CHAPTER III – SUMMARY OF TROPICAL CYCLONES

1. WESTERN NORTH PACIFIC TROPICAL CYCLONES

During 1978, the western North Pacific experienced a near-climatological average with a total of 32 cyclones (Table 3-1; cyclones 10 and 30 occurred in the central North Pacific area). Four, significant tropical cyclones never developed beyond tropical depression (TD) stage. Of the 2° that became tropical storms (TS), 15 developed to typhoon (TY) stage only one of which reached the 130 kt (67 m/sec) intensity necessasry to be classified as a super typhoon (ST).

Even though the 1?78 season had a near -average number of cyclones (Tables 3-2 and 3-3), it was a season full of surprises. Ten of the tropical storms and typhoons exhibited erratic movement. Typhoon Carmen remained quasi-stationary for three days over the East China Sea. Typhoon Faye executed a large anticyclonic loop and subsequently underwent explosive deepening as the surface central pressure fell 18 mb in six hours. The most ill-behaved typhoon of the season, Trix, truly lived up to her name. As Tropical Storm Kit crossed Luzon, the surface circulation dissipated while the mid- and upper-level circulations continued across and eventually became aligned with a secondary or "lee-side" low that had formed west of Luzon. Tropical Storms Hester and Phyllis attained post-recurvature speeds of 40 kt (74 km/hr) and 50 kt (93 km/hr), respectively, in extratropical transition. Typhoons Virginia and Mamie were unusually compact and could, thus, be termed midget typhoons. Virginia also traveled the farthest north (47N) while retaining tropical characteristics. Having first been detected in the central Pacific near 175W, Super Typhoon Rita traveled a record distance for the season (4142 nm (7671 km)), and was second overall only to Typhoon Sarah of 1976 (4499 nm (8332 km)).

During 1978, 32 Tropical Cyclone Formation Alerts were issued. Of these, 27 (84%) developed into significant tropical cyclones (Table 3-4). Five tropical cyclones were immediately placed into warning status without first issuing Formation Alerts due to their rapid development.

During 1978, there were 715 warnings issued for the WESTPAC region with a total of 131 "warning days" (Table 3-5). On 46 of these 131 days, two or more cyclones existed and on 16 days three cyclones were in existence.

TABLE 3-1. WESTERN NORTH PACIFIC

1978 SIGNIFICANT TROPICAL CYCLONES

CYCLONE	TYPE	NAME	PRD OF WARNING	CALENDER DAYS OF WARNING	MAX SFC WIND	MIN OBS SLP	NO. OF WARNINGS TOTAL	NO. OF WARNINGS AS TY	DISTANCE TRAVELLED
01	TS	NADINE	08 JAN-13 JAN	6	60	973	21		1340
02	TY	OLIVE	18 APR-26 APR	9	85	955	36	14	2669
03	TS	POLLY	16 JUN-20 JUN	5	50	985	16		788
04	TS	ROSE	23 JUN-24 JUN	2	40	993	7		352
05	TS	SHIRLEY	30 JUN-30 JUN	1	35	990	3		161
06	TY	TRIX	13 JUL-22 JUL	10	70	967	38	9	2326
07	TY	VIRGINIA	23 JUL-02 AUG	11	70	972	43	31	2052
08	TY	WENDY	24 JUL-03 AUG	11	80	962	42	27	1372
09	TS	AGNES	24 JUL-30 JUL	7	50	985	22		667
11	TS	BONNIE	10 AUG-12 AUG	3	40	984	9		481
12	TY	CARMEN	11 AUG-20 AUG	10	80	961	37	16	2076
13	TS	DELLA	11 AUG-13 AUG	3	45	984	10		774
14	TD	TD-14	19 AUG-20 AUG	2	30	991	6		556
15	TY	ELAINE	23 AUG-28 AUG	6	65	974	20		1036
16	TY	FAYE	28 AUG-07 SEP	11	105	936	44	17	2127
17	TS	GLORIA	29 AUG-01 SEP	4	40	990	12		553
18	TS	HESTER	30 AUG-01 SEP	3	50	987	11		851
19	TY	IRMA	12 SEP-15 SEP	4	65	972	15	3	854
20	TY	JUDY	13 SEP-17 SEP	5	90	950	18	10	1296
21	TS	KIT	21 SEP-26 SEP	6	50	992	21		1382
22	TY	LOLA	24 SEP-03 OCT	10	75	963	35	13	1672
23	TY	MAMIE	30 SEP-04 OCT	5	70	963	19	3	1578
24	TS	NINA	08 OCT-17 OCT	10	60	981	37		1299
25	TY	ORA	10 OCT-15 OCT	6	85	944	22	7	1370
26	TD	TD-26	11 OCT-12 OCT	2	30	998	7		519
27	TD	TD-27	15 OCT-16 OCT	2	20	1003	6		155
28	TY	PHYLLIS	15 OCT-22 OCT	8	95	953	30	17	1687
29	ST	RITA	17 OCT-30 OCT	14	155	878	51	34	4142
31	TS	TESS	01 NOV-07 NOV	7	60	975	22		1346
32	TD	TD-32	17 NOV-20 NOV	4	25	1002	12		296
33	TY	VIOLA	17 NOV-24 NOV	8	125	911	29	15	2042
34	TS	WINNIE	27 NOV-30 NOV	4	55	977	14		1287
			1978 TOTALS	131**			715	216	

** OVERLAPPING DAYS INCLUDED ONLY ONCE IN SUM

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TABLE 3-2.

FREQUENCY OF TYPHOONS BY MONTH AND YEAR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
AVERAGE (1945-58)	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
1959	0	0	0	1	0	0	1	5	3	3	2	2	17
1960	0	0	0	1	0	2	2	8	0	4	1	1	19
1961	0	0	1	0	2	1	3	3	5	3	1	1	20
1962	0	0	0	1	2	0	5	7	2	4	3	0	24
1963	0	0	0	1	1	2	3	3	3	4	0	2	19
1964	0	0	0	0	2	2	6	3	5	3	4	1	26
1965	1	0	0	1	2	2	4	3	5	2	1	0	21
1966	0	0	0	1	2	1	3	6	4	2	0	1	20
1967	0	0	1	1	0	1	3	4	4	3	3	0	20
1968	0	0	0	1	1	1	1	4	3	5	4	0	20
1969	1	0	0	1	0	0	2	3	2	3	1	0	13
1970	0	1	0	0	0	1	0	4	2	3	1	0	12
1971	0	0	0	3	1	2	6	3	5	3	1	0	24
1972	1	0	0	0	1	1	4	4	3	4	2	2	22
1973	0	0	0	0	0	0	4	2	2	4	0	0	12
1974	0	0	0	0	1	2	1	2	3	4	2	0	14
1975	1	0	0	0	0	0	1	3	4	3	2	0	15
1976	1	0	0	1	2	2	2	1	4	1	1	0	15
1977	0	0	0	0	0	0	3	0	2	3	2	1	11
1978	0	0	0	1	0	0	3	2	4	3	2	0	15
AVERAGE (1959-78)	0.25	0.05	0.10	0.70	0.85	0.95	2.85	3.55	3.25	3.20	1.65	0.55	17.95

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TABLE 3-3.

FREQUENCY OF TROPICAL STORMS AND TYPHOONS BY MONTH AND YEAR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
AVERAGE (1945-58)	0.4	0.1	0.4	0.5	0.8	1.3	3.0	3.9	4.1	3.3	2.7	1.1	21.6
1959	0	1	1	1	0	0	3	6	6	4	2	2	26
1960	0	0	0	1	1	3	3	10	3	4	1	1	27
1961	1	1	1	1	3	2	5	4	6	5	1	1	31
1962	0	1	0	1	2	0	6	7	3	5	3	2	30
1963	0	0	0	1	1	3	4	3	5	5	0	3	25
1964	0	0	0	0	2	2	7	9	7	6	6	1	40
1965	2	2	1	1	2	3	5	6	7	2	2	1	34
1966	0	0	0	1	2	1	5	8	7	3	2	1	30
1967	1	0	2	1	1	1	6	8	7	4	3	1	35
1968	0	0	0	1	1	1	3	8	3	6	4	0	27
1969	1	0	1	1	0	0	3	4	3	3	2	1	19
1970	0	1	0	0	0	2	2	6	4	5	4	0	24
1971	1	0	1	3	4	2	8	4	6	4	2	0	35
1972	1	0	0	0	1	3	6	5	4	5	2	3	30
1973	0	0	0	0	0	0	7	5	2	4	3	0	21
1974	1	0	1	1	1	4	4	5	5	4	4	2	32
1975	1	0	0	0	0	0	2	4	5	5	3	0	20
1976	1	1	0	2	2	2	4	4	5	1	1	2	25
1977	0	0	1	0	0	1	4	1	5	4	2	1	19
1978	1	0	0	1	0	3	4	7	5	4	3	0	28
AVERAGE (1959-78)	0.55	0.35	0.45	0.85	1.15	1.65	4.55	5.70	4.90	4.15	2.50	1.10	27.90

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TABLE 3-4.

FORMATION ALERT SUMMARY

WESTERN NORTH PACIFIC

YEAR	NUMBER OF ALERT SYSTEMS	ALERT SYSTEMS WHICH BECAME NUMBERED TROPICAL CYCLONES	TOTAL NUMBERED TROPICAL CYCLONES	DEVELOPMENT RATE
1972	41	29	32	71%
1973	26	22	23	85%
1974	35	30	36	86%
1975	34	25	25	74%
1976	34	25	25	74%
1977	26	20	21	77%
1978	32	27	32	84%

MONTHLY DISTRIBUTION

	J	F	M	A	M	J	J	A	S	O	N	D
FORMATION ALERTS	1	0	0	1	0	4	3	7	5	8	3	0

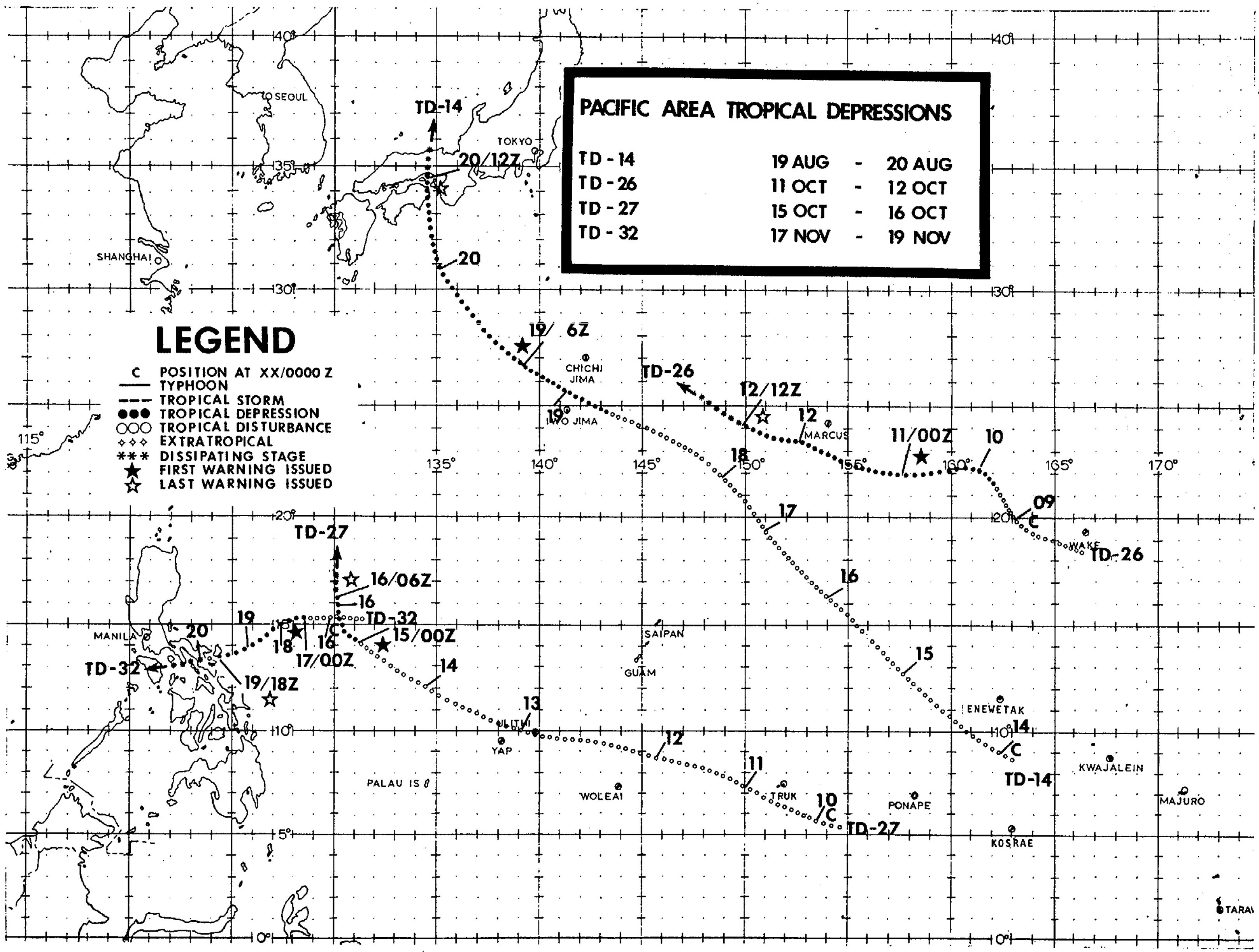
TABLE 3-5.

WARNING SUMMARY

WESTERN NORTH PACIFIC

	1978	AVERAGE 1959-1977
TOTAL NUMBER OF WARNINGS	715	669
NUMBER OF WARNING DAYS	131	141
NUMBER OF WARNING DAYS WITH 2 OR MORE CYCLONES	46	46
NUMBER OF WARNING DAYS WITH 3 OR MORE CYCLONES	16	9
TROPICAL DEPRESSIONS	4	5
TROPICAL STORMS	13	11
TYPHOONS	15	19
TOTAL TROPICAL CYCLONES	32	35

JTWC


PACIFIC AREA TROPICAL DEPRESSIONS
TD - 14 19 AUG - 20 AUG
TD - 26 11 OCT - 12 OCT
TD - 27 15 OCT - 16 OCT
TD - 32 17 NOV - 19 NOV
LEGEND
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SEOUL
TOKYO
SHANGHAI
MANILA
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
SAIPAN
GUAM
ENEWETAK
KWAJALEIN
MAJURO
YAP
ULITHI
PALAU IS
WOLEAI
TRUK
PONAPE
KOSRAE
TARAWA
TD-14
20/12Z
19/6Z
TD-26
12/12Z
11/00Z
TD-27
16/06Z
15/00Z
TD-32
17/00Z
19/18Z
115°
135°
140°
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165°
170°
40°
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20°
15°
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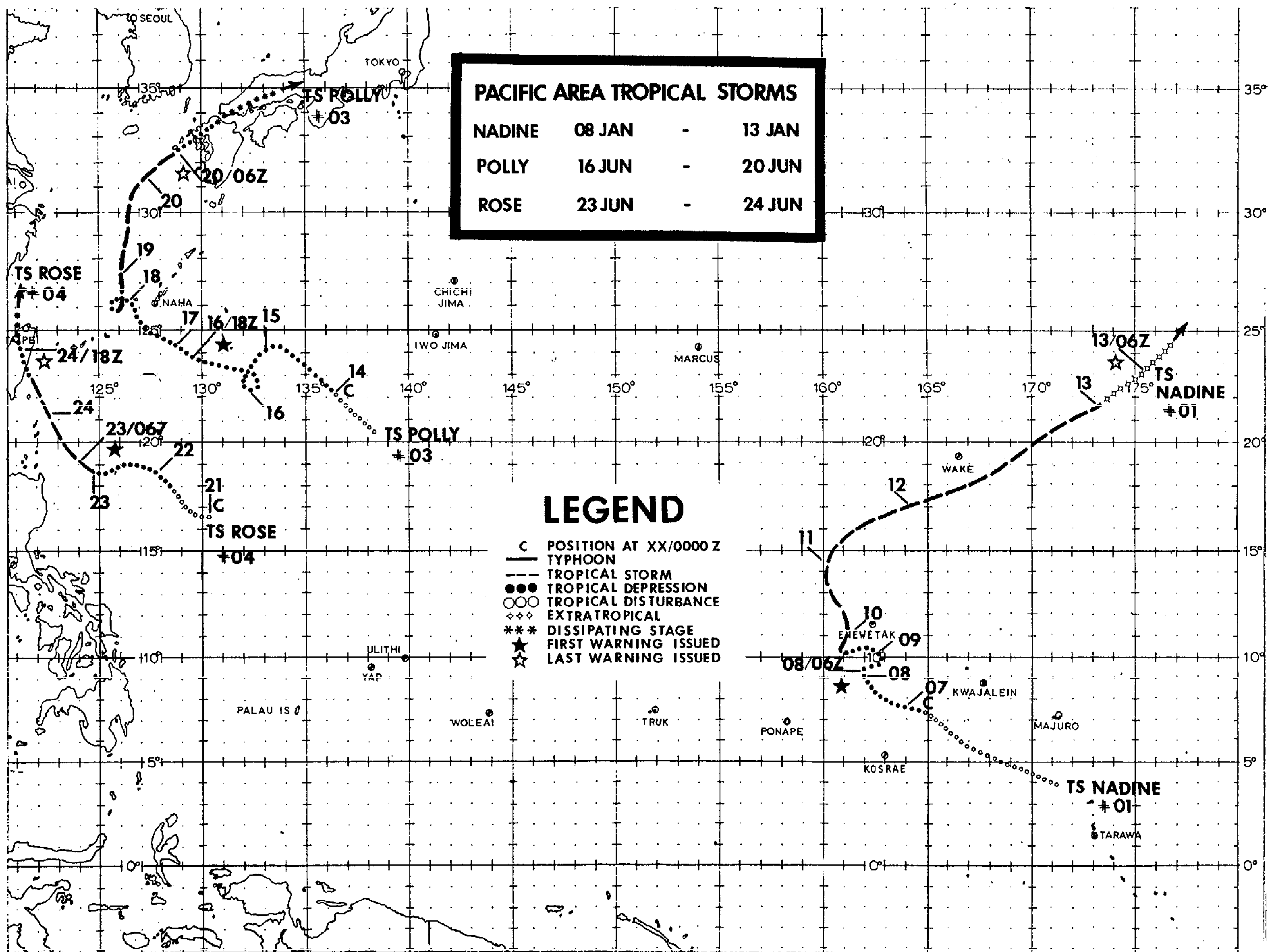
5°
0°


PACIFIC AREA TROPICAL STORMS
NADINE 08 JAN - 13 JAN
POLLY 16 JUN - 20 JUN
ROSE 23 JUN - 24 JUN
LEGEND
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
TS POLLY
03
20/06Z
TS ROSE
04
16/18Z
24/18Z
23/06Z
TS NADINE
01
13/06Z
08/06Z
SEOUL
TOKYO
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
ENEWETAK
KWAJALEIN
MAJURO
PONAPE
KOSRAE
TRUK
WOLEAI
ULITHI
YAP
PALAU IS
TARAWA
125°
130°
135°
140°
145°
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165°
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175°
35°
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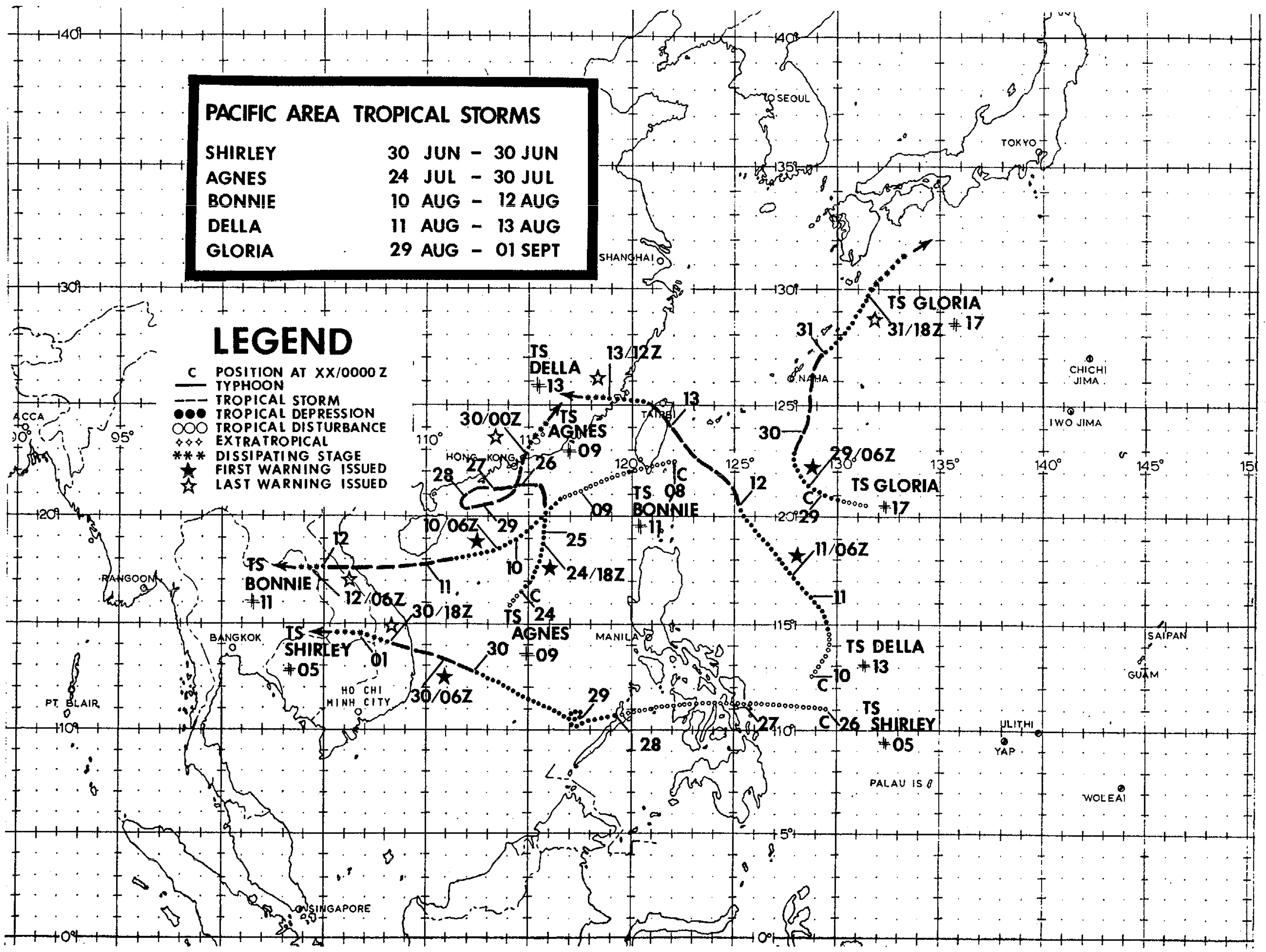
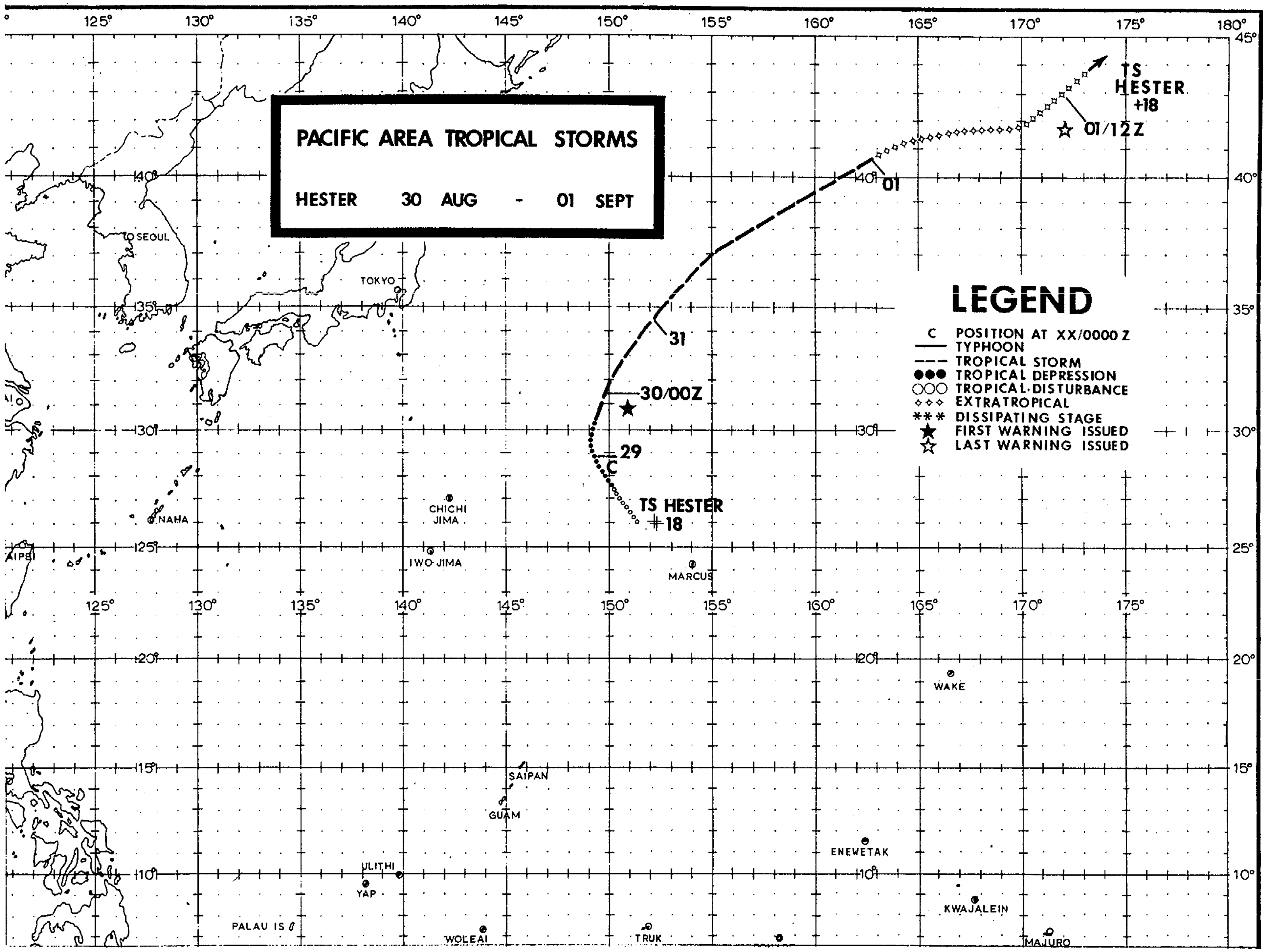
0°



PACIFIC AREA TROPICAL STORMS
SHIRLEY 30 JUN - 30 JUN
AGNES 24 JUL - 30 JUL
BONNIE 10 AUG - 12 AUG
DELLA 11 AUG - 13 AUG
GLORIA 29 AUG - 01 SEPT
LEGEND
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SEOUL
TOKYO
SHANGHAI
NAHA
TAIPEI
CHICHI JIMA
IWO JIMA
HONG KONG
RANGOON
BANGKOK
MANILA
HO CHI MINH CITY
PT BLAIR
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
SINGAPORE
TS GLORIA 31/18Z #17
TS GLORIA #17
29/06Z
TS DELLA #13
13/12Z
TS DELLA #13
11/06Z
TS AGNES #09
30/00Z
TS AGNES #09
24/18Z
TS BONNIE #11
TS 08 BONNIE #11
10/06Z
12/06Z
TS SHIRLEY #05
30/18Z
30/06Z
TS SHIRLEY #05


PACIFIC AREA TROPICAL STORMS
HESTER 30 AUG - 01 SEPT
LEGEND
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
TS HESTER +18
29
30/00Z
31
01
01/12Z
TS HESTER +18
SEOUL
TOKYO
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
ENEWETAK
KWAJALEIN
MAJURO
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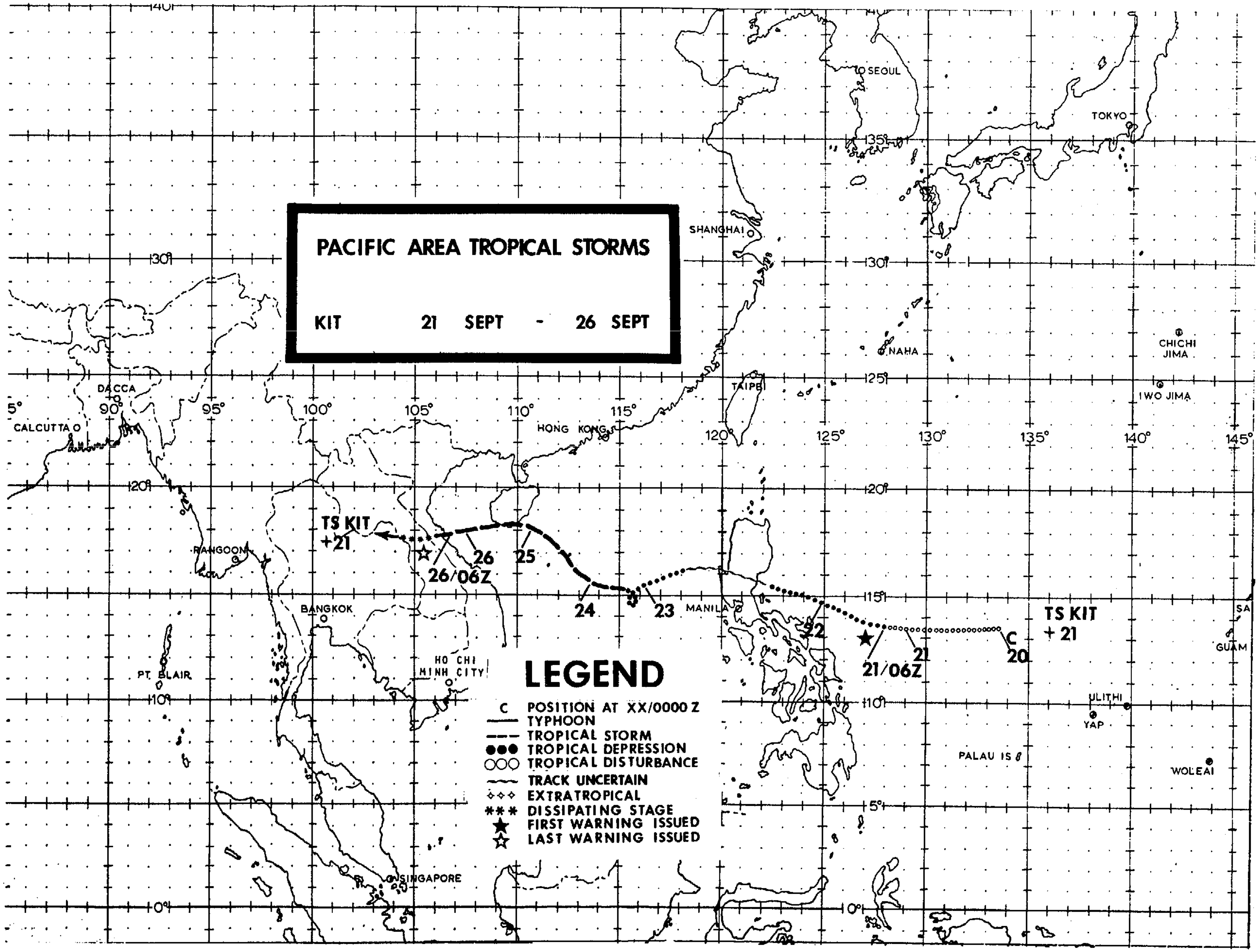
45° 40° 35° 30° 25° 20° 15° 10°


PACIFIC AREA TROPICAL STORMS
KIT 21 SEPT - 26 SEPT
TS KIT
+21
26
25
26/06Z
24
23
22
21
21/06Z
C
20
TS KIT
+ 21
LEGEND
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
TRACK UNCERTAIN
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SEOUL
TOKYO
SHANGHAI
NAHA
CHICHI JIMA
TAIPEI
IWO JIMA
DACCA
CALCUTTA
HONG KONG
RANGOON
BANGKOK
HO CHI MINH CITY
MANILA
GUAM
PT. BLAIR
ULITHI
YAP
PALAU IS
WOLEAI
SINGAPORE
90°
95°
100°
105°
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10°
5°
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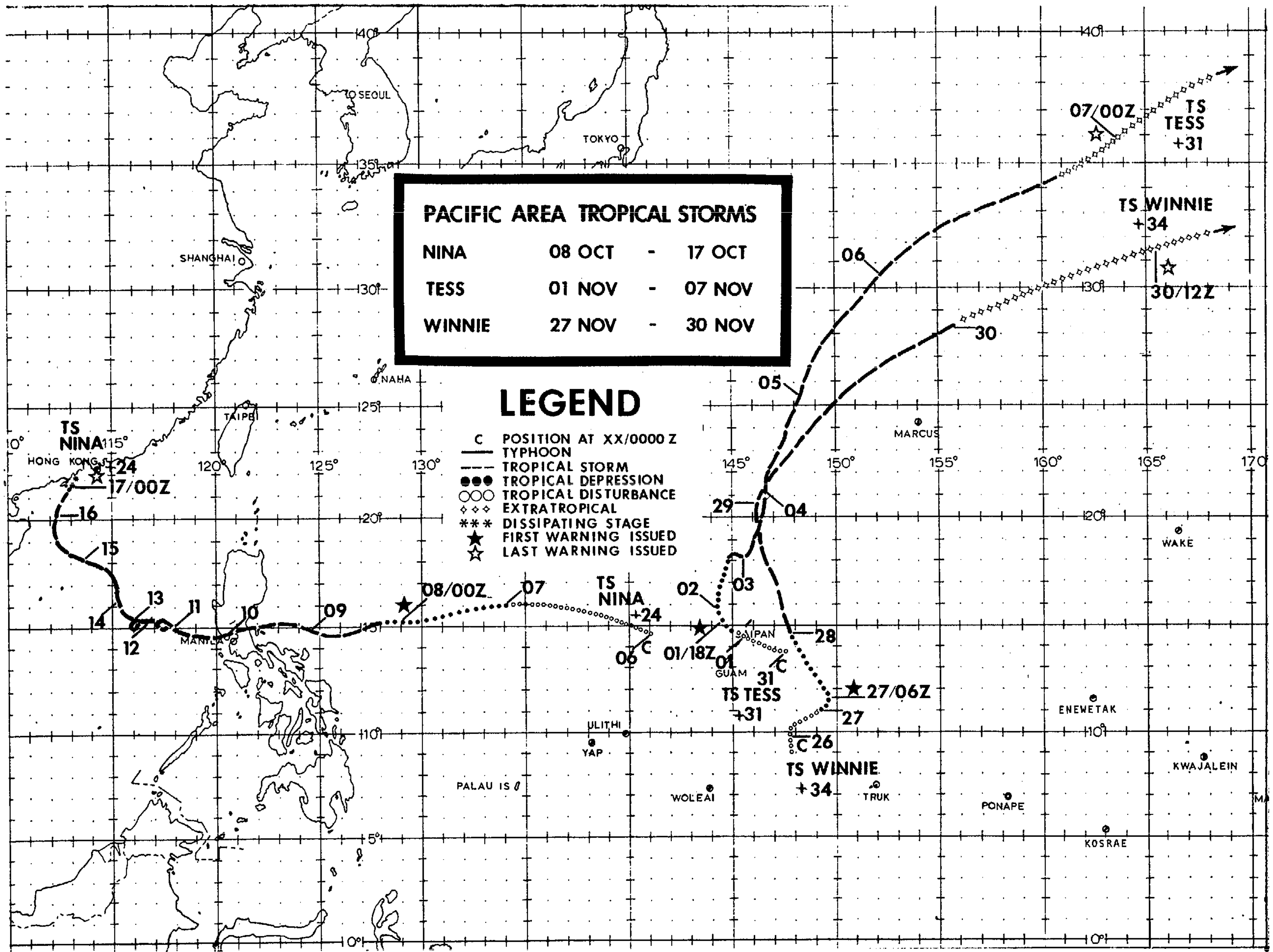
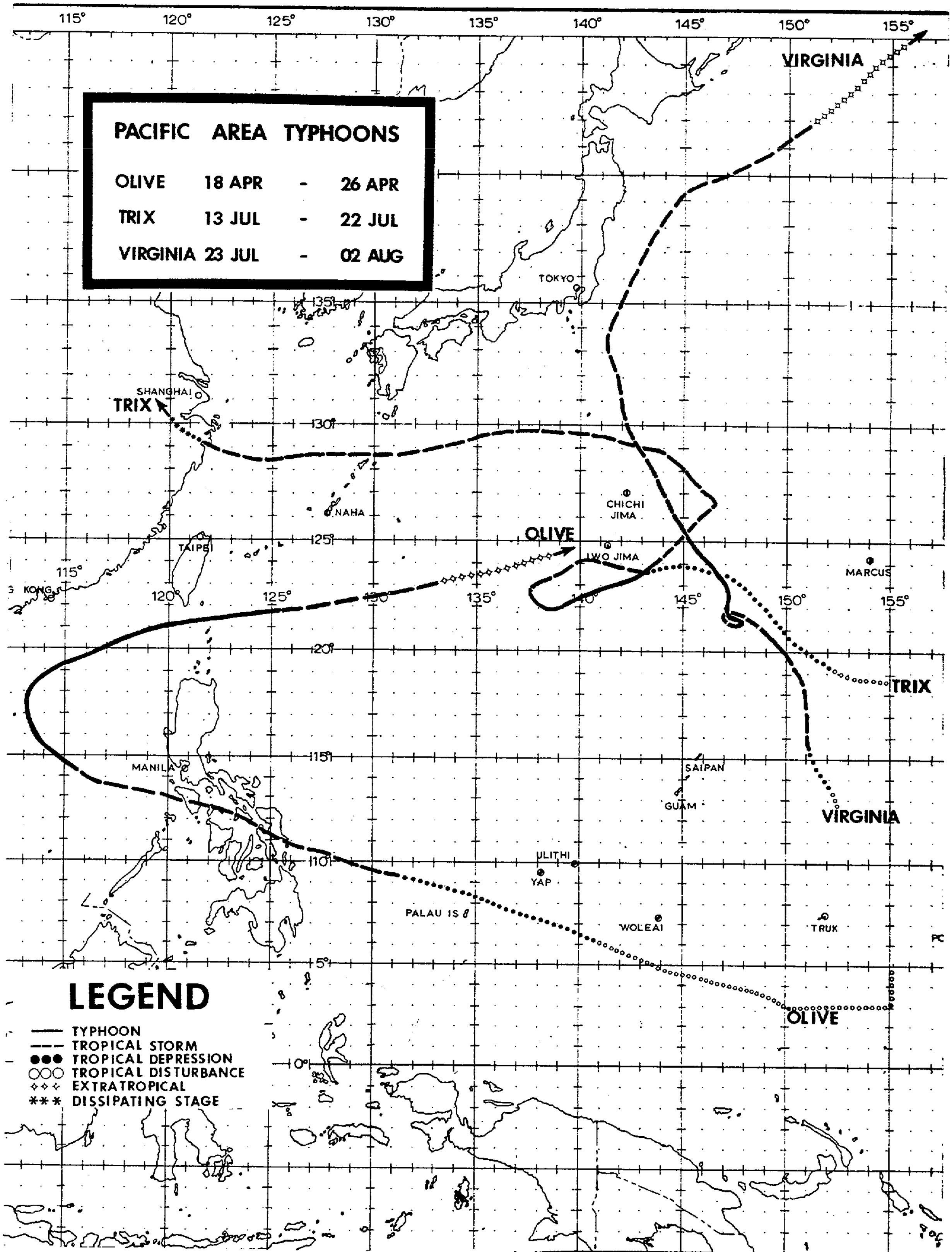

