 nm (120 km) west of northern Luzon. Past movement had been erratic because the low-level circulation was located within the larger monsoonal trough. For forecast movement the tropical cyclone was near the axis of the subtropical ridge and recurvature was favored by the Typhoon Acceleration Prediction Technique (TAPT) (Weir, 1982). However, TAPT guidance identified the 200 mb northwesterly flow as unfavorable for rapid acceleration. The initial track forecasts were correct based on this guidance and Susan recurved and moved slowly to the northeast.

Susan intensified rapidly after recurvature. At 310600Z Susan was upgraded to a typhoon based upon satellite intensity estimates. The sustained winds increased to 75 kt (39 m/sec) at 010600Z June (see Figure 3-02-3). Now packing its most dangerous winds,

Figure 3-02-3. Typhoon Susan at maximum intensity in the Luzon Strait (011109Z June DMSP infrared imagery).

Susan accelerated towards the northeast and the southern tip of Taiwan. Aloft, a mid-level trough in the polar westerlies was advancing across eastern China. The trough became more meridional as it approached Susan. A combination of acceleration along-track, terrain effects (induced by the rugged mountains of Taiwan) and increasing vertical shear stripped away Susan's deep central convection, leaving behind an exposed low-level circulation center (Figure 3-02-4). The typhoon was downgraded to tropical storm intensity at 021200Z and further to a tropical depression at 030000Z. The final warning was issued at 030600Z. Twelve hours later the residual low-level vortex was no longer discernible on satellite imagery or in the synoptic data.

In retrospect, the majority of the damage to the island of Luzon, Republic of the Philippines resulted from heavy rains, not winds. A landslide triggered by these rains in Olongapo City, 50 nm (93 km) northwest of Manila, led to one death. In Manila another landslide killed five people. Flooding closed the main roads in Manila, disrupted travel and caused the loss of millions of prawns and lobsters from fishponds. Also, a tornado destroyed 18 homes outside of Manila.

Although Susan passed about 10 nm (18 km) south of the island of Okinawa, Japan at 022200Z, the system had rapidly weakened and the peak wind recorded at Kadena Air Base was 41 kt (21 m/sec) with 47 kt (24 m/sec) at Naha. No deaths or injuries were reported by authorities on Okinawa. No reports of damage were received from Taiwan.

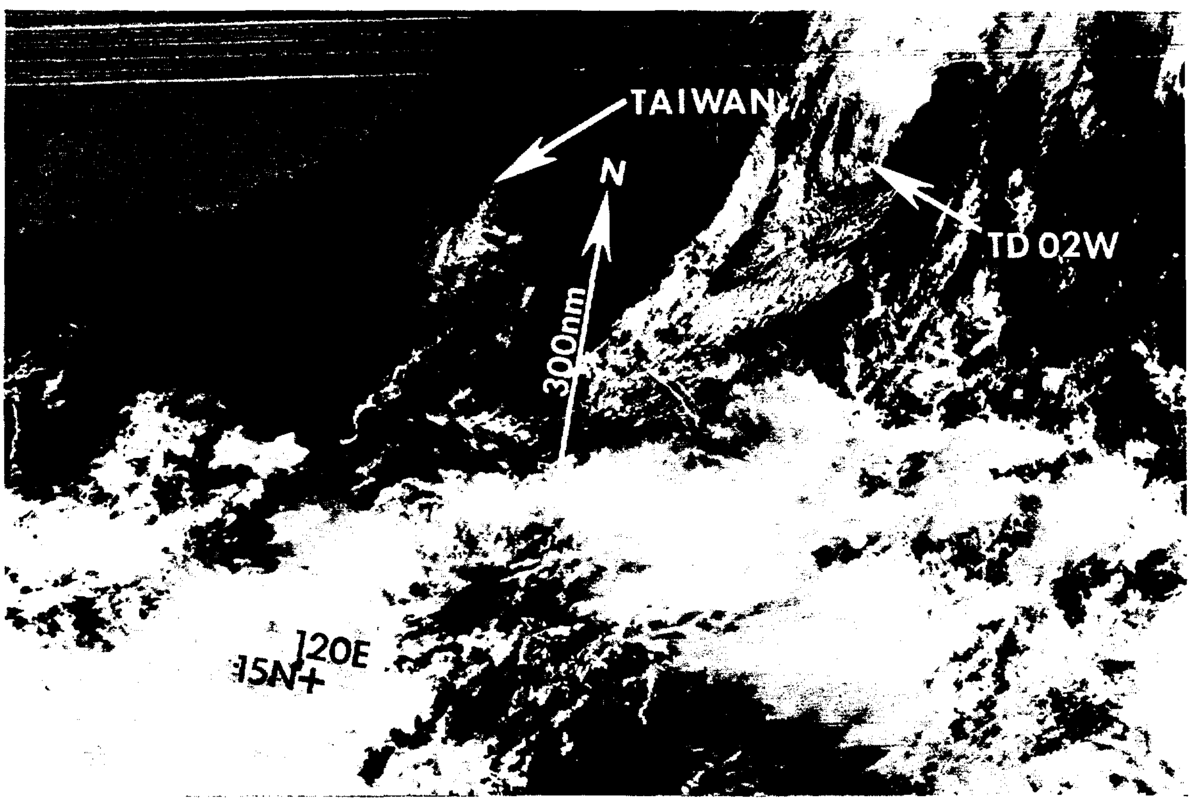
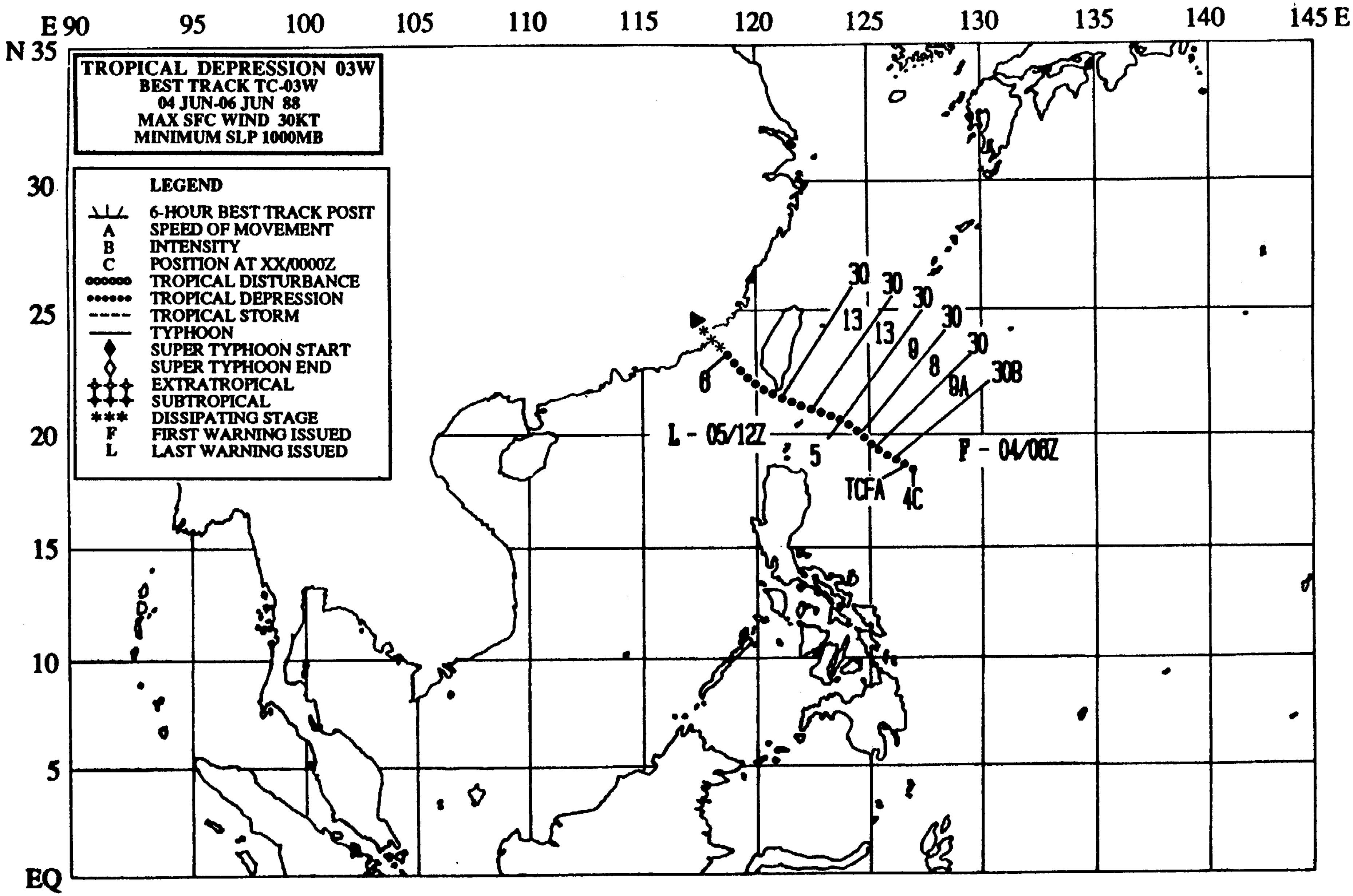


Figure 3-02-4. The residual exposed low-level circulation of Tropical Depression 02W (Susan) (030057Z June DMSP visual imagery).


TROPICAL DEPRESSION 03W
BEST TRACK TC-03W
04 JUN-06 JUN 88
MAX SFC WIND 30KT
MINIMUM SLP 1000MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
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145 E
N 35
30
25
20
15
10
5
EQ
L - 05/12Z
F - 04/06Z
TCFA
4C
30B
9A
6
5
30
13
9
8

TROPICAL DEPRESSION 03W

On 3 June the remains of Typhoon Susan (02W) sped northeastward and left behind the low-level southwest monsoonal flow which terminated abruptly in the northwestern Philippine Sea. Within a day the enhanced convection in the northwestern Philippine Sea acquired convective banding and cyclonic rotation. A Tropical Cyclone Formation Alert documented this event at 040200Z. The convection consolidated near the low-level circulation center and the first warning on Tropical Depression 03W followed at 040600Z based on a satellite intensity estimate of 30 kt (15 m/sec) surface winds. The satellite imagery (Figure 3-03-1) shows Tropical Depression 03W near its maximum intensity of 30 kt (15 m/sec).

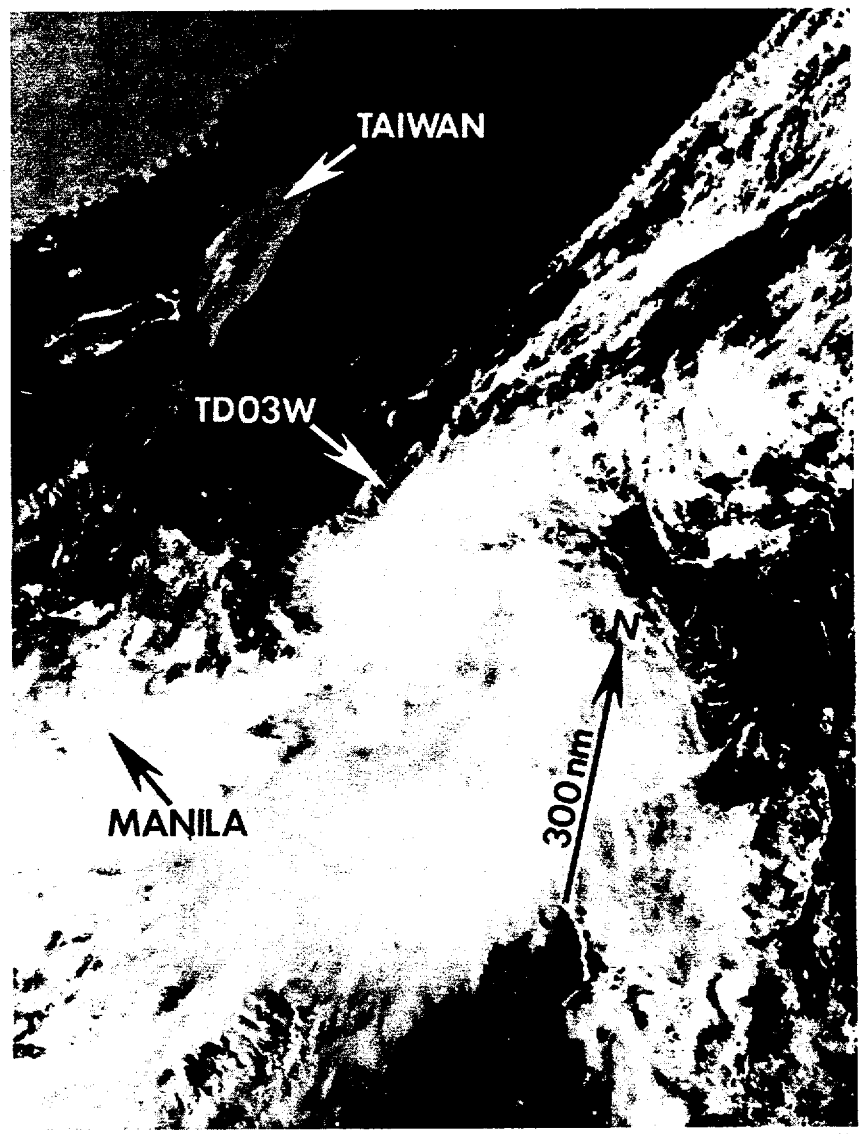


Figure 3-03-1. Tropical Depression 03W near peak intensity (040037Z June DMSP visual data).

Shortly after the first warning was issued, the central convection collapsed and further intensification ceased. In Figure 3-03-2 note that the system center is basically free of deep convection with only remnants of high cloud debris evident. The banding feature is displaced to the south and east. The next daytime visual imagery (Figure 3-03-3) reveals low-level stratiform cloudiness filling the center. The deep convection is well removed from the center with the exception of one transitory cumulonimbus. The final warning was issued on 051200Z June, when it became apparent that the system was dissipating.

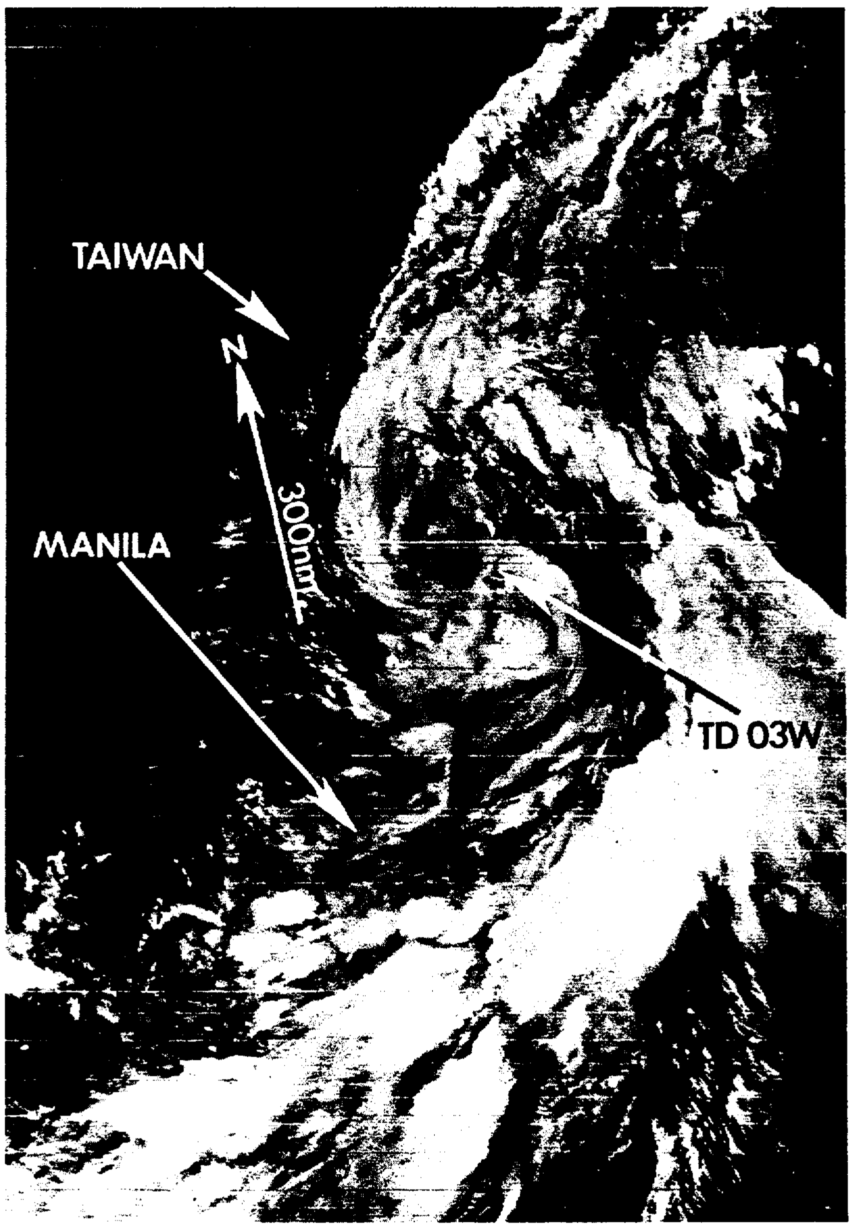


Figure 3-03-2. Only high-level cloud debris are in evidence over the center of the low-level circulation (041318Z June DMSP infrared imagery).

In retrospect Tropical Depression 03W's failure to mature and achieve tropical storm intensity may be related to its track. In contrast to Typhoon Susan (02W), which traveled northeastward along a zone of increased cloudiness, Tropical Depression 03W took a west-northwesterly track into the cloud minimum area that had settled across southeastern China and the northern South China Sea. Bao (1981) developed a hypothesis for forecasting typhoon movement based on satellite observed cloudiness which suggested that tropical cyclones move into, or along, areas of preexisting enhanced cloudiness - or conversely, tropical cyclones don't move into areas of minimum cloudiness. If they do, there is a price. Unless the tropical cyclone is large enough to modify the ambient environment, which is unfavorable, dissipation will result.

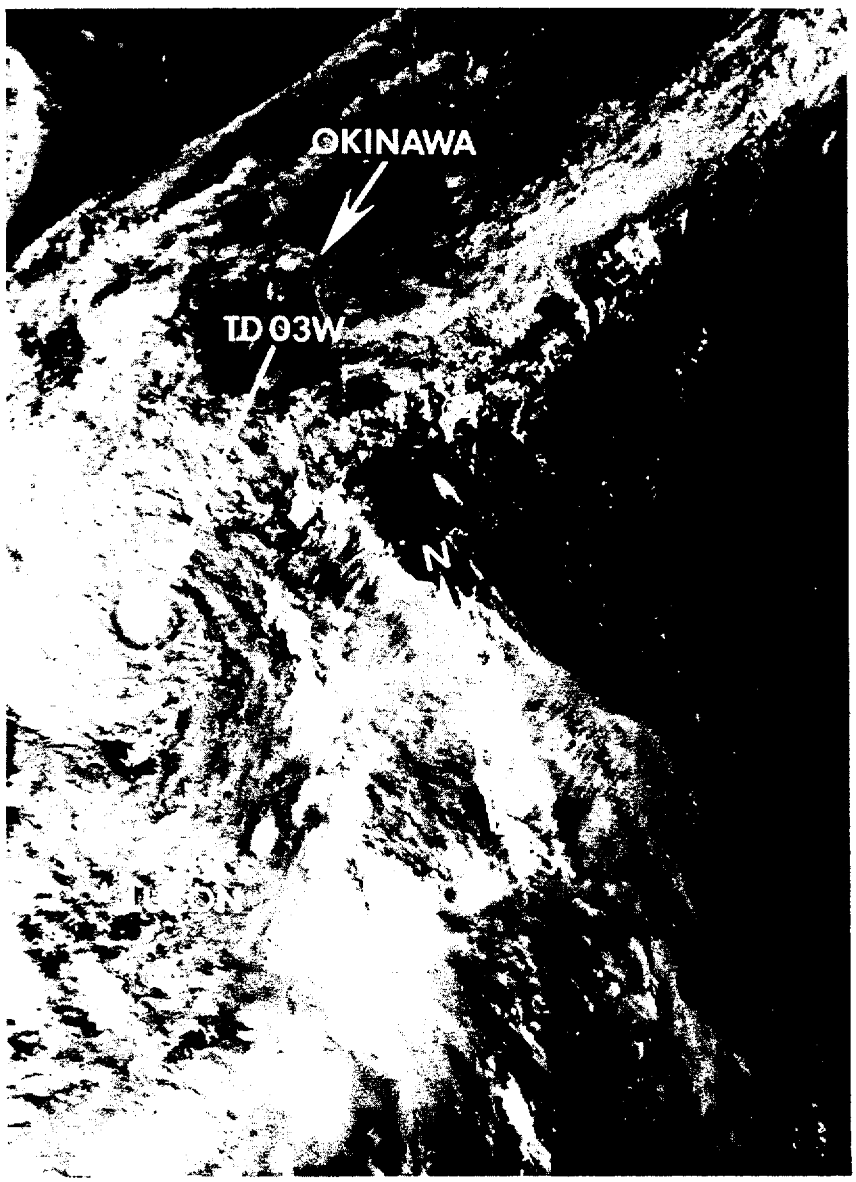
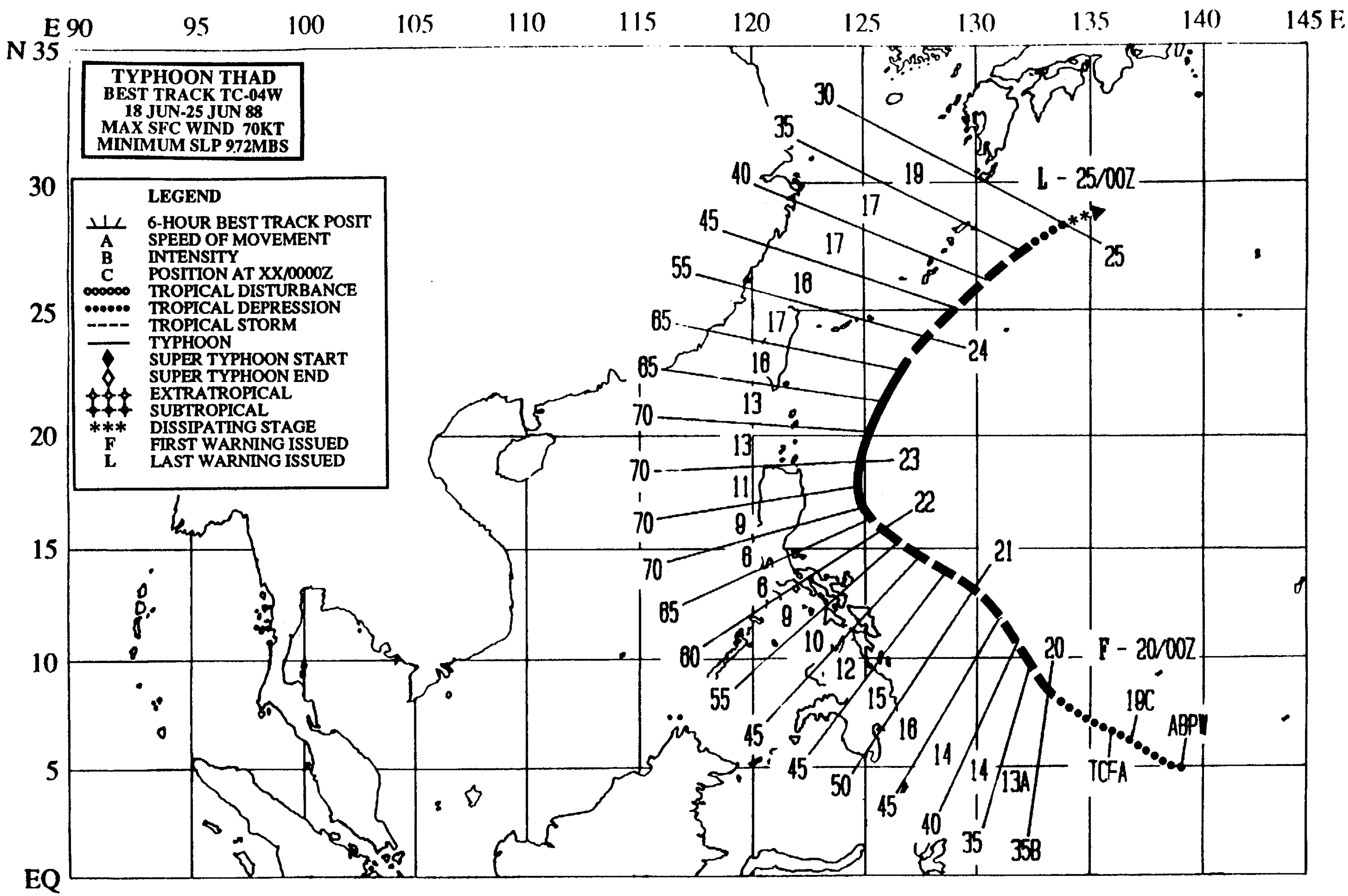


Figure 3-03-3. Stratiform low-level cloudiness fills the center of TD 03W (042302Z June NOAA visual imagery).



TYPHOON THAD
BEST TRACK TC-04W
18 JUN-25 JUN 88
MAX SFC WIND 70KT
MINIMUM SLP 972MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
5
EQ
L - 25/00Z
F - 20/00Z
TCFA
ABPW
10C

44

TYPHOON THAD (04W)

Thad was the second of three tropical cyclones to develop during June and the third typhoon of 1988. Typhoon Thad tracked over 2000 nm (3704 km) during its lifetime, recurved just east of the island of Luzon in the Republic of the Philippines and passed 80 nm (148 km) southeast of the island of Okinawa, Japan before dissipating over water. The recurvature forecast was complicated by a complex interaction of the tropical cyclone with upper-level synoptic features.

After Tropical Depression 03W dissipated during the first week of June, there was a two week hiatus in tropical cyclone activity in the western North Pacific and low-level westerly flow established itself across the southern Philippine Sea. Thad began in the zone of increased cyclonic shear between this westerly flow and the easterly tradewinds 300 nm (556 km) south of Ulithi Atoll in the western Caroline Islands. The disturbance was first mentioned on the Significant Tropical Weather Advisory at 180600Z. Initially Thad's intensification may have been slowed by increased upper-level wind shear across the system, caused by the unfavorable location of an intense Tropical Upper-Tropospheric Trough (TUTT) low to its northeast. However, as the disturbance's central convection consolidated, the separation between Thad's upper-level circulation center and the TUTT low lessened.

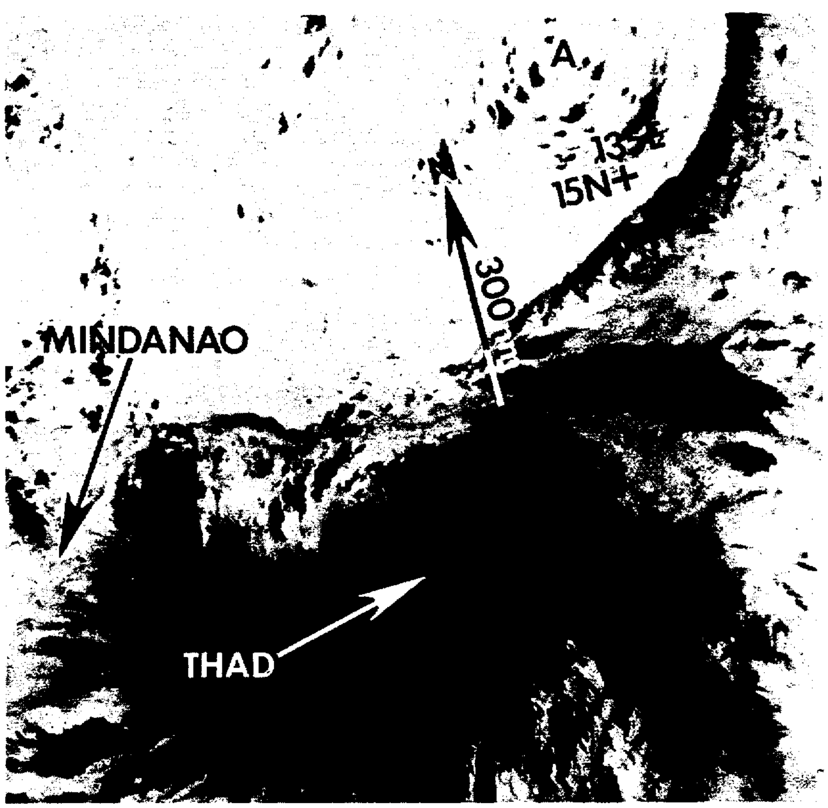


Figure 3-04-1. Thad, shortly before reaching tropical storm intensity. Note the vigorous TUTT cell (at A) to the northeast of the tropical disturbance (191914Z June NOAA infrared imagery).

The system's upper-level outflow pattern improved and a Tropical Cyclone Formation Alert followed at 190800Z (Figure 3-04-1). At 200000Z, satellite intensity analysis indicated a T-number of 2.5, corresponding to maximum sustained surface winds of 35 kt (18 m/sec) (Figure 3-04-2) and the Alert was upgraded to Tropical Storm Thad.

Throughout this period of gradual intensification, Thad was embedded in the flow south of the lower tropospheric subtropical ridge axis and moved northwestward, except for one excursion - the "stair-step" jog in the track from 200000Z to 201800Z. Afterward, Thad continued to track northwestward, intensifying for two more days, until reaching

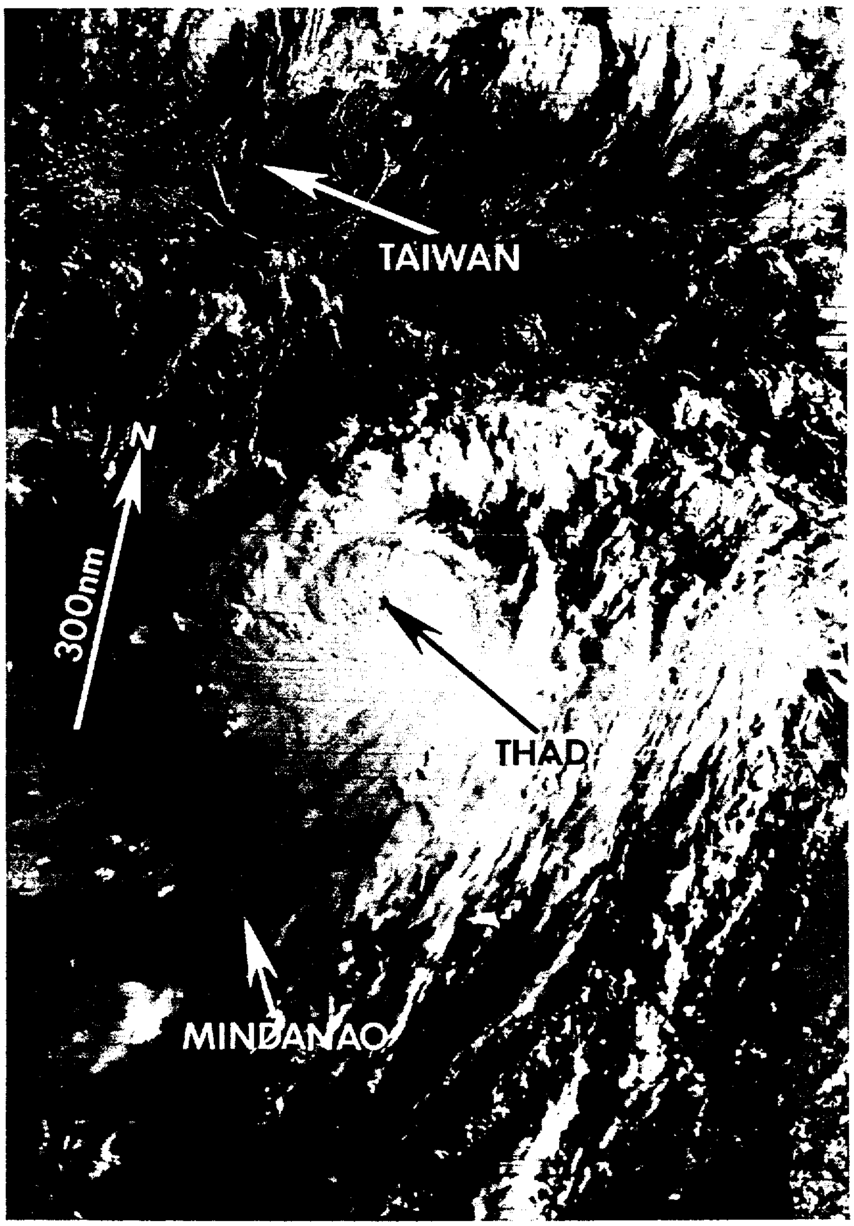


Figure 3-04-2. Thad intensifies as it approaches the island of Luzon (212128Z June NOAA visual imagery).

the westernmost end of the subtropical ridge where it began to recurve at 221800Z. The system reached its peak intensity and was upgraded to typhoon intensity at 220600Z, based on a satellite intensity estimate of 70 kt (36 m/sec) (Figure 3-04-3). Thad then developed a central cold cover (Dvorak, 1984) and further development was arrested.

At 221800Z, Typhoon Thad recurved in response to the approaching mid-level trough in the westerlies aloft over eastern China. The forecast for this event was complicated by the failure of JTWC's dynamic forecast aid, the One Way (Interactive) Tropical Cyclone Model (OTCM), to change from a persistent northwestward track (Figure 3-04-3). At 231200Z, the decision was made to disregard the objective forecast guidance and forecast recurvature based on synoptic data analyses. This decision was correct, but in retrospect, the timing was 18-hours late.

From 240000Z to 250000Z, Thad underwent rapid weakening as it tracked to the northeast and entered a region of increased vertical wind shear. At 240000Z, Typhoon Thad was downgraded to tropical storm intensity and six hours later the system weakened to a 50 kt (26 m/sec) intensity as it made a closest point of approach of 80 nm (148 km) southeast of the island of Okinawa, Japan. Both Kadena Air Base and Naha airport reported wind speeds below 30 kt (15 m/sec) during Thad's passage. With dissipation over water underway, Thad was downgraded to a tropical depression at 250000Z and the final warning issued. No reports of damage were received.

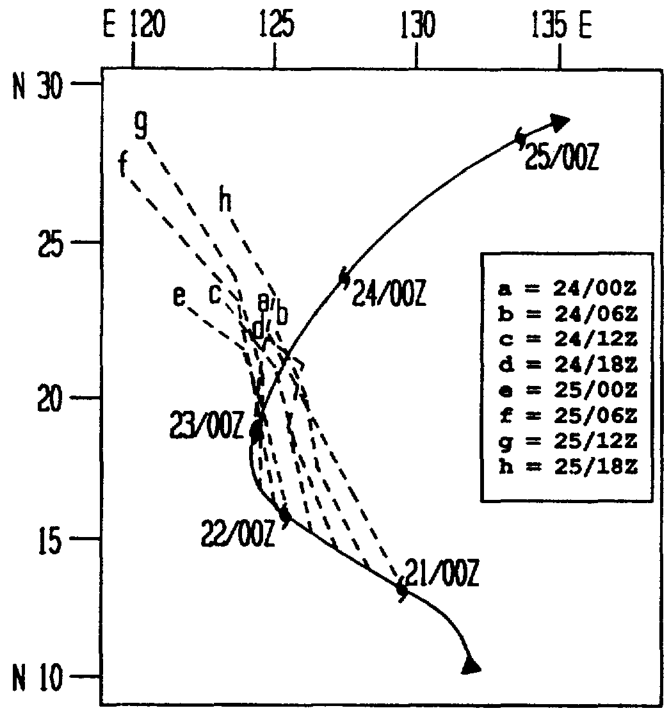
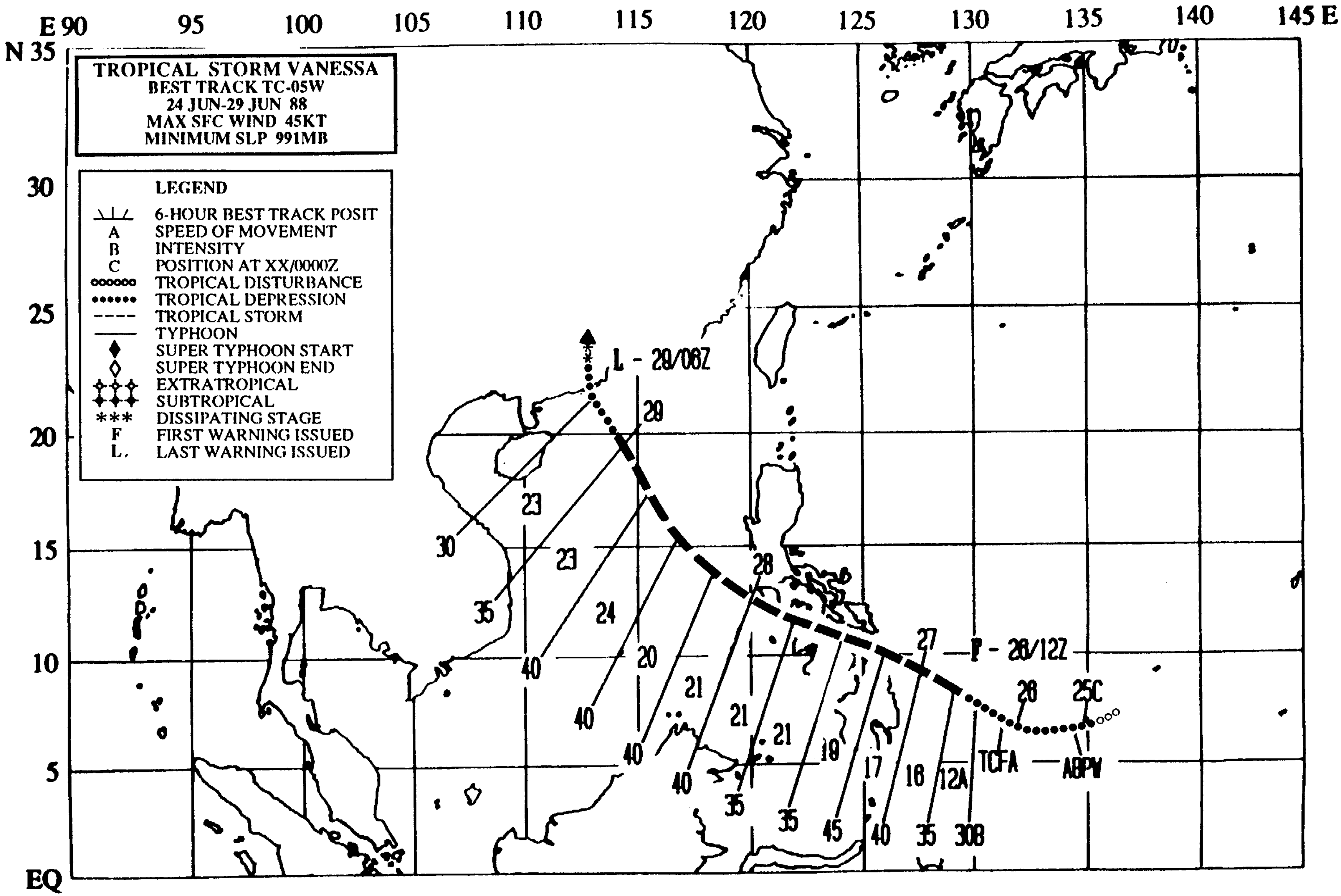


Figure 3-04-3. OTCM forecast guidance (dashed lines) from 210000Z to the point of recurvature at 221800Z basically held Thad to a northwestward track through each 72-hour period, in contrast to the best track (solid line).


TROPICAL STORM VANESSA
BEST TRACK TC-05W
24 JUN-29 JUN 88
MAX SFC WIND 45KT
MINIMUM SLP 991MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
95
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145 E
N 35
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EQ
L - 28/06Z
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TCFA
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12A
30B
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28
25C

TROPICAL STORM VANESSA (05W)

The third of three significant tropical cyclones to develop during the month of June, Vanessa was the first "straight-runner" of the year in the western North Pacific. It tracked across the Philippine Islands and into the South China Sea before dissipating over southern China.

As Thad (04W) moved northeastward and weakened over the Philippine Sea east of the island of Okinawa, Vanessa was first detected at 241200Z by satellite imagery analysts 125 nm (232 km) east of Koror in the western Caroline Islands. A flare-up of convection at 241800Z resulted in an increase in high clouds. The upper-level outflow began to show organization (Figure 3-05-1). At 250600Z, the tropical disturbance was described on JTWC's Significant Tropical Weather Advisory as an area of persistent convection 55 nm (102 km) southeast of Koror. Synoptic data indicated a well organized low-level circulation embedded in the near-equatorial trough. Satellite imagery revealed a Tropical Upper-Tropospheric Trough (TUTT) low located 250 nm (463 km) northeast of the disturbance's low-level circulation. The upper-level cold low interrupted the disturbance's upper-level outflow in its northeast quadrant. At 260440Z, a Tropical Cyclone Formation Alert was issued when satellite imagery revealed increased convection. The TUTT low had weakened and passed north of the low-level circulation, resulting in divergent upper-level flow across the disturbance.

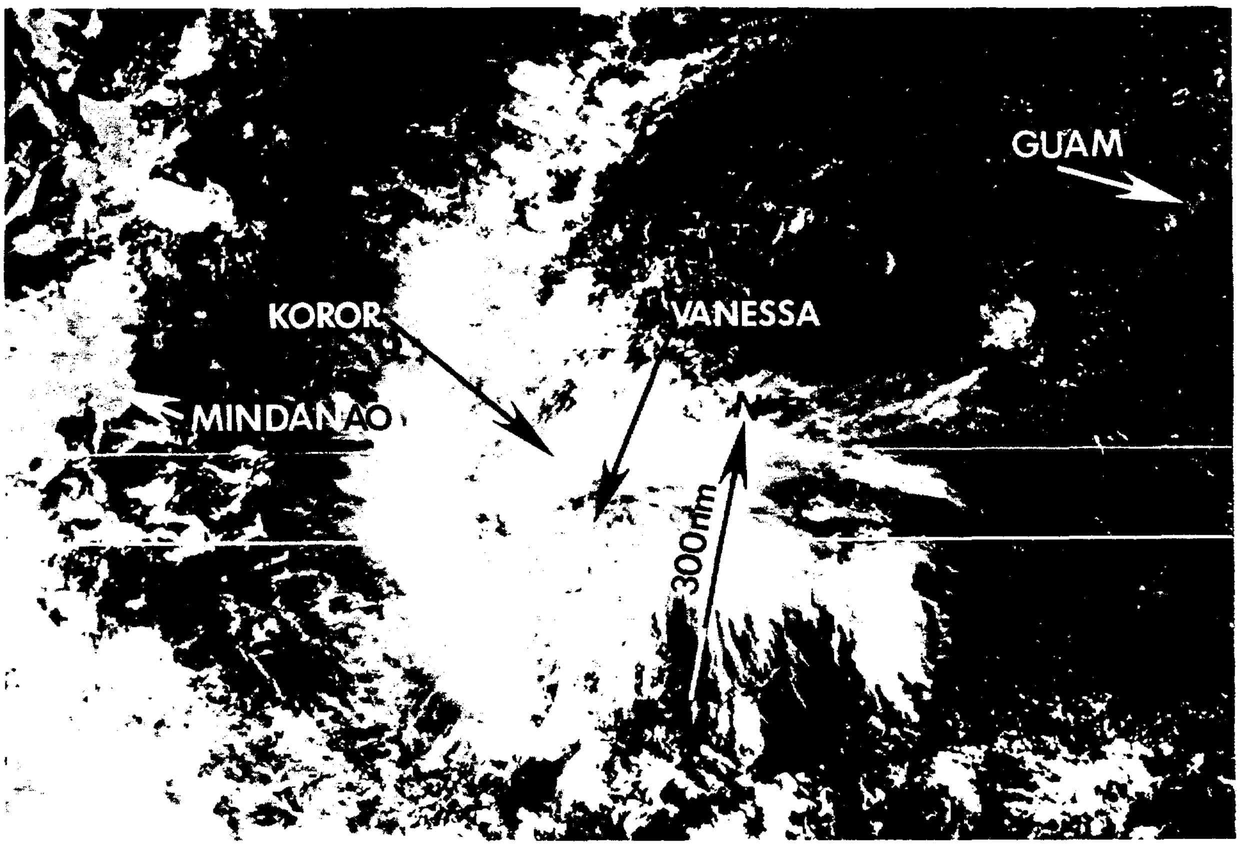


Figure 3-05-1. Vanessa as a tropical disturbance (250028Z June DMSP visual imagery).

The first warning followed at 261200Z, when the tropical disturbance was upgraded to Tropical Depression 05W, based on continued improvement in the system's organization and convection. Satellite intensity analysis indicated surface wind speeds of 30 to 35 kt (15 to 18 m/sec). The system continued to intensify. At 270000Z, Vanessa (Figure 3-05-2) was again upgraded, this time to a tropical storm, based on a satellite intensity analysis of 35 kt (18 m/sec) surface winds. With winds of 45 kt (28 m/sec), Vanessa made landfall over the Republic of the Philippines, at 270600Z, between the islands of Samar and Mindanao.

The tropical cyclone tracked rapidly across the central Philippine Islands, as a weak tropical storm, and entered the South China Sea at 280200Z. Vanessa continued its rapid movement as it tracked across the South China

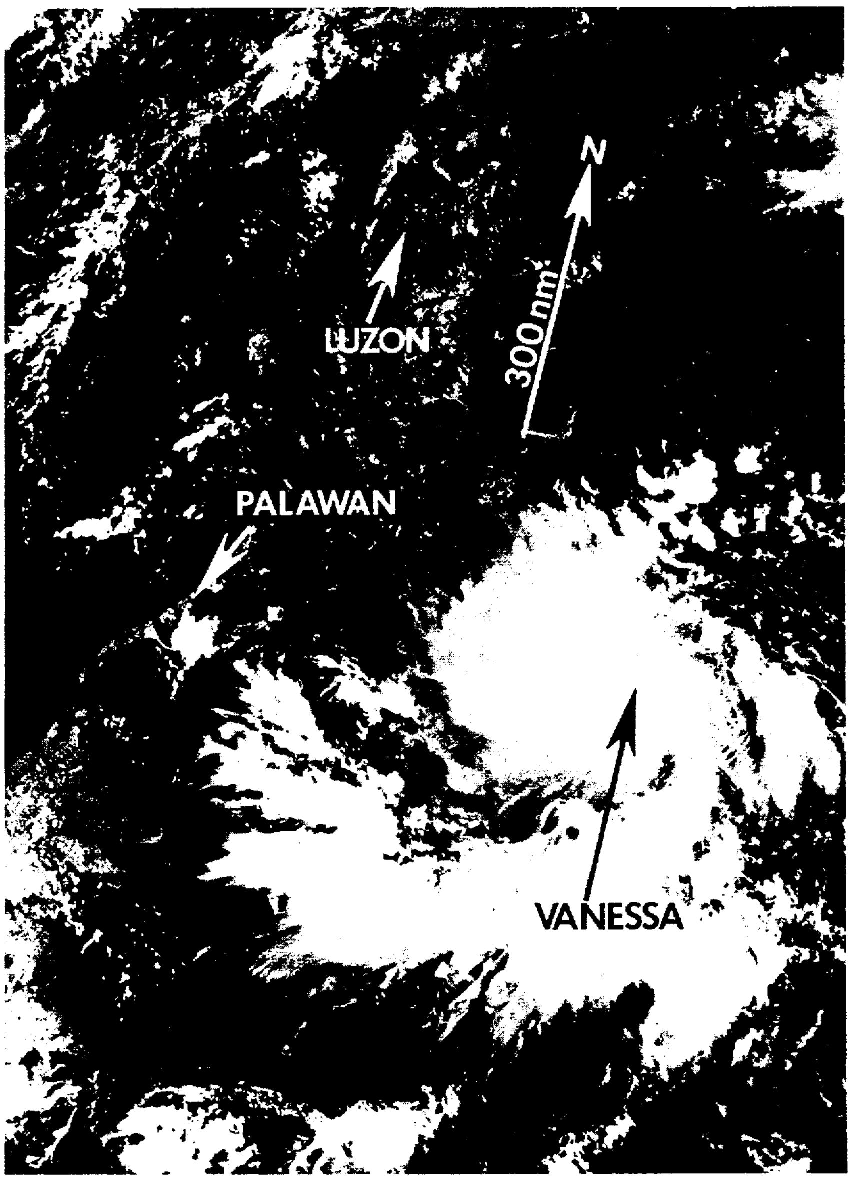


Figure 3-05-2. Nearing peak intensity, Vanessa approaches the central Philippine Islands (270130Z June DMSP visual imagery).

Sea. Despite increased vertical wind shear, Vanessa tenaciously resisted weakening until 290000Z. Over the next six hours, the deep convection was stripped away from the low-level circulation center (Figure 3-05-3) and the final warning followed at 290600Z. Vanessa made landfall just west of Macao on the south coast of China at 290800Z. Nearby land stations reported 35 kt (18 m/sec) maximum surface winds. No reports of major damage were received.

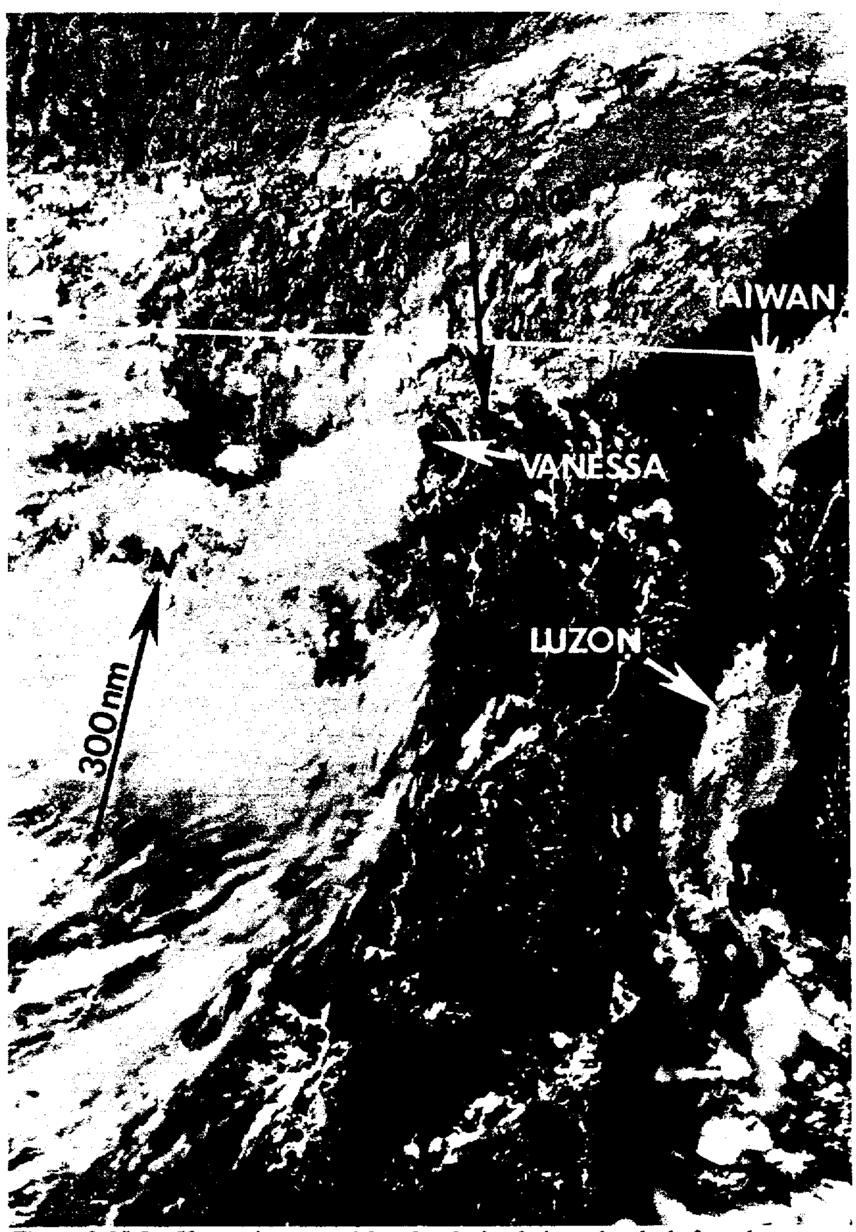
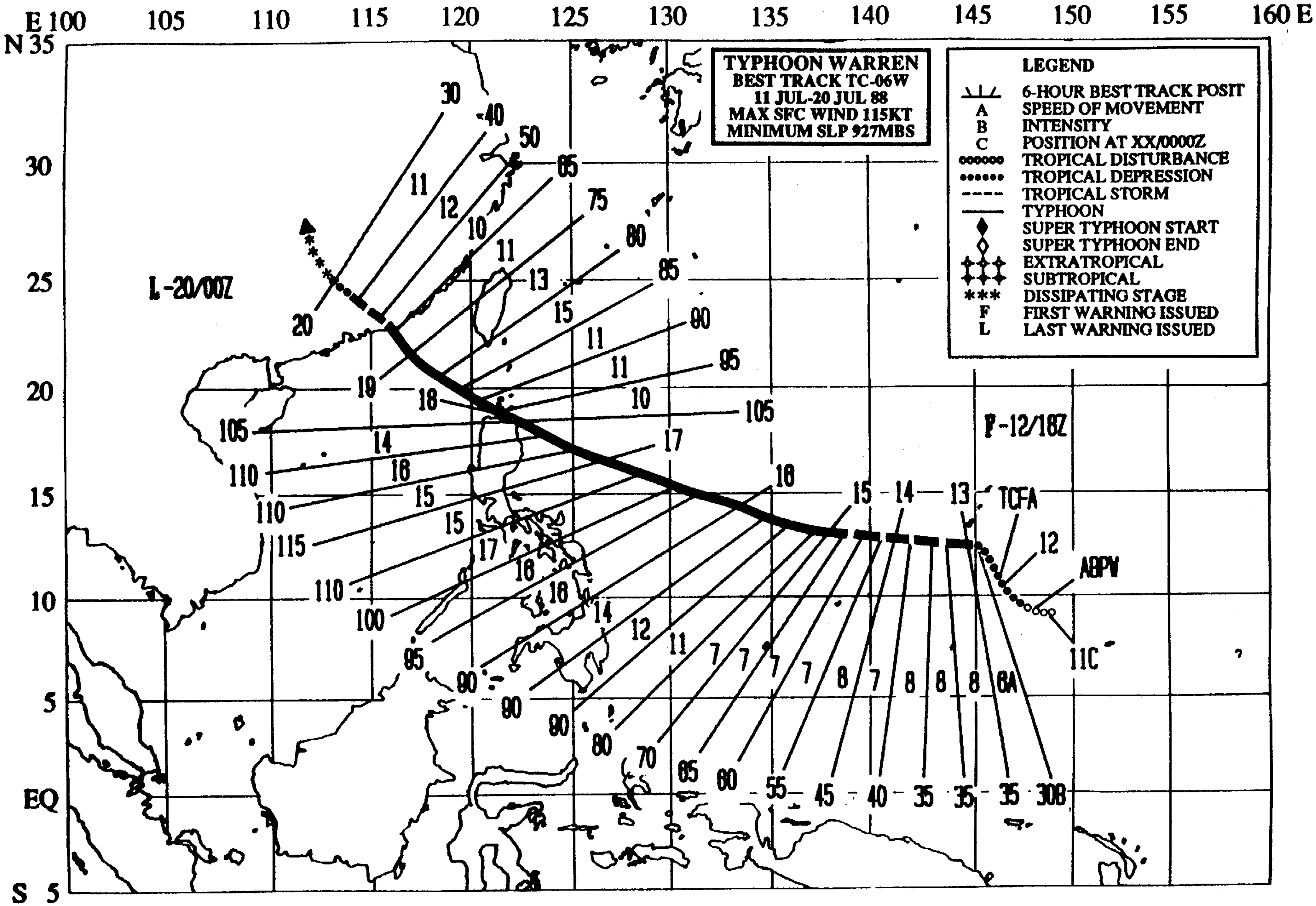


Figure 3-05-3. Vanessa's exposed low-level circulation, shortly before the system made landfall near Macao (290802Z June NOAA visual imagery).


TYPHOON WARREN
BEST TRACK TC-06W
11 JUL-20 JUL 88
MAX SFC WIND 115KT
MINIMUM SLP 927MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L-20/00Z
F-12/18Z
TCFA
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TYPHOON WARREN (06W)

Typhoon Warren was the first of two significant tropical cyclones to develop during the month of July, and the fourth tropical cyclone of the year to reach typhoon intensity. Warren was a "straight-runner" and maintained a west-northwestward direction of movement during almost its entire life span.

The tropical disturbance that eventually developed into Typhoon Warren was first mentioned on the Significant Tropical Weather Advisory at 110600Z. The suspect area had persisted as a poorly organized area of convection for 12-hours in the eastern Caroline Islands. Its potential for further development was assessed as "poor." However, better convective organization and improved upper-level outflow raised the potential for development into a significant tropical cyclone to "fair" and JTWC reissued the Advisory at 111230Z. Increased convection prompted a Tropical Cyclone Formation Alert at 120530Z. The system was now 180 nm (333 km) southeast of Guam and headed for the island. Satellite intensity analysis estimated sustained surface winds of 25 kt (13 m/sec).

The appearance of a central dense overcast (CDO) on the 121237Z satellite imagery led the satellite analyst to increase the intensity estimate of surface winds to 30 kt (15 m/sec). From 121200Z to 121500Z, the system's CDO increased in size. Because of the disturbance's steady development and its proximity to Guam, JTWC issued an abbreviated warning for the tropical depression at 121600Z: the detailed warning followed at 121800Z. The center of the system passed 55 nm (102 km) to the south of Guam at 130000Z.

After returning to a more westerly track, Tropical Depression 06W was upgraded to Tropical Storm Warren at 130600Z. (Post-analysis showed that Warren probably attained tropical storm intensity earlier at 130000Z.) At 141800Z, Warren reached typhoon intensity. This intensification process continued and peaked at 115 kt (58 m/sec) in the Philippine Sea 300 nm (556 km) east of Luzon (Figure 3-06-1). During this same two day period as the winds doubled in intensity, Warren also doubled its forward speed to 15 kt (28 km/hr).

While Warren tracked across the Philippine Sea, the One Way (Interactive) Tropical Cyclone Model (OTCM) outlook began to take the track northward into the

Figure 3-06-1. Typhoon Warren at peak intensity (162247Z July NOAA infrared imagery).

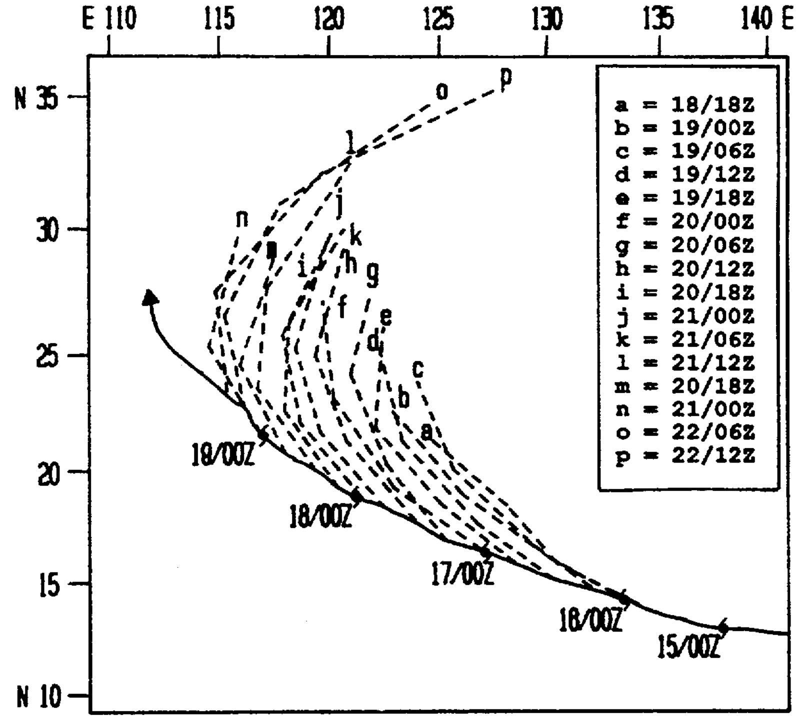


Figure 3-06-2. A comparison of OTCM 72-hour guidance with JTWC's best track. Note OTCM's systematic strong northward bias.

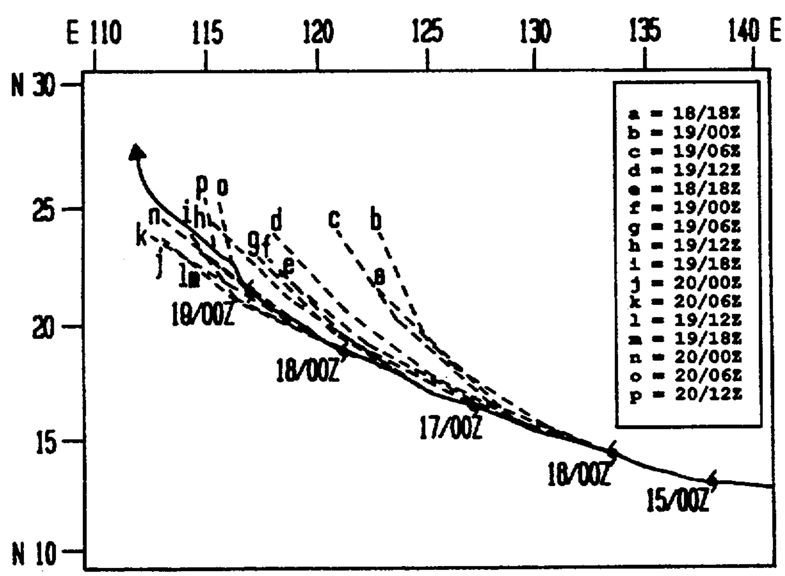


Figure 3-06-3. Seventy-two hour forecasts tended to be north of the best track and more conservative than the OTCM guidance.

subtropical ridge. OTCM is JTWC's operational dynamic aid and in general provides the best performance of all the objective aids. This numerical guidance moved Warren north and east of the island of Taiwan and eventually suggested recurvature within 48- to 72-hours (Figure 3-06-2). However, JTWC's synoptic data analyses and mid-level prognoses maintained the subtropical ridge to the north. This was reinforced by satellite observed persistent minimum cloudiness, which was associated with subsidence and ridging, to the north of Warren. Consequently, recurvature was not forecast (Figure 3-06-3).

From 171800Z to 180000Z, Typhoon Warren weakened as it skirted the northern coast of Luzon with damage to rice and corn crops in northern Luzon estimated to be $10 million.

After its brush with Luzon, the tropical cyclone maintained typhoon intensity until making landfall at 190600Z (Figure 3-06-4) near the city of Shantou in southeastern China. China's official media reported 17 killed and 153 injured by Warren. Additionally, in the province of Guangdong in southeastern China, over 13,000 homes were destroyed and over 150,000 homes damaged. At 200000Z, JTWC issued its final warning on Tropical Storm Warren with the system well inland and northwest of Hong Kong. The remnants of Warren's low-level circulation continued tracking across southern China for another day before merging with a weak summer front, enhancing cloudiness and precipitation.

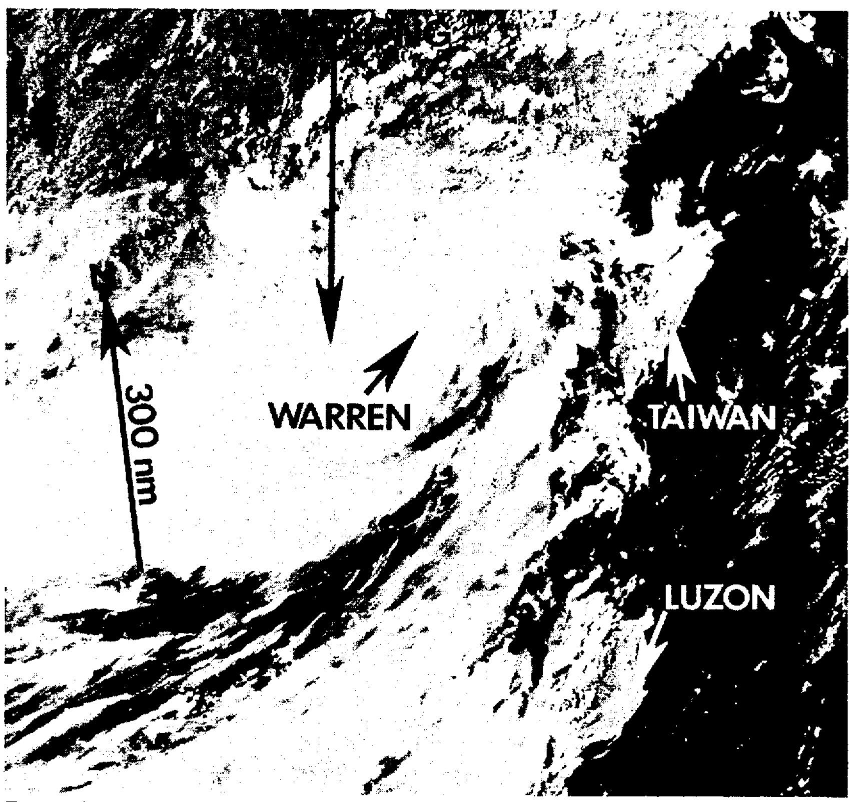
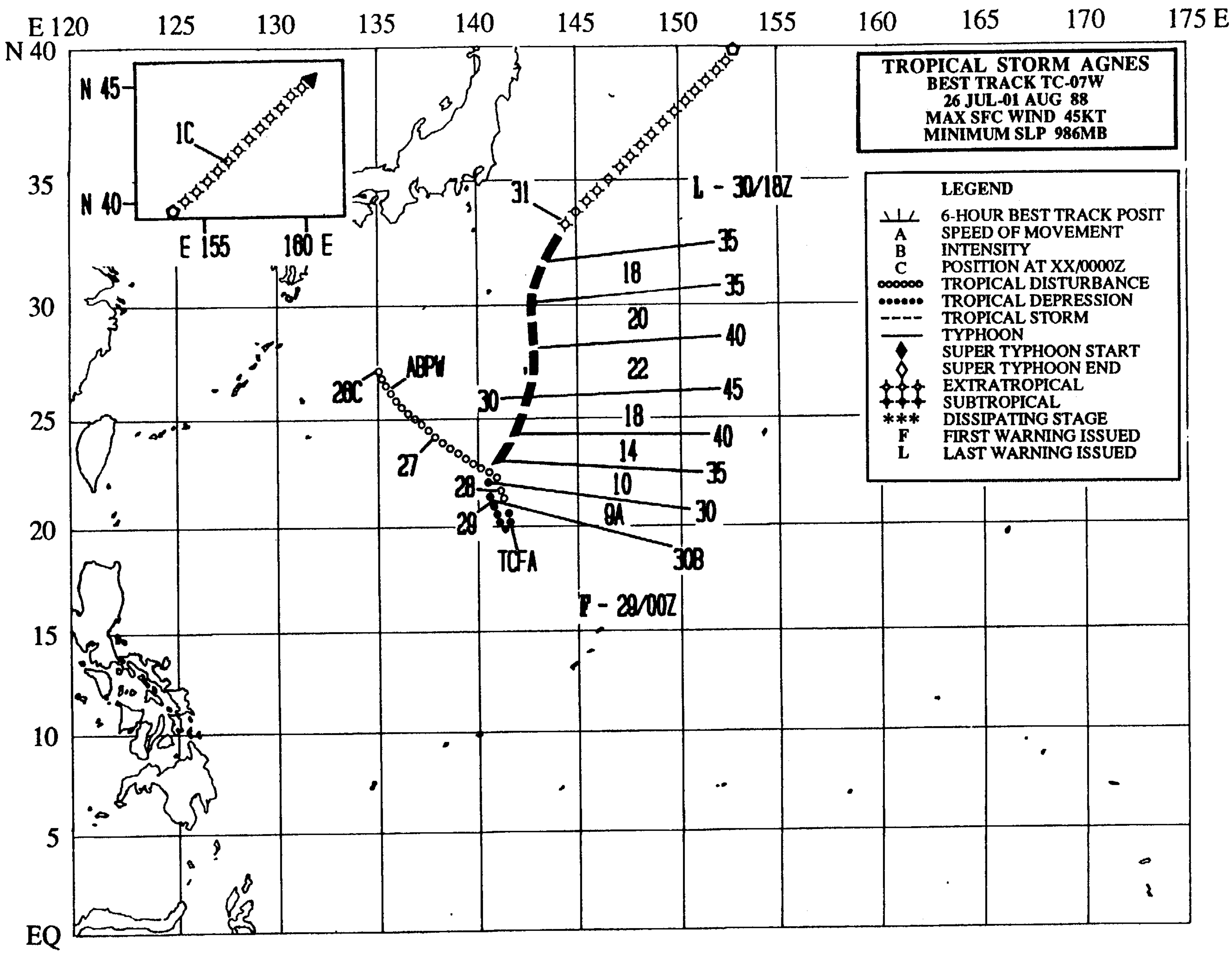


Figure 3-06-4: Tropical Storm Warren after making landfall (190745Z July NOAA visual imagery).


TROPICAL STORM AGNES
BEST TRACK TC-07W
26 JUL-01 AUG 88
MAX SFC WIND 45KT
MINIMUM SLP 986MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
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ABPW
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TROPICAL STORM AGNES (07W)

Agnes was of note in several respects. It was the second of only two tropical cyclones to develop in July, a month that normally averages five. It played a part in the major shift of the synoptic pattern in the western North Pacific in the latter part of July and later became a small, but vigorous, extratropical cyclone.

As Typhoon Warren (06W) moved into southern China on 19 July, lower tropospheric ridging and fair weather prevailed over eastern China and the Philippine Sea. Once Warren (06W) dissipated, the monsoon trough, instead of maintaining its climatological position across the northern Philippine Islands and southern Philippine Sea, remained over Asia. Southeast of Japan, an area of disturbed weather with lower than normal sea-level pressures and enhanced convection generated in the lower tropospheric troughing (Figure 3-07-1). By 27 July, a closed circulation and supporting southwesterly monsoonal flow at 700 mb had developed along this trough (Figure 3-07-2).

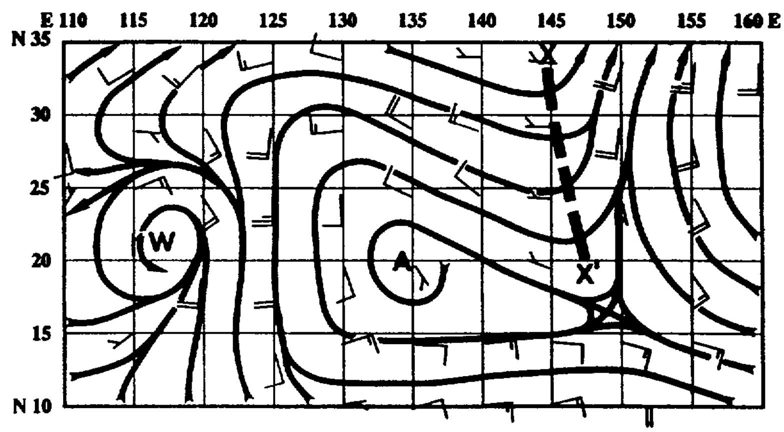


Figure 3-07-1. 700 mb analysis at 190000Z July with Typhoon Warren (06W)(point W) and troughing (line X to X') southeast of Japan.

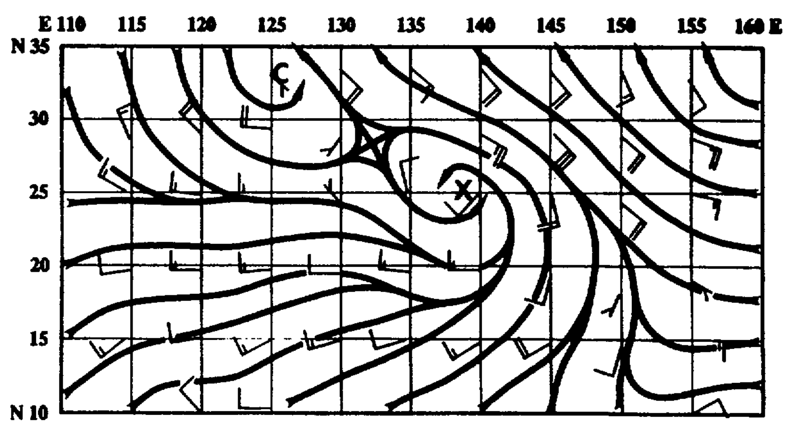


Figure 3-07-2. 270000Z July 700 mb analysis with a closed cyclonic circulation (at point X) and deep west-southwesterly monsoonal flow.

At first, Agnes appeared as a monsoon depression with a low-level cyclonic circulation and deep convection displaced to the south by vertical shear aloft. This was discussed in the Significant Tropical Weather Advisory at 260600Z. The suspect area drifted southeastward in the trough and had a poor potential for development into a significant tropical cyclone due to the unfavorable vertical wind shear of 35 kt (18 m/sec.) When the vertical wind shear dropped to 20 kt (10 m/sec) at 280600Z and satellite imagery indicated increased upper-level outflow and deep convection, the system's potential for significant development was upgraded to "fair". A Tropical Cyclone Formation Alert was issued at 281500Z based on a satellite intensity estimate of 25 kt (13 m/sec). The continued increase in the system's deep convection and overall organization led to the first warning at 290000Z.

Initially, Agnes was forecast to intensify, separate from the monsoon trough and track to the northwest. However, the monsoon trough, which was farther north than normal, merged with a mid-latitude low pressure system to the northeast of Japan. Agnes followed the path of least resistance and accelerated to the north-northeast along this trough axis. The tropical cyclone was upgraded to tropical storm intensity at 291200Z and reached its peak intensity (Figure 3-07-3) of 45 kt (23 m/sec) 12-hours later. The loss of persistent central convection at 301200Z resulted in the issuance of the final warning at 301800Z.

Unfavorable vertical shear from the strong southwesterlies aloft increased and Agnes (Figure 3-07-4) accelerated north-northeastward at more than 30 kt (56 km/hr). Although the system appeared to be

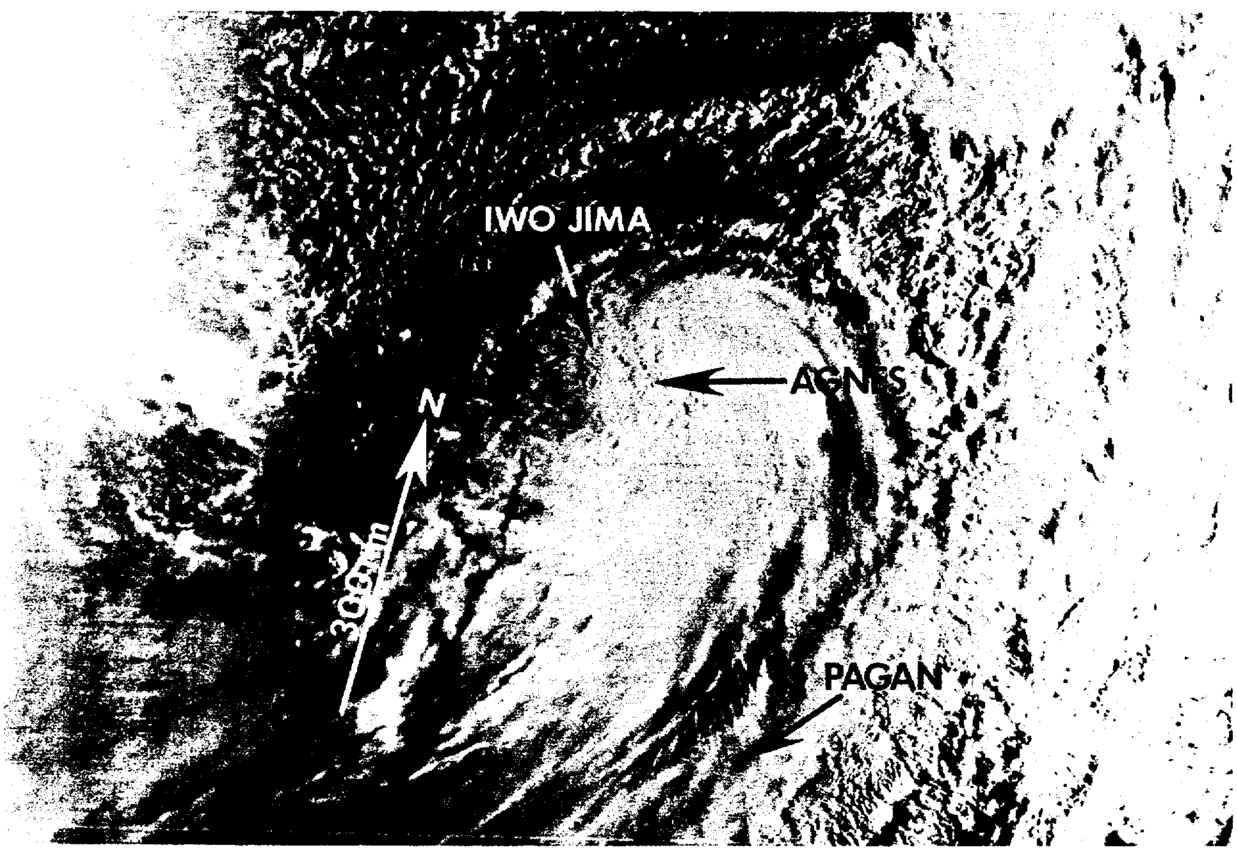


Figure 3-07-3. Agnes, shortly before reaching its peak intensity (292023Z July DMSP visual imagery).

extratropical at 310000Z, ships in the right front quadrant (relative to the forward motion) of this hybrid system reported maximum sustained surface winds of 60 kt (31 m/sec) at 310600Z and 50 kt (26 m/sec) at 311200Z. Herbert and Poteat (1975) address this type of system, or subtropical cyclone, where translational speeds greater than 20 kt (37 km/hr) are added to the intensity estimate determined from the cloud signature. Even though the final warning was issued when the system was at 32 degrees North, Agnes stubbornly maintained some of its tropical characteristics well into the mid-latitudes. No reports of casualties or damages were received.

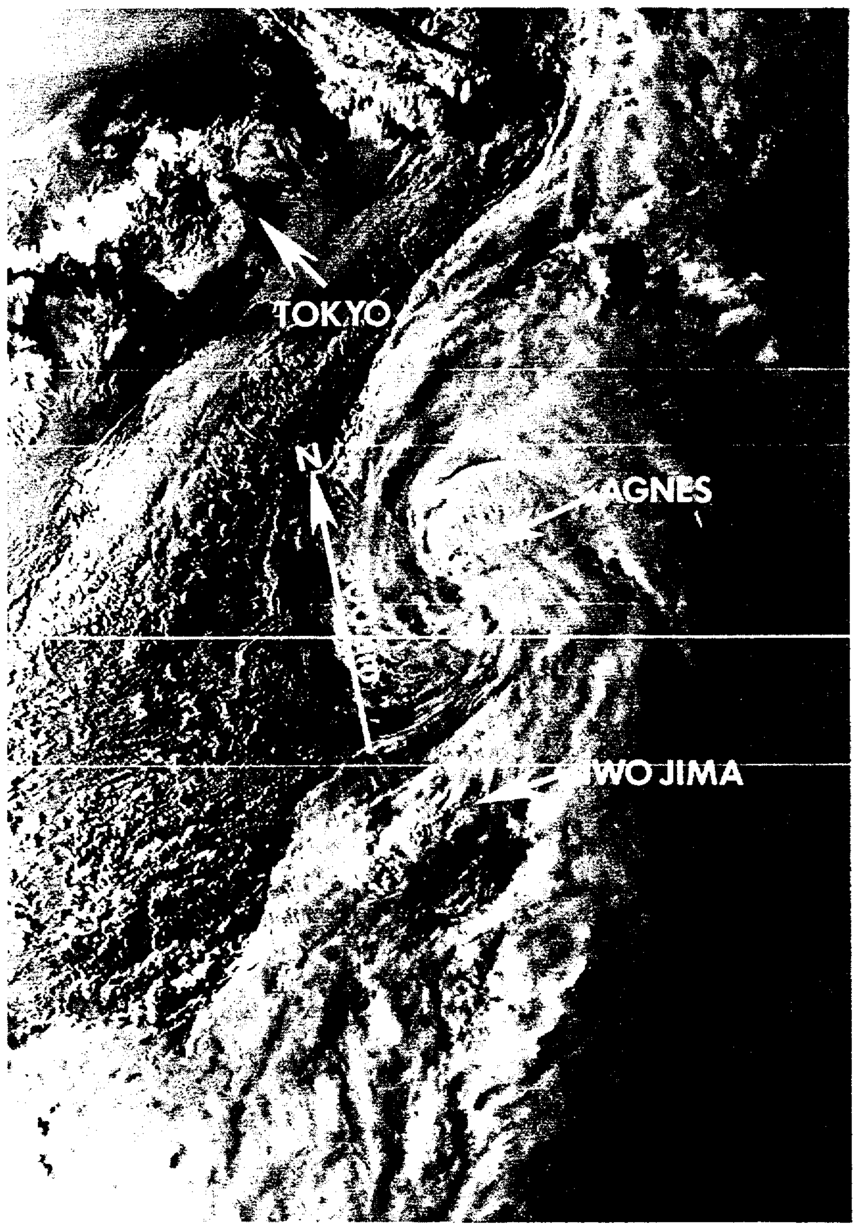
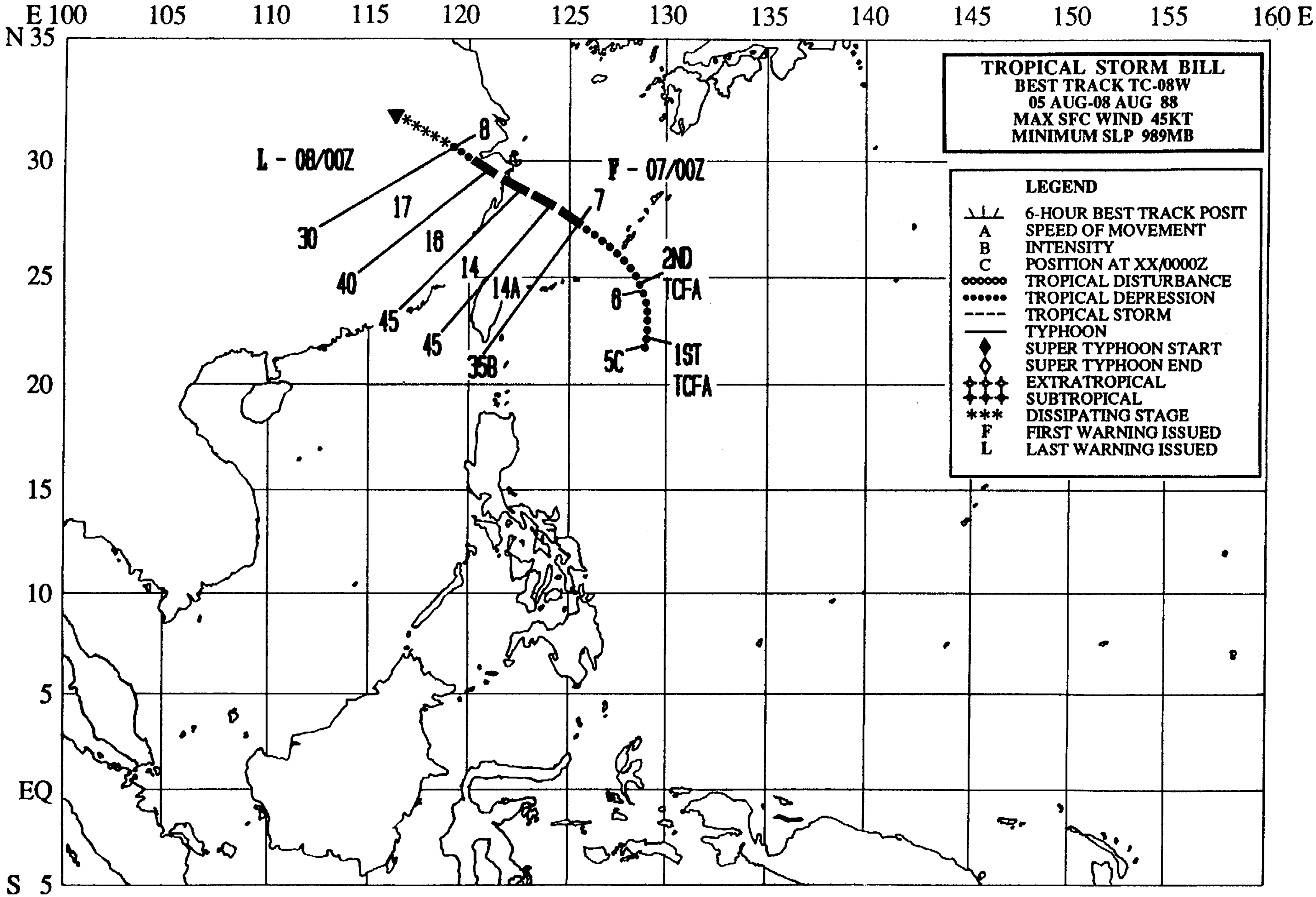


Figure 3-07-4. The remnants of Tropical Storm Agnes during transition into an extratropical system (301829Z July NOAA infrared imagery).


TROPICAL STORM BILL
BEST TRACK TC-08W
05 AUG-08 AUG 88
MAX SFC WIND 45KT
MINIMUM SLP 989MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
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TROPICAL DISTURBANCE
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TYPHOON
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F FIRST WARNING ISSUED
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L - 08/00Z
F - 07/00Z
2ND TCFA
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TROPICAL STORM BILL (08W)

Tropical Storm Bill was the first of five tropical cyclones to develop during the month of August. It formed in the Philippine Sea, brushed by the island of Okinawa and reached a peak intensity of 45 kt (23 m/sec) before making landfall near Shanghai. Bill remained well organized over China, causing widespread destruction and loss of life. It exemplifies the serious impact that is possible from a system of tropical storm intensity that doesn't dissipate rapidly after moving over land.

On the first day of August the monsoon trough (Figure 3-08-1) stretched from the Gulf of Tonkin across the South China Sea to the Luzon Strait and extended northeastward along the Japanese Islands. By 5 August (Figure 3-08-2) this synoptic feature had undergone a

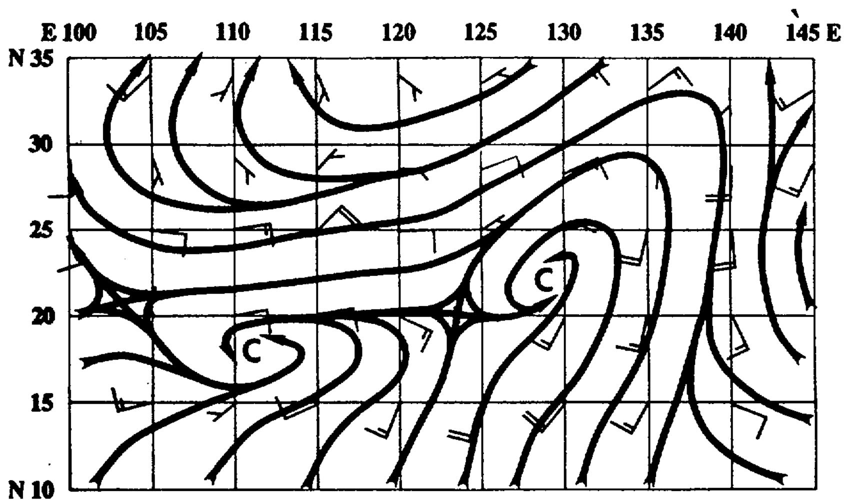

Figure 3-08-1. The 010000Z August 925 mb winds and streamlines show the monsoon trough extending across the South China Sea and northeastward.

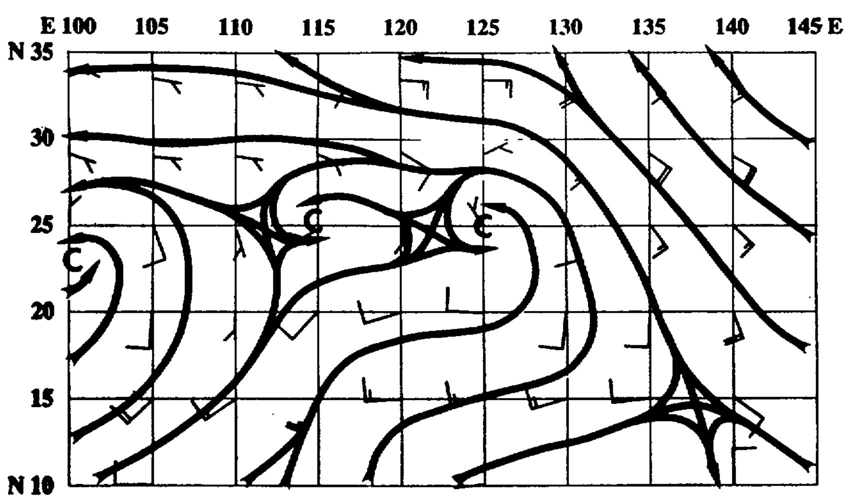

Figure 3-08-2. The 925 mb winds and streamlines for 051200Z, when compared with Figure 3-08-1, reveal the shift of the monsoon trough into China and its abrupt termination near the island of Okinawa, Japan.

major readjustment. Now it was oriented west-to-east over southern China and terminated abruptly near the island of Okinawa, Japan. Excess relative cyclonic vorticity, low-level convergence and associated enhanced convection persisted near the eastern end of the trough. With the environment favorable for tropical cyclogenesis, Bill rapidly consolidated and at 050430Z the first Tropical Cyclone Formation Alert was issued on the system. Early on 6 August the cloudiness associated with the tropical disturbance (Figure 3-08-3) separated from the maximum cloud zone. As the tropical cyclone moved away from the axis of the monsoon trough, it came under the steering influence of the subtropical ridge to the

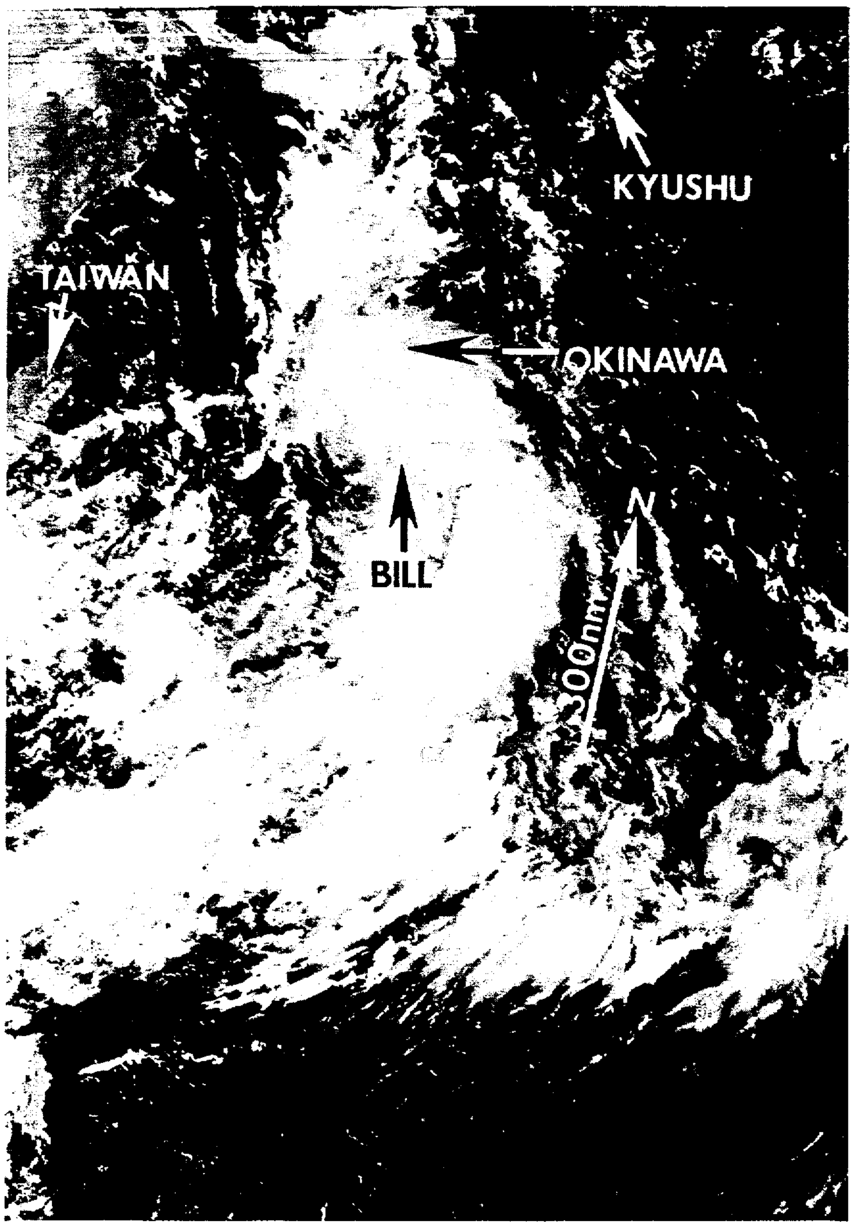

Figure 3-08-3. Bill as a tropical disturbance south of the island of Okinawa (060009Z August DMSP visual imagery).

northeast. The track, which was initially to the north, became northwestward. Consolidation continued, but the pace slowed, and at 060330Z a second Alert was issued. The center of the low-level circulation passed just southwest of the southern tip of Okinawa at 061500Z. Kadena Air Base (WMO 47931) reported a minimum sea-level pressure of 997 mb, sustained surface winds of 20 kt (10 m/sec) and a peak surface gust of 40 kt (21 m/sec). Earlier, Kadena's 061200Z upper-air sounding indicated a layer between the 875 mb and 550 mb levels of 35 to 40 kt (18 to 21 m/sec) winds, which supported the peak gusts.

Slow intensification progressed and the first warning (070000Z) on Tropical Storm Bill followed a satellite intensity estimate of 35 kt (18 m/sec) (Figure 3-08-4). At 070600Z, Bill reached a peak intensity of 45 kt (23 m/sec) and

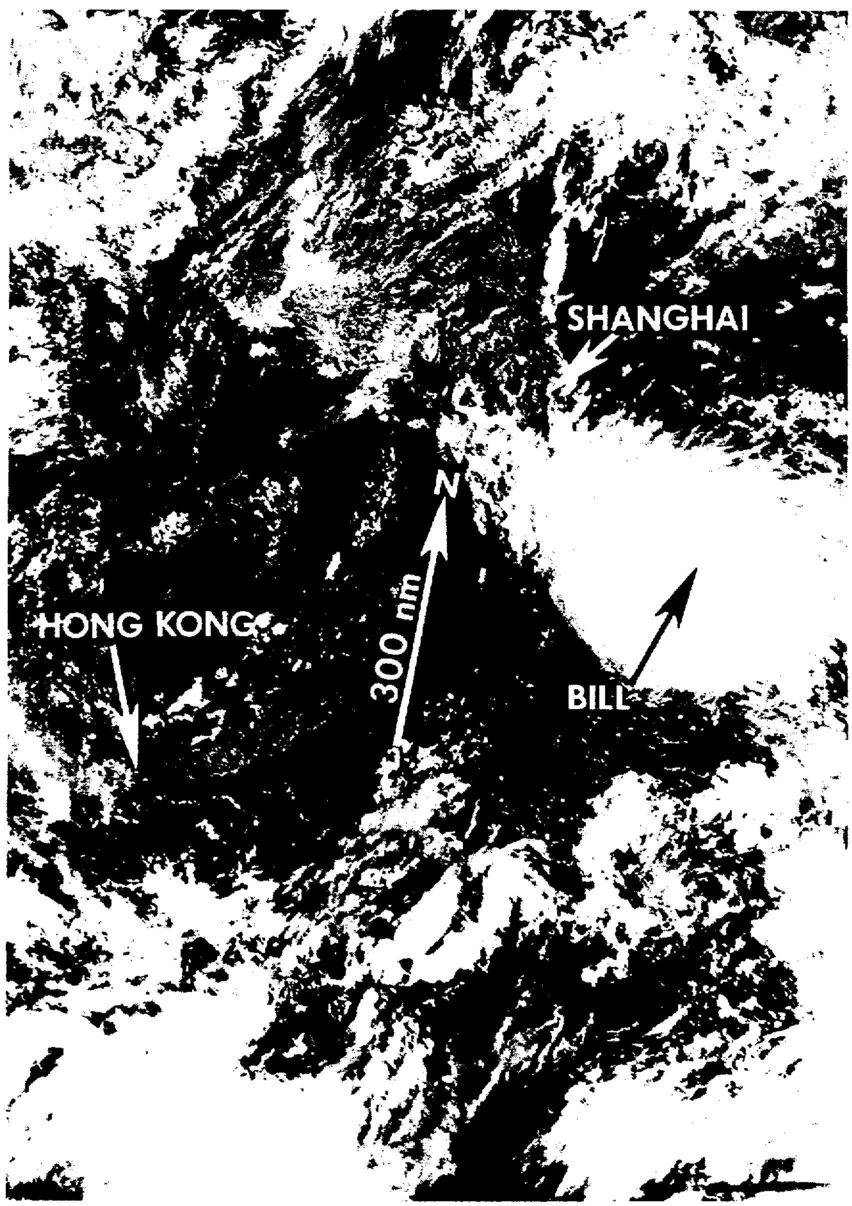

Figure 3-08-4. Bill, shortly after being upgraded to tropical storm intensity (070131Z August DMSP visual imagery).

sustained it until making landfall 120 nm (222 km) south of Shanghai.

Once overland, instead of rapidly dissipating, Bill retained its convection and organization (Figure 3-08-5). At 080000Z, the intensity was downgraded to a tropical depression and the final warning issued. The remains of this cloud system tracked to the northwest and could still be identified on satellite imagery two days later.

Bill's slow dissipation resulted in extensive damage and loss of life in China. Torrential rains led to widespread flooding and local topographic effects may have produced wind gusts as high as 70 kt (35 m/sec). When it was all over, at least 110 people had perished and numerous bridges, dams and watercraft were damaged or destroyed. News releases from China reported "the worst economic loss from a storm in 30 years."

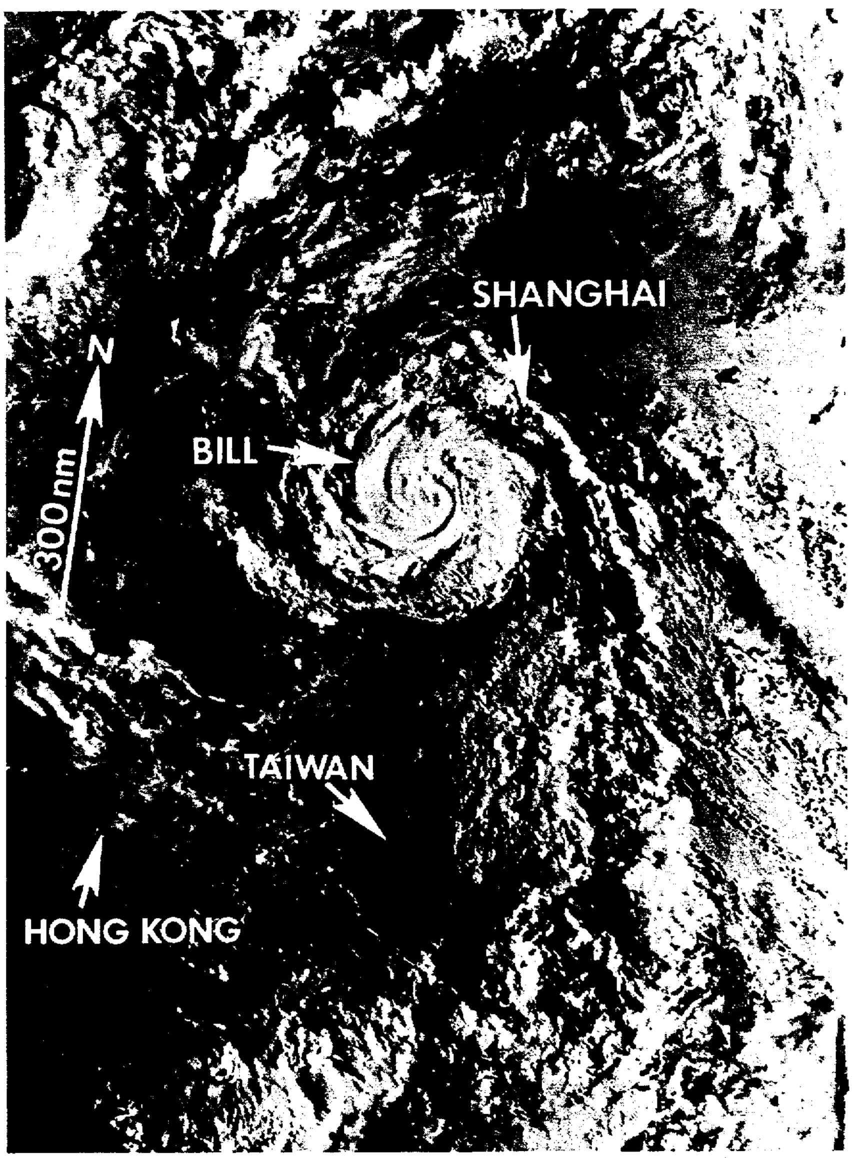

Figure 3-08-5. Tropical Storm Bill continued to be a very well organized system, despite having already been over land for several hours (072156Z August DMSP visual imagery).

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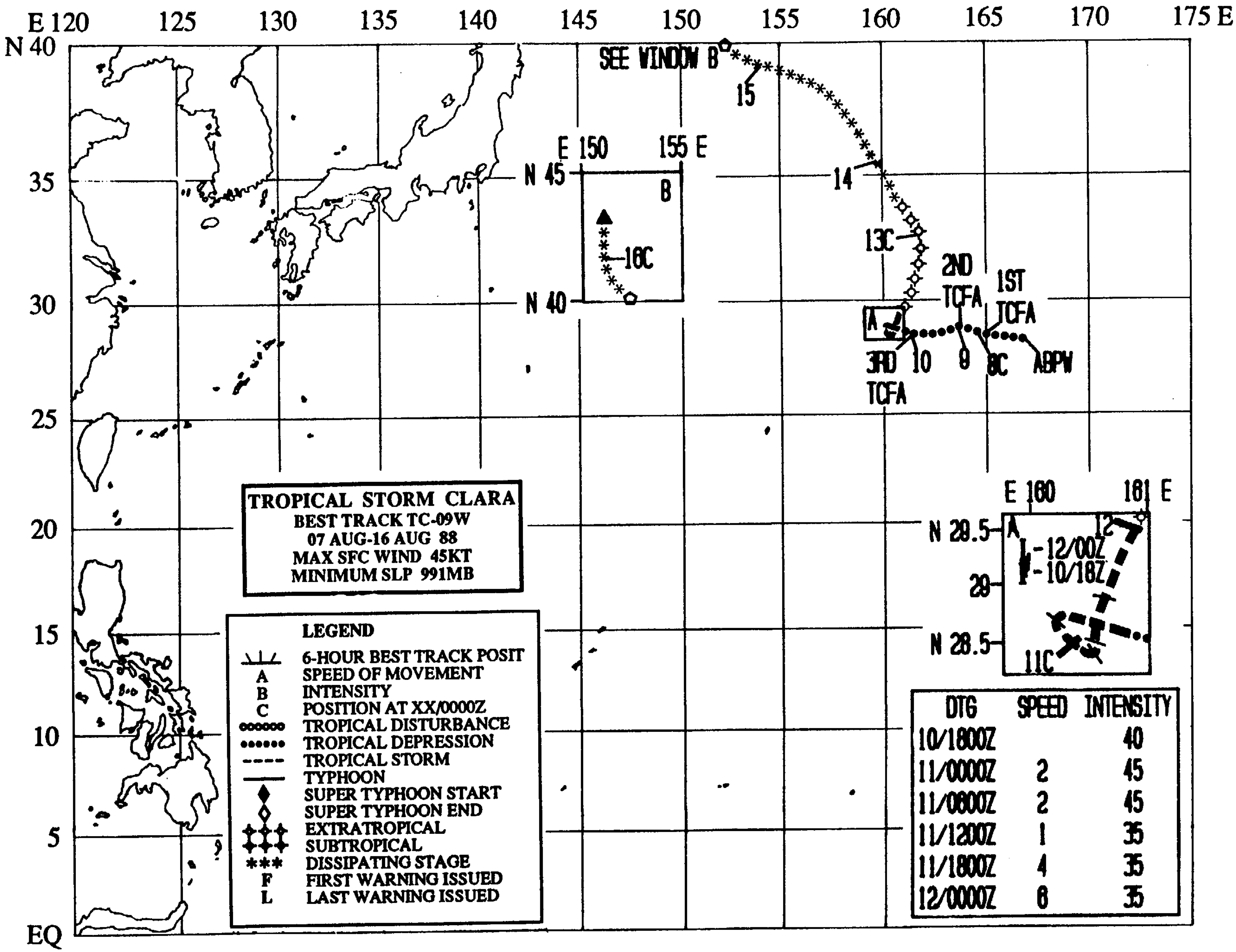


DTG	SPEED	INTENSITY
10/1800Z		40
11/0000Z	2	45
11/0600Z	2	45
11/1200Z	1	35
11/1800Z	4	35
12/0000Z	6	35

TROPICAL STORM CLARA (09W)

Tropical Storm Clara was the second of five significant tropical cyclones to develop during August. Although hindered by vertical wind shear, Clara proved to be very persistent. Even after the central deep convection was stripped away and the final warning issued, the residual cyclonic vorticity could be identified four days later as a spiral of low-level stratocumulus on the satellite imagery.

Clara was originally detected on satellite imagery as an area of weakly organized convection about 540 nm (1,000 km) north of Wake Island and it was mentioned on the Significant Tropical Weather Advisory on 070600Z August. Easterly flow along the southern edge of the subtropical ridge steered the disturbance westward. Over the next 16-hours the convection persisted and became more organized. The satellite intensity analysis at 072126Z indicated a shearing-type cloud pattern with sustained surface winds of 30 kt (15 m/sec) and an exposed low-level circulation defined by cumulus lines spiraling inwards. The first Tropical Cyclone Formation Alert followed at 072330Z. A second Alert was issued at

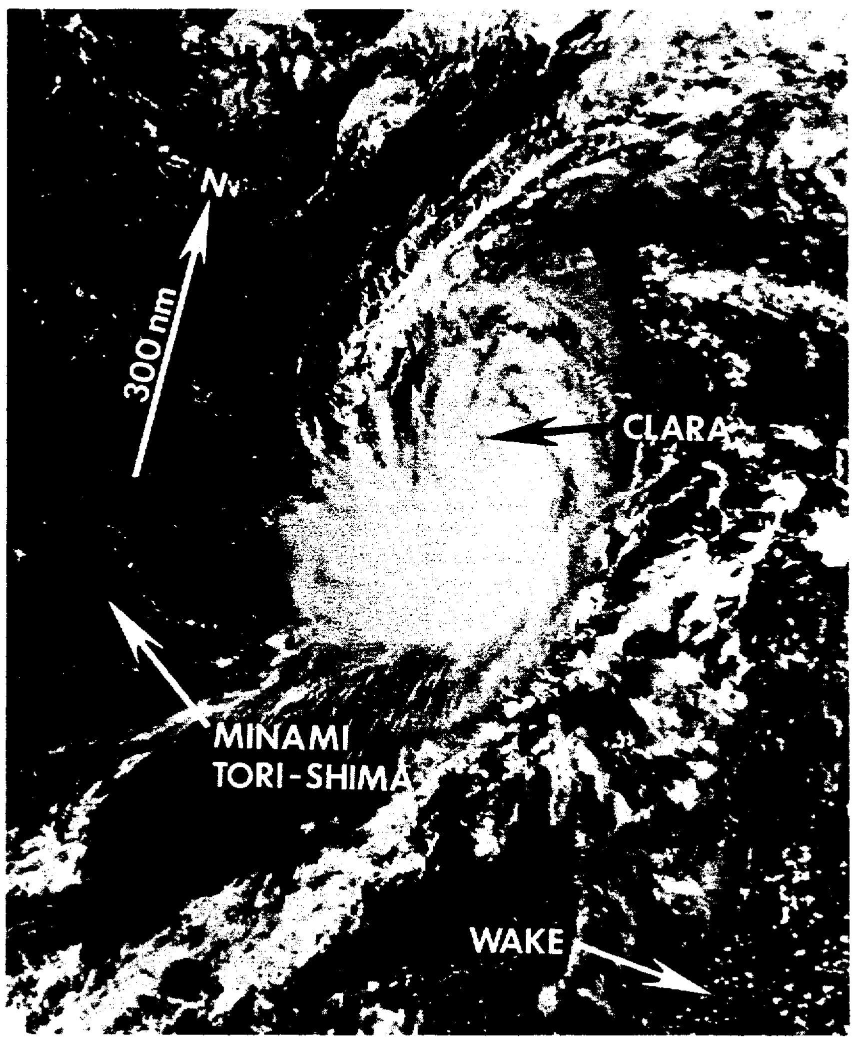


Figure 3-09-1. Tropical Storm Clara, shortly after the first warning (102201Z August NOAA visual imagery).

081600Z for procedural, not meteorological, reasons. However, the disturbance experienced stronger vertical wind shear, and its deep convection was displaced more than 90 nm (167 km) north of the circulation center. Based on this, the second Alert was canceled at 090600Z.

Increased central convection on 10 August and an evaluation of satellite imagery and synoptic data, which indicated 20 to 30 kt (10 to 15 m/sec) sustained surface winds, resulted in a third Alert at 100100Z. As the disturbance continued to move westward, its upper-level outflow improved and its central convection increased. The first warning on Tropical Storm Clara was issued at 101915Z. Sustained surface winds at that time were estimated to be 35 kt (18 m/sec) (Figure 3-09-1). Due to the close proximity to regions of stronger vertical wind shear, Clara was not forecast to intensify beyond the 40 to 45 kt (21 to 23 m/sec) range.