PACIFIC AREA TROPICAL STORMS
NINA 08 OCT - 17 OCT
TESS 01 NOV - 07 NOV
WINNIE 27 NOV - 30 NOV
LEGEND
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SEOUL
TOKYO
SHANGHAI
NAHA
TAIPEI
HONG KONG
MANILA
MARCUS
WAKE
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
PONAPE
KOSRAE
ENEWETAK
KWAJALEIN
TS NINA +24
17/00Z
08/00Z
TS NINA +24
TS TESS +31
01/18Z
07/00Z
TS TESS +31
TS WINNIE +34
27/06Z
30/12Z
TS WINNIE +34


PACIFIC AREA TYPHOONS
OLIVE 18 APR - 26 APR
TRIX 13 JUL - 22 JUL
VIRGINIA 23 JUL - 02 AUG
LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
115°
120°
125°
130°
135°
140°
145°
150°
155°
VIRGINIA
TRIX
OLIVE
TOKYO
SHANGHAI
NAHA
CHICHI JIMA
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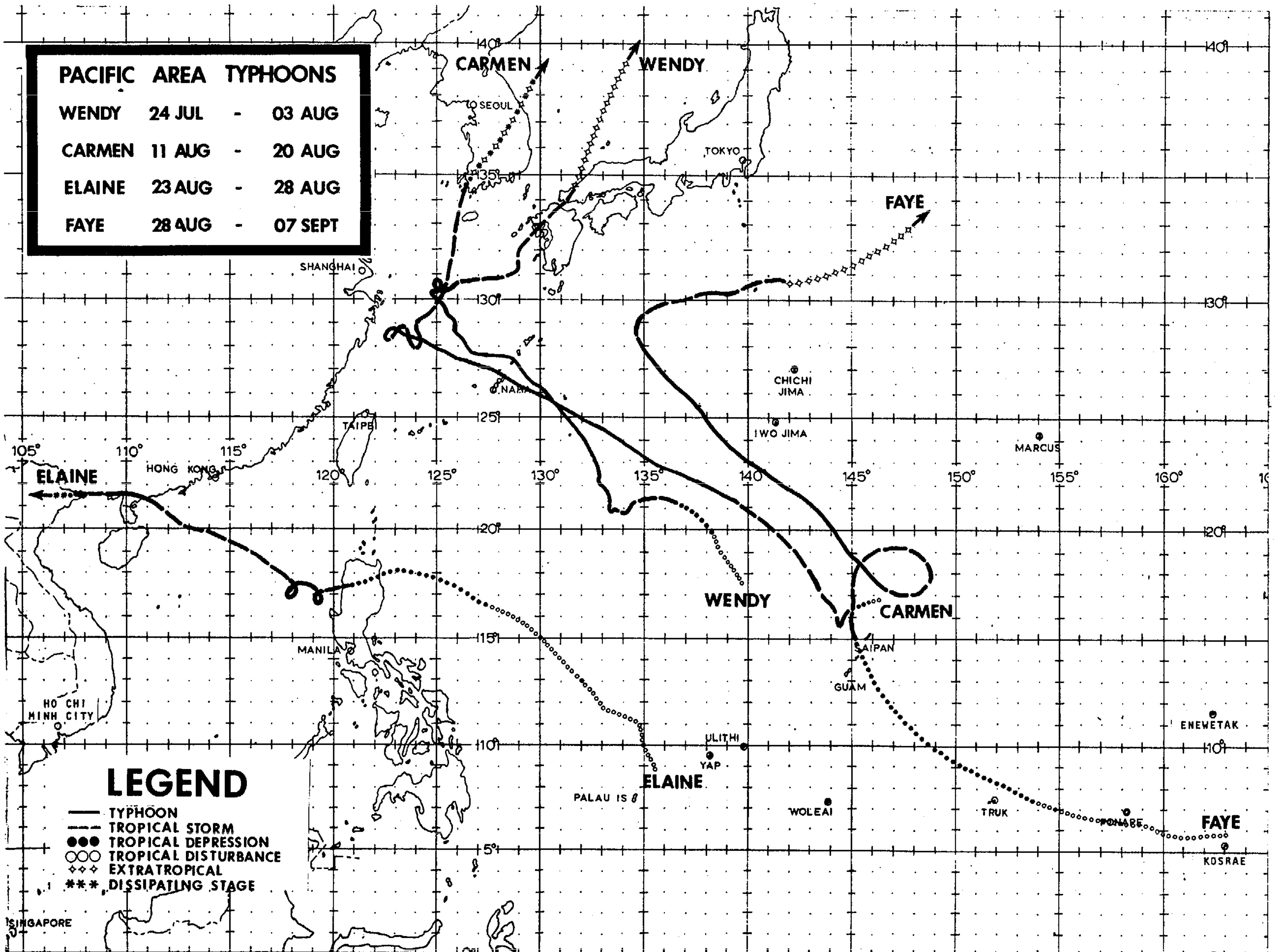
TRUK


PACIFIC AREA TYPHOONS
WENDY 24 JUL - 03 AUG
CARMEN 11 AUG - 20 AUG
ELAINE 23 AUG - 28 AUG
FAYE 28 AUG - 07 SEPT
LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
CARMEN
WENDY
FAYE
ELAINE
WENDY
CARMEN
ELAINE
FAYE
SEOUL
TOKYO
SHANGHAI
NAHA
TAIPEI
HONG KONG
MANILA
HO CHI MINH CITY
SINGAPORE
CHICHI JIMA
IWO JIMA
MARCUS
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
PONAPE
KOSRAE
ENEWETAK
105°
110°
115°
120°
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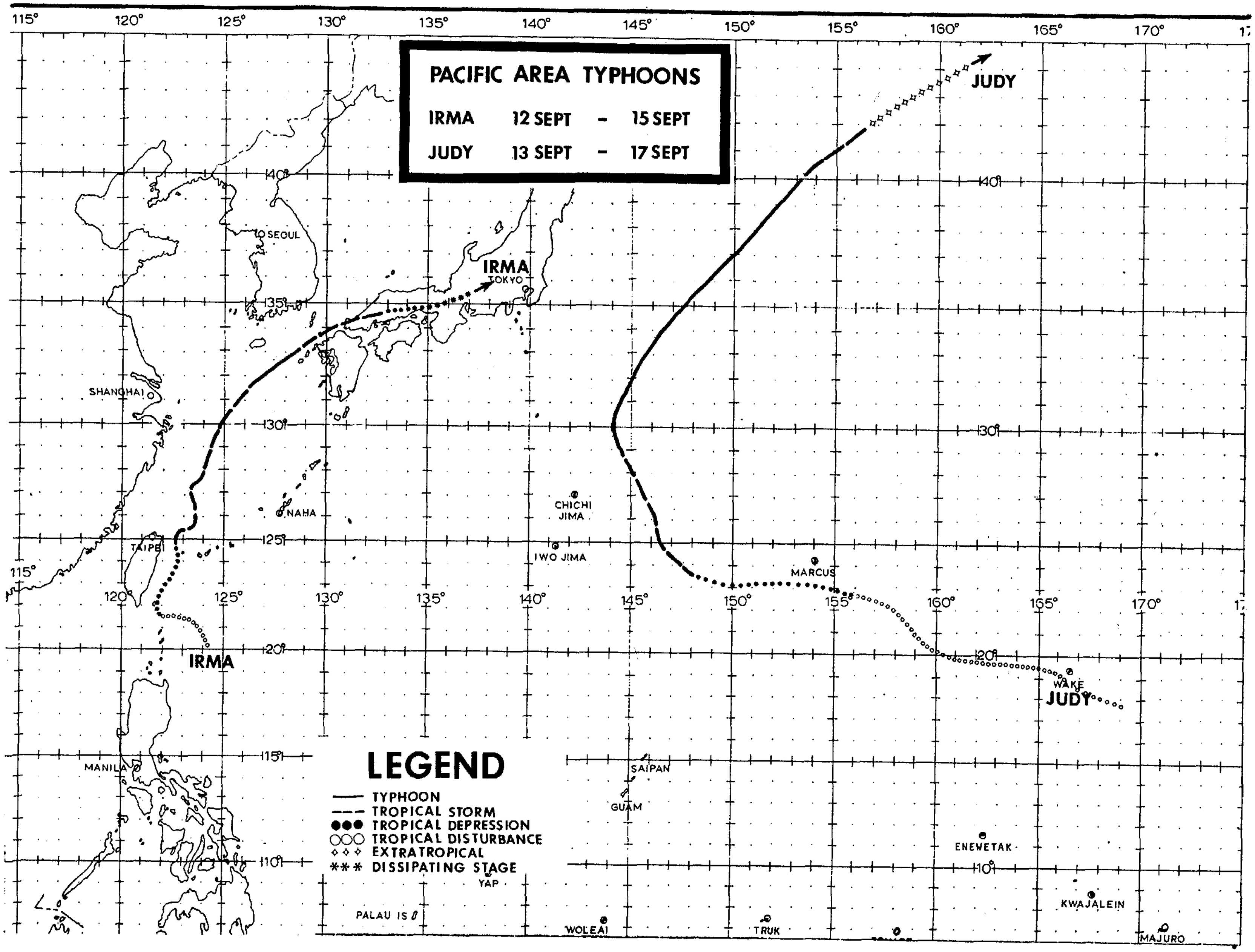
PACIFIC AREA TYPHOONS
IRMA 12 SEPT - 15 SEPT
JUDY 13 SEPT - 17 SEPT
LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
IRMA
JUDY
SEOUL
TOKYO
SHANGHAI
TAIPEI
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
MANILA
SAIPAN
GUAM
ENEWETAK
KWAJALEIN
YAP
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TRUK
MAJURO
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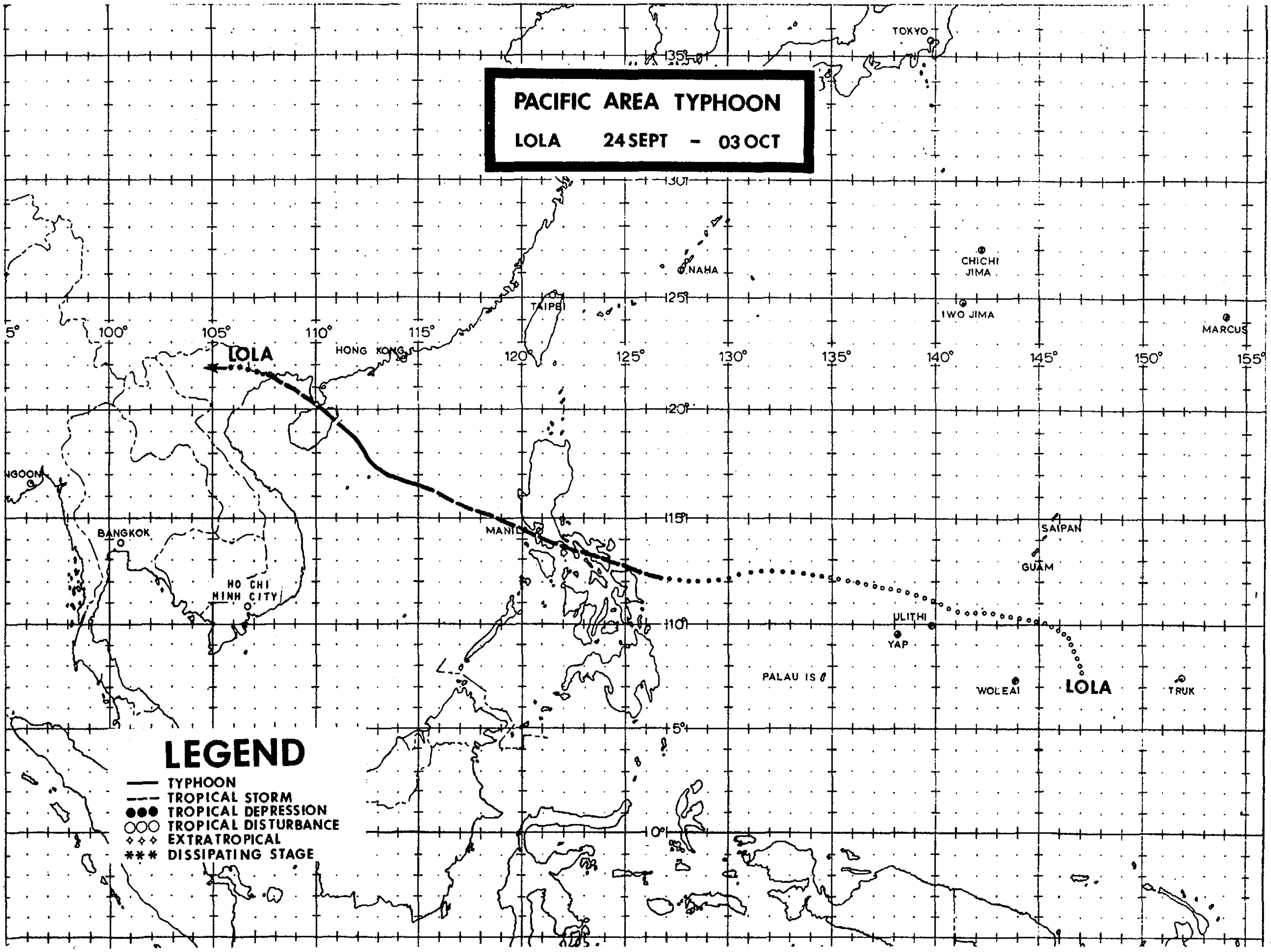
40° 35° 30° 25° 20° 15° 10°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LOLA 24 SEPT - 03 OCT
LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
LOLA
LOLA
TOKYO
NAHA
TAIPEI
HONG KONG
MANILA
BANGKOK
HO CHI MINH CITY
CHICHI JIMA
IWO JIMA
MARCUS
SAIPAN
GUAM
ULITHI
YAP
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100°
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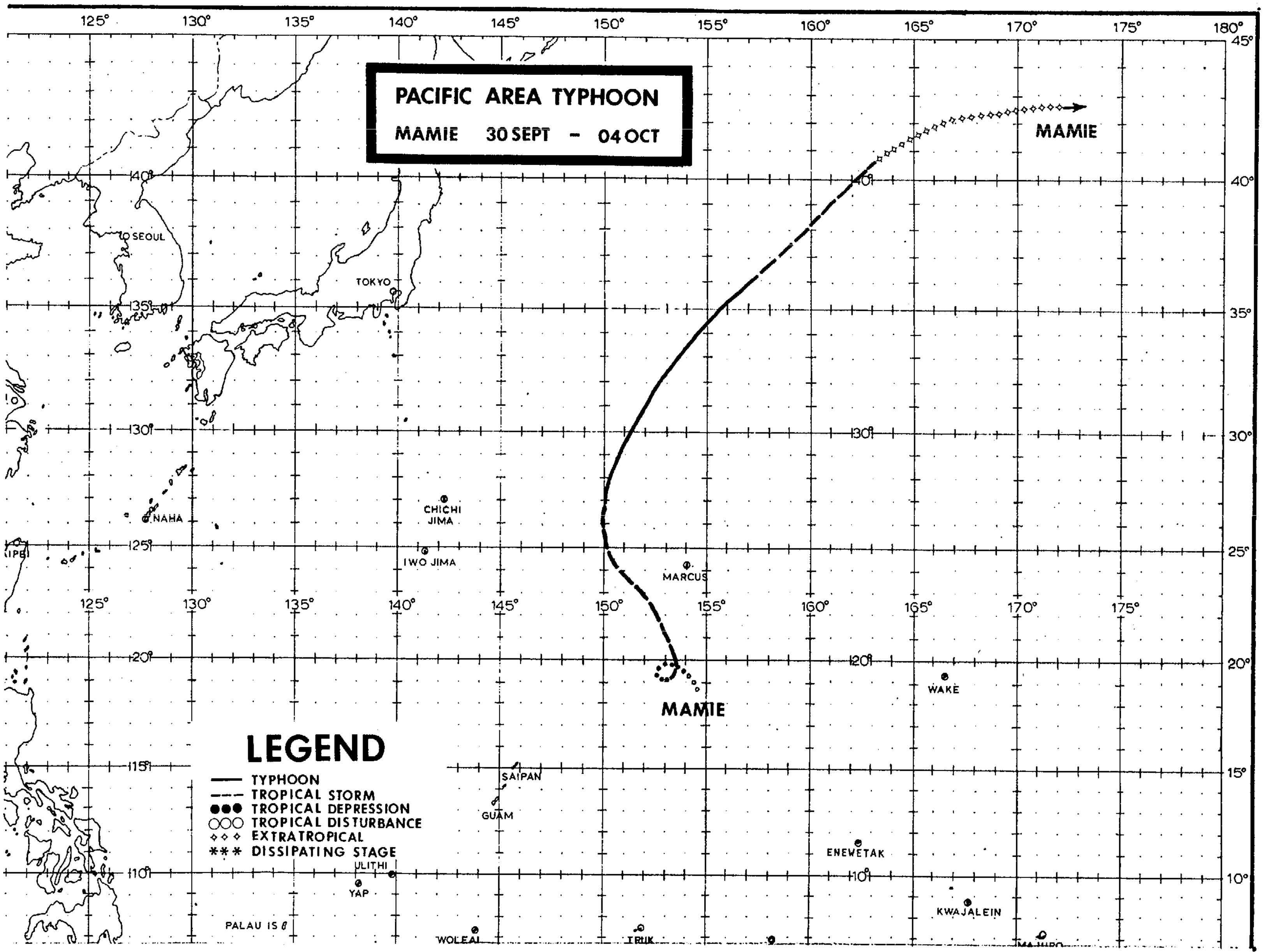
PACIFIC AREA TYPHOON
MAMIE 30 SEPT - 04 OCT
MAMIE
MAMIE
LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
SEOUL
TOKYO
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
SAIPAN
GUAM
ENEWETAK
ULITHI
YAP
PALAU IS
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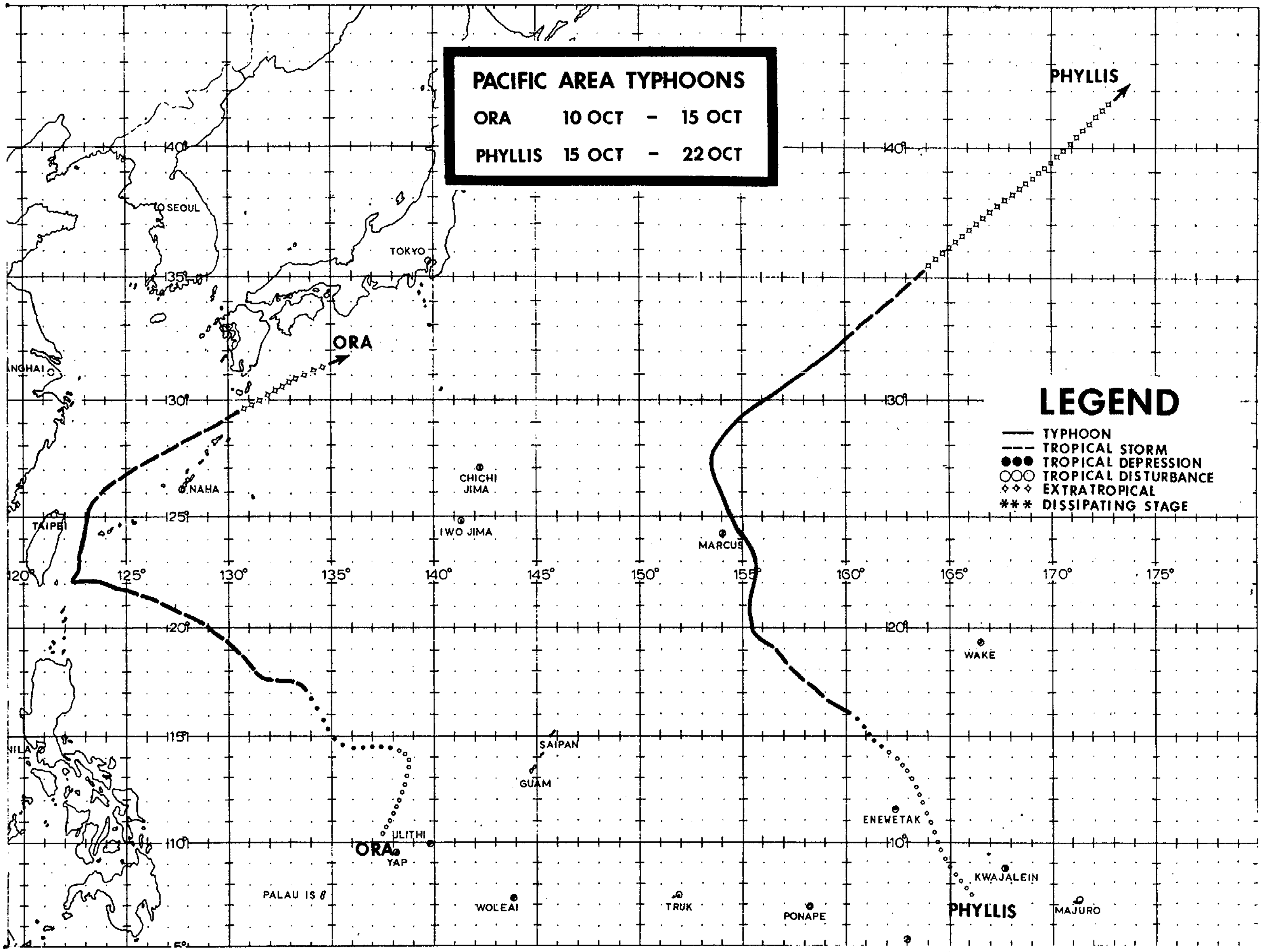
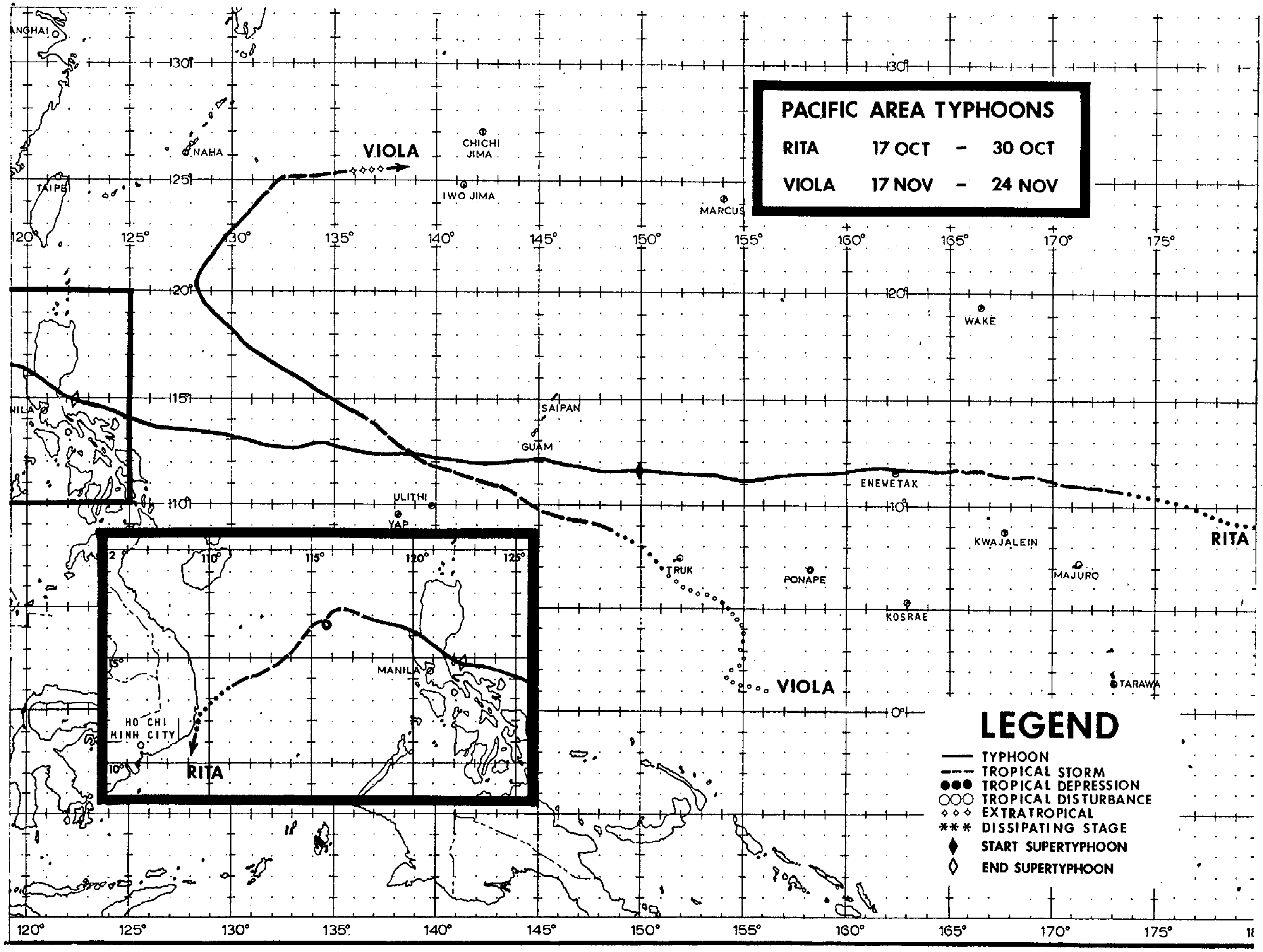
45° 40° 35° 30° 25° 20° 15° 10°


PACIFIC AREA TYPHOONS
ORA 10 OCT - 15 OCT
PHYLLIS 15 OCT - 22 OCT
LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
ORA
PHYLLIS
SEOUL
TOKYO
NAHA
TAIPEI
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
PONAPE
ENEWETAK
KWAJALEIN
MAJURO
120°
125°
130°
135°
140°
145°
150°
155°
160°
165°
170°
175°


PACIFIC AREA TYPHOONS
RITA 17 OCT - 30 OCT
VIOLA 17 NOV - 24 NOV
LEGEND
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
START SUPERTYPHOON
END SUPERTYPHOON
VIOLA
RITA
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
TAIPEI
WAKE
SAIPAN
GUAM
ULITHI
YAP
ENEWETAK
KWAJALEIN
TRUK
PONAPE
KOSRAE
MAJURO
TARAWA
MANILA
HO CHI MINH CITY
120°
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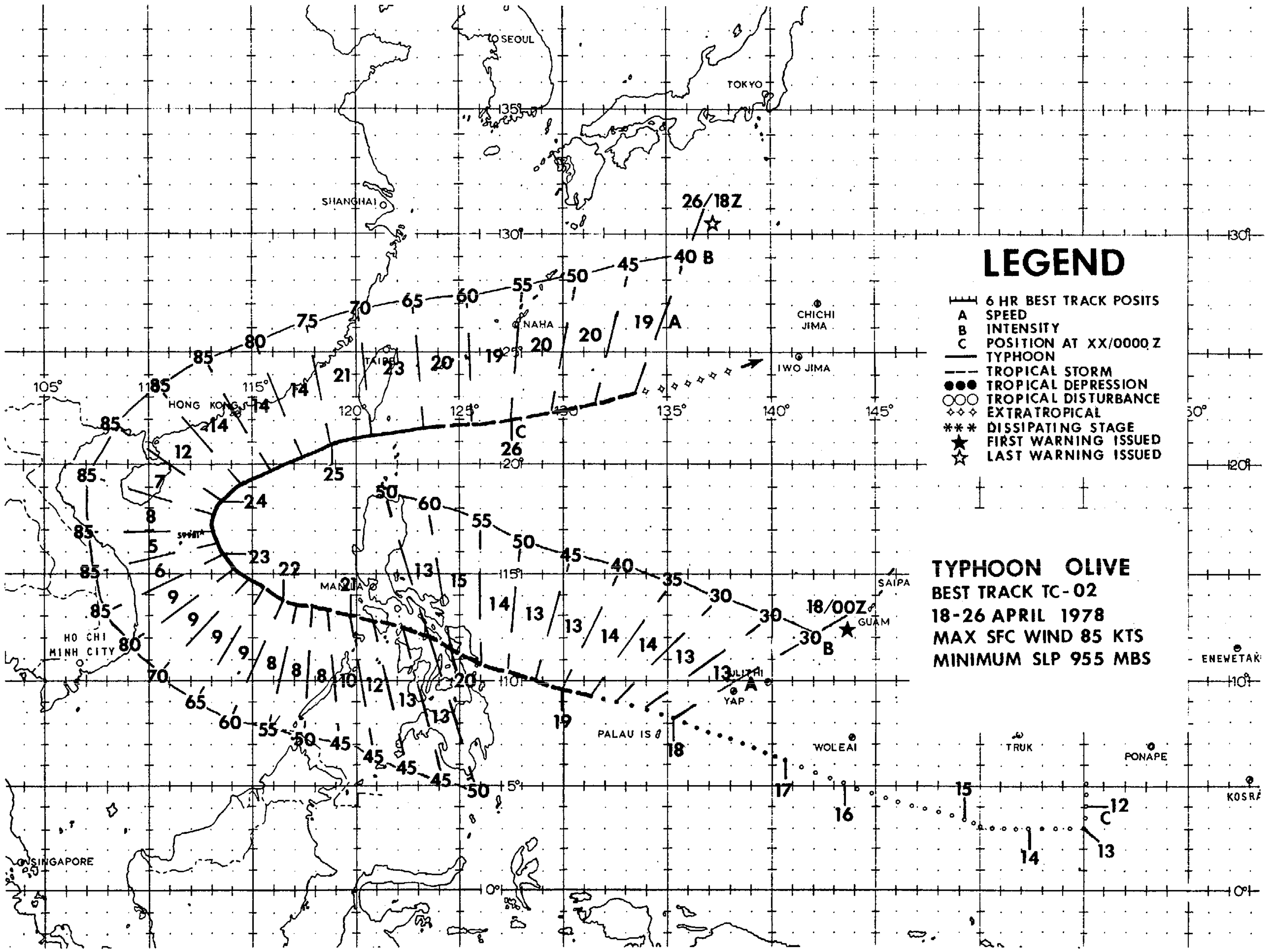
175°


LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
TYPHOON OLIVE
BEST TRACK TC-02
18-26 APRIL 1978
MAX SFC WIND 85 KTS
MINIMUM SLP 955 MBS
26/18Z
18/00Z
SEOUL
TOKYO
SHANGHAI
TAIPEI
NAHA
CHICHI JIMA
IWO JIMA
HONG KONG
MANILA
HO CHI MINH CITY
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
PONAPE
ENEWETAK
KOSRAE
SINGAPORE

Early April 1978 saw the near-equatorial trough (NET) slowly shift northward and become more active as the sun made its seasonal progression toward summer solstice. Within the NET, a surface circulation was first analyzed on the 11th at 1200Z near 05N-155E and initially meandered southward then westward at approximately 8 kt (15 km/hr) over the next four days. This circulation eventually developed into the first typhoon of the year, Olive.

Anticyclonic outflow at the 200 mb level was first noted in the vicinity over the surface circulation at 131200Z. Although weak, this outflow persisted for the next two days. By the 16th, satellite imagery and synoptic data indicated increased organization. A formation alert was issued at 160600Z and extended for another 24 hours at 170600Z as aircraft and satellite data confirmed that development was slower than expected. Based on satellite and synoptic data, the first warning on Tropical Depression 02 was issued at 180000Z. A subsequent aircraft fix at 180252Z found a central pressure of 1001 mb and estimated the maximum surface winds to be 30-35 kt (15-18 m/sec).

The mid-tropospheric subtropical ridge was well established at this time with the east-west axis varying between 17-20N. This resulted in the cyclone, once organized, tracking west-northwest at speeds faster than climatology. Satellite data indicated good outflow aloft with continuous intensification resulting. The intensification noted in the 24 hours prior to landfall was in good agreement with climatology. TD-02 was upgraded to Tropical Storm Olive on the 18th at 1800Z. Tropical Storm Olive passed through the Leyte Gulf with maximum sustained winds of 60 kt (31 m/sec).

While crossing the central Philippine Islands, Olive continued her 13 kt (24 km/hr) speed but weakened to 45 kt (23 m/sec) intensity. Upper level outflow remained good during the transit and Olive exited intact into the South China Sea after 201800Z. The combination of good outflow aloft and warm water in the South China Sea caused Olive to reintensify and reach typhoon intensity at 220600Z. The storm recurved through a break in the subtropical ridge along 113E that had been forming since 220000Z. Figure 3-1 shows the three-hourly surface reports from the Paracel Islands (WMO 59981) when Olive passed nearby. A maximum intensity of 85 kt (44 m/sec) was reached 12 hours before recurvature and continued until the 24th at 1200Z.

The recurvature was quite sharp due to strong, deep westerly upper-air flow in the latitudes of 20-30N. Figure 3-2 shows the cirrus outflow to the north and northeast of Olive being affected by the strong westerlies. After recurvature, Olive accelerated out to the east-northeast, staying approximately 180 nm (330 km) south of the maximum wind zone. Gradual weakening occurred after recurvature as cooler, drier air was ingested into the storm with Olive finally becoming extratropical over cooler waters at 1800Z on the 26th of April.