As ridging to the west increased, Clara made a small counterclockwise loop while maintaining its 35 kt (18 m/sec) intensity. Clara reached a peak intensity of 45 kt (23 m/sec) at 110000Z and began moving northeastward (Figure 3-09-2) at 110600Z. Analysis of satellite imagery on 12 August

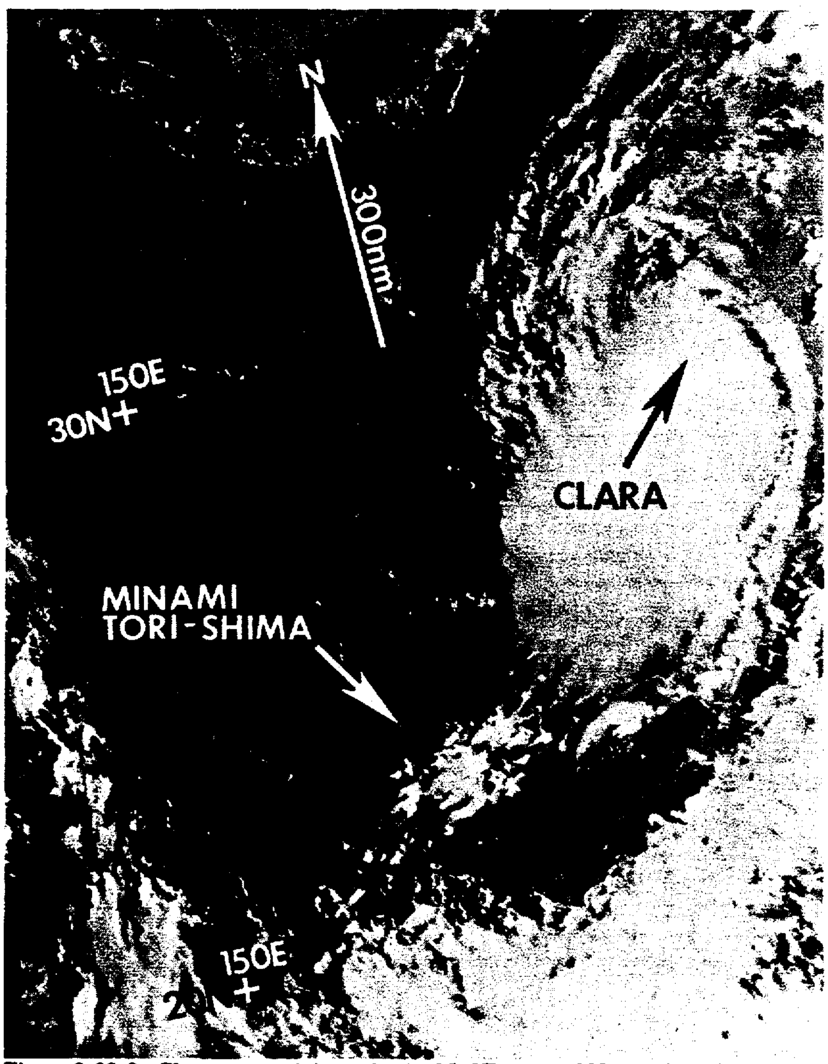
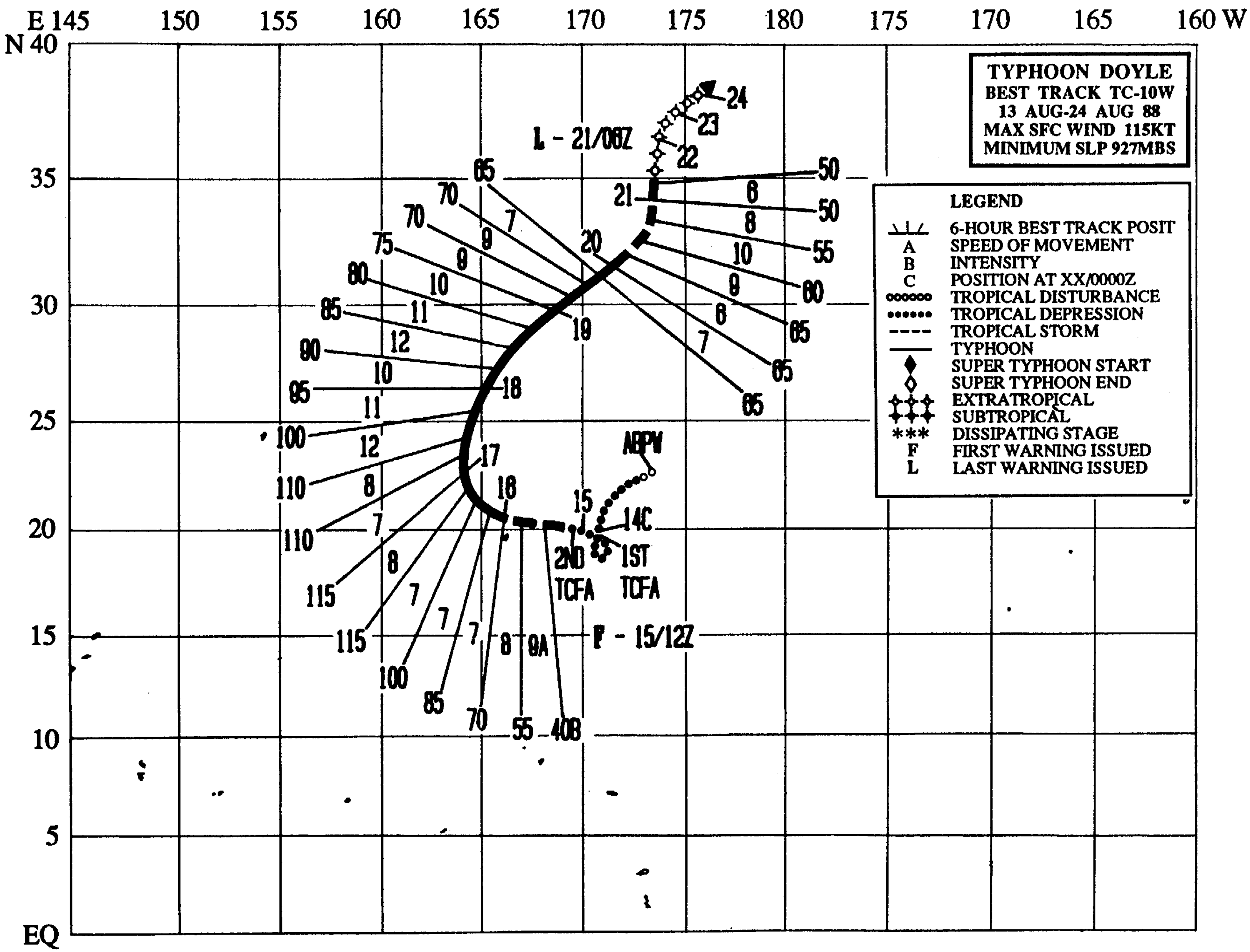


Figure 3-09-2. Clara near peak intensity (110513Z August NOAA visual imagery).

indicated Clara had weakened to 30 kt (15 m/sec) sustained surface winds as its main convection was displaced southeast of the low-level circulation center. The final warning on the system was issued at 120000Z. The remnants of Clara tracked northward, northwestward and, then again, northward for the next four days in response to steering flow around the subtropical ridge to its east. By 16 August, the remains of the system were no longer identifiable. No damage reports relating to Clara were received.


TYPHOON DOYLE
BEST TRACK TC-10W
13 AUG-24 AUG 88
MAX SFC WIND 115KT
MINIMUM SLP 927MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 145
150
155
160
165
170
175
180
175
170
165
160 W
N 40
35
30
25
20
15
10
5
EQ
L - 21/06Z
F - 15/12Z
ABPW
1ST TCFA
2ND TCFA
9A
40B
14C

TYPHOON DOYLE (10W)

Typhoon Doyle was the third of five tropical cyclones and the first of two typhoons to occur in the western North Pacific during August. In keeping with the aclimatological trend for the month, Doyle was no exception. It formed north of 20 degrees North latitude, moved south-southwestward and looped before tracking to the northeast.

On 12 August, as Tropical Storm Clara (09W) moved northward and weakened, a portion of the Central Pacific high moved in from the east to fill the void. The high pushed southwestward across the dateline. During the adjustment process, a low-level cloud vortex appeared along the leading edge of the flow and west of the remnants of Hurricane Fabio (08E). The unusual south-southwestward track of this vortex appeared to be related to the steering provided by a lower-tropospheric anticyclone to the north. The Significant Tropical Weather Advisory at 130600Z mentioned the vortex when deep convection became associated with the low-level cyclonic circulation. Throughout the night of the 13th and early morning hours of the 14th, the convection became centralized. This prompted a Tropical Cyclone Formation Alert at 140130Z. Visual and infrared imagery (Figure 3-10-1) at 140743Z implied a well developed low-level inflow. About this time

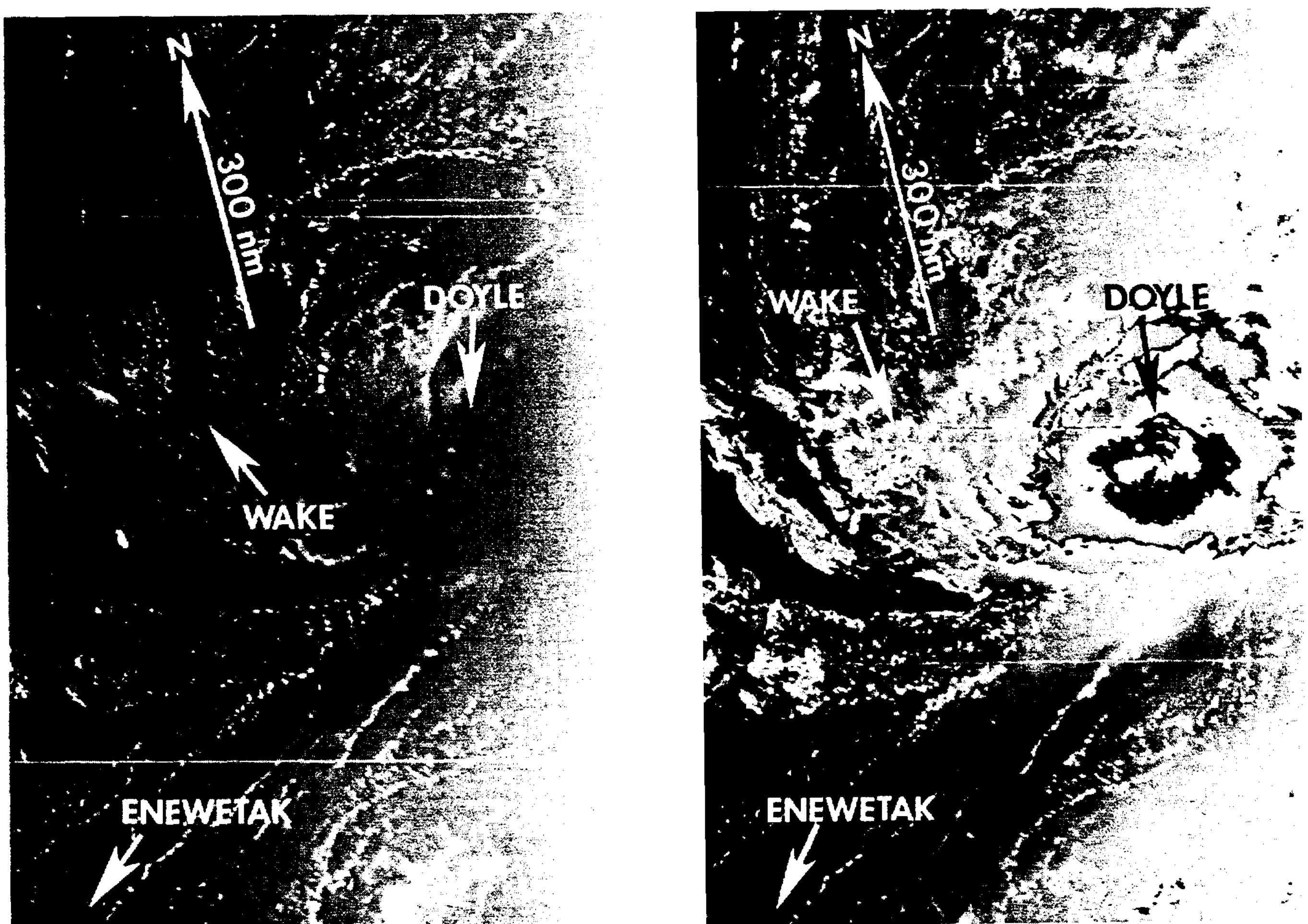


Figure 3-10-1. Satellite imagery of the suspect area (Doyle). Low-level circulation is implied by the lines of cumulus surrounding the center. The left picture is visual and the right is enhanced infrared (140743Z August DMSP visual and infrared imagery).

the system (Doyle) executed a small counterclockwise loop and began tracking west-northwestward. The potential for the system to develop remained good and a second Tropical Cyclone Formation Alert was issued at 150130Z.

The satellite intensity estimate of 40 kt (21 m/sec) maximum surface winds was followed at 151200Z by the first warning, when the system was 96 nm (178 km) east-northeast of Wake Island. For the 24-hour period from 151800Z to 161800Z (Figure 3-10-2) the intensity increased from 50 to 115 kt (26 to 59 m/sec). This was the equivalent of a sixty millibar pressure fall and met the criteria (Dunnavan, 1981) for explosive deepening. Although Doyle, which was close to becoming a compact typhoon, passed 55 nm (102 km) north of Wake Island (WMO 91245) at 152100Z, the island only experienced gusts to 40 kt (21 m/sec). As a result, the low-lying island incurred only minor damage.

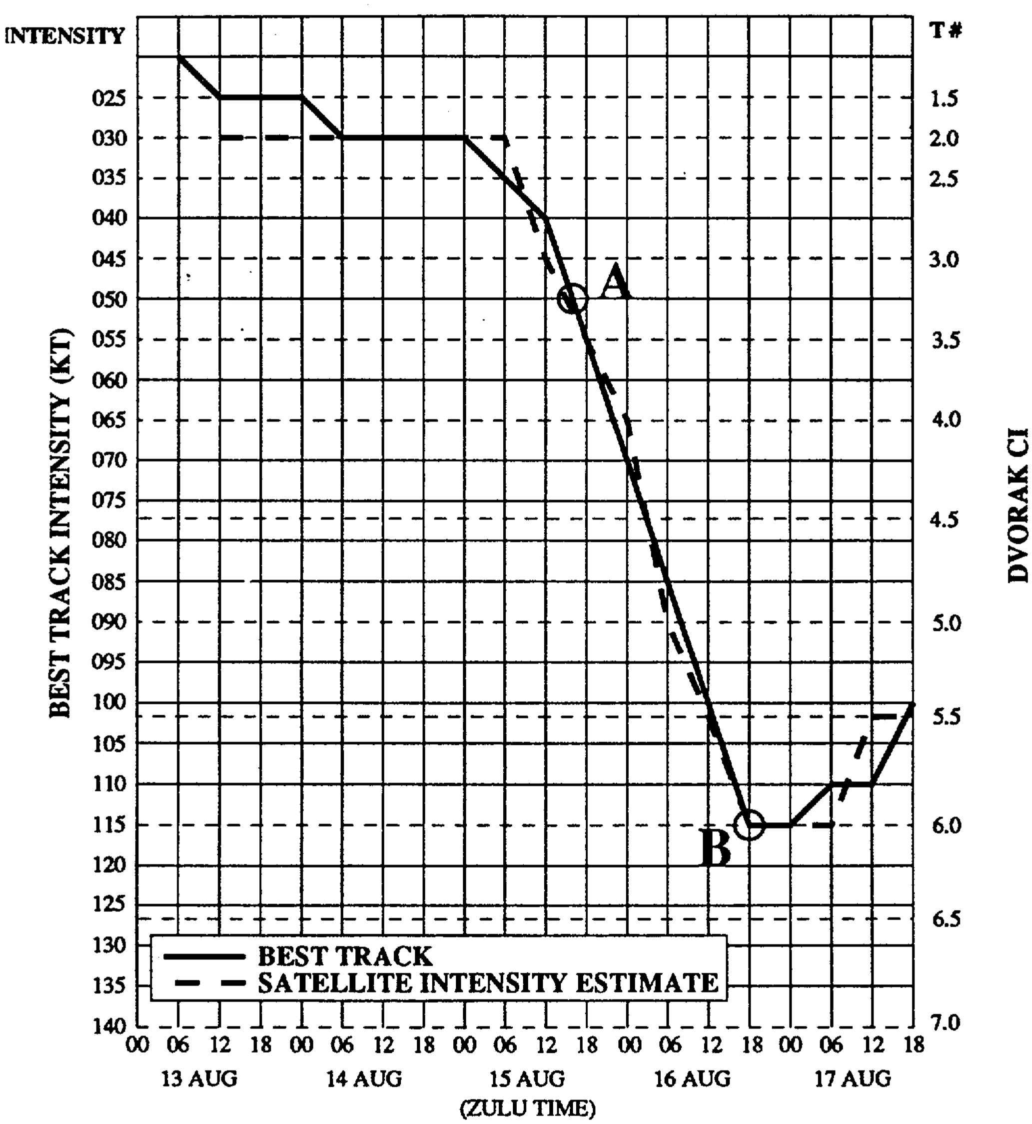


Figure 3-10-2. Time/intensity comparison of satellite intensity estimates for the Guam satellite site and the best track. Notice the extended period of explosive deepening of 30 mb/12-hours from 151800Z (point A) to 161800Z (point B).

Nearing the western periphery of the mid-level subtropical ridge, Doyle peaked in intensity at 161800Z (Figure 3-10-3) and assumed a northward track at 170000Z. To complicate the track forecasts, a TUTT cell stalled, then appeared to dissipate to the north. The main effect of the TUTT cell was to shield the tropical cyclone from strong mid- and upper-level westerlies. As a result, expected acceleration along the track didn't take place and Doyle's speed was never greater than 12 kt (22 km/hr). Doyle's track followed lower pressures and heights present between the subtropical ridge to the southeast and another high cell to the northwest centered near 42° North latitude.

After gradual weakening, Doyle was forecast to become extratropical as the convection began to move into the northeast semicircle at 180900Z. However, some central convection remained until 22 August. Doyle

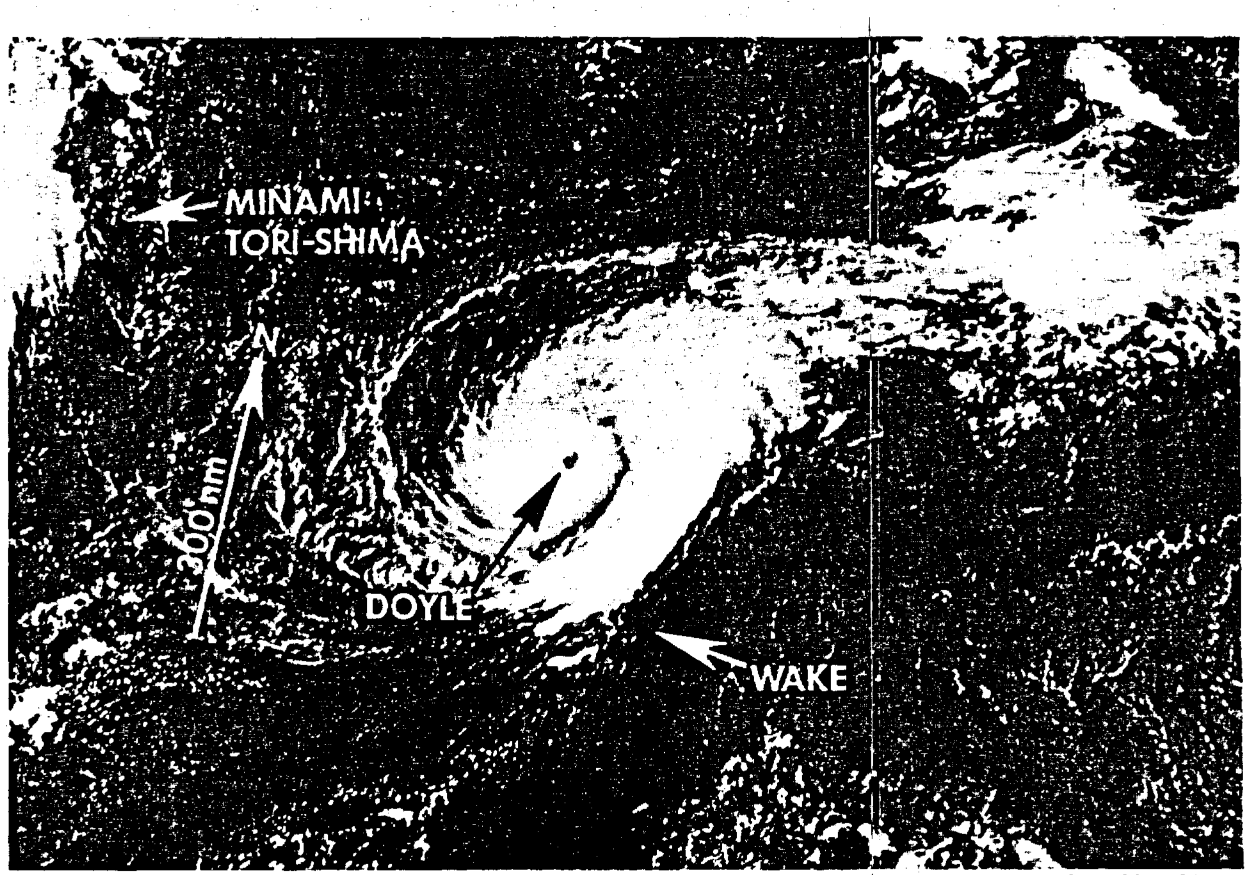


Figure 3-10-3. Satellite imagery of Typhoon Doyle at maximum intensity. The medium sized eye ranged from 20 to 30 nm (37 to 57 km) in diameter (162212Z August DMSP visual imagery).

dissipated over colder water as the system slowed and moved northeastward.

Doyle fell into the "other" track category for several reasons: rapid south-southwestward movement for 24-hours, looping and interaction with a TUTT cell while at typhoon intensity. Normally, tropical cyclone objective forecast guidance does not perform well for aclimatic systems. Figure 3-10-4 compares the final best track and the performance of the two best performing aids, CSUM and OTCM, up to the major track change at 170000Z. Although OTCM had the lowest mean forecast errors at 72-hour's of all the aids, it was slow in catching the major track change to the northeast. CSUM had the same problem predicting this track change.

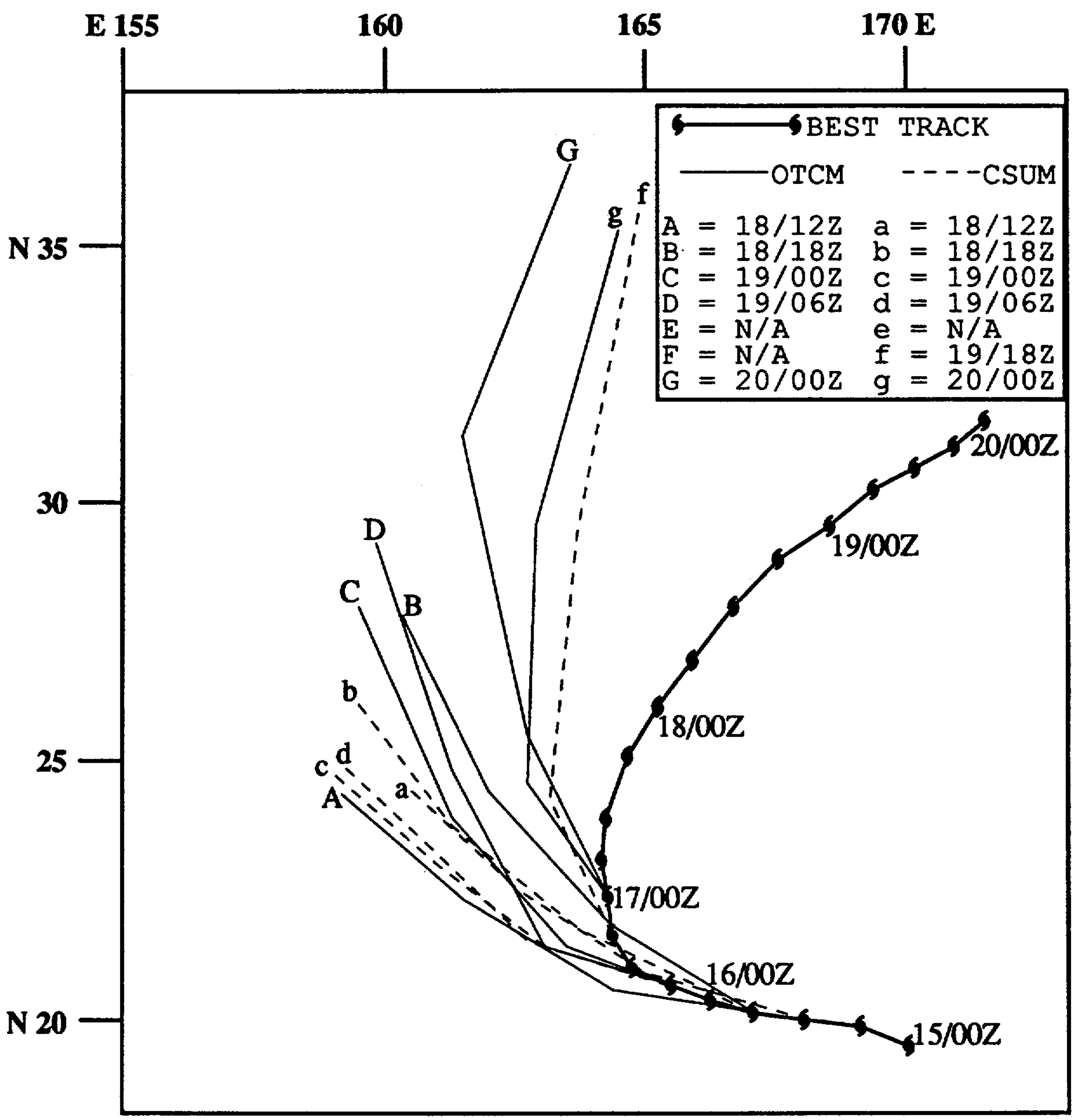
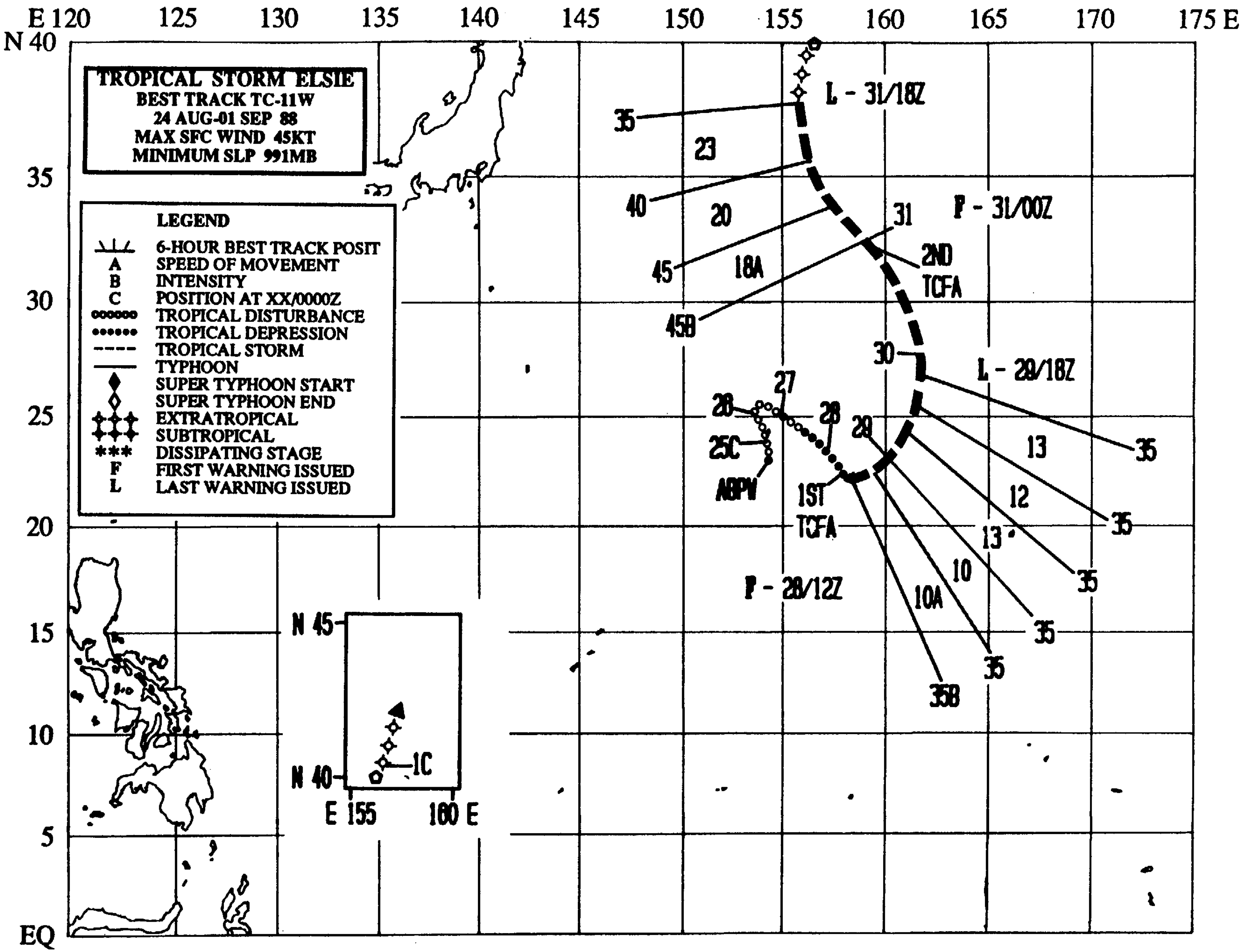


Figure 3-10-4. Graphical display of selected objective aids performance (OTCM and CSUM).


TROPICAL STORM ELSIE
BEST TRACK TC-11W
24 AUG-01 SEP 88
MAX SFC WIND 45KT
MINIMUM SLP 991MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 31/18Z
F - 31/00Z
2ND TCFA
L - 29/18Z
1ST TCFA
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ABPW
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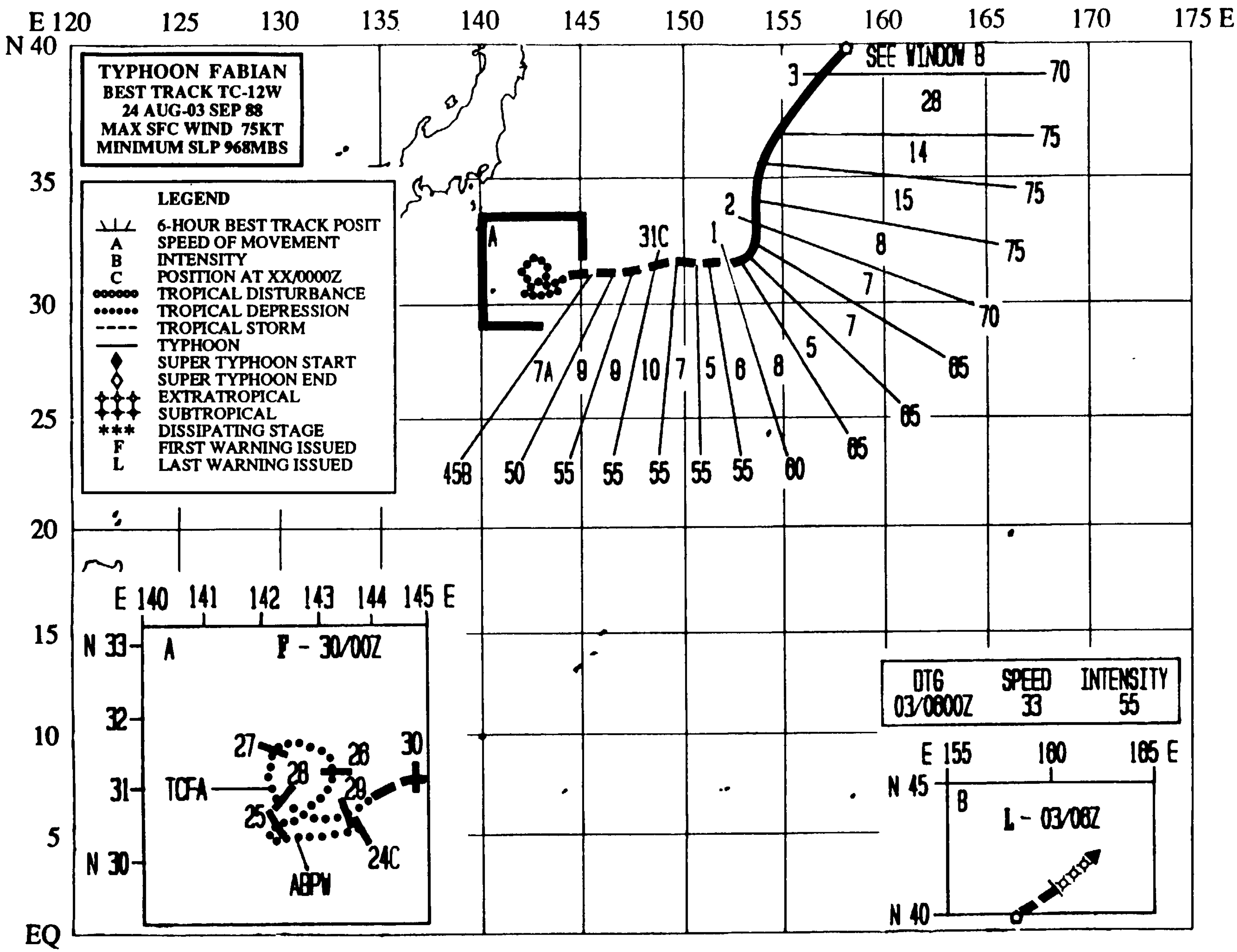
N 40
E 155
160 E
1C


TYPHOON FABIAN
BEST TRACK TC-12W
24 AUG-03 SEP 88
MAX SFC WIND 75KT
MINIMUM SLP 968MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 120
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130
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175 E
N 40
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10
5
EQ
SEE WINDOW B
31C
DTG 03/0600Z
SPEED 33
INTENSITY 55
E 140 141 142 143 144 145 E
N 33
32
31
N 30
A
F - 30/00Z
TCFA
ABPW
24C
E 155 160 165 E
N 45
N 40
B
L - 03/06Z

TROPICAL STORM ELSIE (11W) AND TYPHOON FABIAN (12W)

Elsie and Fabian were the last of five significant tropical cyclones to develop in August. They both initially displayed erratic movement as immature systems within the larger monsoon trough, interacted as a binary pair (Brand, 1968) and, later, became extratropical.

Both systems were first detected on 24 August and mentioned on the Significant Tropical Weather Advisory as areas of persistent convection in the monsoon trough, that was anomalously far north and extended southeastward from Japan. Typical of formative vortices in the larger monsoon trough, their tracks were less than straight forward. Fabian's track wobbled around until 28 August, when it sped off towards the east on a possible collision course with Elsie. In the interim, Fabian required three Tropical Cyclone Formation Alerts: the first at 271430Z based on a 30 kt (15 m/sec) satellite estimate of surface winds, a second at 281430Z and the third at 291230Z when the tropical disturbance retained its potential for development and failed to weaken. Finally, Fabian's convection consolidated (Figure 3-11/12-1), resulting in a satellite intensity estimate of 45 kt (23 m/sec) and the first warning at 300000Z.

In the meantime, Elsie, which was located at the southeastern end of the monsoon trough, was in an area of stronger low-level convergence and associated cloudiness, but

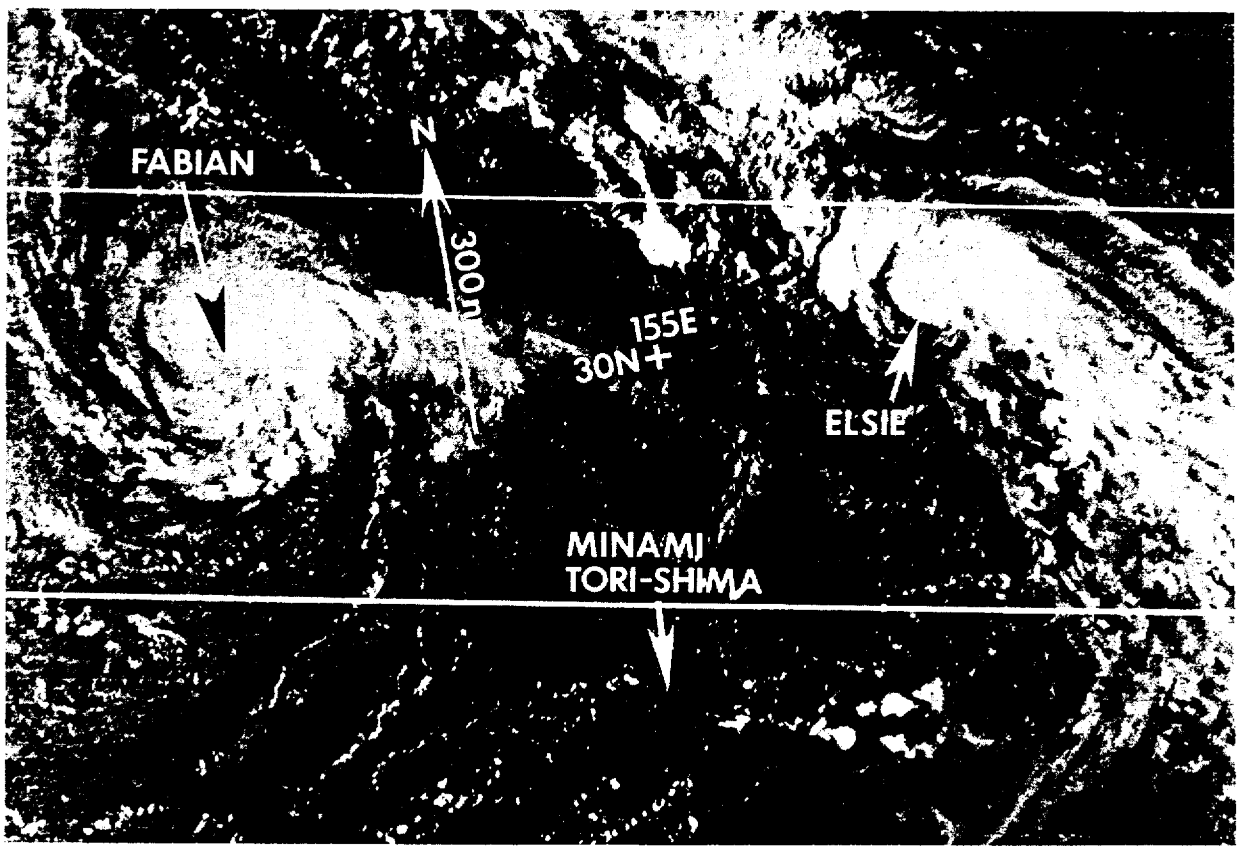

Figure 3-11/12-1. Fabian at tropical storm intensity is on the left. Tropical Storm Elsie is on the right (301140Z August DMSP visual imagery).

suffered from lack of central convection. Better organization at 280600Z with estimated surface winds of 30 kt (15 m/sec) from the satellite analysis led to a Tropical Cyclone Formation Alert at 280900Z. The first warning followed at 281200Z based on satellite intensity estimates of 35 kt (18 m/sec). At this point Elsie's course, which had been southeastward, abruptly changed to northeastward. As a consequence, the monsoon trough also began to shift northward. This reorientation of the trough axis is the most probable explanation for Fabian's unusual track to the east.

At 281200Z, Elsie and Fabian were separated by 1070 nm (1982 km). The two systems closed on each other until only a 400 nm (741 km) separation remained three days later. Figure 3-11/12-2 shows the two best tracks with the locus of midpoints (point A to point B) between each system at six hourly intervals. Plotting the locus of midpoints at one point (C) in Figure 3-11/12-3 and replotting the relative locations of Elsie and Fabian, the cyclonic motion of the binaries (Dong and Neumann, 1983) is captured.

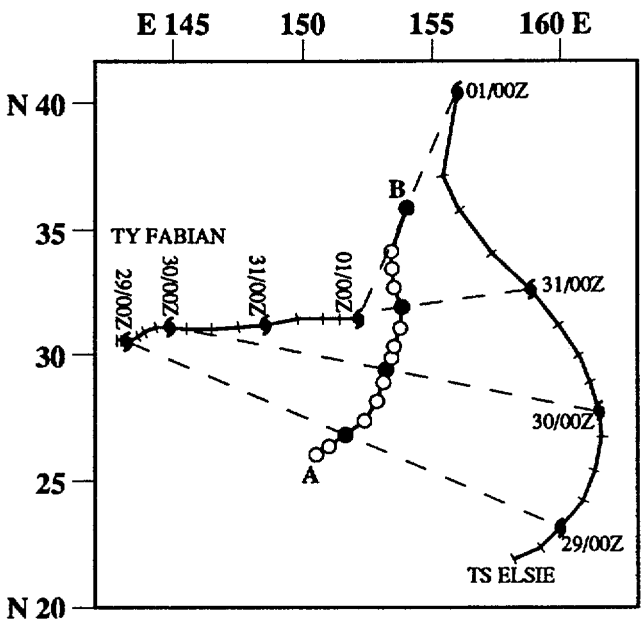

Figure 3-11/12-2. Tracks for Elsie and Fabian for the period 281200Z August to 010000Z September. For each respective six hourly position for the two systems a midpoint is plotted. The locus of these midpoints stretches from point A to point B.

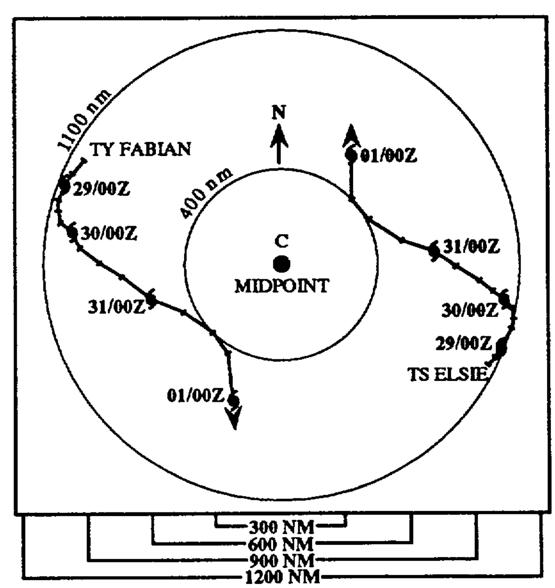

Figure 3-11/12-3. For the period 281200Z August to 010000Z September the plotted positions of Elsie and Fabian relative to the midpoint (reference Figure 3-11/12-2) at point C describe the motion of this binary system.

While this interaction was taking place, Elsie's convection weakened and the forecast intensity estimate dropped below 35 kt (18 m/sec). This prompted an amendment of the 291800Z warning, which had called for dissipation in 48-hours over water with remarks that "signs for regeneration would be monitored." It appears that Elsie stabilized as a weak tropical storm and assumed a track to the northwest. The remnants of Elsie were not expected to flare up again due to the binary interaction with Fabian, which reduced the separation between the two and increased the vertical wind shear across Elsie from Fabian's outflow. However, the central convection returned (Figure 3-11/12-4) and a Tropical Cyclone Formation Alert - the second for Elsie - was issued at 302300Z. Elsie's compact reorganization resisted the unfavorable conditions aloft and the Alert was almost immediately upgraded to a regenerated tropical storm at 310000Z.

Once Elsie was past the closest point of approach to Fabian, it changed course to the northeast, accelerated and rapidly became extratropical. The final warning - the second for Elsie - was issued at 311800Z. In contrast,

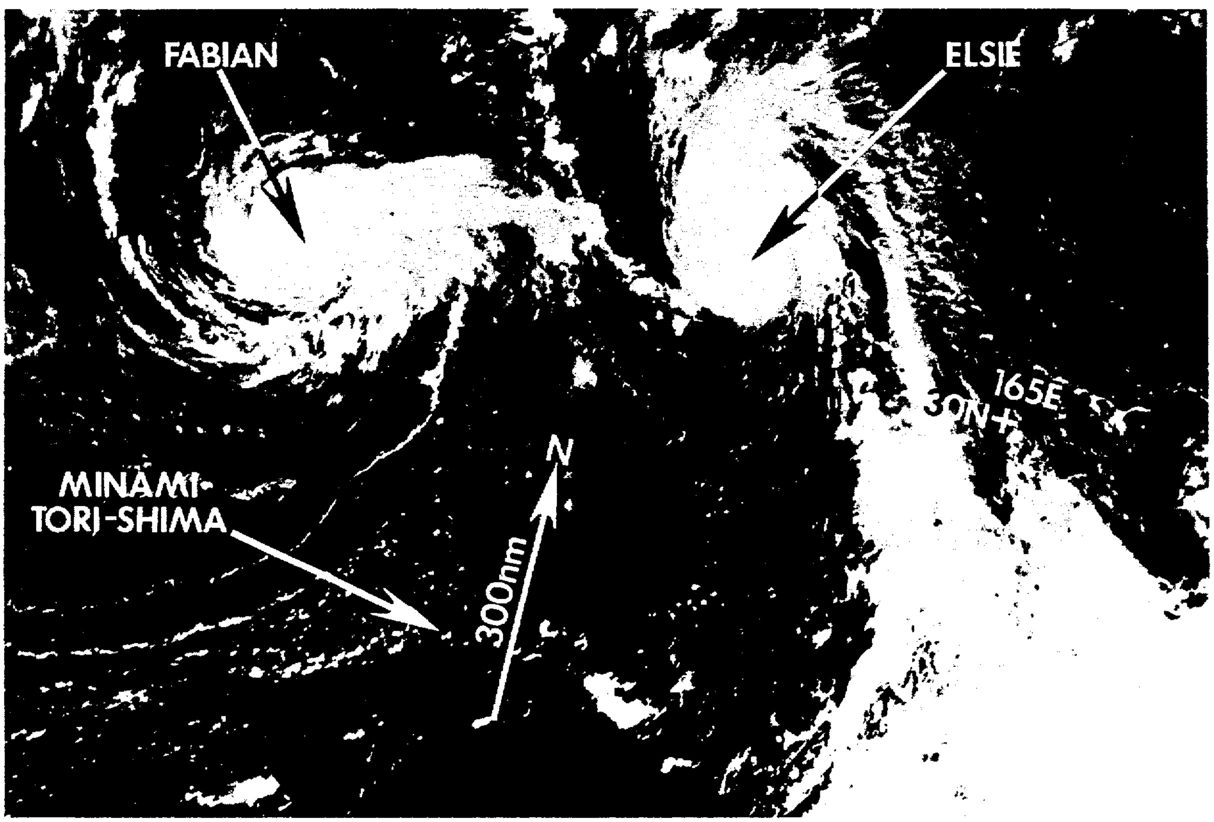

Figure 3-11/12-4. The remnants of Elsie, on the right, undergo a rapid reorganization. The second Tropical Cyclone Formation Alert was issued upon receipt of this picture. Fabian is to the left of Elsie (302240Z August DMSP visual imagery).

Fabian intensified during this encounter and reached typhoon intensity (Figure 3-11/12-5) at 010600Z just prior to making an abrupt track change to the north six hours later. Typhoon Fabian reached a peak intensity of 75 kt (39 m/sec) at 020600Z. By 030000Z, the onset of rapid acceleration and stronger upper-level westerlies led to a loss of convective organization. Fabian was downgraded to tropical storm intensity and finalled at 030600Z. No reports of damage or loss of life were received for these two tropical cyclones.

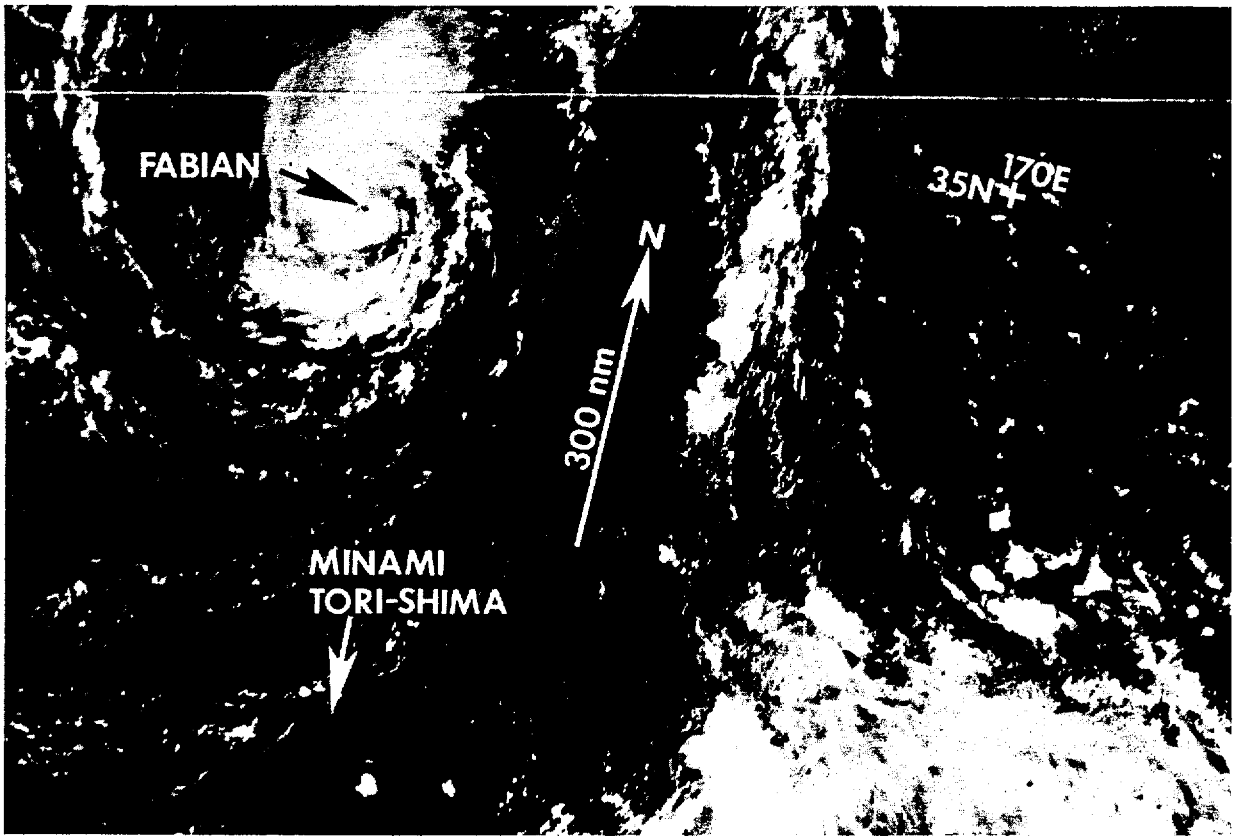

Figure 3-11/12-5. Fabian nearing peak intensity. Elsie has moved off the picture to the northeast of Fabian (312220Z August DMSP visual imagery).

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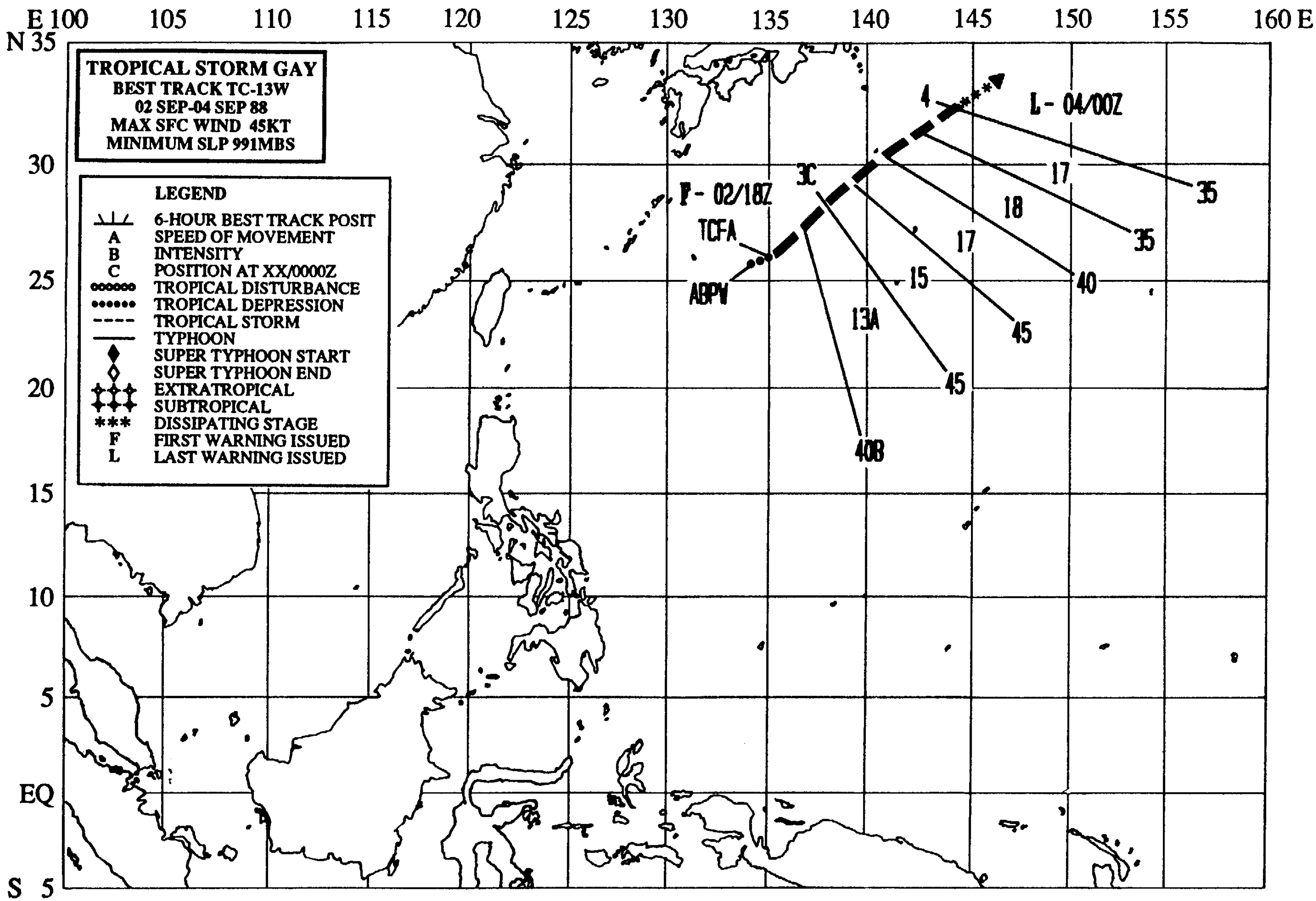
TROPICAL STORM GAY
BEST TRACK TC-13W
02 SEP-04 SEP 88
MAX SFC WIND 45KT
MINIMUM SLP 991MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 100
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130
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145
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160 E
N 35
30
25
20
15
10
5
EQ
S 5
F - 02/18Z
TCFA
ABPW
L - 04/00Z
3C
4
13A
40B
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35

TROPICAL STORM GAY (13W)

Gay was a short-lived (two day) tropical cyclone. Only six warnings were issued on the system before it dissipated over water. The disturbance that eventually became Gay formed in the monsoon trough 420 nm (778 km) east of Okinawa. It was first mentioned on the Significant Tropical Weather Advisory at 020600Z and rated as having a "fair" potential for significant development. The system's convection rapidly increased in amount and became better organized when its low-level circulation moved beneath the divergent area ahead of an approaching upper-level trough. After synoptic data (020600Z) indicated the disturbance had sustained surface winds in the 20 to 30 kt (10 to 15 m/sec) range and satellite wind estimates of 35 kt (18 m/sec), a Tropical Cyclone Formation Alert was issued at 021040Z. The first warning (021800Z) on Tropical Storm Gay followed. Gay moved northeastward at speeds of 14 kt (26 km/hr), or more, and reached a peak intensity of 45 kt (23 m/sec) sustained surface winds (Figure 3-13-1). After peaking, the tropical cyclone tracked into an environment of strong vertical wind shear, which separated the system's deep convection from its low-level circulation. The final warning was issued on Gay at 040000Z while it was dissipating over water 290 nm (537 km) southeast of Tokyo.

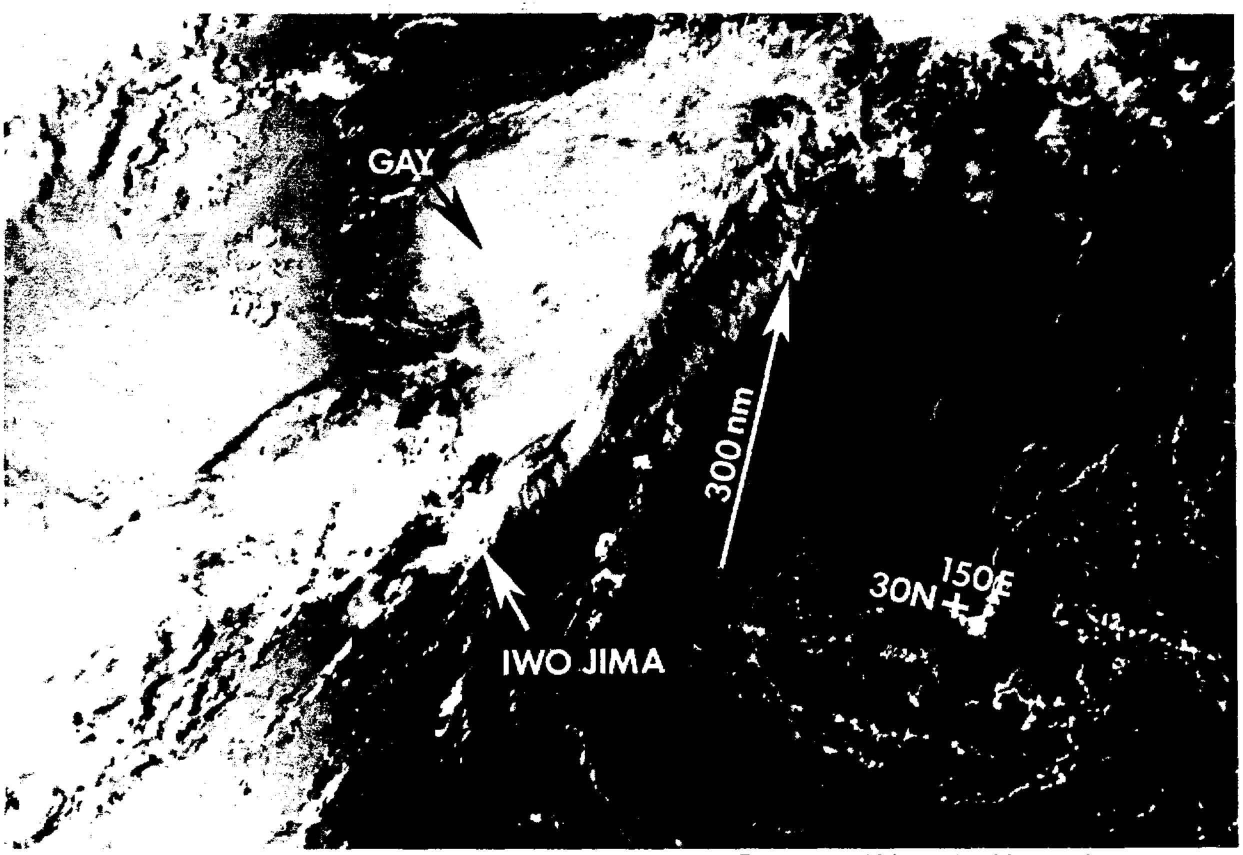
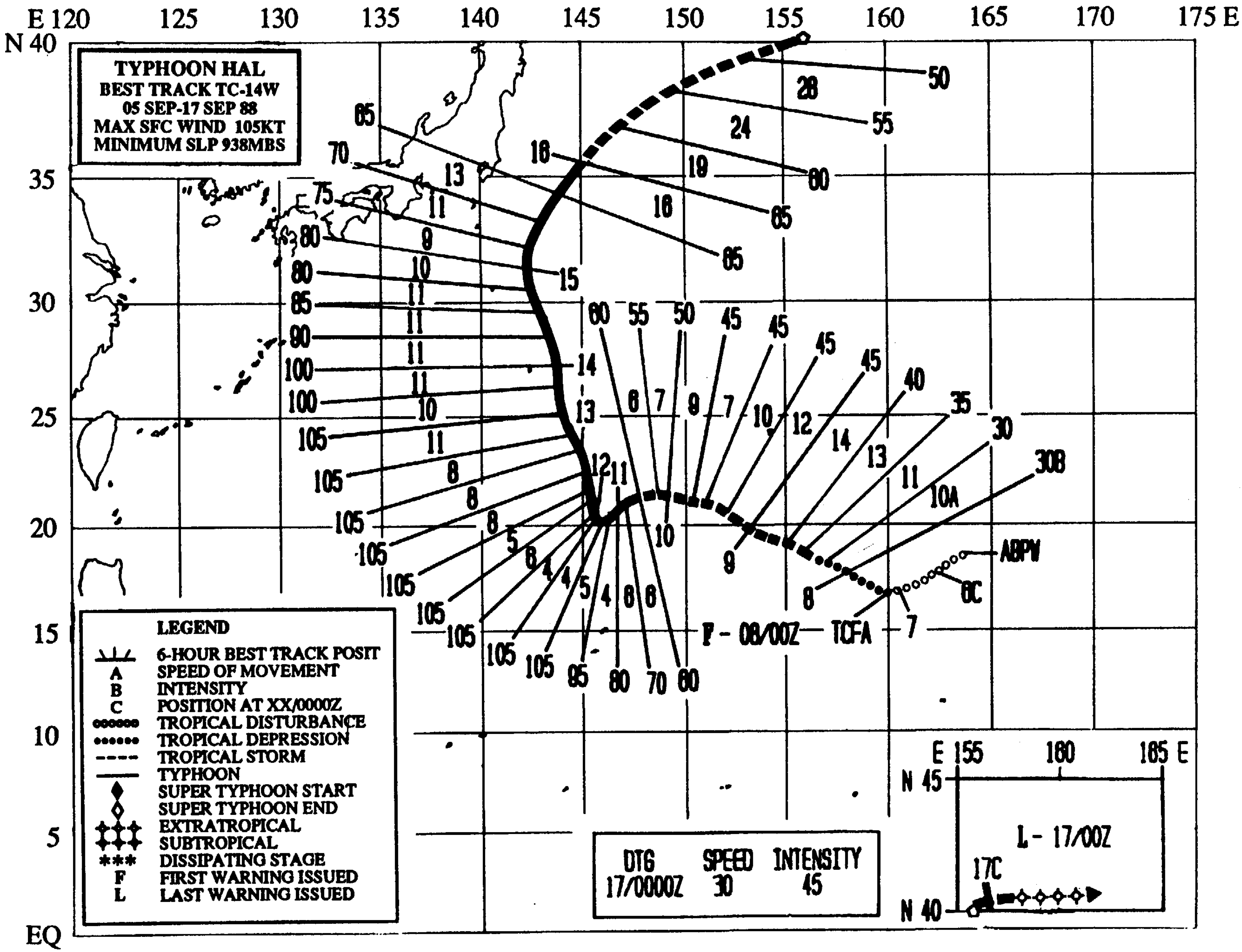


Figure 3-13-1. Tropical Storm Gay at peak intensity (030605Z September NOAA visual imagery).


TYPHOON HAL
BEST TRACK TC-14W
05 SEP-17 SEP 88
MAX SFC WIND 105KT
MINIMUM SLP 938MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
F - 08/00Z
TCFA
ABPW
DTG 17/0000Z
SPEED 30
INTENSITY 45
L - 17/00Z
17C
E 120
125
130
135
140
145
150
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160
165
170
175 E
N 40
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30
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EQ
E 155
180
185 E
N 45
N 40

TYPHOON HAL (14W)

Typhoon Hal was the second of eight significant tropical cyclones and the first of two typhoons to form in the western North Pacific during September. Hal combined with Typhoon Uleki (01C), Tropical Storm Irma (15W), and later with Tropical Storm Jeff (16W) to create the first three-storm situations of 1988 in the western North Pacific.

On 5 September the remnants of Gay (13W) dissipated east of Japan. In the central North Pacific Uleki (01C) churned west-northwestward from Hawaii and a large tropical upper-tropospheric trough (TUTT) low was situated northwest of Wake Island. Hal formed just west of Wake Island as a tropical disturbance induced by this TUTT low. At 050600Z, the system was first mentioned on the Significant Tropical Weather Advisory. Over the next two days, the disturbance moved westward along the southern side of the subtropical ridge and became more organized. This growth prompted a Tropical Cyclone Formation Alert at 070430Z. Hal continued to organize. At 080000Z, the Alert was superseded by the first warning on Tropical Depression 14W, then upgraded (081200Z) to Tropical Storm Hal (Figure 3-14-1), when satellite intensity analysis indicated sustained surface winds of 35 kt (18 m/sec). Initially, Hal tracked west-southwestward, but eventually settled into a west-northwestward track as the subtropical ridge to its north weakened slightly. Hal continued to intensify and, at 101800Z, reached typhoon intensity.

Earlier at 101200Z, when Hal was 120 nm (222 km) northeast of Maug in the northern

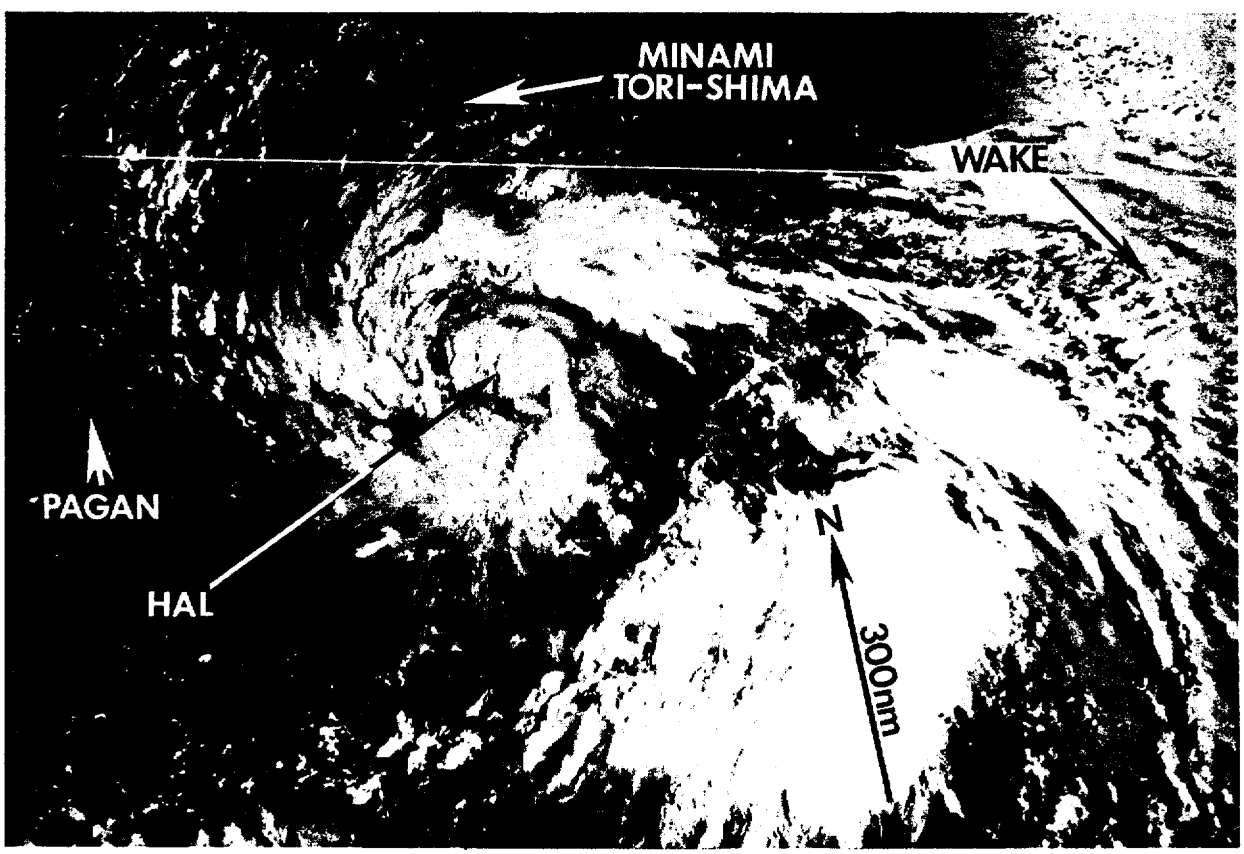


Figure 3-14-1. Hal shortly after being upgraded to a tropical storm (082128Z September NOAA visual imagery).

Marianas, the tropical cyclone started to decelerate and track to the southwest in response to stronger ridging to its north and west. After Typhoon Hal reached its peak intensity of 105 kt (54 m/sec) at 111200Z, it continued onward and passed over Maug, which is uninhabited, at 111800Z. On Guam (WMO 91212), 395 nm (732 km) to the south, the enhanced southwesterly inflow into Hal brought brisk surface winds with gusts to 40 kt (20 m/sec). Power outages and minor property damage were reported on the islands of Guam and Saipan.

With a mid-latitude trough creating lower pressure-heights in the subtropical ridge north of the typhoon, Hal's direction of track changed to the north-northwest. Japan braced for the possibility of being affected by three tropical cyclones: Typhoon Hal (Figure 3-14-2), plus Tropical Storms Irma (15W) and Jeff (16W), which had developed southeast and southwest, respectively. During the next three days, Hal weakened, developed a large 60 nm

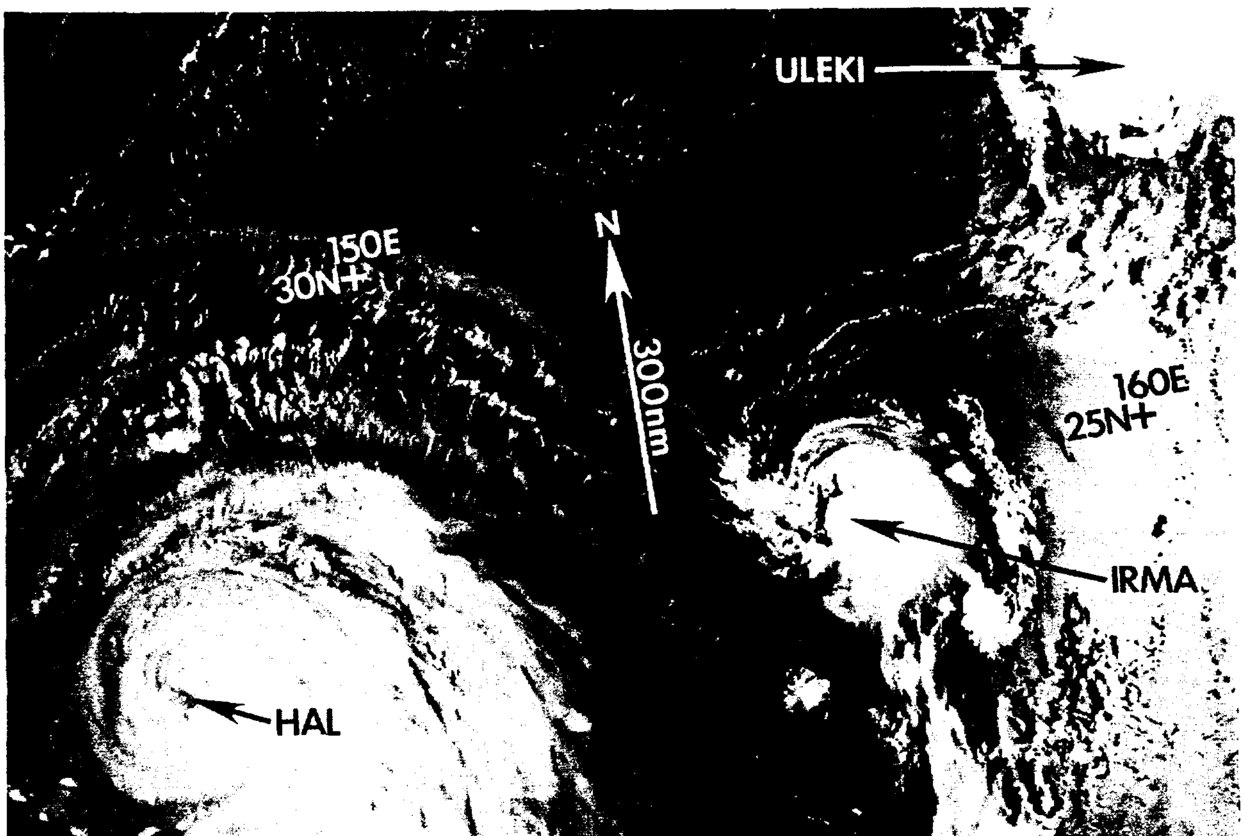


Figure 3-14-2. Typhoon Hal, at peak intensity. Also visible are Tropical Storms Irma (15W) and Uleki (01C) (122141Z September NOAA visual imagery).

(111 km) diameter eye and continued moving north-northwestward. At 150000Z, Hal (Figure 3-14-3) approached 32 degrees North latitude, started to recurve and accelerate. Typhoon Hal further weakened to 65 kt (33 m/sec) and made its closest point of approach - 195 nm (361 km) - to Tokyo, Japan at 151800Z. High surf caused several deaths and injuries along the coastal areas near Tokyo.

As Hal moved off to the northeast, its central convection was stripped away from its low-level circulation center by strong mid-latitude westerlies. When the final warning was issued at 170000Z, the system had weakened to 45 kt (23 m/sec), increased forward speed to 32 kt (59 km/hr) and was extratropical.

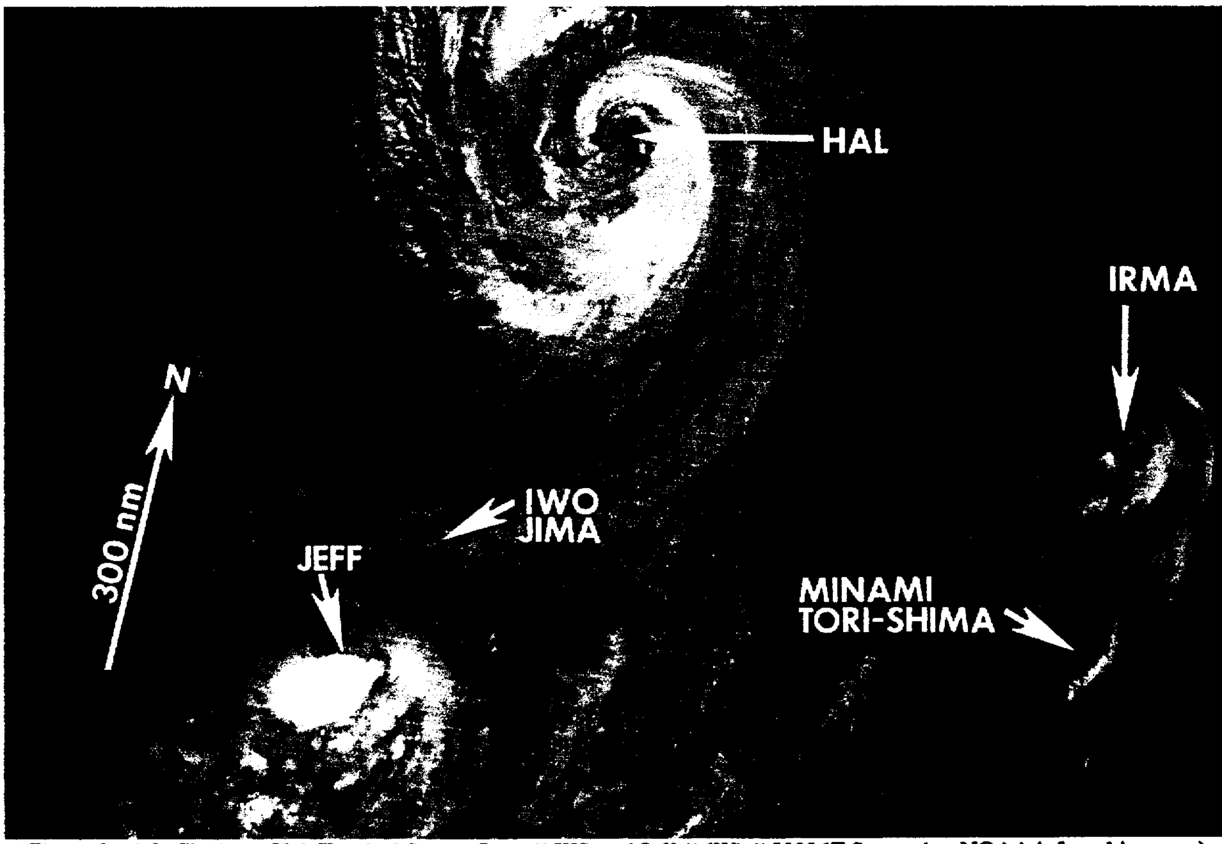
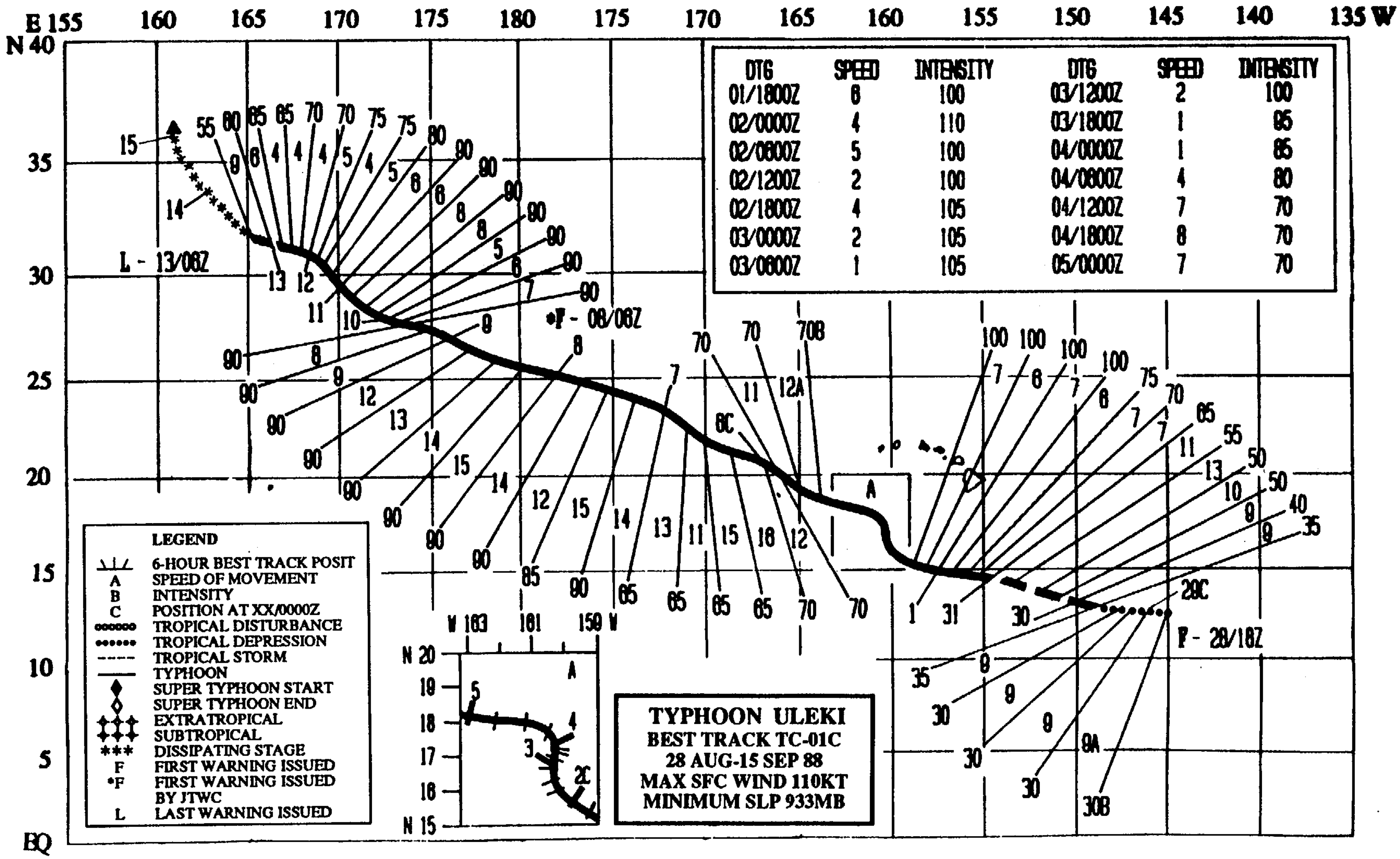


Figure 3-14-3. Typhoon Hal, Tropical Storms Irma (15W) and Jeff (16W) (150936Z September NOAA infrared imagery).



DTG	SPEED	INTENSITY	DTG	SPEED	INTENSITY
01/1800Z	6	100	03/1200Z	2	100
02/0000Z	4	110	03/1800Z	1	85
02/0600Z	5	100	04/0000Z	1	85
02/1200Z	2	100	04/0600Z	4	80
02/1800Z	4	105	04/1200Z	7	70
03/0000Z	2	105	04/1800Z	8	70
03/0600Z	1	105	05/0000Z	7	70

TYPHOON ULEKI (01C)

Uleki was only the third hurricane (Sarah (1967) and Peke (1987) were the previous two) in the past thirty years to form in the eastern North Pacific Ocean and cross the international dateline while in a warning status. Uleki tracked over 3,300 nm (6,105 km) during its eighteen day life span.

Uleki was first detected by the Central Pacific Hurricane Center (CPHC) at 281800Z August. During the next four days, Uleki tracked westward and intensified. CPHC's warnings were disseminated to military customers by the Naval Western Oceanography Center (NWOC). At 291800Z, Uleki had reached tropical storm intensity and was upgraded to a hurricane at 310000Z. The tropical cyclone slowed its forward motion and continued to intensify until 2 September, when it reached a peak intensity of 110 kt (57 m/sec). As Uleki approached the Hawaiian Islands, weather reconnaissance aircraft joined with satellite reconnaissance to watch the hurricane. At peak intensity, the direction of movement changed from west-northwestward to northward. Uleki headed directly towards the island of Oahu. The hurricane approached to within 270 nm (500 km) of Honolulu at 040000Z before changing course to the west-northwest and accelerating. The tropical cyclone began a weakening trend as it entered a shearing environment, and the upper-level outflow in the western semicircle became restricted. Uleki continued to move west-northwestward and approached the international dateline (Figure 3-01C-1). It appeared that

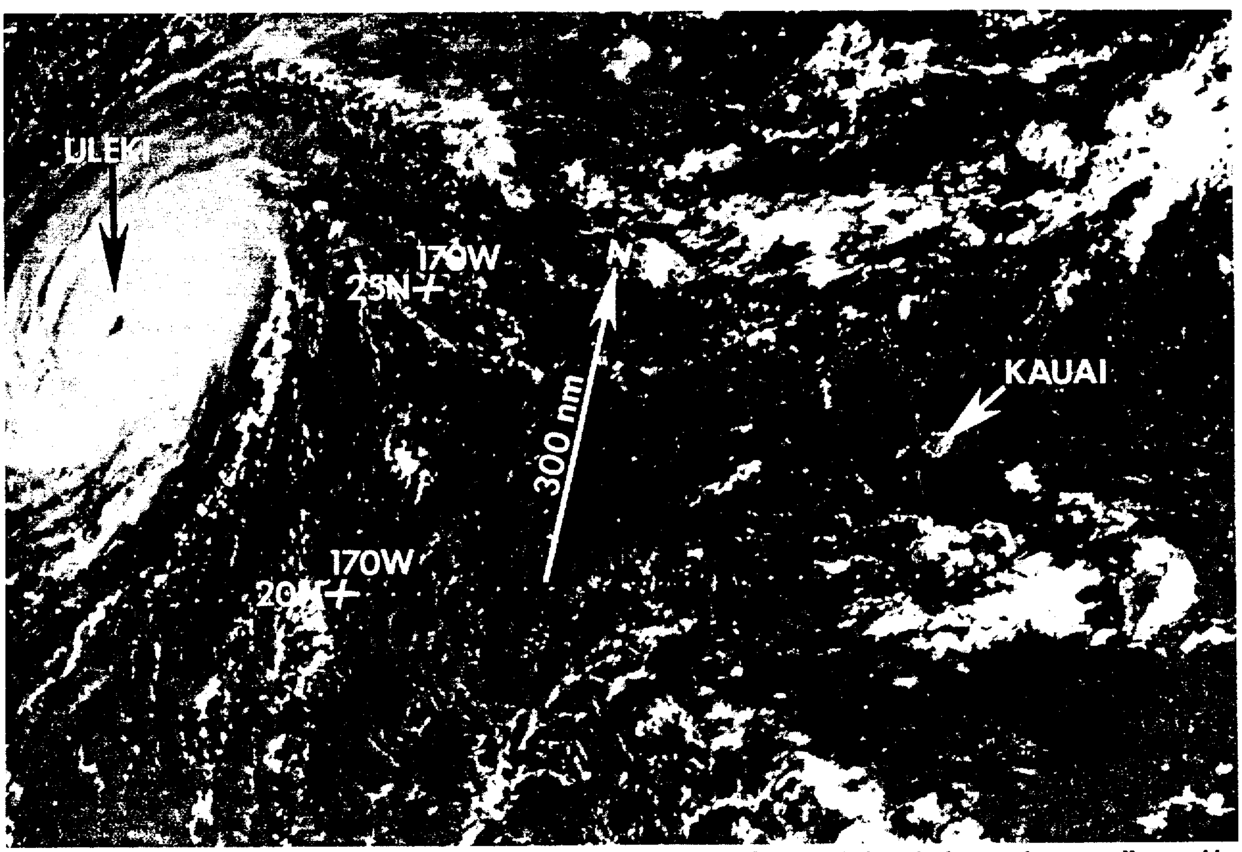


Figure 3-01C-1. Hurricane Uleki heads towards the international dateline. Note the distinct shadow on the eye wall caused by the low sun angle. The Hawaiian Islands are visible to the east of Uleki. Photo courtesy of the National Weather Service Forecast Office, Honolulu, Hawaii (071846Z September GOES West visual imagery).

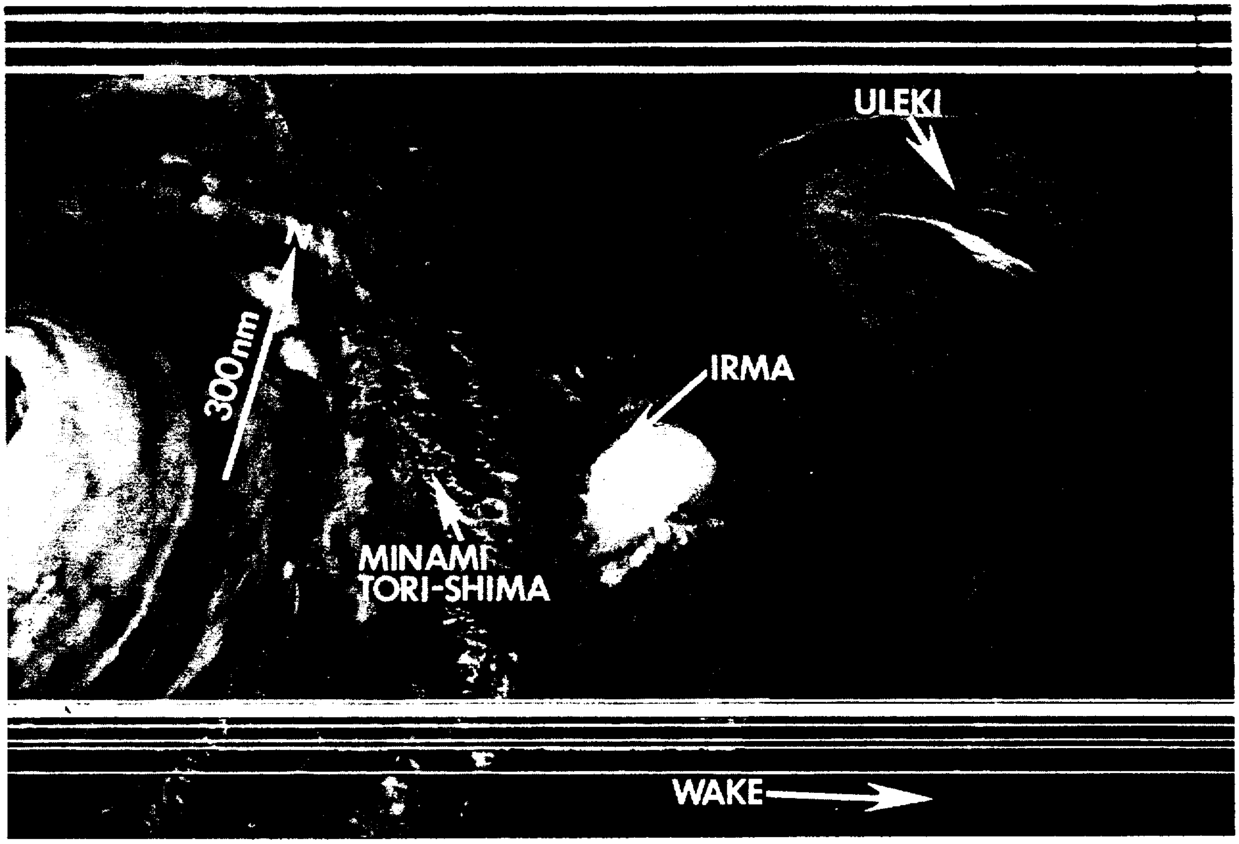


Figure 3-01C-2. Uleki, shortly after the final warning (130839Z September NOAA infrared imagery).

Uleki would be exiting CPHC and NWOC's area of responsibility, and entering JTWC's area of responsibility after the 080000Z warning.

Warning responsibility was transferred for the 080600Z warning and JTWC issued its first warning on Uleki. The system was redesignated Typhoon Uleki. At this time the tropical cyclone had an intensity of 90 kt (46 m/sec). Uleki pressed onward to the west-northwest along the southern edge of a subtropical ridge, and gradually slowed. At 100600Z, the speed of movement had dropped from 15 kt (28 km/hr) to 6 kt (11 km/hr). The typhoon had entered the weak 700 mb steering flow in an area between two anticyclones in the subtropical ridge. With a mid-latitude trough approaching from the west, Uleki was forecast to recurve during the next 24- to 48-hours. The trough caused the tropical cyclone to "step climb" to the north-northwest, but was not able to bring about recurvature. Uleki returned to a northwestward track and weakened in response to increased vertical wind shear and entrainment of low-level cooler air. At 130000Z, strong vertical wind shear associated with a second trough caused the tropical cyclone to weaken rapidly and be downgraded to a tropical storm. Satellite imagery showed a long, narrow plume of cirrus streaming from Uleki to the northeast. The final warning was issued at 130600Z (Figure 3-01C-2) and at 140000Z, all of Uleki's deep convection had been sheared away to the northeast. The low-level circulation center persisted over water until 15 September (Figure 3-01C-3).

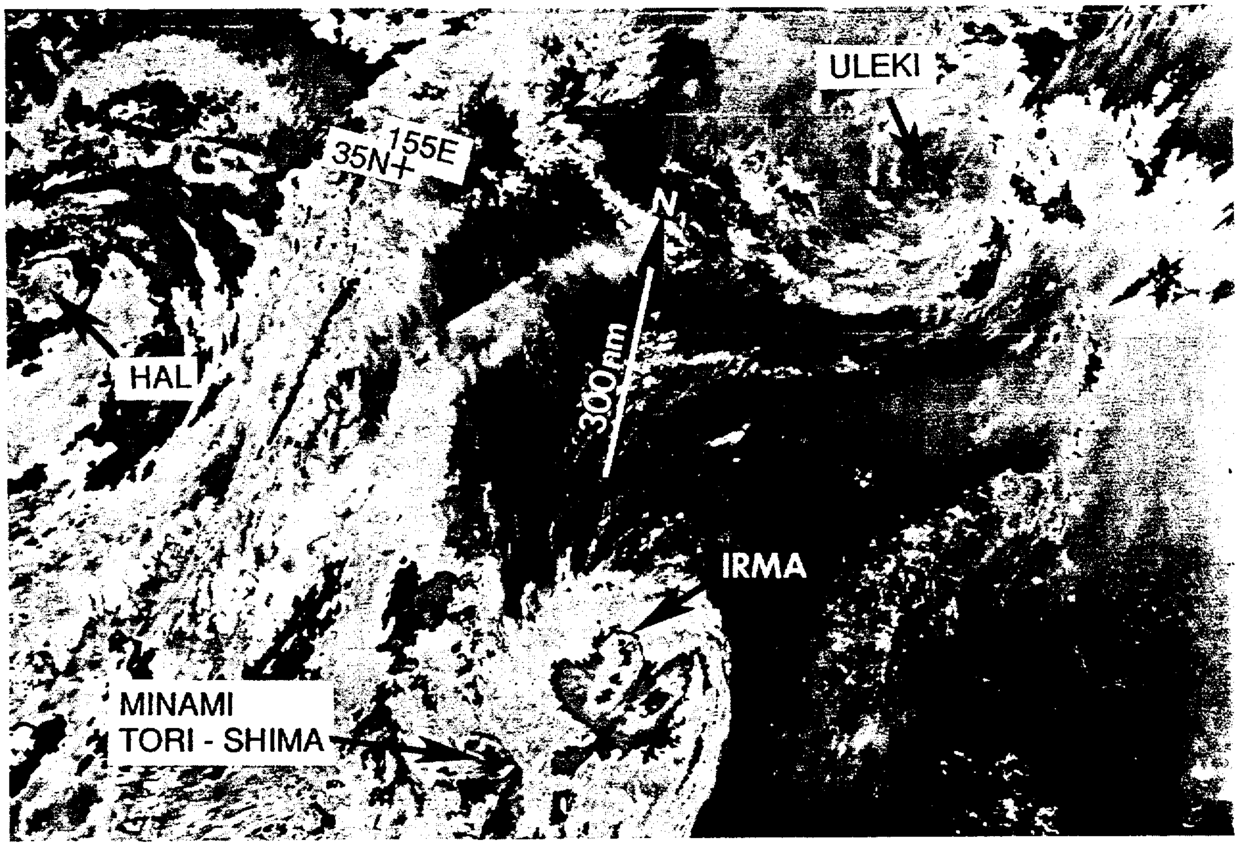


Figure 3-01C-3. Uleki dissipating over water (142247Z September DMSP infrared imagery).

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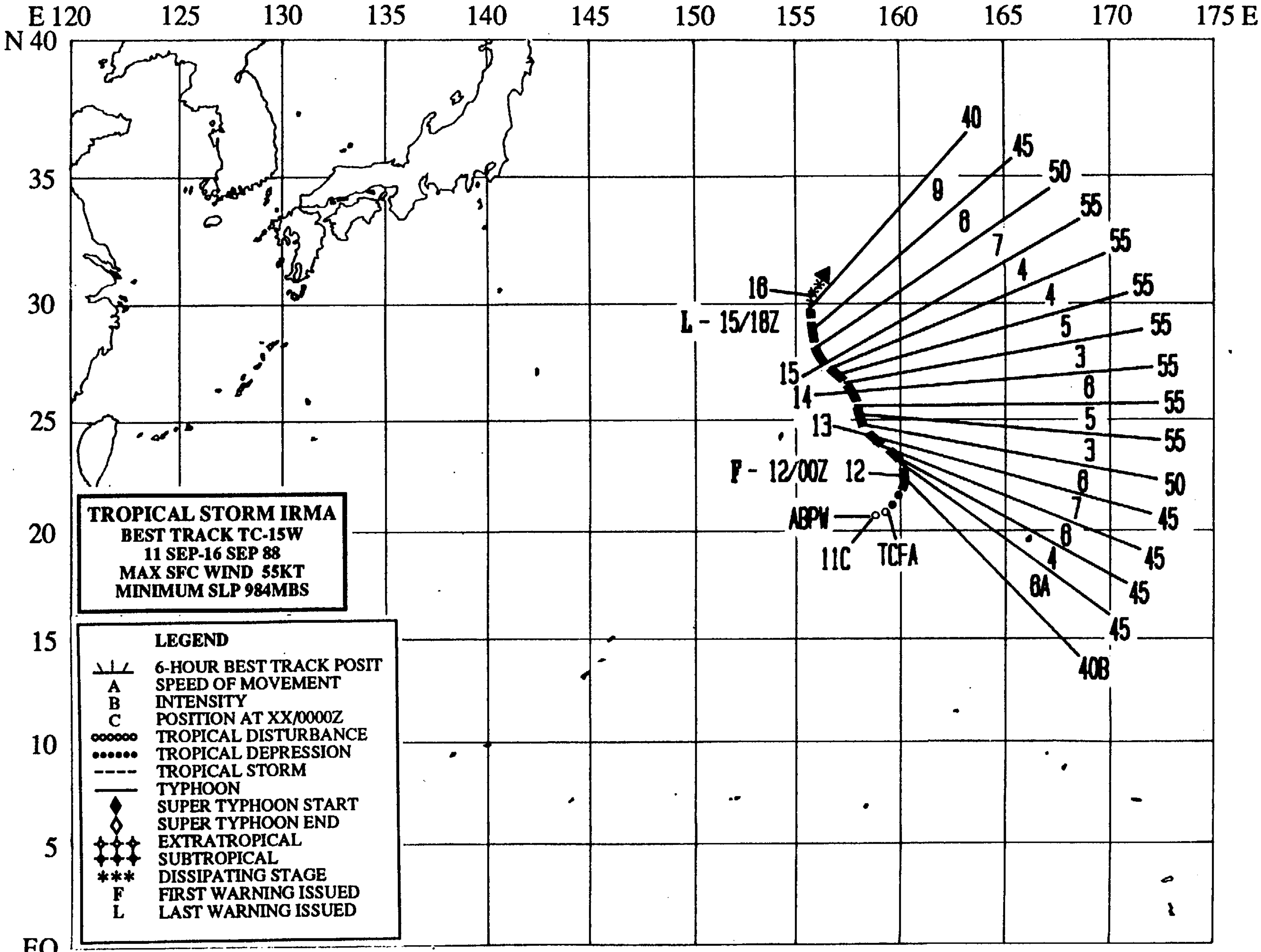
TROPICAL STORM IRMA
BEST TRACK TC-15W
11 SEP-16 SEP 88
MAX SFC WIND 55KT
MINIMUM SLP 984MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 120
125
130
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150
155
160
165
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175 E
N 40
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20
15
10
5
EQ
L - 15/18Z
F - 12/00Z
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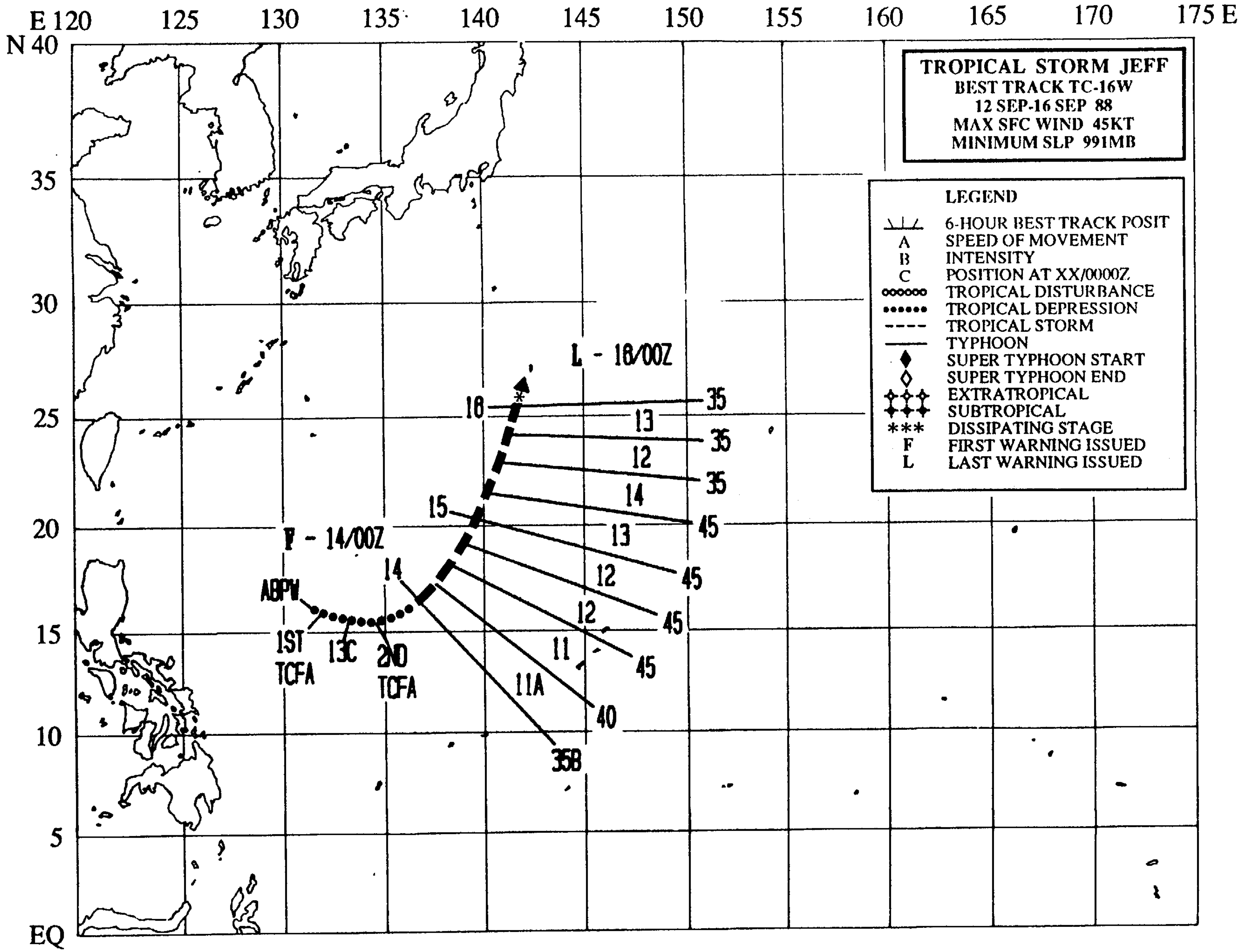
TROPICAL STORM JEFF
BEST TRACK TC-16W
12 SEP-16 SEP 88
MAX SFC WIND 45KT
MINIMUM SLP 991MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
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EQ
L - 16/00Z
F - 14/00Z
ABPW
1ST TCFA
13C
2ND TCFA
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11A
35B

TROPICAL STORM IRMA (15W) AND TROPICAL STORM JEFF (16W)

Irma and Jeff, circulations spawned by enhanced inflow into Typhoon Hal (14W), never achieved typhoon intensity. Both were part of multiple tropical cyclone outbreaks of 12 to 16 September and sheared away when Hal (14W) moved northward through the subtropical ridge.

By the second week of September Hal (14W), which started earlier as a tropical upper-tropospheric trough (TUTT) induced system, had matured south of the subtropical ridge and developed a large supporting low-level southwesterly inflow. (This inflow was separated from, and not the normal eastward extension of, the Asian southwest monsoon.) Jeff formed at the extreme western end and Irma at the extreme eastern end of this southwesterly inflow.

Compared to Jeff, Irma got a head start in central convection and was first noted on the Significant Tropical Weather Advisory at 110000Z. Although the outflow from Hal (14W) to the west streamed across the area, Irma persisted. This increased convective

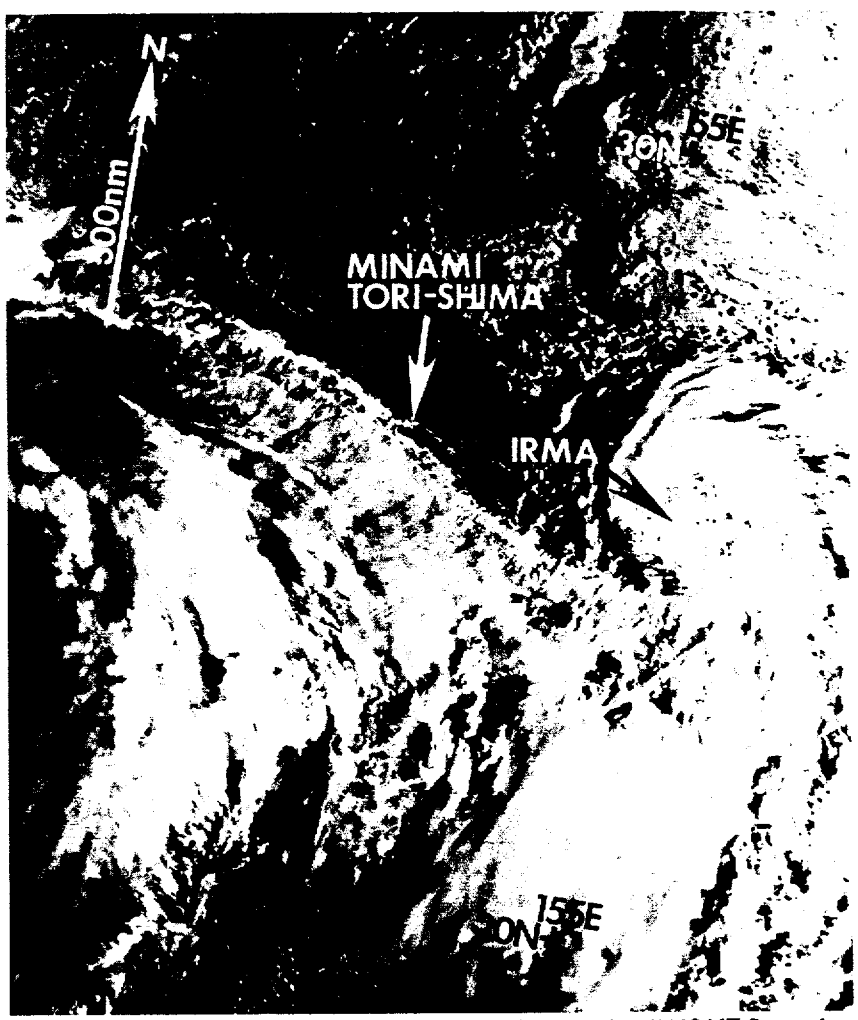

Figure 3-15/16-1. Irma about four hours before the first warning (111946Z September DMSP visual imagery).

activity (Figure 3-15/16-1) required a Tropical Cyclone Formation Alert at 110920Z and a first warning, based on a satellite intensity estimate of 40 kt (21 m/sec), at 120000Z.

Meanwhile, Jeff consolidated and was included on the 120600Z Advisory. Organization of the convection continued and an Alert followed at 121200Z. Another Alert was issued at 131030Z before a 35 kt (18 m/sec) satellite surface wind estimate precipitated the first warning at 140000Z. Jeff's relatively slow development was related to its upper-level outflow being severely restricted in the northeast quadrant by the larger outflow from Hal (14W) to the northeast. This shear in the vertical, in fact, confined Jeff's central convection to the southern half of its low-level circulation for the lifetime of the system.

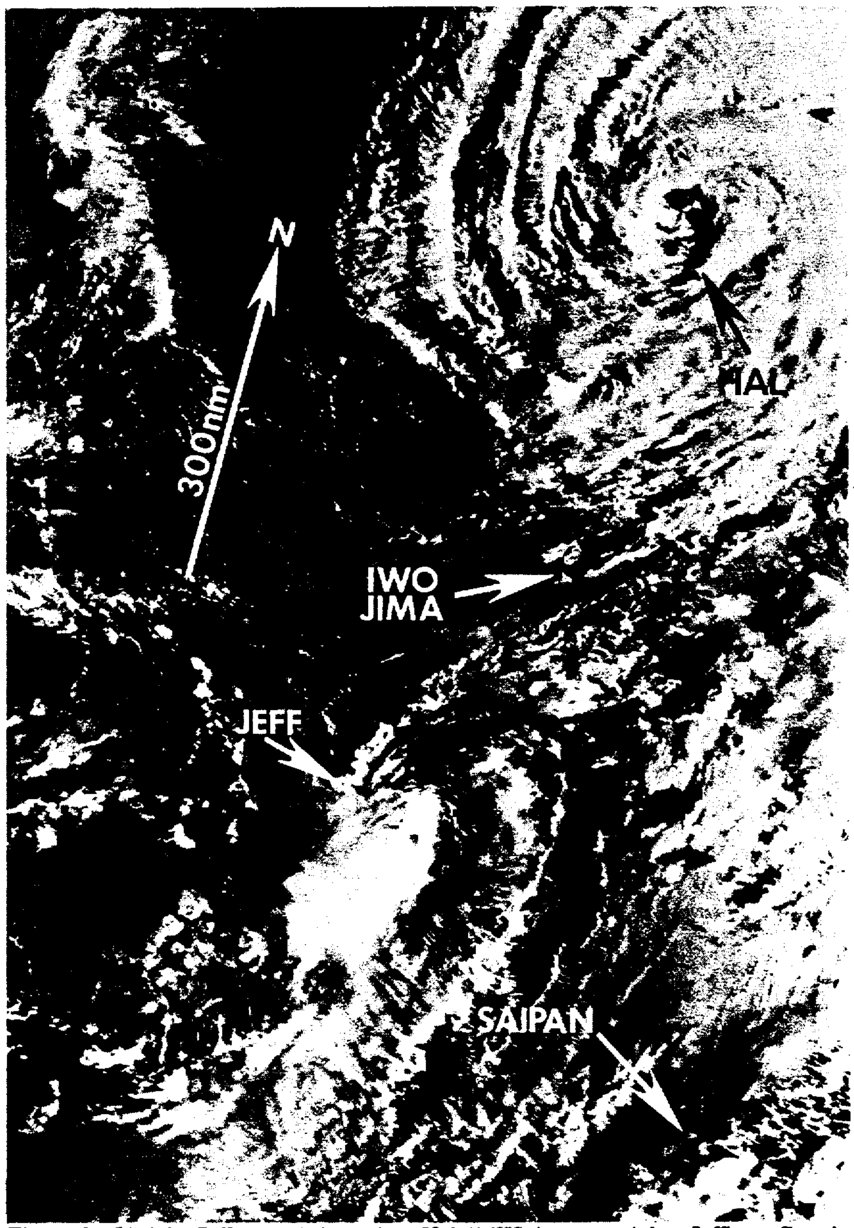

Figure 3-15/16-2. Jeff at peak intensity. Hal (14W) is at top right. Jeff's outflow is severely restricted to the north and east (142051Z September DMSP visual imagery).