Post-analysis showed that numbered warnings should have begun near 170000Z. Although the system was not fully defined at this time and difficult to pinpoint on satellite data, enough information was available to predict storm force winds were possible within 48 hours. Recurvature was considered probable early in Olive's life and discussed on prognostic reasoning messages. However, the recurvature track was much sharper than initially forecast. More emphasis should have been placed on the depth and strength of the westerlies north of the narrow, subtropical ridge and tracks of previous April cyclones (analogs) should have been studied closely.

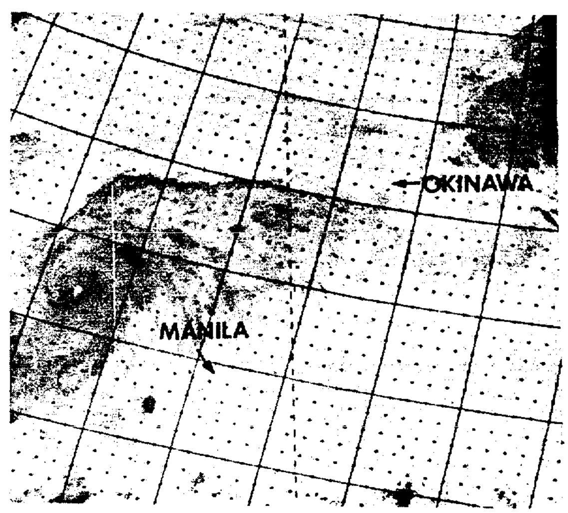


FIGURE 3-2. Infrared imagery of Typhoon Olive at maximum intensity of 85 kt (44 m/sec) during recurvature, 23 April 1978, 1158Z. (NOAA-5 imagery)

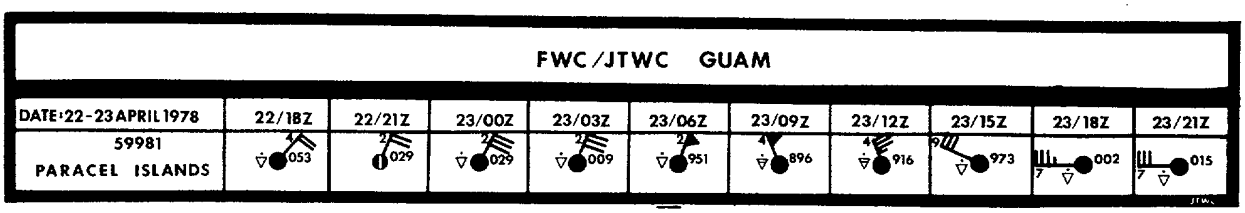
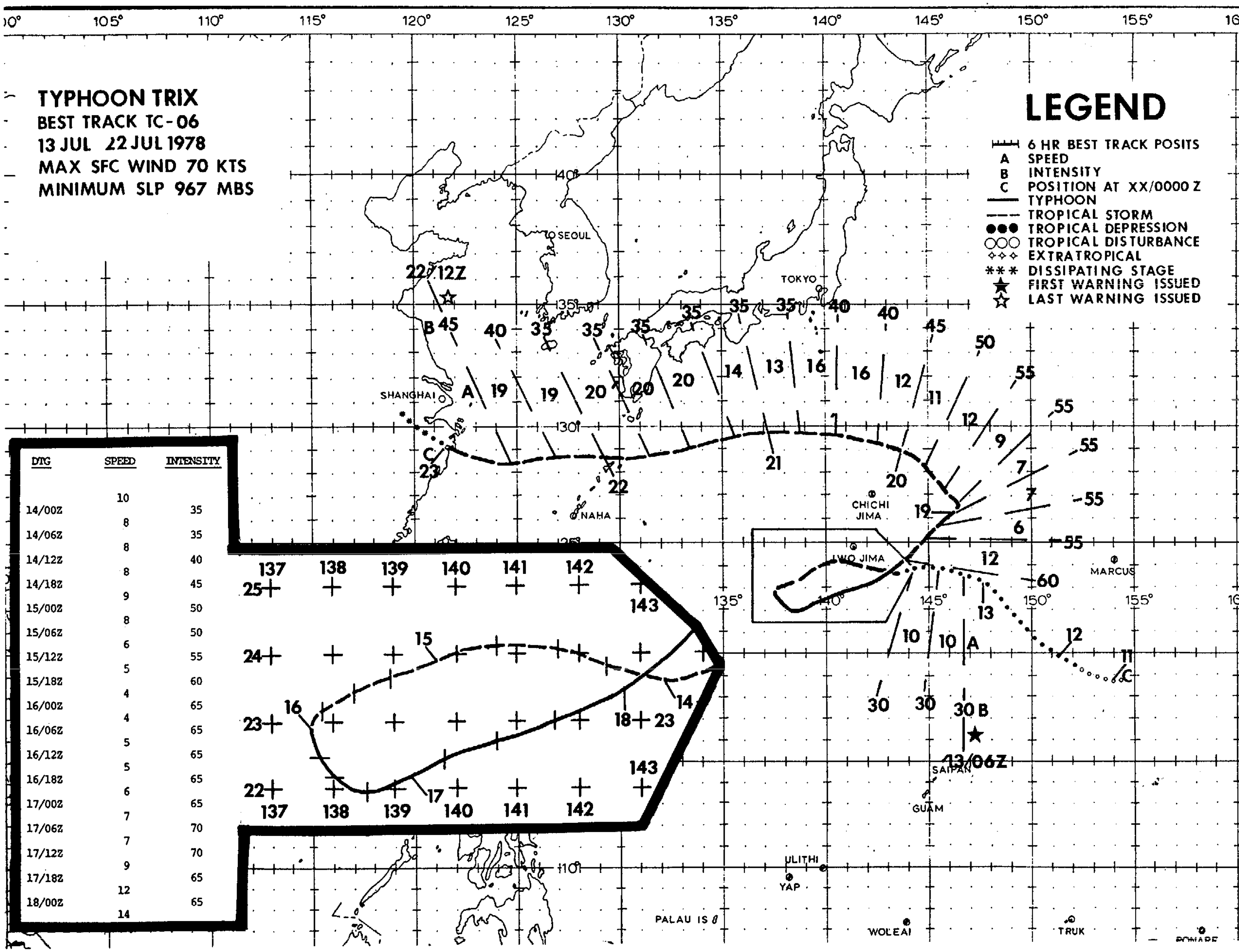


FIGURE 3-1. Three-hourly surface synoptic observations from the Paracel Islands during passage of Typhoon Olive.



DTG	SPEED	INTENSITY
	10	
14/00Z		35
	8	
14/06Z		35
	8	
14/12Z		40
	8	
14/18Z		45
	9	
15/00Z		50
	8	
15/06Z		50
	6	
15/12Z		55
	5	
15/18Z		60
	4	
16/00Z		65
	4	
16/06Z		65
	5	
16/12Z		65
	5	
16/18Z		65
	6	
17/00Z		65
	7	
17/06Z		70
	7	
17/12Z		70
	9	
17/18Z		65
	12	
18/00Z		65
	14	

Trix, 1978's second typhoon, was a difficult tropical cyclone to forecast due to an unusual track which included a four day, 700 nm (1300 km) perimeter, cyclonic loop. The degree of difficulty was reflected in warning statistics such as: eleven warning relocations, two warning amendments, and an average 24 hour forecast error of 174 nm (322 km).

Trix originated from a wave in the easterlies which became significant along 148E from 10N-25N on the 10th of July. A day later, a surface circulation was noted within the wave 550 nm (1000 km) northeast of Guam. Over the next 48 hours, the wave drifted northwest at 05-07 kt (09-13 km/hr) and moved under an area of diffluence caused by a tropical upper tropospheric trough (TUTT) to the west. Potential for development being excellent, a formation alert was issued at 0600Z on the 12th.

The first aircraft reconnaissance flight into the alert area found a cyclonic circulation with a circular area of calm winds, 100 nm (185 km) in diameter. Based on this 130407Z information and continued outflow aloft possible, the first warning was issued at 130600Z on Tropical Depression 06 (TD 06).

Over the next 18 hours, TD 06 moved west at approximately 10 kt (18 km/hr). Subsequent aircraft reconnaissance observed the minimum sea level pressure continuing to decrease; tropical storm intensity was reached on the 14th at 0000Z.

Metsat data at 142220Z (Fig. 3-3) showed Trix to be a very compact tropical storm with outflow only three degrees in diameter. Midget storms have been reviewed in the literature and been found to exhibit erratic intensity trends and Trix held true to form. Figure 3-4 shows the diurnal variation of the sea level pressure as observed by dropsonde. Also shown are the differences between the maximum sustained surface winds as estimated from aircraft reconnaissance and those obtained from an empirically derived JTWC formula:

$$Vmax = 6.7(1010. - MSLP)\exp 0.644$$

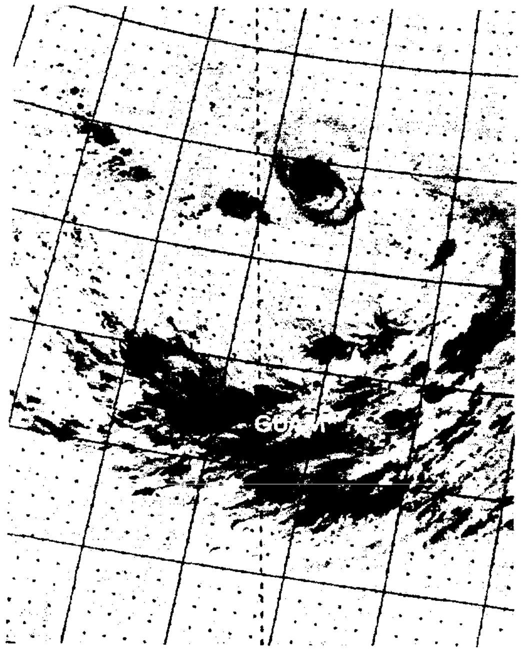


FIGURE 3-3 . Infrared image of Trix at tropical storm intensity, 14 July 1978, 2220Z. The cloudiness over Guam in the deep convergent southwest flow is quite a distance from Trix, signifying the large extent of the cyclonic circulation in which Trix was embedded. (DMSP imagery)

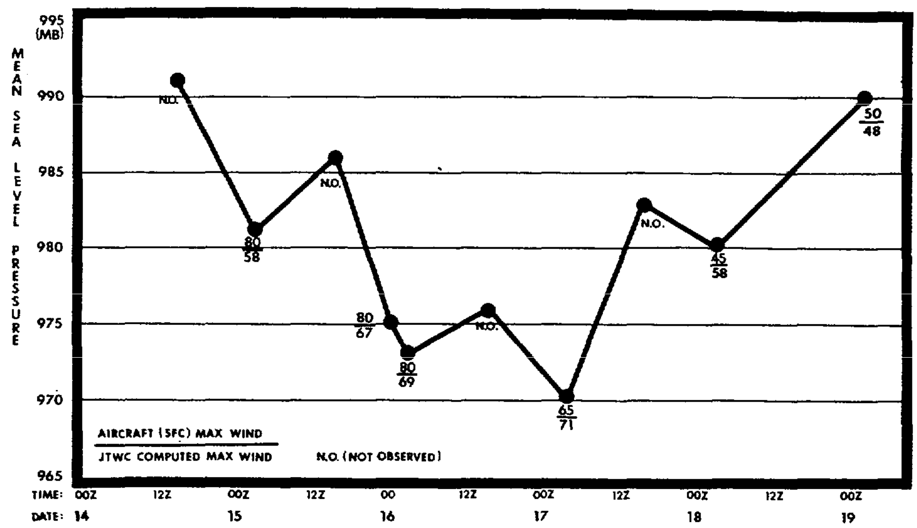


FIGURE 3-4 . Time cross section of Trix's minimum sea level pressure.

These differences may be due to larger gust spreads in compact storms which may give the appearance of stronger maximum surface winds than were actually present.

In addition to erratic intensity trends, Trix's track was quite extraordinary. On the 15th at 0000Z, a large cyclonic circulation dominated the mid-tropospheric flow in the western Pacific between 13N and 23N. Trix, embedded in this large circulation, made a large cyclonic loop along the periphery. During this loop, Trix traveled approximately 700 nm (1300 km) in four days. Trix continued intensifying while looping and typhoon intensity was attained on the 16th at 0000Z.

The Aerial Reconnaissance Weather Officer (ARWO) reported on his post-mission report for the 160326Z fix that "the storm had all the typical parameters of a typhoon but on a miniature scale." Figure 3-5 shows Trix still compact, even as a typhoon.

A large, subtropical high pressure center began building near 40N-170W at 0000Z on the 19th. This feature finally provided the necessary strong easterlies to break Trix out of her loop by 0600Z on the 19th. Prior to this change in track, Trix had weakened again to tropical storm strength (on the 18th at 1200Z).

The subtropical ridge continued building westward over Japan steering Trix westward by 1200Z on the 20th. This was the final, significant change in track. Trix meandered westward thereafter and made landfall on the east coast of China near Linhai.

The 211800Z, official warning indicated downgrading of Trix to tropical depression stage with maximum sustained winds of 30 kt (15 m/sec) as satellite and aircraft reconnaissance data showed a weakening trend. However, post-analysis of synoptic data recieved after-the-fact revealed that Trix maintained minimal tropical storm intensity and reached a secondary maximum intensity just prior to landfall. The aircraft no-fly -line prohibited aircraft reconnaissance from observing this secondary maxima.

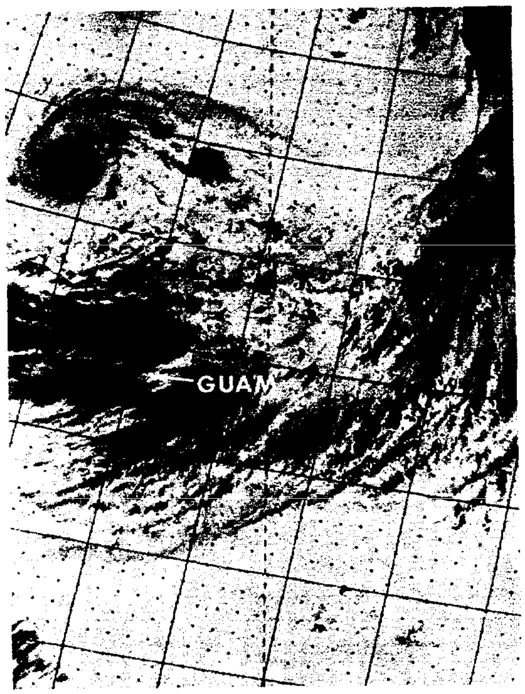
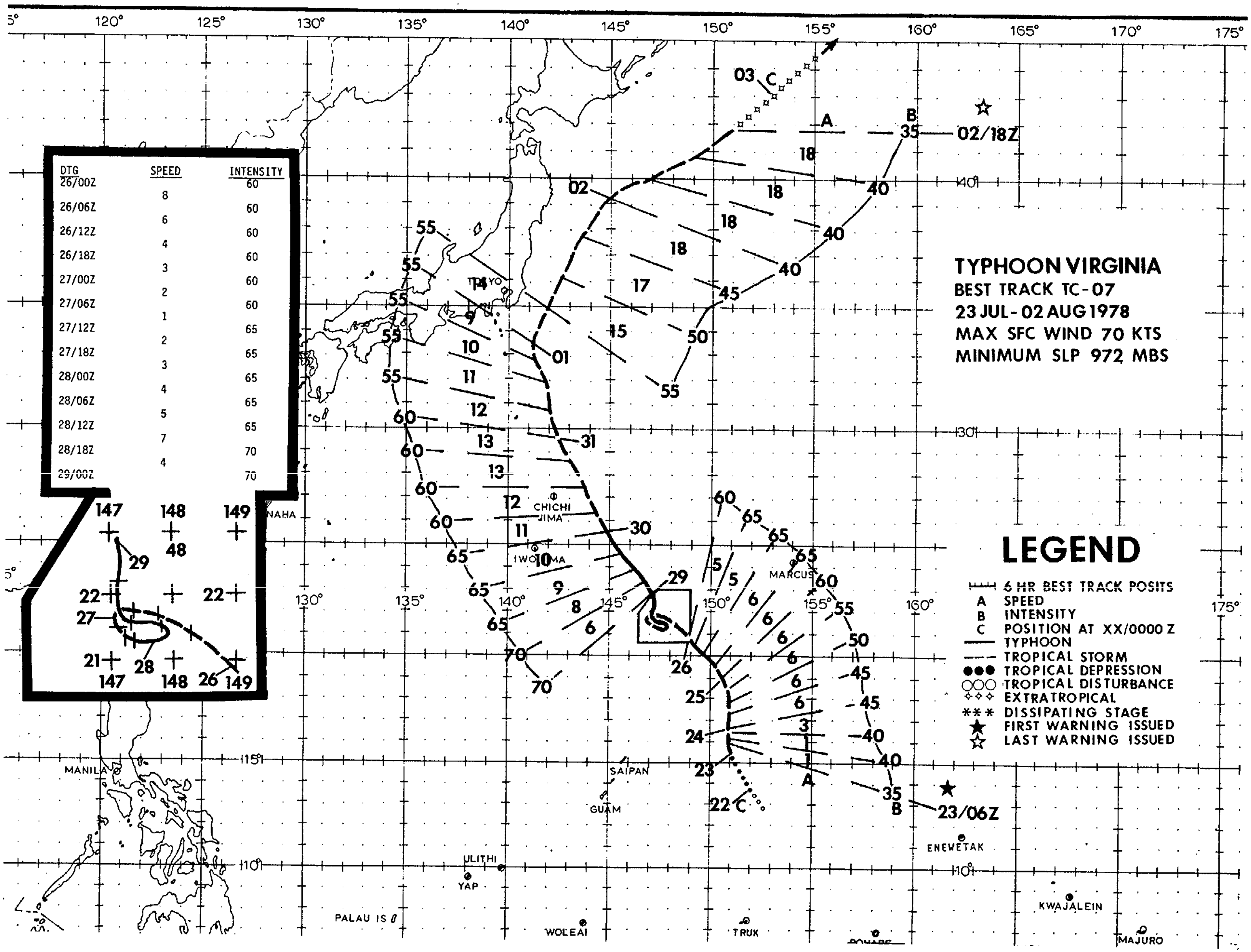


FIGURE 3-5 . *Infrared image of Trix at typhoon intensity, still very compact, and still embedded in the larger circulation, 16 July 1978, 0107Z. (DMSP imagery).*


TYPHOON VIRGINIA
BEST TRACK TC-07
23 JUL - 02 AUG 1978
MAX SFC WIND 70 KTS
MINIMUM SLP 972 MBS
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
DTG SPEED INTENSITY
26/00Z 60
8
26/06Z 60
6
26/12Z 60
4
26/18Z 60
3
27/00Z 60
2
27/06Z 60
1
27/12Z 65
2
27/18Z 65
3
28/00Z 65
4
28/06Z 65
5
28/12Z 65
7
28/18Z 70
4
29/00Z 70
02/18Z
23/06Z
TOKYO
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
SAIPAN
GUAM
ENEWETAK
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
KWAJALEIN
MAJURO
MANILA

Virginia developed during July as the third typhoon of the 1978 season. Virginia was relatively small compared to the much larger Typhoon Wendy which developed simultaneously to the west. Except for an unexpected loop, Virginia's track was definable as an uncomplicated, broad recurvature track. However, higher than average forecast errors resulted due to the difficult forecasting situations produced by complex interactions with the nearby Typhoon Wendy and the Tropical Upper Tropospheric Trough (TUTT).

Virginia first appeared as a small tropical disturbance on satellite imagery on 21 July. This disturbance was believed to be associated with a low-level convergence zone feeding into a much larger disturbance which was developing over the Philippine Sea. There were no nearby land/ship reports to indicate any evidence of a surface circulation at this time. Therefore, this disturbance was discussed in the Significant Tropical Weather Advisory (ABEH PGTW) as having poor potential for development during the advisory period. On the 23rd, a weather reconnaissance aircraft was first sent to investigate the larger disturbance (then estimated at 30 kt (15 m/sec) intensity) and was later sent east into the smaller disturbance. The aircraft penetrated the smaller disturbance and found an unexpected, well-developed circulation. Aircraft radar showed a well-defined 40 nm (74 km) diameter eye and the weather officer estimated surface gusts at 55 kt (28 m/sec). The first tropical cyclone warning was immediately issued on TS Virginia at 230600Z. Post analysis showed tropical storm stage was reached 6 to 12 hours before the first warning. However, the lack of significant data and Virginia's unusually small cloud signature on satellite imagery delayed earlier interpretation of Virginia as a significant tropical cyclone.

Virginia and Wendy intensified simultaneously (Fig. 3-6). Because Wendy's circulation was so much larger, Virginia was expected to travel in a counter-clockwise direction about Wendy. Virginia did travel as predicted for the first four days, but the speed of movement was slower than expected. During the next two days, Wendy moved northwestward away from Virginia and interaction between the two storms became less noticeable. Virginia continued to decrease in speed of movement and then executed a loop; Wendy and Virginia were separated by over 800 nm (1482 km) during the loop.

Macro-scale features over the western North Pacific at this time included a TUTT. The TUTT was initially situated between Virginia and Japan. Analysis of all data sources, including satellite-derived winds, indicated the TUTT extended southward along Virginia's western side during the loop. This caused inconsistent steering flow with height, contributing to Virginia's lack of significant forward movement. Virginia's maximum intensity of 70 kt (36 m/sec) was attained during this period (Fig. 3-7).

Virginia slowly weakened after the loop as the TUTT axis became situated just west of Virginia and restricted upper-level outflow to the west. Virginia also began moving toward recurvature by traveling around the western periphery of a large subtropical anticyclone. Virginia's recurvature was also believed to be partially aided by the TUTT, which provided southerly upper-level steering flow. Virginia remained just east of the TUTT axis throughout recurvature.

Virginia produced no known damage. Even though Virginia passed within 80 nm (148 km) of Japan, only 20 kt (10 m/sec) maximum surface winds were reported along the east coast of Honshu. Besides Virginia's small size, the winds were always weaker on the west side due to the TUTT axis being so close to the storm.

Virginia holds the 1978 record for a tropical cyclone tracking the farthest north (47N) before losing its tropical characteristics.

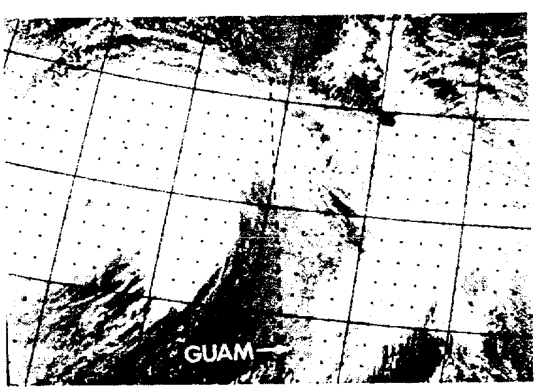


FIGURE 3-6. Early stages of Typhoons Wendy (left) and Virginia (right), 26 July 1978, 0133Z. (DMSP imagery)

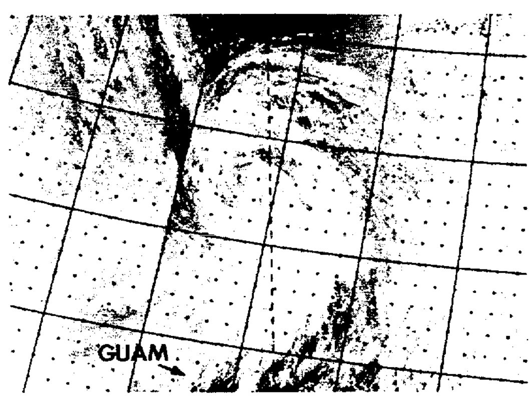
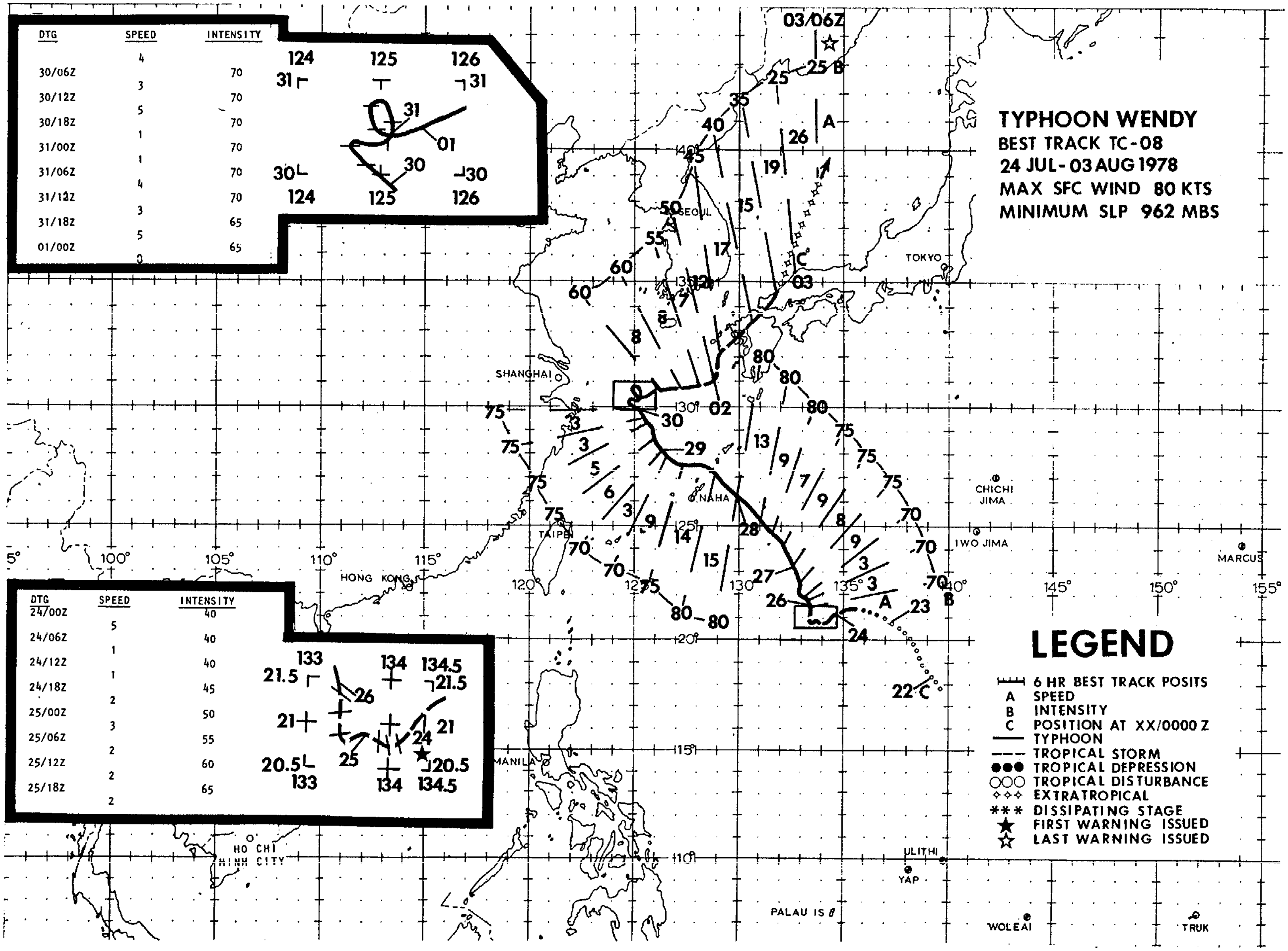


FIGURE 3-7. Typhoon Virginia at maximum intensity of 70 kt (36 m/sec) while undergoing strong TUTT interaction, 28 July 1978, 2141Z. (DMSP imagery)



DTG	SPEED	INTENSITY
	4	
30/06Z	3	70
30/12Z	5	70
30/18Z	1	70
31/00Z	1	70
31/06Z	4	70
31/12Z	3	70
31/18Z	5	65
01/00Z	3	65

DTG	SPEED	INTENSITY
24/00Z	5	40
24/06Z	1	40
24/12Z	1	40
24/18Z	2	45
25/00Z	3	50
25/06Z	2	55
25/12Z	2	60
25/18Z	2	65

Wendy, the fourth typhoon of 1978, developed in a well-established monsoon trough. The trough, which had existed for seven to ten days prior to significant tropical cyclone development, laid over WESTPAC from 07N at the Dateline west-northwest over the Mariana Islands to the Luzon Straits. By 1200Z on the 22nd of July, two weak surface circulations were evident in the trough, one centered at 19.8N-138.2E which eventually became Wendy and the other at 14.5N-151.4E (Virginia). With the Tropical Upper Tropospheric Trough (TUTT) lying just to the north of the surface trough, the dynamics for significant tropical cyclone development were present.

Increased organization on the 22nd prompted the initial reconnaissance aircraft launch at 2130Z. The ARWO observed 25-30 kt (13-15 m/sec) surface winds, but could not locate a definable surface circulation center. Based on this aircraft data and the good potential for increased development a formation alert was issued at 230456Z for an area 660 nm (1222 km) northwest of Guam. The tropical cyclone developed rapidly thereafter; it reached tropical storm intensity near 231800Z (Fig. 3-8) and obtained typhoon strength by 1800Z on the 25th.

Wendy meandered westward from the 23rd till the 25th when a break developed in the subtropical ridge with the high center, northeast of Wendy, dominating and building. In response to stronger, mid-level southeasterlies, Wendy accelerated northwestward. Wendy slowly reached her maximum intensity of 80 kt (41 m/sec) during this time and maintained it for 24 hours before she began a slow weakening trend after passing over the Ryukyu Islands. A marked decrease in low-level inflow and convection near the center appeared to have affected Wendy's development at this point.

Wendy stalled again in the central East China Sea, 180 nm (333 km) east-southeast of Shanghai, when steering currents weakened. The cooler and drier environment, the decreased inflow, and finally the decrease in outflow aloft weakened Wendy. Most storms that stall in movement, intensify; Wendy weakened.

Late on the 31st, the break in the subtropical ridge became more pronounced and Wendy began to recurve northeastward at 8 kt (15 km/hr). A succession of minor, mid-level troughs first forced Wendy northward early on the 2nd of August, then accelerated her northeastward.

The cooler environment and increased frictional effects caused Wendy to weaken and lose tropical characteristics by 18Z on the 2nd after existing as a significant tropical cyclone for 10 days.

Twice during Wendy's existence (240000Z to 260000Z and 300600Z to 311800Z), she slowed significantly. The portions of the best track shown for these periods are among many possible solutions. With fix-to-fix movement near to or less than the fix accuracies, it was almost impossible to determine if Wendy just slowed to 1-3 kt (2-6 km/hr), underwent looping, or simply remained "quasi-stationary".

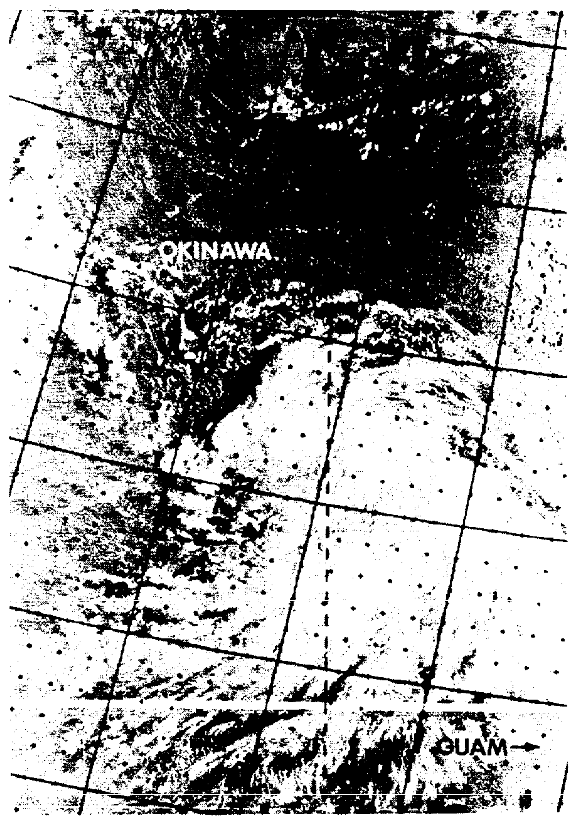
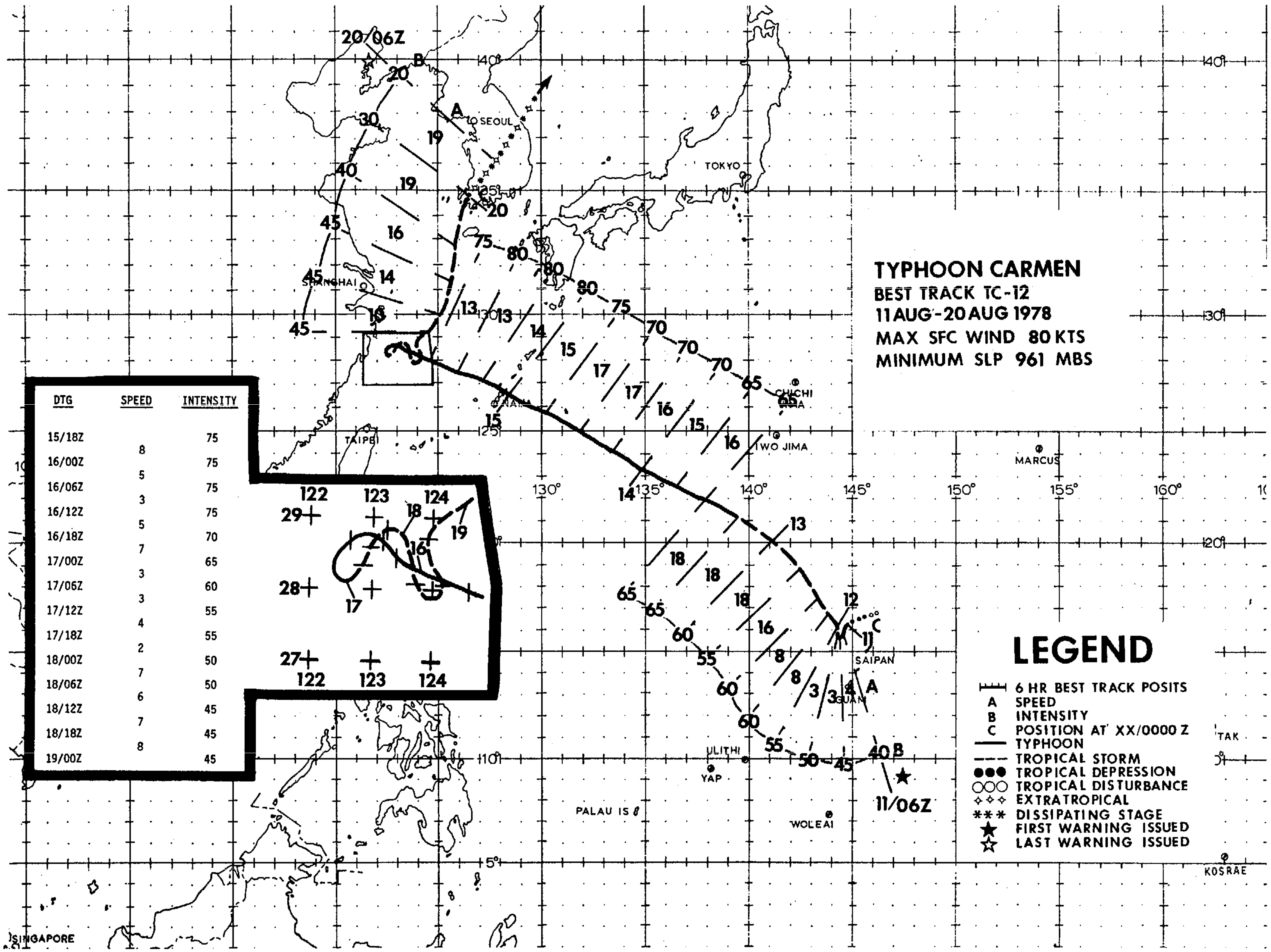


FIGURE 3-8 . *Wendy as a young tropical storm, 23 July 1978, 2117Z. Typical of circulations in the monsoon trough, maximum cloudiness exists in the deep southwesterlies just south of the trough axis. (DMSP imagery)*



DTG	SPEED	INTENSITY
15/18Z		75
	8	
16/00Z		75
	5	
16/06Z		75
	3	
16/12Z		75
	5	
16/18Z		70
	7	
17/00Z		65
	3	
17/06Z		60
	3	
17/12Z		55
	4	
17/18Z		55
	2	
18/00Z		50
	7	
18/06Z		50
	6	
18/12Z		45
	7	
18/18Z		45
	8	
19/00Z		45

The genesis of Typhoon Carmen provides an interesting example of the interaction of two synoptic features in generating a tropical cyclone. These features began interacting on 7 August 1978. On that day, Guam's surface winds shifted from easterly to southwesterly as the southwest monsoon surged well east of its normal habitat. Metsat imagery showed a noticeable upsurge in convective activity along and to the south of the low level monsoon trough, the axis of which now extended from Southeast Asia across the Philippines and over the western North Pacific to near the dateline. In Guam's vicinity, southwesterly flow persisted, deepened and strengthened. At 081200Z Guam's gradient level wind was 20 kt (10 m/sec) from the southwest.

During the same time frame, a Tropical Upper Tropospheric Trough (TUTT) northwest of Guam was deepening southward. Satellite derived upper-air winds at 081200Z confirmed considerable divergence existed south and east of the TUTT overlying the monsoon trough just north of Guam and definite signs of tropical cyclone organization were appearing. Six hours later, Guam's gradient wind had increased to 31 kt (16 m/sec) out of the southwest.

For the next day, this upper-level/lower-level interaction persisted and the developing disturbance, one of many along the monsoon trough discussed in the daily Significant Tropical Weather Advisory (ABEH PGTW), was written as having fair to good development potential. A formation alert was issued at 100156Z and two subsequent aircraft reconnaissance missions showed a minimum sea level pressure of 1004 mb and 25 kt (13 m/sec) estimated maximum surface winds. The surface center, however, was difficult to fix and the decision was to reissue the alert at 110134Z. Three hours later, however, aircraft data reported a 992 mb central pressure. Subsequently, the first warning was issued at 110600z with 40 kt (21 m/sec) intensity. Meanwhile, the activity in the monsoon trough had also rapidly organized in another area; Tropical Storm Della was forming just east of the Philippines.

The TUTT's influence on Carmen continued beyond her early developmental stages. TUTT interaction also influenced her track and affected her size and intensification rate. Initially, Carmen's track was expected to be climatological since the overall synoptic environment in which Carmen was situated was typical of the August climatology. A strong, mid-tropospheric, subtropical ridge existed north of her and Carmen was forecast to follow a west-northwest track. In actuality, Carmen moved erratically for one day and then accelerated to the north-northwest. It appears that upper-level steering from southeasterlies east of the TUTT was a major influence on her track.

The TUTT also influenced Carmen's development rate. At 120000Z, Carmen was beginning to accelerate to the north-northwest with an intensity of 55 kt (28 m/sec). Three days later she had only intensified to 80 kt (41 m/sec) - an intensification rate which was half of the average rate for August cyclones. A partial explanation for this slow intensification was the fact that Carmen had a faster than average forward speed of 16 kt (30 km/hr) during this period and also that she was part of a two storm situation (Fig. 3-9). However, it is equally possible that the TUTT (still west of Carmen) also had a part in influencing Carmen's slow intensification rate and small size by restricting upper level outflow in her western and southern quadrants (Figs. 3-9 & 3-10). The 200 mb analyses indicated that the TUTT moved with Carmen and strengthened from the 11th to the 14th.

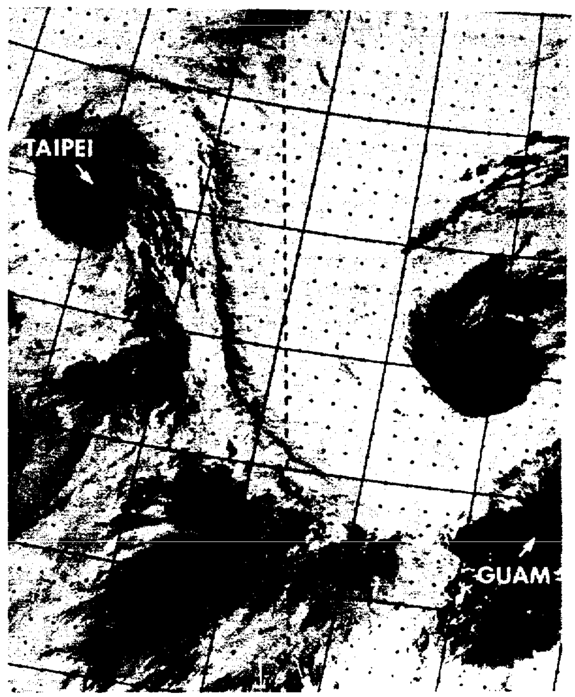


FIGURE 3-9. Infrared image of Typhoon Carmen (right) and Tropical Storm Della (left), 12 August 1978, 2134Z. (DMSP imagery)

By 151200Z, the TUTT axis had curled to the south of Carmen. Satellite imagery at this time (Fig. 3-11) showed a more symmetrical typhoon but small in areal extent. The strong mid-tropospheric subtropical ridge still existed to the north and Carmen was expected to track westward into the China coast. However, a high pressure cell was building ahead of Carmen over the Asian coast. By the 16th, Carmen was caught in a weak steering flow between high pressure cells to the east and west and, for three days, Carmen looped erratically and weakened in intensity. On the 17th, a developing short wave trough was analyzed over the Asian mainland and warnings reflected recurvature toward Korea. At 181200Z, Carmen did begin to track northward and eventually dissipated over Korea. Despite Carmen's erratic behavior, 24-hour forecast errors matched the average for the year.

During her lifetime, Carmen was responsible for considerable damage. Before dissipating over South Korea, she caused widespread flooding, a reported 21 deaths and $3 million worth of property damage. Saipan, affected by Carmen in her formative stage, reported flooding and property damage and was designated a national disaster area. At maximum intensity of 80 kt (41 m/sec) on August 15, Carmen passed over Okinawa about 26 nm (48 km) north of Kadena AB with little damage to DoD facilities.

The disturbance in the monsoon trough that eventually became Carmen was similar to many others that did and did not develop. And, of those that did develop, many only reached the monsoon depression stage. The difficulty in determining the development potential of these monsoon disturbances affected the timeliness of issuance of the formation alert and initial warning on Carmen. Near perfect forecasting to meet customer requirements would have allowed the initial warning to be issued 48 to 72 hours prior to the actual 110600Z issuance.

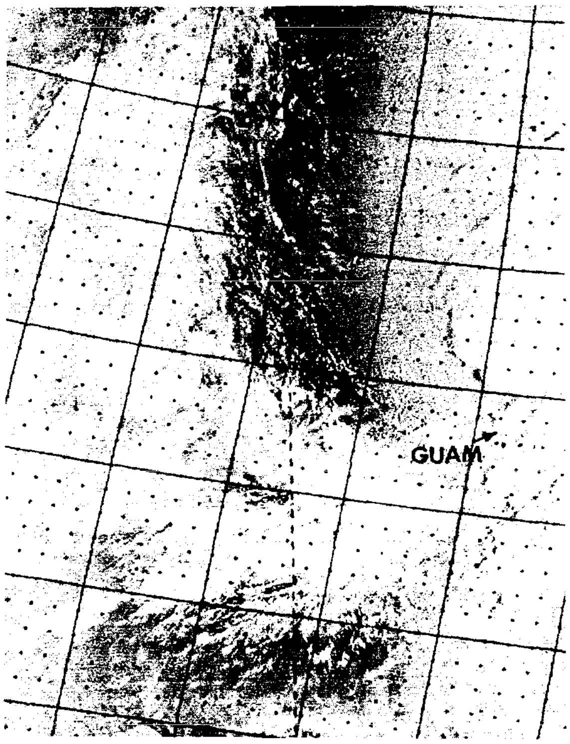


FIGURE 3-10. *Restricted upper-level outflow over Carmen's western and southern quadrants, 11 August 1978, 2243Z. (DMSP imagery)*

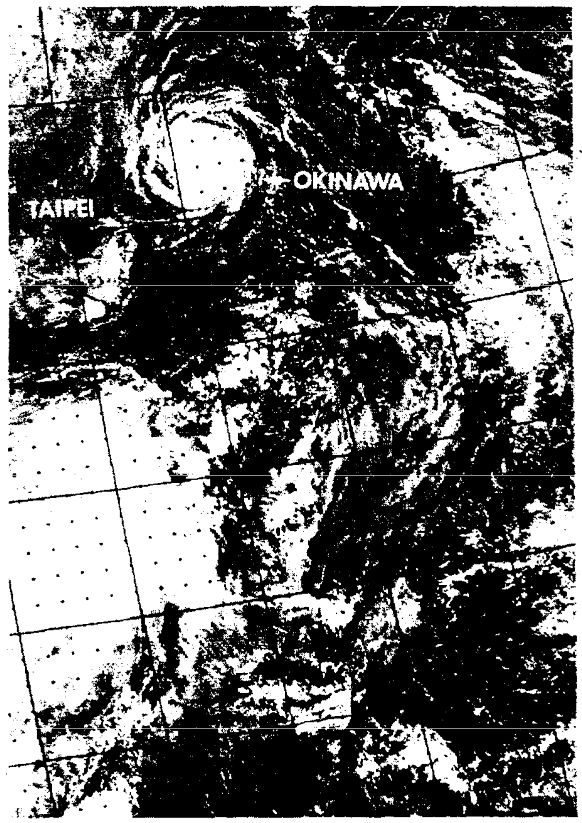
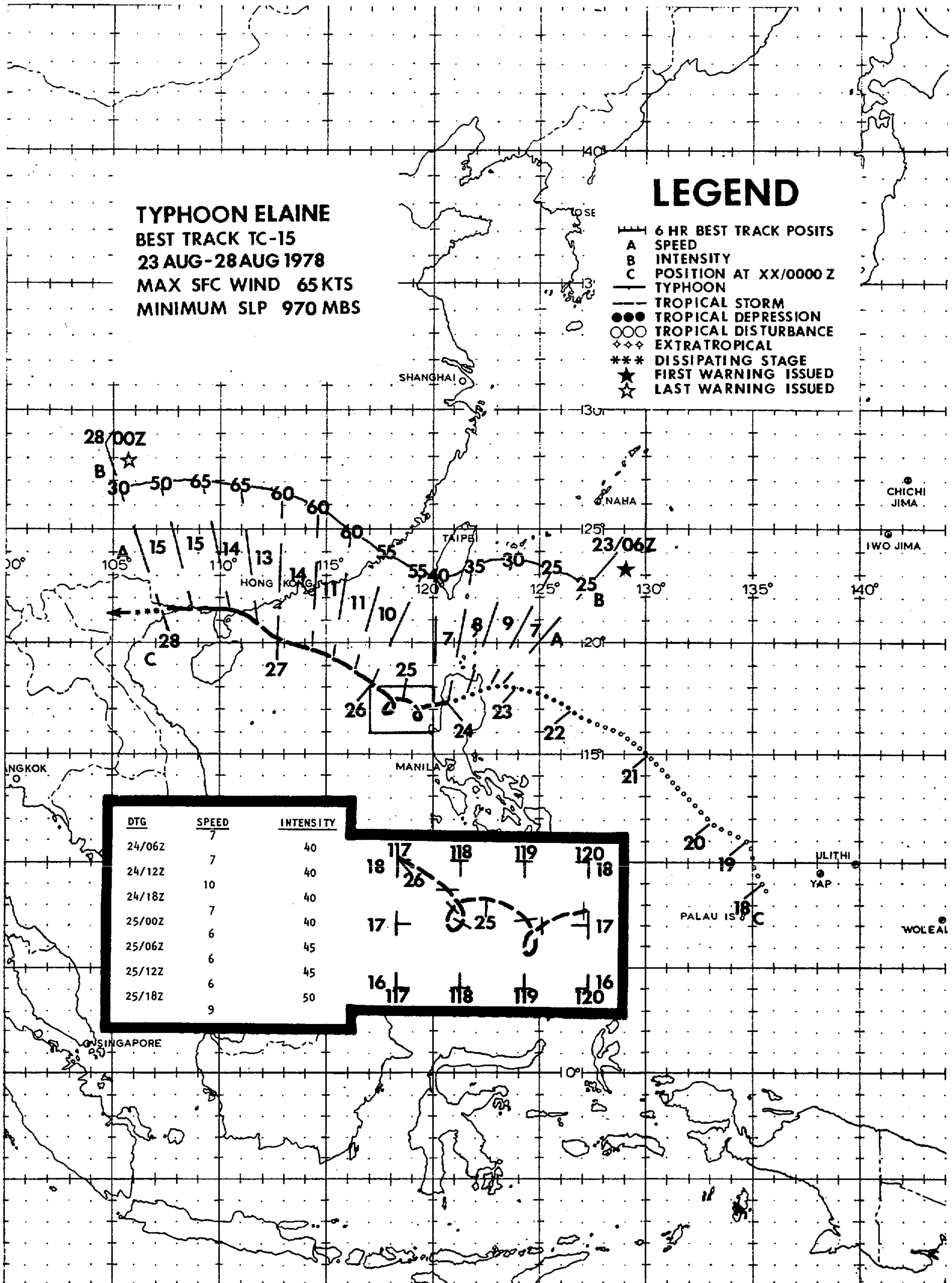


FIGURE 3-11. *Carmen's small areal extent, 15 August 1978, 1505Z. (DMSP imagery)*



TYPHOON ELAINE
BEST TRACK TC-15
23 AUG-28 AUG 1978
MAX SFC WIND 65 KTS
MINIMUM SLP 970 MBS
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
28/00Z
23/06Z
SHANGHAI
NAHA
TAIPEI
HONG KONG
MANILA
CHICHI JIMA
IWO JIMA
ULITHI
YAP
PALAU IS
WOLEAI
SINGAPORE
DTG SPEED INTENSITY
24/06Z 7 40
24/12Z 7 40
24/18Z 10 40
25/00Z 7 40
25/06Z 6 45
25/12Z 6 45
25/18Z 6 50
9

The 17th of August 1978 saw the monsoon trough extending as far east as 140E providing the breeding ground for Typhoon Elaine. Synoptic and satellite data on the 18th indicated a tropical disturbance, with maximum winds of 15 kt (8 m/sec), organizing to the northeast of Palau. From the 18th through the 20th, this system was discussed on the Significant Tropical Weather Advisory (ABEH PGTW) with poor to fair potential for significant tropical cyclone development. The relative position of the Tropical Upper Tropospheric Trough (TUTT), north of the disturbance during this period, indicated suppression of upper level outflow in the northern portion of the system. Issuance of a Tropical Cyclone Formation Alert was delayed as a result of expected strong upper-level directional shear. The advisories on the 21st and the 22nd carried fair to good potential; however, based on sparse synoptic data and little organization evident on the satellite data, the system was still thought to be in the formative stage. The initial warning was issued at 230600Z by which time increased organization and banding features were indicated on satellite imagery. Post analysis indicated the system was a tropical depression 36 hours prior to this time.

By 240000Z, the mid-tropospheric ridge provided more definitive east-northeast steering flow across northern Luzon resulting in Elaine's southwest track, contrary to a favored climatological track to the west-northwest. Climatological studies also indicate weakening during passage over Luzon. Based on synoptic data, however, Elaine continued to intensify and was upgraded to a tropical storm at 240000Z while still over land 170 nm (315 km) north of Manila. Heavy storm damage was reported in northern Luzon.

As Elaine exited Luzon into the South China Sea, her associated cloud pattern lacked sufficient organization for optimum satellite (Fig. 3-12) and radar fixes; aircraft reconnaissance at low flight levels (restricted at times by terrain) was heavily relied on for definitive surface center fixes. During this same period, 24 - 25 August 1978, Elaine was caught between strong southwest monsoon flow and strong northeast flow. As a result, Elaine looped twice and forecast errors increased considerably.

After completing the second loop, Elaine accelerated to the northwest in response to the mid-tropospheric ridge axis' northward migration. A weakness in this ridge was apparent on the 26th and developed northeast of Vietnam due to a mid-latitude short wave. By the 27th this short wave trough was within 10 degrees of Elaine and a noticeable northward adjustment in her track resulted. The closest point of approach (CPA) to Hong Kong occurred at 270200Z with Elaine 155 nm (287 km) to the southwest.

At 270300Z, the S.S. Seal and Trade located at 21N-113E reported surface winds of 65 kt (33 m/sec) and a surface pressure of 974 mb. Based on this ship report, Elaine was upgraded to typhoon strength just prior to landfall over the southern coast of China near the Luichow Peninsula. Subsequent to landfall, Elaine tracked westward and dissipated rapidly as a result of frictional/terrain effects. Downgrading to tropical storm intensity occurred by 271800Z with the final warning issued at 280000Z.

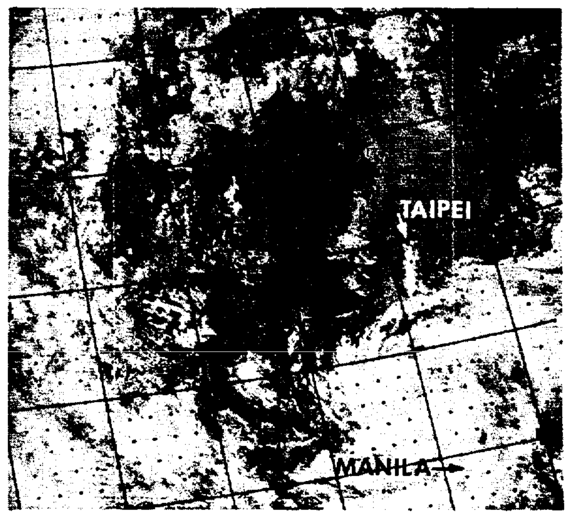
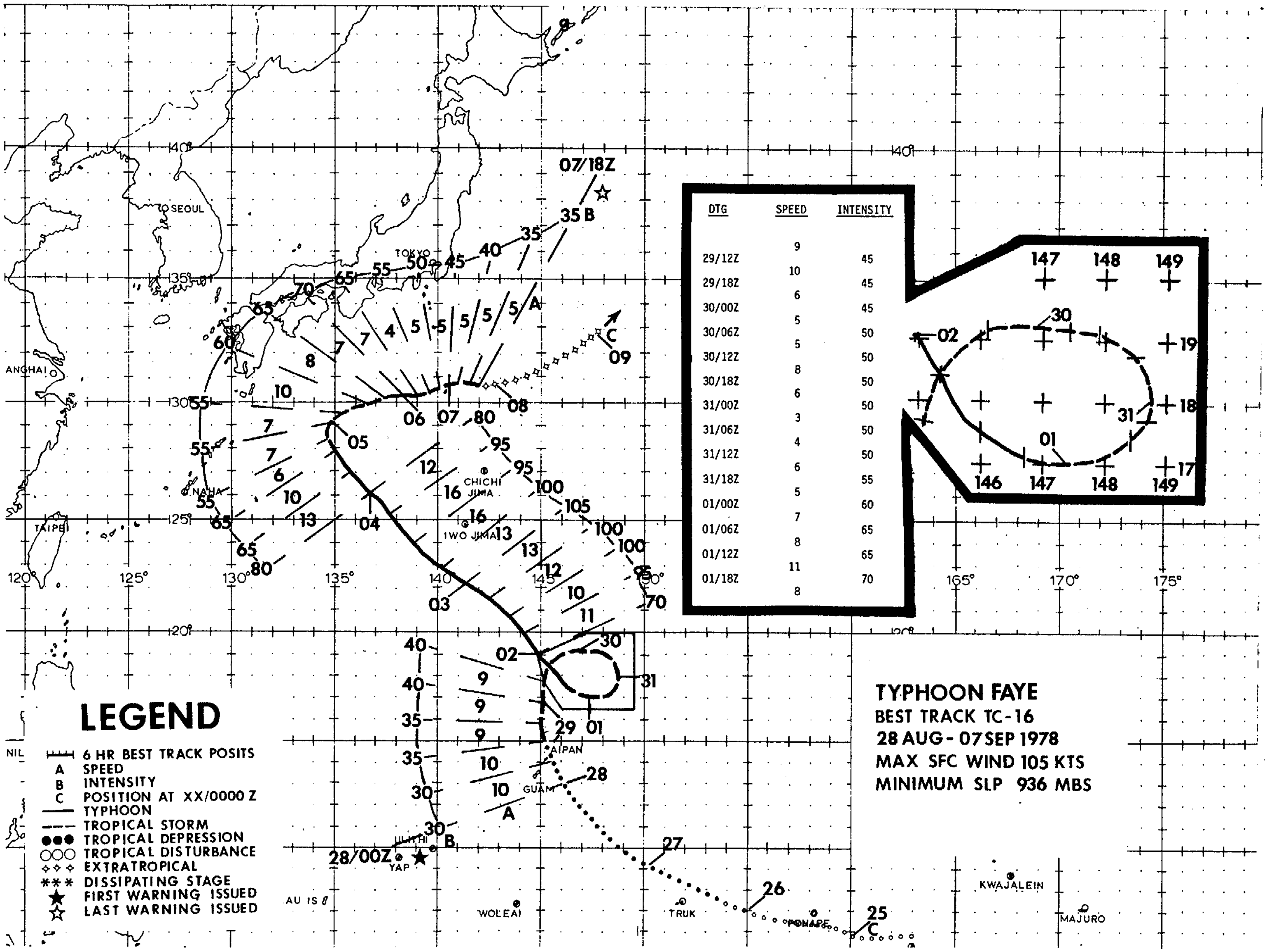


FIGURE 3-12. Visual imagery at 0134Z on 25 August 1978, showing Elaine's typical satellite signature during her erratic movement period, 24 - 25 August 1978. (NOAA-5 imagery)



TYPHOON FAYE
BEST TRACK TC-16
28 AUG - 07 SEP 1978
MAX SFC WIND 105 KTS
MINIMUM SLP 936 MBS
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
DTG | SPEED | INTENSITY
29/12Z 45
29/18Z 45
30/00Z 45
30/06Z 50
30/12Z 50
30/18Z 50
31/00Z 50
31/06Z 50
31/12Z 50
31/18Z 55
01/00Z 60
01/06Z 65
01/12Z 65
01/18Z 70
9 10 6 5 5 8 6 3 4 6 5 7 8 11 8
07/18Z
28/00Z
SEOUL
TOKYO
TAIPEI
NAHA
CHICHI JIMA
IWO JIMA
SAIPAN
GUAM
ULITHI
YAP
WOLEAI
TRUK
PONAPE
KWAJALEIN
MAJURO

Typhoon Faye, the seventh typhoon of the 1978 season, was one of the most interesting, but unfortunately, also one of the year's most difficult typhoons to forecast. Besides executing an uncommon anticyclonic loop early in her development, Faye also unexpectedly reintensified to typhoon strength shortly before becoming extratropical.

The tropical disturbance that was to become Typhoon Faye was first sighted southeast of Ponape at 242142Z, August 1978 by satellite reconnaissance. The disturbance moved west-northwest at 13 kt (24 km/hr) and at 261200Z passed north of Truk. During this period, 200 mb analyses showed a tropical upper tropospheric trough (TUTT) with an imbedded low northwest of the disturbance. This TUTT moved west-northwest in conjunction with the surface circulation thereby keeping excellent upper-level outflow in the diffluent region, southeast of the TUTT cell, over the developing tropical disturbance.

Based on an improved satellite signature and on ship synoptic data, a Tropical Cyclone Formation Alert was issued on the disturbance at 272334Z. Shortly thereafter, a reconnaissance aircraft confirmed the existence of a closed surface circulation with a minimum sea level pressure of 1000 mb. Based on this aircraft data, the disturbance was upgraded to Tropical Depression 16 at 280000Z with max winds of 30 kt (15 m/sec). The 500 mb subtropical ridge axis was at that time oriented east-west along 36N.

At 280600Z, TD-16 passed 60 nm (111 km) to the northeast of Guam and was upgraded to Tropical Storm Faye six hours later. During the next 24 hours the storm moved straight north while slowly intensifying. The 500 mb flow pattern became complex during this period due to the influence of two new developing tropical systems: TS Gloria between Luzon and Japan and TS Hester west of Marcus Island (Fig. 3-13). The 500 mb analysis at 281200Z (Fig. 3-14) showed that the Pacific Ocean south of Japan between Guam and the Philippine Islands was dominated by an elongated monsoon trough holding multiple circulation centers, one of which was to become TS Gloria. High pressure cells were located east of Tokyo and southeast of Marcus Island.

The 281200Z objective steering aids indicated Faye would track northeastward. However, because the initial pattern itself was confused, a more climatological north-northwestward track was forecast.

By 291200Z Faye began to execute a rare, anticyclonic loop. The 300000Z, 500 mb analysis (Fig. 3-15) showed that Faye was now positioned between two high pressure centers: one located between Marcus Island and the Volcano Islands, and the other located south of Guam. This pattern was the result of the combined influence of Gloria, Hester, Faye, and a long-wave, mid-level trough that was developing far to the northeast of Faye. It was now possible for Faye to choose one of two routes: (1) move north-northeast in the weakness between Marcus Island and Wake Island; or (2) move west-northwest along the southern periphery of the high pressure center to her north.

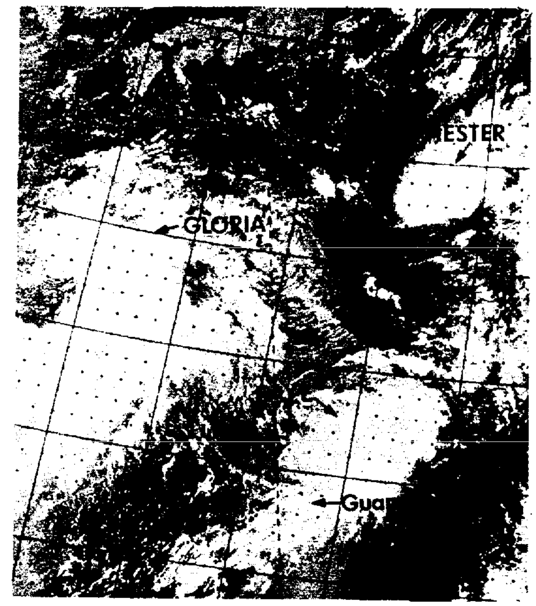


FIGURE 3-13. Tropical Storm Faye just prior to executing an anticyclonic loop north of Guam, while at an intensity of 40 kt (21 m/sec). TS Gloria is southeast of Okinawa and TS Hester is northwest of Marcus Island, 29 August 1978, 0137Z. (DMSP imagery)

Unfortunately, by 310000Z, the high pressure center south of Guam shifted further to the west. This change in the flow pattern allowed Faye to swing to the south and thus complete her anticyclonic loop.

Faye reached the southernmost point of her looping track at 010000Z September and six hours later was upgraded to typhoon strength based upon the development of a poorly defined eye and a central pressure drop to 984 mb as reported by reconnaissance aircraft. At 020000Z September, the 500 mb pattern again changed radically (Fig. 3-16). Ridging, albeit weak, now dominated the Pacific east of Faye. Troughing, enhanced by a long wave east of Japan dominated the Pacific west of Typhoon Faye. Faye was now under the influence of southeasterly steering flow and began tracking steadily northwestward around the western periphery of the ridge.

As the ridge strengthened, Faye accelerated from 8 kt (15 km/hr) to 16 kt (30 km/hr) by 031200Z. Thereafter she began to decelerate again and weaken as she approached the axis of the mid-tropospheric subtropical ridge. By 041800Z, Faye

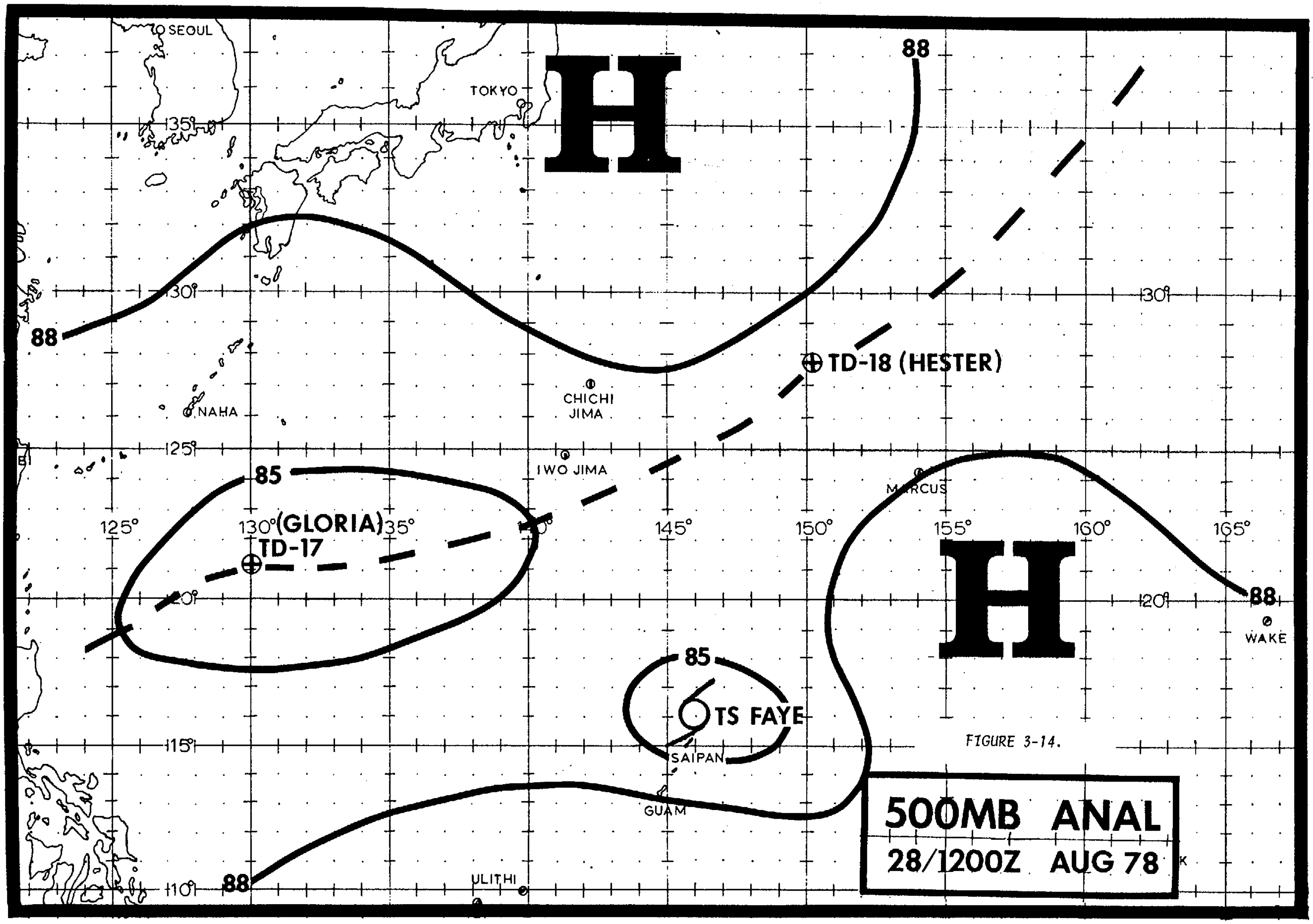

SEOUL
TOKYO
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
SAIPAN
GUAM
ULITHI
TD-18 (HESTER)
(GLORIA) TD-17
TS FAYE
H
H
88
85
125°
130°
135°
145°
150°
155°
160°
165°
500MB ANAL
28/1200Z AUG 78

FIGURE 3-14.

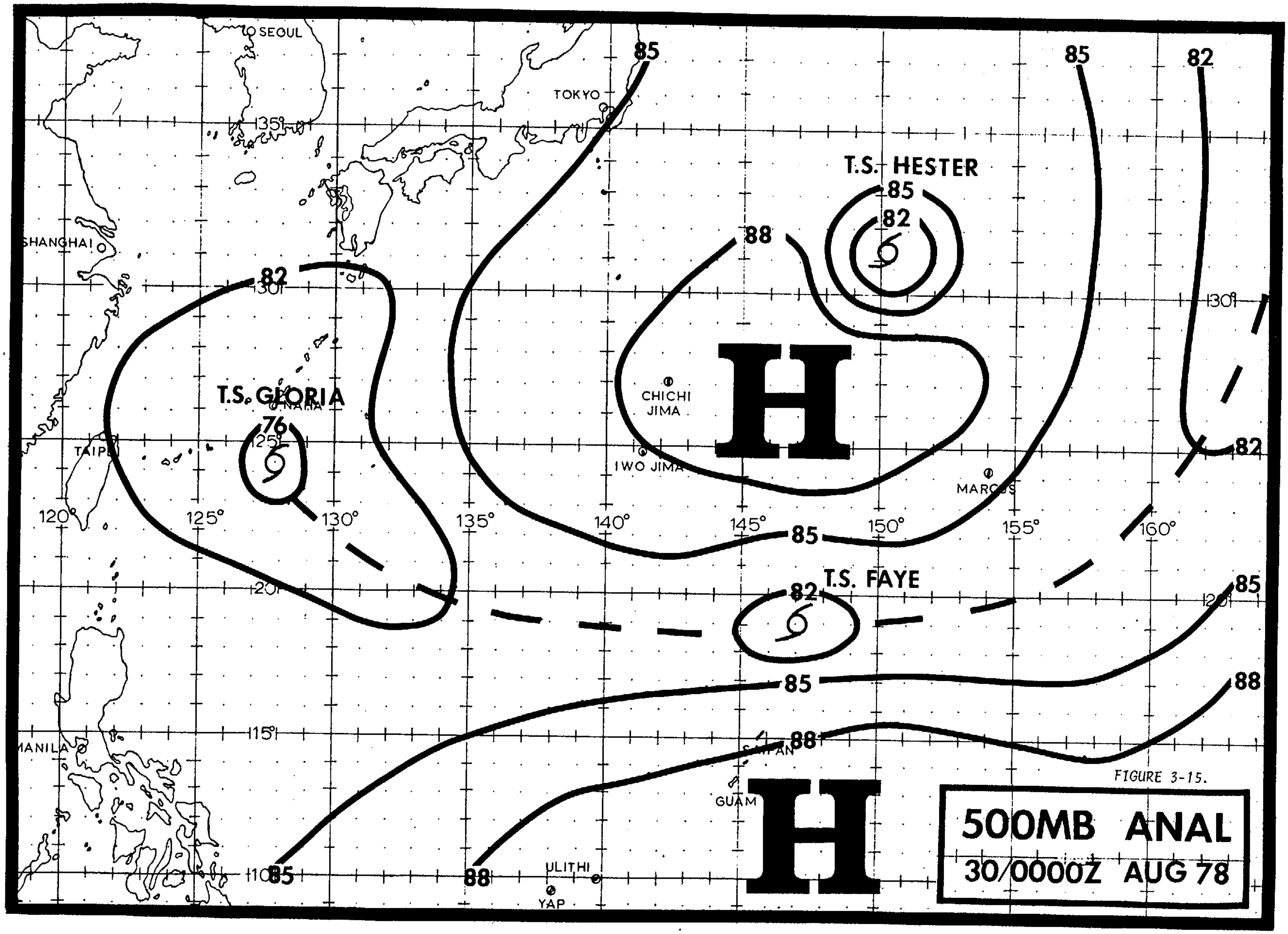

500MB ANAL
30/0000Z AUG 78
T.S. HESTER
T.S. GLORIA
T.S. FAYE
H
H
SEOUL
TOKYO
SHANGHAI
TAIPEI
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
SAIPAN
GUAM
ULITHI
YAP
MANILA
120°
125°
130°
135°
140°
145°
150°
155°
160°
85
82
88
76

FIGURE 3-15.