Briefly, Jeff (Figure 3-15/16-2) reached a peak intensity of 45 kt (23 m/sec) on 14 September before gradually weakening. In contrast, Irma, which was aided by troughing in Hal's (14W) upper-level outflow, attained 55 kt (28 m/sec) at 131200Z half a day earlier and maintained that intensity through 0000Z on 15 September. Later, both Jeff and Irma were finalled within six hours of each other - Irma (Figure 3-15/16-3) at 151800Z and Jeff at 160000Z - as Hal (14W) moved northward through the subtropical ridge.

The relationship between the three tropical cyclones and the subtropical ridge is of interest. Earlier on 12 September, as Hal (14W) tracked to the north, the subtropical ridge segmented into two cells. These high pressure cells worked to narrow and restrict the low latitude inflow into Hal (14W). This appears to have affected the relative positions between Jeff, Irma and Hal (14W) (Figure 3-15/16-4). Initially, at 130000Z, the baseline (from A to B) between Jeff and Irma is relatively long compared to the height (from C to D) between Hal (14W) and the baseline. However, at

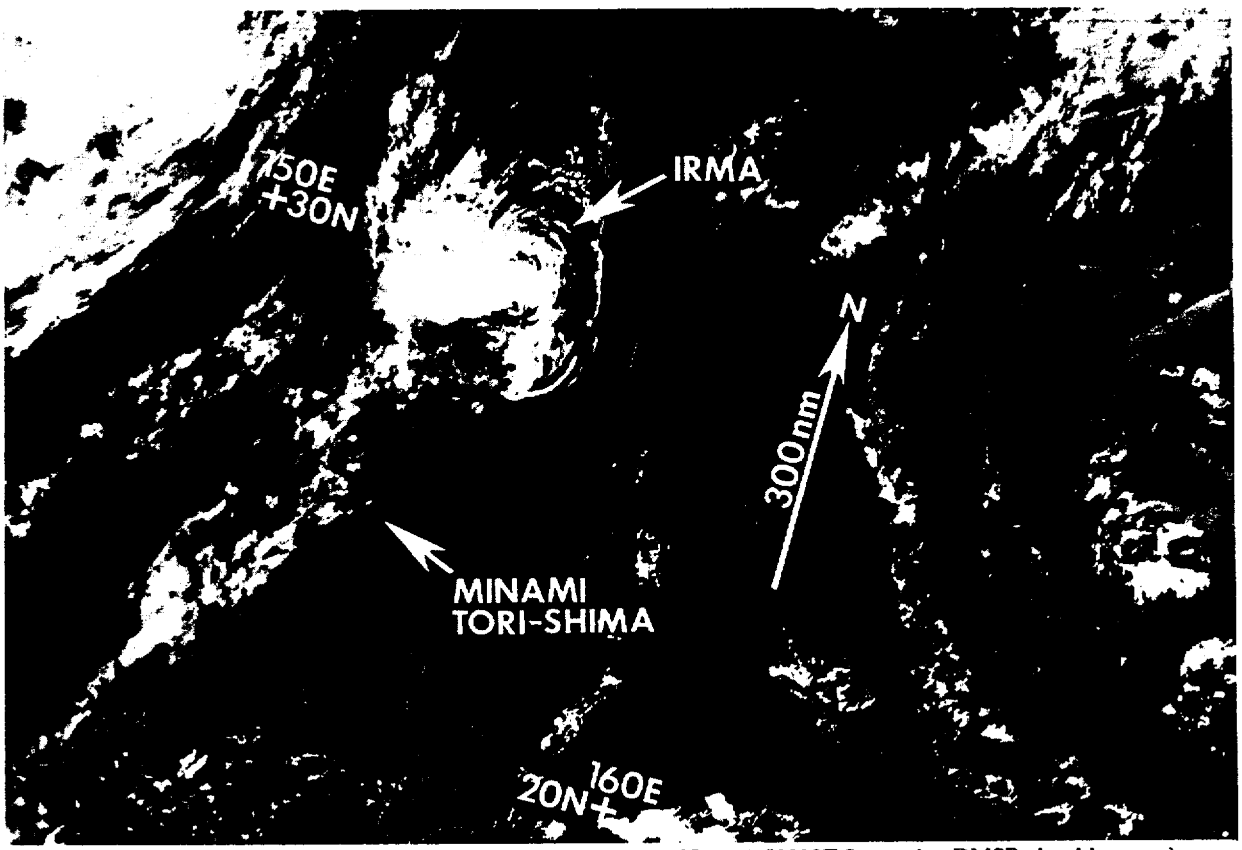

Figure 3-15/16-3. The low-level circulation is all that remains of Irma (152228Z September DMSP visual imagery).

160000Z the baseline has decreased to almost half its previous length and the height has more than doubled. These triangles (Figure 3-15/16-4) suggest a subtle tertiary interaction between Hal (14W) and the two smaller tropical cyclones in an almost non-divergent flow.

This multiple cyclone activity resulted in three sets of warnings being issued from 140000Z to 160000Z. Earlier, from 120000Z to 130600Z, Uleki (01C), Hal (14W) and Irma had required three sets of warnings. No damage reports were received for Jeff and Irma.

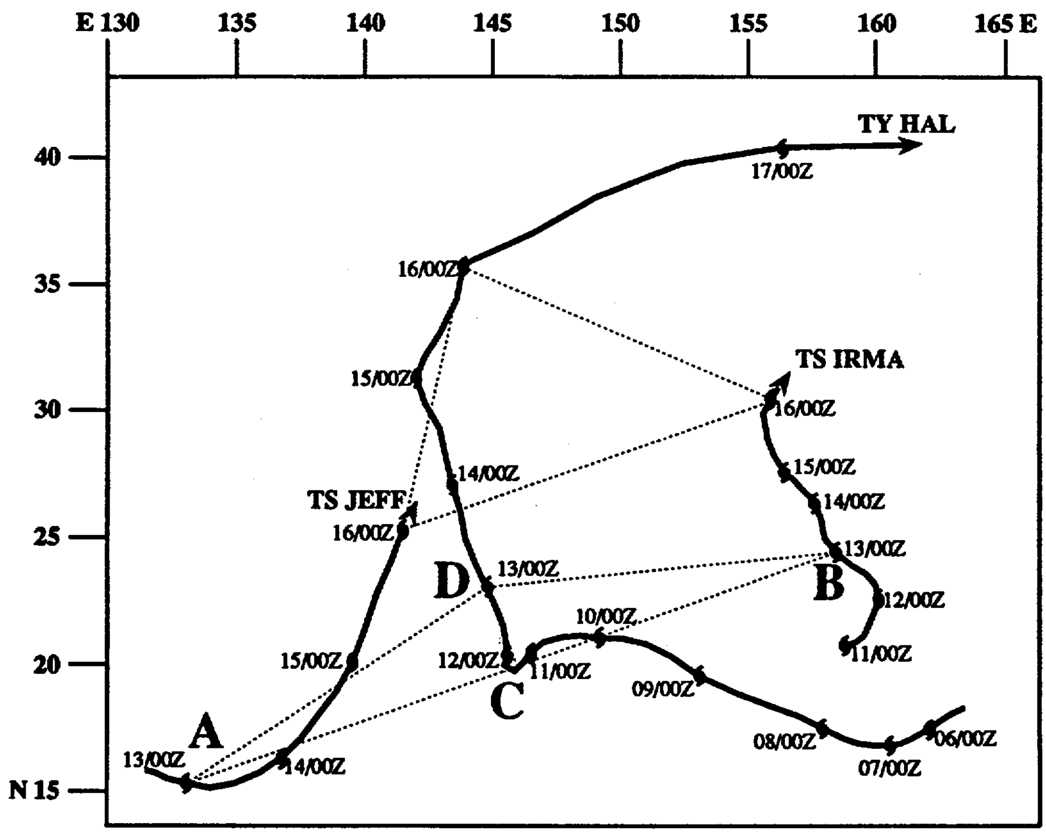

Figure 3-15/16-4. The tracks of Hal (14W), Irma and Jeff. Compare the length of the baseline (from A to B) between Jeff and Irma and the height, which is measured along the vertical (C to D) from the baseline to Hal (14W), at 130000Z with the second triangle at 160000Z. Note the relative adjustment of the three as Hal (14W) moves to the north.

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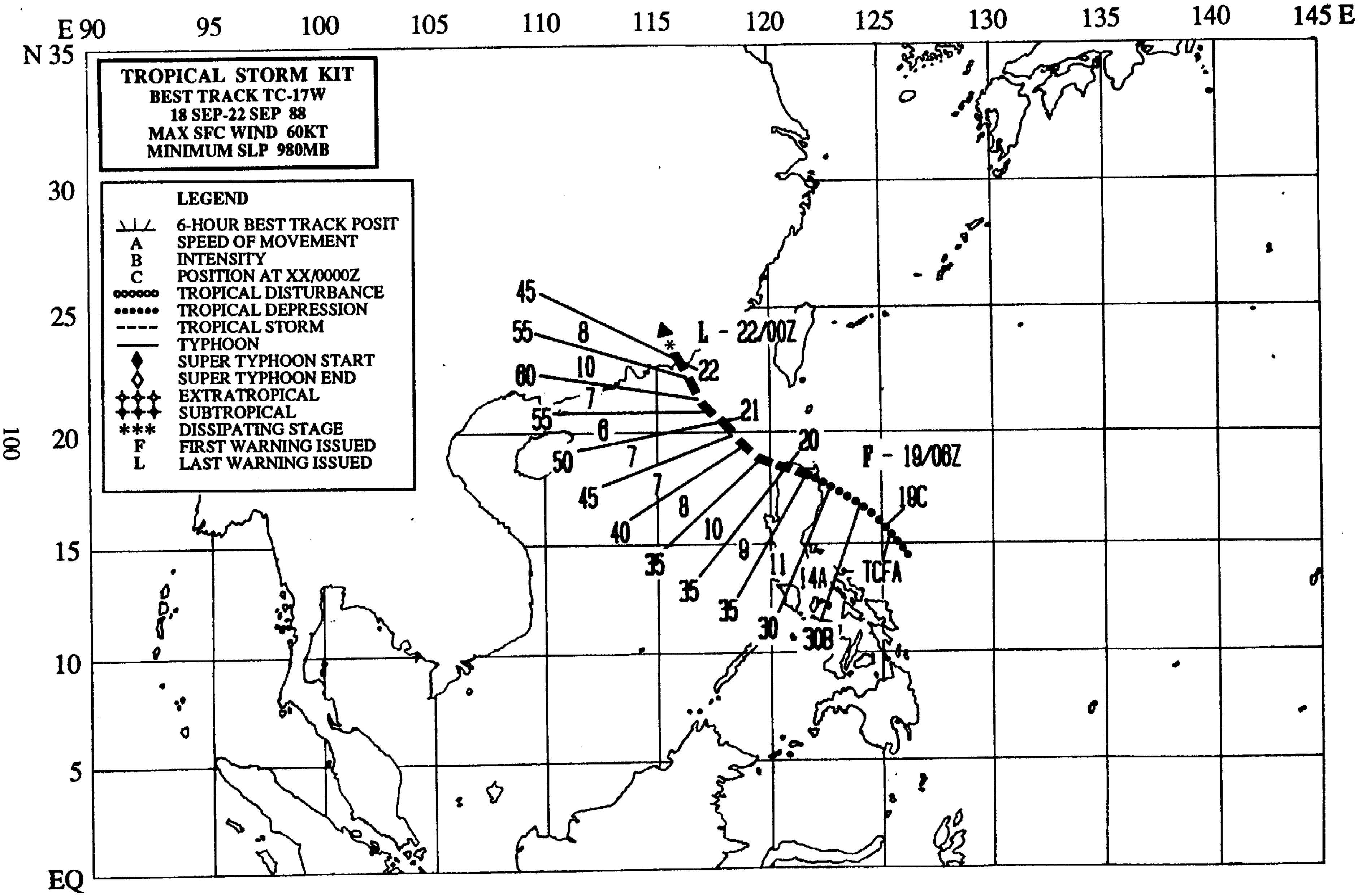
TROPICAL STORM KIT
BEST TRACK TC-17W
18 SEP-22 SEP 88
MAX SFC WIND 60KT
MINIMUM SLP 980MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
95
100
105
110
115
120
125
130
135
140
145 E
N 35
30
25
20
15
10
5
EQ
L - 22/00Z
F - 19/06Z
TCFA
19C
14A
30B
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TROPICAL STORM KIT (17W)

Tropical Storm Kit was the sixth of eight significant tropical cyclones in September. It was a "straight runner" to the northwest and made landfall on the south coast of China. Kit caused loss of life and significant property damage in southeastern China.

The tropical cyclone was first detected on satellite imagery on 18 September 300 nm (556 km) east of Manila. The disturbance rapidly developed in the eastward extension of the monsoon trough and immediately became the subject of a Tropical Cyclone Formation Alert at 182230Z (Figure 3-17-1). Increased deep convection in the banding feature, improved outflow aloft, plus a satellite intensity

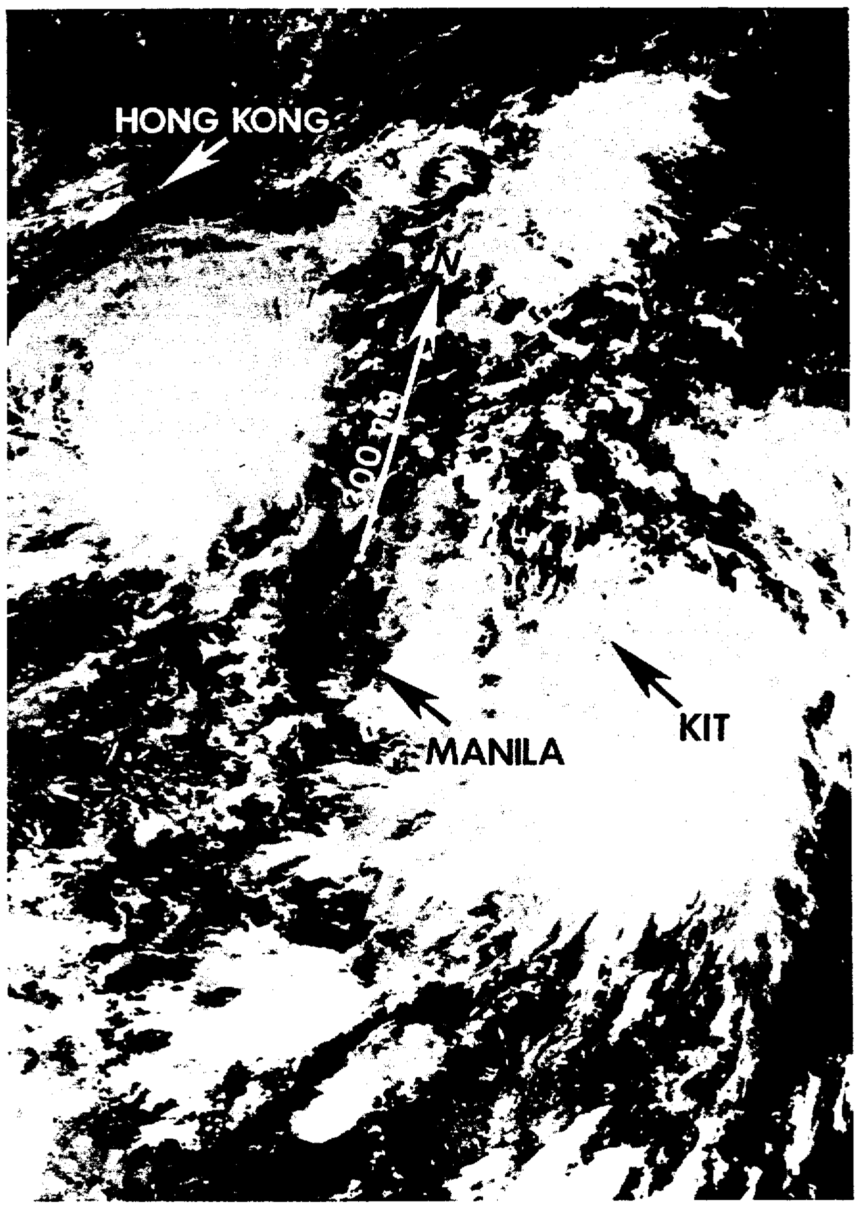

Figure 3-17-1. Kit as a tropical disturbance (190051Z September DMSP visual imagery).

estimate of sustained 30 kt (15 m/sec) surface winds, dictated the upgrade to Tropical Depression 17W at 090600Z.

Even though Kit tracked across the northern tip of Luzon, it continued to intensify. At 191800Z, another upgrade was needed — this time to tropical storm intensity. After being over land for six hours, it once again moved over open waters. The system developed a strong low-level inflow from the southwest and improved its upper-level outflow to the southeast through southwest (Figure 3-17-2). A day later, at 210600Z, Kit reached its peak intensity of 60 kt (31 m/sec).

After the intensity peaked, the tropical storm approached the coast of southern China and weakened. The final warning was issued on Kit at 220000Z, when it made landfall 120 nm (222 km) northeast of Hong Kong. Press releases from China indicated widespread flooding, loss of electrical power and at least three lives lost in the Guangdong province.

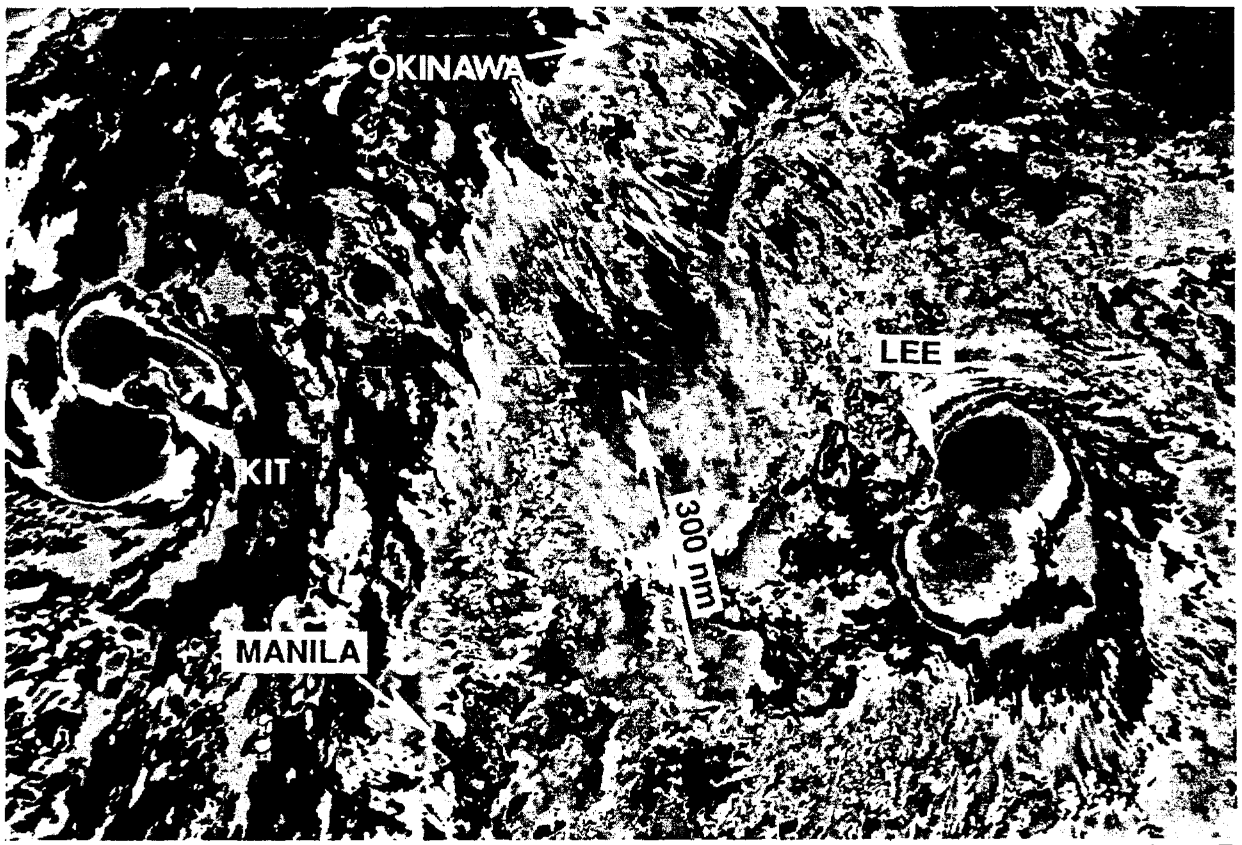

Figure 3-17-2. Kit at peak intensity (to the left) and Tropical Storm Lee (18W) (to the lower right of the picture) (211003Z September DMSP infrared imagery).

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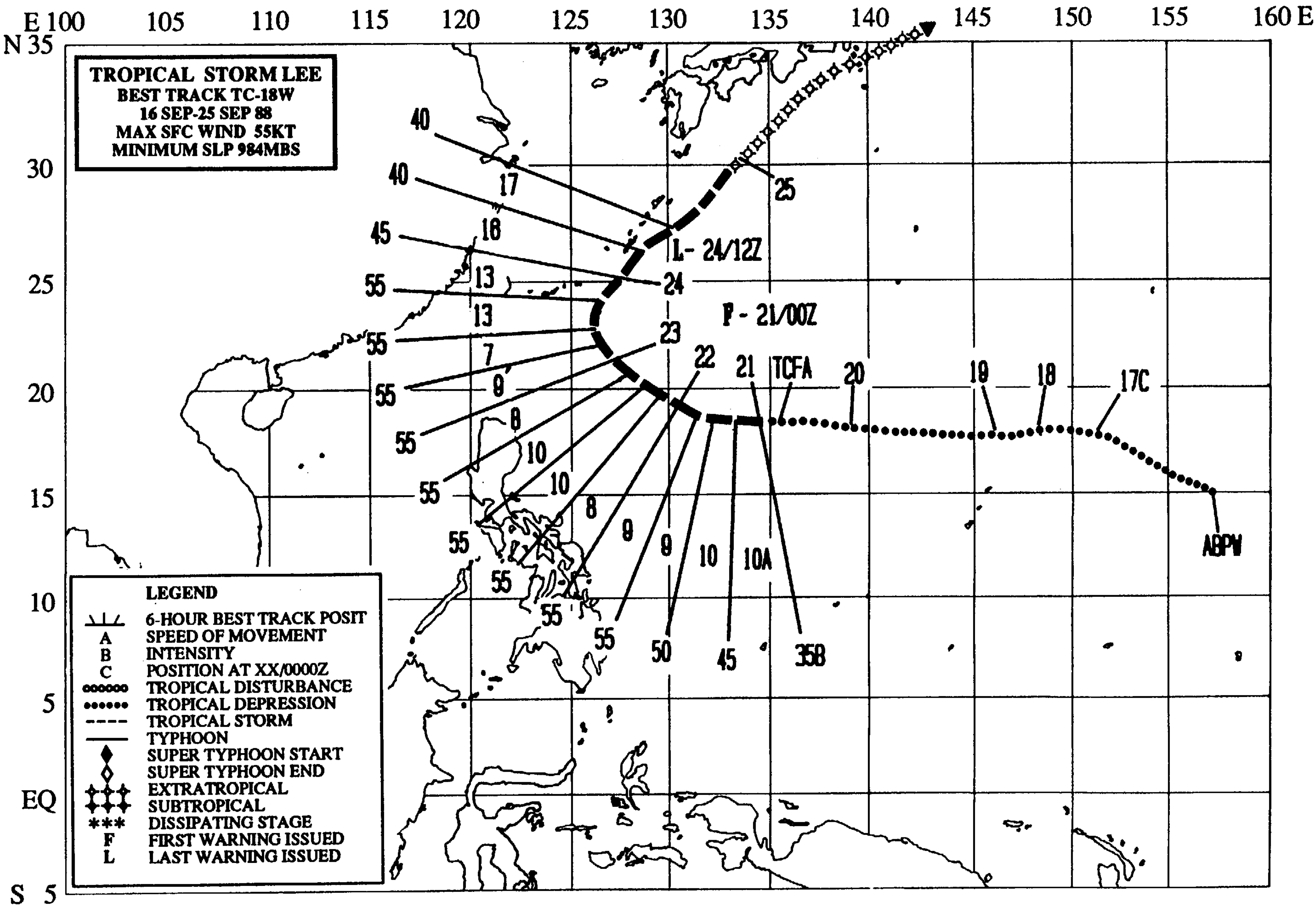
TROPICAL STORM LEE
BEST TRACK TC-18W
16 SEP-25 SEP 88
MAX SFC WIND 55KT
MINIMUM SLP 984MBS
E 100
105
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115
120
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F - 21/00Z
TCFA
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10A
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35B
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TROPICAL STORM LEE (18W)

Tropical Storm Lee was the seventh of eight significant tropical cyclones to occur during September. Lee had a formative period of over four days, and was tracked over 1300 nm (2408 km) as an identifiable area of convection before the first warning was issued.

On 16 September Tropical Storms Irma (15W) and Jeff (16W) had just been finalled, Typhoon Hal (14W) was recurving east of Japan and a new area of persistent convection was mentioned on the Significant Tropical Weather Advisory at 160600Z. This persistent convection was tropical upper-tropospheric trough (TUTT) induced (Sadler, 1979) and was superimposed on the broad low-level easterly flow. A steady westward movement was noted for the next four days, during which time there was little change in the poorly organized convection. At 200600Z the disturbance was upgraded to a "fair" suspect area due to improved organization. A Tropical Cyclone Formation Alert followed at 201730Z after the system continued to show improved organization and intensification to 30 kt (15 m/sec) sustained surface winds, based on a satellite analysis estimate. Another estimate of 35 kt (18 m/sec) sustained surface winds followed at 210000Z and prompted the first warning on Tropical Storm Lee (Figure 3-18-1). Lee

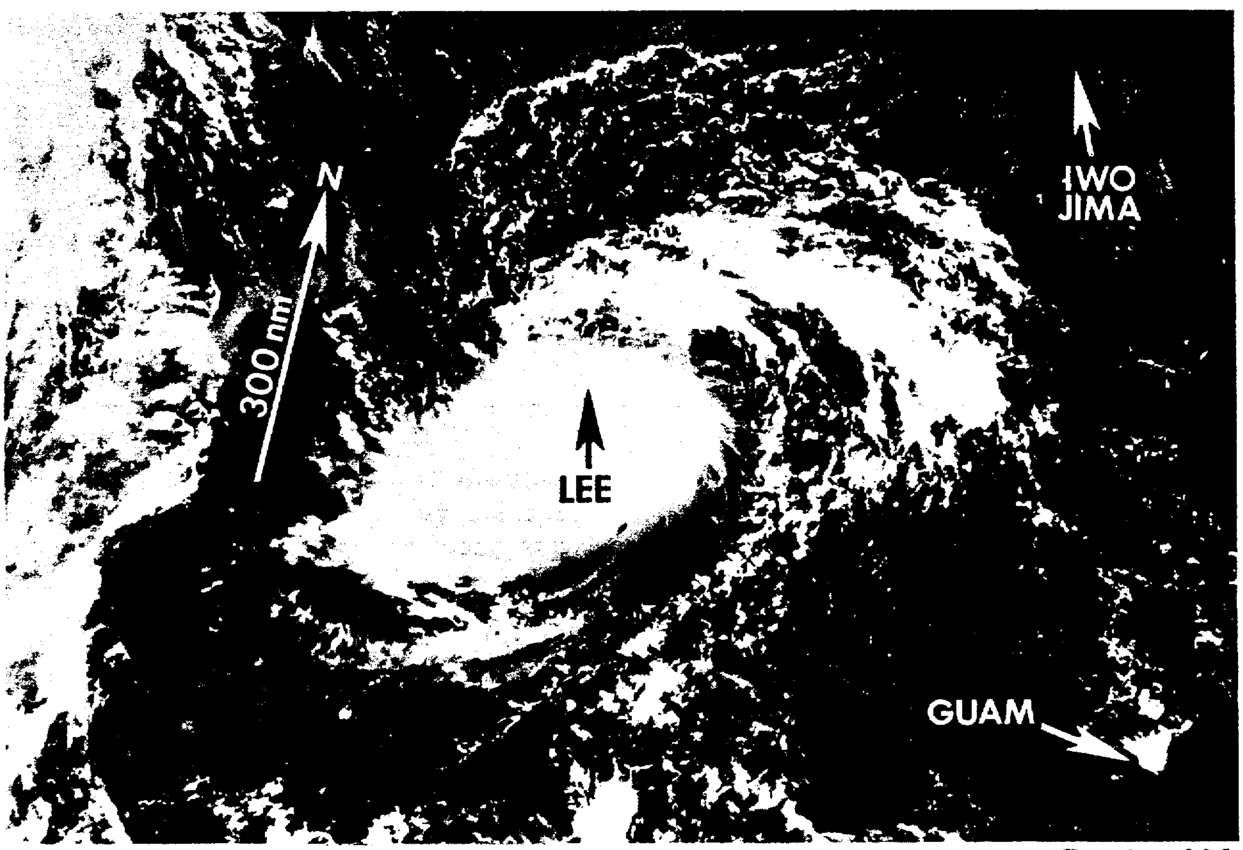

Figure 3-18-1. Tropical Storm Lee just after the first warning. Satellite intensity analysis indicated a T-number of 2.5, corresponding to sustained surface winds of 35 kt (18 m/sec) (210012Z September DMSP visual imagery).

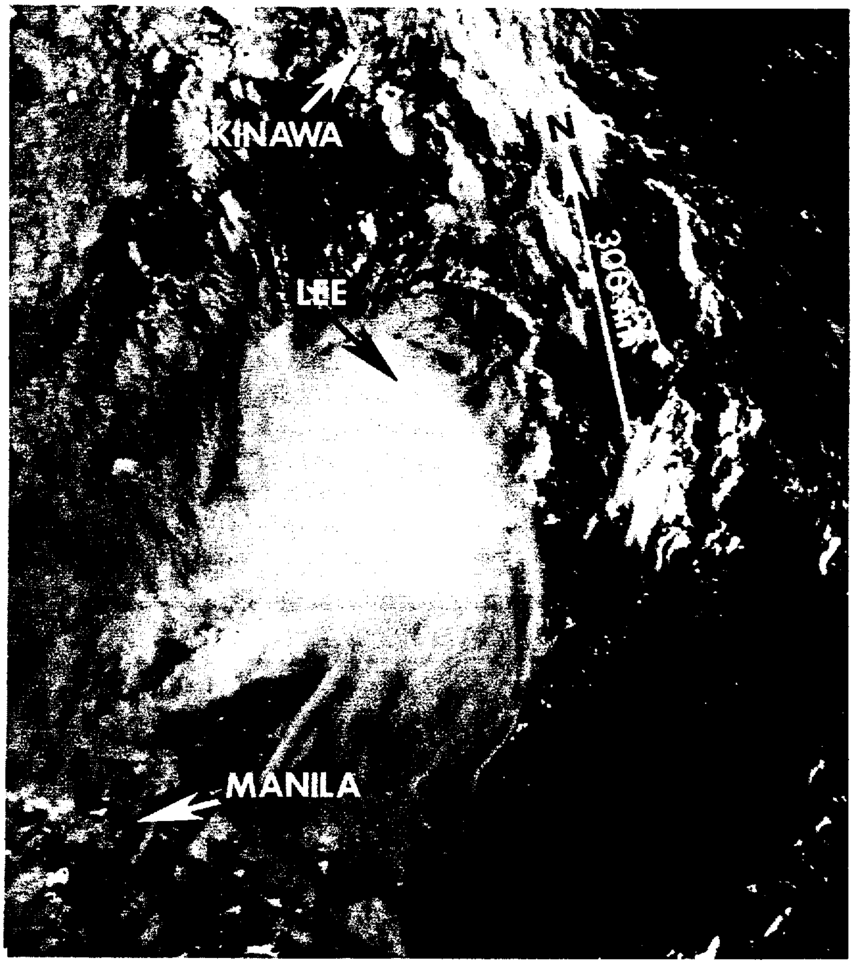

Figure 3-18-2. Shortly before recurvature, Lee shows the effects of increased vertical wind shear. The low-level circulation center is partially exposed to the northeast of the centeral dense overcast (232304Z September DMSP visual imagery).

tracked west-northwestward along the southwestern side of the subtropical ridge for the next 24-hours, and acquired its maximum intensity of 55 kt (28 m/sec) at 211800Z. The forecast was for Lee to continue on its northwestward track around the periphery of the 700 mb subtropical ridge.

Visual satellite imagery (Figure 3-18-2) on 23 September showed a partially exposed low-level circulation center, as Lee encountered increasing vertical wind shear. When night arrived, Lee's poorly defined deep convection provided targets for remote sensing — bright cold tops on the satellite infrared and rain echoes for the radar. Beginning at 231100Z, radar position reports from Ishigaki Jima (WMO 47918) confirmed the movement of the rain echoes to the northwest, which paralleled Kit's (17W) earlier track into southeastern China. However, remarks the following morning on the relocated 240000Z warning summed it up: "Visual satellite pictures indicate Lee has an exposed low-level circulation that has been moving northeastward. Tropical Storm Lee has recurved earlier than expected and should now pass about 55 nm east of Okinawa."

This forecast was accurate and Lee's closest point of approach was 45 nm (83 km) southeast of the island of Okinawa at 240400Z. Lee started to lose its convective organization and showed signs of becoming extratropical at 240600Z. The final warning was issued at 241200Z. Lee became an extratropical low at 242100Z and continued moving rapidly northeastward.

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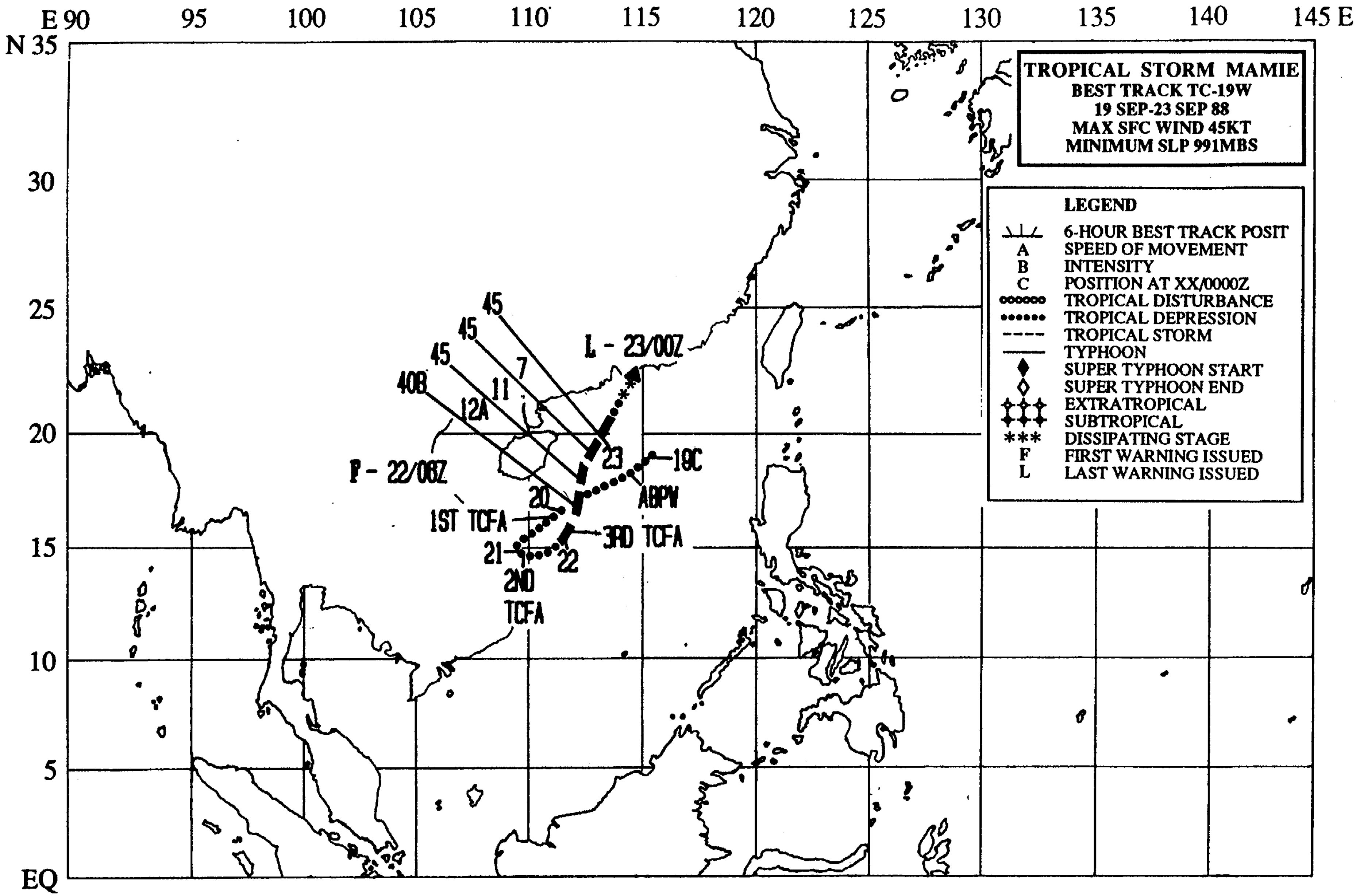
TROPICAL STORM MAMIE
BEST TRACK TC-19W
19 SEP-23 SEP 88
MAX SFC WIND 45KT
MINIMUM SLP 991MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
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135
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145 E
N 35
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EQ
L - 23/00Z
F - 22/06Z
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ABPW
1ST TCFA
2ND TCFA
3RD TCFA

TROPICAL STORM MAMIE (19W)

Mamie was the second significant tropical cyclone of 1988 to develop in the South China Sea. It formed in tandem with Tropical Storm Kit (17W) in the monsoon tough and was slow to develop. Typical of monsoon depressions, Mamie proved to be a particularly difficult system to locate and forecast. Large fluctuations in its central convection within the larger synoptic scale trough contributed to this difficulty.

The disturbance that would become Tropical Storm Mamie formed in September, in the monsoon trough, 600 nm (1111 km) west-northwest of Kit (17W). Kit (17W) was at the eastern end of the monsoon trough. Mamie was first mentioned on the Significant Tropical Weather Advisory at 190600Z. During the next 18-hours, the disturbance moved southwestward at 10 kt (19 km/hr), most probably in response to binary interaction with Kit (17W). As Mamie became better organized, its deep convection began the first of several flare-ups. This prompted the first Tropical Cyclone Formation Alert at 200230Z, after satellite intensity analysis indicated 30 kt (15 m/sec) sustained surface winds. The system (Figure 3-19-1) continued southwestward until 210000Z, when it made a sharp turn to the east. The persistent central convection and potential for development required a second Alert at 210030Z.

Later, at 211800Z, the disturbance was headed northeastward along the trough axis — the opposite direction from its initial track, two days earlier. Apparently Mamie's track to the northeast was the result of increased low-level

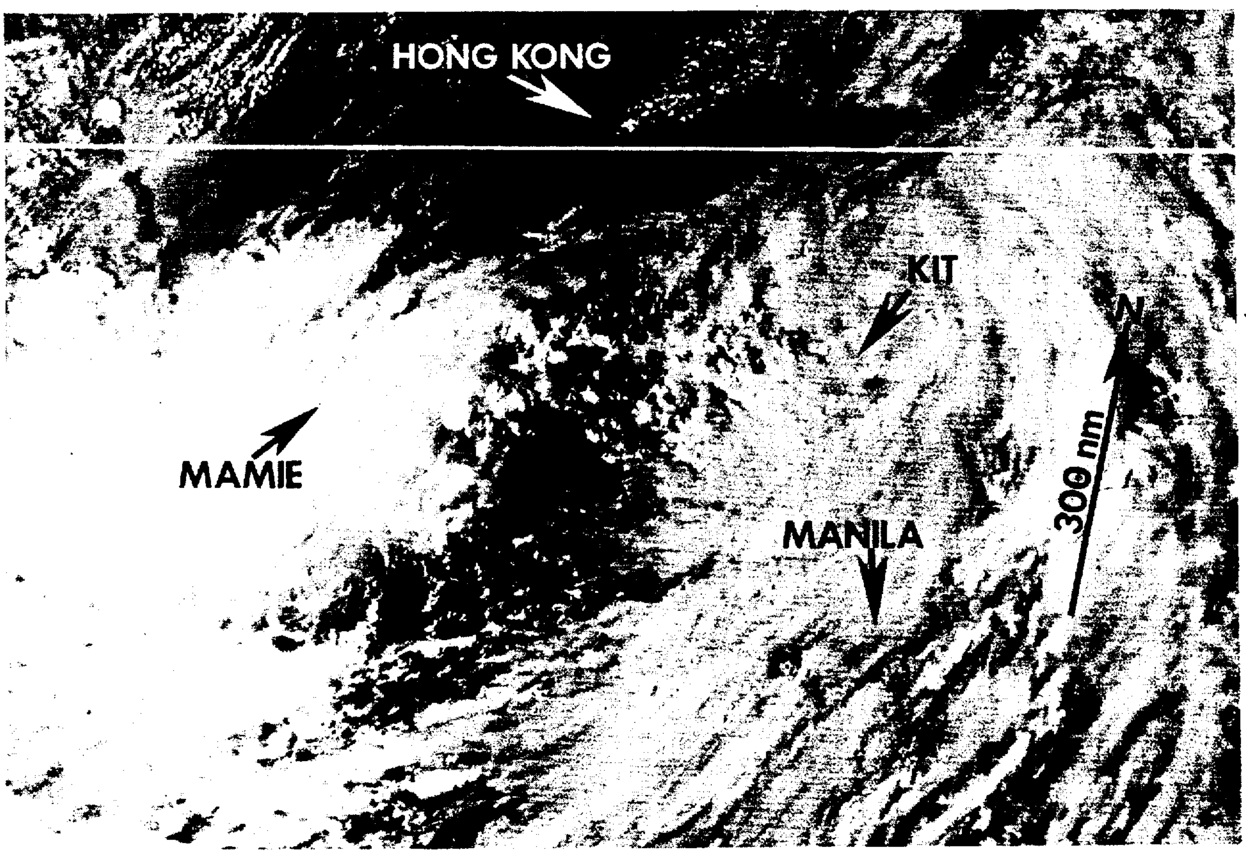

Figure 3-19-1. Mamie, the subject of a Tropical Cyclone Formation Alert, is on the left. To the right of Mamie is Tropical Storm Kit (17W) (200802Z September NOAA visual imagery).

southwesterly inflow into Kit (17W), which was now over water between Luzon and the southeastern coast of China. Mamie maintained its overall convective organization and a third Alert was issued at 220030Z. Based on a ship report of southeasterly surface winds of 40 kt (20 m/sec) and a minimum sea-level pressure of 991 mb, plus a satellite intensity analysis of 35 kt (18 m/sec), the first warning on Tropical Storm Mamie followed at 220600Z. Mamie continued up the monsoon trough axis towards Kit (17W), which had just made landfall in southeastern China. As vertical wind shear increased aloft over Mamie, JTWC issued its final warning at 230000Z. Mamie's remnants, and associated gales, then moved north-northeastward and dissipated on the coast of China northeast of Hong Kong. No reports of damage or loss of life were received.

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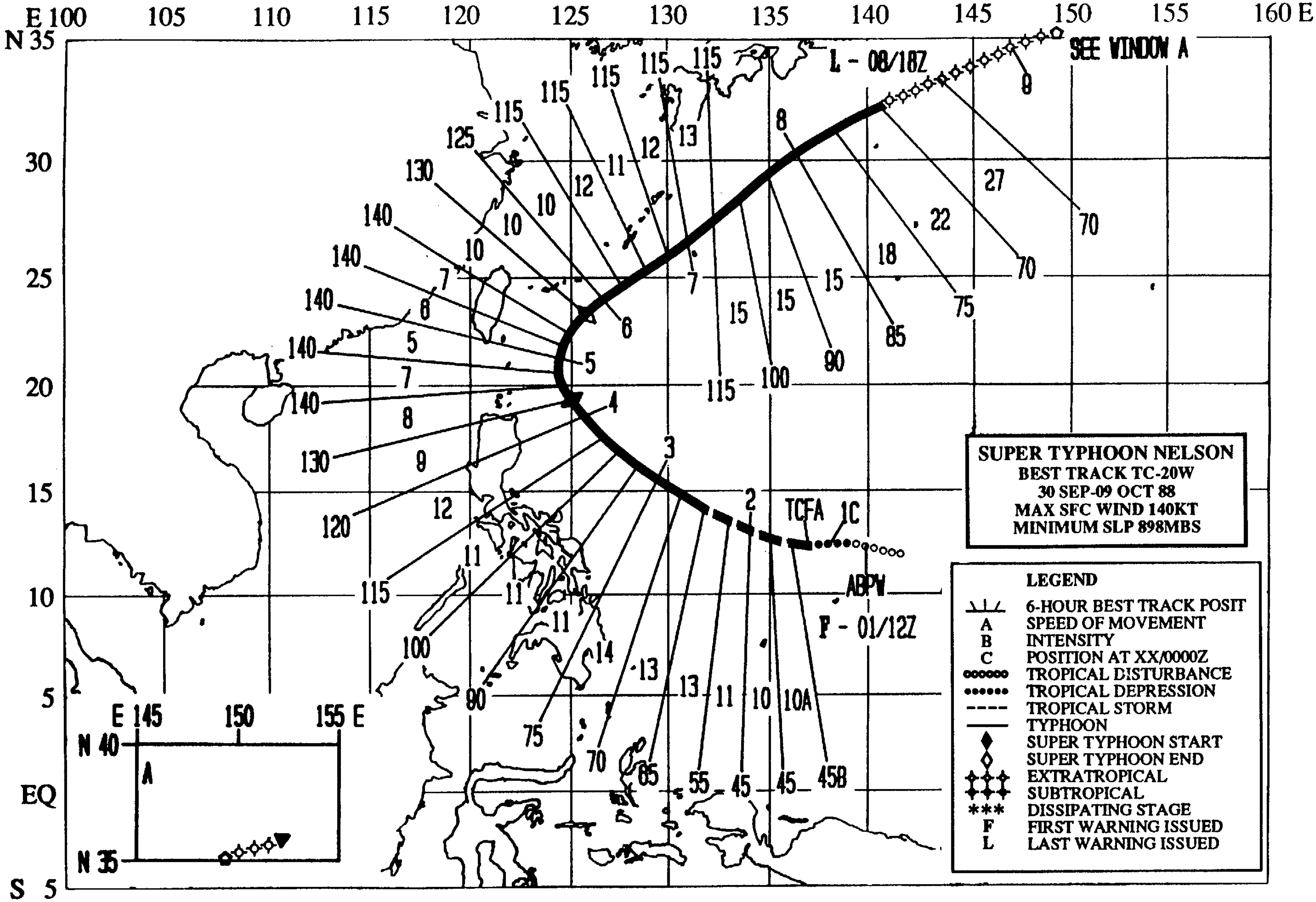


SEE WINDOW A
L - 08/18Z
TCFA
1C
ABPW
F - 01/12Z
SUPER TYPHOON NELSON
BEST TRACK TC-20W
30 SEP-09 OCT 88
MAX SFC WIND 140KT
MINIMUM SLP 898MBS
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 145
150
155 E
N 40
N 35
A

SUPER TYPHOON NELSON (20W)

Nelson was the first significant tropical cyclone of October and the only super typhoon of 1988. It developed in the Philippine Sea in the monsoon trough. The super typhoon recurved and threatened the Ryukyu Islands and the main Japanese Islands of Kyushu and Honshu.

In late September, after the multiple outbreak of Tropical Storms Kit (17W), Lee (18W) and Mamie (19W), there was a week long lull in tropical cyclone activity. In the meantime polar air pushed southward across the Asian mainland and Japanese Islands. The monsoon trough had returned to its normal climatic location along with the maximum cloud zone. The disturbance that would later become Super Typhoon Nelson was first detected in this maximum cloud zone 200 nm (370 km) southwest of Guam by satellite reconnaissance. The Significant Tropical Weather Advisory, that is normally issued at 0600Z each day, was reissued at 301400Z September to include this area of suspect cloudiness. Nelson developed within the monsoon trough and began steadily organizing (Figure 3-20-1). A noticeable increase in central convection led to the issuance of a

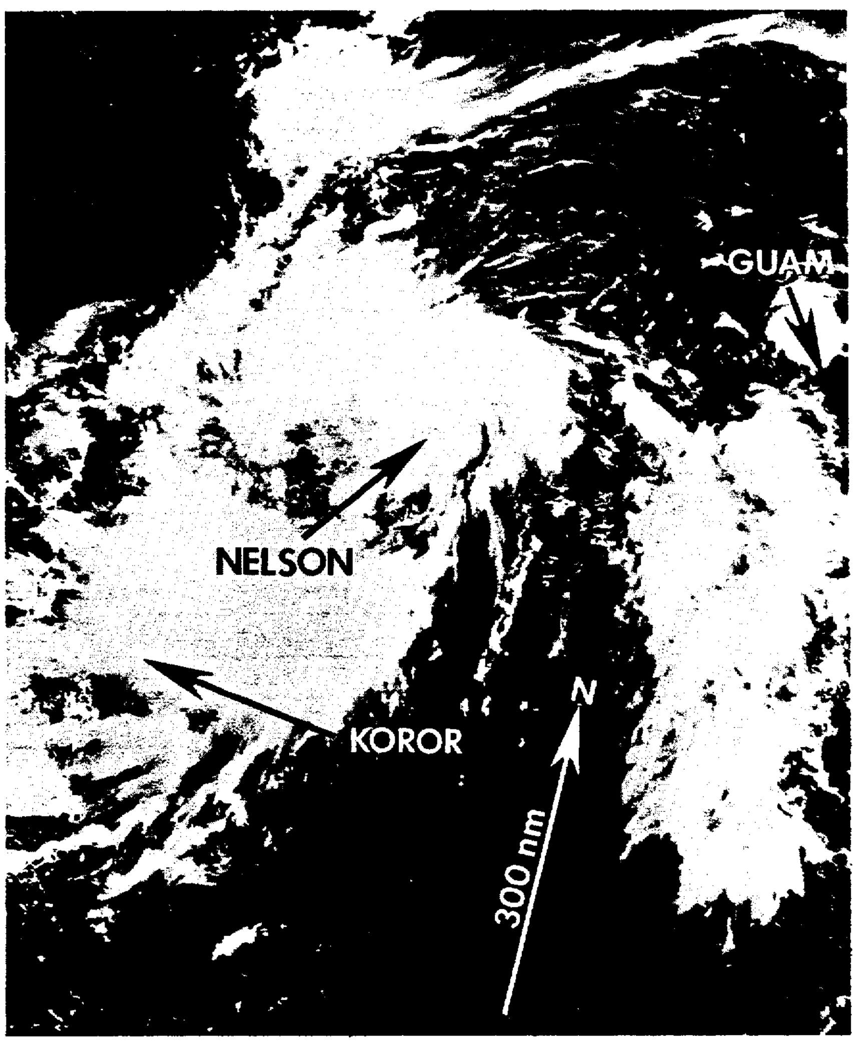


Figure 3-20-1. Nelson as a tropical disturbance (010016Z October DMSP visual imagery).

Tropical Cyclone Formation Alert at 0900Z on 1 October. The first warning followed at 011200Z, based on a satellite intensity estimate of 45 kt (23 m/sec) sustained surface winds. (Post analysis indicates the disturbance, most probably, achieved tropical storm intensity earlier at 010600Z.) Nelson initially moved westward towards the Philippine Islands, and then west-northwestward as it tracked along the periphery of the subtropical ridge.

Only 24 hours after the initial warning was issued, a satellite intensity estimate of 65 kt (33 m/sec) winds resulted in an upgrade to typhoon status at 021200Z. At 022100Z, a 15 nm (28 km) diameter eye first became visible on satellite imagery. (The eye persisted until 7 October.) Nelson continued to rapidly intensify and reached super typhoon intensity at 040600Z (Figure 3-20-2). The normal rate of intensification (Dvorak, 1984) is one T-number per day. From 020000Z to 041200Z, Nelson developed more rapidly than normal (Figure 3-20-3). Conversion (Atkinson and Holliday, 1977) of intensity to minimum sea-level pressure indicates a fall from 991 to 898 mb — 93 mb in 60-hours — and sustained rapid intensification (Holliday and Thompson, 1979)(Figure 3-20-4). On 4 October, Nelson slowed and tracked through an area where, according to climatology (Annual Typhoon Report, 1970), a large number of tropical cyclones reach super typhoon intensity (Figure 3-20-5). The typhoon's intensity peaked at 140 kt (72 m/sec) at 041200Z.

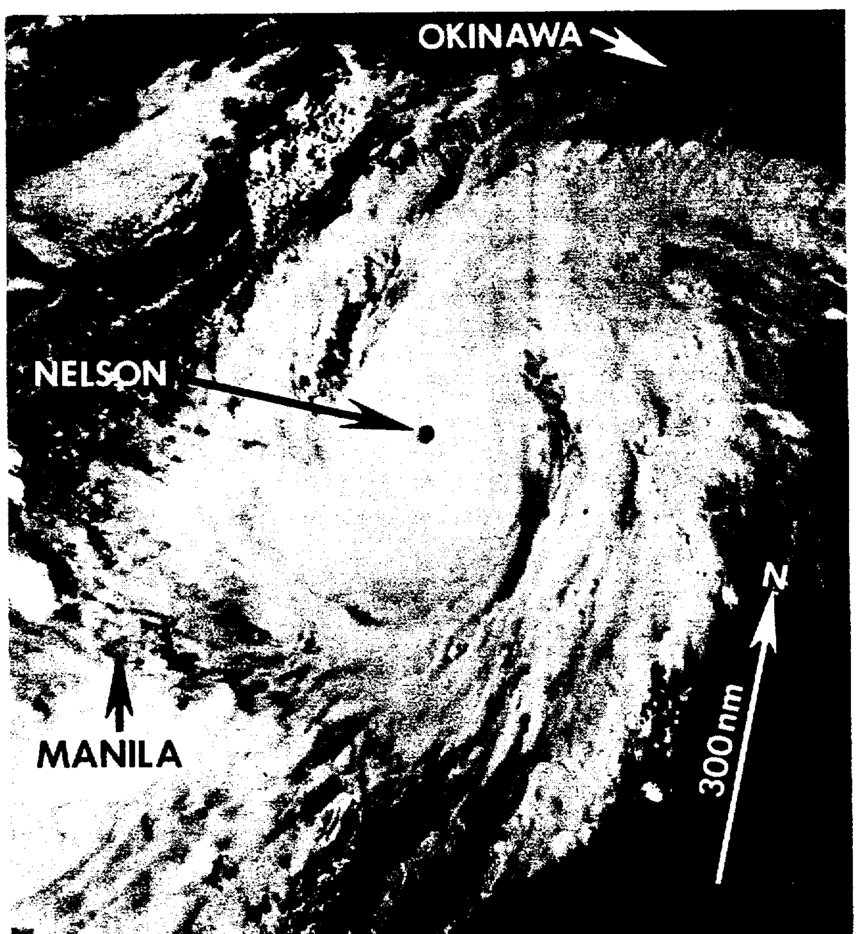


Figure 3-20-2. Super Typhoon Nelson near peak intensity displays a well defined 20 nm (37 km) diameter eye (040709Z October NOAA visual imagery).