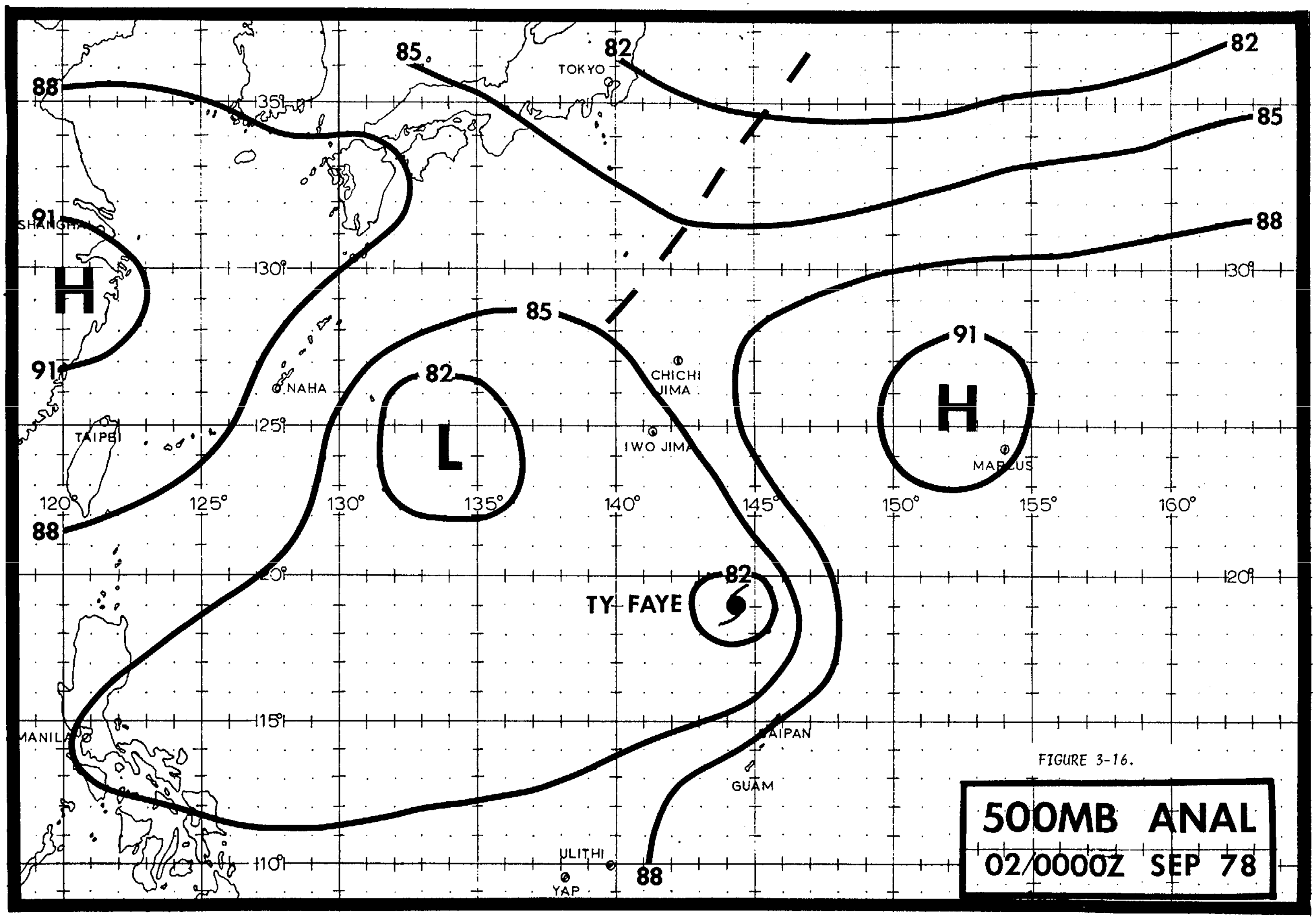

500MB ANAL
02/0000Z SEP 78
TY FAYE
H
L
H
82
85
88
91
TOKYO
SHANGHAI
TAIPEI
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
MANILA
SAIPAN
GUAM
ULITHI
YAP
120°
125°
130°
135°
140°
145°
150°
155°
160°
10°
15°
20°
25°
30°
35°

FIGURE 3-16.

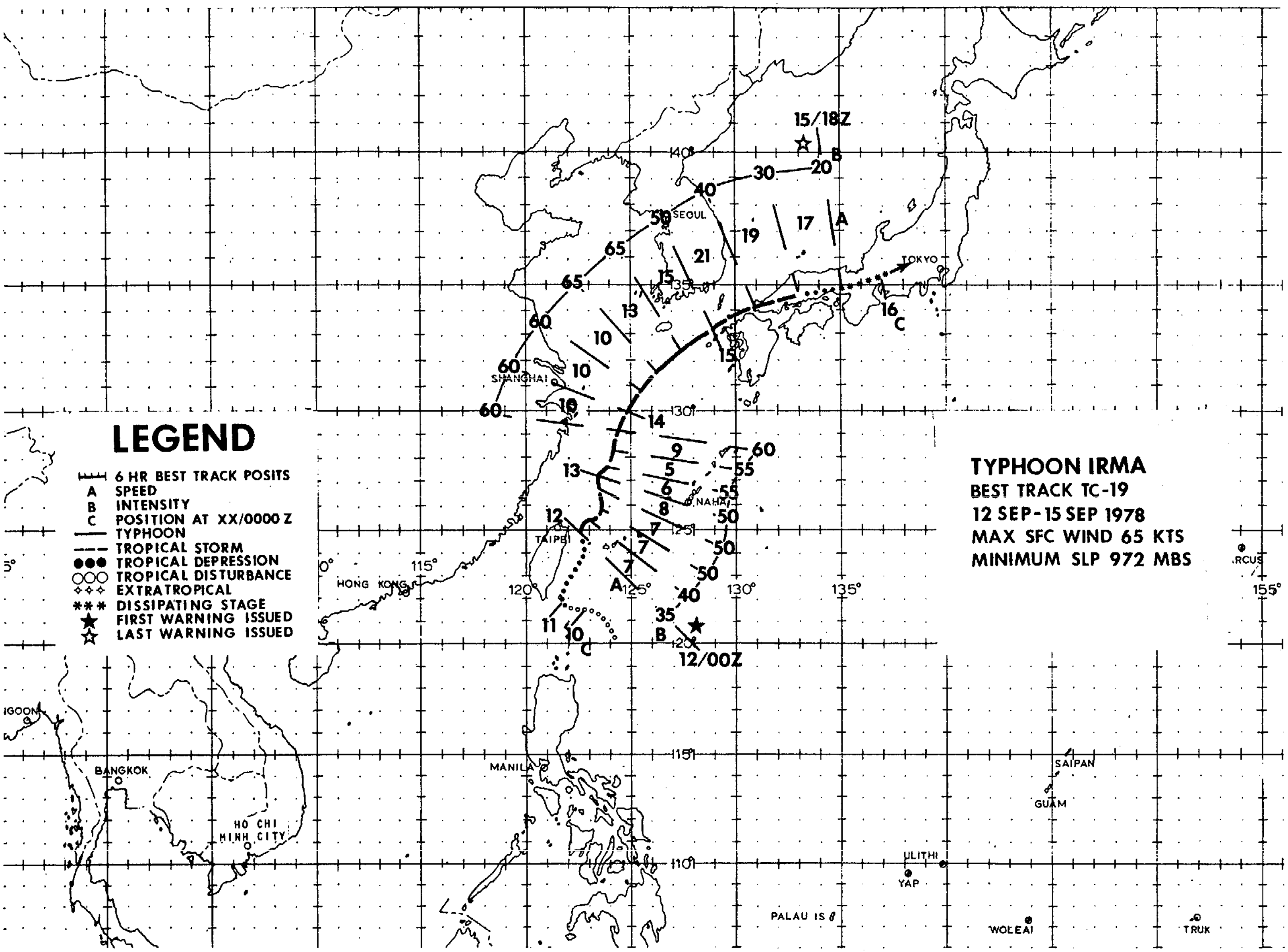
weakened to tropical storm strength and within six hours had crossed the ridge axis and began to recurve to the northeast.

Normally a system would be expected to accelerate after crossing the ridge axis, but in this case the mid-latitude westerly jet stream was located considerably to the north; the mid-level steering was therefore very weak and Faye actually continued a slowing trend. Likewise, a tropical system would be expected to continue weakening after recurvature as it moves over cooler water, begins to entrain cold air at mid-levels from the north and comes under the influence of strong vertical wind shear. A reconnaissance aircraft at 050541Z, however, reported that Faye's central pressure had dropped to 975 mb with an increase in overall organization also noted. Faye was upgraded to typhoon strength based on aircraft reconnaissance and ship data at 051800Z.

The reason for Faye's reintensification was related to the weak, upper-level flow pattern. During Faye's period of reintensification, mid- and upper-level winds were basically zonal and light, thereby minimizing the cold air entrainment. Reconnaissance aircraft reports indicated that Faye was distinctly warm core during this period. Because of the weak flow between 500 and 200 mb, vertical wind shear was small and, thus, Faye was able to maintain vertical organization longer than was anticipated.

By 061200Z September, Faye again weakened to tropical storm intensity due to increasing vertical wind shear. Upper-level winds increased and satellite imagery showed that her upper-level center was finally being sheared off from the surface center. The final warning on TS Faye was issued at 071800Z at which time she was fully extratropical and in the process of merging with the polar front.

Although Typhoon Faye avoided the major land masses of the Pacific area, she did cause damage to the Northern Mariana Islands. During her anticyclonic loop, the islands of Agrihan, Alamagan, and Pagan were directly affected twice. Pagan sustained the most damage with sixty-five homes destroyed and one merchant vessel grounded.


LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
TYPHOON IRMA
BEST TRACK TC-19
12 SEP-15 SEP 1978
MAX SFC WIND 65 KTS
MINIMUM SLP 972 MBS
15/18Z
12/00Z
SEOUL
TOKYO
SHANGHAI
NAHA
TAIPEI
HONG KONG
MANILA
BANGKOK
HO CHI MINH CITY
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
115°
120°
125°
130°
135°
155°

Irma, the eighth typhoon of the 1978 season, developed in the monsoon trough southeast of Taiwan. Located in the Luzon Straits over the previous week, the monsoon trough slowly drifted northward and a weak surface circulation became evident southeast of Taiwan on the 11th. The monsoon trough at 500 mb was also observed to have shifted well northward signifying the trough becoming vertically aligned with the surface circulation. This northward shift also moved the monsoon circulation under favorable outflow aloft. The mechanism for rapid tropical cyclone development being present, numbered warnings began without the issuance of a formation alert.

Aircraft reconnaissance, at 0935Z on the 12th, confirmed TD-19 had undergone rapid development. Post analysis determined that the cyclone reached tropical storm strength at 120000Z. Due to the lack of a strong subtropical high pressure ridge to the north of Irma and the fact that the southwest monsoon flow was more intense than the easterlies north of the monsoon trough, Irma moved northeast. Then, on the 13th at 1800Z, Irma began accelerating northeastward as mid-level steering strengthened when a short-wave, westerly trough tracked eastward off China. Diffluence aloft, ahead of the short-wave, allowed Irma to reach a maximum intensity of 65 kt (33 m/sec) by 141200Z.

Irma remained a typhoon for only 12 hours becoming the shortest-lived typhoon of the season. The 140000Z, 500 mb analysis indicated that Irma was north of the broad subtropical ridge axis, building in behind her, and she was accelerating northeastward. Her maximum forward speed of 21 kt (39 km/hr) was obtained while tracking through the Tsushima Straits prior to making landfall on Honshu.

In the last 24-36 hours of her existence, Irma experienced increased vertical shear which brought on rapid weakening. The terrain effects of Kyushu and Honshu caused Irma to dissipate near 1200Z on the 15th.

Although remaining a typhoon for only 12 hours and weakening rapidly as she tracked towards southwest Japan, Irma produced widespread damage to Kyushu with estimated gusts in excess of 100 mph (45 m/sec) reported. Irma smashed windows, overturned cars, and capsized several fishing boats. Several athletes at the Japan-China Friendship Track and Field Meet in Kitakyushu were injured when a freak gust blew them ten feet in the air.

Irma exhibited a movement to the northeast similar to previous 1978 recurvers (Olive, Polly, Virginia, Gloria and Hester).

Irma's track indicates she traveled parallel to, but just outside, the 200 mb strong wind flow; actually just outside the 50 kt (26 m/sec) isotach (Fig. 3-17). The observed relationship appears to provide an excellent forecast aid and was particularly important during Irma. All forecasts, however, must take into account the possible northward adjustment of the max wind band as well as the possible deepening of short-wave troughs off the China mainland. An accurate 36-hour to 48-hour, 200 mb prog should help greatly.

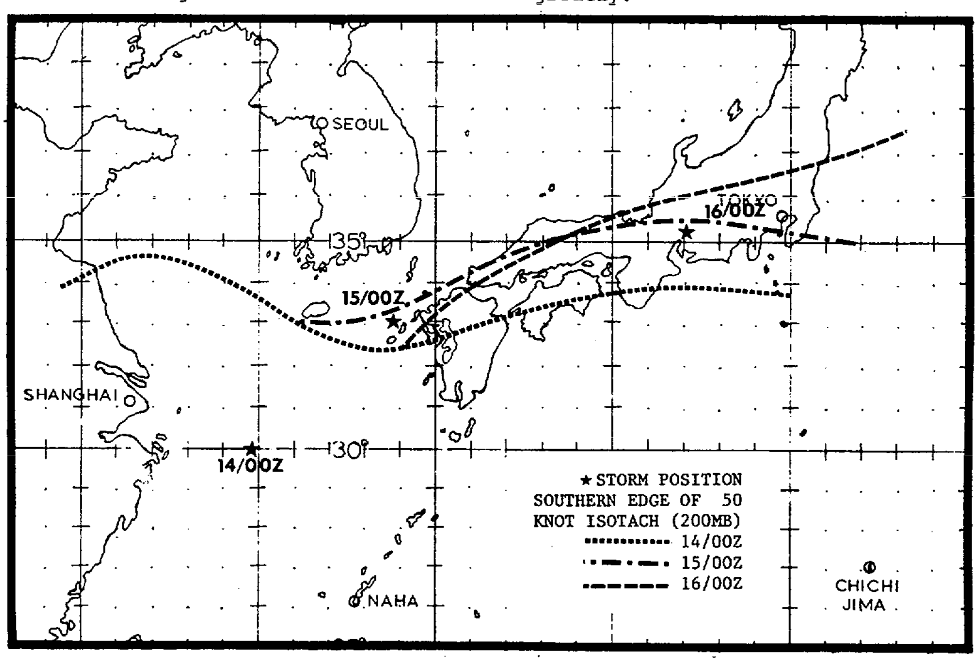
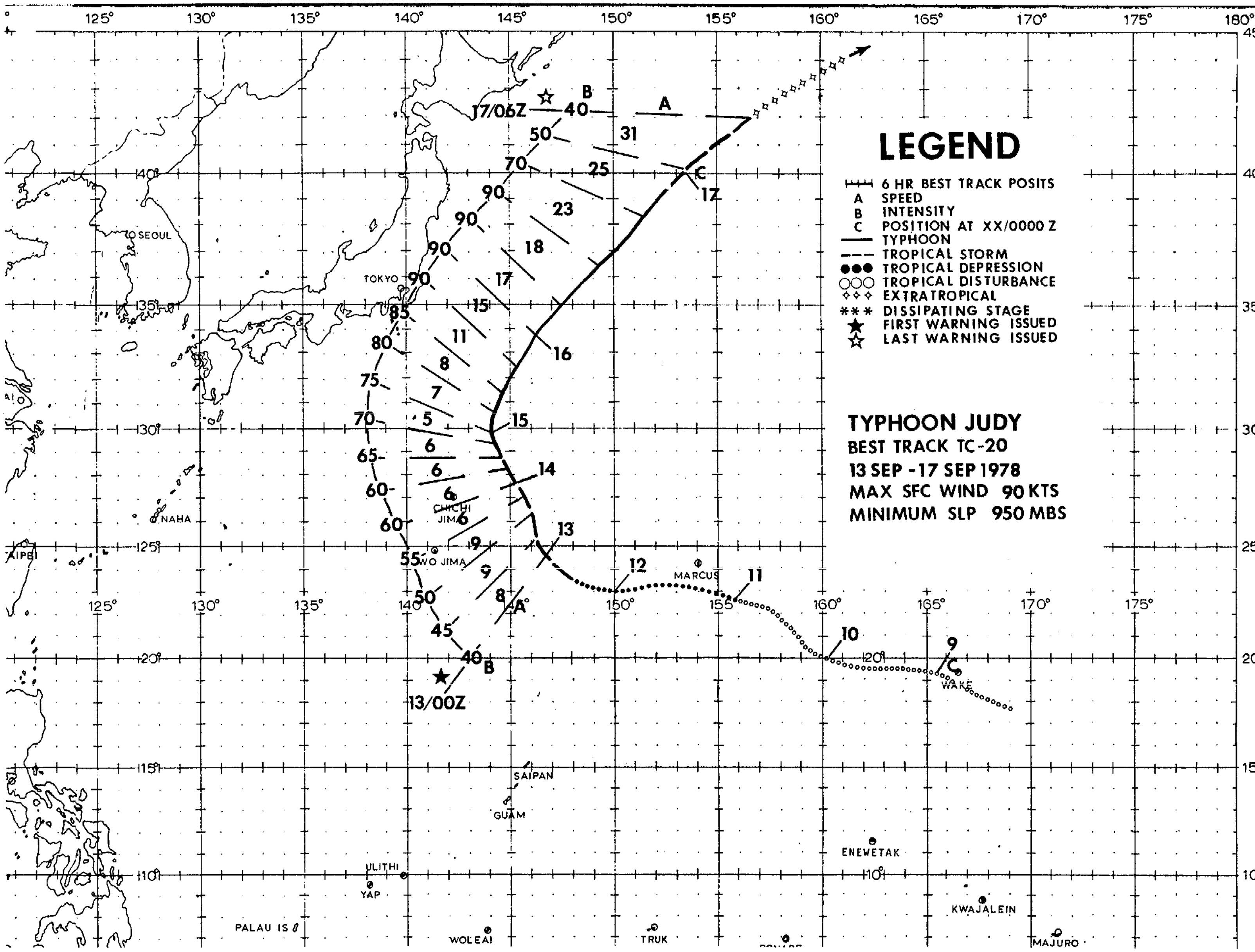


FIGURE 3-17. Irma's positions relative to the southern boundary of the 200 mb, 50 kt isotach from 140000Z to 160000Z September 1978.


LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
TYPHOON JUDY
BEST TRACK TC-20
13 SEP - 17 SEP 1978
MAX SFC WIND 90 KTS
MINIMUM SLP 950 MBS
17/06Z
13/00Z
SEOUL
TOKYO
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
ENEWETAK
KWAJALEIN
MAJURO

Typhoon Judy was first evident on satellite imagery as an area of convective activity in the easterlies. Further evidence of the initial disturbance was provided by surface observations from Wake Island during the period of 081200Z to 090000Z September 1978 showing a wind shift, maximum sustained winds of 20 kt (10 m/sec), and a minimum sea level pressure of 1005 mb. For the next three days, the disturbance was monitored by satellite reconnaissance and discussed in the Significant Tropical Weather Advisory (ABEH PGTW). Based on September's climatology for disturbances north of 20N latitude, potential for development was considered to be poor. At times during this period, this potential was supported by satellite imagery showing weak vertical development associated with the disturbance (Fig. 3-18). However, on the 12th, satellite imagery showed increased organization. A Tropical Cyclone Formation Alert was issued as 120440Z and aircraft reconnaissance was scheduled. The first aircraft penetration was 16 hours later and aircraft data along with satellite imagery (Fig. 3-19) supported a cyclone of tropical storm intensity. Consequently, the first warning was issued at 130000Z. Even though Judy was detected very early in her developmental stages, the issuance of an earlier warning was delayed primarily due to a lack of significant skill over climatology in forecasting rapid tropical cyclone development.

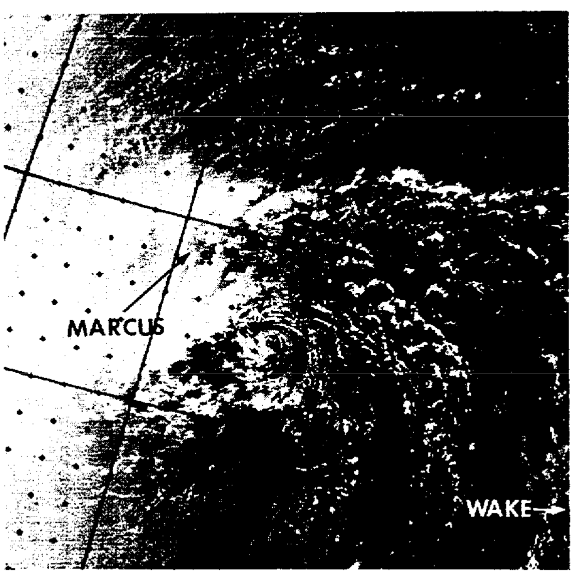


FIGURE 3-18. Tropical Disturbance which developed into Typhoon Judy. At this time the disturbance lacked vertical development, 10 September 1978, 2049Z. (DMSP imagery)

From the time of the first warning until the last, Judy's track was one of classical recurvature, slowing in forward movement to 5 kt (9 km/hr) at the recurvature point and accelerating to 31 kt (57 km/hr) under strong westerly upper-level steering north of the subtropical ridge axis. Although part of a two-storm situation with Typhoon Irma (Fig. 3-20), Judy never appeared to be influenced by Irma's presence. Warnings on Judy showed excellent continuity. From the second warning on, a recurvature path was forecast. This was due in part to the early detection which provided considerable history in Judy's past track before the first warning was issued. As a result, the forecast errors for Typhoon Judy were considerably better than average for cyclones undergoing recurvature. The intensity forecasts for Judy, however, always lagged her true intensification rate. The maximum intensity of 90 kt (46 m/sec) which Judy attained after recurvature was not foreseen, nor was the rate at which Judy weakened.

At the time of the last warning issued on Typhoon Judy at 170600Z, satellite imagery showed that Judy was merging with an extratropical system to the north. The added influx of energy into this system caused it to deepen rapidly in 12 hours from an estimated 1000 mb to 988 mb with observed 50 kt (26 m/sec) surface winds. During her life, no reported damage was done by Typhoon Judy.

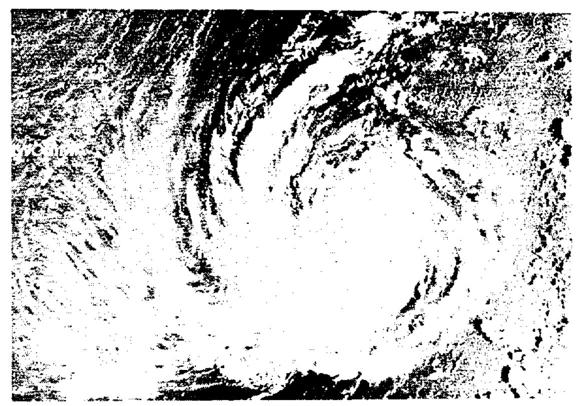


FIGURE 3-19. Judy was at tropical storm intensity at this time, 12 September 1978, 2156Z. (DMSP imagery)

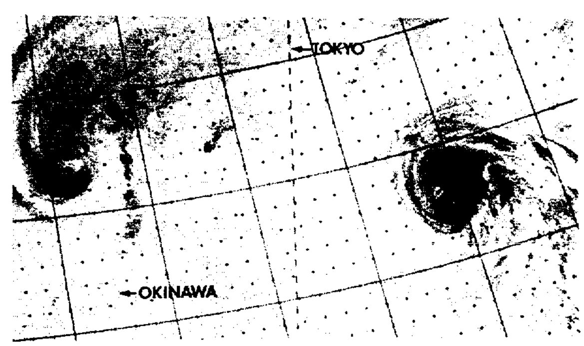
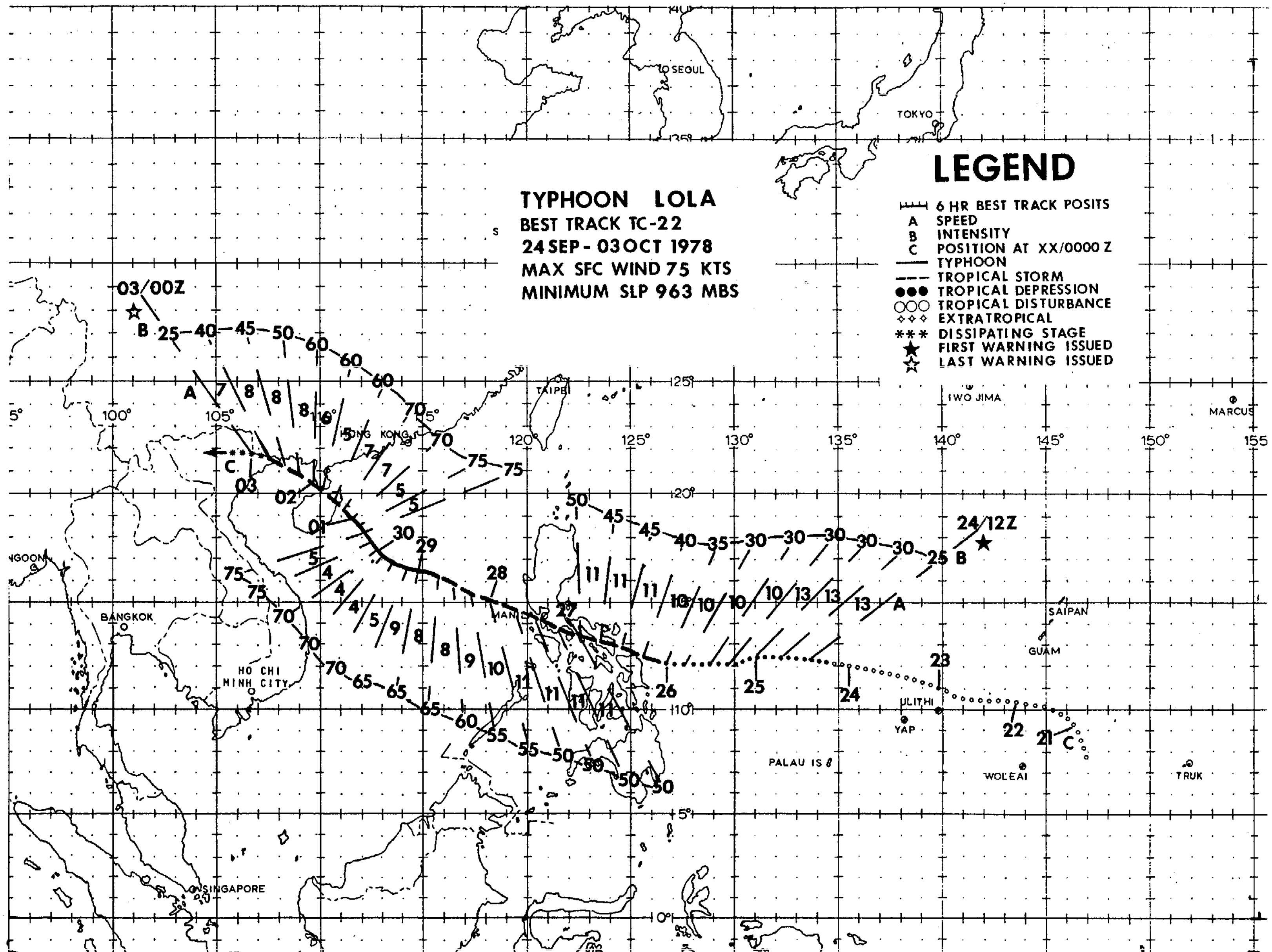


FIGURE 3-20. Infrared imagery of Typhoons Judy (right) and Irma (left), 14 September 1978, 1438Z. (DMSP imagery)

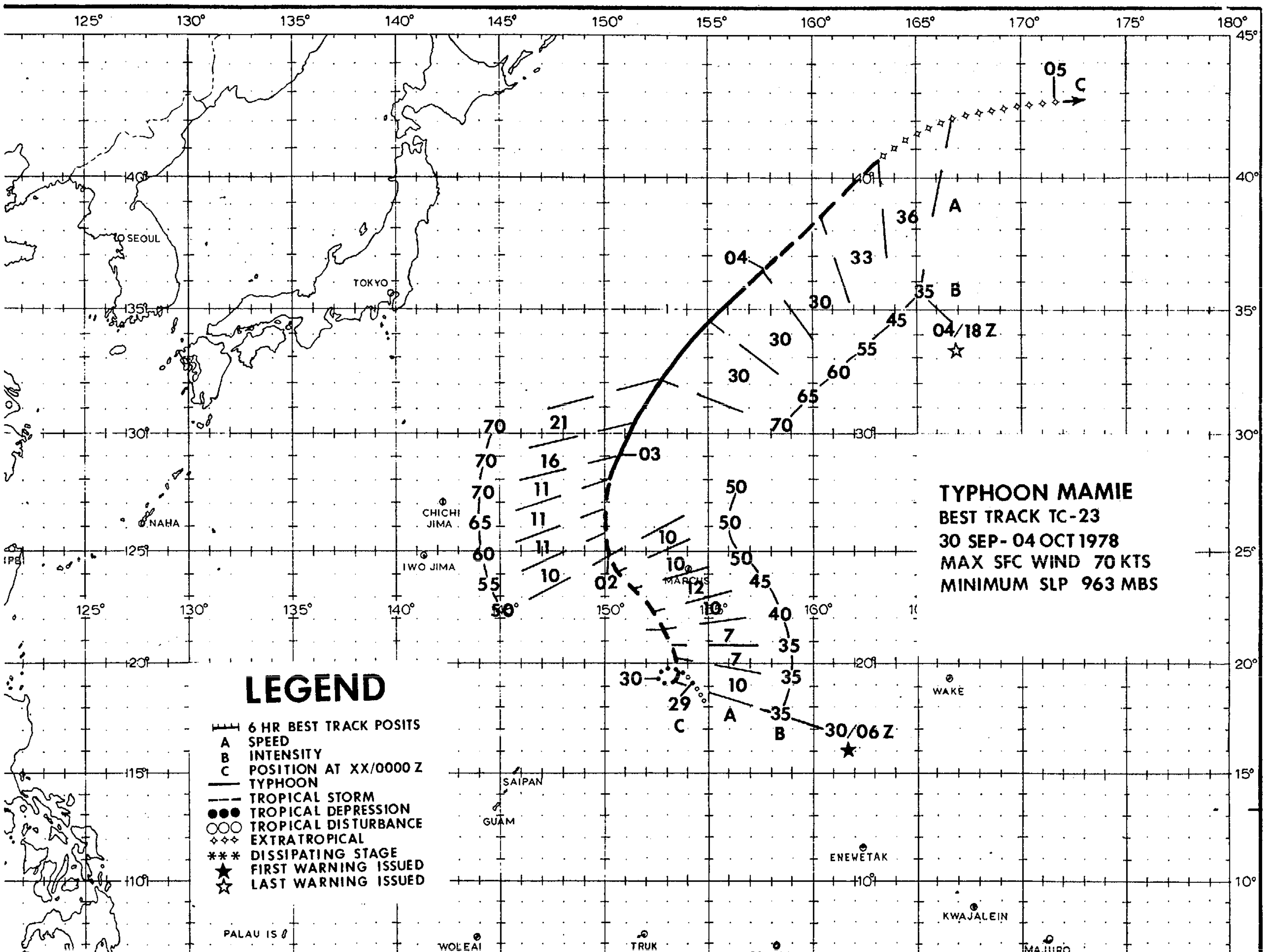


TYPHOON LOLA
BEST TRACK TC-22
24 SEP - 03 OCT 1978
MAX SFC WIND 75 KTS
MINIMUM SLP 963 MBS
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
03/00Z
24/12Z
SEOUL
TOKYO
TAIPEI
HONG KONG
MANILA
BANGKOK
HO CHI MINH CITY
SINGAPORE
IWO JIMA
MARCUS
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK

Typhoon Lola was spawned within a very active trough located between the equator and 12N, from the Philippines eastward to 150E. On the 20th of September 1978, satellite imagery gave the first indication of a disturbance near 08N-147E; however, a distinct surface circulation was not evident. Between the 20th and the 24th, the disturbance slowly accelerated to the northwest then west-northwest through the Caroline Islands passing between Ulithi and Guam on the 22nd with 15-20 kt (7-10 m/sec) intensity. A tropical cyclone formation alert was issued at 240600Z when increased organization in feeder band activity was noted on satellite imagery and potential for further development was evident. Based on aircraft and satellite data, the first warning on Tropical Depression 22 (TD-22) was issued at 241200Z with 25 kt (13 m/sec) intensity.

During the 24th and 25th, TD-22 maintained a westward movement within the near equatorial trough on a heading 10 degrees north of the trough axis. This westward movement toward the central Philippines was supported by easterlies along the southern periphery of the mid-tropospheric subtropical ridge. Aircraft data at 252100Z positioned the circulation 110 nm (205 km) east of Samar. Increased organization and a central pressure of 995 mb were noted which resulted in upgrading the system to Tropical Storm Lola at 260000Z. Landfall was made on the southeastern tip of Luzon at 261500Z. Lola's subsequent track during the 27th took her along the southern coast of Luzon passing over the cities of Legaspi and Batangas. The closest point of approach (CPA) to Manila occurred at 271000Z as Lola passed 35 nm (65 km) to the southwest. At this time, the International Airport at Manila reported 30 kt (15 m/sec) sustained winds with gusts to 50 kt (26 m/sec). The Naval Weather Service Environmental Detachment (NWSED) at Cubi Pt. recorded maximum sustained winds of 40 kt (21 m/sec) with a peak gust of 59 kt (30 m/sec) at 271241Z. Nineteen deaths and heavy property damage in the southern Tagaloc and Bical regions were attributed to Lola's passage. As Lola exited into the South China Sea, the 500 mb analysis indicated a short wave trough in the westerlies over China extending as far south as 27N with a weakness in the subtropical ridge forming over southern China. By 280000Z, the trough extended to 23N along 105E and the subtropical high center east of the weakness had moved eastward across the northern Philippines. This caused Lola's dominant mid-level steering flow to become southeasterly which resulted in her more climatological northwest track over the South China Sea. Supported by good upper-tropospheric outflow and strong low-level energy input, gradual intensification occurred from 271800Z through 301800Z. Based on aircraft data, Lola was upgraded to typhoon intensity at 281800Z. During the 29th and 30th of September, Lola reached maximum intensity with sustained winds of 75 kt (39 m/sec) and a minimum pressure of 963 mb. The mid-tropospheric ridge began strengthening westward resulting in Lola's track becoming more west-northwest toward Hainan Island. Landfall over Hainan occurred at 010900Z October, 10 nm (19 km) southeast of Wenchang.

Weakened by terrain features, Lola was downgraded to a tropical storm at 011200Z as she continued west-northwestward into northern Vietnam. The final warning downgrading Lola to tropical depression intensity was issued at 030000Z. Lola's overall uncomplicated track produced the lowest 24-, 48- and 72-hour forecast vector errors (54, 116 and 139 nm respectively) of the 1978 storm season. The 24- and 48-hour forecast vector errors were expecially low (average of 21 nm (39km) and 40 nm (74km) respectively) during Lola's passage over the Philippines. This resulted from the increased accuracy of fix positions due to additional land radar and synoptic reports, the uncomplicated track, and the fact that Lola remained a well-organized system during transit allowing accurate fixing.



TYPHOON MAMIE
BEST TRACK TC-23
30 SEP- 04 OCT 1978
MAX SFC WIND 70 KTS
MINIMUM SLP 963 MBS
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SEOUL
TOKYO
NAHA
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
SAIPAN
GUAM
ENEWETAK
KWAJALEIN
PALAU IS
WOLEAI
TRUK
MAJURO
30/06 Z
04/18 Z

Typhoon Mamie was yet another of the compact typhoons of 1978. Mamie was also an open ocean typhoon (i.e., it formed and dissipated over the ocean, and affected shipping lanes) and never really threatened any land stations.

Tropical Depression 23 (Mamie) developed from a wave in the easterlies. On the 27th of September at 0000Z this wave was approximately 100 nm (185 km) east of Guam and was oriented southwest-northeast from 10N to 25N. Within the wave, there were two disturbance areas. The northernmost area eventually developed when it moved under an upper air difluent region. By the 30th, a compact tropical depression was easily noted on satellite data (Fig. 3-21). Also noted were cirrus cloud streamers showing outflow existed in all quadrants. The first warning on TD-23 was issued immediately thereafter.

Remaining a very compact system (Fig. 3-22), Mamie tracked on a recurvature path along the western periphery of a mid-tropospheric, subtropical high pressure system whose 500 mb height center was near 25N-175E. The direction-of-track forecasts were good; however, the speed-of-movement forecasts were underestimated. Mamie accelerated much more rapidly than expected (twice climatological speeds) after passing north of 30N. Due to sparse, upper-air reports in the vicinity of the typhoon, analysis and forecast aids did not indicate such a rapid acceleration would occur. Mamie eventually weakened and transitioned into an extratropical system on 4 October 1978. Without satellite reconnaissance it is conceivable that the compact, Typhoon Mamie would not have made history.