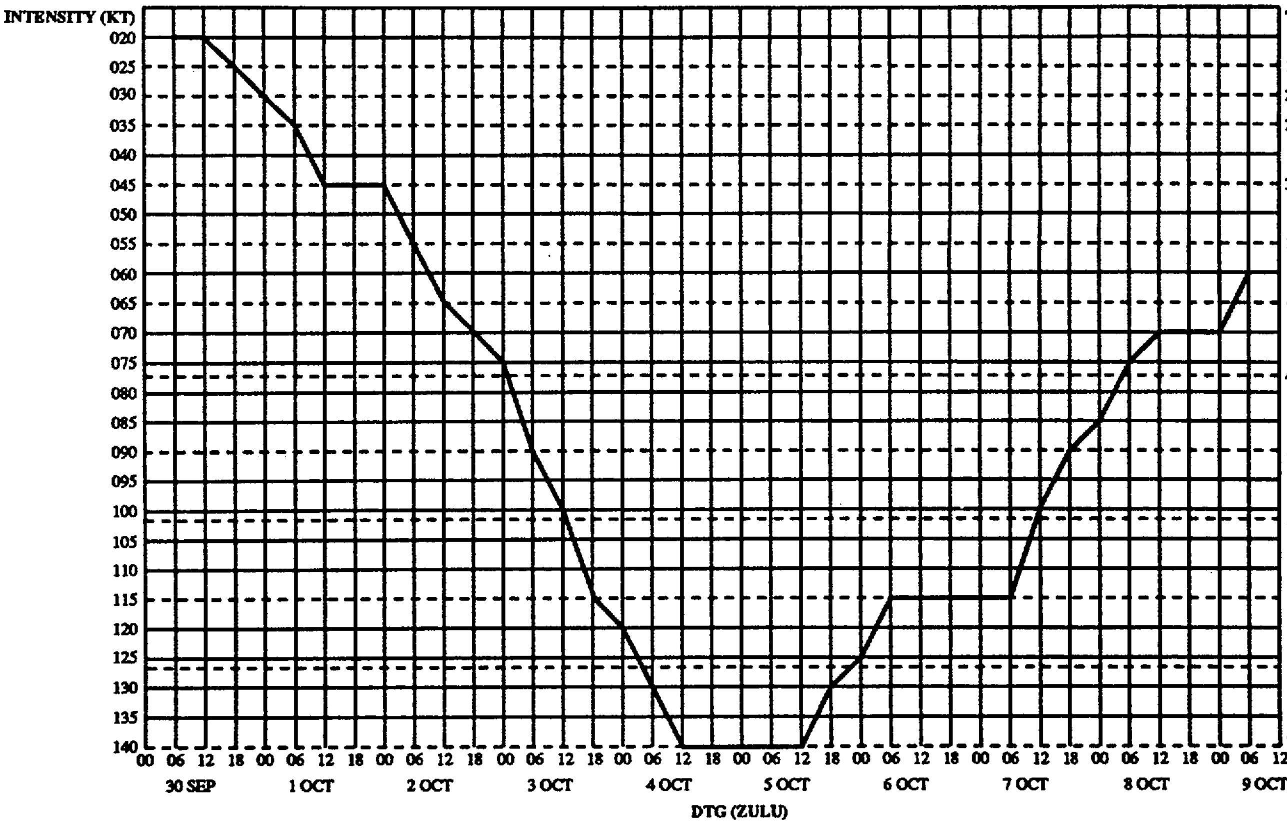


Figure 3-20-3. Analysis of intensity with time shows Super Typhoon Nelson's rapid intensification from 020000Z to 041200Z October. Note the peak intensity of 140 kt (72 m/sec) persisted from 041200Z to 051200Z October.

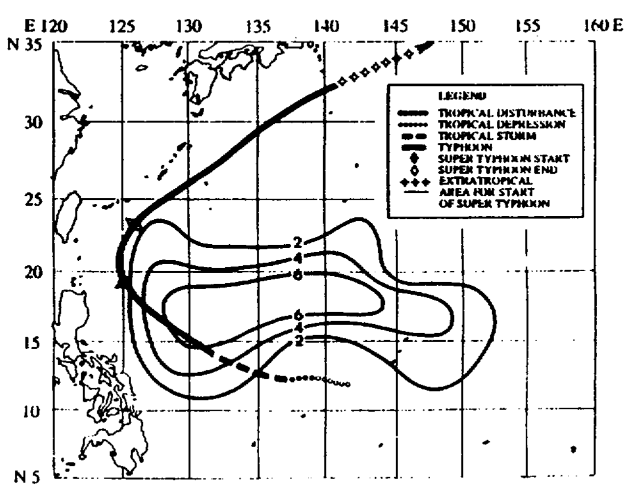


Figure 3-20-4. Nelson's final best track is superimposed upon the areas where tropical cyclones rapidly intensified during summer and early fall (20 June - 16 October) for the years 1956 to 1976 (Holliday and Thompson, 1979).

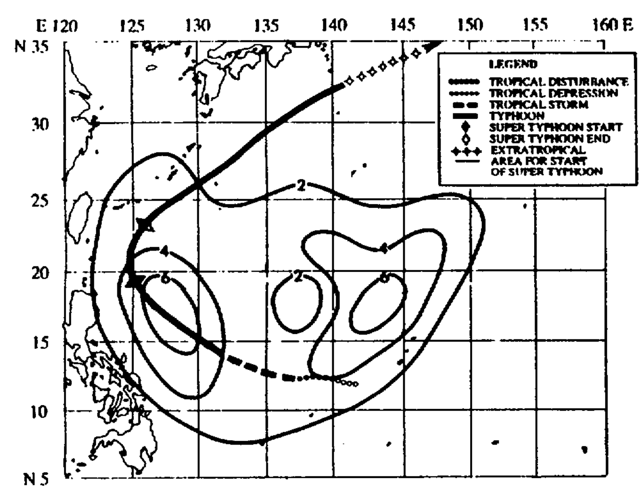


Figure 3-20-5. Nelson's final best track superimposed upon climatic areas of super typhoon occurrence. Areas of first super typhoon intensity include number of occurrances from the period 1959 to 1970 (Annual Typhoon Report, 1970).

Packing the most intense winds of any tropical cyclone for the year, Nelson rounded the western end of the subtropical ridge at a speed of 6 kt (11 km/hr), and slowly accelerated northeastward. In addition to satellite reconnaissance, a total of 177 radar position reports greatly aided the accurate tracking of the typhoon's recurvature and subsequent acceleration. Moving along the edge of the modifying polar air, Nelson weakened and was downgraded to typhoon intensity at 060000Z. The tropical cyclone passed 85 nm (157 km) southeast of the island of Okinawa at 060930Z (Figures 3-20-6 and 3-20-7). The maximum

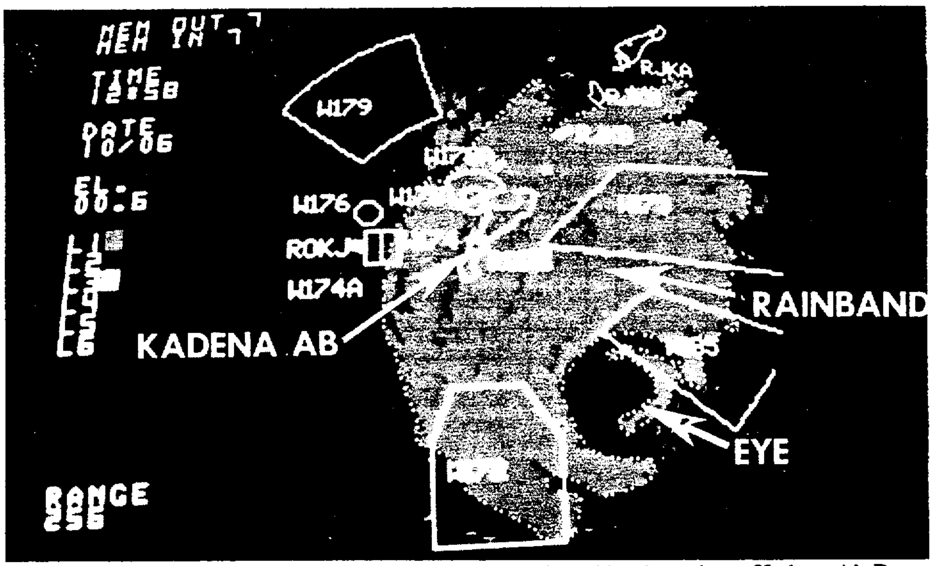


Figure 3-20-6. Nelson's primary rainband and eye as viewed by the radar at Kadena Air Base, Okinawa at 061258Z. Dots have been added to enhance the subtle edge of the rain echoes (photograph courtesy of Detachment 8, 20th Weather Squadron).

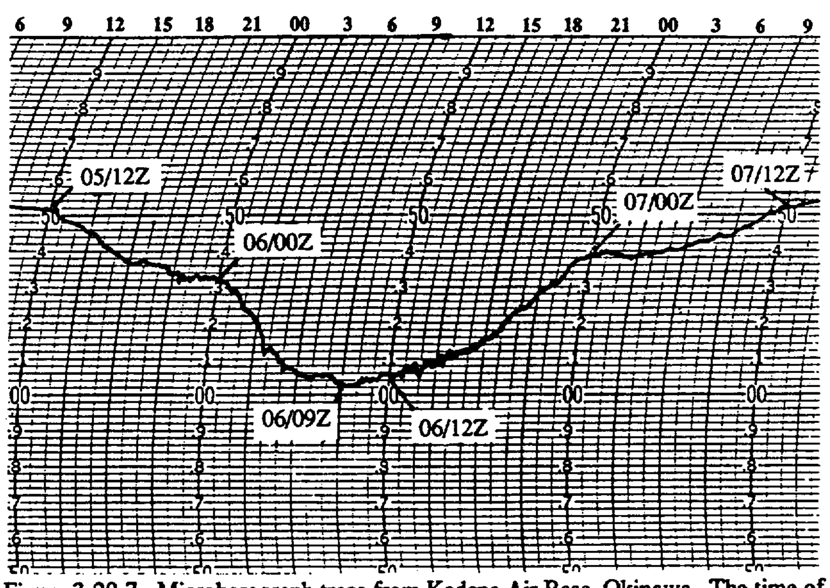


Figure 3-20-7. Microbarograph trace from Kadena Air Base, Okinawa. The time of the lowest minimum sea-level pressure of 29.02 inches Hg coincides with Nelson's closest approach to the island (barograph trace courtesy of Detachment 8, 20th Weather Squadron).

sustained winds reported by Detachment 8, 20th Weather Squadron at Kadena Air Base on Okinawa were 38 kt (20 m/sec), with a peak gust of 59 kt (30 m/sec). Close by, maximum sustained winds of 40 kt (21 m/sec), with a peak gust of 64 kt (33 m/sec) were reported by the Marine Corps Air Station at Futenma. The rainfall totals recorded on Okinawa ranged from 7.30 inches (18.54 cm) at Futenma to 8.35 inches (21.21 cm) at Kadena Air Base.

Nelson continued to weaken, move northeastward and accelerate (Figure 3-20-8). As it lost its persistent central convection, the typhoon transitioned to an extratropical system 190 nm (352 km) southeast of Tokyo, Japan at 081500Z. By this time it was moving at a speed of 28 kt (52 km/hr). Extratropical Nelson retained winds of typhoon intensity and moved rapidly northeastward. The final warning was issued at 081800Z. The remnants of Nelson were identifiable on satellite imagery for the next two days. No reports of significant damage were received.

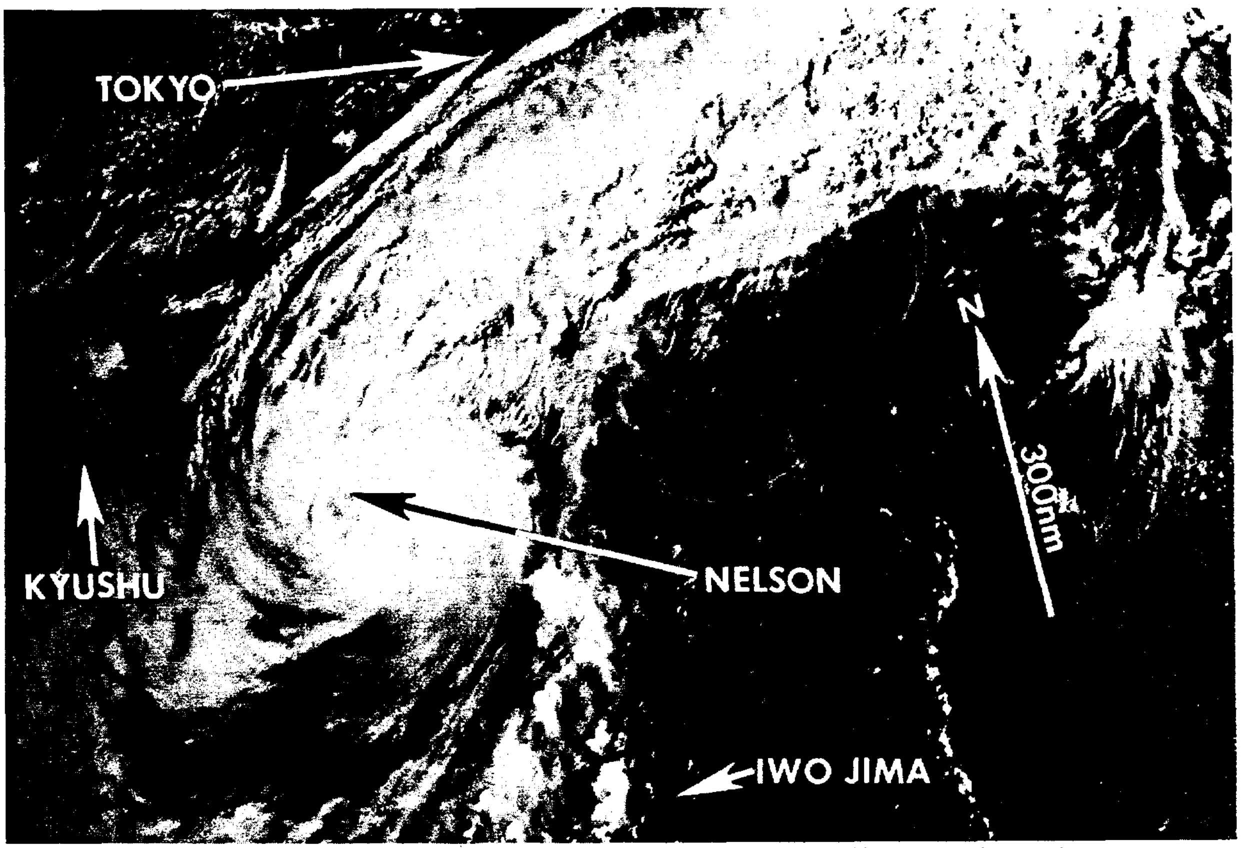
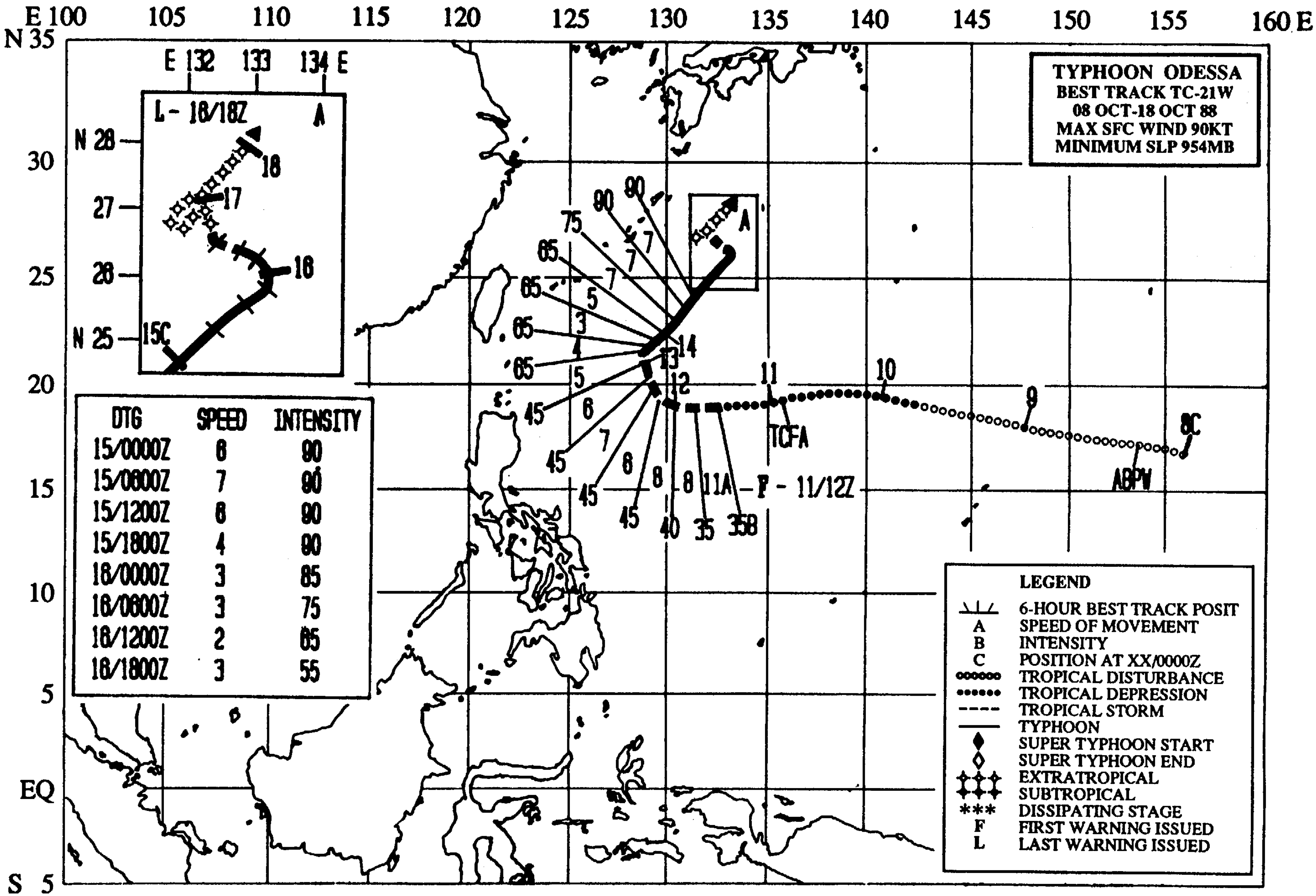


Figure 3-20-8. Nelson during its weakening stage (072235Z October NOAA visual imagery).


TYPHOON ODESSA
BEST TRACK TC-21W
08 OCT-18 OCT 88
MAX SFC WIND 90KT
MINIMUM SLP 954MB
L - 16/18Z
DTG SPEED INTENSITY
15/0000Z 6 90
15/0600Z 7 90
15/1200Z 6 90
15/1800Z 4 90
16/0000Z 3 85
16/0600Z 3 75
16/1200Z 2 65
16/1800Z 3 55
F - 11/12Z
TCFA
ABPW
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TYPHOON ODESSA (21W)

Odessa was the second of four significant tropical cyclones to occur during October. Slow to develop, it was tracked for three and a half days by satellite before the first warning was issued. After recurvature, Odessa rapidly intensified into a midget typhoon, despite interaction with a frontal system.

On 8 October, as Super Typhoon Nelson (20W) was weakening and accelerating to the northeast in higher latitudes, Odessa began as an area of convection superimposed on broad low-level easterly tradewinds 460 nm (852 km) south-southeast of Minami Tori-Shima. The persistence of this convective area was first mentioned on the Significant Tropical Weather Advisory at 080600Z. After two days of faster than normal — 17 to 18 kt (32 to 33 km/hr) — movement to the west-northwest, surface winds in the area increased to 30 kt (15 m/sec). At 102100Z, the Significant Tropical Weather Advisory was reissued to address this increase (Figure 3-21-1) and a Tropical Cyclone Formation Alert followed at 102300Z. A satellite intensity estimate of 35 kt (18 m/sec) prompted the first warning at 111200Z.

At 121800Z, Odessa was moving north-northwestward toward the cooler, drier polar air that was spilling off the Asian mainland. As interaction with this air mass commenced, the tropical cyclone began tracking to the northeast and intensifying. Satellite intensity analysis at 131106Z indicated sustained surface winds of 65 kt (33 m/sec) and Odessa was upgraded to a typhoon at 131200Z. Initially, the interaction with the cold front was expected to weaken the tropical cyclone; instead Odessa intensified into

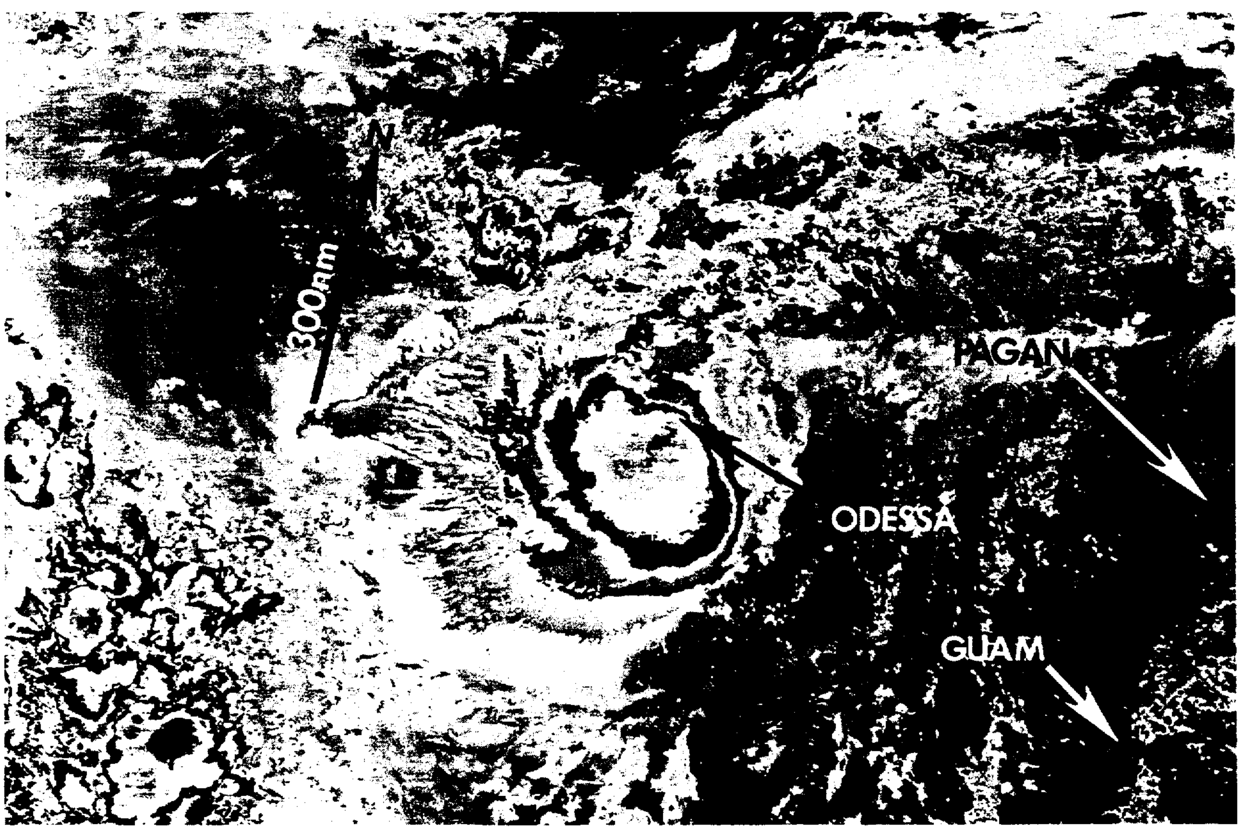


Figure 3-21-1. Odessa as a tropical disturbance (110021Z October DMSP infrared imagery).

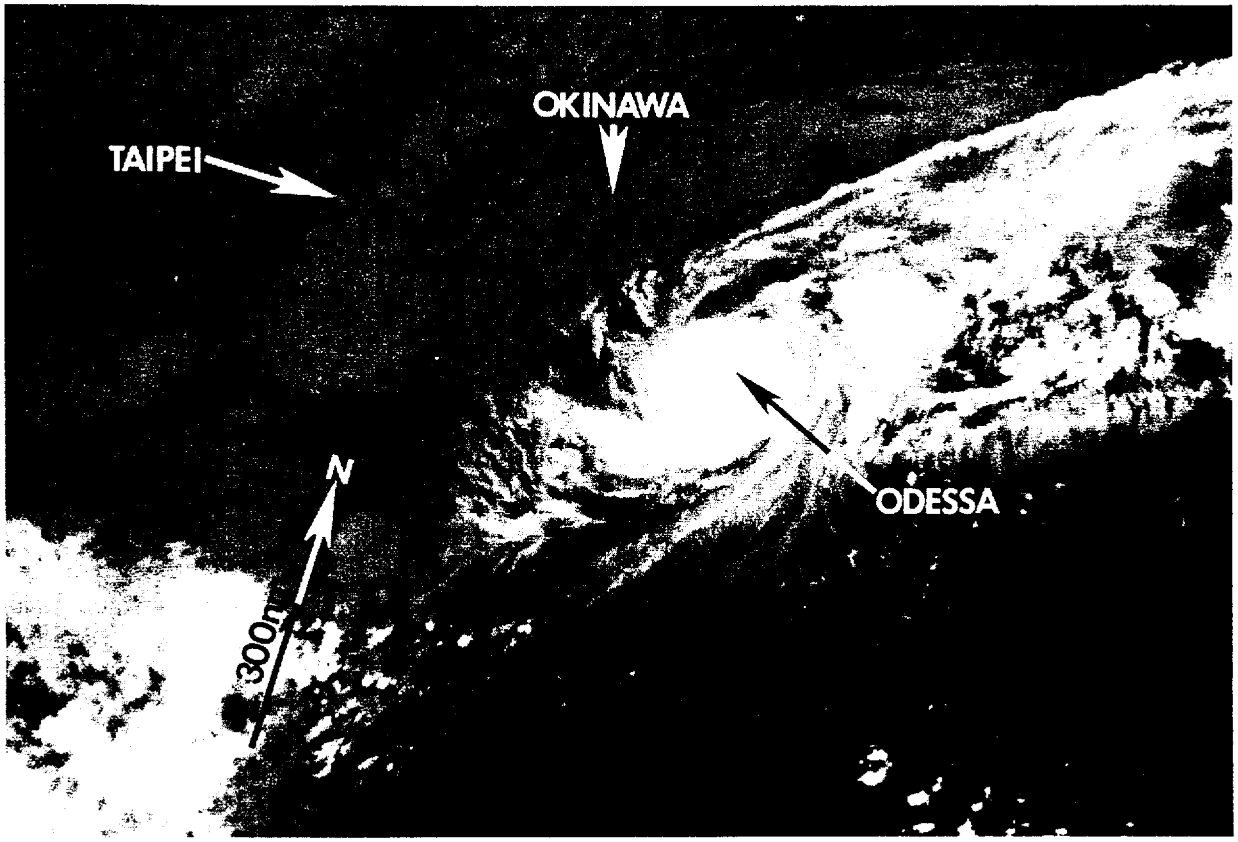


Figure 3-21-2. Typhoon Odessa displays a small eye before attaining its peak intensity (141044Z October NOAA visual imagery).

a midget typhoon. At 141200Z, the intensity peaked at 90 kt (46 m/sec) (Figure 3-21-2).

Loss of organization and deep convection started to be evident at 151200Z. With extratropical transition underway and the low-level circulation exposed, the final warning was issued at 161800Z. The extratropical circulation (Figure 3-21-3) made a counter-clockwise loop on 17 October before moving off to the northeast along the frontal zone.

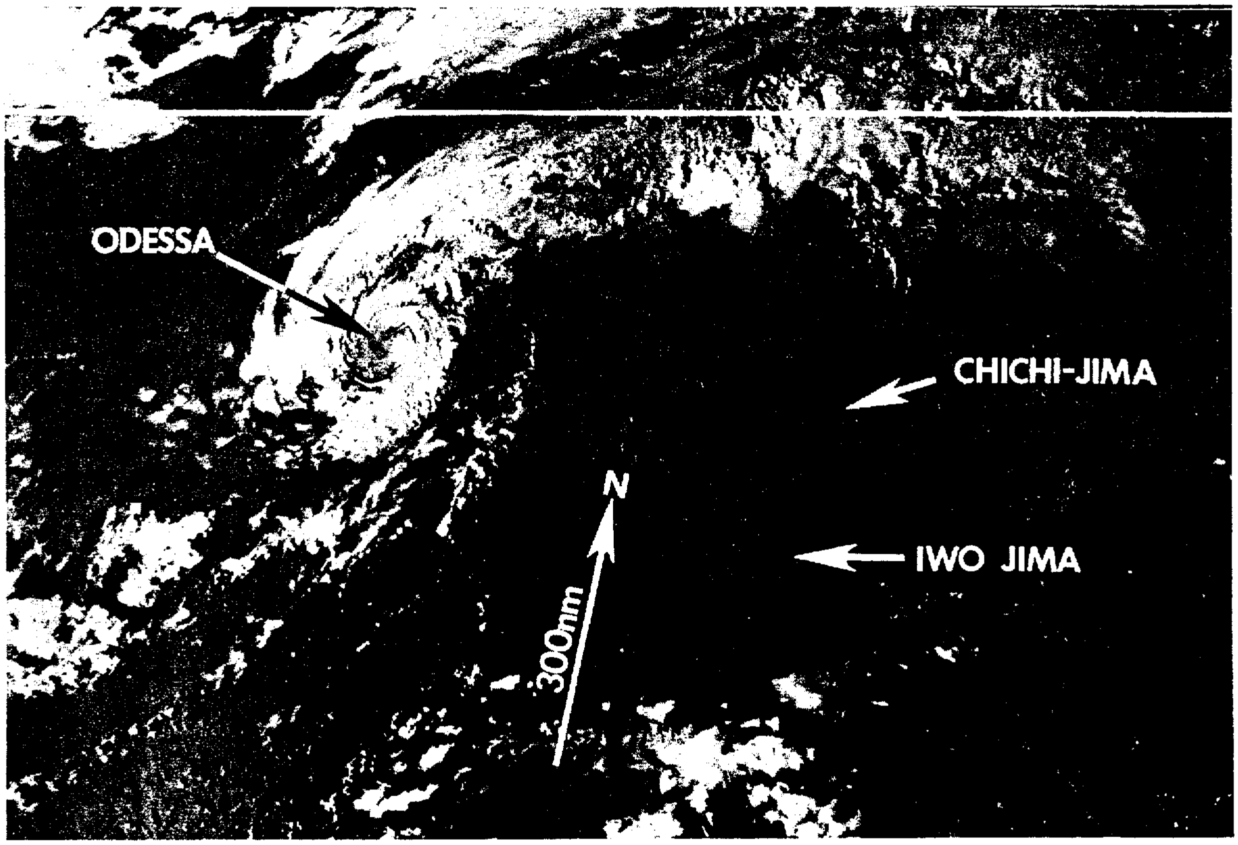
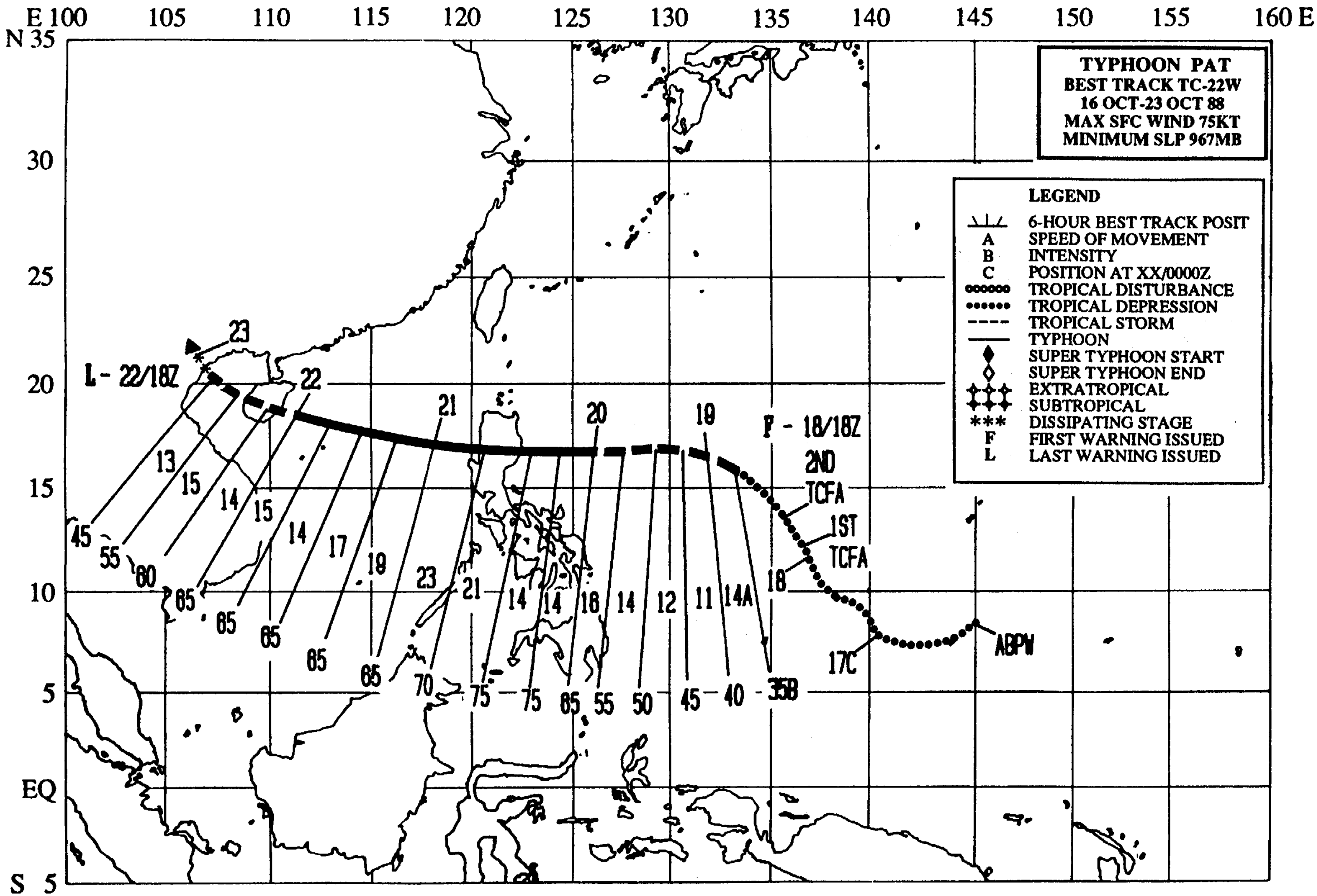


Figure 3-21-3. Odessa's well organized low-level circulation persists (170627Z October NOAA visual imagery).


TYPHOON PAT
BEST TRACK TC-22W
16 OCT-23 OCT 88
MAX SFC WIND 75KT
MINIMUM SLP 967MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 22/18Z
F - 18/18Z
2ND TCFA
1ST TCFA
ABPW
17C
35B
14A

TYPHOON PAT (22W)

Pat was the third of four typhoons to develop during October. Unlike most of the western North Pacific tropical cyclones in 1988 that preceded, it formed equatorward of 10 degrees North latitude.

The tropical cyclone was first detected on satellite imagery and the Significant Tropical Weather Advisory was reissued at 160630Z to include the low-level cyclonic circulation, which was located 300 nm (556 km) south of Guam. Initially, synoptic and satellite data comparison indicated the maximum convection was in a convergent zone south of the low-level circulation. From 16 to 18 October, Pat slowly developed over the warm Philippine Sea and moved through an area of relatively low vertical wind shear. By 18 October the convection had organized and the first Tropical Cyclone Formation Alert was issued at 180300Z. Surface synoptic data indicated a minimum sea-level pressure (MSLP) of about 1002 mb and winds of 25 to 30 kt (13 to 15 m/sec). Satellite imagery continued to show an uneven distribution of deep convection with significantly more convection in the system's eastern semicircle. Pat's slow development required a second Alert at 181530Z. Improving upper-level outflow and increasing central convection prompted the first warning at 181800Z.

Then Pat (Figure 3-22-1) assumed a more westerward course along the edge of the

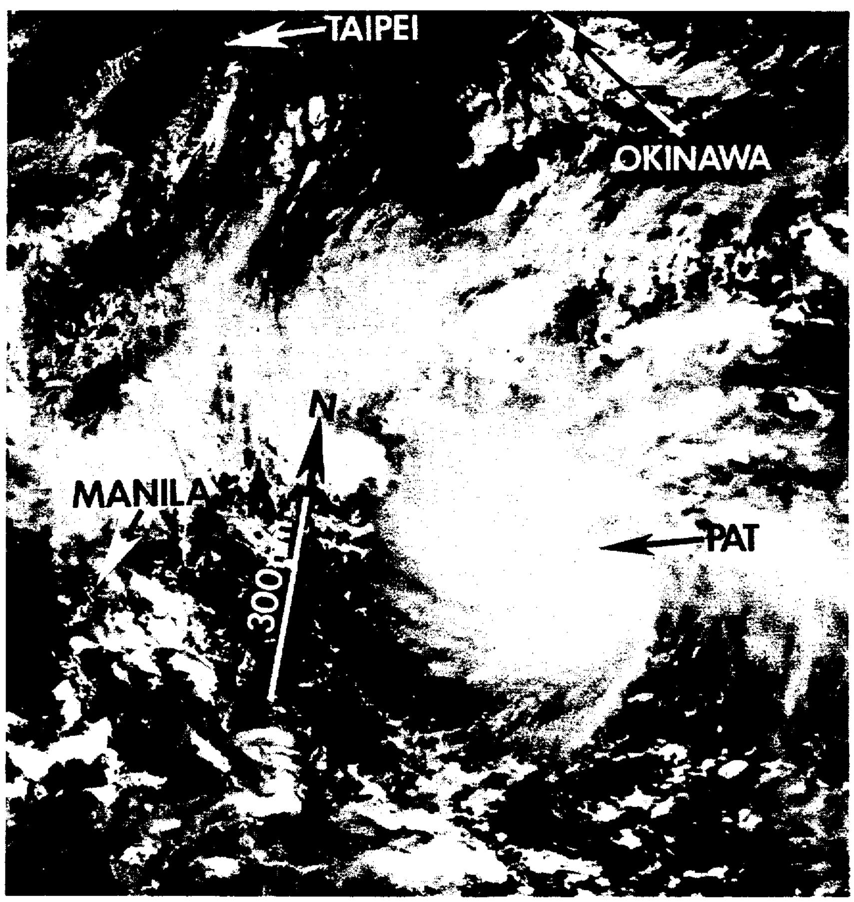


Figure 3-22-1. Pat crossing the Philippine Sea (190514Z October NOAA visual imagery).

modifying polar high to the north. The tropical cyclone's convection and organization increased again, which required an upgrade to typhoon intensity at 200000Z. Shortly before making landfall on the island of Luzon, Pat reached its peak intensity of 75 kt (39 m/sec). Maintaining typhoon intensity as it crossed central Luzon, the system (Figure 3-22-2) passed 75 nm (139 km) north of Clark Air Base at 201800Z. The base, due to the sheltering effect of the nearby mountain ranges, only recorded peak gusts of 21 kt (11 m/sec).

After entering the South China Sea, Pat (Figure 3-22-3) pressed on to the west-northwest and sustained minimal typhoon intensity. It crossed the South China Sea and was downgraded to a tropical storm, as interaction with Hainan Dao occurred. Once across the island, the weakening system moved into the Gulf of Tonkin and entered northern Vietnam. It passed 30 nm (56 km) northeast of Hanoi and dissipated inland.

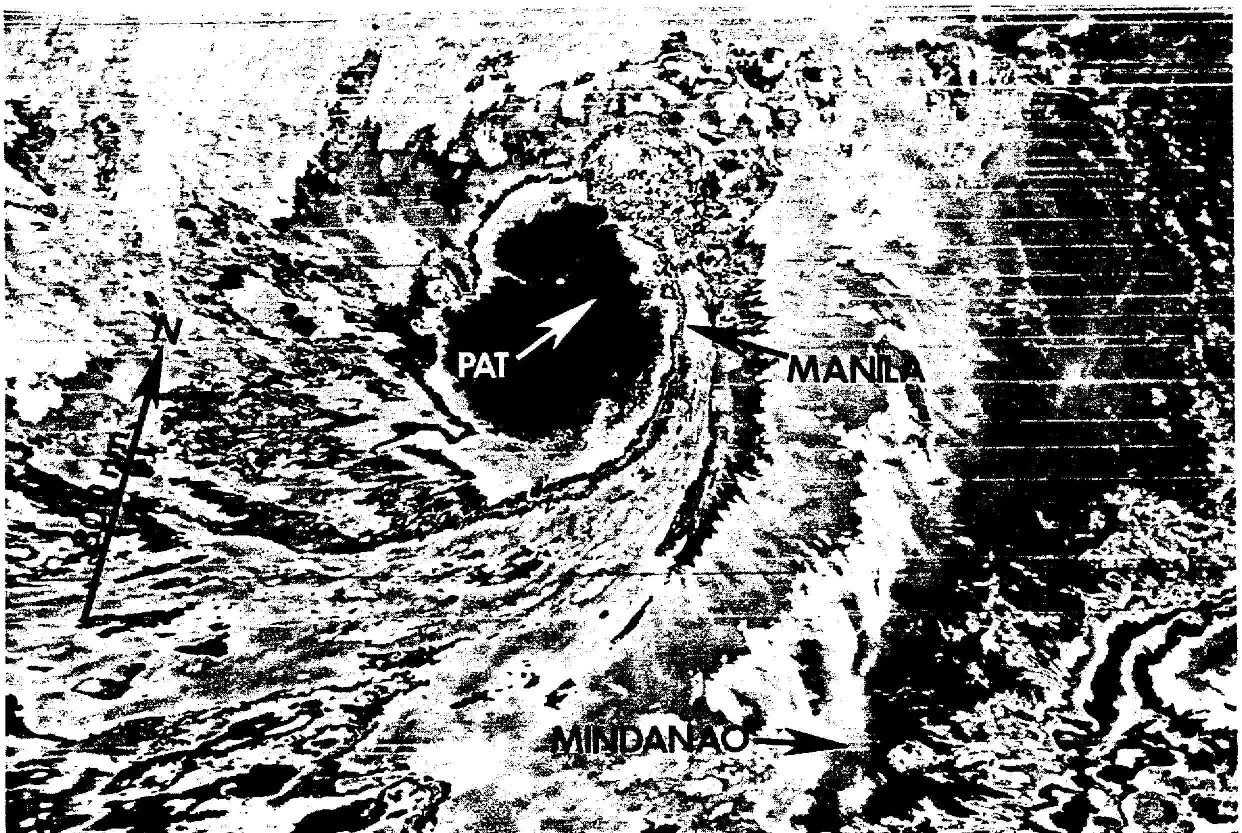


Figure 3-22-2. Typhoon Pat entering the South China Sea (202152Z October DMSP infrared imagery).

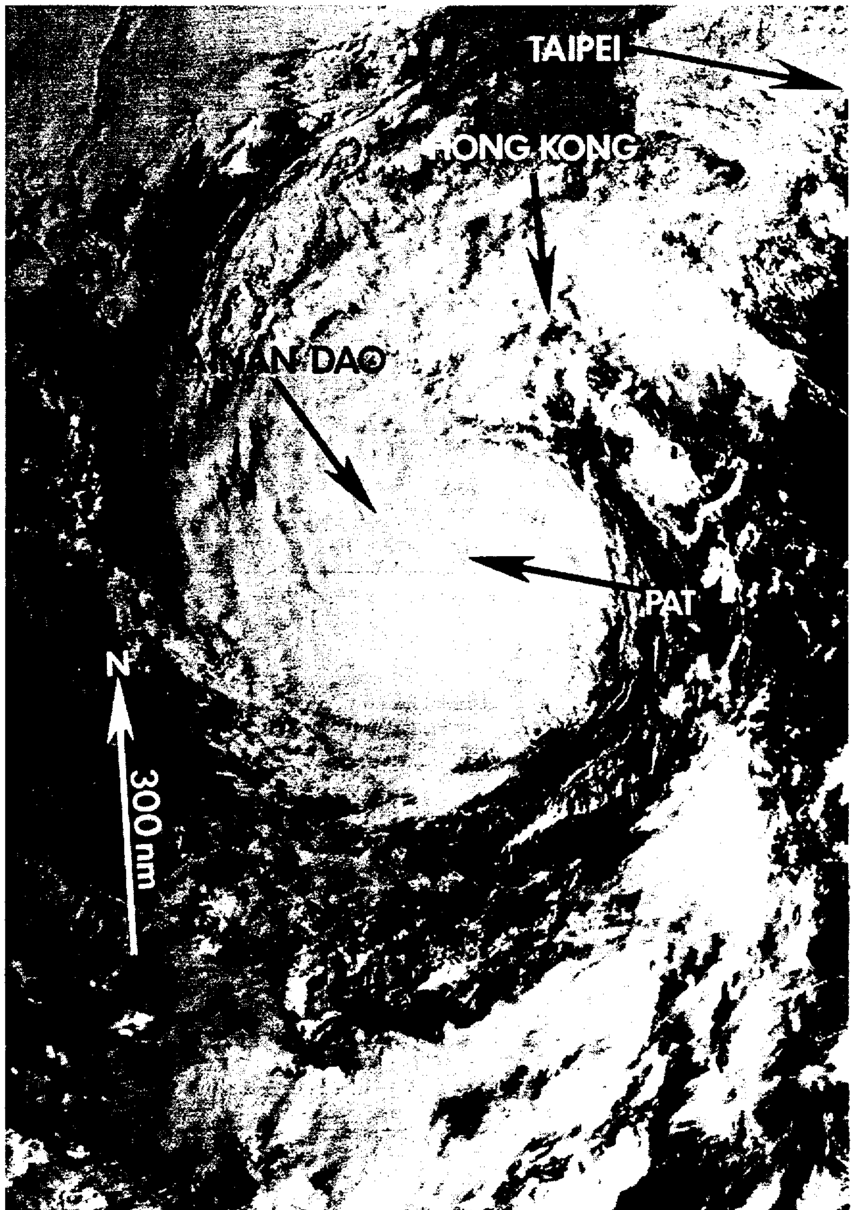
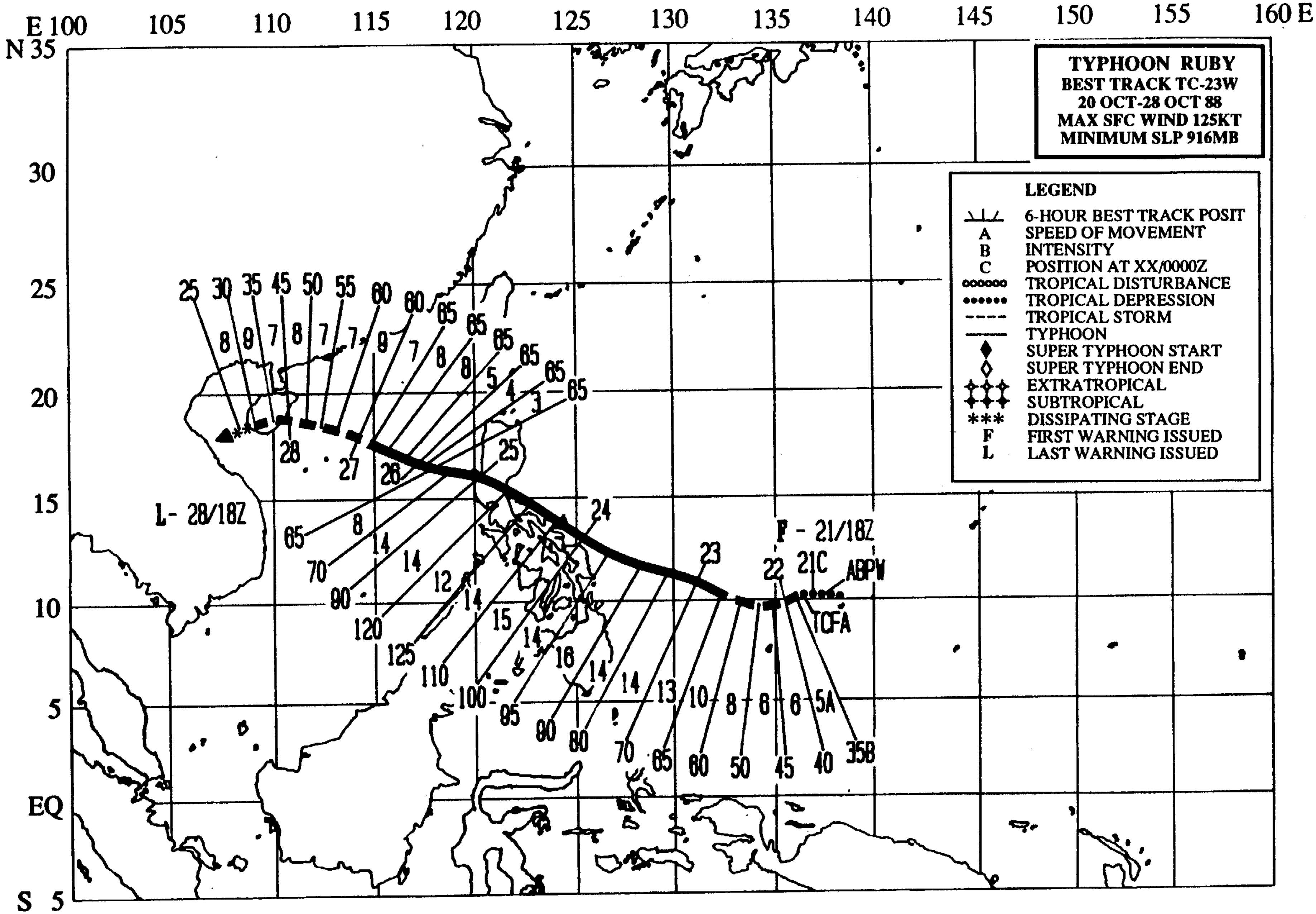


Figure 3-22-3. Typhoon Pat approaches Hainan Dao (220011Z October NOAA visual imagery).


TYPHOON RUBY
BEST TRACK TC-23W
20 OCT-28 OCT 88
MAX SFC WIND 125KT
MINIMUM SLP 916MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 28/18Z
F - 21/18Z
ABPW
TCFA

TYPHOON RUBY (23W)

The last of four typhoons to develop in the western North Pacific during October, Ruby became the fifth tropical cyclone to hit the Philippine Islands in 1988.

On 20 October, as Typhoon Pat (22W) approached the Philippine Islands, Ruby formed to the east in the Philippine Sea. The Significant Tropical Weather Advisory was reissued at 201800Z to include this new disturbance. Increased central convection and organization warranted a Tropical Cyclone Formation Alert at 210430Z and the first warning at 211200Z.

Ruby assumed the track of a "straight runner" and continued to intensify. At 240600Z, as it neared land, Ruby developed a 15 nm (28 km) diameter eye and reached its peak intensity of 125 kt (64 m/sec) at 241200Z. The eye persisted for twelve hours before Ruby tracked into the mountainous terrain of central Luzon (Figure 3-23-1).

Like most tropical cyclones that track over the Philippine Islands, Ruby weakened significantly as it moved across Luzon; however, it was near super typhoon intensity shortly before it made landfall. The result was widespread damage and loss of life. More than three hundred people were killed, including over 150 who drowned when the ferry DONA MARILYN capsized at sea 300 nm (556 km) southeast of Manila, and over 470,000 people

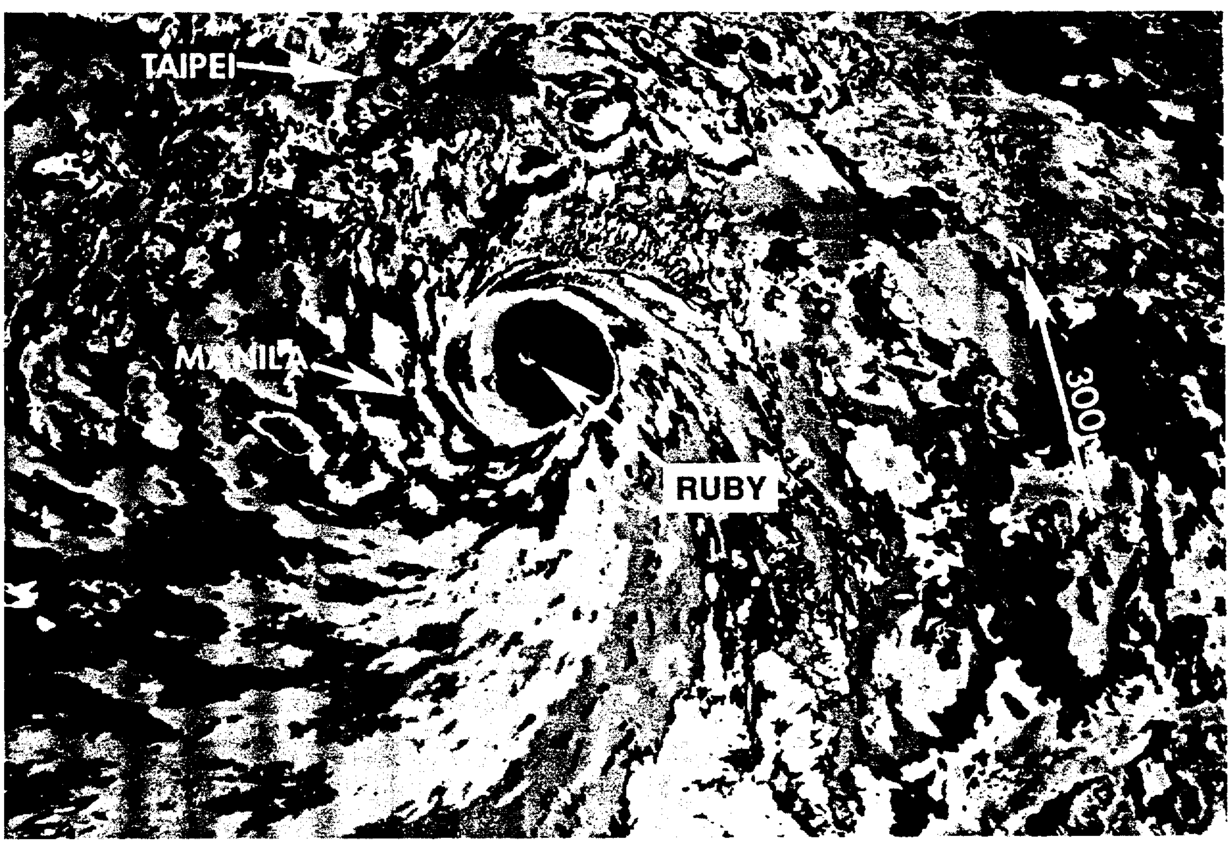


Figure 3-23-1. Ruby, shortly before reaching its peak intensity and making landfall over central Luzon (241000Z October DMSP infrared imagery).