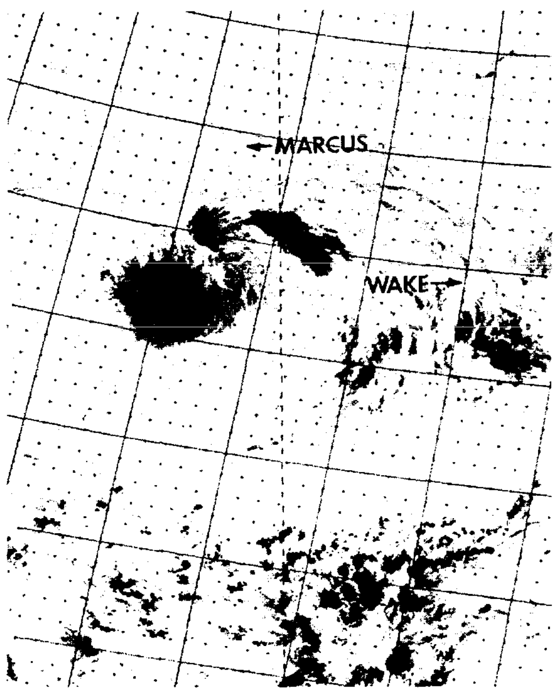


FIGURE 3-21. Infrared imagery of TD-23 (Mamie) at 30 kt (15 m/sec) intensity, 30 September 1978, 0035Z. (DMSP imagery)

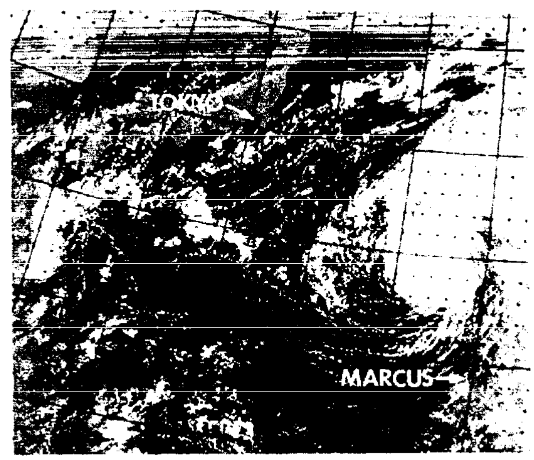
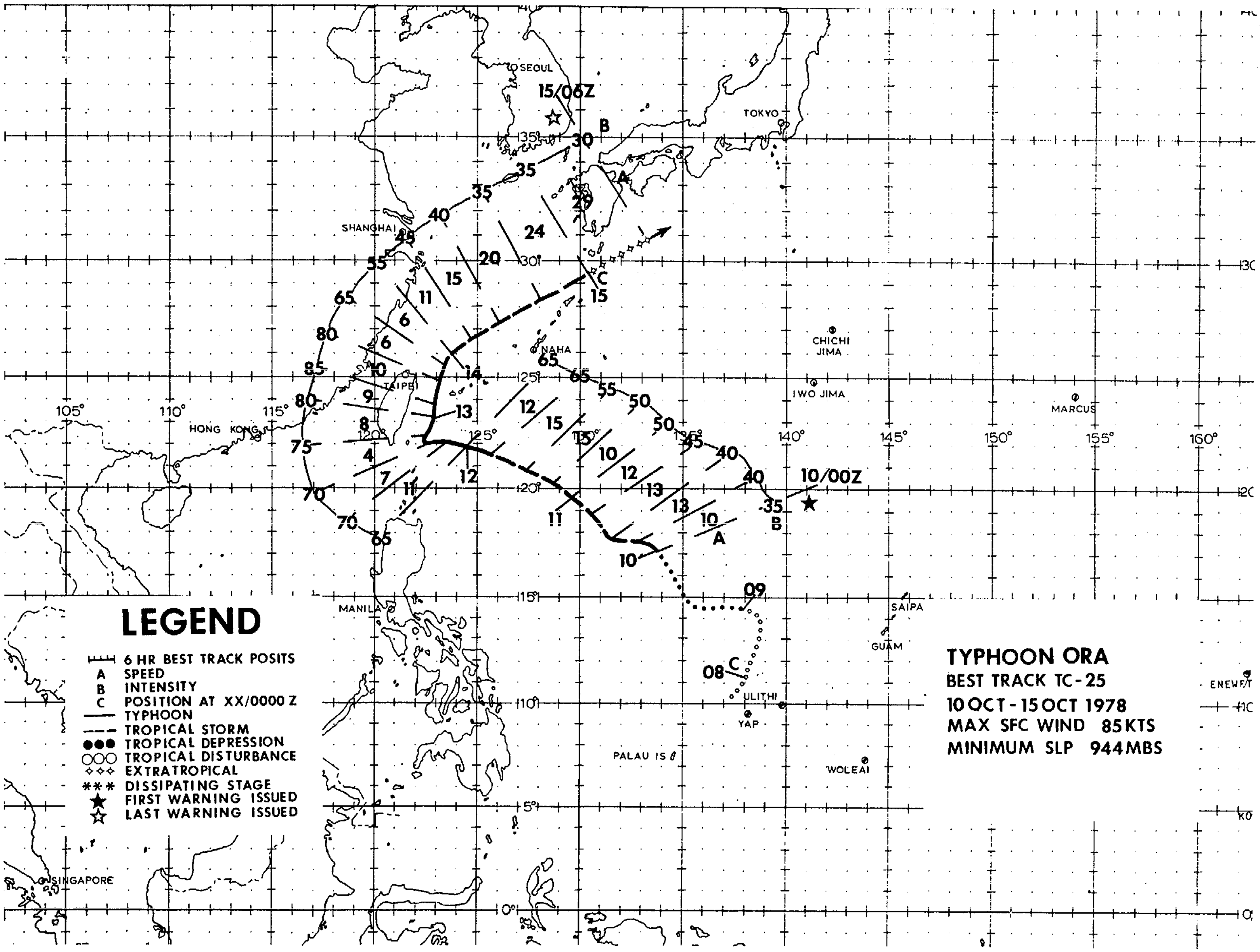


FIGURE 3-22. Typhoon Mamie, remaining compact, moving northeastward while at maximum intensity of 70 kt (36 m/sec), 03 October 1978, 0123Z. (DMSP imagery)


LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
TYPHOON ORA
BEST TRACK TC-25
10 OCT - 15 OCT 1978
MAX SFC WIND 85 KTS
MINIMUM SLP 944 MBS
15/06Z
10/00Z
SEOUL
TOKYO
SHANGHAI
NAHA
TAIPEI
HONG KONG
MANILA
CHICHI JIMA
IWO JIMA
MARCUS
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
SINGAPORE
105°
110°
115°
120°
125°
130°
135°
140°
145°
150°
155°
160°

During the early part of October, extensive monsoon troughing existed from the South China Sea, across the Philippine Islands to an area southeast of Guam. The surface analyses for that period showed a combination of strong northeasterlies north of the monsoon trough axis and well defined cross-equatorial flow into the trough from the Southern Hemisphere. The entire area was, therefore, ripe for continued tropical cyclone development and, indeed, by 081200Z, Tropical Storm Nina was gathering strength east of the Philippines. At about the same time an area of convergence about 300 nm (556 km) west-southwest of Guam began to show increased organization.

JTWC began to monitor this area using satellite and ship synoptic data and issued a Tropical Cyclone Formation Alert at 090707Z. Based on reconnaissance aircraft data at 092254Z October, the disturbance was upgraded to Tropical Storm Ora with the first warning valid at 100000Z October 1978.

The 500 mb analysis at this time showed that the mid-tropospheric subtropical ridge axis was broken between Japan and the Philippine Islands, with a high pressure cell centered over Thailand and another located near Marcus Island. This break was created by a deepening long wave trough that was moving into the western Pacific from the Asian mainland. The circulations of Tropical Storm Nina and Tropical Storm Ora also helped to maintain this break.

Computer aids, climatology and the current synoptic situation supported a northward track; the JTWC forecast showed Ora recurving to the north-northeast around the western periphery of the high pressure cell that was centered near Marcus Island.

By 101800Z, however, it became apparent that Ora and Nina were beginning to interact. At this time Nina, the dominant system, was trying to force Ora to follow a westward track, while at the same time the long-wave trough, then over the Sea of Japan, was inducing more northward movement. The net effect of these two steering influences caused Ora to follow an overall northwestward track at a speed of 12-15 kt (22-28 km/hr).

On the 11th, it was apparent that Tropical Storm Nina and Tropical Storm Ora were engaging in a Fujiwhara interaction. Nina would have been expected to move eastward in the classic Fujiwhara style. However, because she was the dominant system, the axis of rotation was closer to her. (Figure 3-23 shows the relative positions of Nina and Ora at 112342Z.) Instead of moving eastward, therefore, she merely stalled and then executed two, small loops while causing Ora to move west-northwestward. During this time period, JTWC continued to forecast Ora to cross the southern tip of Taiwan. This forecast was based on persistence and objective forecast aids which had been verifying quite well up to that point. Tropical Storm Ora then began to show increased organization on satellite and radar data. Aircraft reconnaissance at 120304Z reported the first signs of eye formation and a central pressure of 969.6 mb. Post analysis revealed that typhoon intensity was reached at 111800Z.

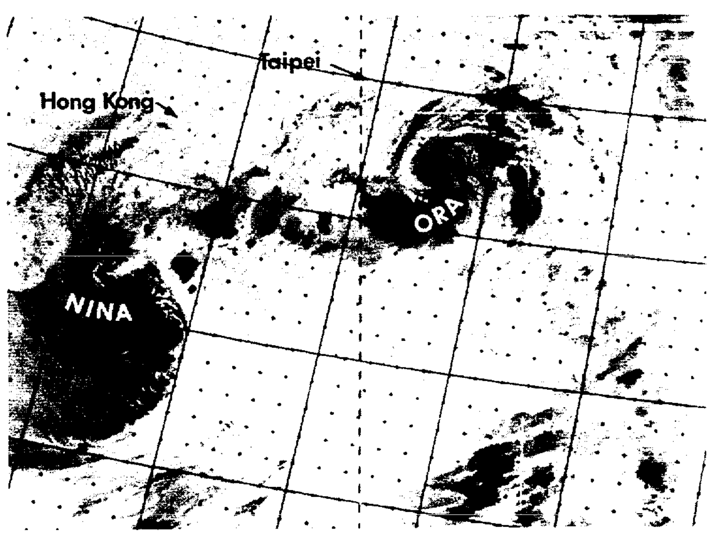


FIGURE 3-23. Infrared image of Typhoon Ora and Tropical Storm Nina during Fujiwhara interaction, 11 October 1978, 2342Z. Post-analysis showed that when the feeder band connecting the two cyclones disappeared, interaction ceased and Ora later turned north. (DMSP imagery)

As Ora approached the east coast of Taiwan, hourly radar fixes from Ishigaki-Shima, Miyako-Jima and Hua-lien indicated deceleration and by 121200Z, Ora had slowed to 4 kt (7 km/hr). By this time, Tropical Storm Nina had evidently weakened to the point where she no longer had any major influence on Ora's movement. The break in the ridge axis then became the controlling factor in determining Ora's track. Westward movement was forecast, in keeping with the upper-air, numerical progs that showed the ridge building back. Fortunately for Taiwan, this ridge failed to build back and Ora veered sharply to the north never making landfall on Taiwan (Fig. 3-24). When unexpected, northward movement was noted, an amended forecast was issued. Without constant reconnaissance, it is conceivable that the change in Ora's movement would not have been noticed until the next scheduled, 6-hourly fix.

Ora reached her peak intensity of 85 kt (44 m/sec) near 130600Z October as a compact typhoon (Fig. 3-25). By 131800Z, however, reconnaissance aircraft indicated that her central pressure had increased rapidly (44 mb in 17 hours) and there was evidence that her upper level center was beginning to shear off. By 140000Z Ora had weakened to tropical storm strength and was accelerating to the northeast under the influence of strong mid-level westerlies. Tropical Storm Ora then merged with the polar front and was fully extratropical by 150600Z October.

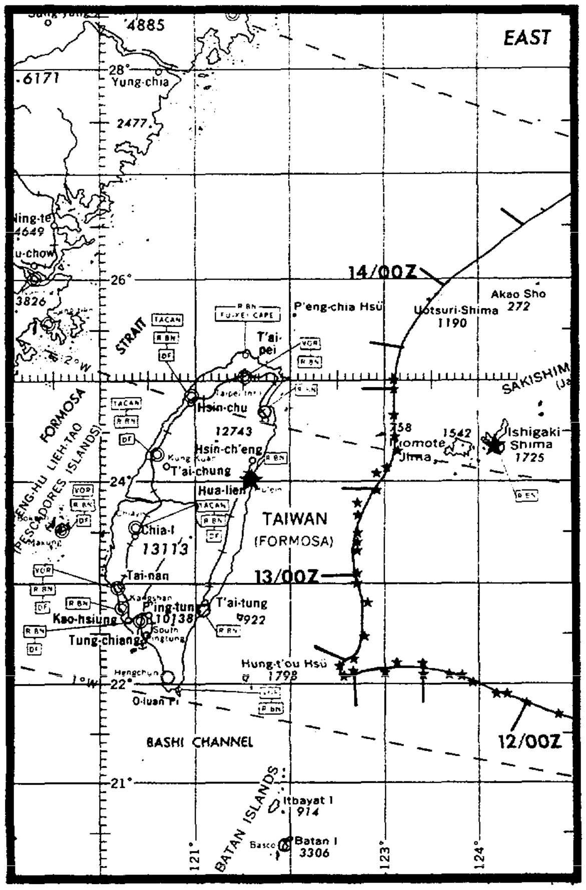


FIGURE 3-24. *Hourly radar fixes show Ora's sudden turn to the North after 121200Z October 1978.*

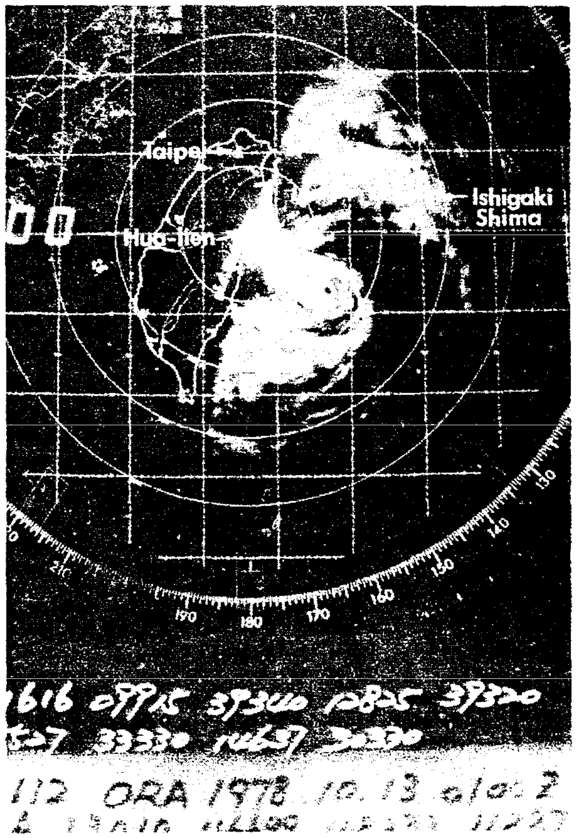
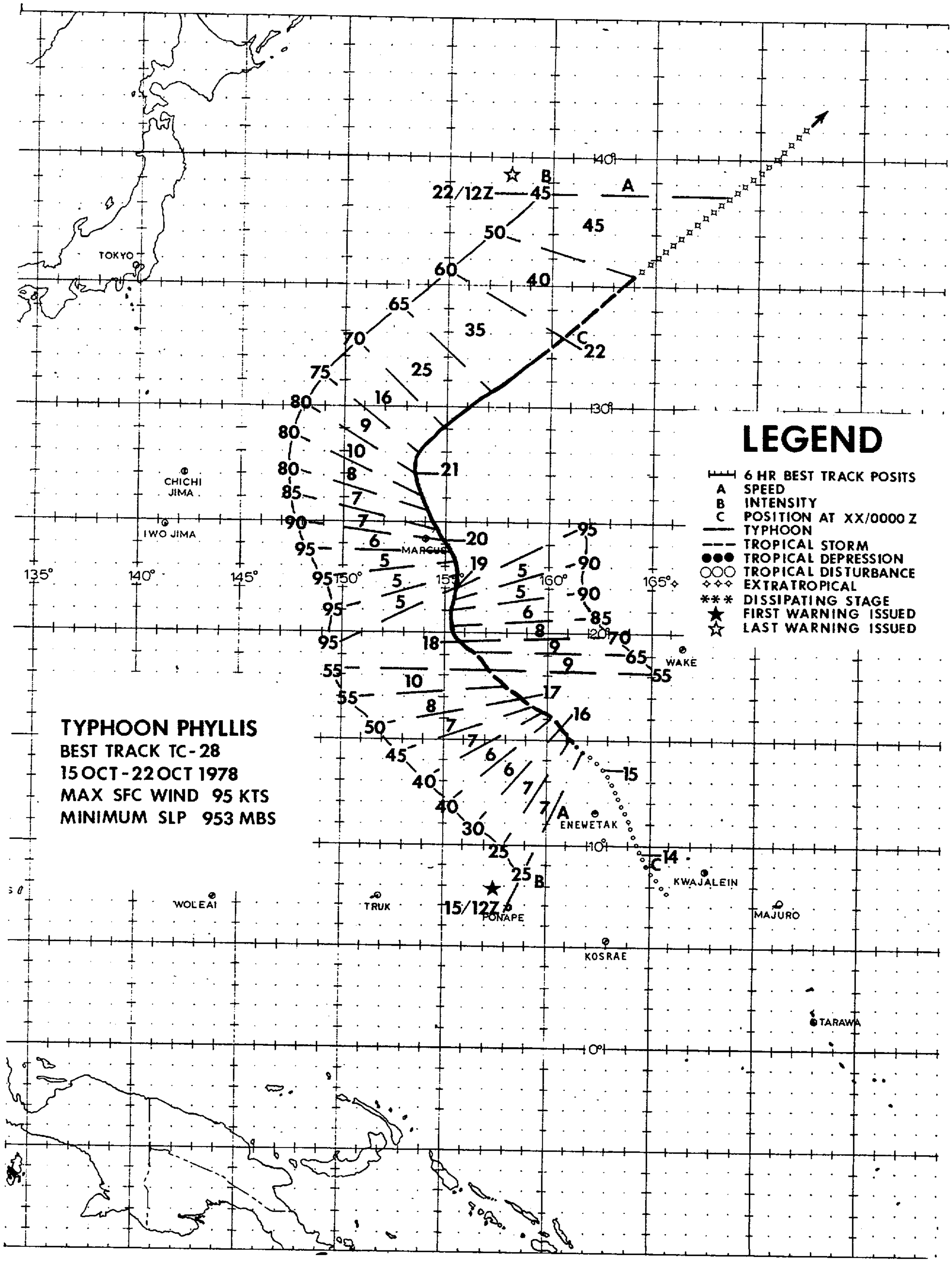


FIGURE 3-25. *Hua-Lien radar presentation of Typhoon Ora at 130100Z October just prior to her reaching maximum intensity. (Photograph courtesy of the Central Weather Bureau, Taipei, Taiwan.)*


LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
TYPHOON PHYLLIS
BEST TRACK TC-28
15 OCT - 22 OCT 1978
MAX SFC WIND 95 KTS
MINIMUM SLP 953 MBS
TOKYO
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
ENEWETAK
KWAJALEIN
WOLEAI
TRUK
PONAPE
MAJURO
KOSRAE
TARAWA
22/12Z
15/12Z
135°
140°
145°
150°
155°
160°
165°
40°
30°
20°
10°
0°

The tropical disturbance that eventually developed into Typhoon Phyllis formed in a well established, near-equatorial trough lying over the southern Marshall Islands on 13 October 1978. By 1200Z on the 14th, the disturbance had moved north-northwest and under moderate upper level divergence which existed south of a TUTT. Increased organization of the disturbance was observed on satellite imagery at 142108Z and a Tropical Cyclone Formation Alert (TCFA) was issued at 142235Z for an area 100 to 350 nm (185-556 km) north and north-northwest of Enewetak.

Upper-air data at 150000Z suggested a weakness in the subtropical ridge (STR) axis near 155E. As the tropical disturbance tracked northwestward toward the weakness, increasing vertical organization between low-level inflow and upper-level outflow continued. The disturbance was upgraded to tropical depression (TD) status and numbered warnings on TD-28 began at 151200Z. Phyllis remained a tropical depression for 18 hours and was upgraded to a tropical storm based on aircraft reconnaissance information which indicated Phyllis to be a small compact storm with small wind radii and therefore virtually invisible from synoptic reports alone.

By the 16th, the break in the STR axis was well established. The dominant high pressure center was northeast of Wake Island and the secondary center was southwest of Iwo Jima. The dominant high slowly strengthened causing Phyllis to accelerate northwestward from 6-10 kt (11-19 km/hr). Simultaneously, the TUTT moved northward allowing Phyllis to continue to have excellent outflow aloft. In this regime, Phyllis gradually intensified to typhoon strength by the 17th at 1800Z.

When Phyllis finally reached the break in the STR on the 18th, the dominant high weakened leaving a large col area causing Phyllis to drift slowly for a day. Then on the 19th, the high pressure system east of Phyllis began building to the west which eventually caused Phyllis to slowly accelerate northwestward and delayed recurvature for two more days. Cooler waters and reduced, upper -level outflow weakened Phyllis as she recurved northeastward. Then, north of the STR, Phyllis rapidly accelerated under stronger -than-expected steering currents. Phyllis accelerated from 9 kt (17 km/hr) at the ridge axis to 45 kt (83 km/hr) in less than 30 hours.

Increased vertical shear caused Phyllis to weaken to tropical storm intensity by 0000Z on the 22nd. Thereafter, the pressure gradient between a major surface low moving eastward off Japan and the strong surface ridge east of Phyllis helped maintain storm force winds around Phyllis as she became extratropical.

The STR built westward as Phyllis began her track toward recurvature (Fig. 3-26). After recurvature, Phyllis' foward speed increased dramatically; extratropical transition was complete after 220600Z.

Phyllis remained a typhoon for four days during which her closest approach to land was 40 nm (74 km) northeast of Marcus Island. Her compactness and over-open water track resulted in no major reported damage.

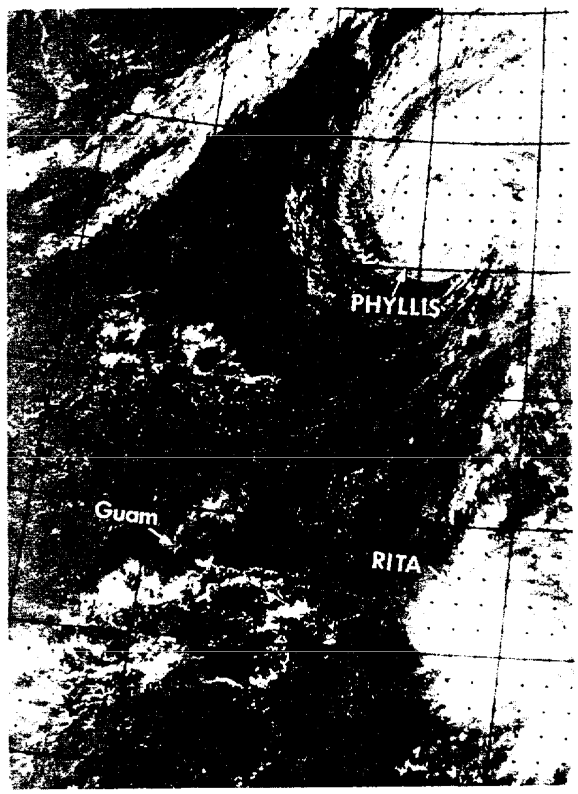
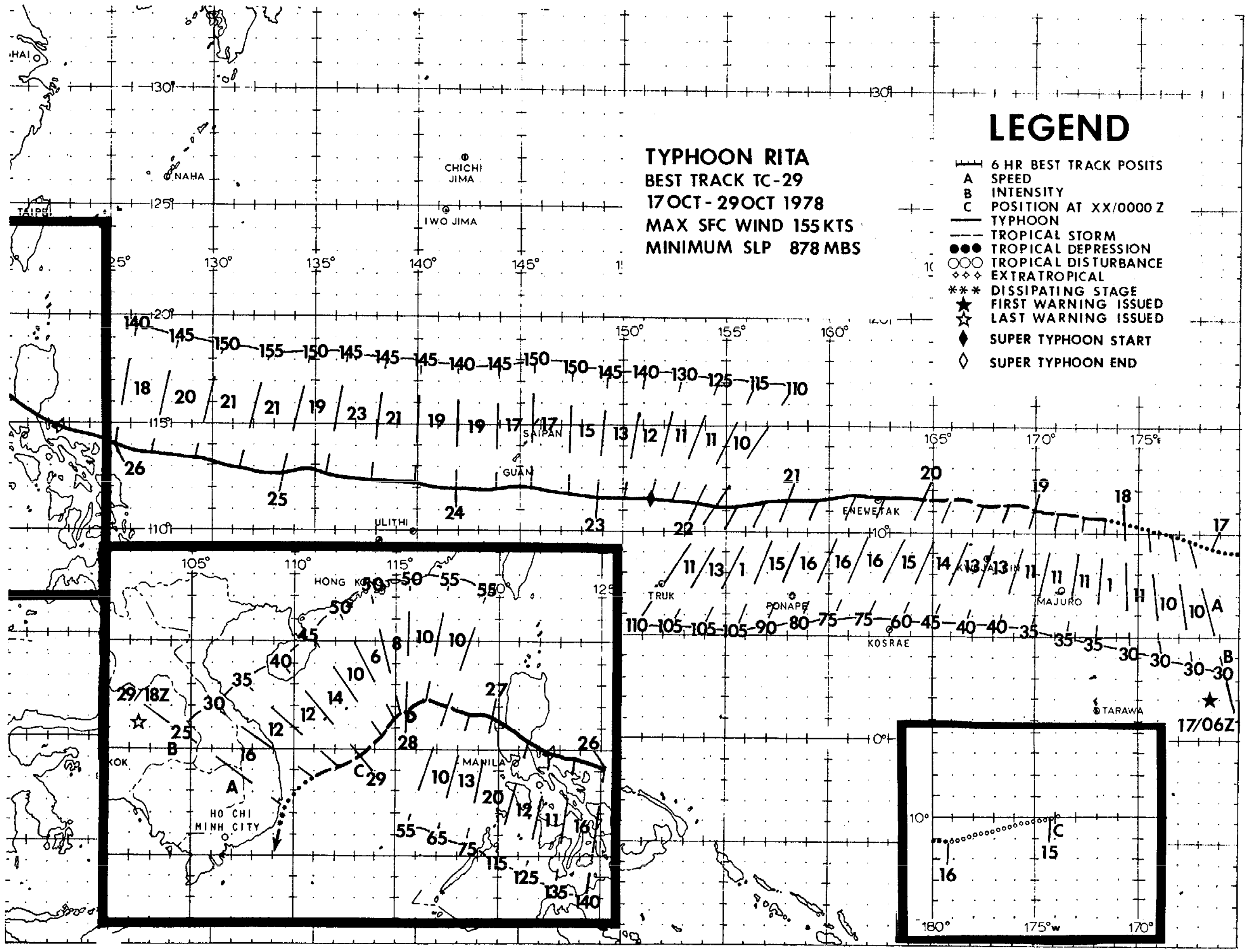


FIGURE 3-26. Typhoon Phyllis at her recurvature point, Typhoon Rita on a track toward Guam and the STR builds in between them as noted by the weakness in the band of showers connecting the two compact typhoons, 21 October 1978, 0106Z. (DMSP imagery)


TYPHOON RITA
BEST TRACK TC-29
17 OCT - 29 OCT 1978
MAX SFC WIND 155 KTS
MINIMUM SLP 878 MBS
LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SUPER TYPHOON START
SUPER TYPHOON END
NAHA
CHICHI JIMA
IWO JIMA
TAIPEI
SAIPAN
GUAM
ULITHI
ENEWETAK
TRUK
PONAPE
KOSRAE
MAJURO
TARAWA
HONG KONG
MANILA
HO CHI MINH CITY
17/06Z
29/18Z

Rita, 1978's only super typhoon, was first detected as a cloud cluster in the tropical central North Pacific on the 14th of October. Migrating westward, she crossed the dateline early on the 16th and by 162300Z (Fig. 3-27) satellite imagery showed increased organization and developing feeder band activity. Consequently, a formation alert was issued on the system at 162347Z and six hours later, after continued development, the first warning was issued with 30 kt (15 m/sec) intensity. Thus, Rita was detected very early in her developmental stages and, based on the availability and maximum use of satellite data, a timely warning service was provided.

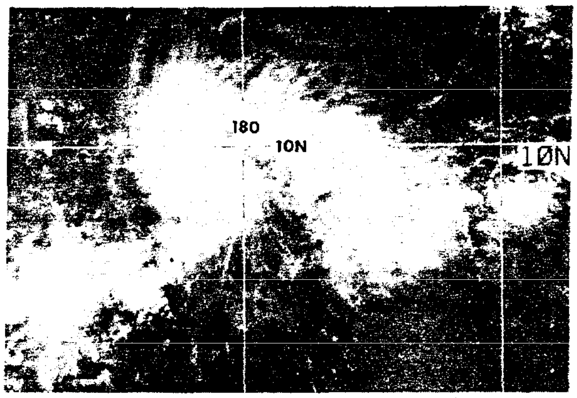


FIGURE 3-27. Rita, as she appeared just before issuance of her first warning, 16 October 1978, 2245Z. (DMSP imagery from AFGWC, Offutt AFB, NE)

From the time of the first warning until landfall on the Philippines, Rita tracked virtually straight westward. The major influence on her movement was the unusually strong mid-tropospheric subtropical ridge that built in over WESTPAC as Typhoon Phyllis was recurving. The strength of the easterly current south of the ridge steered Rita at forward speeds of up to 20 to 23 kt (37 to 43 km/hr); almost twice that of the climatological average. As could be anticipated from her track, JTWC's forecasts were consistent and errors were less than average. The larger errors were due to underestimates of forward speed and initial expectations of recurvature similar to Phyllis'. During her track across WESTPAC, Rita threatened a number of Pacific islands and atolls including those in the northeastern Marshalls, Enewetak and Guam. Rita's track near Enewetak brushed the northern tip of the atoll when maximum sustained winds were 75 kt (39 m/sec). At this time, Rita was a very compact typhoon and the main island on the southeastern portion of the atoll reported maximum sustained winds of only 35 kt (18 m/sec) with gusts to 45 kt (23 m/sec). By the time Rita approached Guam (Fig. 3-28) however, she had intensified dramatically to 150 kt (77 m/sec) and, therefore, posed a serious threat to the island.

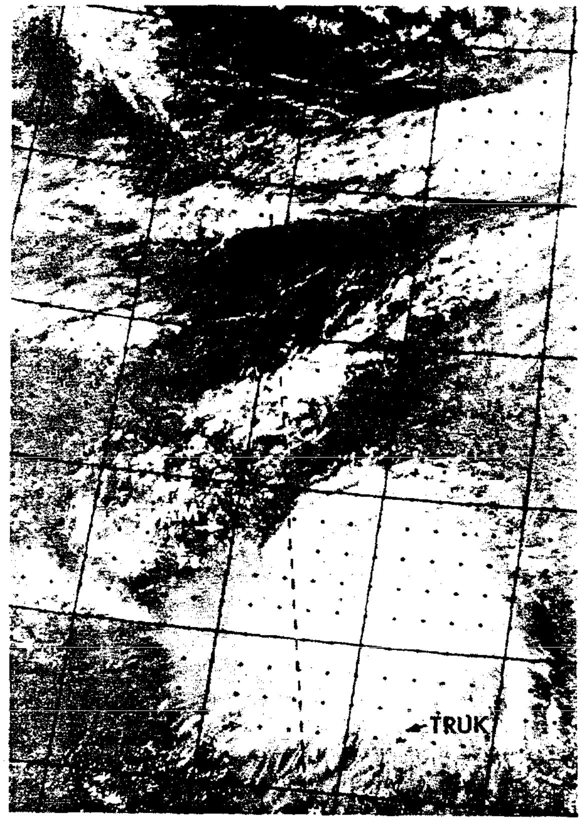


FIGURE 3-28. Rita, at 145 kt (75 m/sec) intensity, 16 hours before her closest point of approach to Guam, 22 October 1978, 2212Z. (DMSP imagery)

Rita was forecast to track south of Guam and maximum sustained winds expected for the center of the island (at Naval Air Station (NAS), Agana) were 70 kt (36 m/sec). Rita did indeed track south of Guam as forecast but maximum sustained winds reported at NAS Agana were only 35 kt (18 m/sec) with gusts to 55 kt (28 m/sec). In addition, precipitation on the island from Rita was unusually low. Post analysis reveals that the overestimation of the maximum winds on the island was caused by two factors. The first factor was that Rita's actual track was 30-35 nm (56-65 km) south of the forecast track with actual CPA (closest point of approach) to NAS, Agana of 85 nm (157 km). Because Rita was compact, this 30 nm (56 km) error in track meant a large difference in Rita's influence on Guam. Had this been the only error, sustained winds would nevertheless have been over 50 kt (26 m/sec) at NAS, Agana. The second factor was the over-estimation of the over-30-kt (15 m/sec) and over-50-kt (26 m/sec) wind radii. These radii were based on surface wind estimates from aircraft reconnaissance (Fig. 3-29) and were forecast to expand. The 230600Z warning

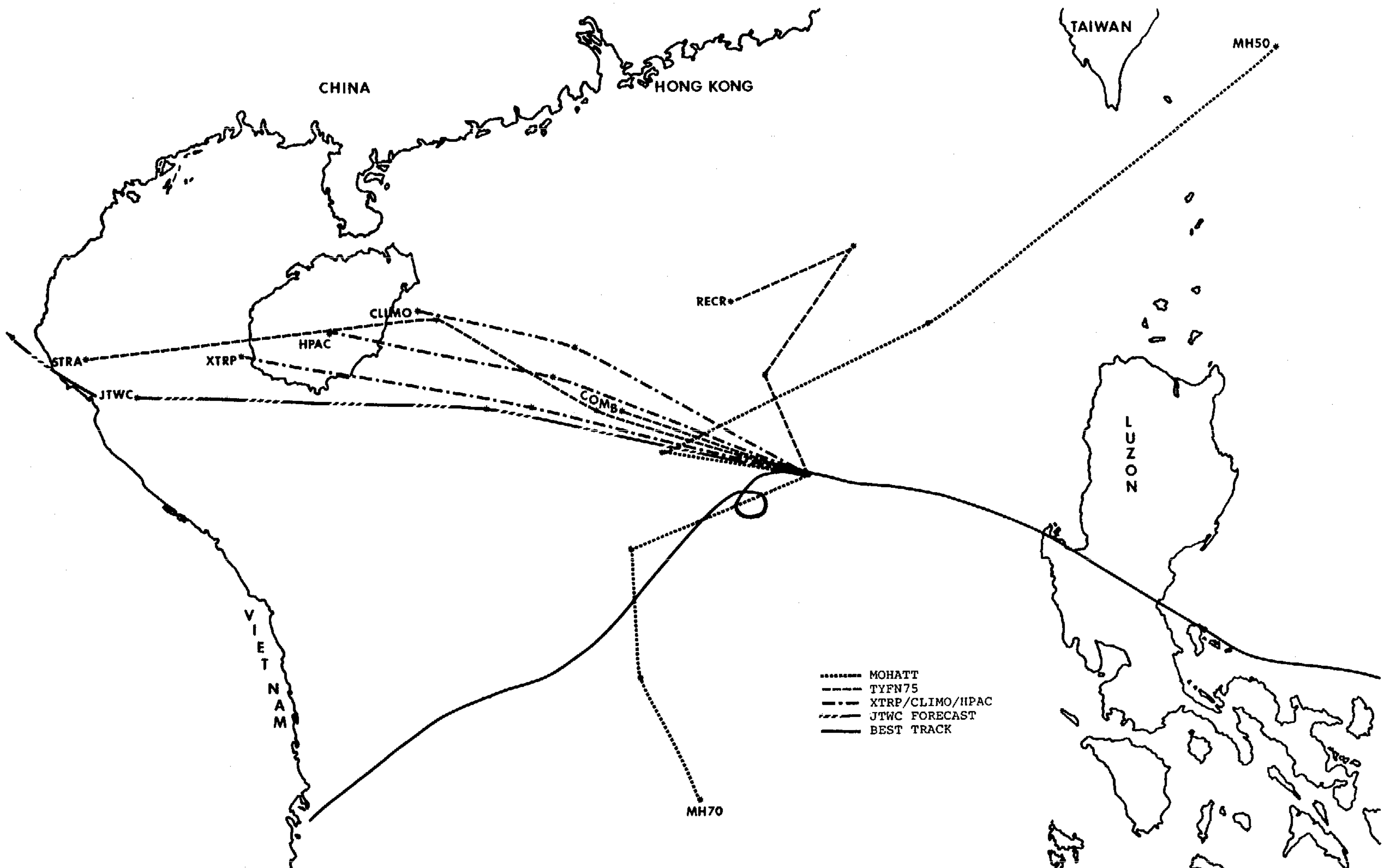


*FIGURE 3-30. Plot of objective forecast techniques for 271200Z. Reference Chapter IV for description of each objective technique. Each * represents a 24-hour forecast segment. The solid line represents Rita's best track.*

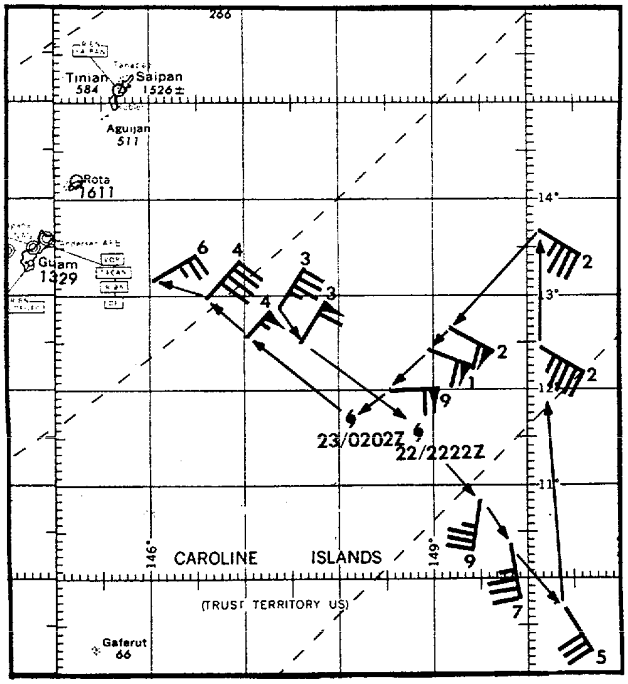


FIGURE 3-29. *Plot of aircraft reconnaissance data. Typhoon positions are noted at 230200Z and 222222Z. Wind barbs are the estimated surface winds from the ARWO aboard the aircraft. The tens digit of the wind direction is also plotted with the wind barbs.*

showed a 185 nm (343 km) radius for over-30-kt (15 m/sec) winds and 100 nm (185 km) radius for over-50-kt (26 m/sec) winds in Rita's northern semicircle. Actual surface reports from the southern tip of Guam indicated the over-50-kt (26 m/sec) radius was actually only 70 nm (130 km). The over-30-kt (15 m/sec) wind radius was also too large as judged by the nine hour duration of sustained 30 kt (15 m/sec) winds at NASA Dan Dan. If the over-30-kt (15 m/sec) wind radius had been 185 nm (343 km), the duration of sustained 30 kt (15 m/sec) winds would have been closer to 19 hours. It was evident that the wind field did not expand as forecast.