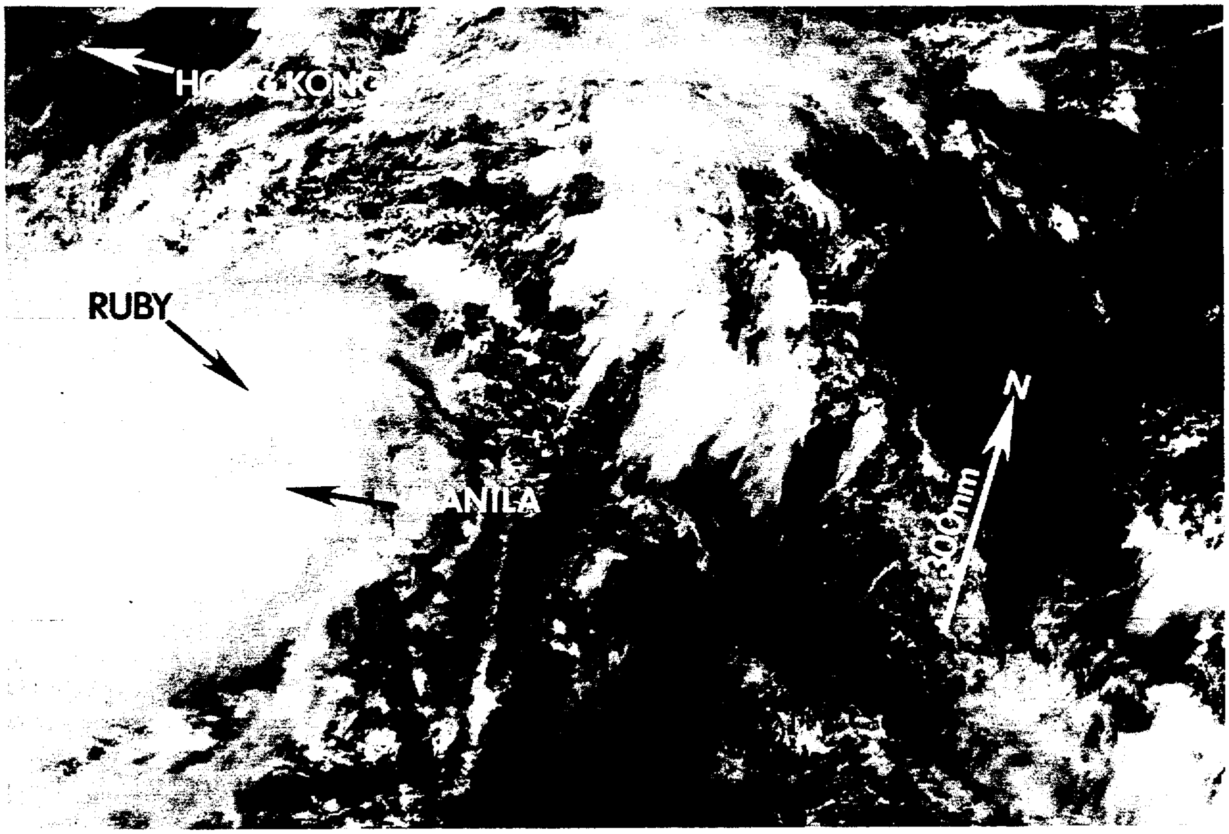


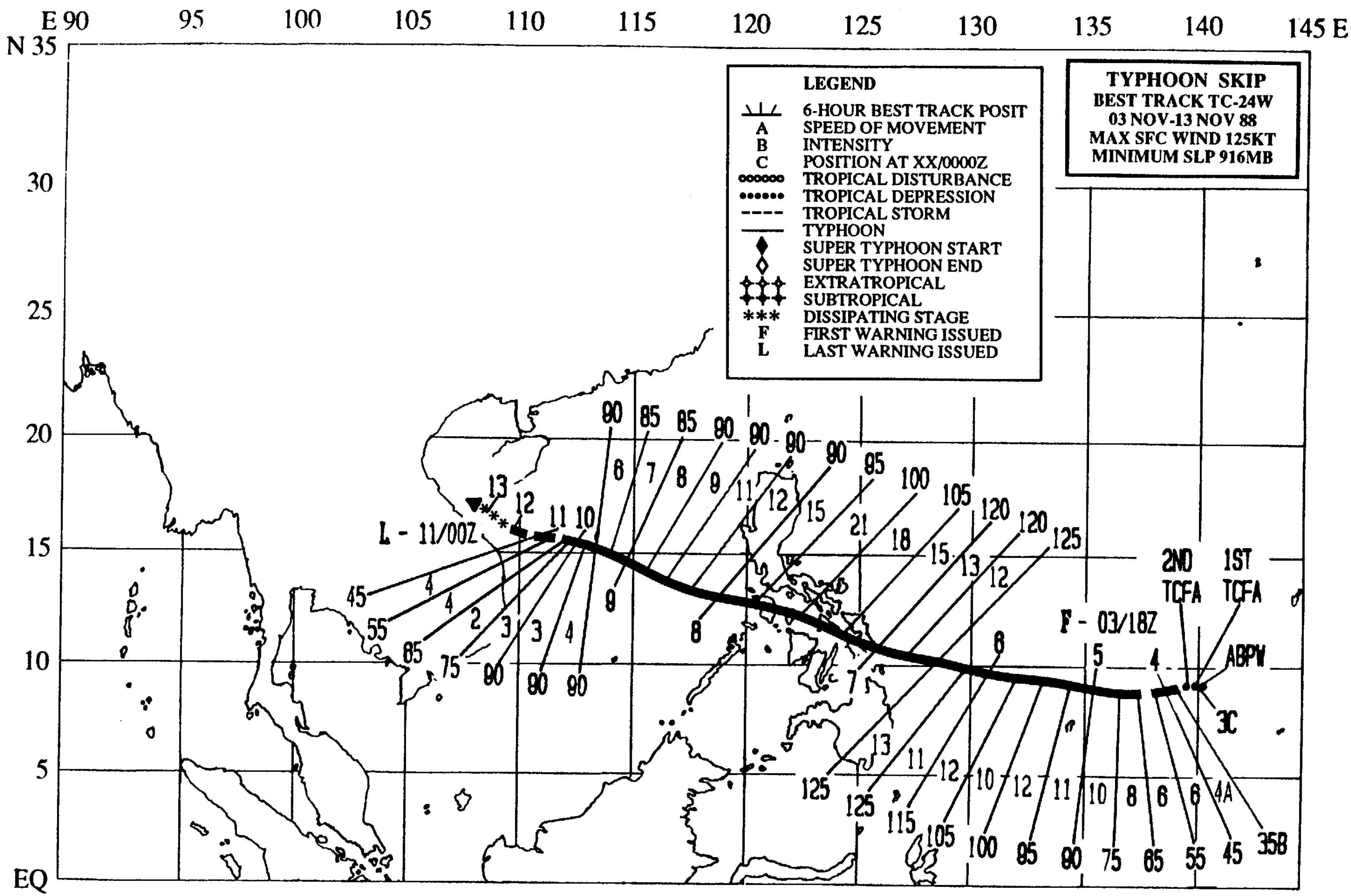
Figure 3-23-2. Convective bands brought prolonged torrential rains, high winds and hazardous surf conditions to western Luzon, as Ruby slowly entered the South China Sea (250048Z October DMSP visual imagery).

were left homeless. Also the freighter JET ANN FIVE sank near Bohol Island in the southern Philippines after encountering rough seas from Typhoon Ruby.

Entering the South China Sea at 250300Z, Ruby (Figure 3-23-2) slowed. As a result of Ruby's slow departure from Luzon, Subic Bay Naval Base and Clark Air Base received their worst weather following the passage of the typhoon's center. Bands of wind and rain from the southwest slammed into western Luzon, causing torrential downpours and strong, gusty winds. Peak gusts recorded were 69 kt (36 m/sec) at Subic Bay (Figure 3-23-3) and 46 kt (24 m/sec) at Clark Air Base. (These were the strongest winds reported at Clark Air Base since Super Typhoon Rita (1978) produced gusts to 58 kt (30 m/sec).)

Ruby then began to track toward the island of Hainan and made landfall at 280400Z. Interaction with the mountainous terrain of Hainan caused the tropical cyclone to weaken. The final warning was issued at 281800Z, after satellite imagery indicated the absence of central convection. Although Ruby's circulation dissipated over water, heavy rainshowers caused flash floods in northern Vietnam that killed at least 100 people, left thousands homeless and destroyed over 300,000 tons of agricultural produce.


Figure 3-23-3. Ruby's high winds caused widespread damage. This tree toppled into a housing unit. (Photo courtesy of the Naval Oceanography Command Facility, Cubi Point, Republic of the Philippines.)


TYPHOON SKIP
BEST TRACK TC-24W
03 NOV-13 NOV 88
MAX SFC WIND 125KT
MINIMUM SLP 916MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 11/00Z
F - 03/18Z
2ND TCFA
1ST TCFA
ABPW

TYPHOON SKIP (24W)

The first of two significant tropical cyclones to develop during November, Skip was a classic "straight runner" that covered over 2,000 nm (3,704 km) during its ten day lifetime. This typhoon was especially damaging to the Philippine Islands because it followed close behind Typhoons Ruby (23W) and Tess (25W).

On the first of November the northeast monsoon was well established across the South China Sea and southeastern Asia. Easterly tradewinds dominated the Philippine Sea north of the near-equatorial trough and a disturbance, that was to become Typhoon Tess (25W), was bringing more rain and wind to the central Philippine Islands. The next day Skip began as an area of convection in the monsoon trough about 360 nm (667 km) southwest of the island of Guam. After the convection had persisted for a day, the disturbance was listed on the Significant Tropical Weather Advisory at 030600Z. Visual satellite imagery indicated a well defined low-level cyclonic circulation immediately west of the curved band of convection (Figure 3-24-1). A satellite intensity analysis estimate of 30 kt (15 m/sec) surface winds precipitated the first Tropical Cyclone Formation Alert at 030700Z. The disturbance continued to develop and moved out of the Alert box, necessitating the issuance of a second Alert at 031400Z. Four hours later, after a satellite intensity estimate of 35 kt (18 m/sec),

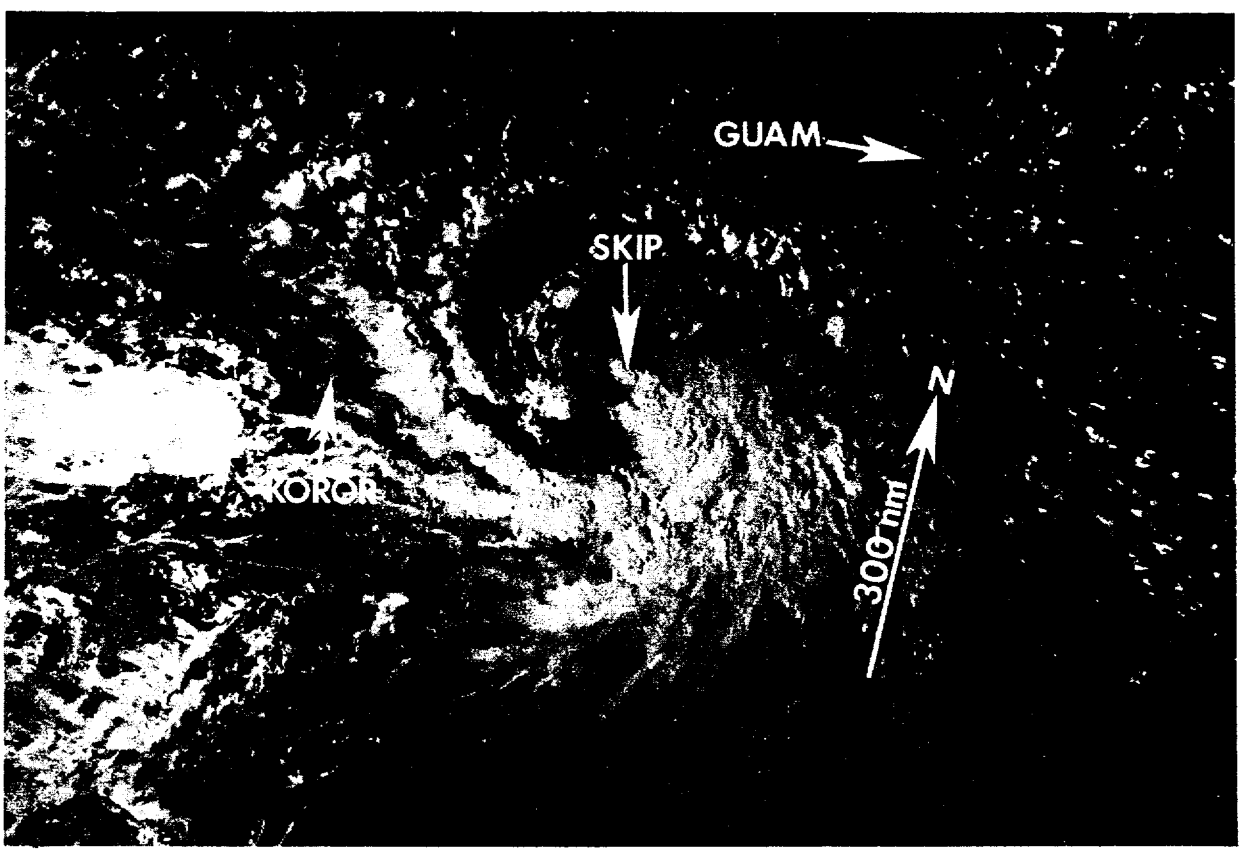


Figure 3-24-1. Skip, shortly before the first Tropical Cyclone Formation Alert (030642Z November NOAA visual imagery).

the first warning was issued. Skip (Figure 3-24-2) tracked westward and intensified, peaking in intensity at 125 kt (64 m/sec) at 060600Z.

As the typhoon approached the central Philippine Islands, it began to weaken and accelerate. The tropical cyclone reached a forward speed of 21 kt (39 km/hr), as it tracked across the island of Mindoro. The typhoon's trek through the Philippine Islands caused significant damage and loss of life. At least 104 people were killed by mudslides, floods and flying debris and another 95 persons were listed as missing. In all, Skip left over 600,000 homeless, caused extensive damage to coconut, rice and sugar crops, and widespread disruption of power and communication lines. Numerous watercraft were reported lost, missing or aground.

After weakening over the Philippine Islands, Skip slowed as it entered the South China Sea at 071800Z. During the next four days, Skip pushed west-northwestward along the southern side of the narrow subtropical ridge. At 100600Z the typhoon was downgraded to a tropical storm and further weakening led to the final warning at 110000Z. The remnants of Skip (Figure 3-24-3) drifted into the Gulf of Tonkin and dissipated.

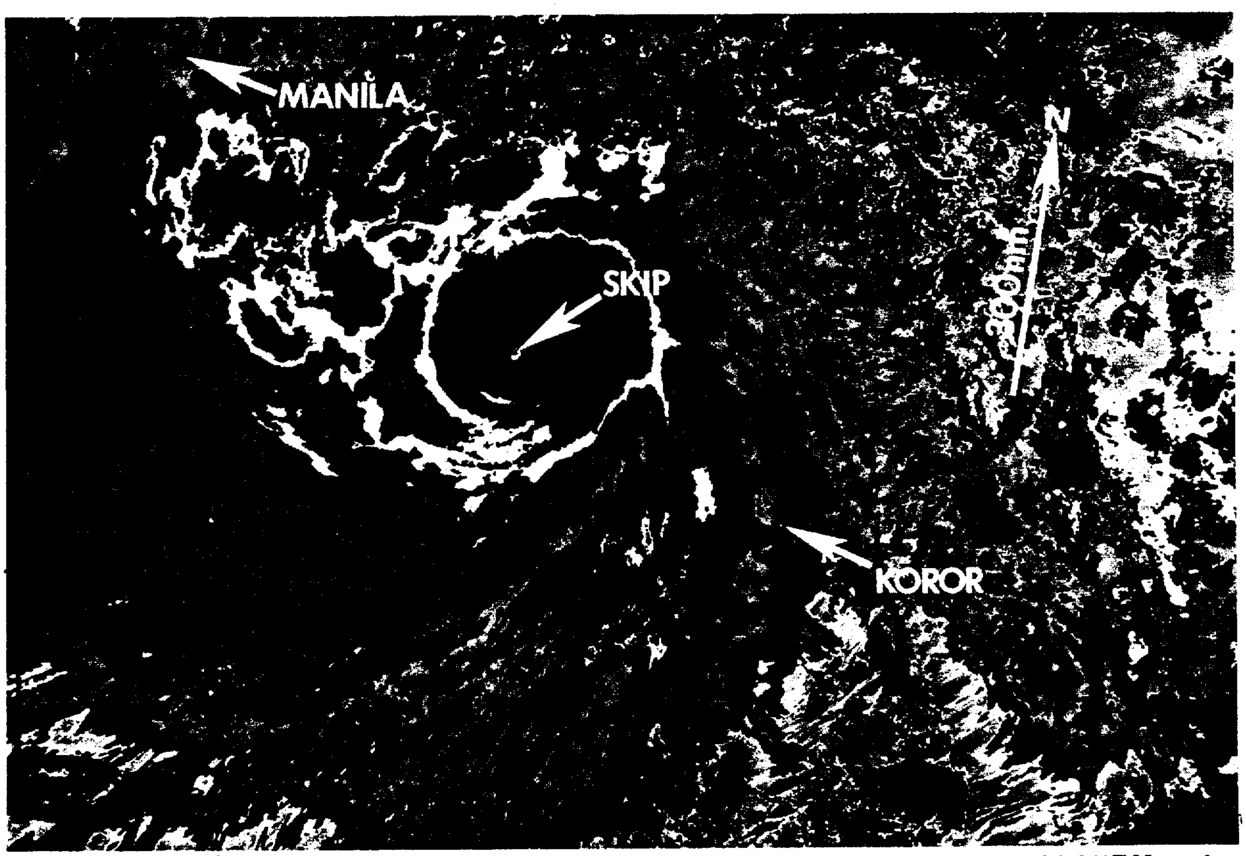


Figure 3-24-2. Typhoon Skip at peak intensity. Note the eye feature and symmetry of deep convection (061041Z November NOAA infrared imagery).

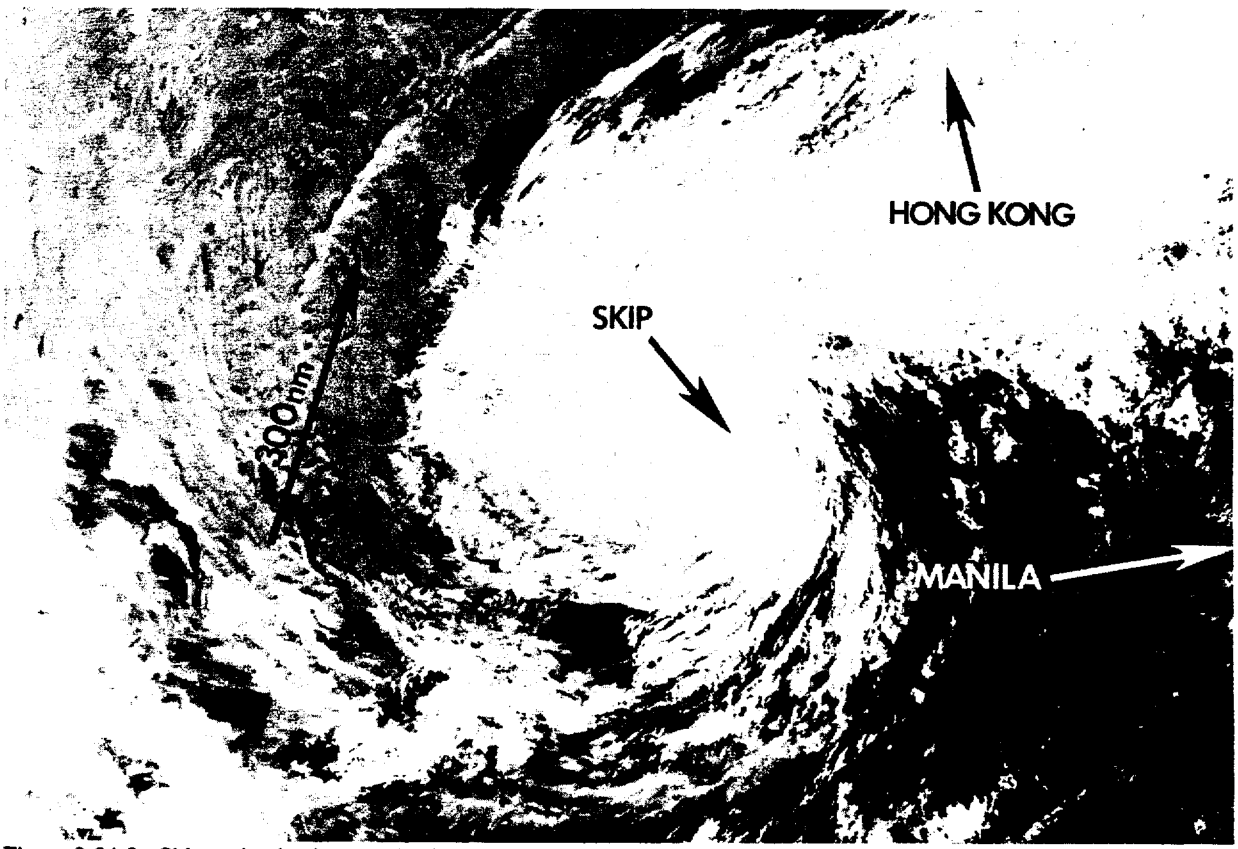
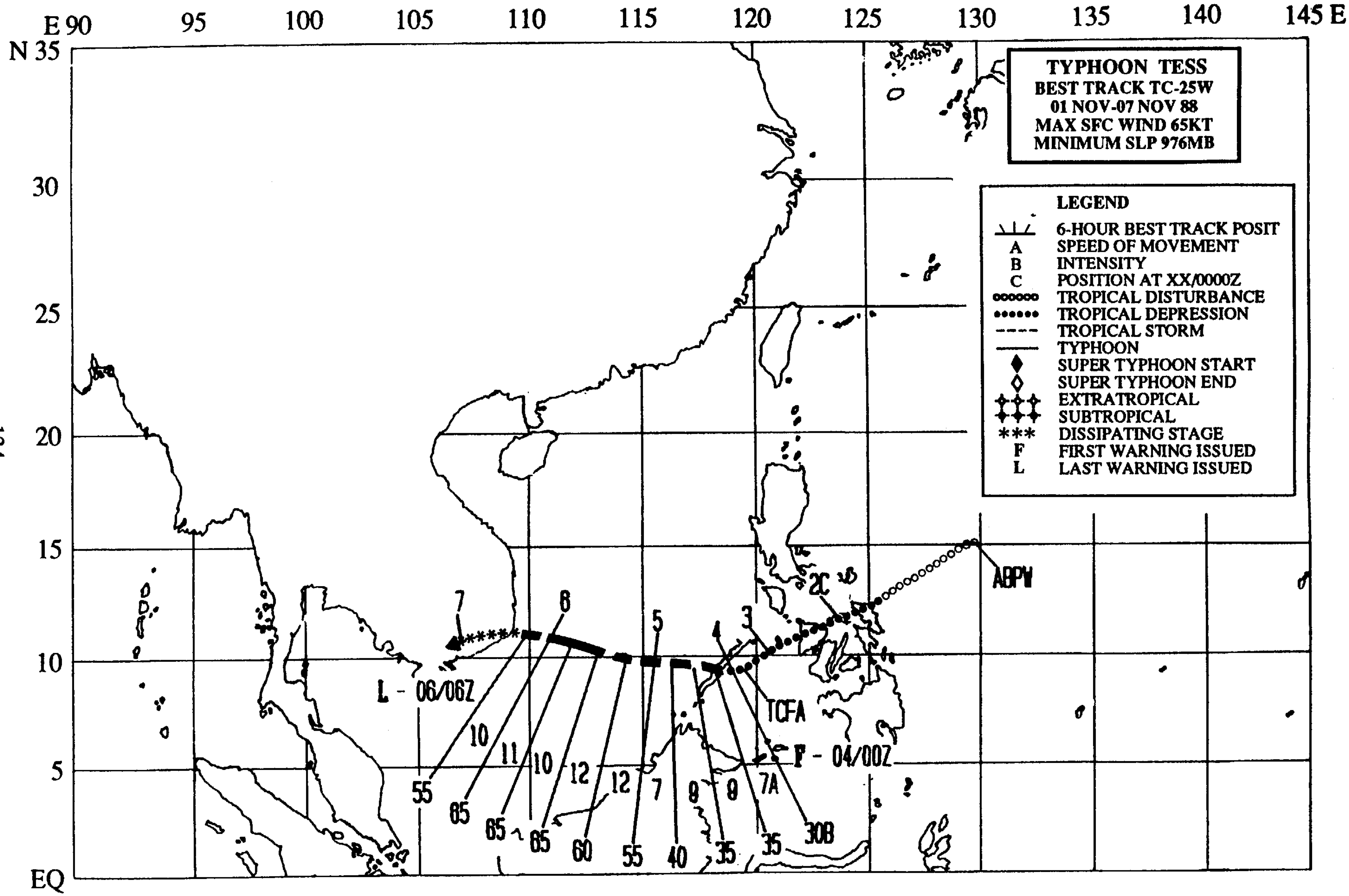


Figure 3-24-3. Skip maintains its organization, shortly after the final warning was issued (110157Z November DMSP visual imagery).


TYPHOON TESS
BEST TRACK TC-25W
01 NOV-07 NOV 88
MAX SFC WIND 65KT
MINIMUM SLP 976MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 90
95
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ABPW
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TYPHOON TESS (25W)

The last of two significant tropical cyclones to occur during November, Tess developed slowly for three days before the first warning. Tess was the only tropical cyclone to track across southern Vietnam during 1988.

Tess' persistent area of convection was first mentioned on the Significant Tropical Weather Advisory at 010600Z. For the next three days the disturbance tracked southwestward along the edge of the deep northeasterly flow of the winter monsoon. Once across the rugged Philippine Islands and over open water in the Sulu Sea, the tropical cyclone (Figure 3-25-1) became more organized and required a Tropical Cyclone Formation Alert at 031730Z. A satellite intensity estimate of 30 kt (15 m/sec) prompted the first warning

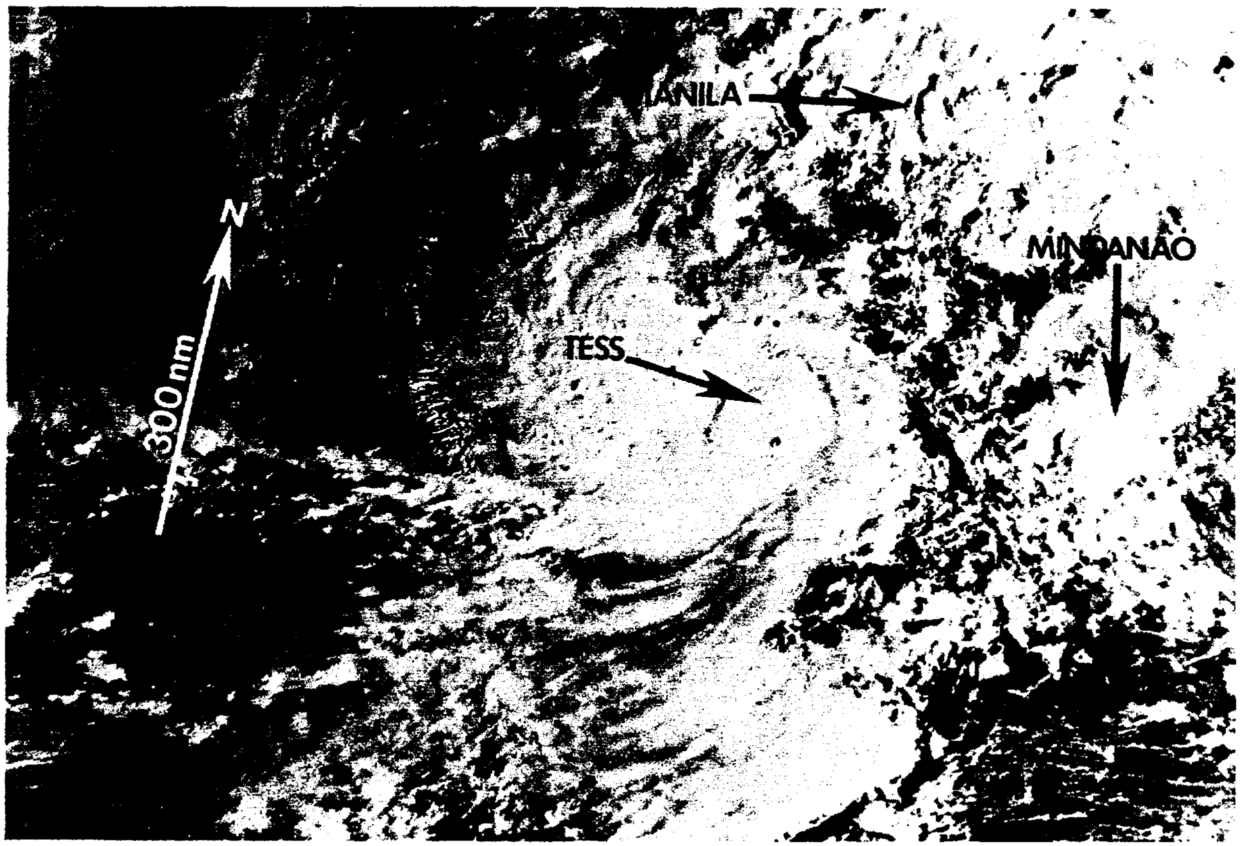


Figure 3-25-1. As a disturbance, Tess showed improved convection and organization as it entered the Sulu Sea (032221Z November DMSP visual imagery).

on Tropical Depression 25W (Figure 3-25-2) at 040000Z.

Almost immediately after the first warning, the track became westward. The most probable explanation for this change appeared in the low-level northeasterly gradient flow. The pressure gradient between the winter high and the lower pressure associated with Tess had sustained a persistent flow of at least 30 kt (15 m/sec) upstream of the tropical cyclone since 1 November. This upstream pressure gradient relaxed on 4 November and the gales clustered around Tess.

Along with this track change came intensification, as the system crossed Palawan Island and entered the South China Sea. At 040600Z, satellite intensity estimates indicated 35 kt (18 m/sec) surface winds and the tropical depression was upgraded to tropical storm intensity. The system (Figure 3-25-3) reached its peak intensity of 65 kt (33 m/sec) at 051200Z.

As Tess approached the coast of southern Vietnam, it began to weaken. The tropical cyclone was downgraded to tropical storm intensity and finalled at 060600Z. The remnants of Tess continued to track westward across the Mekong river delta. No reports of damage or loss of life were received.

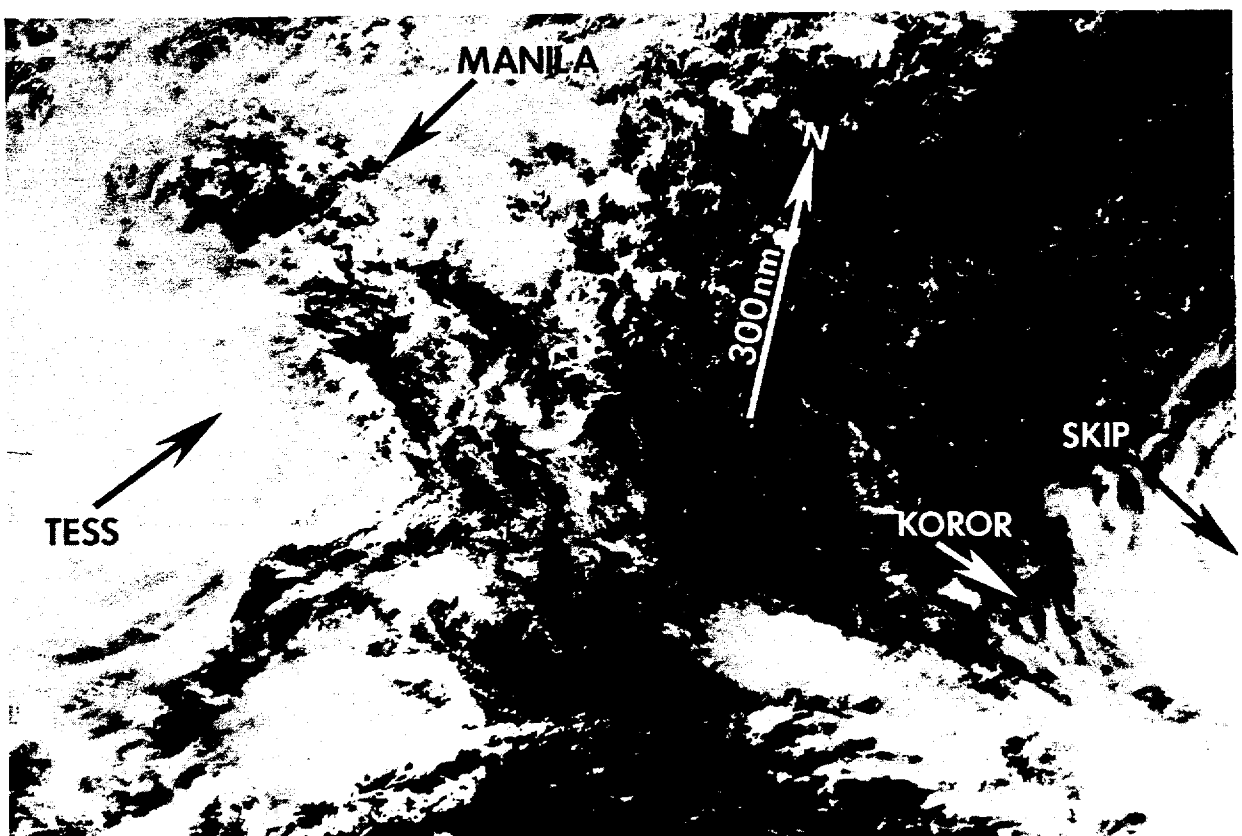


Figure 3-25-2. Tess, shortly after the first warning was issued. The cloudiness at the picture's lower right is associated with Skip (24W) (040053Z November DMSP visual imagery).

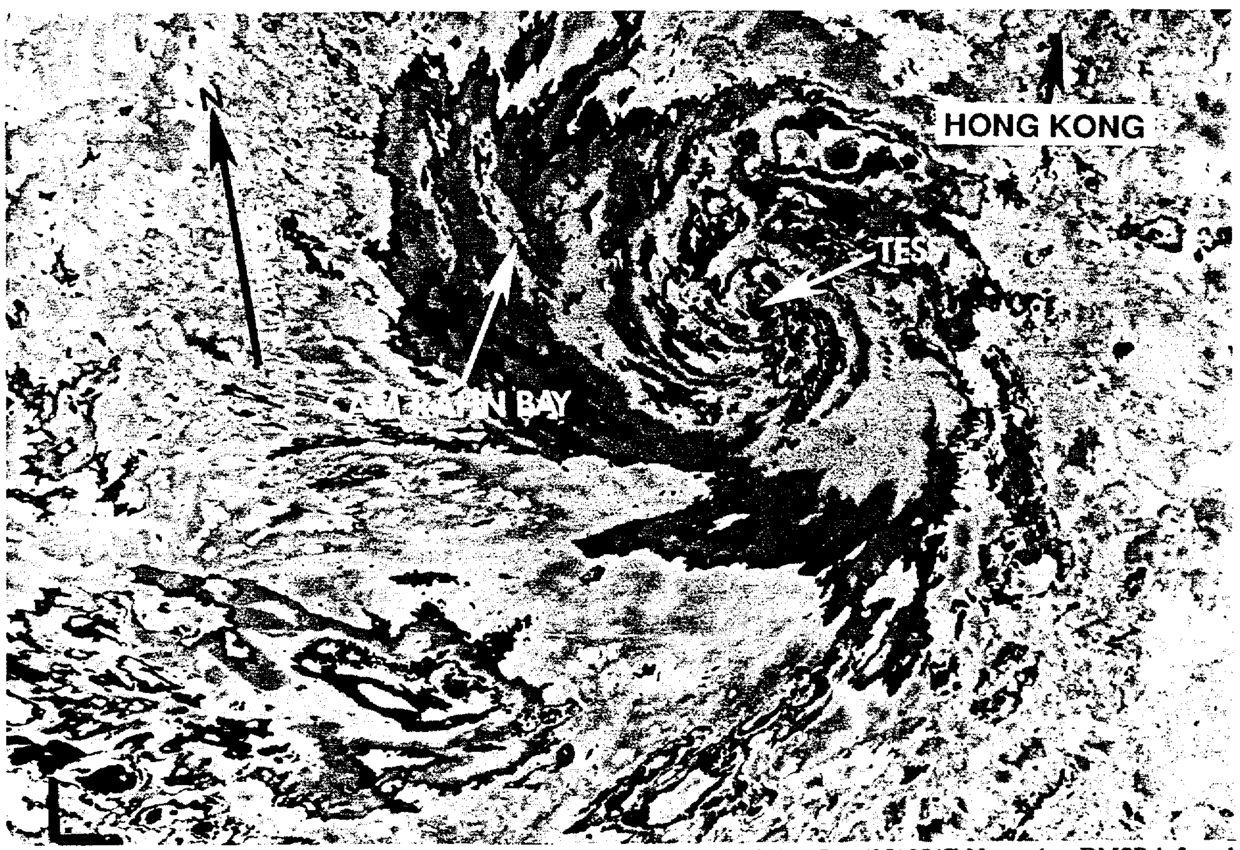
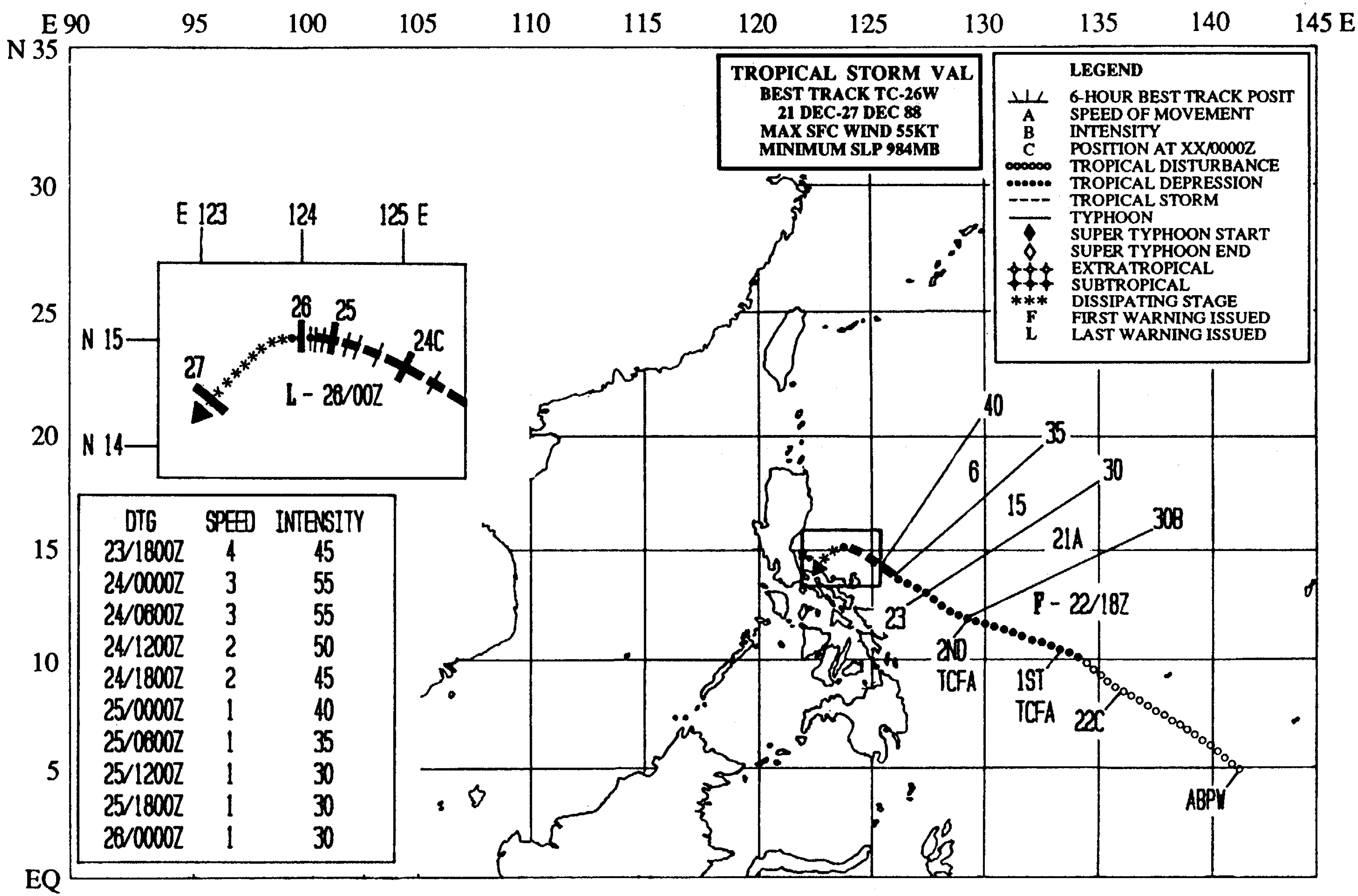


Figure 3-25-3. Tess just before reaching its peak intensity in the South China Sea (051054Z November DMSP infrared imagery).



DTG	SPEED	INTENSITY
23/1800Z	4	45
24/0000Z	3	55
24/0600Z	3	55
24/1200Z	2	50
24/1800Z	2	45
25/0000Z	1	40
25/0600Z	1	35
25/1200Z	1	30
25/1800Z	1	30
26/0000Z	1	30

TROPICAL STORM VAL (26W)

Tropical Storm Val (26W) was the final significant tropical cyclone of 1988 and the only storm to develop during December. It proved difficult to position and hard to forecast. In less than 24-hours, Val decelerated from a 25 kt (46 km/hr) to quasi-stationary. Also, the system's cirrus outflow prevented timely detection of shearing and decoupling of the low-level circulation center from the central convection.

On 13 December a massive outbreak of polar air started to push southeastward from Asia across the Philippine Sea. By 18 December the leading edge of the air mass stretched from the southern Philippine Islands to the northern Marianas and northeastward. As the major thrust of the cold air diminished, the southern Philippine Sea filled with deep convection and a near-equatorial trough formed. Multiple low-level cyclonic circulations appeared in the trough with nearby gales to the north due to the strong northeast monsoon. Finally, the convection began to consolidate in the western Caroline Islands and the area was initially mentioned at 210600Z on the Significant Tropical Weather Advisory. The convection continued to organize and a Tropical Cyclone Formation Alert was issued at 220700Z based on satellite imagery that indicated an increase in upper-level organization. Plus, surface synoptic reports revealed pressures as low as 1005 mb and 20 kt (10 m/sec) westerly winds to the south of the circulation center.

A second Alert was issued at 221800Z to cover the unusually rapid movement — 25 kt (46 km/hr) — of the circulation to the west. Still, the area (Figure 3-26-1) developed, and the upper-level outflow and surface circulation

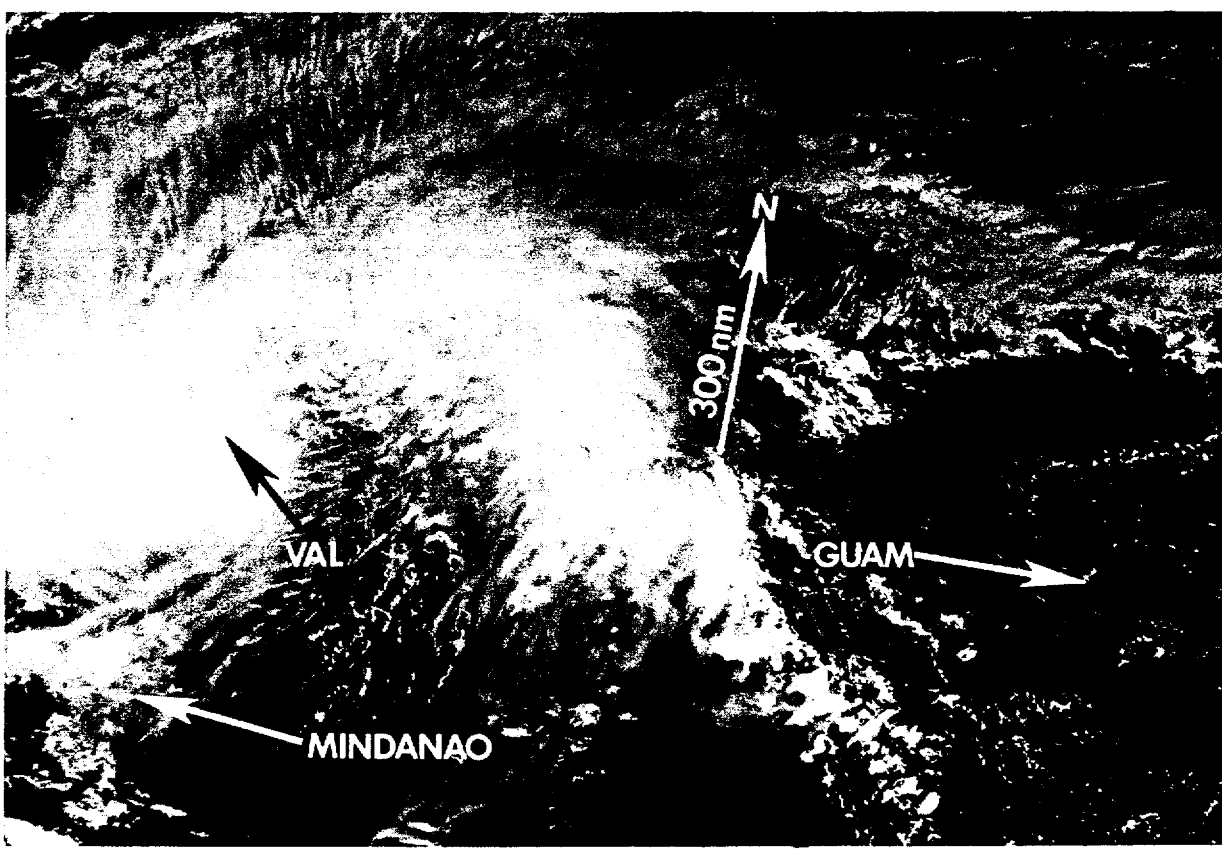


Figure 3-26-1. Val with its major convective band (230429Z December NOAA visual imagery).

improved. The first warning followed close behind with a valid time at 221800Z based on a satellite intensity analysis estimate of 30 kt (15 m/sec). Then Val (26W) began to decelerate and intensify. It reached a peak intensity of 55 kt (28 m/sec) at 240000Z (Figure 3-26-2).

As the intensity peaked and forward motion ground to a halt on 24 December, high cloudiness obscured the low-level circulation center. The deep central convection and upper-level circulation center, which were the targets for remote sensing, tracked northward. The shallow system (Figure 3-26-3) continued to weaken and the final warning was issued at 260000Z. The dissipating low-level circulation center accelerated to the southwest along the eastern boundary of the northeast monsoon. No reports of damage or loss of life were received.

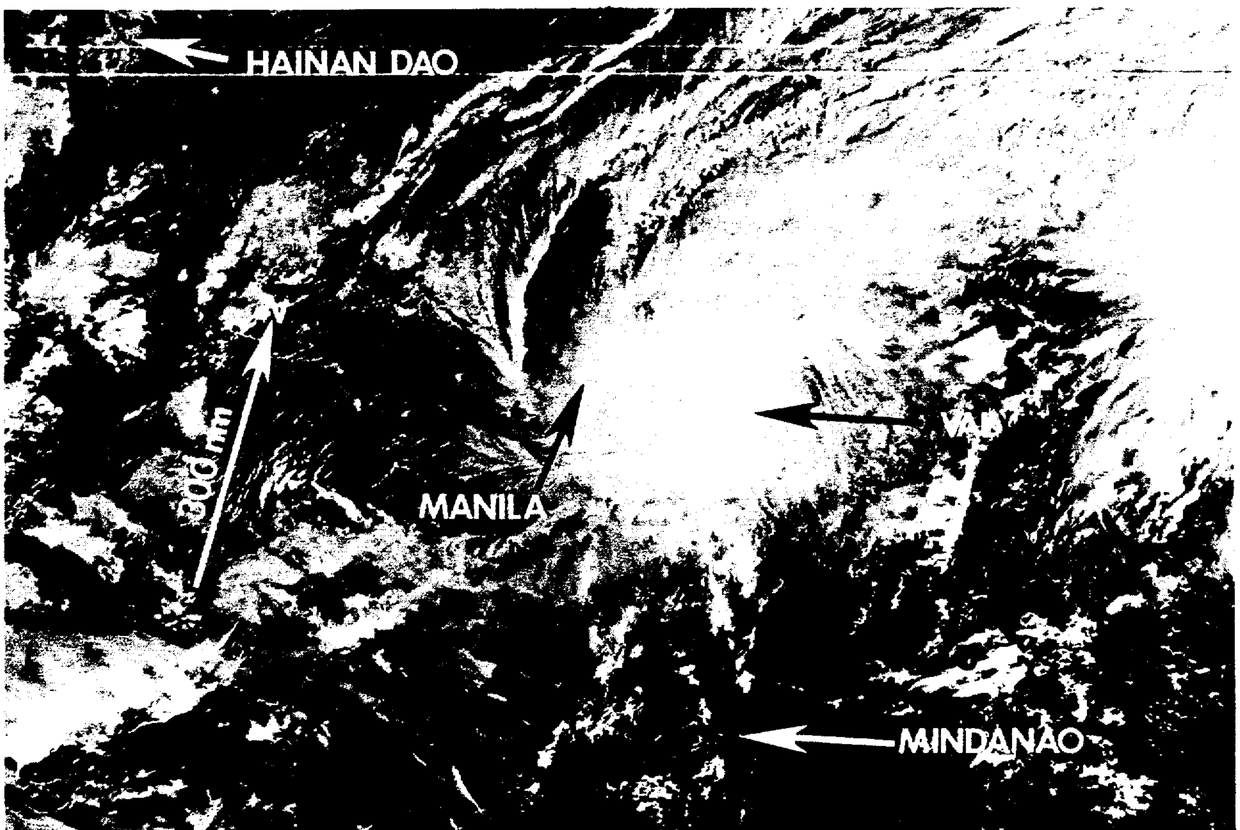


Figure 3-26-2. Tropical Storm Val at maximum intensity (240114Z December DMSP visual imagery).

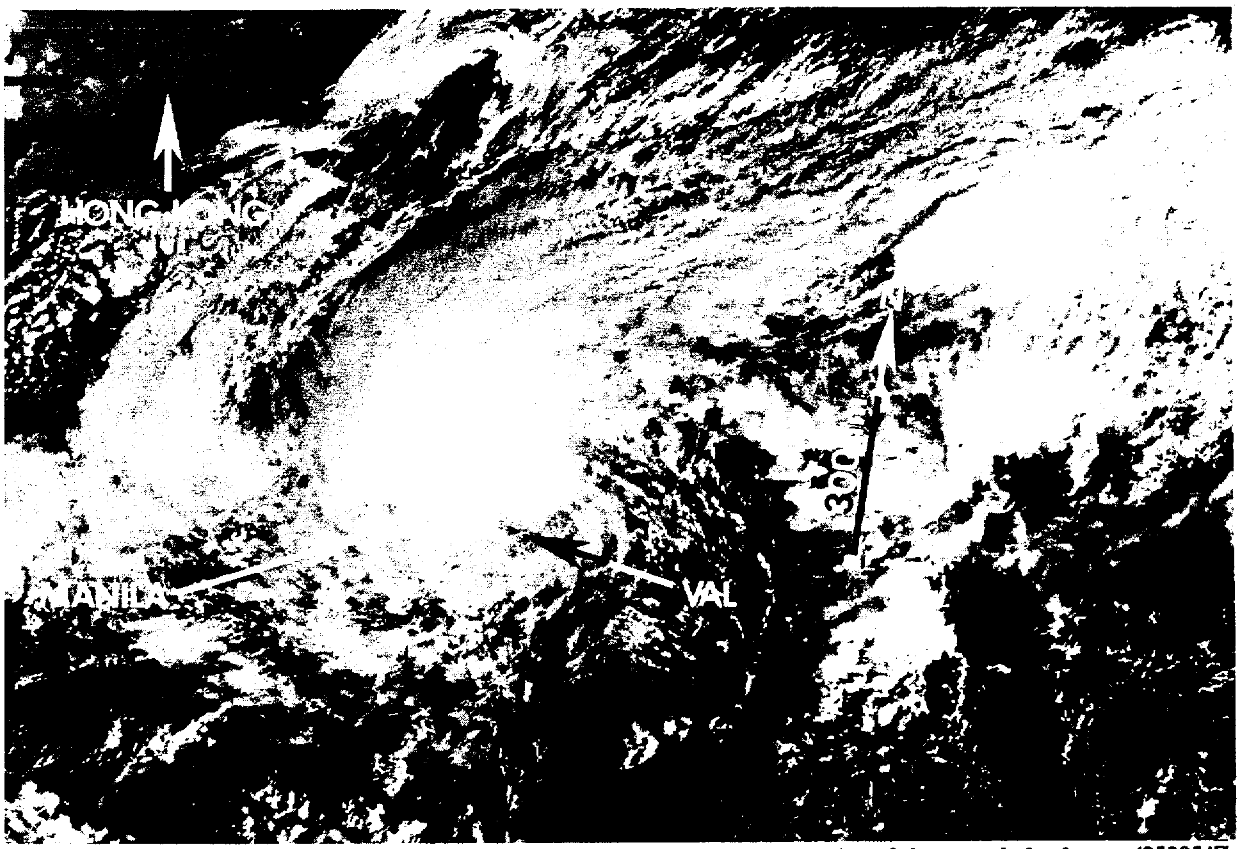


Figure 3-26-3. Val's exposed low-level circulation center appears at the southern edge of the central cloud mass (250054Z December DMSP visual imagery).

3. NORTH INDIAN OCEAN TROPICAL CYCLONES

Five significant tropical cyclones developed in the North Indian Ocean during 1988. This was average and well below 1987's all-time record of eight tropical cyclones. The only tropical cyclone to form in the Arabian Sea, Tropical Cyclone 01A, was also the only cyclone of the spring transition season. In contrast, the other four tropical cyclones were all part of the fall transition season and occurred in the Bay of Bengal. The most damaging of these, Tropical Cyclone 04B, was one of the most intense to strike the Ganges River delta in this century. The spring and fall in the North Indian Ocean are periods of transition between major climatic controls - the summer, or southwest monsoon, and the winter, or northeast monsoon - and the most favorable seasons for tropical cyclone formation. Tables 3-5 and 3-6 provide a summary of information for 1988 and comparison with earlier years.

TABLE 3-5

1988 SIGNIFICANT TROPICAL CYCLONES
NORTH INDIAN OCEAN

TROPICAL CYCLONE	PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/S)	ESTIMATED MSLP - MB
TC 01A	10 JUN - 12 JUN	10	35 (18)	996
TC 02B	18 OCT - 19 OCT	3	35 (18)	996
TC 03B	18 NOV	3	55 (28)	984
TC 04B	24 NOV - 29 NOV	22	110 (57)	933
TC 05B	07 DEC - 08 DEC	6	45 (23)	991
	TOTAL	44		

TABLE 3-6

FREQUENCY OF NORTH INDIAN OCEAN
TROPICAL CYCLONES

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1971*	-	-	-	-	-	0	0	0	0	1	1	0	2
1972*	0	0	0	1	0	0	0	0	2	0	1	0	4
1973*	0	0	0	0	0	0	0	0	0	1	2	1	4
1974*	0	0	0	0	0	0	0	0	0	0	1	0	1
1975	1	0	0	0	2	0	0	0	0	1	2	0	6
1976	0	0	0	1	0	1	0	0	1	1	0	1	5
1977	0	0	0	0	1	1	0	0	0	1	2	0	5
1978	0	0	0	0	1	0	0	0	0	1	2	0	4
1979	0	0	0	0	1	1	0	0	2	1	2	0	7
1980	0	0	0	0	0	0	0	0	0	0	1	1	2
1981	0	0	0	0	0	0	0	0	0	1	1	1	3
1982	0	0	0	0	1	1	0	0	0	2	1	0	5
1983	0	0	0	0	0	0	0	1	0	1	1	0	3
1984	0	0	0	0	1	0	0	0	0	1	2	0	4
1985	0	0	0	0	2	0	0	0	0	2	1	1	6
1986	1	0	0	0	0	0	0	0	0	0	2	0	3
1987	0	1	0	0	0	2	0	0	0	1	2	2	8
1988	0	0	0	0	0	1	0	0	0	1	2	1	5
(1975-1988)													
AVERAGE	0.1	0.1	0.0	0.1	0.6	0.5	0.0	0.1	0.2	1.0	1.5	0.5	4.7
TOTAL	2	1	0	1	9	7	0	1	3	14	21	7	66

* JTWC WARNING RESPONSIBILITY BEGAN ON 4 JUNE 1971 FOR THE BAY OF BENGAL, EAST OF 90° EAST LONGITUDE. AS DIRECTED BY CINCPAC, JTWC ISSUED WARNINGS ONLY FOR THOSE TROPICAL CYCLONES THAT DEVELOPED OR TRACKED THROUGH THAT PART OF THE BAY OF BENGAL. COMMENCING WITH THE 1975 TROPICAL CYCLONE SEASON, JTWC'S AREA OF RESPONSIBILITY WAS EXTENDED WESTWARD TO INCLUDE THE WESTERN PART OF THE BAY OF BENGAL AND THE ENTIRE ARABIAN SEA. ALL FOUR TROPICAL CYCLONE FORMATION ALERTS DEVELOPED INTO SIGNIFICANT TROPICAL CYCLONES. FORMATION ALERTS WERE ISSUED FOR ALL OF THE SIGNIFICANT TROPICAL CYCLONES THAT DEVELOPED IN 1988, EXCEPT TROPICAL CYCLONE 02B.

WARNINGS: NUMBER OF CALENDAR WARNING DAYS: 14
THERE WERE NO CALENDAR WARNING DAYS WITH TWO OR MORE TROPICAL CYCLONES.

4. NORTH INDIAN OCEAN CLIMATOLOGY

This climatology* of peak tropical cyclone intensity for the North Indian Ocean was prepared from data in the 1971 through 1988 Annual Tropical Cyclone Reports and Annual Typhoon Reports. JTWC became responsible for the Bay of Bengal east of 90° East longitude on 4 June 1971. Table 3-7 lists the number of significant tropical cyclones by peak intensity and month for the Bay of Bengal. JTWC became responsible for the Arabian Sea in 1975; thus the Arabian Sea data are from 1975 through 1988. Table 3-8 lists the number of significant tropical cyclones by peak intensity and month for the Arabian Sea.

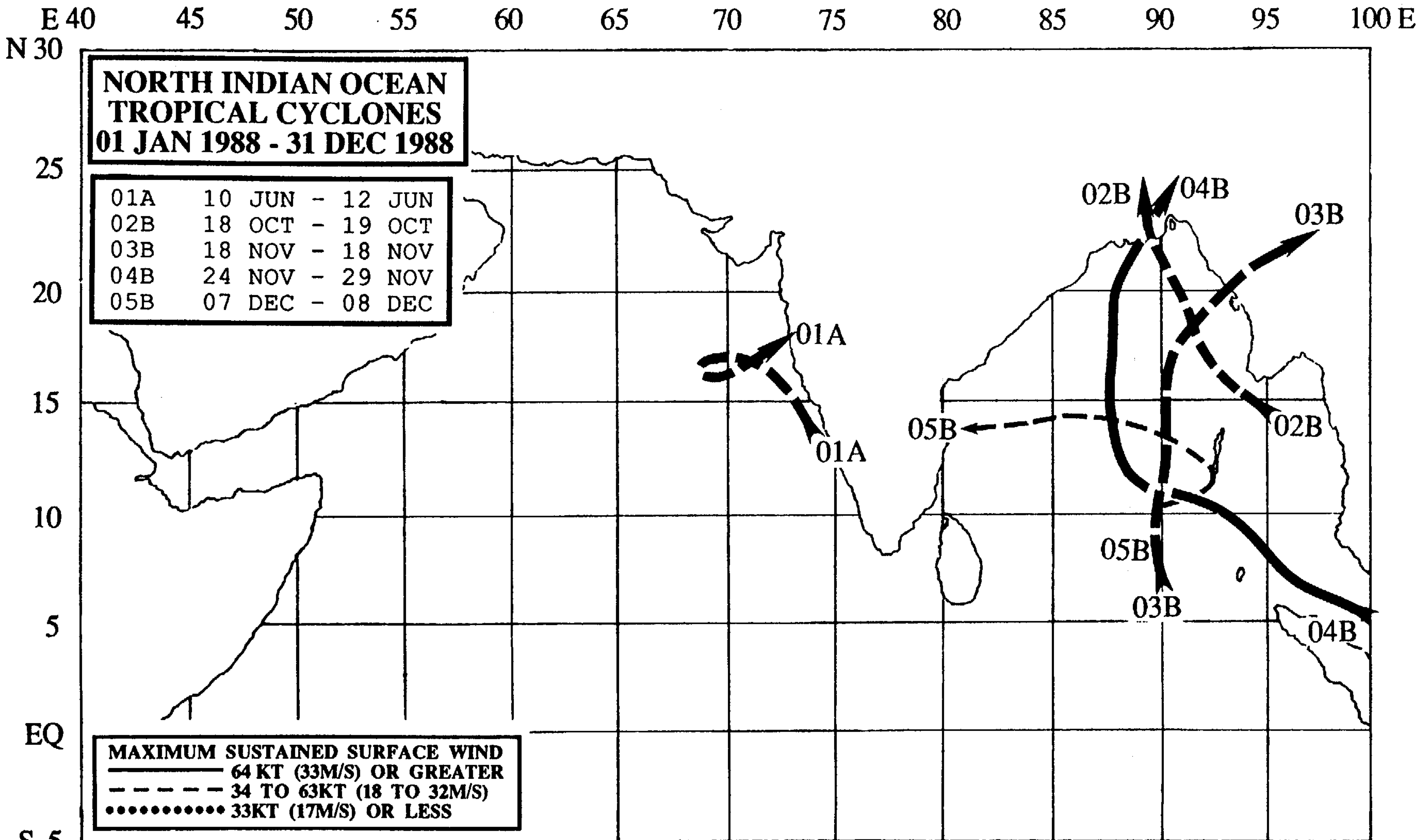
Note: data for tropical cyclones that passed from the Bay of Bengal into the Arabian Sea were included in the statistics for both basins when the peak intensity was 35 kt (18 m/sec) or greater in both basins. If the peak intensity was 35 kt (18 m/sec) or greater and the tropical cyclone transitioned from one month to another, it was included in each month's statistics. Tropical cyclones with less than 35 kt (18 m/sec) were not considered. The data set for 1971 through 1974 in the Bay of Bengal is incomplete, because the AOR at that time only included tropical cyclones that developed or tracked east of 90° East longitude. These years are included since they provide limited additional data on the peak intensities.

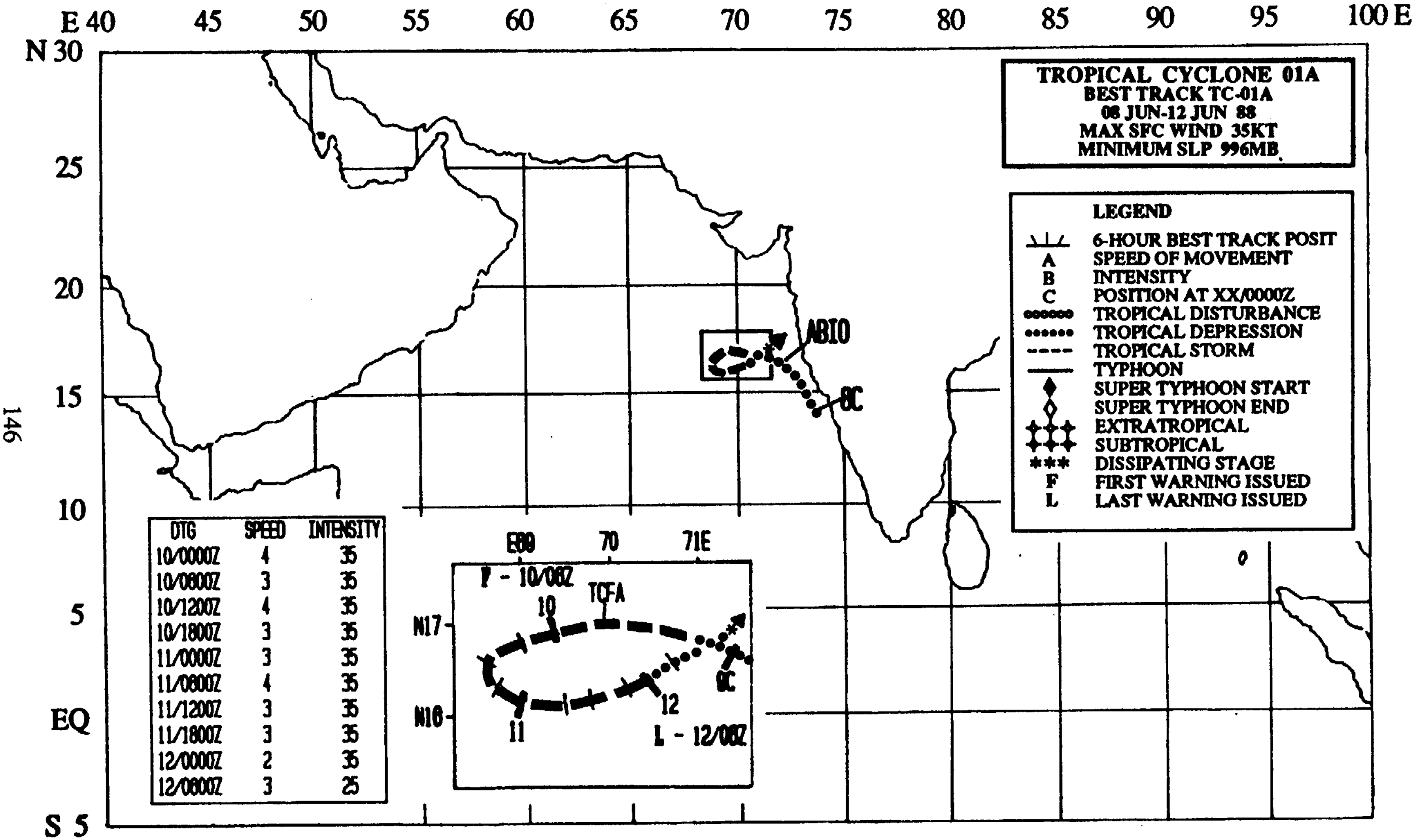
* Climatology prepared by Capt John Rogers, USAF.

TABLE 3-7 BAY OF BENGAL (1971-1988)

Peak Intensity (kt)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
125					1								1
120													0
115											1		1
110											1		1
105													0
100										1			1
95											1		1
90											1		1
85				1	1						1		3
80									1				1
75					1						2	2	5
70									1		1		2
65											1		1
60					3						1	1	5
55		1				2					5	1	9
50				1	1					5	3	1	11
45	1									2	1	1	5
40	1								1	4			6
35	1									2		3	6
Total	3	1	0	2	7	2	0	0	3	14	19	9	60

Peak Intensity (kt)	TABLE 3-8 ARABIAN SEA (1975-1988)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
95					1								1
90											1		1
85													0
80										1	1		2
75													0
70											1		1
65													0
60						1				1	1	1	4
55									1				1
50					1	2				1			4
45					1			1			1	1	4
40						1					1		2
35						1					2		3
Total	0	0	0	0	3	5	0	1	1	3	8	2	23


NORTH INDIAN OCEAN
TROPICAL CYCLONES
01 JAN 1988 - 31 DEC 1988
01A 10 JUN - 12 JUN
02B 18 OCT - 19 OCT
03B 18 NOV - 18 NOV
04B 24 NOV - 29 NOV
05B 07 DEC - 08 DEC
MAXIMUM SUSTAINED SURFACE WIND
64 KT (33M/S) OR GREATER
34 TO 63KT (18 TO 32M/S)
33KT (17M/S) OR LESS
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5
01A
01A
02B
02B
03B
03B
04B
04B
05B
05B



DTG	SPEED	INTENSITY
10/0000Z	4	35
10/0600Z	3	35
10/1200Z	4	35
10/1800Z	3	35
11/0000Z	3	35
11/0600Z	4	35
11/1200Z	3	35
11/1800Z	3	35
12/0000Z	2	35
12/0600Z	3	25

TROPICAL CYCLONE 01A

Tropical Cyclone 01A was the first and only significant tropical cyclone to develop in the North Indian Ocean during the spring transition season. Due to persistent upper-level cloudiness (Figure 3-01A-1) the system proved difficult to position, track and forecast. Tropical Cyclone 01A was initially identified as an area of convection about 240 nm (444 km) south of Bombay, India on 8 June by the Air Force Global Weather Central. It was first mentioned on the Significant Tropical Weather Advisory at 081800Z. After satellite imagery indicated a central dense overcast, increased convection and upper-level organization, a Tropical Cyclone Formation Alert was issued at 091430Z. The system's organization continued

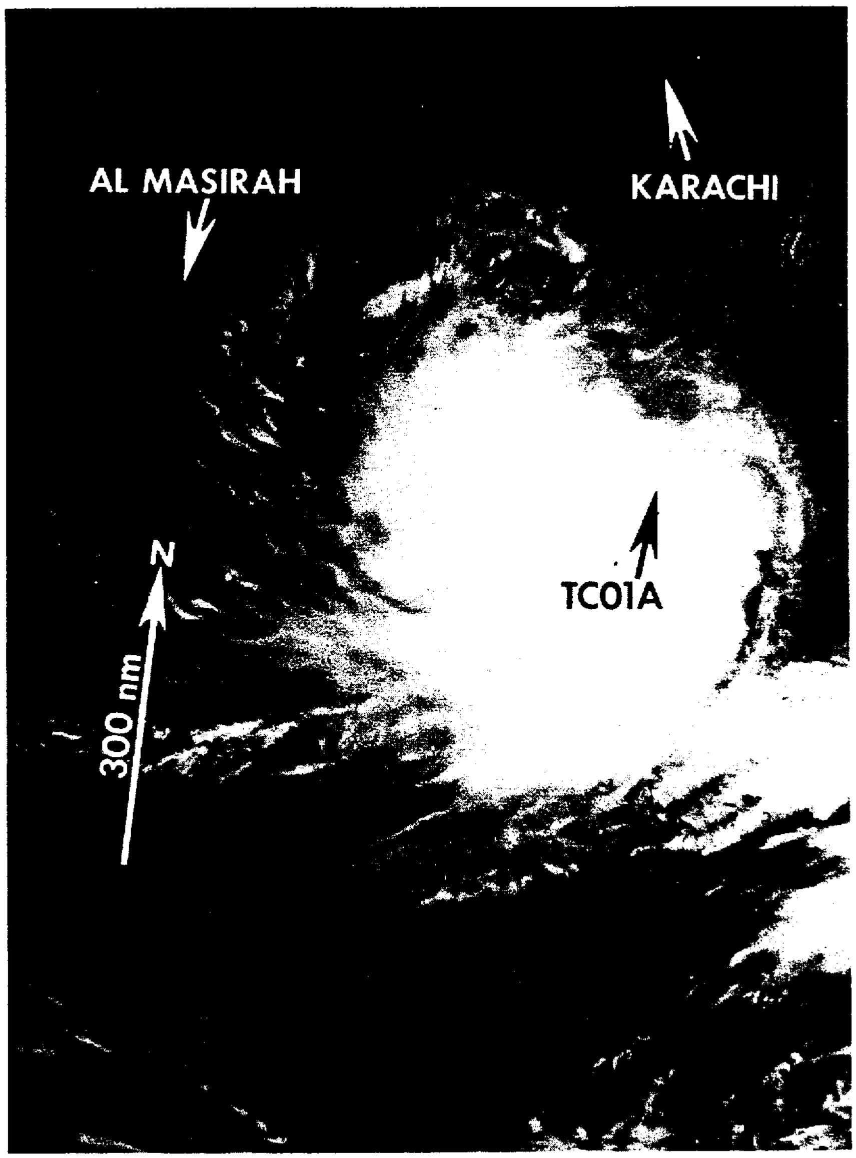


Figure 3-01A-1. The bright, cold cloudiness persisted over and masked the low-level circulation (100530Z June DMSP infrared imagery).

to improve and JTWC issued its first warning at 100000Z when satellite imagery and synoptic data indicated an intensity of 35 kt (18 m/sec). Finally, vertical wind shear exposed the low-level circulation center. As a result, the 110000Z warning was amended and relocated - the circulation center appeared 240 nm (407 km) east-southeast of the upper-level circulation center (Figure 3-01A-2). Unfavorable conditions aloft continued and at 120600Z the final warning was issued, as the tropical cyclone dissipated over water.

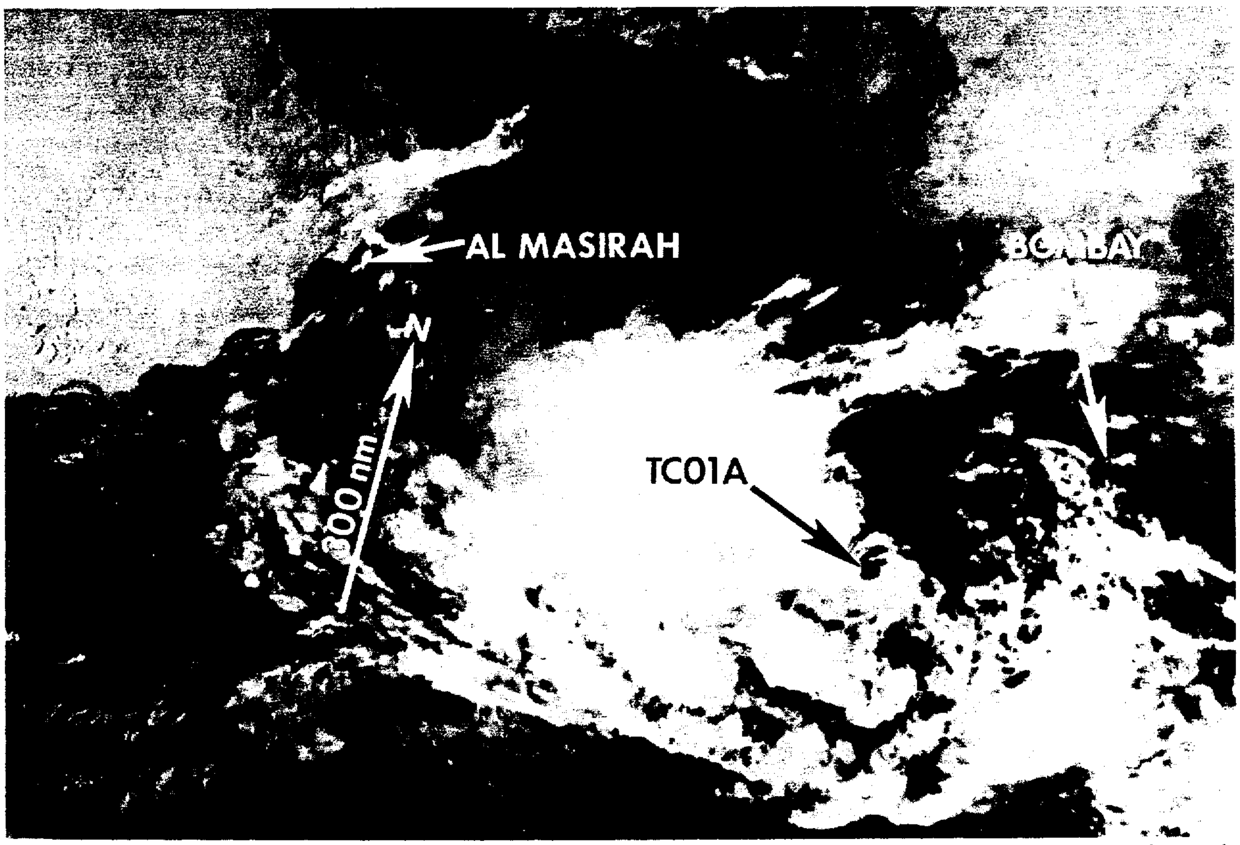


Figure 3-01A-2. The low-level circulation is exposed. Note the dust blowing seaward from coastal areas to the north (110511Z June DMSP visual imagery).

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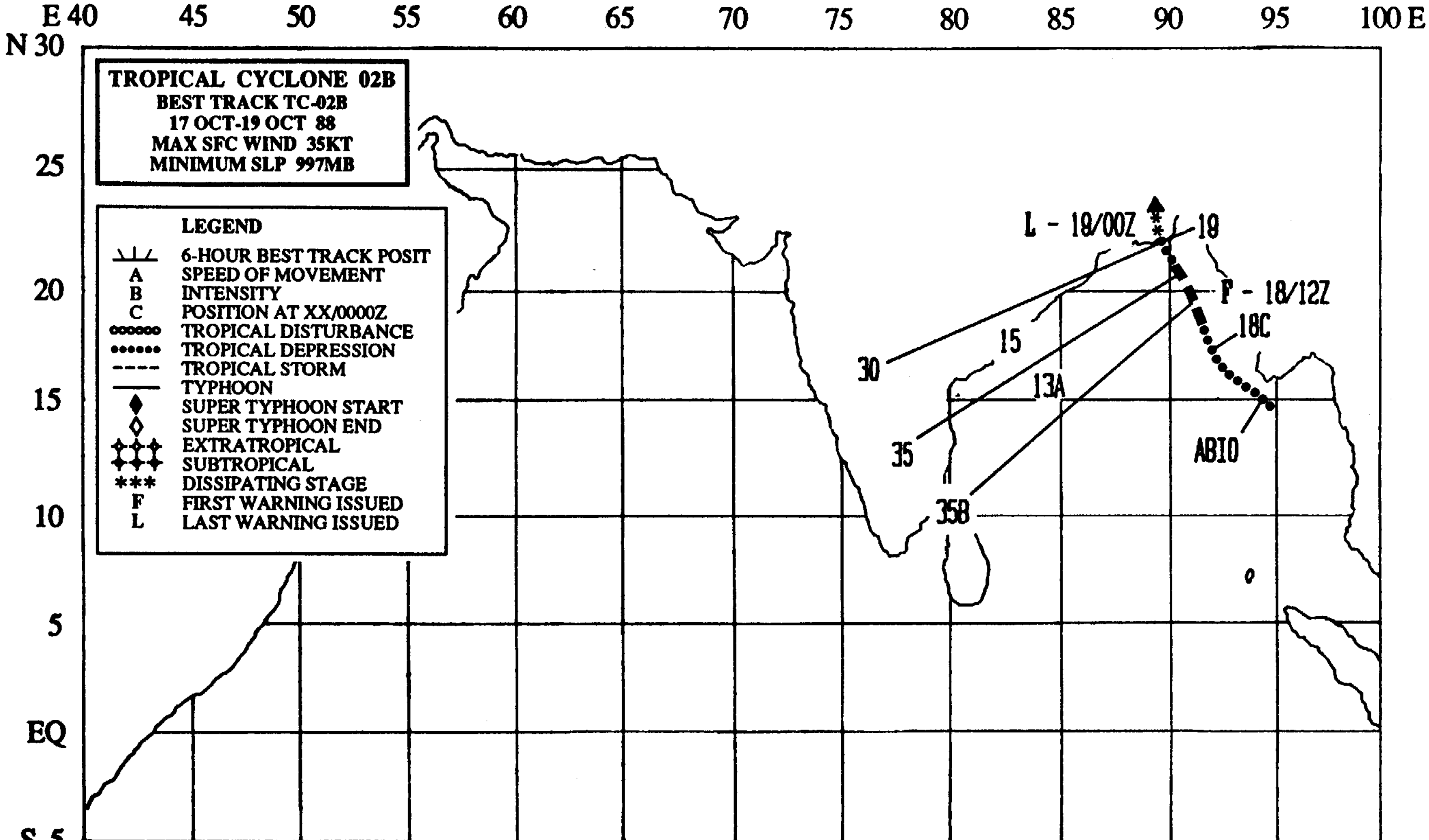

TROPICAL CYCLONE 02B
BEST TRACK TC-02B
17 OCT-19 OCT 88
MAX SFC WIND 35KT
MINIMUM SLP 997MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5
L - 19/00Z
19
F - 18/12Z
18C
ABIO
30
15
13A
35
35B

TROPICAL CYCLONE 02B

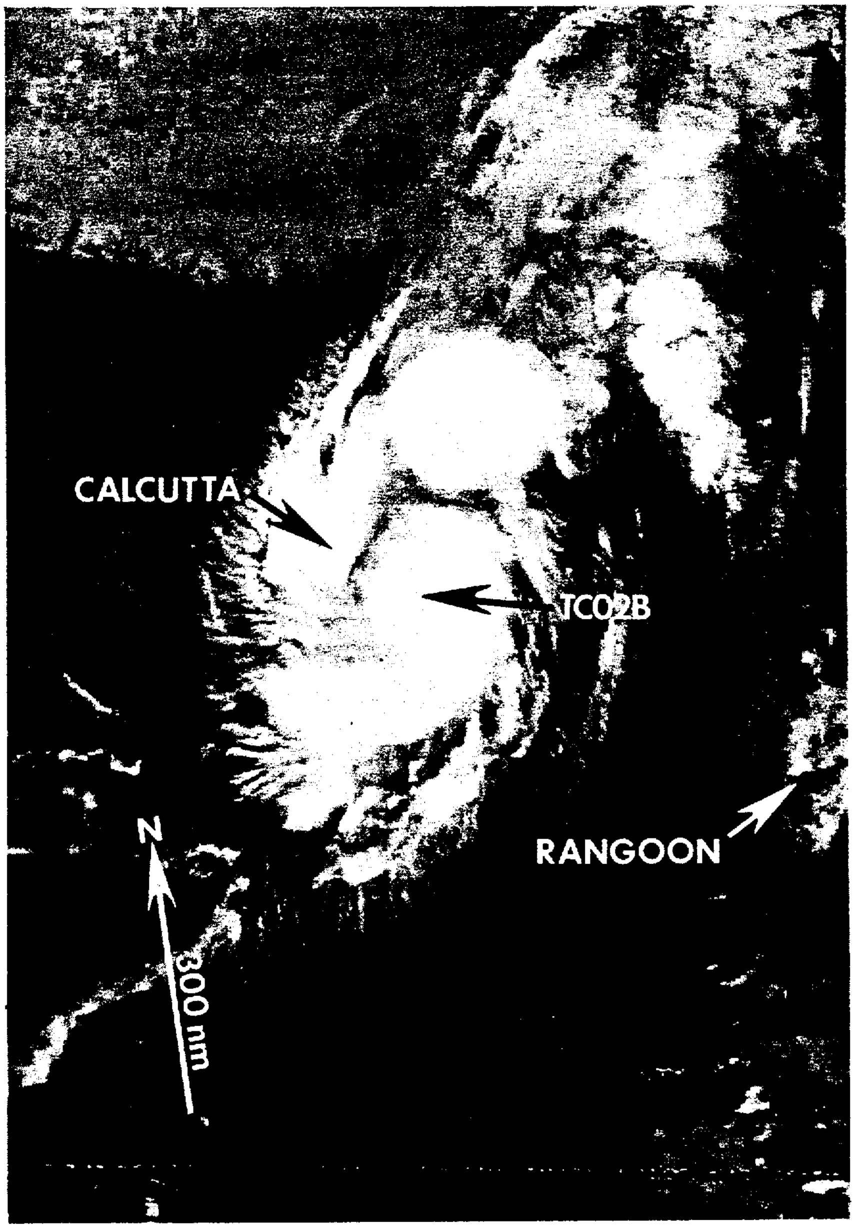
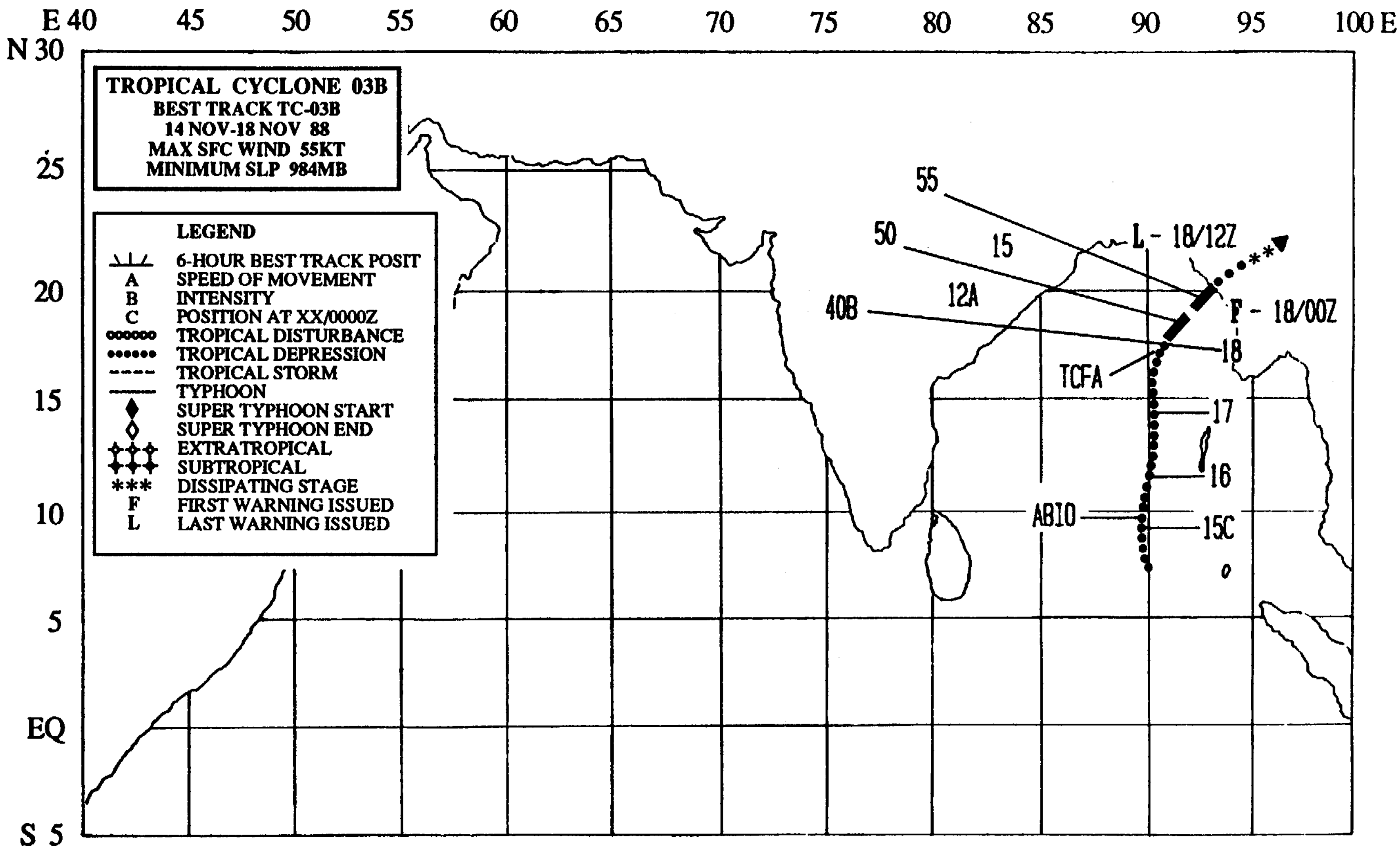


Figure 3-02B-1. The tropical disturbance was first detected 135 nm (250 km) southwest of Rangoon, Burma and the Significant Tropical Weather Advisory was reissued at 170800Z to include it. The first warning followed at 181200Z as the cyclone reached a peak intensity of 35 kt (18 m/sec). Once onshore, the final warning was issued at 190000Z. Press releases cited at least 35 deaths, more than 1000 injuries and an estimated 1500 missing. The fishing fleet was particularly hard hit and there were press reports of 15 ft (4.6 m) waves and winds as high as 65 kt (33 m/sec). The above photo shows Tropical Cyclone 02B at the coast of Bangladesh (182219Z October NOAA visual imagery).


TROPICAL CYCLONE 03B
BEST TRACK TC-03B
14 NOV-18 NOV 88
MAX SFC WIND 55KT
MINIMUM SLP 984MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5
55
50
15
12A
40B
L - 18/12Z
F - 18/00Z
18
TCFA
17
16
ABIO
15C

TROPICAL CYCLONE 03B

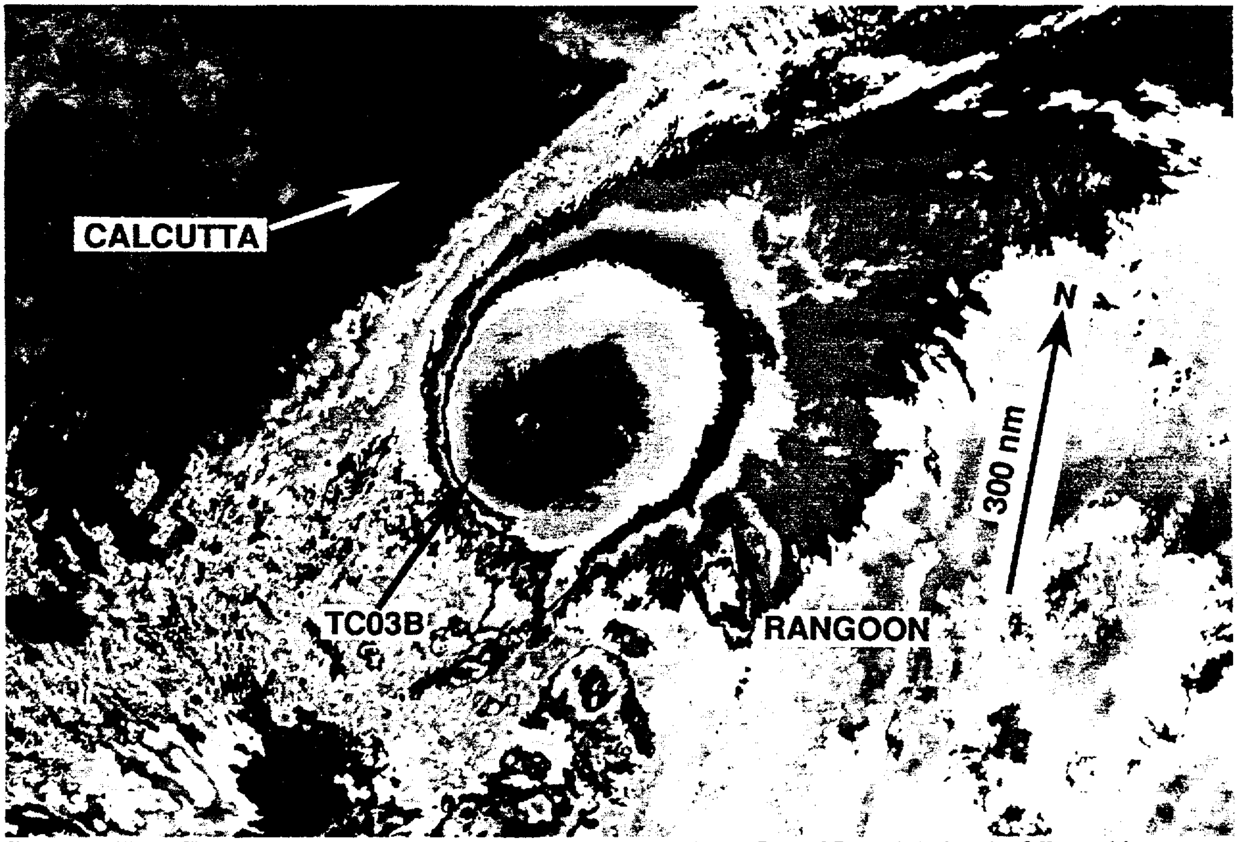
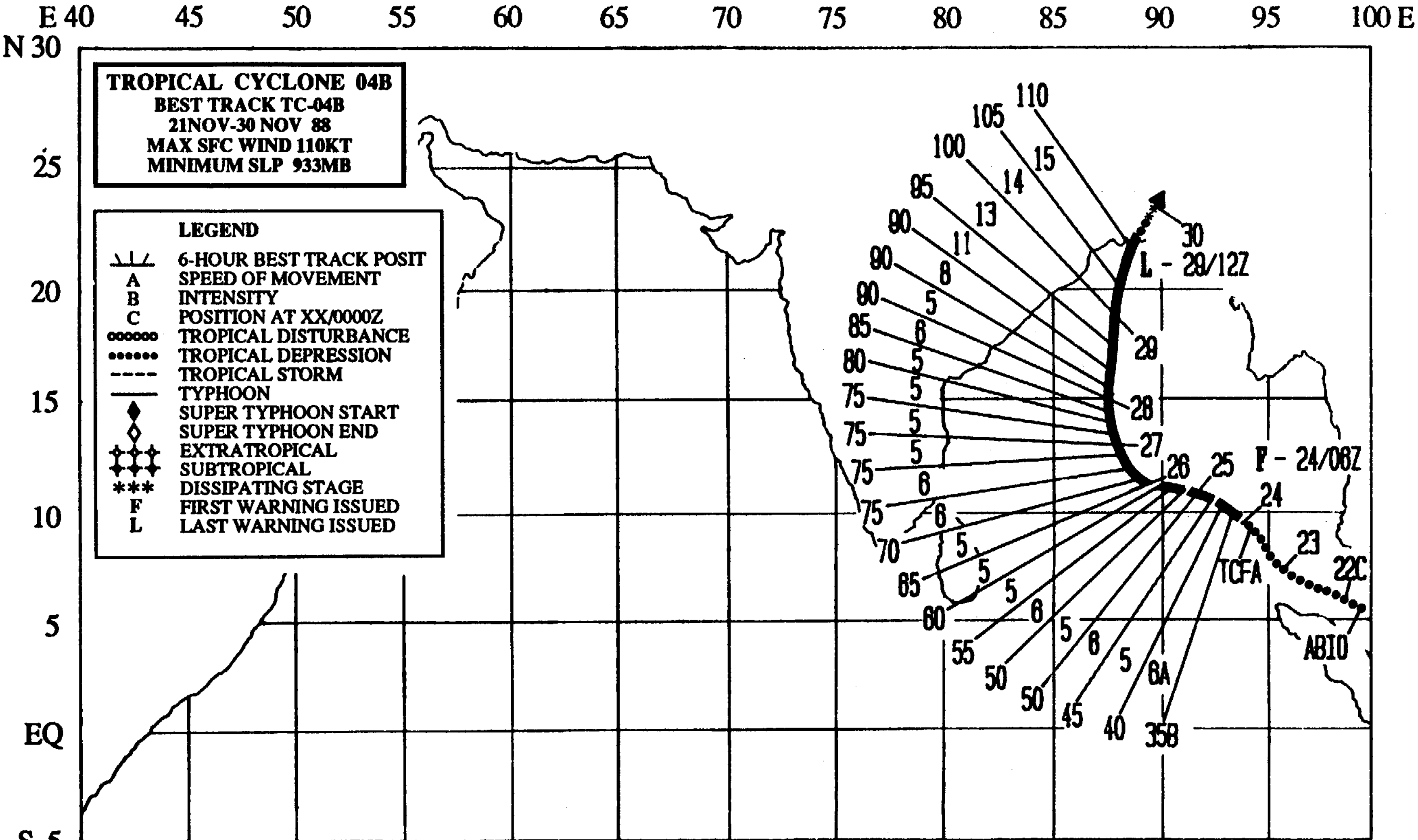


Figure 3-03B-1. The second significant tropical cyclone to develop in the Bay of Bengal during the fall transition season, Tropical Cyclone 03B was the first to make landfall over Burma. By 12 November the presence of Tropical Cyclone 01S in the South Indian Ocean strengthened the low-level westerlies along the equator and across the southern portion of the Bay of Bengal. As Tropical Cyclone 01S moved west-southwestward, a disturbance organized north of the equator. The Significant Tropical Weather Advisory was reissued at 150600Z to describe the circulation. The system tracked northward around the western edge of a subtropical anticyclone. At 172230Z, a Tropical Cyclone Formation Alert was issued after satellite intensity analysis indicated sustained surface winds of 30 kt (15 m/sec). The disturbance's organization continued to improve and, at 180000Z, the first warning was issued. The final warning followed 12-hours later as Tropical Cyclone 03B made landfall on the coast of Burma. The enhanced infrared picture above shows the tropical cyclone during intensification (180309Z November DMSP infrared imagery).


TROPICAL CYCLONE 04B
BEST TRACK TC-04B
21NOV-30 NOV 88
MAX SFC WIND 110KT
MINIMUM SLP 933MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
L - 29/12Z
F - 24/06Z
TCFA
ABIO
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5

TROPICAL CYCLONE 04B

Tropical Cyclone 04B was the second of two significant tropical cyclones to develop in the Bay of Bengal during November. This cyclone (Figure 3-04B-1) was one of the most intense to strike Bangladesh and eastern India in this century.

The formation of Tropical Cyclone 04B was preceded by a sustained surge of the northeast winter monsoon and low-level convergence across the Malay Peninsula. Beginning 19 November, prolonged, heavy rains occurred in northern Malaysia and southern Thailand. Flash flooding and mud-

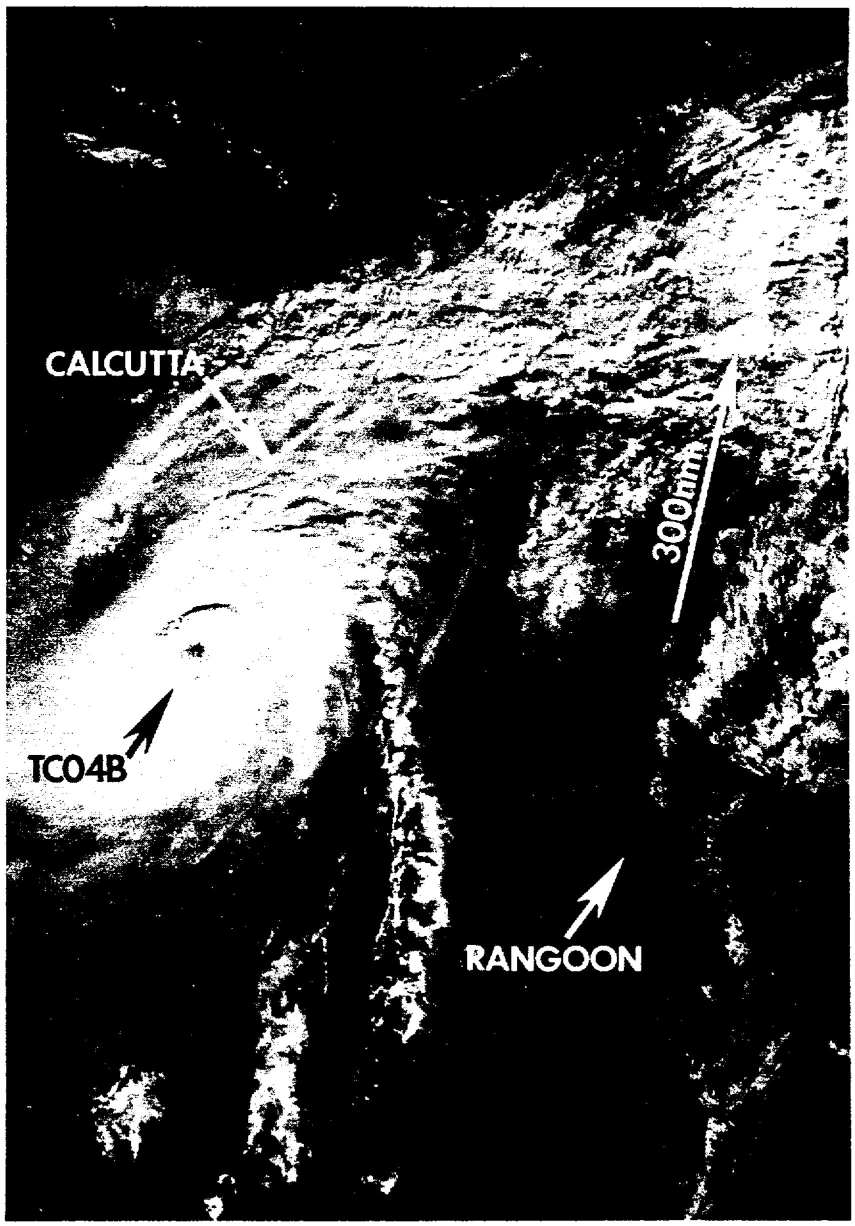


Figure 3-04B-1. Tropical Cyclone 04B approaching the coast with maximum sustained winds of over 100 kt (51 m/sec) (290251Z November DMSP visual imagery).

slides from deforested hillsides swept across low-lying villages, killing at least 1000 people and rendering another 100,000 homeless. At 211800Z, Tropical Cyclone 04B consolidated in the Straits of Malacca and was first mentioned on the Significant Tropical Weather Advisory. The central convection, organization and satellite intensity estimates quickly increased and a Tropical Cyclone Formation Alert was issued at 231830Z. The system tracked northwestward while remaining south of the subtropical ridge. The central convection continued to increase and organize, and the first warning followed at 240600Z.

Shortly after attaining typhoon intensity, at 260000Z, the system began tracking around the western periphery of the mid-level subtropical ridge. The ridge was broad, which allowed the tropical cyclone to move northward for three days prior to making landfall over the delta of the Ganges River. During this period Tropical Cyclone 04B gradually intensified, reaching a peak of 110 kt (57 m/sec) at the coast. As the cyclone swept inland, it ravaged the southern Bangladesh and northeastern India coastal zones, leaving at least 2000 people dead, 6000 missing and almost three million homeless. Up to seventy percent of the crops ready for harvest were destroyed. Bangladesh, which was attempting to recover from earlier flooding during the summer, in which 1500 lives were lost and countless were left homeless, was particularly hard hit.

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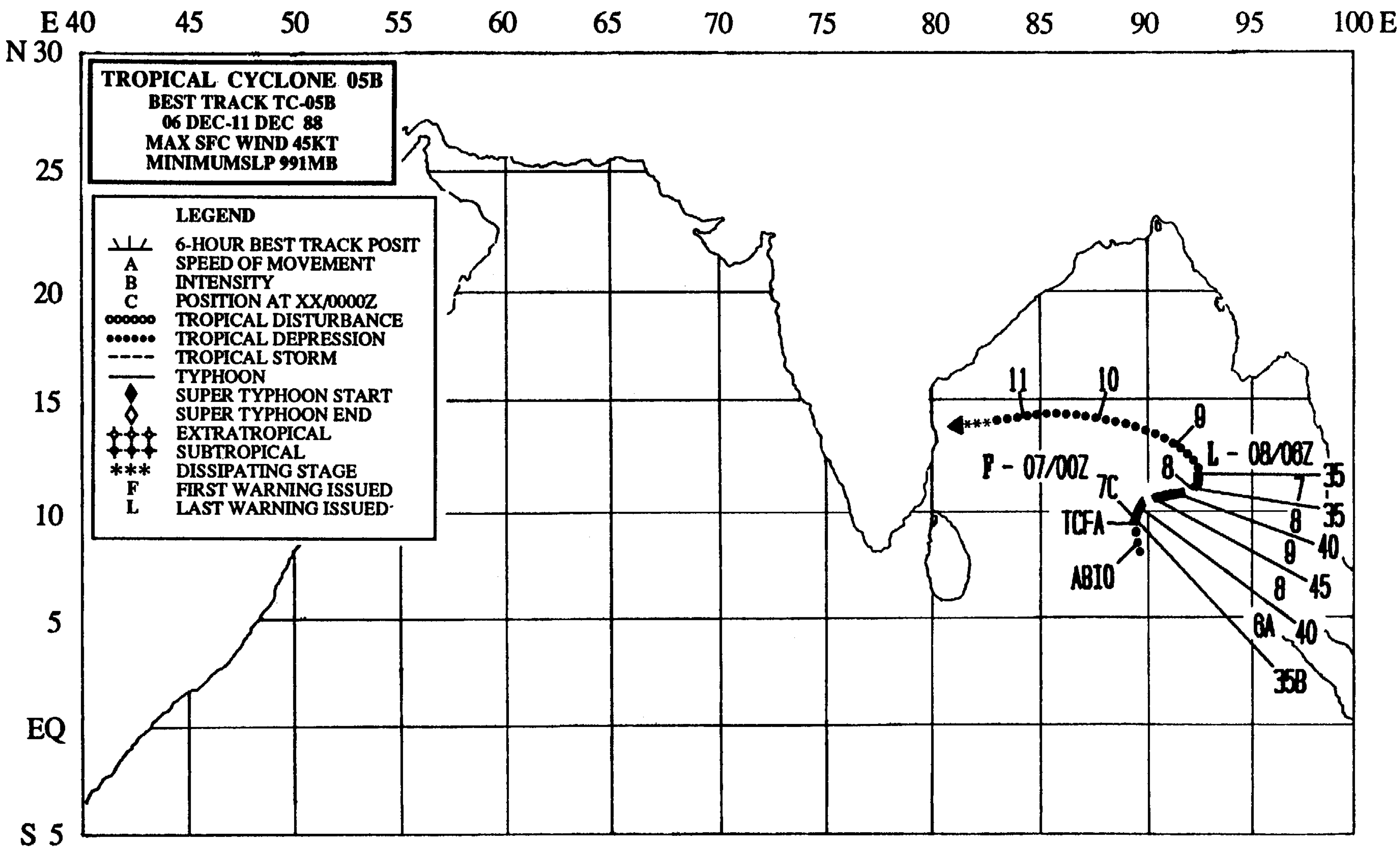
TROPICAL CYCLONE 05B
BEST TRACK TC-05B
06 DEC-11 DEC 88
MAX SFC WIND 45KT
MINIMUMSLP 991MB
LEGEND
6-HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
*** DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED
E 40
45
50
55
60
65
70
75
80
85
90
95
100 E
N 30
25
20
15
10
5
EQ
S 5
F - 07/00Z
L - 08/06Z
TCFA
ABIO
11
10
9
8
7C
6A
35B
35
40
45

TROPICAL CYCLONE 05B

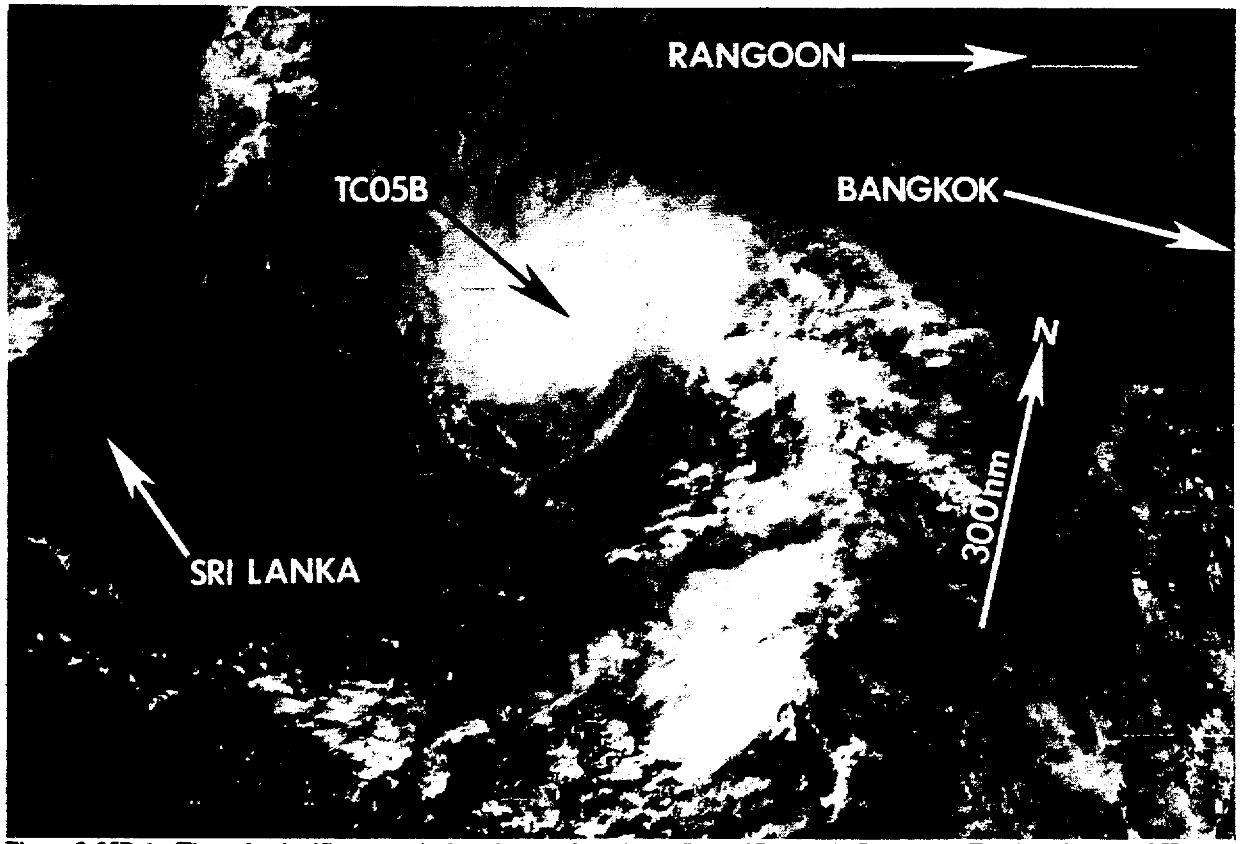

Figure 3-05B-1. The only significant tropical cyclone to form in the Bay of Bengal in December, Tropical Cyclone 05B was first detected as a poorly defined area of cloudiness in the southern Bay of Bengal. The Significant Tropical Weather Advisory was reissued at 061230Z to include the disturbance as suspect for further development. The cloud system continued to develop and a Tropical Cyclone Formation Alert was issued at 062100Z. The first warning followed at 070000Z, after satellite intensity analysis indicated 35 kt (18 m/sec) sustained surface winds. Once the peak intensity of 45 kt (23 m/sec) was reached, the tropical cyclone began to weaken and the final warning was issued at 080600Z. The remnants of Tropical Cyclone 05B persisted and struck off westward across the Bay of Bengal for three additional days, before dissipating along the east coast of India north of the city of Madras. The photo above shows Tropical Cyclone 05B shortly before peak intensity (070332Z December DMSP visual imagery).

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