Unlike the relatively mild influence on Guam and Enewetak, the Philippines experienced considerable damage and many lives were lost during Rita's passage. Heavy flooding was reported throughout many of the cities and villages on Luzon, especially those just east and north of Clark AB. DoD facilities, however, sustained little damage in Rita's 12-hour passage over central Luzon. As she entered the South China Sea, aircraft and satellite data indicated that she had weakened considerably.

In contrast to the persistent synoptic situation over the Western Pacific which had steered Rita ever westward, the large scale features in the South China Sea were complex. As Rita exited the Philippines, a short-wave westerly trough was developing and moving eastward over the Asian mainland. The trough created a break in the mid-tropospheric subtropical ridge allowing for a northward adjustment in Rita's track. During this same time, however, a surge in the northeast monsoon was developing over China at low tropospheric levels which tended to steer Rita southward. Objective aids lacked consistency and reflected the contrast in the synoptic situation (Fig. 3-30). Eventually, the northeast monsoon surge proved to be the deciding factor in Rita's movement and she tracked southwestward toward the Vietnam coast and dissipated over water. Forecast errors were considerably larger during this latter segment of Rita's track.

Overall, Rita was the record setter for the 1978 season. Her track was the longest of the season and at her peak intensity of 155 kt, aircraft data recorded an 878 mb central pressure, only 2 mb higher than the record set by Typhoon June in 1975 (Fig. 3-31).

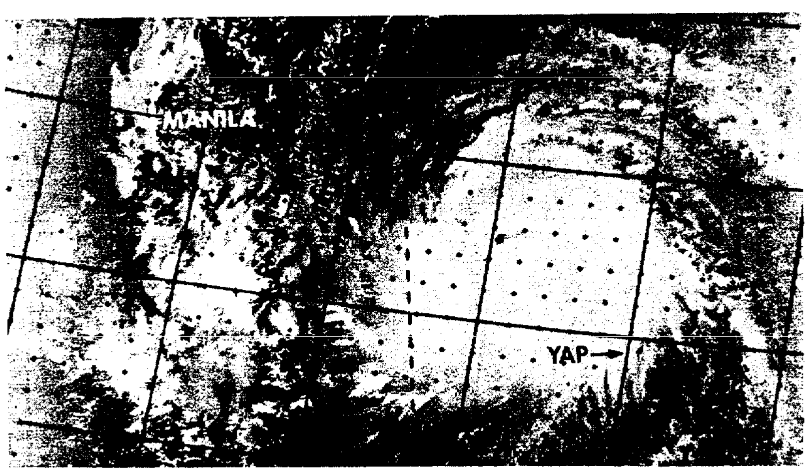
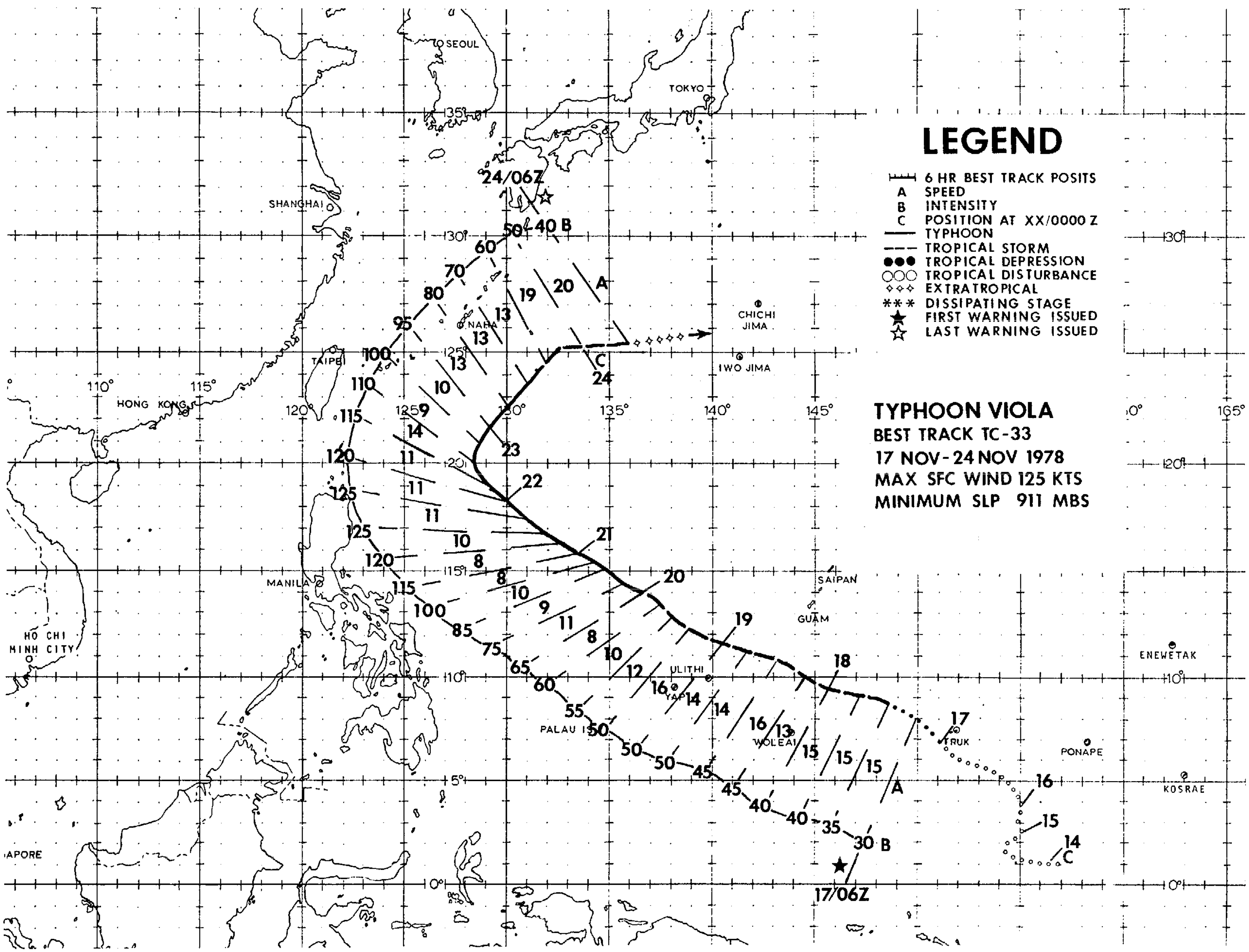


FIGURE 3-31. *Rita, at 150 kt (77 m/sec) intensity, 6 hours prior to her peak intensity, 24 October 1978, 2319Z. (DMSP imagery).*


LEGEND
6 HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
TYPHOON VIOLA
BEST TRACK TC-33
17 NOV-24 NOV 1978
MAX SFC WIND 125 KTS
MINIMUM SLP 911 MBS
SEOUL
TOKYO
SHANGHAI
NAHA
TAIPEI
HONG KONG
CHICHI JIMA
IWO JIMA
MANILA
SAIPAN
GUAM
ULITHI
YAP
PALAU IS
WOLEAI
TRUK
PONAPE
ENEWETAK
KOSRAE
HO CHI MINH CITY
24/06Z
17/06Z

Of the typhoons of 1978, none could be considered to be more classic or more well -behaved than Typhoon Viola, the last typhoon of the season.

Increased convective activity in the monsoon trough about 600 nm (1111 km) southeast of Truk was first noticed on satellite data at 132159Z November. By 162142Z, satellite data showed continued development and a Tropical Cyclone Formation Alert was issued. Well-defined, upper atmospheric outflow was evident in all quadrants and at 170710Z, a reconnaissance aircraft reported surface winds of 30 kt (15 m/sec) and a surface pressure of 998 mb. Based on this information the disturbance was upgraded to Tropical Depression 33 and numbered warnings began

The mid-tropospheric flow pattern at this time was characterized by strong high pressure ridging to the north and east of TD-33 with a weakness apparent in the ridge axis near Luzon. This weakness was induced both by a deepening long wave trough that extended from Siberia south along the coast of China and by TD-32, which was at this time off the coast of Luzon in the Philippine Sea. Although TD-32 was short-lived and never intensified above tropical depression strength, it nonetheless was strong enough to alter the mid-level flow pattern and become a determining factor in TD-33's (Viola's) ultimate movement.

Under the influence of the strong easterlies south of the mid-tropospheric ridge, TD-33 began tracking to the west-northwest at 12 to 16 kt (22 to 30 km/hr) toward the weakness near Luzon.

Based on an improved satellite signature, TD-33 was upgraded to Tropical Storm Viola at 171200Z. A careful comparison of the satellite data, along with the aircraft reports, indicated that Viola was still not vertically stacked. Late on the 19th, she slowed to 8 kt (15 km/hr) and this deceleration was apparently enough to allow her time to become better organized in the vertical. A 191505Z reconnaissance aircraft confirmed that: the surface center was within 5 nm (9 km) of the 700 mb center; Viola's surface pressure had fallen to 977 mb; and, an eye was beginning to form. She finally reached typhoon strength near 200000Z. By this time, Viola had completely overpowered TD-32, whose circulation was no longer evident on the surface analysis. With TD-32 "out of the way", Viola now had access to all available energy and, as a result, rapid intensification followed. At 211200Z she attained her minimum sea level pressure of 911 mb and maximum wind speed of 125 kt (64 m/sec) just 5 kt (2.6 m/sec) below super-typhoon strength (Fig. 3-32). Viola's tremendous intensification is reflected in the ten thousand foot temperatures that were reported by aircraft at about that time; the outside temperature was 14 Celsius but the inside (eye) was a very warm 29 Celsius (with a dewpoint of 16 Celsius).

Up to this point JTWC's forecasts had been verifying quite well. While Viola was forecast to cross the northern tip of Luzon, the break in the ridge near the Philippines was continually monitored and the prospects for Viola to recurve were evaluated with the issuance of each warning.

500 mb reports in that area were sparse; as a result, the true situation was often difficult to evaluate due to the generally weak overall pattern. Available numerical progs continued to show the ridge building back between Luzon and Taiwan, and as late as 210000Z the 500 mb analysis, more definitive than usual, seemed to support this rebuilding.

In an attempt to obtain more steering level data to augment the sparse land station reports, reconnaissance aircraft were requested to fly at 500 mb in the area directly north of Viola. The wind data provided was invaluable and confirmed that a definite break in the ridge axis existed. The first forecast noting a recurvature track was issued at 220600Z. Subsequent aircraft and satellite fixes verified northward, then northeastward movement.

After recurvature, satellite data began to show that Viola's upper-level center was being sheared off from her surface circulation center. By 231800Z she had weakened to tropical storm strength. She weakened rapidly thereafter; the 240030Z reconnaissance aircraft was unable to locate a 700 mb center. A weak low-level circulation remained for a short time after losing tropical characteristics.

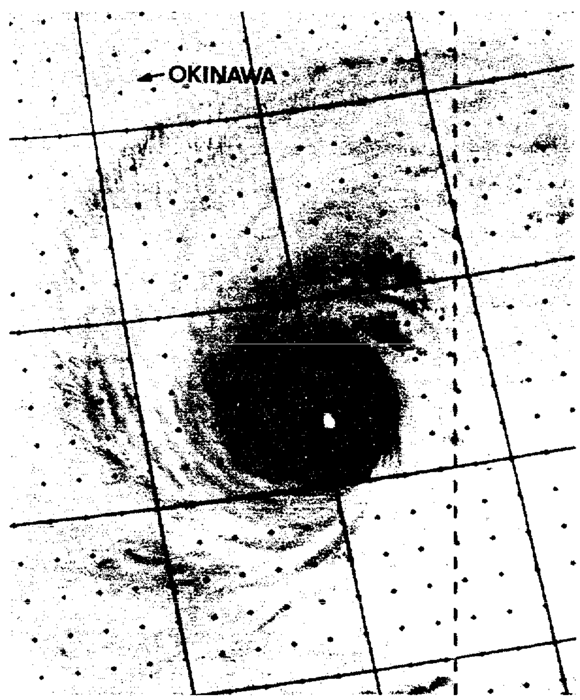


FIGURE 3-32. Infrared image of Typhoon Viola nearing her maximum intensity of 125 kt (64 m/sec), 21 November 1978, 0945Z. (DMSP imagery)

2. NORTH INDIAN OCEAN TROPICAL CYCLONES

During 1978, four significant tropical cyclones occurred in the North Indian Ocean area (Table 3-6). As usual, the transition seasons between the northeast and southwest monsoon periods were the favored "cyclone seasons" (Table 3-7). This year's cyclones lived longer than others on record as noted by the above-average number of warnings shown in Table 3-8.

Tropical Cyclone (TC) 18-78 occurred just prior to the start of the southwest monsoon season over Southeast Asia. Steering flow was weak which caused forecasting the speed of movement to be difficult. The lack of surface observations forced reliance on the interpretation of satellite data for position and intensity. TC 18-78 made landfall on Burma with estimated, maximum sustained winds of 50 kt (26 m/sec). News reports stated, " the town of Kyaukpyu reported 90% property damage and the coastal village of Narakway was demolished when estimated peak wind gusts of 80 to 100 mph were experienced." These extreme winds, although estimated, could have been produced by squall lines or tornados.

TC 19-78 dissipated prior to making landfall on Bangladesh; no "ground truth" reports were received confirming it's strength.

TABLE 3-6. NORTH INDIAN OCEAN AREA

1978 TROPICAL CYCLONES

CYCLONE	PRD OF WARNING	CALENDAR DAYS OF WARNING	MAX SFC WIND	EST MIN SLP	NO. OF WARNINGS	DISTANCE TRAVELLED
TC 18-78	15 MAY-17 MAY	3	60	955	4	362
TC 19-78	26 OCT-28 OCT	3	40	995	7	451
TC 20-78	06 NOV-11 NOV	6	80	965	12	1213
TC 21-78	20 NOV-29 NOV	10	95	955	19	1397
	1978 TOTALS	22			42	

JTWC

TABLE 3-7.

FREQUENCY OF NORTH INDIAN OCEAN CYCLONES BY MONTH AND YEAR

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
AVERAGE (1971-78)	0.1	0	0	0.3	0.5	0.3	0	0	0.4	0.8	1.4	0.3	3.9

*1971-1974 REPRESENT BAY OF BENGAL CYCLONES ONLY

**JTWC RESPONSIBILITY FOR BAY OF BENGAL CYCLONES BEGAN ON 4 JUNE 1971

TABLE 3-8.

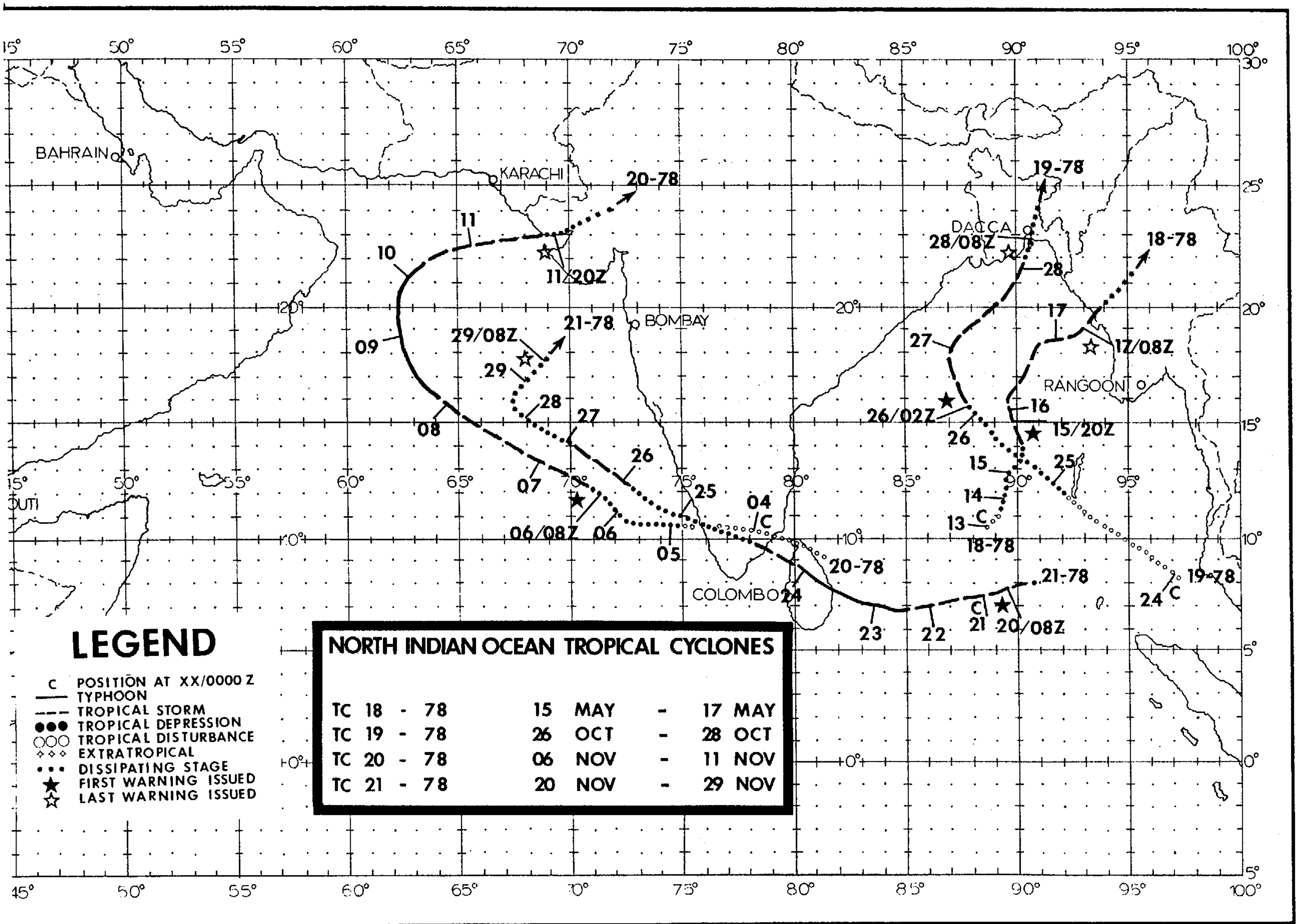
WARNING SUMMARY

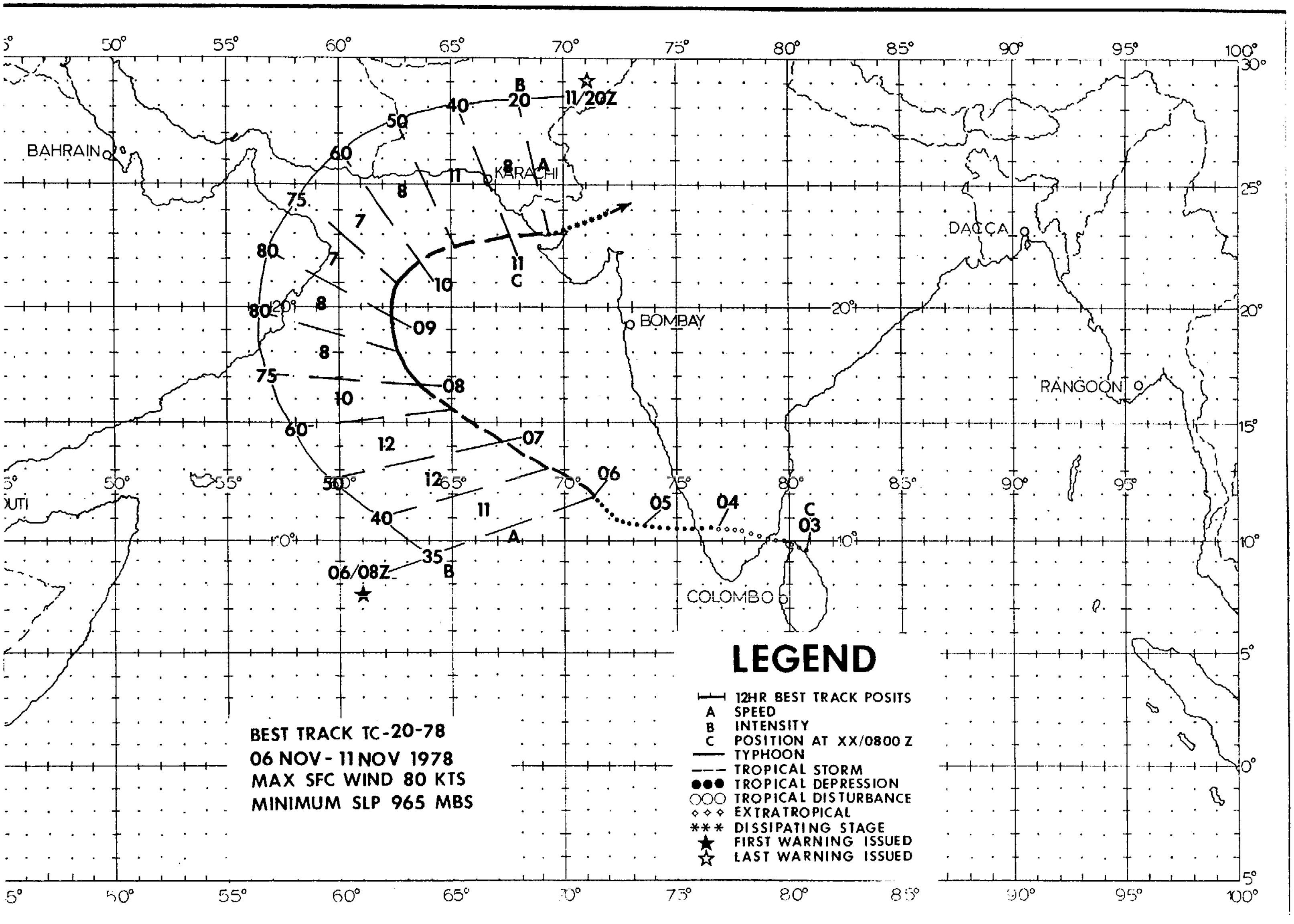
NORTH INDIAN OCEAN

	1978	AVERAGE 1971-1977*
TOTAL NUMBER OF WARNINGS	42	29
NUMBER OF WARNING DAYS	22	17
NUMBER OF WARNING DAYS WITH 2 OR MORE CYCLONES	0	2
NUMBER OF WARNING DAYS WITH 3 OR MORE CYCLONES	0	0
TOTAL TROPICAL CYCLONES	4	4

*From 1971 through 1974, only Bay of Bengal cyclones were considered; the JTWC area of responsibility was extended in 1975 to include Arabian Sea cyclones.

JTWC


NORTH INDIAN OCEAN TROPICAL CYCLONES
TC 18 - 78 15 MAY - 17 MAY
TC 19 - 78 26 OCT - 28 OCT
TC 20 - 78 06 NOV - 11 NOV
TC 21 - 78 20 NOV - 29 NOV
LEGEND
C POSITION AT XX/0000 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
BAHRAIN
KARACHI
BOMBAY
DACCA
RANGOON
COLOMBO
18-78
19-78
20-78
21-78
11/20Z
29/08Z
06/08Z
28/08Z
26/02Z
17/08Z
15/20Z
20/08Z



BAHRAIN
KARACHI
BOMBAY
DACCA
RANGOON
COLOMBO
11/20Z
06/08Z
LEGEND
12HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0800 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
BEST TRACK TC-20-78
06 NOV - 11 NOV 1978
MAX SFC WIND 80 KTS
MINIMUM SLP 965 MBS

A cyclonic wind shift and decreasing surface pressures on Sri Lanka were the first indications of the tropical disturbance which eventually developed into Tropical Cyclone 20-78. Tracking west-northwest along the monsoon trough axis, the disturbance made landfall over the southern tip of India 66 nm (122 km) east of Madura at 1800Z on the 3rd of November 1978. Still in the formative stage, with 20 kt (10 m/sec) intensity, the disturbance tracked westward over southern India during the 3rd and 4th with little intensification. Property damage was limited to, and essentially caused by, flooding on the coastal plains.

After exiting into the Arabian Sea, a westward movement at 07 kt (13 km/hr) and gradual intensification occurred. Satellite data at 050647Z indicated increased organization and feeder band activity had formed south of the center. JTWC thus issued a Tropical Cyclone Formation Alert at 051239Z as the system moved into the Laccadive Islands. During the 5th and 6th, the mid-tropospheric subtropical ridge axis shifted northward from 16N to 20N allowing TC 20-78 to track more north of west from 051400Z through 082000Z.

Increased feeder band activity and good outflow aloft indicated that steady intensification occurred from the 5th through the 8th. Tropical storm intensity was attained by 060800Z with satellite data revealing an eye early on the 7th. As indicated by satellite imagery on the 7th and 8th, upper-level outflow was enhanced by a channel to the strong westerlies existing to the north of the cyclone center. By 080200Z, TC 20-78 had reached typhoon intensity according to the Dvorak visual satellite intensity analysis. Evaluation of the cyclone's position and intensity estimates provided by the USS LaSalle's (AGF-3) TIROS-N APT satellite data proved to be an invaluable addition to the normal DMSP satellite coverage of this area.

By the 9th of November, the mid-level subtropical ridge axis in the Arabian Sea was oriented east-west along 19N. Recurvature around this axis occurred during the 9th concurrent with TC 20-78's maximum intensity of 80 kt (41 m/sec) at 090900Z. TC 20-78 then moved northeastward into an area dominated by strong westerlies aloft. The strong vertical shear that resulted caused the system to weaken to tropical storm intensity by 100800Z (Fig. 3-33). By the 11th, the strong vertical wind shear had reduced the cyclone to a shallow system noted on satellite imagery as spiral bands of low clouds and minimum to no deep convection - "an exposed low level circulation". Continued dissipation caused the satellite fixes to decrease in accuracy and conventional data, being sparse, aided little in pinpointing the center. As a result, the landfall of TC 20-78 on northwest India could only be approximated.

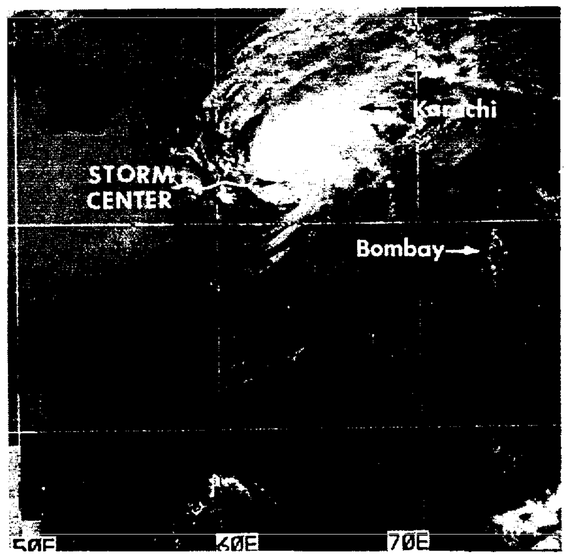
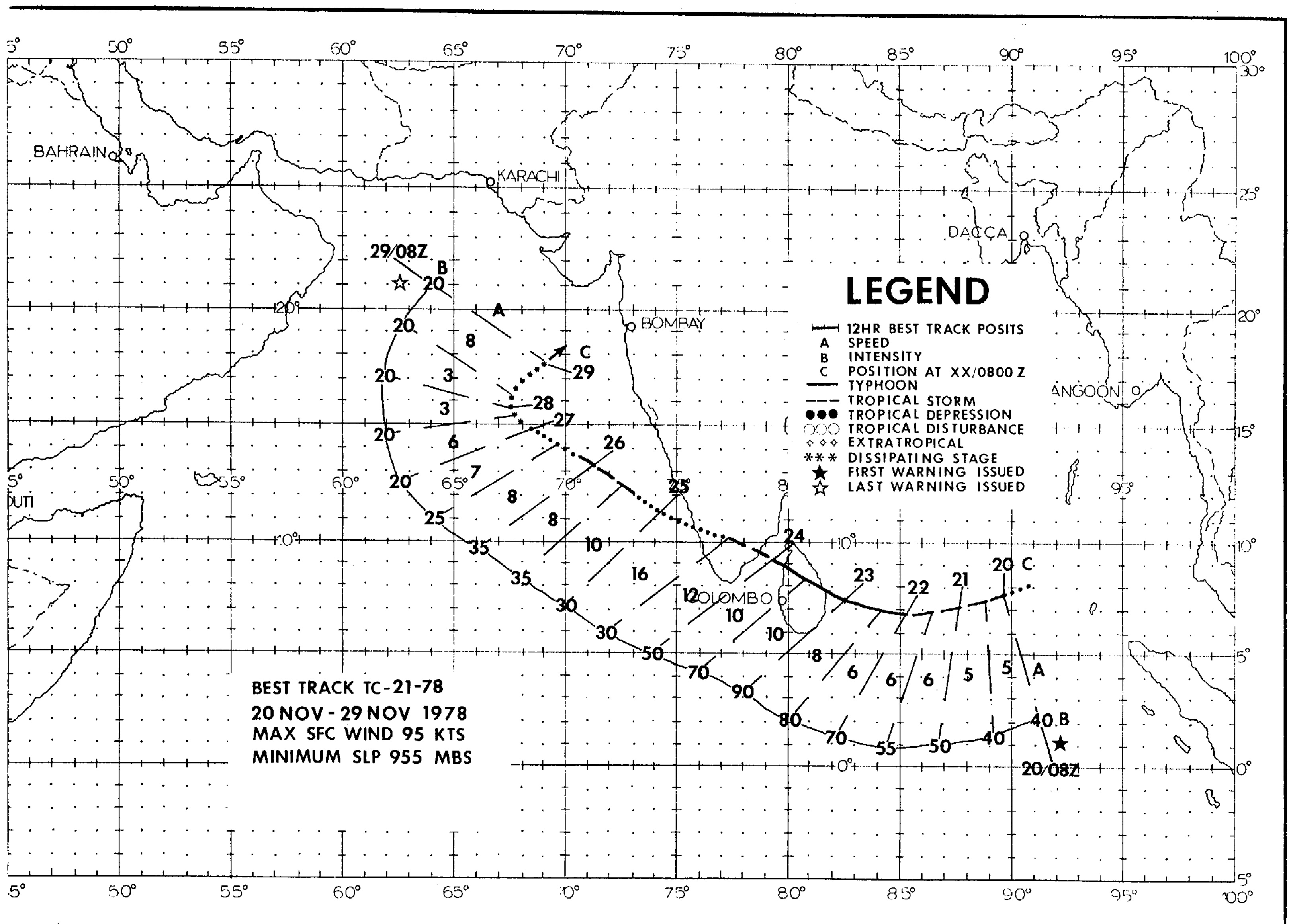


FIGURE 3-33. TC 20-78, 260 nm (482 km) southwest of Karachi on 10 November 1978 at 0659Z. The concentration of convective activity to one side of the cyclone and the cirrus showing unidirectional, upper-air flow are typical of cyclones in strong, vertical shear environments. A cyclonic circulation is becoming evident in the orientation of low clouds over the southern "exposed" portion of the cyclone. (DMSP imagery from AFGWC, Offutt AFB, NE)


BAHRAIN
KARACHI
DACCA
BOMBAY
COLOMBO
RANGOON
LEGEND
12HR BEST TRACK POSITS
A SPEED
B INTENSITY
C POSITION AT XX/0800 Z
TYPHOON
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
29/08Z
20/08Z
BEST TRACK TC-21-78
20 NOV - 29 NOV 1978
MAX SFC WIND 95 KTS
MINIMUM SLP 955 MBS

Tropical Cyclone 21-78, the 4th cyclone of the year in the north Indian Ocean, presented forecast problems for JTWC. More importantly, however, the small country of Sri Lanka suffered one of the worst disasters in its history.

Forecasting problems were related, primarily, to the paucity of data in the Indian Ocean. Reconnaissance aircraft are not routinely tasked on missions in the Bay of Bengal. Radar data is practically unheard of, and conventional data, especially from ships and aircraft transitting the Arabian Sea and Bay of Bengal, are minimal to non-existent. Therefore, almost total reliance on satellite data is the rule. Real-time satellite imagery of this area is not available at JTWC. Data is received at AFGWC, analyzed and reports are sent some three to five hours after data time. Analysis of TIROS-N, APT satellite data from the USS LaSalle was used to supplement fix data.

On the 19th of November, an area of convective activity about 300 nm (556 km) northwest of Sumatra began to show increased organization, and a Tropical Cyclone Formation Alert was issued at 0705Z on the 20th of November. 200542Z satellite data, received from AFGWC just after the formation alert was issued, showed that a 15 nm (28 km) eye had formed and the tropical disturbance was immediately upgraded to Tropical Cyclone 21-78 with maximum winds of 40 kt (21 m/sec). The presence of an eye is often indicative of typhoon intensity; however, because TC 21-78 appeared quite compact and also because satellite intensity analysis techniques are not specifically designed for application to Indian Ocean cyclones, a more conservative 40 kt (21 m/sec) was deemed more representative of the cyclone's true surface intensity.

Even though synoptic data were generally quite sparse, sufficient upper-air reports were available to indicate that a well-defined mid-tropospheric high pressure cell was situated over central India, with strong ridging extending eastward over the Bay of Bengal to Southeast Asia. 500 mb winds over the east Indian coast were from the northeast at 25 to 30 kt (13 to 15 m/sec) at that time. Initial forecasts showed TC 21-78 tracking slightly north of west, then west. It was reasoned that the west-northwest track would be forced more westward as the cyclone came under the influence of mid-level northeasterly steering flow nearer the Indian coast.

The mid-level northeasterlies apparently extended considerably further into the Bay of Bengal than analyzed, because TC 21-78 actually moved west-southwest at 5 to 7 kt (9 to 13 km/hr) for the next 48 hours (Fig. 3-34), continued to intensify slowly and reached typhoon intensity by 220800Z November.

During the subsequent 48-hour period, the high pressure cell over central India migrated eastward into the Bay of Bengal to a position north of the cyclone. Northerly 500 mb winds reported by stations along the

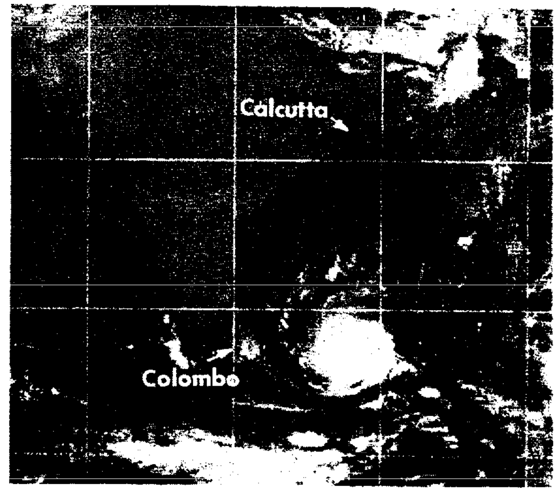


FIGURE 3-34. Infrared image of TC 21-78 at 50 kt (26 m/sec) intensity moving slowly toward Sri-Lanka, 21 November 1978, 0542Z. (DMSP imagery from AFGWC; Offutt AFB, Nebraska as received by FWF Suitland, Maryland)

west coast of India were the first clue that still another high pressure cell had developed over the Arabian Sea. TC 21-78 reached the southernmost point of its track at 220800Z and thereafter began to move to the west-northwest toward a weakness between the Arabian Sea and Bay of Bengal highs.

The system continued to intensify and made landfall on the east coast of Sri Lanka, near Batticaloa, with maximum sustained winds of 95 kt (49 m/sec), at 231400Z. At 231200Z, Batticaloa had reported a surface wind of 85 kt (44 M/sec) from the north. TC 21-78 crossed Sri Lanka in slightly over 12 hours and exited into the Gulf of Mannar (near the city of Mannar) on Sri Lanka's west coast (Fig. 3-35).

With max winds reduced to 45 kt (23 m/sec) due to the terrain effects of Sri Lanka, the cyclone then struck the southern coast of India north of Tuticorin weakening still further to 30 kt (15 m/sec), before it moved into the Arabian Sea north of Cochin.

From 240000Z to 280000Z a basic northwestward track was evident. The key to understanding this movement can be found by examining the 500 mb analyses during that period. The high pressure cell that was over the Arabian Sea moved eastward into central India, then shifted east-southeastward into the Bay of Bengal. 500 mb reports from Sri Lanka and southern India at 251200Z showed 20 to 25 kt (10 to 13 m/sec) winds from the southeast, which supported the cyclone's northwest movement.

TC 21-78 did not reintensify significantly after its passage across Sri Lanka and India. (It was expected to reintensify once it was again over warm water, but reintensification was slight and the system never again developed above tropical storm strength.) By 270600Z the cyclone's upper level center began to shear off from its surface center and satellite data revealed only low-level cloudiness signifying a low-level circulation. Warnings continued on the cyclone until 290800Z because it was felt that regeneration was still possible. By the 29th, satellite data indicated that TC 21-78 had weakened to the point that it was no longer a significant tropical circulation.

TC 21-78 was one of the most destructive storms of the year in either the Indian Ocean or West Pacific. Approximately one thousand people were killed and thousands of acres of crops were destroyed in Sri Lanka by the cyclone's winds, rain, and associated storm surge. In southern India only 10 people were killed; however, eighteen to twenty-five foot waves produced by the storm surge submerged 45 villages. Luckily, because of ample advance warning, the inhabitants were evacuated in time.

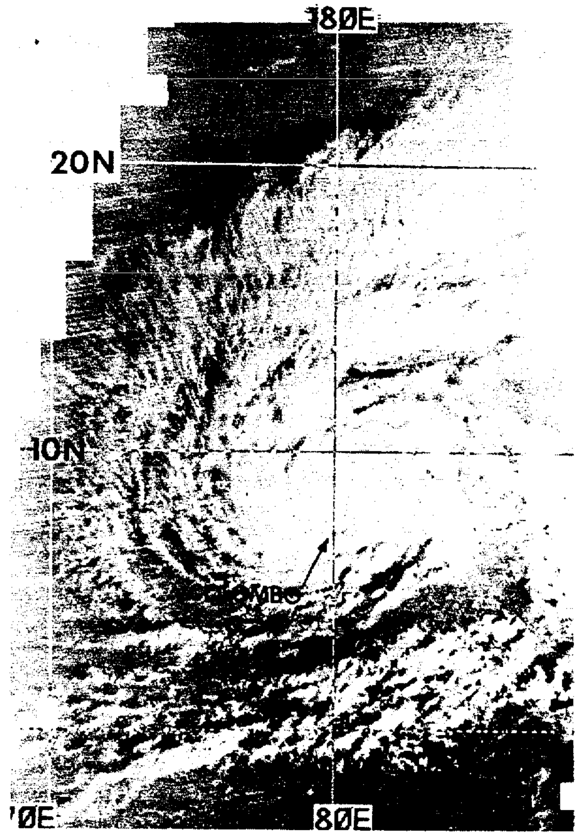


FIGURE 3-35. TC 21-78 located over north-central Sri-Lanka, 24 November 1978, 0118Z. (DMSP imagery from AFGWC, Offutt AFB, Nebraska)

3. CENTRAL NORTH PACIFIC TROPICAL CYCLONES

The Central Pacific Hurricane Center (CPHC) personnel saw 1978 as the most active tropical cyclone year on record for their area of responsibility (north of the equator from 140W to 180). Table 3-9 details the seven tropical cyclones that either formed in the central Pacific area or moved in from the eastern Pacific area. Table 3-10 shows the central Pacific tropical cyclone "season" is well-defined and that 1978 was a record year for the number of tropical storms and hurricanes. This season not only set a record number of occurrences but also produced a cyclone with an exceptional length of travel and persistence of hurricane intensity (Fico), as well as one of the two most intense hurricanes on record in the central Pacific (Susan). Table 3-11 is a warning summary for the central North Pacific.

TABLE 3-9.

CENTRAL NORTH PACIFIC

1978 SIGNIFICANT TROPICAL CYCLONES

CYCLONE	TYPE	NAME	PRD OF WARNING*	CALENDAR DAYS OF WARNING	MAX SFC WIND	MIN OBS SLP	NO. OF WARNINGS TOTAL	NO. OF WARNINGS AS HU
07	HU	FICO	17 JUL - 28 JUL	12	100	955	43	39
10A**	TD	TD 10A	07 AUG - 09 AUG	3	30	-	11	-
12	HU	JOHN	23 AUG - 31 AUG	9	90	965	31	8
13	TS	KRISTY	26 AUG - 28 AUG	3	50	-	11	-
14	TS	LANE	20 AUG - 24 AUG	5	50	-	18	-
15	TS	MIRIAM	28 AUG - 01 SEP	5	55	-	18	-
30**	HU	SUSAN	18 OCT - 24 OCT	7	120	954	24	15
			1978 TOTALS	35***			156	62

* Warning period while in central Pacific area.

** Cyclones that formed in the central Pacific area; all others began in the eastern Pacific area. Tropical Depression 10A was given the "A" suffix to clarify its individuality when Tropical Depression 10 formed in the eastern Pacific area.

*** Overlapping days included once in sum.

TABLE 3-10.

FREQUENCY OF CENTRAL PACIFIC STORMS BY MONTH AND YEAR

(NUMBERS IN PARENTHESES INDICATE STORMS REACHING HURRICANE INTENSITY)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1967	0	0	0	0	0	0	0	0	0	1	0	0	1
1968	0	0	0	0	0	0	0	2	0	0	0	0	2
1969	0	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	1	0	0	0	0	1(1)
1971	0	0	0	0	0	0	1(1)	1	0	0	0	0	2(1)
1972	0	0	0	0	0	0	0	3(1)	1	0	0	0	4(1)
1973	0	0	0	0	0	0	1(1)	0	0	0	0	0	1(1)
1974	0	0	0	0	0	0	0	2(1)	0	0	0	0	2(1)
1975	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	1(1)	0	0	0	1(1)
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	1(1)	4(1)	0	1(1)	0	0	6(3)
AVERAGE (1967-78)	0	0	0	0	0	0	.3(.3)	1.1(.3)	.2(.1)	.2(.1)	0	0	1.8(.8)

TABLE 3-11.

WARNING SUMMARY

CENTRAL NORTH PACIFIC

	1978	AVERAGE 1971-1977
TOTAL NUMBER OF WARNINGS	156	30
NUMBER OF WARNING DAYS	35	9
NUMBER OF WARNING DAYS WITH 2 OR MORE CYCLONES	8	1
NUMBER OF WARNING DAYS WITH 3 OR MORE CYCLONES	1	0
TROPICAL DEPRESSIONS	1	1
TROPICAL STORMS	3	1
HURRICANES	3	1
TOTAL TROPICAL CYCLONES	7	3

JTWC

Hurricane Fico, 9-28 July, was the longest lived and most intense eastern Pacific cyclone of historical record. Fico reached hurricane strength at 111 degrees west longitude and maintained winds in excess of 65 kt (33 m/sec) for 18 days while traveling 4,200 miles (6758 km) westward to 176W, near Midway Island. Although Fico's maximum intensity of 115 kt (59 m/sec) occurred just prior to entering the central Pacific (140W), Hurricane Susan, in October attained winds of 120 kt (62 m/sec) while 360 miles (579 km) southeast of Hilo, Hawaii, making her the strongest tropical cyclone ever observed near the Hawaiian Islands.

Hurricane John and Tropical Storm Kristy were named at the same time, 0000 GMT, 19 August 1978, while in the eastern Pacific. At this time Tropical Storm Lane was centered further west than the others, thereby explaining why it entered the central Pacific out of alphabetical order.

GOES-3 imagery (Fig. 3-36) depicts three cyclones; John, Kristy, and Miriam. At the time of this satellite photograph, John was at tropical storm intensity and subsequently weakened further and meandered west-southwestward to 170W.

With the demise of Tropical Storm Miriam, the Honolulu staff felt that the central Pacific season was likely over. But on the 18th of October, a suspicious area southeast of Hawaii rapidly developed into a full-fledged tropical storm. This was the capricious Susan, the last storm of the season. Susan attained tropical storm intensity at precisely the same location where the first eastern Pacific storm of the season, to threaten the central Pacific area, Bud, dissipated; near 10N-145W. Continuing to intensify, by the 21st, Susan became one of the two most intense hurricanes on record in the central Pacific. Maximum sustained winds of 120 kt (62 m/sec) equaled those attained by Celeste in August of 1972. Figure 3-37 depicts Susan at 220016Z during peak intensity while a very real threat to the Hawaiian Islands. After reaching a point 220 nm (408 km) southeast of the Big Island, however, Susan turned sharply to the southwest, very rapidly dissipated, and luckily the Hawaiian Islands were once again spared.

An individual summary of Hurricane Fico follows.

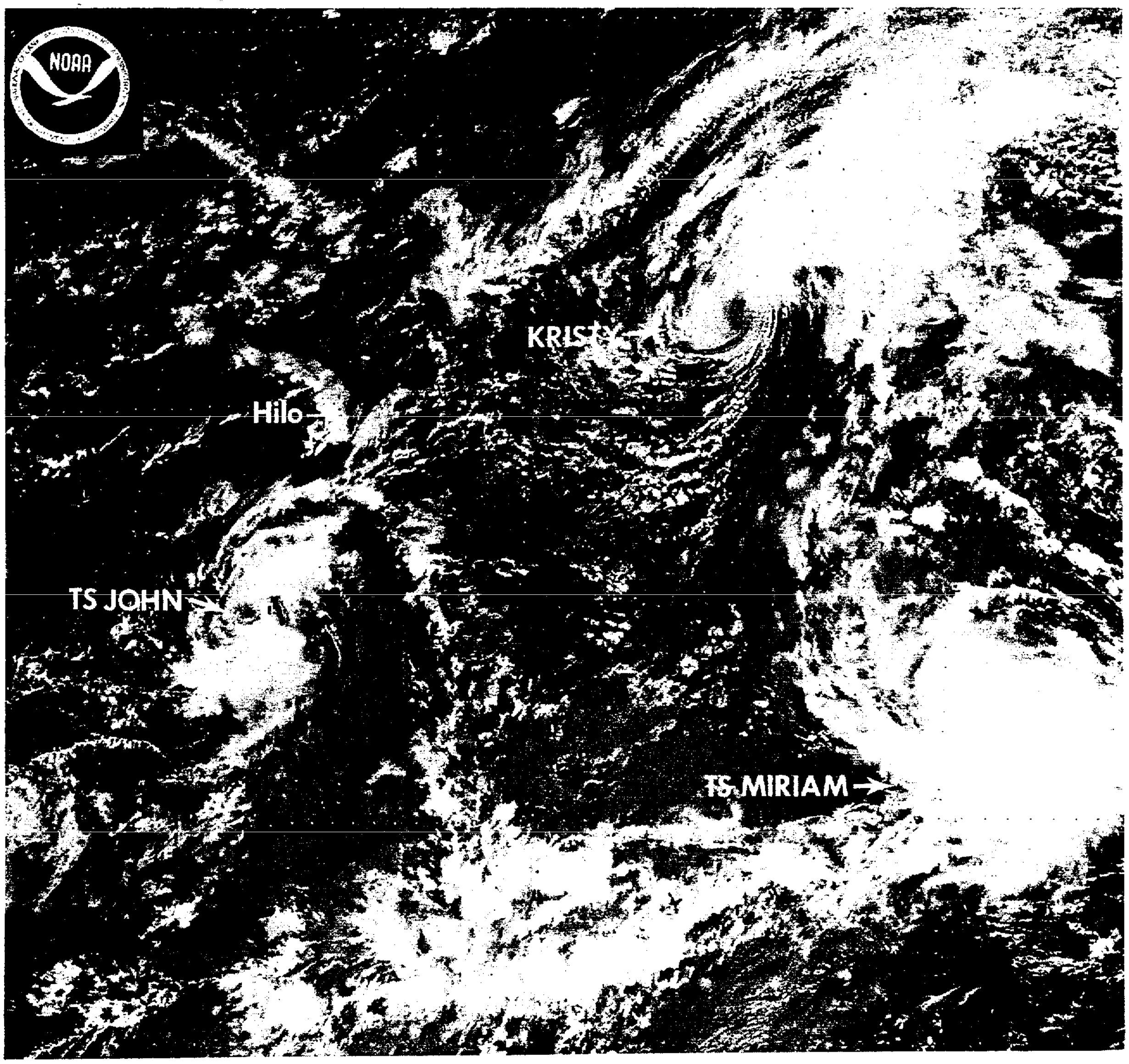


FIGURE 3-36. *Tropical Storm John (downgraded from Hurricane John) is centered 240 nm (417 km) south-southwest of South Point, Hawaii. Kristy, downgraded to a tropical disturbance, 600 nm (1120 km) east-northeast of Hilo, Hawaii, and Tropical Storm Miriam 925 nm (1714 km) southeast of Hilo, Hawaii, 27 August 1978, 2315Z.* (GOES *imagery from* SFSS, *Honolulu, Hawaii*)

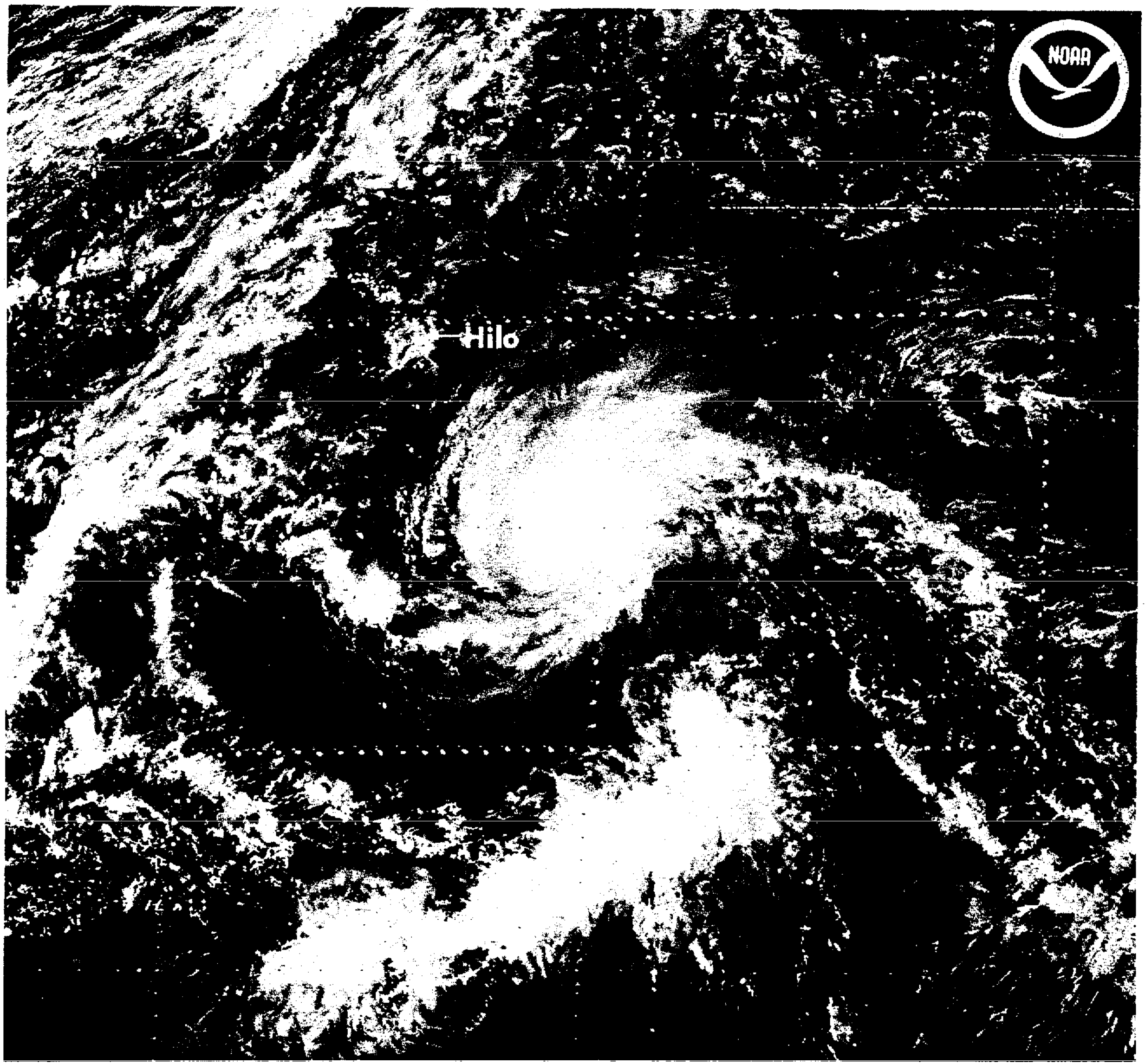
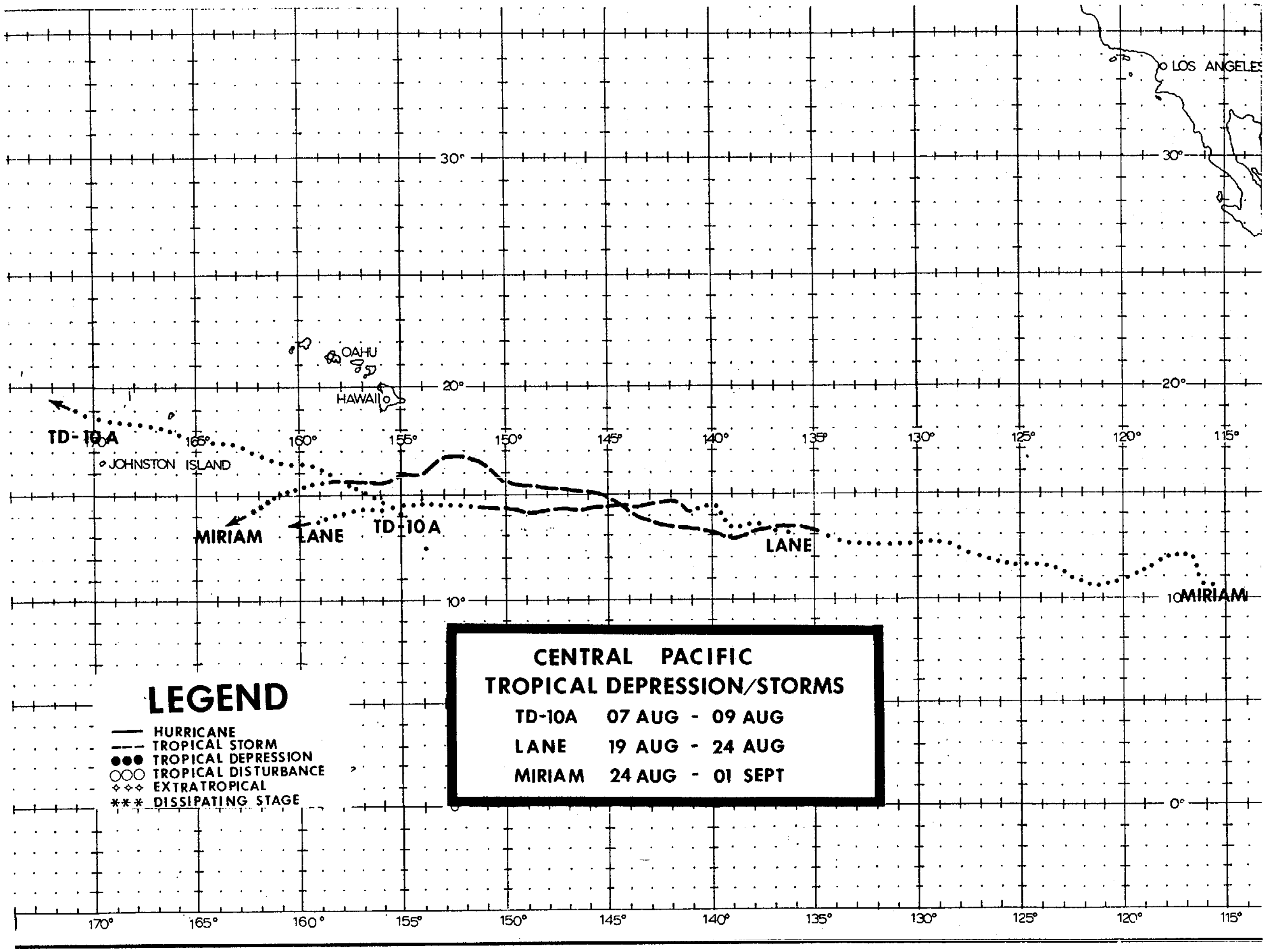
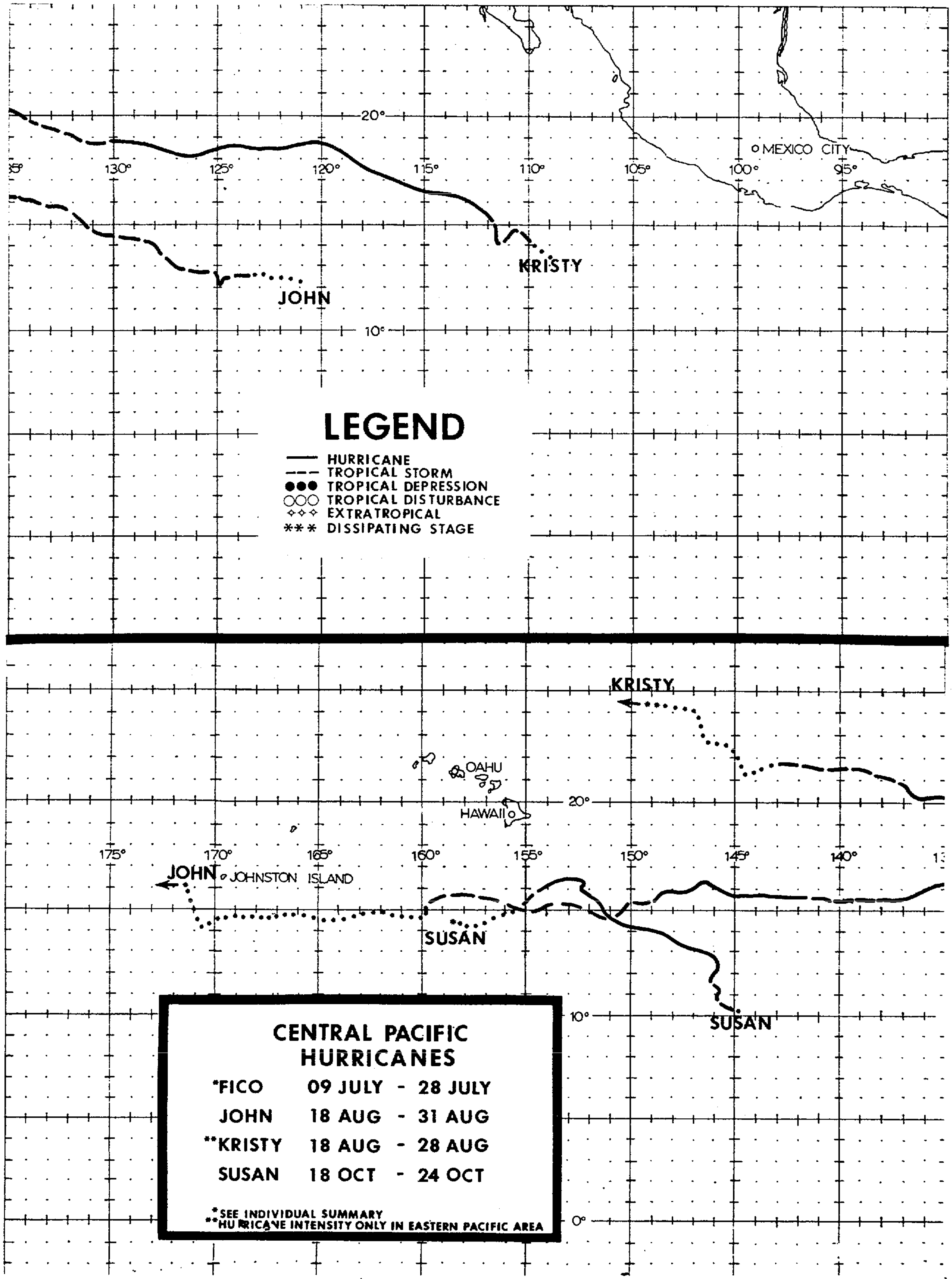
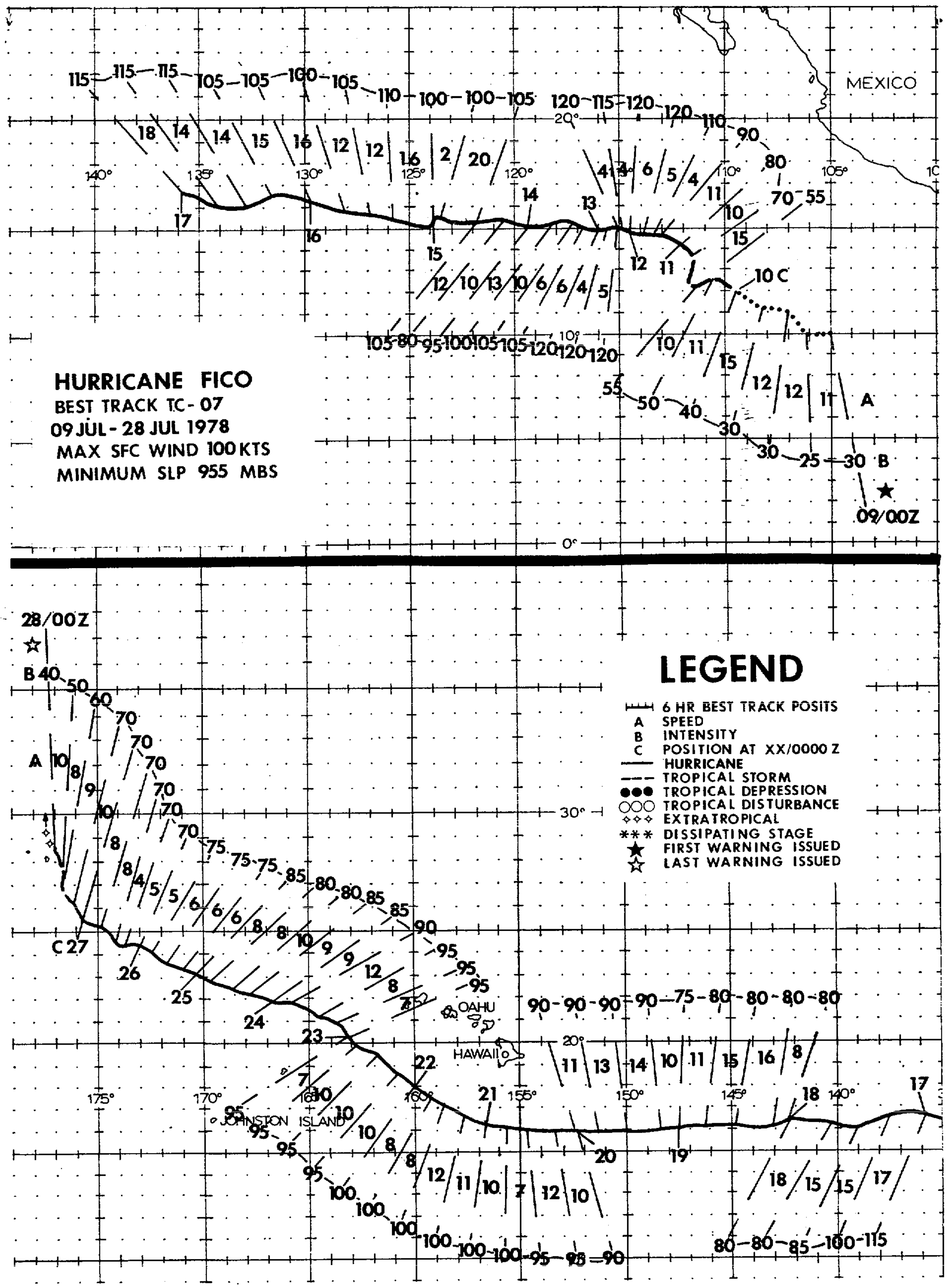


FIGURE 3-37. *Hurricane Susan at 120 kt (62 m/sec) maximum intensity, 22 October 1978, 0016Z. (GOES imagery from SFSS, Honolulu, Hawaii)*



CENTRAL PACIFIC
TROPICAL DEPRESSION/STORMS
TD-10A 07 AUG - 09 AUG
LANE 19 AUG - 24 AUG
MIRIAM 24 AUG - 01 SEPT
LEGEND
HURRICANE
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
LOS ANGELES
OAHU
HAWAII
JOHNSTON ISLAND
TD-10A
MIRIAM
LANE
TD-10A
LANE
MIRIAM
30°
20°
10°
0°
170°
165°
160°
155°
150°
145°
140°
135°
130°
125°
120°
115°


20°
130°
125°
120°
115°
110°
105°
100°
95°
MEXICO CITY
KRISTY
JOHN
10°
LEGEND
HURRICANE
TROPICAL STORM
TROPICAL DEPRESSION
TROPICAL DISTURBANCE
EXTRATROPICAL
DISSIPATING STAGE
KRISTY
OAHU
HAWAII
20°
175°
170°
165°
160°
155°
150°
145°
140°
JOHN
JOHNSTON ISLAND
SUSAN
10°
SUSAN
CENTRAL PACIFIC HURRICANES
*FICO 09 JULY - 28 JULY
JOHN 18 AUG - 31 AUG
**KRISTY 18 AUG - 28 AUG
SUSAN 18 OCT - 24 OCT
*SEE INDIVIDUAL SUMMARY
**HURRICANE INTENSITY ONLY IN EASTERN PACIFIC AREA
0°


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

Hurricane Fico entered the Central Pacific at 16N-140W on 17 July 1978 with maximum sustained winds near 80 kt (41 m/sec). Fico attained a maximum intensity of 115 kt (59 m/sec) while still in the Eastern Pacific east of 140W. Fico proceeded along the 16th parallel to a point due south of South Point, Hawaii. U. S. Air Force aircraft and satellite reconnaissance and NESS satellite imagery showed a steady increase in Fico's intensity during its travel from 140W to its position south of South Point.

Surf due to open ocean swell from Fico began to rise on the 18th, with some beach road flooding along the southeast coast of the Big Island when Fico was 500 nm (927 km) to the southeast. Higher than normal surf at this time was also enhanced by southerly swell from a southern hemisphere storm. By the morning of the 19th, Civil Defense officials reported 30 foot (9.1 m) surf breaking well offshore with smaller 15 to 20 foot (4.6 to 6.1 m) short period surf doing considerable damage to beachfront homes and roads on the Big Island. Eight to 12 foot (2.4 to 3.7 m) surf was observed on Eastern Maui by noon of the 19th, with water over roads but no damage reported. Very short period surf of similar heights reached southern Oahu and southern Kauai on the following day.

On July 20 (Fig. 3-38), the hurricane was 175 nm (324 km) south-southeast of South Point with maximum sustained winds of 100 kt (51 m/sec). Late on the 20th, Fico began moving northwestward and maintained 100 kt (51 m/sec) winds until 190 nm (325 km) due south of Kauai. A strong trade wind gradient, increased by the proximity of Fico, caused strong gusty winds over all the Hawaiian Islands with numerous reports of 50 kt (26 m/sec) or more, accompanied by falling trees and power line outages.

Fico maintained hurricane intensity for 17 days and was tracked by the Honolulu and San Francisco National Weather Service forecast offices (with much support from respective NESS units) for approximately 5000 nm (9266 km). The effects of Fico were felt during and after extratropical transition; remnants of Fico, enmeshed in a strong cold frontal system, inflicted heavy rain and up to 40 kt (21 m/sec) winds on ships southeast of Cold Bay in the Aleutians on July 31.

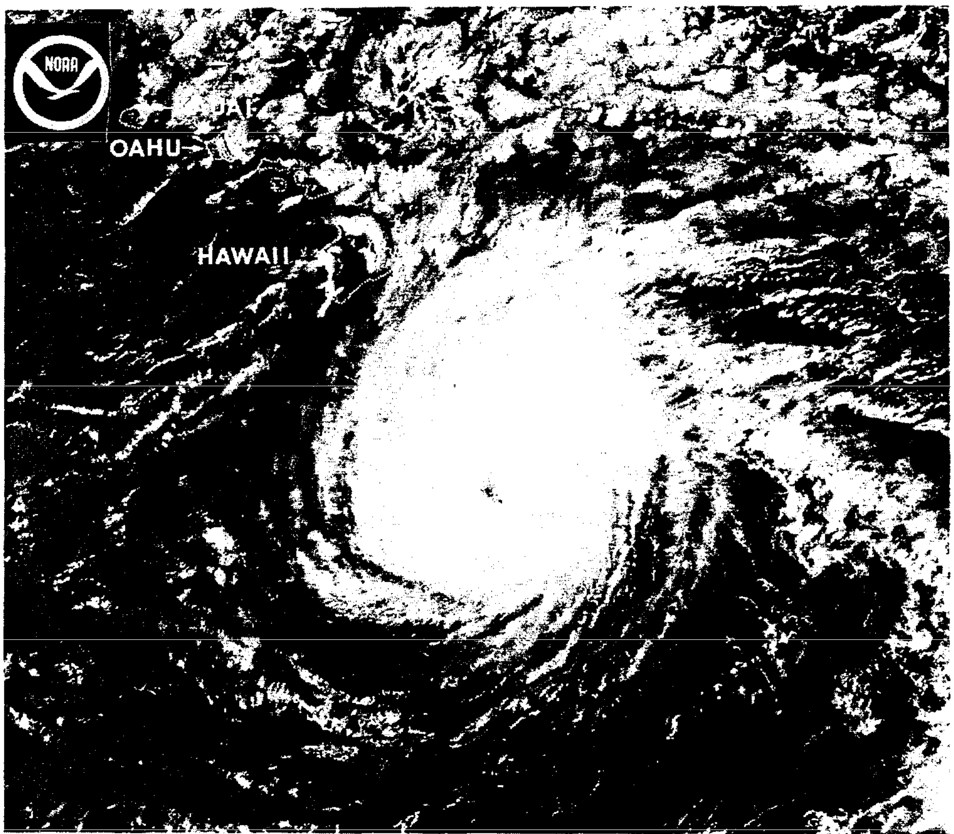


FIGURE 3-38. Hurricane Fico threatening Hawaii, 20 July 1978, 0115Z. (GOES imagery from SFSS, Honolulu, HI)